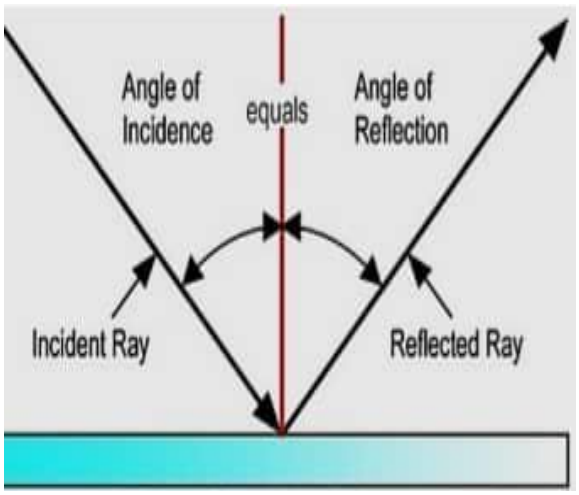
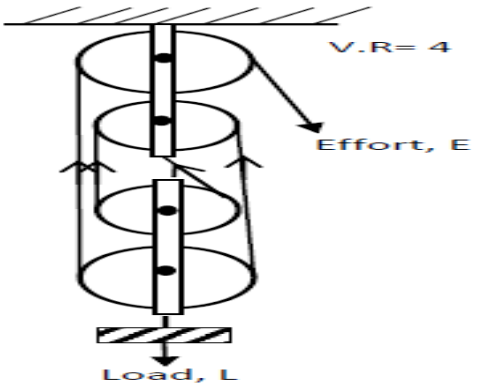
PHYSICS ITEMS AND THEIR SOLUTIONS 2025





PHYSICS ITEM BANK

01/02/ 2025

ABSTRACT

This document is supposed to guide you through physics items

Windows User

Understanding nature

Mechanics and Heat solution from item 1 to 33

ITEM 1 (LINEAR MOTION)

A driver parked the car under hot day sunshine to have lunch at homc and noticed that he was late to pick up his boss from a meeting in town. Worried as he was about being late, he drove as fast as possible for 120 minutes but as he approached the town, one of the car's tyre burst, prompting him to take the car to a garage. He noticed when the mechanic opened the car radiator that it was painted black and water was being used as a coolant but couldn't understand anything. He also questioned what caused the tyre to burst but couldn't get satisfactory explanation having been answered that he was over speeding.

HINT

- The car traveled 300 km before the tyre burst.
- The speed limit on the road is 80 km/h.

TASK

As a physics student, help the driver;

a) Understand why water is used in the car radiator.
b) Explain what caused the tyre to burst.
c) Know if he was over speeding.

solution

a) Why water is used in the car radiator

In most cars, the radiator serves to cool the engine and prevent it from overheating. Water is often used as the coolant in a car radiator for a couple of reasons:

- **High Heat Capacity**: Water has a high specific heat capacity, which means it can absorb a lot of heat before its temperature increases significantly. This makes it efficient for cooling the engine, which produces a lot of heat during operation.
- **Availability and Cost**: Water is readily available and inexpensive, which makes it a practical choice for use in cooling systems.
- **Water Antifreeze Mixture**: In colder climates, water alone is not ideal because it freezes in low temperatures. That's why it's usually mixed with antifreeze (like ethylene glycol) to lower the freezing point and raise the boiling point. This ensures that the coolant can still flow and protect the engine in various temperature conditions.

b) What caused the tyre to burst

1. **Overheating**: Driving at high speeds (especially for long periods) can generate excessive heat in the tyres. As the temperature of the tyre increases, the air inside expands, putting pressure on the tyre. If the tyre is already under-inflated or damaged, this can lead to a blowout.

2. **High Speed and Tyre Stress**: The driver was pushing the car to go as fast as possible for 120 minutes (2 hours). If the car was driving faster than the recommended speed limit, the tyres may have been subjected to stress beyond their design limits, increasing the risk of a burst.
3. **Possible Under-inflation**: If the tyres were not properly inflated, this could cause them to overheat faster because the tire's surface area in contact with the road increases, causing more friction. This, in turn, raises the temperature of the tyre and could lead to a blowout.

From the context of the scenario, it seems the driver's high speed could have contributed to the overheating and eventual burst of the tyre.

c) Was the driver over speeding?

Let's calculate the speed the driver was driving and compare it with the speed limit.

- The driver traveled **300 km** in **120 minutes** (which is 2 hours).
- To find the speed, we use the formula:

Speed = Distance/Time

Substituting the given values:

Speed = 300 km/2 hours = 150 km/h

The speed limit on the road was **80 km/h**, and the driver was traveling at **150 km/h**, which is clearly **over speeding**.

ITEM 2 (HEAT EXPANSION)

A plumber was designing a water pump system to transport water from a higher reservoir to a lower reservoir and vice versa. However, he encountered challenges due to the anomalous behavior of water at certain temperatures. The plumber realized that the pump will need to lift 1000 litres of water from a depth of 3000 cm to a height of 10000 cm at 27^{o}c and discovered (hat the efficiency of the pump decreases at temperatures close to 4 ^{0}C. He notified the community members about this situation which may affect the process of water supply they couldn’t understand.

HINT

- The densities of water at 4 ^{o}c and 27 ^{o}c are 1000 kgm-3 and 998.2 kgm-3 respectively.
- Acceleration due to gravity is 10 ms-2

TASK

As a leaner of Physics, help the community members;

a) Understand the behavior of water encountered during the design of the water supply system.
b) Explain the mechanism of supplying water from the higher reservoir to a lower reservoir and from lower reservoir to a higher reservoir.
c) Know the additional energy required to supply the water from 300 cm to 1000 cm at 4 ^{o}C compared to temperature of 27 ^{o}C

solution

a) Understanding the behavior of water encountered during the design of the water supply system

Water's behavior changes with temperature, and the problem mentions that the efficiency of the pump decreases near **4°C**. Here's why:

1. **Density of Water**:
   - The **density** of water decreases as the temperature increases. At **4°C**, water has its maximum density (1000 kg/m³), and as the temperature increases to **27°C**, the density decreases to **998.2 kg/m³**.
   - This is important because the density of water affects the amount of energy required to pump it. Lower density means the water is "less heavy," so it may be easier to pump in terms of the weight that needs to be lifted.
2. **Pump Efficiency**:
   - The **viscosity** of water also changes with temperature. As temperature increases, water's viscosity decreases, meaning water flows more easily. But, the pump's **efficiency** at lower temperatures (like around 4°C) can decrease due to the **increased resistance** in the mechanical parts of the pump (like friction between the moving parts). This could explain why the pump is less efficient at 4°C.
   - Additionally, the pump may be designed to operate efficiently at temperatures around 27°C, so at 4°C, the performance may not be optimal due to the combination of high viscosity and other mechanical factors.

b) Mechanism of supplying water from the higher reservoir to a lower reservoir and vice versa

Here's how the pumping system works:

- **Pumping water from a higher reservoir to a lower reservoir**:
  - When you pump water from a higher to a lower reservoir, you are essentially lifting water to a greater height (overcoming the force of gravity).
  - The pump needs to work against the gravitational potential energy of the water. This requires energy (work), which is calculated using the formula: $W = m \cdot g \cdot h$ where:
    - m is the mass of water,
    - g is the acceleration due to gravity (10 m/s²),
    - h is the height to which the water is lifted.
- **Pumping water from a lower reservoir to a higher reservoir**:
  - This involves using energy to lift water against gravity. The pump needs to do more work because the water is being raised to a higher point, requiring more energy to overcome the gravitational pull.
  - The challenge at colder temperatures (like 4°C) comes from the increase in **viscosity** of water, which makes it harder to pump because the water flows less easily.

c) Additional energy required to supply water from 300 cm to 1000 cm at 4°C compared to 27°C

Now, let's calculate the energy difference for pumping the water at **4°C** and **27°C**.

Step 1: Calculate the mass of water to be lifted

We need to convert 1000 liters of water into mass.

- Since 1 liter = 1 kg of water (approximately, but this changes slightly with temperature), we assume the mass of the water is: Mass of water=1000 kg

Step 2: Calculate the energy to lift the water at both temperatures

Energy is required to lift the water from **300 cm** (3 meters) to **1000 cm** (10 meters), which is a height difference of 7 meters. The formula to calculate the energy (work done) is:

$W = m \cdot g \cdot h$

where:

- $m=1000$ kg ,
- $g=10$ m/s^2,
- $h=7$ m.

So, the energy required at **27°C** (using the given density of water at 27°C, 998.2 kg/m³) is:

$W_{27} = 1000 \cdot 10 \cdot 7 = 70{,}000$ Joules

Step 3: Difference in energy at 4°C vs 27°C

The energy required to pump the water primarily depends on the **mass** of the water, which is influenced by the **density**. At **4°C**, the density is 1000 kg/m³, which is slightly higher than at 27°C, where the density is 998.2 kg/m³.

Let's calculate the mass at each temperature for the same volume of 1000 liters (1 m³):

- **At 27°C**: The mass of 1000 liters is:

  $m_{27}=998.2$ kg

  So the energy at 27°C is:

  $W_{27} = 998.2 \cdot 10 \cdot 7 = 69{,}874$ Joules

- **At 4°C**: The mass of 1000 liters is:

  $m_4 = 1000$ kg

  So the energy at 4°C is:

  $W_4 = 1000 \cdot 10 \cdot 7 = 70{,}000$ Joules

Step 4: Comparing the energies

- At **4°C**, the mass is higher (1000 kg), so the energy required is **70,000 Joules**.
- At **27°C**, the mass is slightly lower (998.2 kg), so the energy required is **69,874 Joules**.

Conclusion:

- **The additional energy required at 4°C compared to 27°C is**: $\Delta E = 70{,}000 - 69{,}874 = 126$ Joules

Thus, pumping water at **4°C** requires about **126 Joules more** than at **27°C** due to the slightly higher density of water at 4°C.

ITEM 3 (HEAT MEASUREMENT AND PRESSURE)

A certain hotel has its bathrooms situated on the 3rd floor of a building. A customer of the hotel expects to bathe water at 32 ^{o}C. The hotel provides 10 litres of water at 20 ^{o}C to each customer. A boiler on ground floor heats water to 80 ^{o}C for the customers to use. The hotel management does not allow its workers to carry the hot water via the staircase.

TASK

Having studied physics;

a) Help the hotel management to determine the quantity of hot water to be given to a customer for bathing.
b) Advise the hotel management on how to keep the boiled water hot for a long period of time without keeping the boiler on.
c) Explain to the management how the water from the boiler can reach the third floor safely.

Use:

Density of water = 1000 kgm^{-3}.

Specific heat capacity of water = 4200 J kg^{-1} K^{-1}.

Acceleration due to gravity = 10 ms^{-2}

a) Determine the quantity of hot water to be given to a customer for bathing

The hotel provides **10 liters of water at 20°C** and expects the customer to bathe with water at **32°C**. To achieve this temperature, the hotel needs to mix hot water (from the boiler) at **80°C** with the cold water.

The principle behind this is **thermal equilibrium**, which states that the heat lost by the hot water equals the heat gained by the cold water.

Step 1: Define variables

- Mass of cold water = 10 liters = 10 kg (since 1 liter of water = 1 kg)
- Initial temperature of cold water = 20°C
- Final desired temperature = 32°C
- Temperature of hot water = 80°C
- Specific heat capacity of water = 4200 J/kg·K
- Mass of hot water = unknown

Step 2: Use the heat energy equation

The heat lost by the hot water will be equal to the heat gained by the cold water:

Heat lost by hot water=Heat gained by cold water

$m_{hot} \cdot c_{water} \cdot (T_{hot} - T_{final}) = m_{cold} \cdot c_{water} \cdot (T_{final} - T_{cold})$

Since the specific heat capacity of water is the same on both sides, it cancels out:

$m_{hot} \cdot (T_{hot} - T_{final}) = m_{cold} \cdot (T_{final} - T_{cold})$

Step 3: Substitute values and solve for m_{hot}

Substitute the given values:

$m_{hot} \cdot (80°C - 32°C) = 10 \cdot (32°C - 20°C)$

$m_{hot} \cdot 48 = 10 \cdot 12$

$m_{hot} \cdot 48 = 120$

$m_{hot} = 120/48 = 2.5$ kg

Since the density of water is **1000 kg/m³**, the mass of water in kg is equivalent to the volume in liters. So, the volume of hot water required is **2.5 liters**.

Answer to part (a):

The hotel needs to provide **2.5 liters of hot water** at 80°C to mix with **10 liters of cold water** at 20°C in order to give the customer **12.5 liters of water at 32°C** for bathing.

b) Advise the hotel management on how to keep the boiled water hot for a long period of time without keeping the boiler on

To keep the boiled water hot without continuously running the boiler, the hotel management can use the following methods:

1. **Insulated storage containers**:
   Hot water can be stored in thermally insulated containers or tanks. These containers have insulating materials (such as foam or fiberglass) that significantly reduce heat loss by conduction and convection, keeping the water hot for a long time.
2. **Hot water tanks** with **double walls**:
   A hot water tank with double walls and a vacuum between the walls can prevent heat transfer through conduction and convection. This kind of tank is highly efficient at keeping water hot for extended periods.
3. **Solar water heaters**:
   If available, the hotel can use solar energy to heat the water during the day, and then use thermal storage tanks to keep the water hot. This is environmentally friendly and cost-effective in the long run.
4. **Electric heating pads or jackets**:
   Wrapping the water tank in an electric heating jacket or pad can maintain the temperature of the water without the need for a constant supply of energy. This method will only use energy when needed to maintain the desired temperature.

Answer to part (b):

The hotel management can use **insulated storage tanks**, **double-walled water tanks**, or **solar water heaters** to keep the hot water at the desired temperature for a longer period without continuously running the boiler.

c) Explain to the management how the water from the boiler can reach the third floor safely

The hotel needs to transport hot water from the boiler on the ground floor to the third floor where the bathrooms are located. To do this safely and efficiently, consider the following methods:

1. **Pumped water system**:
   The simplest and most reliable method is to use a **water pump** to pump the hot water from the boiler to the third floor. The pump ensures that the water reaches the required height and pressure for safe use in the bathrooms. A **centrifugal pump** can be used to push the water through pipes from the ground floor to the third floor.
2. **Gravity-fed system**:
   If a pump is not available, another option is to use a **gravity-fed system**. The hotel could store the hot water in an elevated **storage tank** located on the roof or higher floors. The water would flow naturally down to the third floor due to gravity. This would require a **pressure difference** to ensure proper flow, but gravity would eliminate the need for a pump.
3. **Insulated pipes**:
   To prevent heat loss while the hot water travels from the boiler to the third floor, **insulated pipes** should be used. These pipes minimize the loss of thermal energy, ensuring the water remains at a safe, high temperature when it reaches the third floor.
4. **Safety valves and pressure regulation**:
   If a pump is used, it's essential to install **pressure regulation valves** and **safety valves** in the system to prevent excessive pressure build-up, which could lead to pipe bursts or leaks. These valves ensure that the water is delivered safely and consistently.

Answer to part (c):

To safely transport water from the boiler on the ground floor to the third floor, the hotel can use a **pumped water system** with **insulated pipes**. Alternatively, a **gravity-fed system** with an elevated storage tank could also work. The use of **pressure regulation and safety valves** is important to ensure safety during the water delivery process.

ITEM 4 (HEAT MEASUREMENT AND PRESSURE)

A certain home owner intends to put up a metallic tank of height 4 m with a maximum volume of 5000 *l* fitted with an electrical heater which supplies 20,000 kJ of heat energy as shown in figure

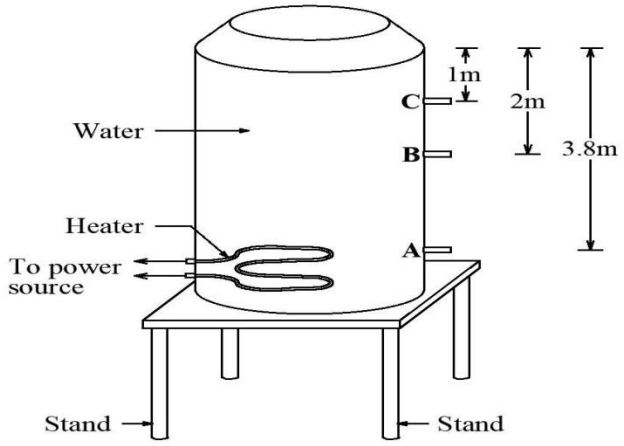


Fig. 1

The home owner found out that the heater was fitted at the lower part of the tank but he did not understand why it was done like that. Just before the hole for the outlet pipe was drilled at point **A**, the home owner told the person with the drill that the correct position was either **B** or **C**.

TASK

As a learner of Physics;

a) Explain to the home owner why;
   i. The electrical heater was fitted at the lower part of the tank and how eventually all the water gets hot.
   ii. The outlet pipe was drilled at point **A**.
b) If the initial temperature of the water in the tank is 20 ^{o}C, help the home owner to find out if the heater is working.
c) Advise the home owner on measures that can be taken to ensure that the tank stand can withstand the weight of the tank and water for a long time.

Use:

Density of water = 1000kgm^{-3}.

Specific heat capacity of water = 4200 J kg^{-1} K

Acceleration due to gravity = 10 ms^{-2}

Let's break down the problem and address each part systematically.

a) Explanation of the heater and outlet pipe placement

i. Why the electrical heater is fitted at the lower part of the tank and how all the water gets hot

The heater is positioned at the **lower part of the tank** because of the way heat transfer works in fluids, specifically **water** in this case.

- **Heat rises**: When the electrical heater at the bottom of the tank heats the water, the water at the bottom becomes warmer and less dense. As the warm water rises due to convection, cooler water from the upper part of the tank moves down to replace it.
- **Convection currents**: This continuous process of warm water rising and cool water sinking creates convection currents, which allows the heat to be distributed throughout the tank. Over time, the entire volume of water is heated as the warm water moves upward and mixes with the cooler water.
- This ensures **efficient and uniform heating** of the water, making sure that even the upper parts of the tank reach the desired temperature.

ii. Why the outlet pipe should be drilled at point A

The outlet pipe is positioned at **point A** (presumably near the top of the tank) because:

- **Hot water at the top**: As the heater heats the water at the bottom of the tank, the warm water rises and collects near the top. If the outlet were placed at the bottom or mid-point (like at points B or C), it would primarily drain the cooler water from the tank, leaving the hot water at the top unused.

- **Efficient hot water extraction**: By placing the outlet pipe near the top of the tank (point A), the homeowner ensures that the **hot water** is drawn first, making the heating system more efficient and convenient for use.

Answer to part (a):

- **(i)** The heater is placed at the lower part of the tank because heat rises, creating convection currents that allow the water to heat evenly throughout the tank.
- **(ii)** The outlet pipe is placed at **point A** (near the top) to ensure that hot water is drawn from the tank, not the cooler water at the bottom.

b) Determining if the heater is working

We can calculate whether the heater is working by determining if it has provided sufficient energy to heat the water from the initial temperature (20°C) to a higher temperature.

Step 1: Calculate the mass of the water in the tank

- Volume of the tank = **5000 liters** = **5000 kg** (since the density of water is 1000 kg/m³ and 1 liter of water = 1 kg).

Step 2: Calculate the temperature change needed

- Initial temperature = **20°C**.
- Let's assume the desired final temperature is **50°C** (as a reasonable heating target).
- The temperature change (ΔT) is: $\Delta T = T_{final} - T_{initial} = 50°C - 20°C = 30°C$

Step 3: Use the formula for heat energy

The formula to calculate the energy required to heat the water is:

$Q = m \cdot c \cdot \Delta T$

where:

- Q is the heat energy in joules (J),
- m is the mass of the water (5000 kg),
- c is the specific heat capacity of water (4200 J/kg·K),
- ΔT is the temperature change (30°C).

Substitute the values into the formula:

$Q = 5000 \cdot 4200 \cdot 30 = 630{,}000{,}000\ J = 630{,}000\ kJ$

Step 4: Compare with the heater's energy output

- The heater is supplying **20,000 kJ** of energy.
- However, based on our calculation, **630,000 kJ** of energy is required to heat the water by 30°C, which is much more than the heater's output of 20,000 kJ.

Conclusion for part (b):

- The **heater is not sufficient** to heat all 5000 liters of water by 30°C. It will take **more time** to heat the water, and if the desired temperature increase is large, the heater may need to run for an extended period to achieve it.
- To check if the heater is working properly, the homeowner should monitor the water temperature after the expected heating time to see if the desired temperature is reached.

c) Measures to ensure the tank stand can withstand the weight of the tank and water

To ensure the tank stand can withstand the weight of both the tank and the water for a long time, we need to calculate the total weight and consider the materials and design of the stand.

Step 1: Calculate the total weight

- The mass of the water is **5000 kg** (since 1 liter = 1 kg).
- The mass of the tank itself (assumed to be a metal tank) needs to be estimated. Let's assume the tank weighs **200 kg**.

Total mass = **5000 kg (water) + 200 kg (tank)** = **5200 kg**

Step 2: Calculate the total weight

The total weight W of the tank and water is:

$W = m \cdot g$

where:

- $m=5200$ kg,
- $g=10$ m/s^2 (acceleration due to gravity).

$W = 5200 \cdot 10 = 52{,}000$ N

The total weight is **52,000 N**.

Step 3: Ensure the stand is robust

To support this weight, the stand must be designed to handle at least **52,000 N**. The following considerations should be taken into account:

1. **Material strength**: The material used for the stand (e.g., steel or reinforced concrete) should have sufficient **compressive strength** to bear the load without bending or breaking.
2. **Size and structure**: The stand should have a wide base or several supporting legs to distribute the weight evenly. A **wide base** will reduce pressure on any single point and prevent the tank from tipping over.
3. **Regular checks**: The stand should be regularly inspected for signs of wear or corrosion, especially if it's made of metal, as it could weaken over time.

Conclusion for part (c):

To ensure the stand can withstand the weight of the tank and water:

- The stand must be designed to support at least **52,000 N**.
- The material should be strong, and the stand should have a wide base to distribute the weight evenly.
- Regular inspections should be done to ensure its integrity over time.

ITEM 5 (WORK, ENERGY AND POWER)

A heap of weed of mass 3 Tonnes is moving towards the turbines at the Jinja power station. A group of engineers needs to use a machine operating at 20 KW for five minutes to remove the weed from the river and place it at the bank which is 15 M above the river.

a) Determine the efficiency of the machine.
b) Comment on the efficiency of the machine.

solution

Given data:

- **Mass of the weed** (m) = 3 tonnes = 3000 kg (since 1 tonne = 1000 kg)
- **Height to lift the weed** (h) = 15 m
- **Power of the machine** (P) = 20 kW = 20,000 W (since 1 kW = 1000 W)
- **Time the machine operates** (t) = 5 minutes = 300 seconds (since 1 minute = 60 seconds)

The goal is to lift the weed to a height of 15 meters, and we need to calculate the **efficiency** of the machine in performing this task.

a) Determine the efficiency of the machine

Step 1: Calculate the work done (energy required to lift the weed)

The work done to lift an object is given by the formula:

$W = m \cdot g \cdot h$

where:

- W is the work done (in joules),
- m is the mass of the weed (3000 kg),
- g is the acceleration due to gravity (10 m/s^2),
- h is the height the weed is lifted (15 m).

Substitute the values:

$W = 3000 \cdot 10 \cdot 15 = 450{,}000$ Joules

Thus, the **work done** to lift the weed is **450,000 J**.

Step 2: Calculate the energy supplied by the machine

The power of the machine is given as **20 kW** (20,000 W), and the machine operates for **5 minutes** (300 seconds).

The energy supplied by the machine is calculated using the formula:

$E = P \cdot t$

where:

- E is the energy supplied by the machine (in joules),
- P is the power (20,000 W),
- t is the time the machine operates (300 s).

Substitute the values:

$E = 20{,}000 \cdot 300 = 6{,}000{,}000$ Joules

Thus, the **energy supplied** by the machine is **6,000,000 J**.

Step 3: Calculate the efficiency of the machine

The efficiency of the machine is given by the formula:

$\text{Efficiency} = \text{Useful energy output}/\text{Total energy input} \times 100$

where:

- **Useful energy output** is the work done, which is **450,000 J**,
- **Total energy input** is the energy supplied by the machine, which is **6,000,000 J**.

Substitute the values:

$\text{Efficiency} = 450{,}000/6{,}000{,}000 \times 100 = 7.5\%$

Thus, the **efficiency of the machine** is **7.5%**.

b) Comment on the efficiency of the machine

The efficiency of the machine, **7.5%**, is relatively low. This means that only 7.5% of the energy supplied by the machine is effectively used to perform the useful task of lifting the weed. The remaining **92.5%** of the energy is lost in various forms, such as:

- **Heat** due to friction in the machine's moving parts,
- **Sound energy** from the operation of the machine,
- **Other losses** due to inefficiencies in the conversion of electrical energy to mechanical energy.

ITEM 6 (MECHANICAL PROPERTIES OF MATTER)

There is a parent project in your school to construct two rectangular pit latrines. One at the girls 'wing and another at the staff quarter's wing. However, the Board of Governors and the school administration have failed to agree on the choice of materials to use in construction.

TASK

Using the knowledge and skills learnt in ''mechanical properties of materials'' Suggest the choice of materials you would advise the school board to use in the construction of the latrines

When selecting materials for the construction of latrines, it's important to consider various mechanical properties such as **strength**, **durability**, **corrosion resistance**, **cost**, and **ease of maintenance**. Given that latrines will be exposed to moisture, pressure, and wear over time, these properties are especially important in ensuring the latrines are functional and last a long time.

Here are the materials I would suggest for constructing the latrines, taking into account the **mechanical properties** of materials:

1. Concrete Blocks or Bricks

- **Reason**: Concrete is a widely used material due to its **strength** and **durability**. It is also resistant to moisture, which is crucial in a latrine environment where water and waste will be present.
- **Mechanical properties**:
    - **Compressive strength**: Concrete has high compressive strength, which is ideal for withstanding the pressure from the soil and the load of the structure.
    - **Durability**: Concrete is highly durable, especially if reinforced, and can withstand harsh weather conditions and moisture exposure.
    - **Corrosion resistance**: While steel reinforcement may corrode over time, proper curing and treatment of concrete minimize this risk.
- **Cost**: It is relatively affordable, especially if locally sourced, and the construction process is straightforward.

2. Reinforced Concrete

- **Reason**: In areas where the latrine structure needs to support additional weight (e.g., the roof or walls under heavy load), **reinforced concrete** should be used for extra strength.
- **Mechanical properties**:

    - **Flexural strength**: The reinforcement (usually steel bars) helps concrete handle bending and tensile forces.
    - **Durability**: Reinforced concrete is excellent for structures that are exposed to moisture and soil, as it is highly resistant to water penetration when mixed and cured properly.
    - **Maintenance**: Requires minimal maintenance compared to other materials like wood.

3. Clay Bricks (Optional for Aesthetic Design)

- **Reason**: Clay bricks are another option for constructing the latrine walls. They provide a traditional look and offer good compressive strength.
- **Mechanical properties**:
    - **Compressive strength**: Clay bricks are strong enough for wall construction and can support the weight of the structure.
    - **Insulation**: They provide good thermal insulation and might be more comfortable in terms of temperature regulation inside the latrine.
- **Durability**: Clay bricks are durable and resistant to water damage when properly fired and treated.

4. Steel (for Roofing and Structural Support)

- **Reason**: **Steel** can be used for the roofing framework and other structural elements due to its strength and versatility.
- **Mechanical properties**:
    - **Tensile strength**: Steel has high tensile strength, making it ideal for supporting the roof structure.
    - **Corrosion resistance**: Steel should be galvanized or coated to prevent rust due to exposure to moisture.
- **Cost**: Steel can be more expensive than concrete, but it is still a commonly used material in construction for its reliability.

5. Plastic (for Toilets and Fixtures)

- **Reason**: For fixtures inside the latrines (e.g., toilet bowls, washbasins), **plastic** is a good choice due to its **water resistance**, **light weight**, and **ease of maintenance**.
- **Mechanical properties**:
    - **Lightweight**: Easy to handle and install, reducing labor costs.
    - **Water resistance**: Plastic is completely waterproof and resistant to moisture, which is important in a latrine.
    - **Durability**: Plastic is durable and easy to clean, but it should be checked for UV degradation if exposed to direct sunlight.

6. Tiles (for Floor and Walls)

- **Reason**: **Tiles** can be used for the floor and walls of the latrine to create a smooth surface that is easy to clean and resistant to stains.
- **Mechanical properties**:
    - **Wear resistance**: Ceramic or porcelain tiles are resistant to wear and abrasion, making them ideal for high-traffic areas like latrines.
    - **Water resistance**: Tiles are highly resistant to water and help to prevent mold or mildew buildup.
    - **Ease of maintenance**: Tiles are easy to clean, which is important for maintaining hygiene in latrines.

Recommendations:

- **For the walls and structure**: I would recommend **reinforced concrete** or **concrete blocks**. These materials are strong, durable, and resistant to moisture, which is essential for the longevity of the latrine. Additionally, **clay bricks** could be considered for aesthetic purposes if desired.
- **For the roof**: **Steel** would be a good choice for the roof structure because it is strong, lightweight, and can support the weight of roofing materials. Ensure that it is treated or galvanized to prevent rusting over time due to moisture exposure.
- **For the floor and internal surfaces**: **Tiles** are an excellent option because they are easy to clean, durable, and moisture-resistant. They also add a hygienic and visually appealing finish to the latrines.
- **For the fixtures (toilets, sinks, etc.)**: Use **plastic** fixtures for water resistance and easy maintenance.

ITEM 7 (HEAT MEASUREMENT)

During a party, 2 liters of water at 24 ^{o}C were served to a man and a woman. They complained that it was warm and were given 50g of ice at -10^{o}C blocks. They mixed the water and blocks in a wooden container with a negligible specific heat capacity. They were surprised by the ice cubes disappearing in the water. The man put his mixture in a plastic container **(shc = 2800 JKg^{-1}K^{-}1)** while the woman put her mixture in a metallic container **(shc = 800 JKg^{-1}K^{-1})**. They were surprised to find their water at different temperatures after some time.

Specific Heat capacity of water = 4200 JKg^{-1}K^{-1}

Latent heat of fusion of ice = 340000 JKg^{-1}

Use your knowledge of Physics to;

a) Determine if the water cooled when mixed with ice.
b) Why do the ice cubes disappear when mixed with water?
c) Explain why there was a difference in temperatures in the water kept in the plastic and the metallic container.

Let's address each of the questions systematically using the principles of thermodynamics and heat transfer.

Given:

- **Volume of water** = 2 liters = 2 kg (since 1 liter of water has a mass of 1 kg)
- **Initial temperature of water** = 24°C
- **Mass of ice** = 50g = 0.05 kg
- **Initial temperature of ice** = -10°C
- **Specific heat capacity of water** = 4200 J/kg·K
- **Specific heat capacity of plastic container** = 2800 J/kg·K
- **Specific heat capacity of metallic container** = 800 J/kg·K
- **Latent heat of fusion of ice** (L_f) = 340,000 J/kg

a) Determine if the water cooled when mixed with ice

To determine if the water cooled when mixed with the ice, we need to calculate the heat exchanged during the process.

Step 1: Heat required to warm the ice from -10°C to 0°C

The heat required to warm the ice to 0°C is calculated using the formula:

$Q(\text{ice to warm}) = m_{ice} \cdot c_{ice} \cdot \Delta T$

where:

- $m_{ice}=0.05$ kg,
- $c_{ice}=2100$ J/kg·K (specific heat capacity of ice),
- $\Delta T=0-(-10)=10$ K.

Substitute the values:

$Q(\text{ice warm}) = 0.05 \cdot 2100 \cdot 10=1050$ J

Step 2: Heat required to melt the ice at 0°C

The heat required to melt the ice is:

$Q(\text{ice melt}) = m_{ice} \cdot L_f$

where:

- $L_f = 340{,}000$ J/kg (latent heat of fusion of ice).

Substitute the values:

$Q(\text{ice melt}) = 0.05 \cdot 340{,}000=17{,}000$ J

Step 3: Heat required to warm the melted ice (water) from 0°C to 24°C

Now, we need to heat the melted ice (which is now water) from 0°C to the final temperature of the mixture, which we will call T_f. The heat required for this step is:

$Q(\text{melted ice warm}) = m_{ice} \cdot c_{water} \cdot (T_f-0)$

$Q(\text{melted ice warm}) = 0.05 \cdot 4200 \cdot Tf=210Tf$ J

Step 4: Heat available from the water at 24°C

The heat lost by the warm water as it cools down to the final temperature T_f is:

$Q(\text{water cool}) = m_{water} \cdot c_{water} \cdot (24-T_f)$

$Q(\text{water cool}) = 2 \cdot 4200 \cdot (24-T_f) = 8400(24-T_f)$ J

Step 5: Energy balance

The heat lost by the water must equal the heat gained by the ice (warming and melting):

$Q(\text{water cool}) = Q(\text{ice warm}) + Q(\text{ice melt}) + Q(\text{melted ice warm})$

Substitute the expressions:

$8400(24-T_f) = 1050+17,000+210T_f$

Simplify the equation:

$8400(24-T_f)=18,050+210T_f$

Move all terms involving T_f to one side:

$201,600-18,050 = 8400T_f + 210T_f$

Solve for T_f :

$T_f = 183,550/8610 \approx 21.3°C$

Conclusion for part (a):

Since the final temperature of the mixture is **21.3°C**, which is lower than the initial temperature of the water (24°C), the water **did cool** when mixed with the ice.

b) Why do the ice cubes disappear when mixed with water?

The ice cubes disappear when mixed with water because of the **heat exchange** between the ice and the water:

- The water at 24°C transfers heat to the ice at -10°C. This causes the ice to **warm up**, melt, and eventually become liquid water at 0°C.
- The **latent heat of fusion** (340,000 J/kg) is required to convert the ice into water without changing its temperature.
- As the ice absorbs heat from the water, it melts completely, disappearing in the process.

Since the water is at a temperature high enough (24°C), it provides sufficient heat to warm the ice to 0°C, melt it, and raise the melted water to a temperature above 0°C. Hence, the ice cubes **disappear** as they melt and become part of the water.

c) Explain why there was a difference in temperatures in the water kept in the plastic and the metallic container.

The difference in temperatures in the water in the **plastic container** and the **metallic container** arises due to the **different heat capacities** and **thermal conductivities** of the two materials:

1. **Specific Heat Capacity**:
    - The **plastic container** has a specific heat capacity of 2800 J/kg·K, while the **metallic container** has a specific heat capacity of 800 J/kg·K.
    - A material with a higher specific heat capacity can store more heat for the same temperature change. Therefore, the plastic container requires more heat to increase its temperature compared to the metallic container.
2. **Thermal Conductivity**:
    - **Metal** has higher thermal conductivity than **plastic**, meaning it can transfer heat more quickly. This allows the metallic container to exchange heat with the surroundings more efficiently.
    - The plastic container, having lower thermal conductivity, does not allow heat to flow in or out as quickly, causing the water in the plastic container to **retain its heat** longer.

Conclusion for part (c):

The **metallic container** has a lower specific heat capacity and higher thermal conductivity, allowing it to lose or gain heat more quickly, which results in a **faster cooling** of the water compared to the **plastic container**. The **plastic container**, with its higher specific heat capacity and lower thermal conductivity, **retains heat longer**, leading to a higher final temperature in the water compared to the water in the metallic container.

ITEM 8 (WORK, ENERGY AND POWER AND HEAT MEASUREMENT)

Workers at a construction site are meant to raise pieces of scrap of mass 6 kg through a height of 15m. Their boss always complains that the workers who carry the pieces of metal do the work slowly, especially in the afternoon when the temperatures are high and in the morning when it is cold. In response, the workers claim their hands are burnt by the hot metals which slows them down. One of the workers suggested they use a pulley of velocity ratio 4 and an efficiency of 80%.

Use your knowledge of physics to;

a) Explain why the metals are very cold in the morning and hot in the afternoon.
b) Draw a design of the required pulley and explain how it can be used to solve their problem.
c) Determine the minimum force required to ensure an 80% is achieved.

The string they used had a mass of 120g and a specific heat capacity of 2510 $JKg^{-1}K^{-1}$, and the work done to lift the load would be converted to heat energy in the string at the contact point of the pulley.

HINT

The string would break if its temperature reaches by 28^{o}C.

a) Determine if the string suggested above would be suitable for the purpose.
b) Suggest ways in which the efficiency of the pulley system can be improved.

Let's address each part of the problem systematically.

Given:

- **Mass of scrap metal** (m) = 6 kg
- **Height** (h) = 15 m
- **Pulley velocity ratio** (VR) = 4
- **Efficiency** (η\eta) = 80% = 0.80
- **Mass of string** = 120 g = 0.12 kg
- **Specific heat capacity of string** = 2510 J/kg·K
- **Temperature rise limit for string** = 28°C

We will use the concepts of **work**, **energy conversion**, **velocity ratio**, and **efficiency** to solve each part.

a) Explain why the metals are very cold in the morning and hot in the afternoon.

This phenomenon can be explained by the **thermal properties** of metals and **heat exchange**.

- **In the morning**, the temperature is cooler. Metals, like most substances, have a high **thermal conductivity**, meaning they can lose heat quickly. When the temperature of the surrounding air is lower,

metals will absorb heat more slowly from the environment. As a result, metals in the morning will feel **cold** because they have not yet absorbed much heat.

- **In the afternoon**, when the air temperature is higher, metals will absorb heat from the surroundings more rapidly. As the metal absorbs more thermal energy, its temperature rises. This is why the metals feel **hot** in the afternoon: they have absorbed heat from the environment and reached a higher temperature.

Metals, being good conductors of heat, will always tend to reach thermal equilibrium with their surroundings. In the morning, when it's colder, they lose heat to the surroundings, but in the afternoon, they absorb more heat.

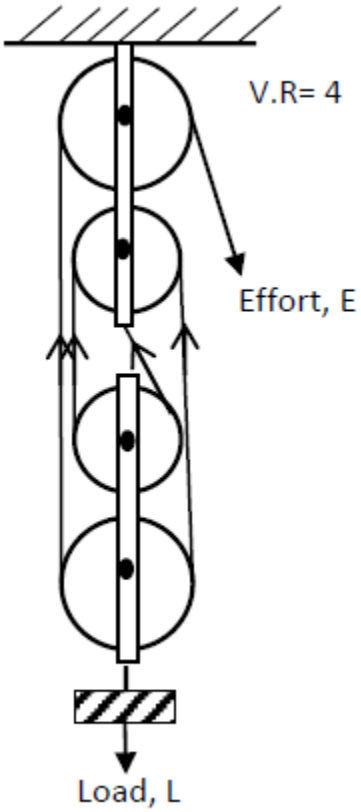
b) Draw a design of the required pulley and explain how it can be used to solve their problem.

A **pulley system** can reduce the effort needed to lift the scrap metal. Given the **velocity ratio (VR)** of 4 and the **efficiency of 80%**, we can explain the working principle of the pulley system.

Pulley Design:

- The pulley system could be a **simple mechanical advantage system** with a fixed and a movable pulley.
- The **velocity ratio** of 4 means that the distance the effort moves is 4 times the distance the load moves.

Diagram:



How the Pulley Works:

- The load (metal scrap) has to be lifted through a height of 15 m.

- The effort moves four times the distance, so the effort moves $4 \times 15 = 60$ m.
- By applying the pulley system, the force needed to lift the scrap metal is reduced, but the distance over which the force is applied is increased.
- **Efficiency** of 80% indicates that 80% of the input work goes into lifting the load, while the rest is lost due to friction in the pulley.

c) Determine the minimum force required to ensure 80% efficiency is achieved.

Step 1: Calculate the work done to lift the load.

The work done (W) to lift the metal scrap is given by the formula:

$W = m \cdot g \cdot h$

where:

- $m = 6$ kg,
- $g = 10$ m/s^2,
- $h = 15$ m.

Substituting the values:

$W = 6 \cdot 10 \cdot 15 = 900$ J

Step 2: Work input due to the efficiency.

The work input is related to the efficiency (η) as follows:

η = Useful work output/Work input$=0.80$

Rearranging to find the work input:

Work input = Useful work output/$\eta = 900/0.80 = 1125$ J

Step 3: Minimum force required.

Now, we use the formula for work in terms of force and distance:

$W_{input} = F_{effort} \cdot d$

where:

- F_{effort} is the minimum force required,
- $d = 60$ m (distance the effort moves, which is 4 times the height lifted).

Rearranging to solve for the effort force:

$F_{effort} = W_{input} / d = 1125/60 = 18.75$ N

Thus, the **minimum force required** to lift the scrap metal with 80% efficiency is **18.75 N**.

a) Determine if the string suggested above would be suitable for the purpose.

To determine if the string would be suitable, we need to ensure that its temperature does not rise by more than 28°C. The work done in lifting the scrap metal is converted into heat energy in the string. This heat raises the string's temperature, and if the temperature increases too much, the string could break.

Step 1: Calculate the heat energy converted in the string.

Since the work done to lift the scrap metal is converted into heat in the string, the energy transferred to the string is:

$Q = W_{input} = 1125\ J$

Step 2: Calculate the temperature rise in the string.

The heat required to raise the temperature of the string is given by the formula:

$Q = m_{string} \cdot c_{string} \cdot \Delta T$

where:

- m_{string}=0.12 kg
- c_{string}=2510 J/kg·K,
- ΔT is the temperature rise.

Rearranging the formula to solve for the temperature rise:

$\Delta T = Q/(m_{string} \cdot c_{string} = 1125/(0.12x2510) \approx 3.74\ °C$

Conclusion for part (a):

The temperature rise in the string is **3.74°C**, which is much lower than the limit of **28°C**. Therefore, the string would be **suitable** for the purpose, as its temperature rise does not exceed the limit.

b) Suggest ways in which the efficiency of the pulley system can be improved.

To improve the efficiency of the pulley system, several strategies can be employed:

1. **Reduce Friction**: Use lubricants or high-quality bearings in the pulley system to reduce friction between the moving parts. Less friction results in less energy loss.
2. **Use of Stronger Materials**: Using stronger materials for the pulley and the rope can reduce wear and tear, improving long-term efficiency.
3. **Proper Alignment**: Ensuring the pulleys are properly aligned and the rope moves smoothly can minimize energy losses due to misalignment and unnecessary friction.
4. **Use of Multiple Pulleys**: Increasing the number of pulleys can help distribute the load more efficiently, although it must be balanced with the increase in complexity and friction.
5. **Regular Maintenance**: Ensuring that the pulleys and ropes are regularly maintained, cleaned, and lubricated will help maintain their efficiency over time.

By implementing these measures, the pulley system’s efficiency can be improved, reducing the overall force needed and increasing the performance of the system.

ITEM 9 (HEAT MEASUREMENT)

a) In a certain family, a house maid is required to make tea for breakfast for all the family members before 7:00 am. The house maid made it a routine to wake up early to set fire on a charcoal stove so that she could boil water for tea. The house maid could only remove the water from fire when the steam starts to come out from the water boiling in the saucepan.

TASK

Imagine you are one of the family members, explain to the house maid house how cold water becomes hot ready for tea. **(4 scores)**

b) In a certain school, senior four students carried out an experiment to determine specific latent heat of fusion of ice by mixture method as their end of term one assessment.

Apparatus: Pieces of ice, thermometer, calorimeter, stirrer, hot water.

TASK

As a physics learner, explain the process of change of state of ice to liquid. (**8 scores**)

a) Explanation of How Cold Water Becomes Hot and Ready for Tea

As one of the family members, I would explain to the housemaid how cold water becomes hot and ready for tea as follows:

When you put cold water on a charcoal stove, the heat energy from the burning charcoal is transferred to the water in the saucepan. Here's what happens in steps:

1. **Heat Transfer**: The heat from the burning charcoal passes to the saucepan and then to the water inside. This is an example of **conduction** — where heat moves from the hot surface (the bottom of the saucepan) to the cooler water.
2. **Heating of Water**: As the water absorbs heat, its temperature begins to rise. The molecules in the water gain energy and start moving faster. This process continues until the water reaches a certain temperature.
3. **Boiling Point**: Once the water reaches the boiling point, which is 100°C at standard pressure, it starts to change from a liquid to a gas (steam). The steam is made up of water molecules that have gained enough energy to escape the liquid state and enter the air as vapor.
4. **Evaporation of Water**: The moment you see the steam rising from the water, it means the water has reached the boiling point and has started to change from liquid to gas. This process is known as **boiling**, and the water is now hot enough to make tea.

So, in summary, cold water becomes hot through the process of **heat transfer**, where heat from the stove is absorbed by the water, causing it to reach the boiling point. The water then begins to turn into steam, signaling that it's ready for tea.

b) Explanation of the Process of Change of State of Ice to Liquid

As a physics learner, I would explain the process of change of state of ice to liquid (melting) during the experiment as follows:

When the ice is placed in a calorimeter with warm water, the heat energy from the warm water is transferred to the ice. Here’s how the process works:

1. **Heat Transfer to Ice**: The warm water in the calorimeter has a higher temperature than the ice. Heat energy flows from the hot water to the ice. This heat energy is transferred through the process of **conduction** — from the warmer water molecules to the cooler ice molecules.
2. **Raising the Temperature of Ice**: As the ice absorbs heat, its temperature increases, but the temperature of the ice will only rise until it reaches **0°C**. At this point, the ice begins to melt.
3. **Melting Process**: To change from solid (ice) to liquid (water), the ice needs to absorb a certain amount of heat without increasing its temperature. This is because the heat energy is used to **break the bonds** between the molecules in the solid ice, causing the ice to turn into liquid water. This process is called **melting**.
4. **Latent Heat of Fusion**: The amount of heat required to change a unit mass of ice at 0°C into water at 0°C is called the **latent heat of fusion**. During this phase, the temperature of the ice remains constant at 0°C, despite the continuous absorption of heat, because all the heat energy is used for breaking the bonds and not for raising the temperature.
5. **Ice Completely Melts**: Once enough heat has been absorbed, all the ice turns into liquid water at 0°C. The liquid water can then be heated further to increase its temperature.

In summary, the process of turning ice into water involves **heat transfer**, **melting**, and the absorption of **latent heat of fusion**, which allows the ice to change from a solid to a liquid without increasing its temperature. This process is crucial for determining the specific latent heat of fusion of ice in the experiment.

ITEM 10 (LINEAR MOTION)

a) Patience and Pius went outing during holidays. The two went where there was a Pool table. The two became interested to playing pool game. Patience was the first to play. During her time, she knocked one pool ball of mass 3 kg with an initial velocity of **5** ms^{-1}. The ball then moved and collided with another **stationary** ball of mass 2 kg. The two balls thereafter moved **separately**. The first ball moved with final velocity of **2.8** ms^{-1} and the second ball moved with final velocity of **V** ms^{-1}.

Pius also played the ball of mass 4 kg with initial velocity of **3.5** ms^{-1}. The ball then collided with another ball of mass 3 kg moving with initial speed of **6** ms^{-1}. the two balls moved together after collision with the same final velocity **V** ms^{-1}. As they were cheering up, a friend told them that the pool balls they played moved elastically and inelastically while obeying law of conservation of momentum.

TASKS

As a physics learner;

i. Help Patience and Pius identify the type of collisions that the pool balls moved with and state the principle of conservation of linear momentum. **(3 scores)**
ii. Support Patience and Pius to know the final velocities that the balls moved with after collisions. **(6 scores)**

b) In a certain village people collect water from the well for drinking and cooking. One day, a young girl from this village went to collect water from the well with her 20-liter jerrycan. When she deep her jerrycan in water, it was very difficult for the jerrycan to sink below the water surface. Afterwards when some amount of water enters the jerrycan, it was able to sink easily and the girl was able to collect the water for taking home. These two situations puzzle the young girl.

TASK

As a physic learner, explain to the young why she got difficulties at first and later the collected the water with ease. (**3 scores**)

a) Pool Ball Collisions and Momentum

i) Identify the Type of Collisions and State the Principle of Conservation of Linear Momentum

When explaining the collisions and the principle of conservation of linear momentum, here's what Patience and Pius should understand:

1. **Types of Collisions**:
   - **Elastic Collision**: In an elastic collision, both momentum and kinetic energy are conserved. This means that after the collision, the total kinetic energy of the system before and after the collision is the same. Elastic collisions are typically seen in ideal situations, like when pool balls collide on a frictionless surface, and the balls bounce off each other without loss of energy.
   - **Inelastic Collision**: In an inelastic collision, while momentum is still conserved, **kinetic energy is not conserved**. Some of the energy is transformed into other forms of energy, such as sound, heat, or deformation. In this case, the balls may move together after the collision, as seen in the case where Pius's balls stick together after the collision.

From the descriptions:

- **Patience's collision**: Since the balls move separately after the collision, it suggests that the collision is **elastic**.
- **Pius's collision**: Since the two balls move together after the collision, this is an **inelastic collision** (specifically a perfectly inelastic collision).

2. **Principle of Conservation of Linear Momentum**: The **conservation of linear momentum** states that the total momentum of a closed system (i.e., no external forces) remains constant before and after a collision. Mathematically, it can be expressed as:

   $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ where:

   - m_1 and m_2 are the masses of the two objects,
   - u_1 and u_2 are their initial velocities,
   - v_1 and v_2 are their final velocities.

This principle applies to both elastic and inelastic collisions, though in the case of elastic collisions, kinetic energy is also conserved.

ii) Determine the Final Velocities After the Collisions

Patience's Collision (Elastic Collision): Given:

- Mass of ball 1, m_1=3 kg,
- Initial velocity of ball 1, u_1=5 m/s
- Mass of ball 2, m_2=2 kg,
- Initial velocity of ball 2, u_2=0 m/s,
- Final velocity of ball 1, v_1=2.8 m/s,
- Final velocity of ball 2, v_2=V m/s.

Using the conservation of linear momentum:

$m_1u_1+m_2u_2=m_1v_1+m_2v_2$

Substitute the known values:

$3\times5+2\times0=3\times2.8+2\times V$

Simplifying the equation:

$15=8.4+2V$

Solving for V:

$15-8.4=2V$

$6.6=2V \qquad V = 6.6/2 = 3.3$ m/s

Thus, the final velocity of ball 2 is **3.3 m/s**.

Pius's Collision (Perfectly Inelastic Collision): Given:

- Mass of ball 1, $m_1=4$ kg,
- Initial velocity of ball 1, $u_1=3.5$ m/s,
- Mass of ball 2, $m_2=3$ kg,
- Initial velocity of ball 2, $u_2 = 6$ m/s,
- Final velocity of both balls, V m/sV \, \text{m/s} (same final velocity).

In this case, since the two balls stick together after the collision, we use the conservation of linear momentum:

$m_1u_1 + m_2u_2 = (m_1+m_2)V$

Substitute the known values:

$4\times3.5+3\times6=(4+3)V$

Simplifying the equation:

$14+18=7V$

$32=7V$

Solving for V:

$V = 32/7 \approx 4.57$ m/s

Thus, the final velocity of the two balls after the collision is approximately **4.57 m/s**.

b) Explanation of the Difficulty in Sinking the Jerrycan

As a physics learner, here's how I would explain to the young girl why it was difficult for her jerrycan to sink at first and easier after collecting some water:

1. **Difficulty in Sinking the Empty Jerrycan**: When the girl initially tries to sink the **empty jerrycan**, it has **low density** compared to the water. The buoyant force acting on the jerrycan (the upward force exerted by the water) is equal to the weight of the water displaced by the jerrycan. Since the jerrycan is

relatively light and has a large volume, it displaces enough water to exert an upward force greater than its weight, causing it to float. This is why it is **difficult to sink** the empty jerrycan.

2. **Ease in Sinking the Jerrycan After Collecting Water**: When the girl collects some water in the jerrycan, the total **mass of the jerrycan increases**. Since the jerrycan now contains water, it has **greater weight**. As the weight of the jerrycan increases, it displaces more water, and the buoyant force increases. Once the weight of the jerrycan exceeds the buoyant force, the jerrycan will sink easily because it is now denser than the surrounding water. This is why the girl was able to collect the water with ease after the jerrycan filled up.

ITEM 10 (PRESSURE)

James was sent by the director of studies to go and pick one box of chalk from the library. The box contained 150 pieces of chalk. Each piece of chalk has a radius of 2mm and a height of 7cm while the box measures 4mx3mx2m and weight of 120g. Unfortunately, when James was moving, he fell down and the box of chalk had to get broken by leaving ¾ of the total pieces into smaller pieces. The school instructed James to replace back the broken pieces of chalk. So what James did, had to go to the market and replace the broken chalk. Each piece of chalk costs UGX.50.

TASK

Determine the;

a) Maximum pressure that was exerted on the ground by the box.
b) Minimum pressure that could have been exerted on the ground.
c) Calculate the volume that was occupied by the 2/3 of the total pieces of chalk
d) Calculate the number of pieces chalk that were not broken
e) Find how much did James pay for the broken pieces of chalk

Let's go step by step to answer each part of the problem:

a) Maximum Pressure Exerted on the Ground by the Box

Pressure is defined as the force exerted per unit area and can be calculated using the formula:

$P = F/A$

Where:

- P is the pressure,
- F is the force,
- A is the area.

The **force** exerted by the box is its weight, which is given as 120 g, or 0.12 kg. The weight is the force due to gravity, which can be calculated as:

$F=mg$

Where:

- $m=0.12$ kg (mass of the box),

- $g=10\ m/s^2$ (acceleration due to gravity).

$F = 0.12\ kg \times 10\ m/s^2 = 1.2\ N$

The **area** is the area of the box's base. The dimensions of the box are 4 m, 3 m, and 2m. The area of the base is:

$A = \text{length} \times \text{width} = 4\ m \times 3\ m = 12\ m^2$

Now, calculate the maximum pressure:

$P = 1.2\ N/12\ m^2 = 0.1\ Pa$

So, the **maximum pressure** exerted on the ground by the box is 0.1 Pa.

b) Minimum Pressure Exerted on the Ground by the Box

To find the **minimum pressure**, we assume the box is resting on one of its smallest sides, which has an area of:

$A = \text{height} \times \text{width} = 2\ m \times 3\ m = 6\ m^2$

Now, calculate the minimum pressure:

$P = 1.2\ N/6\ m^2 = 0.2\ Pa$

Thus, the **minimum pressure** exerted on the ground by the box is 0.2 Pa.

c) Volume Occupied by 2/3 of the Total Pieces of Chalk

Each piece of chalk is cylindrical, and the volume of a cylinder is given by the formula:

$V=\pi r^2 h$

Where:

- $r=2\ mm=0.002\ m$ (radius of each chalk),
- $h=7\ cm=0.07\ m$ (height of each chalk),
- $\pi \approx 3.1416$.

Now, calculate the volume of one piece of chalk:

$V=3.1416\times(0.002\ m)^2\times 0.07\ m$
$V\approx 3.1416\times 4\times 10-6\times 0.07$
$V\approx 8.796\times 10-7\ m^3$

Now, calculate the total volume of **150 pieces of chalk**:

$V_{total} = 150\times 8.796\times 10-7\ m^3$
$V_{total} \approx 1.3194\times 10-4\ m^3$

Next, calculate the volume occupied by **2/3 of the chalk pieces**:

$V_{2/3} = 2/3 \times 1.3194 \times 10{-}4$ m3
$V_{2/3} \approx 8.796 \times 10{-}5$ m^3
Thus, the volume occupied by 2/3 of the total pieces of chalk is approximately **8.8×10^{-5} m^3**.

d) Number of Pieces of Chalk that Were Not Broken

James broke ¾ of the total pieces of chalk. Therefore, the number of pieces that were not broken is:

Pieces not broken = $1/4 \times 150 = 37.5$

Since the number of pieces must be a whole number, we round it to **38 pieces** of chalk that were not broken.

e) Cost of the Broken Pieces of Chalk

The number of broken pieces of chalk is ¾ of the total pieces, so:

Broken pieces = $3/4 \times 150 = 112.5$

Rounding to the nearest whole number, the number of broken pieces is **113 pieces**.

Each piece costs **UGX 50**, so the total cost for replacing the broken pieces is:

Cost=113×50 UGX=5650 UGX

Thus, James paid **UGX 5650** for the broken pieces of chalk.

ITEM 11 (WORK, ENERGY AND POWER)

During the term, the head teacher moved around the school to see whether learners had done some general cleaning. Firstly, he entered s.4 by moving 6m East from one corner of the class, then 2m South, 6m West and finally 2m North back to the corner where he had started from and went out of the class. He continued to check by going to the girls' dormitory which was 12m apart with S4 class. It took 4minutes for the head teacher to move from s4 to girls' dormitory. He found the dormitory captain for girls fighting with one student who was supposed to sweep the d0rmitory. The head teacher separated the two from fighting by throwing a ball of mass 145g at a speed of 25km/hr. with the energy of 50J to them. The ball got stuck on top of the roof of the dormitory of height 10m. Later alone the ball fell down

TASK

a) Determine the distance the head teacher moved while moving around s4 class and the displacement.
b) Determine the speed the head teacher moved with between girls' dormitory and s4 class.

By ignoring frictional forces,

c) Determine the velocity when the ball hits the ground.
d) Determine the kinetic energy of the ball as it hits the ground
e) Comment on how kinetic energy varies as the ball falls under the action of gravity.

Let's solve each part of the problem step by step.

a) Distance Moved and Displacement of the Head Teacher Around S4 Class

Distance Moved:

The head teacher moves as follows:

1. 6 m East
2. 2 m South
3. 6 m West
4. 2 m North

The total **distance** moved is the sum of all these movements:

Distance = 6 m+2 m+6 m+2 m= 16 m

Displacement:

Displacement is the straight-line distance from the starting point to the endpoint, with direction. Since the head teacher ends up back at the same point where he started, the **displacement** is **0 m**.

So, the answers are:

- **Distance moved** = 16 m
- **Displacement** = 0 m

b) Speed of the Head Teacher Moving Between Girls' Dormitory and S4 Class

We are told that it took 4 minutes for the head teacher to move from S4 to the girls' dormitory, which is 12 m apart.

First, we need to convert the time to seconds:

Time=4 minutes=4×60 seconds=240 seconds

Now, speed is given by the formula:

Speed = Distance/Time =12 m/240 s = 0.05 m/s

Thus, the **speed** of the head teacher moving between S4 and the girls' dormitory is **0.05 m/s**.

c) Velocity of the Ball When It Hits the Ground

We are told that the ball was thrown with an initial speed of 25 km/h, and it got stuck on the roof of the dormitory at a height of 10 m. We are asked to determine the **velocity** of the ball when it hits the ground.

To solve this, we will use the principles of **conservation of mechanical energy** (where potential energy at the top is converted to kinetic energy as it falls) and the kinematic equations for motion under gravity.

First, we need to convert the speed of the ball into meters per second:

Initial speed = 25 km/h = 25×1000/3600 m/s = 6.94 m/s

Now, we can calculate the final velocity when the ball hits the ground. Since the ball falls freely under gravity, we will use the kinematic equation:

$v^2 = u^2 + 2gh$

Where:

- v is the final velocity,
- u=6.94 m/s is the initial velocity (horizontal component),
- g=10 m/s^2 is the acceleration due to gravity,
- h=10 m is the height from which the ball falls.

Since the ball is initially moving horizontally and falling vertically, we need to calculate the vertical velocity and combine it with the horizontal velocity to get the resultant velocity at the point of impact.

Using the kinematic equation for vertical motion:

$V(vertical)^2 = 0^2+2gh$

$V(vertical)^2 = 2gh=2\times10\times10=200$

$v\approx14.14$ m/s

Now, the **total final velocity** is the vector sum of the horizontal and vertical velocities:

$V^2 = v(horizontal)^2 + v(vertical)^2$

$V^2 = (6.94)^2 + (14.14)^2 = 48.16+199.97=248.13$

$V \approx 15.77$ m/s

Thus, the **velocity** of the ball when it hits the ground is approximately **15.77 m/s**.

d) Kinetic Energy of the Ball When It Hits the Ground

The **kinetic energy** of an object is given by:

KE = 1/2mv

Where:

- m=145 g=0.145 kg (mass of the ball),
- v=15.77 m/s (velocity of the ball when it hits the ground).

Substitute the values:

$KE = 1/2\times0.145\times(15.77)^2K$

$KE = 0.0725\times248.13 \approx 18.0$ J

Thus, the **kinetic energy** of the ball when it hits the ground is approximately **18.0 J**.

e) How Kinetic Energy Varies as the Ball Falls Under Gravity

As the ball falls under the action of gravity, its **potential energy** (due to height) is gradually converted into **kinetic energy**. At the top of the fall (on the roof), the ball has maximum potential energy and zero kinetic energy (assuming it's not moving vertically initially). As the ball falls, its speed increases, and its kinetic energy increases while its potential energy decreases. When the ball hits the ground, all the potential energy has been converted into kinetic energy.

Thus, **kinetic energy increases** as the ball falls because it gains speed due to the acceleration from gravity.

ITEM 12 (HEAT AND PRESSURE)

A group of scouts on a camping trip noticed something peculiar about their flag at the lake shore. During hot days, the flag flew towards land and at night, it flew toward the sea, even when there was no wind. They were puzzled by this observation. Later, they met a local farmer who had recently built a dam on his farm. He was unsure about whether it was safe to fill the dam to its full capacity and why the walls of the dam were so thick. Additionally, the farmer was concerned about the quality of milk produced on his farm and suspected that his employees might be diluting it.

HINT:

The dam is 8m deep and can support a maximum pressure of $70000Pa$.

TASK

As a student of physics;

a) Explain to the scouts why the flag behaved that way.
b) Help the farmer understand the purpose of thick walls in the dam and advise him on filling the dam to capacity.
c) Suggest away for the farmer to determine if his milk was being diluted or if there were other factors affecting it.

Use: *density of water* $= 1000kgm^{-3}$

1) Explanation of Flag Behavior (Scouts' Observation)

The scouts noticed that during hot days, the flag flew towards land, and at night, it flew towards the sea, even without wind. This behavior is due to **differences in air pressure** caused by temperature changes, which results in **land and sea breezes**.

- **During the day**: The sun heats the land, causing the air above the land to warm up and expand. As the air becomes warmer, it becomes lighter (less dense) and rises, creating a **low-pressure zone** over the land. Cooler, denser air from the sea, which is relatively cooler than the land, flows into the low-pressure zone to replace the rising warm air. This movement of air from the sea towards the land is known as a **sea breeze**, which is why the flag blows toward the land during the day.
- **At night**: The land cools down more quickly than the sea. The air above the land becomes cooler and denser, creating a **high-pressure zone** over the land. Meanwhile, the air over the sea remains warmer and lighter. The cooler, denser air from the land moves toward the sea to replace the rising warmer air, creating a **land breeze**, which is why the flag flies towards the sea at night.

Thus, the flag's movement is due to the differences in air pressure caused by temperature variations between the land and the sea, leading to land and sea breezes.

2) Purpose of Thick Walls in the Dam and Safety of Filling It to Capacity

Purpose of Thick Walls in the Dam:

The dam's walls are thick to withstand the **hydrostatic pressure** exerted by the water stored in the dam. The pressure at the base of the dam increases with the depth of the water, and the thicker walls provide more strength and stability to prevent the dam from breaking under this pressure.

The **hydrostatic pressure** at a depth in a fluid is given by:

$P = \rho gh$

Where:

- P is the pressure at a given depth,
- $\rho = 1000\ kg/m^3$ is the density of water,
- $g = 10\ m/s^2$ is the acceleration due to gravity,
- h is the depth of the water.

For the dam, the maximum depth is 8 meters, so the pressure at the base of the dam is:

$P = 1000 \times 10 \times 8 = 80{,}000\ Pa$

However, the maximum pressure the dam can support is given as 70,000 Pa, which is **less than** the calculated pressure (80,000 Pa). This suggests that the dam **cannot safely be filled to its full capacity** without exceeding the pressure limits. The farmer should **fill the dam to a depth less than 8 meters** to ensure the dam remains safe, ideally ensuring that the water level does not create pressures higher than 70,000 Pa.

3) Determining if the Milk Was Being Diluted

To determine if the milk was being diluted, the farmer can measure the **density of the milk**. Fresh milk has a typical density close to that of water but slightly higher, around **1.03 kg/L**. If the milk is diluted with water, the density will decrease, as water has a lower density than milk.

The farmer can perform a simple experiment:

- **Measure the mass and volume** of a sample of milk.
- Calculate the density using the formula:

Density = Mass/Volume
If the density is found to be significantly less than the standard density of fresh milk (around 1.03 kg/L), it could indicate that the milk has been diluted with water.

Alternatively, the farmer can use a **lactometer** or a **refractometer**, both of which are devices that can measure the density or composition of milk. A lower-than-normal reading on these instruments would suggest dilution.

ITEM 13 (MECHANICAL PROPERTIES OF MATTER)

During the midday heat of a scorching day, district engineers made a visit to a construction site situated near a primary school. However, one of the engineers expressed concern about a foul odor emanating from the primary school latrines. This prompted him to approach the school administrators, who admitted their lack of knowledge regarding the cause of the odor, attributing it to hot weather conditions beyond their control. A week later the engineers presented their findings:

- Some construction materials lacked sufficient mechanical properties.
- Carrying concrete on their heads posed a risk to the builder's safety. They urged them to continue using concrete however recommended reinforcing concrete for increased strength.
- A small material of the same type as the iron bars used at the site measuring $14cm$ in length, exhibited an extension of $0.3cm$ when subjected to a load of $20kg$.

This information caused confusion among the builders.

HINT

The diameter of the iron sample material was $3 \times 10^{-2}mm$ *,the recommended iron bars should have a Young's modulus of at least* $4.0 \times 10^{9}Nm^{-1}$*, acceleration due to gravity,* $g = 10ms^{-2}$

TASK

Having acquired some physics knowledge, help

a) The builders understand
   i. The emphasized mechanical properties highlighted in the report.
   ii. Why they urged them to continue using concrete, what it means by reinforcing concrete and suggest alternative methods for transporting concrete to higher floors.
b) The builders evaluate whether the iron bars used were suitable for construction of such structures.
c) The school administrators understand why the odor worsened only during hot days and provide strategies to minimize the odor.

1) Understanding Mechanical Properties in the Report

The engineers highlighted **mechanical properties** of construction materials. In this context, these properties refer to how materials respond to applied forces, such as:

- **Strength**: The ability of a material to withstand an applied load without breaking.
- **Elasticity**: The ability of a material to return to its original shape after being deformed (e.g., stretching or compressing).
- **Young's Modulus**: A measure of the stiffness of a material, which quantifies the amount of strain experienced by a material when subjected to stress.

Young's Modulus (E) is particularly important in construction because it helps engineers understand how much a material will deform under load. The higher the Young's Modulus, the less the material will stretch or compress when subjected to a given force.

2) Why Concrete Was Recommended and What Reinforcing Concrete Means

Why Continue Using Concrete?

Concrete is commonly used in construction due to its **compressive strength**, which allows it to bear heavy loads. It's ideal for structural elements such as beams, columns, and foundations. Concrete also has the advantage of being relatively inexpensive and readily available.

What Does Reinforcing Concrete Mean?

Reinforced concrete is concrete that is embedded with **steel rebar (iron bars)** or **steel mesh** to improve its **tensile strength**. Concrete is strong in compression but weak in tension, so it can crack under tensile stress. Reinforcing concrete with steel bars (which are strong in tension) helps the structure resist both compressive and tensile forces, thereby making it safer and stronger.

3) Alternative Methods for Transporting Concrete to Higher Floors

Transporting concrete to higher floors on a construction site can be difficult if it's done manually. Here are a few safer and more efficient methods:

1. **Concrete Pumping**: A concrete pump can be used to move wet concrete from the ground level to the upper floors using hoses or pipelines.
2. **Elevators**: Construction site elevators or cranes can be used to lift the concrete (in buckets or other containers) to higher floors.
3. **Wheelbarrows or Carts**: For smaller amounts or when only small distances need to be covered, wheelbarrows or carts can be used to manually carry the concrete.

4) Evaluating Whether the Iron Bars Used Are Suitable for Construction

The engineer provided the following details:

- The **extension** of the iron sample is 0.3 cm when a **load** of 20 kg is applied.
- The **diameter** of the iron sample is 3×10^{-2} mm = 3×10^{-5} m.
- **Young's Modulus** of the iron bars should be at least $4.0\times10^{9}\ \text{Nm}^{-2}$

Step 1: Calculate the Force Applied

The force applied to the iron sample is the weight of the 20 kg load:

$F = mg = 20\ \text{kg}\times10\ \text{m/s}^2 = 200\ \text{N}$

Step 2: Calculate the Cross-Sectional Area of the Iron Sample

The cross-sectional area A of the sample is calculated from its diameter. Assuming the sample has a circular cross-section, the area A is given by:

$A=\pi r^2$

Where r = diameter/2 $=3\times10^{-5/}2 =1.5\times10^{-5}$ m.

$A = \pi(1.5\times10^{-5})^2 =7.07\times10{-}10\ \text{m}^2$

Step 3: Calculate the Strain

Strain (ϵ) is the ratio of extension (ΔL) to the original length (L) of the iron sample:

$\epsilon = \Delta L/L = 0.3 \text{ cm}/14 \text{ cm} = 0.0214$

Step 4: Calculate the Young's Modulus

Young's Modulus (E) is defined as the ratio of stress to strain:

$E = \text{Stress/Strain} = F/A\epsilon\}$

Substitute the values:

$E = 200 \text{ N}/7.07\times10-10 \text{ m}^2 x 0.0214$

$E = 2.83\times10^{11}/0.0214 \approx 1.32\times10^{12} \text{ Nm}^{-2}$

Since $1.32\times10^{12} \text{ Nm}^{-2}$ is much greater than the required $4.0\times10^{9} \text{ Nm}^{-2}$, the iron bars used are **much stronger** than necessary and are suitable for construction.

5) Why the Odor Worsened During Hot Days and How to Minimize It

Why the Odor Worsened:

The foul odor from the latrines is likely caused by **decomposition of organic matter** (such as fecal matter) in the presence of bacteria, which produces gases such as methane and hydrogen sulfide. **Temperature** affects the rate of chemical reactions and the activity of bacteria:

- **Hot weather** increases the rate of bacterial decomposition, causing the production of more odorous gases.
- **Increased evaporation** due to heat can also release these gases into the air, making the odor more noticeable.

Strategies to Minimize the Odor:

- **Ventilation**: Improving ventilation in the latrines by installing vents or fans can help disperse the gases and reduce the concentration of odors.
- **Regular Cleaning**: Cleaning the latrines more frequently can reduce the buildup of organic waste and decrease the odor.
- **Use of Deodorizers**: Adding substances that neutralize or absorb odors, such as charcoal, lime, or commercial deodorizers, can help.
- **Covering Waste**: Using covers for waste or placing chemicals that neutralize odors can prevent the release of gases into the air.

ITEM 14 (TURNING EFFECT)

The figure below shows a uniform metallic rod of length 4.0m pivoted at its centre that is used at a certain children's play resort.

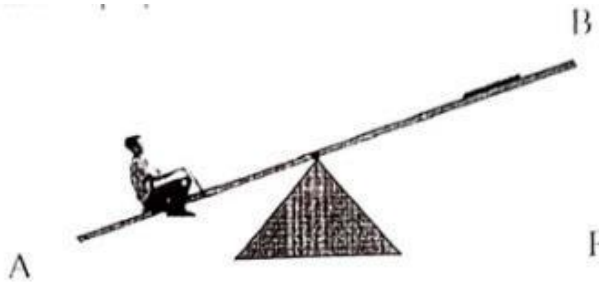


Figure 1

TASK

As a physics scholar;

a) Given that a boy of mass 48kg sits 1.5m from end A. Help the guide at play resort to determine if another boy of mass 40kg will restore equilibrium in the beam if he sits at a distance of 0.6m from the centre.
b) Identify two other instances in which the knowledge in this scenario would be applicable in real life.
c) With the boys off the rod, explain what would happen to the beam if the end B was heated by a considered hot flame.

solution

a) Equilibrium Condition

To determine whether the second boy will restore equilibrium, we need to apply the principle of **torque equilibrium**. For the beam to be in equilibrium, the sum of the torques (moments) about the pivot point must be zero. Mathematically, this means:

Sum of torques=0

The torque (τ) exerted by a force is given by:

$\tau = F \times d$

Where:

- F is the force applied (which is the weight of the boys, i.e., F=mg,
- d is the perpendicular distance from the pivot point to the point where the force is applied.

In this case:

- The first boy with a mass of 48 kg sits 1.5 m from **end A**. The weight of this boy is:

$F_1 = m_1 \times g = 48\ kg \times 10\ m/s^2 = 480\ N$

The torque due to this boy will be:

$\tau_1 = F_1 \times 0.5\ m = 480\ N \times 0.5\ m = 240\ Nm$

- The second boy with a mass of 40 kg is sitting at a distance of 0.6 m from the **centre**. The weight of this boy is:

$F_2 = m_2 \times g = 40\ kg \times 10\ m/s^2 = 400\ N$

The torque due to this boy will be:

$\tau_2 = F_2 \times 0.6\ m = 400\ N \times 0.6\ m = 240\ Nm$

For equilibrium, the sum of the torques on either side of the pivot must be equal, so:

$\tau_1 = \tau_2 = 240\ Nm = 240\ Nm$

b) Two Other Instances in Real Life

The concept of torque and equilibrium is commonly applied in various real-life situations, such as:

1. **Seesaw or Playground Swing**: The balance of a seesaw depends on the torques applied by the children sitting on it. If one child is heavier, they may need to move further from the pivot to balance the seesaw.
2. **Wrench and Nut**: When using a wrench to loosen a bolt or nut, the torque exerted by the force on the handle is what helps to turn the bolt. A longer wrench provides greater leverage, making it easier to apply the necessary torque.

c) Effect of Heating the Beam at End B

When end B of the metallic beam is heated by a hot flame, several things would happen:

1. **Expansion of the Metal**: Most metals expand when heated. The increase in temperature will cause the metal at end B to expand, resulting in the beam becoming slightly longer on that side. Since the beam is pivoted at its centre, this expansion will create a **bending** or **tilting** effect on the beam. The side of the beam that is heated (end B) will lengthen more than the other side (end A), causing the beam to tilt downwards at end B.
2. **Change in Shape**: The thermal expansion could lead to a **change in the angle** of the beam, making it uneven, and thus **destroying the equilibrium** of the system.
3. **Stress and Strain**: If the temperature increase is significant, it may cause **stress** in the material, especially if the expansion is not uniform across the entire beam, which could lead to **permanent deformation** if the material exceeds its elastic limit.

ITEM 15 (WORK, ENERGY AND POWER)

At a certain construction site in a given town casual labourers were required to raise construction materials to the 3rd level which was 2400m from the ground, they requested for a crane consisting of a pulley system of velocity ratio 7. The operator raised a total load of 40,000N using an effort of 8,000N.

TASK

As a learner of physics;

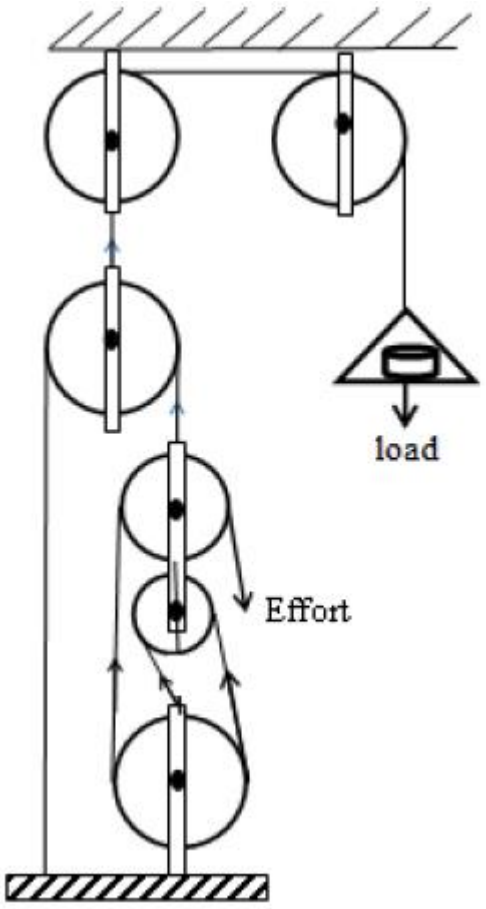
a) Draw a diagram to illustrate the pulley system contained in the crane.
b) Determine the efficiency of the pulley system.
c) (i) Explain why the efficiency of the machines is always less than 100% and state how it can be improved.
(ii)State the applications of pulleys in our daily life.

solution

a) Diagram of the Pulley System

The crane at the construction site uses a pulley system with a **velocity ratio** (VR) of 7. We can represent this system using a block and tackle configuration with 7 supporting ropes or pulleys.

Here's a simplified diagram:



- The load (40,000 N) is lifted by a system of pulleys.
- The operator applies an effort (8,000 N).
- The velocity ratio (VR) of the system is 7, meaning the effort distance is 7 times the load distance.

b) Determining the Efficiency of the Pulley System

The efficiency (η) of a pulley system can be calculated using the formula:

η= Mechanical Advantage (MA)/Velocity Ratio (VR)×100

Where:

- **Mechanical Advantage (MA)** is the ratio of the load force to the effort force:

  MA = Load/Effort = 40,000 N/8,000 N =5

- **Velocity Ratio (VR)** is given as 7.

Now, substitute the values into the efficiency formula:

$\eta = 57 \times 100 = 71.43\%$

Thus, the **efficiency of the pulley system is 71.43%**.

c) (i) Explanation of Why the Efficiency is Less Than 100%

Efficiency in a machine is always less than 100% due to **energy losses** caused by factors such as:

- **Friction** between the moving parts of the pulley system, which causes energy to be converted into heat.
- **Air resistance** affecting the load.
- **Deformation** of the ropes or pulleys under load.
- **Wear and tear** of the components over time, which increases friction.

To **improve the efficiency**, the following steps can be taken:

- **Lubricating the pulleys and ropes** to reduce friction.
- **Using materials** with low friction coefficients for the pulleys and ropes.
- **Regular maintenance** of the system to ensure all components are in good working condition.
- **Using high-quality, durable components** that reduce wear and tear over time.

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c) (ii) Applications of Pulleys in Daily Life

Pulleys are commonly used in various applications in daily life. Some examples include:

1. **Elevators**: Pulleys are used to lift and lower elevator cabins.
2. **Crane systems**: As in this problem, pulleys help lift heavy loads in construction sites.
3. **Well Systems**: Pulleys are used in traditional wells to lift water from the well.
4. **Theater Curtains**: Pulleys are used to lift and lower curtains on stage.
5. **Clotheslines**: Pulleys are used in clotheslines to help raise and lower clothes to dry them.
6. **Exercise Equipment**: Many gym machines use pulleys to lift weights.
7. **Garage Doors**: Pulleys are often used in automatic garage door systems to raise and lower the door.

ITEM 16 (WORK, ENERGY AND POWER)

For man to earn a living, he has to do some work. A certain business man has to climb 20 stairs each of height 20cm to reach out his business store on the first floor of their business Arcade in Kampala city.

TASK

As a physics scholar;

a) Help a lay man to understand the meaning of the term “work” and state its appropriate S.I units.
b) If the businessman has a mass of 73.5kg and is holding a bag of mass 1.5kg, determine the work done by the man when climbing the stairs and the power dissipated in 5minutes.
c) Explain why it is easier for the man to move down stairs than climbing them.

solution

a) Understanding the Term "Work" and Its SI Units

Work in physics refers to the transfer of energy that occurs when a force is applied to an object, and that object moves in the direction of the applied force. Mathematically, work is defined as:

Work = Force×Distance

Where:

- **Force** is the applied force (in Newtons),
- **Distance** is the displacement of the object in the direction of the force (in meters),

The **SI unit of work** is the **Joule (J)**, where:

1 J=1 Newton×1 meter

b) Work Done by the Man and Power Dissipated

We need to determine the **work done** by the businessman when climbing the stairs and the **power dissipated** in 5 minutes.

Work Done in Climbing Stairs

First, we calculate the **force** exerted by the businessman in lifting his body and the bag against gravity. The **force** is equal to the weight, which is given by:

Force = Total Mass×g

Where:

- **Total Mass** = Mass of the businessman + Mass of the bag = 73.5 kg + 1.5 kg = 75 kg
- **g** = acceleration due to gravity = 9.8 m/s²

Force = 75 kg×9.8 m/s^2 = 735 N

Now, we calculate the **distance** traveled in the upward direction. Each stair has a height of 20 cm, and the businessman climbs 20 stairs:

Distance = Height of One Step × Number of Steps =20 cm×20 = 400 cm= 4 m

Finally, the **work done** is:

Work = Force×Distance = 735 N×4 m = 2940 J

Power Dissipated in 5 Minutes

Power is the rate at which work is done. It is calculated as:

Power = Work/Time

Given that the time taken is 5 minutes (which is 300 seconds):

Power = 2940 /J300 s = 9.8 W

Thus, the **work done** by the businessman when climbing the stairs is **2940 J**, and the **power dissipated** is **9.8 W**.

c) Why It Is Easier to Move Downstairs Than Climbing Them

It is easier for the businessman to move **downstairs** than to climb them due to the **gravitational force** acting on his body.

1. **Climbing Up**: When climbing stairs, the businessman has to work against gravity to lift his body and the bag upwards. This requires energy because he needs to exert a force to overcome the gravitational pull. Essentially, his muscles are doing work to raise his body and bag against gravity.
2. **Moving Down**: When going downstairs, the force of gravity aids the movement, as it pulls the businessman downwards. The businessman doesn't need to exert as much effort. In fact, his muscles mainly act to control the descent and prevent falling too quickly. This makes the movement less energy-intensive compared to climbing.

ITEM 17 (WORK, ENERGY AND POWER)

A jackfruit of mass 2500g is plucked off fruit the jackfruit tree from a height 4m above the ground and falls freely. The jackfruit accelerated to the ground and hit the ground. **Task.**

As a learner of physics;

a) State and calculate the form of mechanical energy stored in the jackfruit before falling.
b) Determine the kinetic energy of the fruit as it hits the ground stating clearly the assumption and hence calculate the velocity with which it hits the ground.
c) Explain why the jackfruit comes to rest after hitting the ground and does not bounce back to the original height hence state the law shown by the behaviour of the fruit.
d) Determine the kinetic energy possessed by the fruit as it passes a point 1.5m above the ground.

solution

a) Mechanical Energy Stored in the Jackfruit Before Falling

Before the jackfruit falls, the mechanical energy is purely in the form of **gravitational potential energy (GPE)** because it is at a height above the ground.

Gravitational Potential Energy (GPE) is given by the formula:

$GPE = m \cdot g \cdot h$

Where:

- m = mass of the jackfruit = 2500 g = 2.5 kg (converted to kilograms),
- g = acceleration due to gravity = 9.8 m/s^2,
- h = height = 4 m.

Substituting the values:

$GPE = 2.5\ kg \times 9.8\ m/s2 \times 4\ m$
$GPE = 98\ J$

So, the mechanical energy stored in the jackfruit before falling is **98 J** and this is in the form of **gravitational potential energy**.

b) Kinetic Energy of the Fruit as It Hits the Ground and Velocity

As the jackfruit falls freely, its potential energy is converted into kinetic energy. When the fruit hits the ground, all the potential energy has been converted to kinetic energy (assuming no air resistance).

Kinetic Energy (KE) is given by:

$KE = 1/2mv^2$

Where:

- m = 2.5 kg (mass of the fruit),
- v = velocity of the fruit as it hits the ground (this is what we need to find).

Since all the potential energy has been converted to kinetic energy, we can equate the two:

GPE=KE

From part (a), we know the GPE is 98 J. So:

$98 = 12 \times 2.5 \times v^2$

Solving for v:

$98 = 1.25 \times v^2$
$v^2 = 98/1.25$
$v^2 = 78.4 m/s$
$v = 8.86 m/s$

Thus, the velocity with which the jackfruit hits the ground is approximately **8.86 m/s**.

c) Why the Jackfruit Comes to Rest After Hitting the Ground

The jackfruit comes to rest after hitting the ground because the **kinetic energy** of the fruit is converted into other forms of energy (such as **heat** and **sound**) when it hits the ground. The collision between the fruit and the ground is inelastic, meaning the energy is not fully conserved as mechanical energy.

When the fruit hits the ground:

- It compresses slightly, and this deformation dissipates some energy as **heat** and **sound**.
- The **elastic potential energy** that could have been stored in the fruit is not sufficient to overcome the energy lost in the collision, so it does not bounce back to its original height.

This behavior illustrates the **law of conservation of energy**, which states that energy cannot be created or destroyed, only transformed from one form to another. In this case, the mechanical energy of the falling fruit is transformed into heat, sound, and other forms of energy upon impact.

d) Kinetic Energy as the Fruit Passes a Point 1.5 m Above the Ground

At a height of 1.5 m, the jackfruit still possesses some potential energy, and part of the initial potential energy has been converted into kinetic energy. We can use the conservation of mechanical energy to determine the kinetic energy at this point.

At height h = 4 m, the total mechanical energy (initial GPE) was 98 J. At height h=1.5 m, part of this energy is still potential, and the rest is kinetic.

First, calculate the potential energy at 1.5 m:

GPE at 1.5 m $= m \cdot g \cdot h = 2.5\ kg \times 9.8\ m/s^2 \times 1.5\ m$
GPE at 1.5 m=36.75 J

The remaining energy is converted into **kinetic energy**. Since total mechanical energy is conserved:

KE at 1.5 m = Total Mechanical Energy−GPE at 1.5 m
KE at 1.5 m =98 J−36.75 J=61.25 J

Thus, the kinetic energy possessed by the jackfruit as it passes 1.5 m above the ground is **61.25 J**.

ITEM18 (DENSITY)

Some bottles of colourless liquids were being labelled when the technicians accidentally mixed them up and lost track of their contents. $\mathbf{15}.\mathbf{0}\boldsymbol{ml}$ sample withdrawn from one bottle weighed 22.3 g. The technicians knew that the liquid was either acetone, benzene, chloroform, or carbon tetrachloride. He however has challenges identifying the right chemical to label.

SUPPORT MATERIAL (hint 1ml =1cm^3)

LIQUID	Acetone	Benzene	Chloroform	Water	Carbon tetrachloride
DENSITY ($\boldsymbol{g/cm3}$)	0.792	0.899	1.487	1.0	0.595

a) What was the identity of the liquid? (Clearly show each step of your work out)
b) Using the table above Name those liquids which can float on water and explain why they float on water
c) Using the table Name those liquids on which water floats on top and explain why water floats on those liquids named.

a) Identifying the Liquid

We are given the following information:

- A 15.0 mL sample of liquid weighs 22.3 g.
- The liquids to choose from are: acetone, benzene, chloroform, and carbon tetrachloride.
- The density of the liquids is provided in the table.

Step 1: Calculate the density of the unknown liquid

Density is defined as:

Density = Mass/Volume

We know the mass of the sample is 22.3 g, and the volume is 15.0 mL (or 15.0 cm³ since 1 mL = 1 cm³).

Density of unknown liquid = 22.3 g/15.0 cm^3 = 1.487 g/cm^3

Step 2: Compare the calculated density with the provided densities

From the table, we see the densities of the given liquids:

- Acetone: 0.792 g/cm³
- Benzene: 0.899 g/cm³
- Chloroform: 1.487 g/cm³
- Carbon tetrachloride: 0.595 g/cm³

The density of the unknown liquid (1.487 g/cm³) matches the density of **chloroform**.

Conclusion:

The identity of the liquid is **chloroform**.

b) Liquids that can float on water

For a liquid to float on water, it must be **less dense** than water. The density of water is 1.0 g/cm³.

From the table, the following liquids have densities less than 1.0 g/cm³:

- **Acetone (0.792 g/cm³)**
- **Benzene (0.899 g/cm³)**
- **Carbon tetrachloride (0.595 g/cm³)**

These liquids can float on water because they are less dense than water, meaning they will not sink but will float on top of water.

Conclusion:

The liquids that can float on water are **acetone, benzene, and carbon tetrachloride**.

c) Liquids on which water floats on top

For water to float on top of a liquid, **the density of water must be less than the density of the liquid**. This happens when the liquid is denser than water.

From the table, the following liquids have densities greater than 1.0 g/cm³:

- **Chloroform (1.487 g/cm³)**

Water, with a density of 1.0 g/cm³, will float on top of **chloroform** because chloroform is denser than water.

Conclusion:

Water will float on top of **chloroform** because it is denser than water.

ITEM 19 (EXPANSION OF HEAT)

Zacharias is puzzled because his metallic doors are always very hard to close during day time when it is shining too much, and he says that the same doors are very easy to close in the evenings when the temperatures have lowered by considerable amounts.

TASK

As a Physics learner who understands better, the effect of temperature change on matter:

a) Explain the cause and applications of Zacharias' puzzle in our daily life

b) Basing on the kinetic theory, explain why liquids expand much more than solids for the same temperature change?
c) Explain the Biological importance of the anomalous expansion of water in preserving aquatic life in countries like Switzerland where temperatures go below 0^{o} C, relating to the diagram shown below.

a) Cause and Applications of Zacharias' Puzzle

Zacharias' puzzle can be explained by **thermal expansion** and **thermal contraction** of metals. Here's how it works:

- **Thermal Expansion**: When a material is heated, its particles (atoms or molecules) gain energy and vibrate more vigorously. This causes them to move apart, making the material expand.
- **Thermal Contraction**: Conversely, when a material is cooled, its particles lose energy and vibrate less, causing the material to contract as the particles move closer together.

In Zacharias' case:

- During the day, when the temperature is high, the metallic doors expand due to the heat from the sun. As the metal expands, the doors may become slightly larger, making it harder for the door to fit within its frame or to close properly.
- In the evening, when the temperature drops, the metal contracts, and the door shrinks, making it easier for Zacharias to close it.

Applications in Daily Life:

- **Railroad tracks**: Engineers design gaps between railroad tracks to allow for expansion during hot weather, preventing them from buckling.
- **Bridges**: Expansion joints are used in bridges to accommodate the thermal expansion and contraction of the material during different temperature changes.
- **Thermometers**: Mercury or alcohol thermometers rely on the expansion and contraction of the liquid inside the tube to measure temperature changes.

b) Why Liquids Expand More Than Solids for the Same Temperature Change (Kinetic Theory Explanation)

According to the **kinetic theory of matter**, the particles in matter are always in motion, and their motion increases with temperature. Here's how the kinetic theory explains why liquids expand more than solids:

- **Solids**: In solids, the particles are tightly packed in a fixed structure, and they can only vibrate in place. When the solid is heated, the particles vibrate more, but their movement is constrained by the rigid structure, so they can only move slightly apart. This results in a relatively small expansion.
- **Liquids**: In liquids, the particles are not as tightly packed as in solids, and they are able to move past each other. When the liquid is heated, the particles move more freely and can spread out more. This freedom of movement allows liquids to expand more than solids for the same temperature change.

Thus, the greater ability of liquid particles to move and spread out compared to solid particles leads to a larger expansion for the same increase in temperature.

c) Biological Importance of the Anomalous Expansion of Water in Preserving Aquatic Life

The **anomalous expansion of water** refers to the fact that water behaves unusually compared to most substances: as it cools, it initially contracts, but below 4°C, it begins to expand again until it freezes at 0°C. This

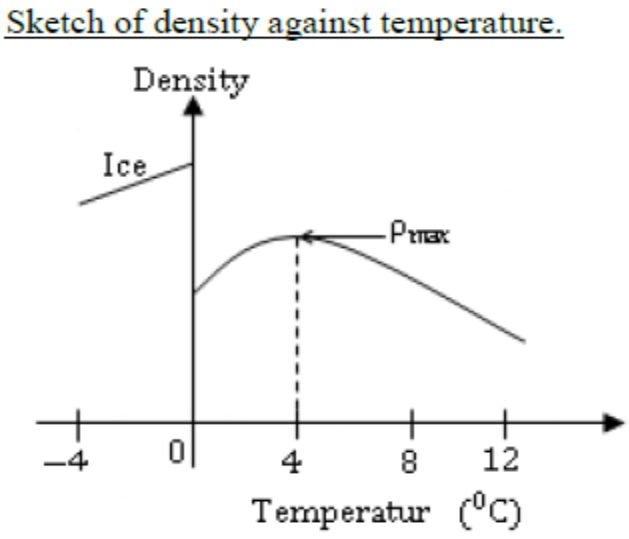
is crucial for life in aquatic environments, especially in colder regions like Switzerland, where temperatures can drop below 0°C.

Explanation:

- **Water Expands Upon Freezing**: As water cools below 4°C, it begins to expand, and at 0°C, it forms ice. This is unusual because most liquids contract when they cool. The expansion of water below 4°C causes ice to be less dense than liquid water, so ice floats on top of the water.

Diagram Explanation ():

- The diagram likely shows that the water density decreases as it approaches 0°C, and then the ice forms and floats on top of the liquid water.



Biological Importance:

- **Insulation for Aquatic Life**: When water freezes at the surface of lakes or rivers, it forms a layer of ice that insulates the water below, preventing it from freezing completely. This layer of ice acts as a barrier, keeping the water underneath at a stable temperature (usually above 0°C) even if the air temperature is below freezing.
- **Survival of Aquatic Life**: This insulation is crucial for the survival of aquatic organisms in cold climates. If the water at the surface were to sink, it could cause the entire body of water to freeze, which would be catastrophic for aquatic life. Instead, the ice on top prevents the water below from freezing, allowing fish and other organisms to survive even in freezing temperatures.

Conclusion:

The anomalous expansion of water is vital for the survival of aquatic life in colder climates, such as Switzerland, because it prevents lakes and rivers from freezing completely, thereby maintaining a habitable environment for organisms during the winter months.

ITEM 20 (LINEAR MOTION)

In certain town it's a must for drivers to be tested together with their vehicles for road worthiness. On certain day, a car started from rest and accelerated to 50m/s in ten seconds. The driver maintained that velocity for 20s and suddenly decelerated to rest in 2s making him to crash into the wind screen.

TASK

As a learner of physics,

a) Draw a graph to show the relationship between velocity and time for the car.
b) State whether the driver's average velocity does not exceed the town's speed limit of 8m/s.
c) Find the rate at which the car's velocity reduces
d) Explain why the driver crashed into the wind screen and how this can be prevented

a) Graph of Velocity vs. Time for the Car

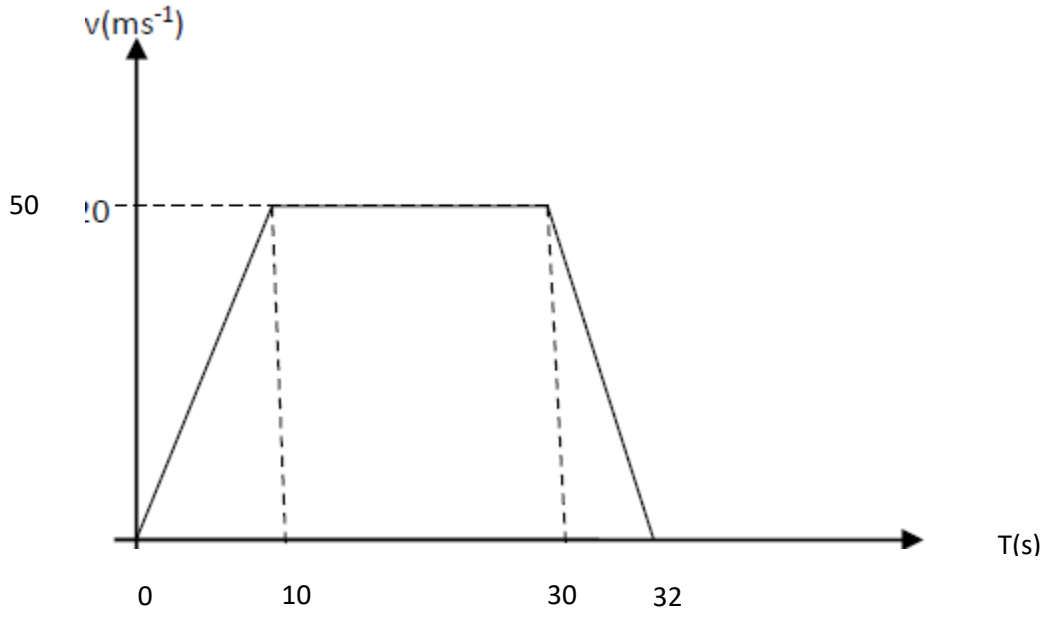
To draw the graph showing the relationship between velocity and time, we will break the motion into three stages:

1. **Acceleration (0 to 10 seconds)**: The car starts from rest and accelerates to 50 m/s in 10 seconds. This means the velocity increases steadily.
2. **Constant Velocity (10 to 30 seconds)**: The car maintains a constant velocity of 50 m/s for 20 seconds.
3. **Deceleration (30 to 32 seconds)**: The car decelerates from 50 m/s to 0 m/s in 2 seconds.

Here's a step-by-step breakdown:

- **From 0 to 10 seconds**: The car accelerates from 0 m/s to 50 m/s. The graph will be a straight line with a positive slope.
- **From 10 to 30 seconds**: The car travels at a constant velocity of 50 m/s. The graph will be a horizontal line at 50 m/s.
- **From 30 to 32 seconds**: The car decelerates from 50 m/s to 0 m/s. The graph will have a negative slope, ending at 0 m/s at the 32-second mark.

The graph will look like this:



- The graph starts at (0, 0) because the car starts from rest.
- The graph reaches 50 m/s at 10 seconds and stays flat until 30 seconds.
- The graph then slopes downward to 0 m/s at 32 seconds.

b) Does the driver's average velocity exceed the town's speed limit of 8 m/s?

To calculate the average velocity, we use the formula:

Average velocity = Total displacement/Total time

- **Displacement during acceleration (0 to 10 seconds)**: The car starts from rest and accelerates uniformly. The displacement can be found using the equation for displacement in uniformly accelerated motion:

Displacement = $1/2\times(u+v)\times t = 1/2\times(0+50)\times 10 = 250$ m

- **Displacement during constant velocity (10 to 30 seconds)**: The car travels at a constant velocity of 50 m/s for 20 seconds.

Displacement = $50\ m/s\times 20\ s = 1000$ m

- **Displacement during deceleration (30 to 32 seconds)**: The car decelerates uniformly from 50 m/s to 0 m/s in 2 seconds. The displacement is:

Displacement = $1/2\times(50+0)\times 2 = 50$ m
Now, add up the displacements:
Total displacement$=250+1000+50=1300$ m

The total time is 32 seconds. Now, calculate the average velocity:

Average velocity $=1300\ m/32\ s \approx 40.625$ m/s

Since the average velocity (40.625 m/s) is much higher than the town's speed limit of 8 m/s, **the driver's average velocity exceeds the speed limit**.

c) Find the rate at which the car's velocity reduces (deceleration)

During the deceleration phase, the car reduces its velocity from 50 m/s to 0 m/s in 2 seconds. To find the rate of deceleration, we use the formula for acceleration (or deceleration):

$a = \Delta v/\Delta t$

Where:

- $\Delta v = v_{final} - v_{initial} = 0-50 = -50$ m/s
- $\Delta t = 2$ seconds

Now, calculate the deceleration:

$a = -50\ m/s/2\ s = -25\ m/s^2$

Thus, the car's deceleration is **25 m/s²**.

d) Why the driver crashed into the windscreen and how to prevent it

The driver crashed into the windscreen during deceleration because the deceleration rate (25 m/s²) was very high. In such cases, the sudden reduction in velocity can cause the driver and passengers to continue moving forward due to inertia, which can lead to them being thrown into the windscreen if not properly restrained by seat belts.

Prevention:

To prevent such accidents, the following measures can be taken:

1. **Seat Belts**: Ensuring the driver and passengers are wearing seat belts is crucial. Seat belts reduce the impact of deceleration by restraining the motion of the body during sudden stops.
2. **Gradual Deceleration**: A less abrupt deceleration (i.e., slower and more controlled braking) would prevent the passengers from being thrown forward. This can be achieved by maintaining a safe following distance and braking gradually rather than abruptly.
3. **Airbags**: Airbags can also help cushion the impact during a sudden deceleration, reducing the risk of injury.

In general, abrupt decelerations should be avoided whenever possible to ensure the safety of the driver and passengers.

ITEM 21 (HEAT MEASUREMENT)

In a certain home, it is the children's responsibility to draw water for cooking and also to boil it for drinking. They draw the water from an underground well using a rope and a bucket. The children have raised a complaint to their father that pulling water using a rope and a bucket is tiresome and are suggesting that a simple machine for drawing water be designed for them. Every day, they use an aluminium saucepan of mass 2 kg to boil 10 litres of water from a temperature of 24 ^{0}C to 90 ^{0}C. The father is planning to address his children's concern but is not certain of how to solve it, and is looking for guidance.

TASK

Using the knowledge of physics, help the father to;

a) i) Design the simple machine that can be used and explain how it works.

(ii) Understand how to improve on efficiency of the machine designed in (a)(i).

b) Understand how much heat energy is used daily by the family to boil drinking water.

Use;

Specific heat capacity of aluminum $= 900Jkg^{-1}K^{-1}$

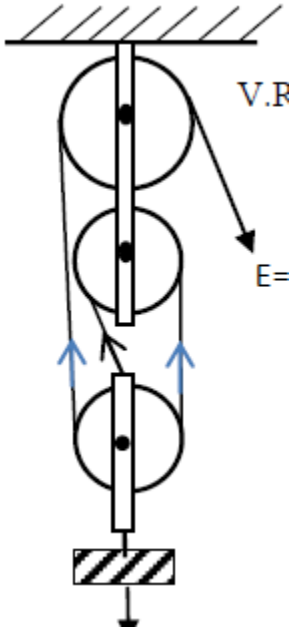
Specific heat capacity of water $= 4200Jkg^{-1}K^{-1}$

Density of water $= 1000kgm^{-3}$

Solution

a) Design a Simple Machine for Drawing Water

i) **Design of the Simple Machine**: The children are finding it tiring to draw water using a rope and bucket. To reduce the effort involved in lifting the water from the well, a **pulley system** can be designed.



How it Works:

A **pulley** is a simple machine that changes the direction of the force needed to lift an object. By using a **fixed pulley** or a **combination of fixed and movable pulleys** (called a **block and tackle system**), the children can reduce the force needed to lift the water. Here's how the pulley system works:

- **Fixed Pulley**: The pulley is fixed at the top of the well. The rope runs over the pulley, and one end of the rope is attached to the bucket while the other end is pulled by the children. The force required to pull the bucket is the same as lifting the weight of the water, but the rope's direction changes, which is helpful.
- **Movable Pulley**: By attaching a movable pulley to the bucket, the children can use a block and tackle system. In this setup, the force required to lift the bucket is reduced because the weight of the bucket is shared by multiple ropes. This makes the task easier for the children.

Example Design:

- A **single fixed pulley** could reduce the effort of pulling the water by changing the direction of the force.
- A **block and tackle system** could further reduce the effort by distributing the load over multiple pulleys, so the children can lift the bucket with less force.

ii) **Improving Efficiency of the Pulley System**: The efficiency of a pulley system depends on the friction in the pulleys and the ropes. Here's how to improve the efficiency:

1. **Use Low-Friction Pulleys**: Choose pulleys made from materials like metal or plastic with low friction. This will reduce energy loss as the rope moves over the pulleys.
2. **Use Strong, Smooth Ropes**: Ensure the rope is strong and smooth so it moves easily over the pulleys with minimal friction.

3. **Lubricate the Pulleys**: Apply lubricant to the moving parts of the pulley system to reduce friction further and make the system work more efficiently.
4. **Use the Right Number of Pulleys**: Too many pulleys can add unnecessary friction, while too few can make the system inefficient in reducing the effort required. The right combination of fixed and movable pulleys will balance the mechanical advantage and efficiency.

b) Heat Energy Used Daily to Boil Drinking Water

To calculate the amount of heat energy required to boil the water, we can use the **specific heat capacity** formula:

$Q = mc\Delta T$

Where:

- Q = heat energy (Joules)
- m = mass of the substance (kg)
- c = specific heat capacity of the substance (J/kg·K)
- ΔT = change in temperature (°C or K)

Step 1: Calculate the Heat Energy for Boiling the Water

- **Mass of water**: The mass of 10 liters of water is $10\ L \times 1\ kg/L = 10\ kg$ (since the density of water is $1000\ kg/m^3$).
- **Specific heat capacity of water**: $c_{water} = 4200\ J/kg \cdot K$
- **Temperature change**: $\Delta T = 90°C - 24°C = 66°C$

Now, calculate the heat energy required to heat the water:

$Q_{water} = m_{water} \times c_{water} \times \Delta T$

$Q_{water} = 10\ kg \times 4200\ J/kg.K \times 66\ K$

$Q_{water} = 2{,}772{,}000\ J$

So, the heat energy required to boil the 10 liters of water is **2,772,000 J** (Joules).

Step 2: Calculate the Heat Energy for Boiling the Aluminum Pan

Next, we calculate the energy required to heat the aluminum pan, which is also heated from 24°C to 90°C.

- **Mass of aluminum pan**: $m_{aluminum} = 2\ kg$
- **Specific heat capacity of aluminum**: $c_{aluminum} = 900\ J/kg \cdot K$
- **Temperature change**: $\Delta T = 66°C$

Now, calculate the heat energy required to heat the aluminum pan:

$Q_{aluminum} = m_{aluminum} \times c_{aluminum} \times \Delta T$

$Q_{aluminum} = 2\ kg \times 900\ J/kg.K \times 66\ K$

$Qaluminum = 118{,}800\ J$

So, the heat energy required to heat the aluminum pan is **118,800 J**.

Step 3: Total Heat Energy Used

To find the total energy used to boil both the water and the pan:

$Q_{total}=Q_{water}+Q_{aluminum}$

Q_{total} = 2,772,000 J+118,800 J

Q_{total}=2,890,800 J

Therefore, the total heat energy used daily by the family to boil drinking water is **2,890,800 J**.

ITEM 22

Ms. Kobusingye is a new mother who has given birth to a new born child in Kalama village last month of March. The Doctor advised Ms. Kobusingye to bathe the child with water at temperatures ranging from **35^0**C to **45 ^{0}C** to avoid skin burn of the new born child. When Ms. Kobusingye told her mother-in-law, the mother-in-law boiled **2 liters** of water up to **70 ^{0}C**.If mother-in-law tasked her last born to mix the boiled water with **4 liters** of cold water at **15 ^{0}C** in a basin.

TASK

i. If you were the last born, help your mother to know if the water has cooled to the required temperature as directed by the doctor to Ms. Kobusingye.
ii. When your brother who lives in Kampala heard that his wife Kobusingye gave birth to their first-born baby he traveled to their village where the wife gave birth. When he arrived, everyone run to welcome him from the gate before bathing the child. Advise your mother on how she can keep the boiled water hot.
iii. If the building they live in has upper flow and the bath room is in the upper room. Your brother who came wants to take his bathe and your mother said the water should not be carried via stair case. As a physics learner, give other ways you use to transport water to the bathroom for your brother in the upper room. **(3 scores)**

HINT

Specific heat capacity of water, $\boldsymbol{c_w = 4200 Jkg^{-1}k^{-1}}$

Density of water, $\boldsymbol{c_w = 1000 Jkgm^{-3}}$

Specific heat capacity of basin, $\boldsymbol{c_b = 120 Jkg^{-1}k^{-1}}$

Mass of basin $M_b = \boldsymbol{6\ kg}$

Acceleration due gravity $= \boldsymbol{10 ms^{-2}}$

Take **1 liter of water** = **1 kg**

solution

i) Identify the masses and temperatures of the water involved.

- Mass of boiled water (m_1) = 2 liters = 2 kg
- Initial temperature of boiled water (T_1) = 70 °C
- Mass of cold water (m_2) = 4 liters = 4 kg
- Initial temperature of cold water (T_2) = 15 °C

Use the principle of conservation of energy to find the final temperature (T_f) of the mixture. The heat lost by the hot water will equal the heat gained by the cold water.

The formula is:

$M_1 \times c_w \times (T_1 - T_f) = m_2 \times c_w \times (T_f - T_2)$

Since the specific heat capacity (c_w) cancels out, we have:

$m_1 \times (T_1 - T_f) = m_2 \times (T_f - T_2)$

3. Substitute the known values into the equation:

$2 \ (70 - Tf) = 4 \ (T_f - 15)$

4. Expand and simplify the equation:

$140 - 2T_f = 4T_f - 60$

5. Rearrange the equation to solve for Tf:

$140 + 60 = 4T_f + 2T_f$

$200 = 6T_f$

$T_f = 200/6 \approx 33.33°C$

6. Check if the final temperature is within the advised range (35 °C to 45 °C):
    - The final temperature is approximately 33.33 °C, which is below the advised range.

ii) Advise on keeping the boiled water hot.

Advice: To keep the boiled water hot, Ms. Kobusingye can:

1. **Use a Thermos:** Transfer the hot water into a thermos to minimize heat loss.
2. **Cover the Basin:** If using a basin, cover it with a lid or a thick blanket to retain heat.
3. **Use Insulating Materials:** Place the basin on an insulating surface or wrap it in towels to reduce heat loss.

iii) Alternative methods to transport water to the upper bathroom.

1. Identify alternative methods to transport water:
    1. **Use a Pulley System:** Set up a pulley system to lift the water from the ground floor to the upper floor.
    2. **Use a Bucket on a Rope:** Lower a bucket tied to a rope from the upper floor to fill with water and then pull it back up.

3. **Use a Water Pump:** If available, use a water pump to transfer water directly to the upper bathroom.

ITEM 23 (MEASUREMENTS)

Rita has just completed her primary seven at heavens primary school and admitted to standard high school. On reaching the school, she was told by her friends that she needs to take 10 books to class each day for the lesson. She was given 20 black books from the bursar's office, each of dimensions 30cm by21cm by 2cm. And was given a bag that has a volume 10080 cm3. She is really wondering of how she will be carrying the books to class in the bag every morning.

TASK

a) If Rita can only take the books that can fit in the bag, help her determine how many books she can carry at a time.

b) If she sits on a single sitter of the upper deck of dimensions 105cm by 18cm. how many books can she put on the upper deck at a time.

c) If Rita reported late and she found that the teacher had already taught about fundamental and derived quantities, how best can you help her differentiate between the two giving example in each case

solution

a) How many books Rita can carry at a time

To determine how many books Rita can carry at a time, we need to compare the volume of the bag with the volume of each book.

1. **Volume of one book**: The dimensions of one book are 30 cm by 21 cm by 2 cm. So, the volume of one book can be calculated as:

Volume of one book = length×width×height = 30 cm×21 cm×2 cm

Volume of one book=1260 cm^3

2. **Volume of the bag**: The volume of the bag is given as 10080 cm^3.
3. **Number of books that can fit in the bag**: To find out how many books can fit in the bag, divide the volume of the bag by the volume of one book:

Number of books = Volume of bag/Volume of one book=10080 cm^3/1260 cm^3

Number of books=8

Therefore, Rita can carry **8 books** at a time.

b) How many books can Rita put on the upper deck of the bus

The dimensions of the upper deck are given as 105 cm by 18 cm. To find out how many books can fit on the upper deck, we first calculate the area of the deck and the area required by each book when laid flat.

1. **Area of the upper deck**: The area of the deck is:

Area of upper deck=105 cm×18 cm=1890 cm^2

2. **Area of one book**: If the book is laid flat, the area it occupies is the length × width:

Area of one book=30 cm×21 cm=630 cm^2

3. **Number of books that can fit on the upper deck**: Divide the area of the upper deck by the area of one book:

Number of books= Area of upper deck/Area of one book =1890 cm/2630 cm2

Number of books=3

Therefore, Rita can put **3 books** on the upper deck at a time.

c) Differentiating between fundamental and derived quantities

- **Fundamental quantities** are the basic physical quantities that cannot be defined in terms of other quantities. They are independent and form the foundation of physical measurement. The SI system defines seven fundamental quantities:
    1. **Length** (meter, m)
    2. **Mass** (kilogram, kg)
    3. **Time** (second, s)
    4. **Electric current** (ampere, A)
    5. **Thermodynamic temperature** (kelvin, K)
    6. **Amount of substance** (mole, mol)
    7. **Luminous intensity** (candela, cd)

Example:

- **Length**: The length of a rod is measured in meters (m).
- **Time**: The time taken for an event to occur is measured in seconds (s).

- **Derived quantities** are physical quantities that are derived from fundamental quantities through mathematical relationships (such as multiplication or division). These quantities are combinations of fundamental quantities.

Example:

- **Speed**: Speed is derived from distance (length) and time, and its SI unit is meters per second (m/s).
- **Force**: Force is derived from mass and acceleration (both of which are fundamental quantities). The SI unit of force is newton (N), where $1\ N = 1\ kg \cdot m/s^2$.

To summarize:

- **Fundamental quantities**: Length, mass, time, etc.
- **Derived quantities**: Speed, force, energy, etc.

ITEM 24

Juliet and Rahman failed to agree in a discussion that was organized towards the end of term one last year. The discussion was whether energy exists in forms or not. Juliet said there can't be forms of energy whereas Rahman said they exist about seven of them. During holiday of Term 3, the father asked his son to go and join a

certain construction site. As he was at work, an engineer lifted a heavy stone of2, 200kg from a deep hole through a vertical height of 7m from the bottom of the hole using crane within 2 minutes.

TASK

a) As a S.2 student, write a report guiding them clearly about their argument and include the applications of content in daily life.
b) As a physicist, help him to get how much work was done by the crane and its power. (Use g =10ms^{-2}).

a) Report on Forms of Energy

Introduction
Energy is a fundamental concept in physics, and it plays a central role in understanding how the world around us functions. The argument between Juliet and Rahman stems from whether energy can exist in different forms or not. To settle this debate, let's explore the nature of energy and its various forms.

Energy and its Forms
Energy indeed exists in different forms, and these forms are how energy manifests in the physical world. Some of the most common forms of energy include:

1. **Kinetic Energy**: This is the energy an object possesses due to its motion. For example, a moving car or a flowing river has kinetic energy.
2. **Potential Energy**: This is energy stored in an object due to its position or configuration. A book held at a height has gravitational potential energy, as does water stored behind a dam.
3. **Thermal Energy**: This is the energy associated with the temperature of an object. It arises from the random motion of molecules and atoms in a substance. A hot cup of coffee or a heated stove are examples of objects with thermal energy.
4. **Chemical Energy**: This form of energy is stored in the bonds of atoms and molecules. It is released during chemical reactions, such as in the burning of wood or the metabolism of food.
5. **Electrical Energy**: This is energy caused by the movement of electric charges. It powers devices like light bulbs, phones, and computers.
6. **Nuclear Energy**: This is energy stored in the nucleus of atoms. It can be released during nuclear reactions, as seen in nuclear power plants or the sun's fusion process.
7. **Radiant Energy**: This is the energy carried by electromagnetic waves, including light, radio waves, and X-rays. Solar energy is an example of radiant energy.

Applications in Daily Life

- **Kinetic Energy**: Used in transportation (cars, bicycles) and in the motion of machines.
- **Potential Energy**: Water in dams has potential energy, which can be converted into electricity.
- **Thermal Energy**: Used for cooking (stoves, ovens) and heating (central heating systems).
- **Chemical Energy**: Used in batteries (for phones, laptops) and fuels (for vehicles).
- **Electrical Energy**: Powers almost all electronic devices, from refrigerators to televisions.

- **Nuclear Energy**: Provides power in nuclear reactors, offering a clean energy source.
- **Radiant Energy**: Solar panels convert solar energy into electrical energy.

Conclusion
Juliet's view that energy does not have forms is incorrect. Rahman is right that energy exists in several distinct forms, which can be transformed from one to another. Understanding these forms is crucial for understanding many physical phenomena and is applied extensively in our daily lives to power machines, transport, and perform various other tasks.

b) Physics Problem: Work Done and Power

Now, let's calculate the work done and the power exerted by the crane on the stone.

Given:

- Mass of the stone, $m=2200$ kg
- Height lifted, $h=7$ m
- Gravitational acceleration, $g=10$ m/s^2
- Time taken to lift the stone, $t=2$ minutes$=120$ seconds

1. Work Done by the Crane:

Work done is defined as the force applied to an object multiplied by the distance over which the force is applied. The force required to lift the stone is equal to its weight, which is the product of mass and gravitational acceleration.

The formula for work done is:

$W= F \times h$

where F is the force and h is the height.

The weight (force) of the stone is:

$F = m \times g = 2200 \text{ kg} \times 10 \text{ m/s}^2 = 22{,}000 \text{ N}$

Now, calculating the work done:

$W=22{,}000 \text{ N} \times 7 \text{ m}=154{,}000 \text{ J}$

So, the work done by the crane is **154,000 Joules**.

2. Power Exerted by the Crane:

Power is the rate at which work is done. The formula for power is:

$P= Wt$

where W is the work done and t is the time taken.

Substituting the values:

$P = 154{,}000 \text{ J} \times 120 \text{ s} = 1283.33 \text{ W}$

So, the power exerted by the crane is **1283.33 Watts** or approximately **1.28 kW**.

Conclusion

- The **work done** by the crane is **154,000 Joules**.
- The **power** exerted by the crane is approximately **1.28 kW**

ITEM 25

JOAN bought two oranges and two eggs from a market as they went to the trip after which they went for a boat ride on Lake Victoria. She had feared to sit in the boat because it was made of metals of which she knew that it was denser than water. However looking the other side of the lake, she discovered that it was possible for the boat to float on water even though it is metallic. While on the boat, she peeled one of the oranges and accidentally the peeled and the unpeeled oranges fell in water, she was again amazed by the fact that the peeled one sunk and the unpeeled one floated and was able to get it back.

TASK

As a physics student, explain Joan's observations .

1. Why the Metal Boat Floats Despite Being Denser Than Water

Joan was initially afraid to sit in the boat because she knew that metals are typically denser than water. However, the boat still floated. This phenomenon can be explained by **Archimedes' Principle**, which states that:

"An object submerged in a fluid experiences an upward buoyant force equal to the weight of the fluid displaced by the object."

For an object to float, the buoyant force must equal the weight of the object. Even though metals are denser than water, the **boat** is shaped in such a way that it displaces a large volume of water relative to its weight. Here's why the boat floats:

- **Density** is mass per unit volume. Metals like iron or steel are indeed denser than water, but the boat is designed with a **hollow shape** (having a large volume and a low mass), meaning the overall density of the boat (including the air inside it) is less than that of water.
- As a result, the boat displaces enough water to produce a buoyant force that is greater than or equal to the weight of the boat. This is why the boat floats on water even though the material itself is denser than water.

Key Point: It's the **overall density** of the boat (including air) that matters. A boat can float as long as it displaces enough water to counteract its weight.

2. Why the Peeled Orange Sinks and the Unpeeled Orange Floats

Joan was amazed to see that when both oranges (peeled and unpeeled) fell into the water, the unpeeled orange floated while the peeled orange sank. This can be explained using the concept of **density** and **buoyancy**:

- **Density of the Oranges**: An object will float in a fluid if its density is less than the density of the fluid (in this case, water). If the density of the object is greater than that of water, it will sink.
- The **unpeeled orange** has a peel that is **less dense** than water and also traps air inside it. This air-filled structure makes the unpeeled orange **more buoyant**, allowing it to displace enough water to produce an upward buoyant force greater than its weight. As a result, the unpeeled orange **floats**.

- The **peeled orange**, on the other hand, loses the buoyant effect of the peel and the air it trapped. Without the peel, the fruit's pulp is denser and denser than water, causing the peeled orange to displace less water and therefore sink.

Key Points:

- The **peel of the orange** is lighter and less dense than water, contributing to the buoyancy of the unpeeled orange.
- When the orange is peeled, the peel is removed, and the remaining fruit pulp is denser than water, causing it to sink.

Conclusion

- **Metal Boat Floating**: The metal boat floats because it is designed to displace a large volume of water, making the overall density of the boat (including air inside) less than the density of water, thus allowing it to float according to Archimedes' Principle.
- **Peeled Orange Sinking and Unpeeled Orange Floating**: The unpeeled orange floats because its peel and air trapped inside make it less dense than water. The peeled orange sinks because the removal of the peel makes the remaining pulp denser than water, leading it to sink.

ITEM 26

Ibrahim was driving under a light drizzle towards Jinja at 45 kmh-1. 2 km after leaving Mukono town, motorcycle rider suddenly skidded off the road 85 m in front of the car. Ibrahim immediately applied his brakes but it was a useless move. There was an accident but fortunately enough, no one sustained injuries.

The slammed onto the motorcycle despite the vigorous application of brakes. Soon after the police arrived at the accident scene and carried out their own Observations and measurements.

a) By simply looking at the car tyres, why did the Police Officers conclude that the car was in bad mechanical condition, yet the car was fairly new as it was only one year old? (04 scores)

b) What was the problem between the tyres and the road? (04 scores)

c) What should the tyres have looked like? (02 scores)

d) What should have been the case between the tyres and the road for a car in good mechanical condition?

e) From the above scenario, how is friction useful? (05 scores)

solution

a) Why the Police Officers Concluded the Car Was in Bad Mechanical Condition

The police officers concluded that the car was in bad mechanical condition despite being fairly new (only one year old) by observing the **tyres**. The likely reason for their conclusion could be the **tyres' tread wear** or **lack of proper traction** on the road. Here's why:

- **Tread wear**: If the tyres were bald or had worn-out treads, the car would not have been able to grip the road properly, especially in slippery conditions such as light drizzle. Worn-out tyres increase stopping distance and reduce traction, making the car prone to skidding or accidents. Even though the car was new, poor maintenance or substandard tyres could have caused this issue.

- **Tyre pressure**: The tyres could have been under-inflated, which can also reduce the vehicle's grip on the road, leading to an accident even with a fairly new car.

b) What Was the Problem Between the Tyres and the Road?

The problem between the tyres and the road was likely the **reduced friction**. This could have been caused by one or more of the following:

1. **Tyre wear or bald tyres**: If the tyres were worn out, they would not have been able to maintain adequate contact with the road surface, reducing the friction between the tyres and the road. This would result in the car losing grip and sliding, especially on wet or slippery surfaces.
2. **Wet or slippery road surface**: The drizzle made the road slippery, reducing the friction between the road and the tyres. If the tyres were in poor condition, they would not have been able to create enough friction to stop the car in time.
3. **Tyre pressure**: Incorrect tyre pressure can also affect the contact between the tyres and the road, reducing the efficiency of friction and thus the ability to stop the vehicle.

c) What Should the Tyres Have Looked Like?

The tyres should have had **adequate tread depth** and should not have been worn out. Here's what they should have looked like:

1. **Tread patterns**: The tread should be deep and well-defined. These patterns help channel water away from the tyre, preventing hydroplaning (where the tyre rides on a thin layer of water and loses contact with the road).
2. **Even wear**: The tyres should have even wear across the surface. Uneven wear can be a sign of alignment or suspension problems, which could affect the car's ability to stop properly.
3. **Proper tyre pressure**: The tyres should have been properly inflated to the recommended pressure. This ensures the maximum contact area with the road, optimizing traction and braking ability.

d) What Should Have Been the Case Between the Tyres and the Road for a Car in Good Mechanical Condition?

For a car in good mechanical condition, the following should have been the case between the tyres and the road:

1. **Adequate friction**: The tyres should have provided good friction between the car and the road surface, allowing the car to stop effectively, even in wet conditions.
2. **Good tread depth**: The tyres should have had sufficient tread depth, ensuring that the car could maintain a proper grip on the road, especially in wet or slippery conditions like the drizzle described.
3. **Proper alignment and suspension**: The car's alignment and suspension should have been in good condition, ensuring that the tyres made even contact with the road, improving stability and reducing the chances of skidding.
4. **Correct tyre pressure**: The tyres should have been properly inflated, ensuring optimal contact with the road and better braking performance.

e) How Is Friction Useful in This Scenario?

In this scenario, friction plays a crucial role in the car's ability to stop and in the car's overall control. Here's how friction is useful:

1. **Braking**: Friction between the car's tyres and the road allows the brakes to convert the car's kinetic energy into heat, slowing down the vehicle. In this case, friction could have helped Ibrahim stop the car in time if the tyres were in good condition.
2. **Prevents skidding**: Adequate friction prevents the car from sliding or skidding, which is important when driving on a wet or slippery surface. The tyres' ability to grip the road ensures stability, even in difficult conditions.
3. **Maintains control**: Friction between the tyres and the road helps the driver maintain control of the car. Without enough friction, the car would not have been able to steer properly, and the likelihood of an accident increases.
4. **Safety in slippery conditions**: In the case of rain or drizzle, friction is particularly important. It prevents the car from hydroplaning (losing contact with the road surface) and ensures that the car can stop or slow down effectively.
5. **Stopping distance**: Adequate friction helps reduce the stopping distance of a vehicle. In this scenario, the reduced friction (due to bad tyres or slippery road conditions) contributed to the car's inability to stop in time to avoid the accident.

ITEM 27

Senior Two students of Fountain of Hope High School visited a textile industry at Kalangala Island. They used MV Kalangala Ferry to cross the lake to the Island. On the Ferry, they loaded all their cargo including the school bus. They were all amused to see that the ferry could not sink. On reaching the industrial site, they observed the following:

- Sharp knives being used to cut the cotton bales.
- Factory trucks being lifted up on a hydraulic machine for servicing and maintenance.
- Overhead tanks supplying water to the different sections of the factory.
- Sprinklers watering flowers in the backyard of the factory.
- Small aircrafts (helicopters) airlifting cargo and employees to the mainland.
- Workers using vacuum cleaners to remove dust from carpets.

These learners were eager to understand how all these activities were possible and what principles they operate on.

Supposing you are an industry tour guide

TASK

Write a detailed explanation for each of the above observations including why the ferry did not sink and how the aircraft is able to fly. (20 scores)

SOLUTION

1. Why the MV Kalangala Ferry Did Not Sink

The **ferry** did not sink despite carrying a significant amount of cargo, including a school bus. This is because the ferry's ability to float is explained by **Archimedes' Principle** and the concept of **buoyancy**.

- **Archimedes' Principle** states that an object submerged in a fluid experiences an upward buoyant force equal to the weight of the fluid it displaces. The ferry, although heavy, displaces a large volume of water due to its size and design.
- The **density** of the ferry (including the air inside) is less than that of water, so the overall **average density** of the ferry (including the cargo) is less than the density of water. As a result, the buoyant force (upward force) is greater than or equal to the weight of the ferry, causing it to float rather than sink.
- The **hull of the ferry** is designed to displace a large volume of water, and this displacement produces the necessary buoyant force to keep the ferry afloat.

2. Sharp Knives Used to Cut Cotton Bales

Sharp knives are used to cut cotton bales efficiently due to the principle of **force concentration** and **pressure**. Here's why:

- **Pressure** is defined as force per unit area. A sharp knife has a very **small surface area** at its edge, which concentrates the applied force into a very small area. This concentrated force results in high pressure, allowing the knife to cut through the cotton bales with ease.
- By applying a sharp knife, workers can overcome the resistance of the cotton fibers with less effort and create a clean, controlled cut. This is in contrast to using a dull knife, where the force would be spread over a larger area, making it harder to cut through the bales.

3. Hydraulic Machine Lifting Factory Trucks for Servicing and Maintenance

The hydraulic machine used for lifting the factory trucks is based on **Pascal's Law**, which states that:

"When pressure is applied to a confined fluid, the pressure is transmitted equally in all directions."

- The hydraulic lift works by applying force to a small piston, which increases the pressure in the fluid (typically oil). This increased pressure is transmitted through the fluid to a larger piston, causing the larger piston to move and lift the heavy factory truck.
- Because the force applied on the small piston is multiplied due to the difference in piston sizes, the hydraulic machine can lift heavy loads with relatively little effort. This is a practical application of **pressure** and **force multiplication**.

4. Overhead Tanks Supplying Water to Different Sections of the Factory

The **overhead water tanks** rely on the principle of **gravitational potential energy** and **pressure**. Here's how:

- The water is pumped into the tanks, which are positioned high above the ground. The height gives the water **gravitational potential energy**.
- When the water is allowed to flow from the tanks, gravity causes it to move downwards. The water pressure increases as it falls, and this pressure is used to distribute the water to various sections of the factory.
- The **pressure** at the bottom of the tank is proportional to the height of the water column above it, and this pressure is used to force the water through pipes to different areas of the factory. This is a simple but effective application of gravitational potential energy to generate pressure.

5. Sprinklers Watering Flowers in the Backyard of the Factory

The **sprinklers** are based on the principle of **fluid dynamics** and **pressure**. Here's how:

- Water is pumped through pipes at a higher pressure, and as the water reaches the sprinkler, it is forced through small openings (or nozzles) that spray the water in a fine mist or droplets.
- The pressure causes the water to move through the nozzle and break into fine droplets, which then cover a large area of flowers.
- The distribution of water over the flowers is achieved by controlling the **flow rate** and the **size of the nozzle openings**. This allows efficient watering, ensuring that the plants receive the right amount of water.

6. Small Aircrafts (Helicopters) Airlifting Cargo and Employees to the Mainland

The flight of small aircrafts, such as **helicopters**, relies on the principles of **aerodynamics**, specifically **Bernoulli's Principle** and **Newton's Third Law of Motion**.

- **Bernoulli's Principle** states that an increase in the velocity of a fluid (in this case, air) leads to a decrease in pressure. The helicopter's blades are designed to move air faster over the top surface of the blades than beneath them. As a result, the pressure on top is lower than the pressure beneath the blades, creating **lift** that raises the helicopter into the air.
- **Newton's Third Law of Motion** also comes into play: as the helicopter blades push air downwards (action), the air pushes the helicopter upwards (reaction), providing the necessary lift to overcome gravity.
- Helicopters can hover in place or move vertically by adjusting the angle of the blades (pitch) and the speed of rotation. This allows them to airlift cargo and people to and from the mainland.

7. Workers Using Vacuum Cleaners to Remove Dust from Carpets

The **vacuum cleaner** operates based on the principle of **air pressure** and **suction**.

- The vacuum cleaner creates a **low-pressure environment** inside the vacuum chamber by rapidly sucking air in. This is achieved by using a motor that drives a fan to create suction.
- When the air pressure inside the vacuum cleaner drops, the air outside (at higher pressure) pushes dust, dirt, and debris into the vacuum cleaner. The suction force effectively pulls the dust from the carpet into the vacuum's dust container.
- This principle of **suction** is used to clean carpets and other surfaces efficiently, as the difference in air pressure causes the dirt to be pulled in.

ITEM 28

The school welfare department is facing a challenge of rain affecting their catering activities due to lack of a kitchen. The school is planning to construct a modern kitchen, which can save energy and reduce on the temperature inside.

TASK

You are appointed as the head of construction committee for this kitchen, conduct a survey and compile a report you will present to the school welfare department showing the kind of cooking utensils required, how to paint the walls to reduce heat inside and outside the kitchen and how to manage air exchange inside the kitchen. (20 scores)

SOLUTION

1. Cooking Utensils Required for the Kitchen

A modern kitchen should have a range of efficient and durable cooking utensils that are appropriate for large-scale food preparation. The following utensils are essential for the kitchen:

- **Cooking Pots and Pans**:
    - Large cooking pots for boiling, steaming, and preparing soups.
    - Frying pans with non-stick coatings to ensure easy cooking and cleaning.
    - Pressure cookers for faster cooking, particularly for rice, beans, and other grains.
- **Cooking Tools**:
    - Spoons, ladles, tongs, and spatulas made of stainless steel or heat-resistant materials.
    - Large chopping boards for preparing vegetables, fruits, and meat.
    - Knives with durable blades for cutting, slicing, and dicing.
- **Ovens and Stoves**:
    - Energy-efficient gas stoves and electric ovens for baking and grilling.
    - A microwave oven for reheating food and quick cooking tasks.
- **Storage Containers**:
    - Stainless steel or food-grade plastic containers to store prepared ingredients, sauces, and leftovers.
    - Shelves and cabinets to store dry ingredients like flour, sugar, rice, etc.
- **Other Utensils**:
    - Mixing bowls, strainers, and colanders for washing and preparing ingredients.
    - A food processor or blender for efficient chopping, grinding, and mixing.
    - Food thermometers for checking the internal temperature of cooked food.

These utensils should be selected based on durability, ease of cleaning, and energy efficiency. Stainless steel is a preferred material as it is non-reactive, long-lasting, and easy to maintain.

2. How to Paint the Walls to Reduce Heat Inside and Outside the Kitchen

Proper wall treatment can help in reducing the temperature inside the kitchen, creating a more comfortable working environment, and improving energy efficiency. Here are some recommendations for painting the kitchen walls:

- **Use Reflective or Light-Colored Paint**:
    - Light-colored paints (such as white, off-white, or pastel shades) help reflect sunlight, reducing the amount of heat absorbed by the walls. This will prevent the kitchen from becoming too hot, especially during sunny days.
    - **Reflective paints** or coatings designed to bounce off heat and UV rays can further help reduce heat absorption. These paints are commonly used on roofs and walls to keep interiors cool.

- **Thermal Insulation Paints**:
    - Special **thermal insulation paints** are available that help prevent heat from entering the kitchen from outside and can also help reduce heat loss inside. These paints contain microscopic ceramic beads that provide insulation, similar to how insulating materials work in construction.
- **Eco-Friendly and Heat-Resistant Paints**:
    - Eco-friendly paints with low volatile organic compounds (VOCs) are safer for the kitchen environment and contribute to maintaining good indoor air quality.
    - Choose heat-resistant paints for areas of the kitchen that are exposed to direct heat, such as around stoves or ovens.

By selecting the right paints, the temperature inside the kitchen can be controlled, helping to reduce the need for excessive cooling or heating.

3. Managing Air Exchange Inside the Kitchen

Proper air exchange is essential for maintaining a fresh and comfortable environment inside the kitchen, as well as for ensuring proper ventilation to prevent heat buildup and the accumulation of cooking fumes. Here are the methods to manage air exchange in the kitchen:

- **Ventilation System**:
    - Install **exhaust fans** in the kitchen to expel hot air, steam, smoke, and cooking odors. Exhaust fans should be installed near cooking areas, such as above the stove and oven, to directly remove heat and fumes.
    - **Air conditioning units** or **air coolers** can be considered to maintain a comfortable temperature during particularly hot weather, especially in larger kitchens with high cooking volumes.
- **Natural Ventilation**:
    - Design the kitchen with **large windows** that allow natural airflow. These windows should be positioned on opposite sides of the kitchen to promote cross-ventilation. Opening these windows during cooking will help expel hot air and allow cooler air to enter, reducing indoor temperatures.
    - Install **ventilation grills** or **vents** in the walls or roof to allow for continuous airflow even when windows are closed.
- **Proper Airflow and Circulation**:
    - Install **ceiling fans** or **floor fans** to circulate the air inside the kitchen. These fans will help distribute cool air and push hot air upwards, improving comfort levels.
    - Ensure that the kitchen layout allows for easy movement of air by avoiding obstructions in front of windows, doors, or vents.
- **Heat Recovery Ventilation (HRV)**:
    - If possible, install a **Heat Recovery Ventilation (HRV) system**. This system helps regulate air exchange by allowing fresh air to enter the kitchen while recovering heat from the outgoing air. This helps in maintaining a comfortable temperature without wasting energy.

4. Additional Considerations for the Kitchen Design

- **Flooring**: Use **non-slip flooring materials** such as tiles or vinyl that are easy to clean and maintain. These materials also help in reducing heat buildup in the kitchen, especially when used in combination with reflective paints.
- **Lighting**: Choose **LED lighting** for energy efficiency. LED lights emit less heat and consume less electricity compared to traditional bulbs. Proper lighting can also improve the working environment inside the kitchen.
- **Waste Disposal**: Ensure that the kitchen has adequate provisions for waste disposal, including bins for food waste and recycling. This helps maintain hygiene and reduces clutter.

ITEM 29(WORK ENERGY AND POWER)

At a construction site, Milky was tasked to carry bricks from where they were to the masons. The task was tiresome. She applied a lot of energy and would carry a few bricks a day. She asked the foreman for a wheelbarrow. Soon, she had to take the bricks up the building. This time, she asked for a plank of wood which she used to make an inclined plane. But she would be tired by noon! So, the foreman suggested that she makes a single machine that would move the bricks up vertically. When the foreman looked in the vicinity, he realized that there was a motorcycle wheel, long ropes, straight poles, tall enough to reach the position where the bricks were to be put, and a large hemispherical pan.

TASK

(a) Make a brief explanation why and how each machine was able to simplify work.(08 scores)

(b) Show how Milky could assemble the items to come up with a simple machine and how she would use it to lift the building materials up to the floor in the shortest time possible. (12 scores)

SOLUTION

(a) Explanation of Why and How Each Machine Simplified Work (08 scores)

Each of the machines or tools Milky was provided with simplified her work by reducing the amount of effort or energy required to carry and move the bricks. Here's how each of the items helped:

1. **Wheelbarrow**:
    - The **wheelbarrow** simplified the task of carrying bricks by providing **mechanical advantage**. It has a wheel, which allows Milky to move multiple bricks at once without having to carry them individually. The wheel reduces the friction between the load (bricks) and the ground, making it easier to move heavy loads with less force.
    - **How it simplified work**: The wheelbarrow distributes the weight of the load, allowing Milky to transport bricks more efficiently and with less physical strain.
2. **Inclined Plane (Plank of Wood)**:
    - The **inclined plane** helps Milky move bricks up to the building without having to lift them vertically. By slanting the plane, the force required to move the bricks up is reduced. Instead of lifting a heavy brick straight up, Milky pushes it along the inclined plane, which spreads the effort over a longer distance, reducing the force needed.
    - **How it simplified work**: It reduced the lifting force required by using the concept of mechanical advantage, making it easier to move bricks up a height.
3. **Motorcycle Wheel**:

- The **motorcycle wheel** could be used as part of a **pulley system** to help lift the bricks vertically. By attaching a rope to the wheel, Milky could use the wheel to change the direction of the applied force and lift the load more easily.
- **How it simplified work**: The wheel allows for the use of a pulley system, which reduces the direct physical effort of lifting bricks vertically by allowing Milky to apply force in a more controlled manner.

4. **Ropes**:
   - The **ropes** would be used in conjunction with the motorcycle wheel to create a **pulley system**, allowing Milky to lift heavy bricks by applying force horizontally, which is easier than lifting them vertically. The ropes also distribute the load, reducing the effort needed.
   - **How it simplified work**: The ropes work with the pulley system to lift heavy loads with less effort and in a more controlled manner, reducing Milky's physical strain.
5. **Straight Poles**:
   - The **straight poles** would be used as the support structure for the pulley system. They would hold the pulley (motorcycle wheel) in place, allowing the rope to move freely and carry the load up.
   - **How it simplified work**: By using the poles as supports, Milky could build a stable structure to use the pulley system efficiently and safely.
6. **Hemispherical Pan**:
   - The **hemispherical pan** could be used as a container for holding the bricks. It might be placed on the pulley system to act as a **bucket** that holds the load. By using the pan, Milky could lift several bricks at once, reducing the number of trips needed to transport bricks.
   - **How it simplified work**: The pan allows for easy transportation of bricks as a single load, and combined with the pulley, it simplifies lifting heavy materials.

(b) Assembling the Items to Create a Simple Machine (12 scores)

To create a simple machine that would move the bricks up vertically, Milky can build a **pulley system** using the items provided. Below is a step-by-step guide to assembling and using the machine:

Step 1: Setting up the Pulley System

- **Motorcycle Wheel**: Attach the motorcycle wheel securely to the top of one of the straight poles. The wheel will act as the **pulley** in the system. It should be positioned high enough to lift the bricks to the required height.
- **Straight Poles**: Use two or more poles to create a **support structure** for the pulley. The poles should be tall enough to reach the height where the bricks need to be placed. The poles should be firmly anchored into the ground to ensure the system remains stable when lifting heavy loads.
- **Ropes**: Attach one end of the rope to the **hemispherical pan** (acting as a bucket to hold the bricks). Pass the rope over the motorcycle wheel (pulley) and secure the other end to a point where Milky can easily pull it.

Step 2: Preparing to Lift

- Milky will place the bricks in the **hemispherical pan**. This pan can hold multiple bricks at once, reducing the need for multiple trips.
- Milky will pull the rope horizontally (or slightly downward) from the opposite side of the pulley.

Step 3: Lifting the Bricks

- By pulling on the rope, Milky will use the **mechanical advantage** provided by the pulley system to lift the bricks vertically. The pulley changes the direction of the force, so Milky will exert less effort by pulling the rope horizontally or downward instead of lifting the bricks directly upward.
- As Milky pulls the rope, the **hemispherical pan** will rise, carrying the bricks up to the required height.

Step 4: Moving the Bricks

- Once the pan reaches the desired height, Milky can easily move the bricks into place by either tilting the pan or lowering the rope and letting the bricks drop into position.

Step 5: Repeating the Process

- Milky can repeat the process by adding more bricks to the pan and lifting them up using the pulley system. The mechanical advantage makes it much easier to lift heavy materials in a vertical direction with less effort and faster than doing it manually.

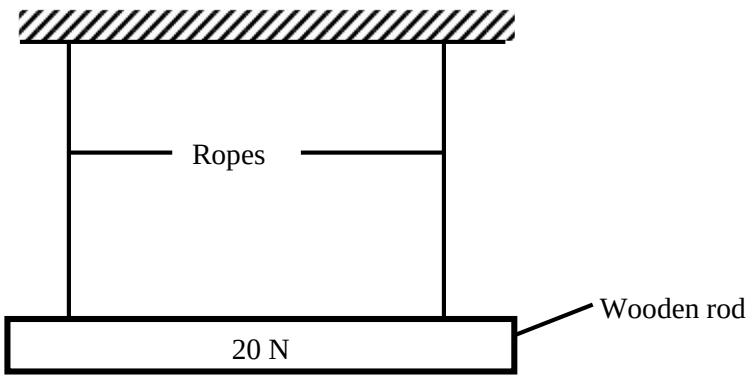
ITEM 32

A farmer uses one of his rooms for poultry. He uses a hot metallic charcoal stove to warm the room. Of recent, he is facing the following challenges

i. Some chicken lay eggs from a raised platform and the eggs at times accidentary slide and drop on the bare floor and break. This has greatly affected his poultry business.
ii. When bodies of the featherless bird touch the hot stove body, they get burnt.
iii. The odour from the birds' dung spreads throughout the other rooms on the house. This has become an inconvenience to the occupants in the house.

When the birds fight using their sharp beaks, they seriously damage each other. Inside the room, there is a wooden rod of weight 30 N supported by two identical strings. Usually cocks jump and rest on this rod. The two strings can only support a total tensional force of 90 N. At one moment, 3 cocks of average mass 3 kg each were resting on the rod and the ropes snapped. Use =

10 ms^{-2}



Using the knowledge of physics

a) Help the farmer understand the origin of his challenges and suggest the possible solutions to these challenges.
b) Help the farmer to find out why the ropes snapped.

solution

(a) Origin of the Farmer's Challenges and Possible Solutions

i. Eggs Breaking When They Fall on the Bare Floor

Origin of the Problem:

- The eggs break because when they slide off the raised platform, they fall from a certain height, and upon hitting the **hard surface of the floor**, they experience a significant **impact force**. The force upon impact is large enough to break the eggs due to their delicate shells.
- This issue arises from the **lack of a cushion** or protection to absorb the impact energy when the eggs fall.

Solution:

- To prevent the eggs from breaking, the farmer could consider placing a **soft material** such as foam padding, rubber mats, or sawdust on the floor to absorb the impact when eggs fall.
- Another solution could be installing a **guardrail** or a **soft platform** around the raised platform to prevent the eggs from sliding off in the first place.

ii. Birds Getting Burnt When They Touch the Hot Stove

Origin of the Problem:

- The stove is metallic and **conducts heat**. When the birds, especially the featherless ones, touch the stove, the heat is transferred to their bodies, causing **burns**. The direct contact with a hot metallic surface creates thermal damage to the birds' sensitive skin.

Solution:

- To prevent burns, the farmer can consider **insulating the stove** or using a **non-metallic** cover over the stove to reduce the heat transfer.
- Another solution would be placing the stove in a separate **enclosed area** or **raising the stove** above the bird's level so they are less likely to come into contact with it.

iii. Odour From Bird Dung Spreading Throughout the House

Origin of the Problem:

- The **bird dung** in the poultry room emits foul smells, which spread throughout the house due to inadequate ventilation. Without proper ventilation, the odour remains trapped in the room and can spread to other rooms in the house.

Solution:

- The farmer can improve **ventilation** by installing **air vents** or using **exhaust fans** in the poultry room to allow fresh air in and push the odour out.
- Alternatively, the farmer can place **deodorizers** or use natural absorbents like **activated charcoal** or **baking soda** to reduce the spread of the odour.
- Ensuring that the poultry room is **regularly cleaned** and that the bird dung is removed frequently will help in reducing the accumulation of odour.

iv. Birds Fighting and Damaging Each Other

Origin of the Problem:

- The fighting behavior among birds is likely caused by **aggressive tendencies** during **mating** or due to limited space in the poultry room. The sharp beaks and claws of the birds cause injuries when they fight.

Solution:

- The farmer can reduce fighting by providing **more space** for the birds. Reducing overcrowding will reduce stress and aggression.
- Another option is to use **dividers** or **individual cages** to separate aggressive birds from the others, allowing them to interact more peacefully.
- Ensuring the birds have access to adequate food, water, and shelter can also help reduce aggression.

(b) Why the Ropes Snapped

To understand why the ropes snapped, we can apply the principles of **force** and **tension** in physics.

- The **total weight of the 3 cocks** is the key factor. Each cock has an average mass of 3 kg, so the total mass of the 3 cocks is:

  Total mass=3 cocks×3 kg/cock=9 kg

- The force due to gravity (weight) on these 3 cocks is calculated using the equation:

  $F = m \times g$

  where:

  m=9kg (total mass of the cocks)

  - $g=10\ m/s^2$

  So, the total weight (force due to gravity) is:

  $F = 9\ kg \times 10\ m/s^2 = 90\ N$

- The total force of 90 N due to the weight of the cocks is distributed across the two strings. Since the ropes are identical, each rope supports half of the total weight. Therefore, the tension in each rope is:

  T=90 /2=45 N

- **Rope Snapping Condition:**

- The two ropes are capable of supporting a **total tensional force of 90 N** (this is the combined strength of both ropes). Therefore, if the total force from the cocks is exactly 90 N, the ropes are at their maximum load capacity.
- However, when the cocks **jumped** onto the rod, the weight and force on the ropes likely **increased** temporarily due to the dynamic load created by the sudden motion. This creates a **shock load**, which can exceed the rope's rated capacity of 90 N and cause the ropes to snap.
- If the cocks were moving or jumping onto the rod, the **dynamic force** (force due to acceleration) can be significantly higher than their static weight. This sudden increase in load likely caused the ropes to snap.

MODERN PHYSICS ITEMS SOLUTION 1 TO 12

ITEM 1

Kilembe farmer's association in Kasese district deals in vegetable growing near R. Nyamwamba for their livelihood. The natives near the river bank have been complaining of health complications that drew the attention of the government under the ministry of health. The ministry of Health sent a nuclear Physicist, Dr. Fredrick to make a survey on the occurring problem in Kasese. Dr. Fredrick later surveyed and wrote a report to the Ministry of health on the main cause of the issues in Kasese. In the report, it was reported that the vegetables contained radioactive materials that emit radiations to the grown vegetables coming from water and this was not known to the natives near the river bank.

TASK:

As a physic learner;

i) In the reports, terms such as **radioactivity** and **radioactive decay** were reported. Help the natives to understand these terms. **(2 scores)**

ii) Guide the natives at the river bank using reaction equations to understand the types of radioactive decays that their vegetables have been prone to. **(6 scores)**

iii) Advise the natives about the dangers of these radiations and the safety precautions they should take to take against the emitted radiations. **(4 scores)**

SOLUTION

i) Explanation of Radioactivity and Radioactive Decay:

Radioactivity: This refers to the process by which unstable atomic nuclei release energy in the form of radiation. These unstable nuclei "decay" or change into more stable forms, often releasing harmful radiation such as alpha particles, beta particles, or gamma rays.

Radioactive Decay: This is the process by which an unstable atom loses energy by emitting radiation. It can involve the emission of particles (such as alpha or beta) or energy (in the form of gamma rays). The decay leads to the transformation of the unstable atom into a more stable form, often turning into a different element.

ii) Types of Radioactive Decays:

The vegetables near R. Nyamwamba have likely been exposed to radioactive materials, and these materials undergo different types of radioactive decay. Below are the three main types of radioactive decay with their corresponding reactions:

1. **Alpha Decay**:
    - In alpha decay, the unstable nucleus emits an alpha particle (which is made up of 2 protons and 2 neutrons). This results in the loss of 2 protons and 2 neutrons from the original atom, turning it into a different element.

    Example:
    Uranium-238 undergoes alpha decay to form Thorium-234:

    $\text{Uranium-238} \rightarrow \text{Thorium-234} + \alpha(\text{Helium-4 nucleus})$

    $\text{U-238} \rightarrow \text{Th-234} + \alpha$

2. **Beta Decay**:
    - In beta decay, a neutron in the nucleus of an atom is transformed into a proton, and a beta particle (an electron) is emitted. The result is that the atom's atomic number increases by 1, creating a different element.

    Example:
    Carbon-14 undergoes beta decay to form Nitrogen-14:

    $\text{Carbon-14} \rightarrow \text{Nitrogen-14} + \beta(\text{electron})$

    $\text{C-14} \rightarrow \text{N-14} + \beta$

3. **Gamma Decay**:
    - In gamma decay, the nucleus of an atom loses excess energy in the form of gamma radiation (high-energy photons) without changing the number of protons or neutrons. This often occurs after other types of decay (alpha or beta), as the nucleus stabilizes.

    Example:
    Cobalt-60, after undergoing beta decay, emits gamma radiation:

    $\text{Cobalt-60} \rightarrow \text{Nickel-60} + \gamma(\text{gamma radiation})$

    $\text{Co-60} \rightarrow \text{Ni-60} + \gamma$

These radioactive decays can release harmful radiation into the environment and, if absorbed by living organisms (like humans or vegetables), may lead to health risks.

---

iii) Dangers of Radiation and Safety Precautions:

Dangers of Radiation:

1. **Health Risks**: Prolonged exposure to radiation can cause serious health problems, including cancer, radiation burns, genetic mutations, and damage to organs. The radiation emitted by radioactive materials in the vegetables can enter the body through ingestion or inhalation, causing internal harm.
2. **Contamination of Food**: If vegetables contain radioactive materials, consuming them may lead to radiation being absorbed into the body, increasing the risk of developing diseases like cancer or other radiation-induced illnesses over time.

Safety Precautions for the Natives:

1. **Avoid Direct Contact with Contaminated Vegetables**: The natives should stop eating vegetables that are grown near the river until the source of contamination is identified and cleared. They should also avoid handling the vegetables without protective equipment.
2. **Boiling and Washing Vegetables**: Though washing or boiling may help reduce some contaminants, radioactive materials may not be fully eliminated by these methods. It is advisable to discard vegetables that are suspected to be contaminated.
3. **Limit Exposure**: Avoid staying near the riverbank for prolonged periods, especially during the rainy season when the flow of the river might carry more radioactive materials into the soil and water.
4. **Monitoring and Awareness**: It is important to regularly monitor the radiation levels in the area and ensure that the government or relevant authorities take the necessary steps to clean up the contamination. Awareness campaigns on the dangers of radiation should also be conducted to educate the locals on the risks and the importance of following safety measures.

By taking these precautions, the natives can protect themselves and their families from the harmful effects of radiation.

ITEM 2.

In a certain town, people are concerned about the waste disposal from the factory into the nearby lake which is their source of water for home use. They raised this issue to the chairperson Local Council 1 (LC1) who directed the management of the factory to stop disposing waste into the lake. A scientist was contacted to investigate the presence of radioactive material in the water. The scientist found out that the water was indeed radioactive as shown in Table 1.

TABLE 1:

Time (days)	0	5	10	15	20	25	30
Activity (counts per minute)	1200	740	440	260	160	90	60

Although the water from the lake remains radioactive for a long time, the scientist recommended that water will be safe for use again when the activity is less than 38counts per minutes.

TASK:

As a student of physics;

(a) Advise the chairperson LC1 about the time the community will wait for the water to be safe for use again.

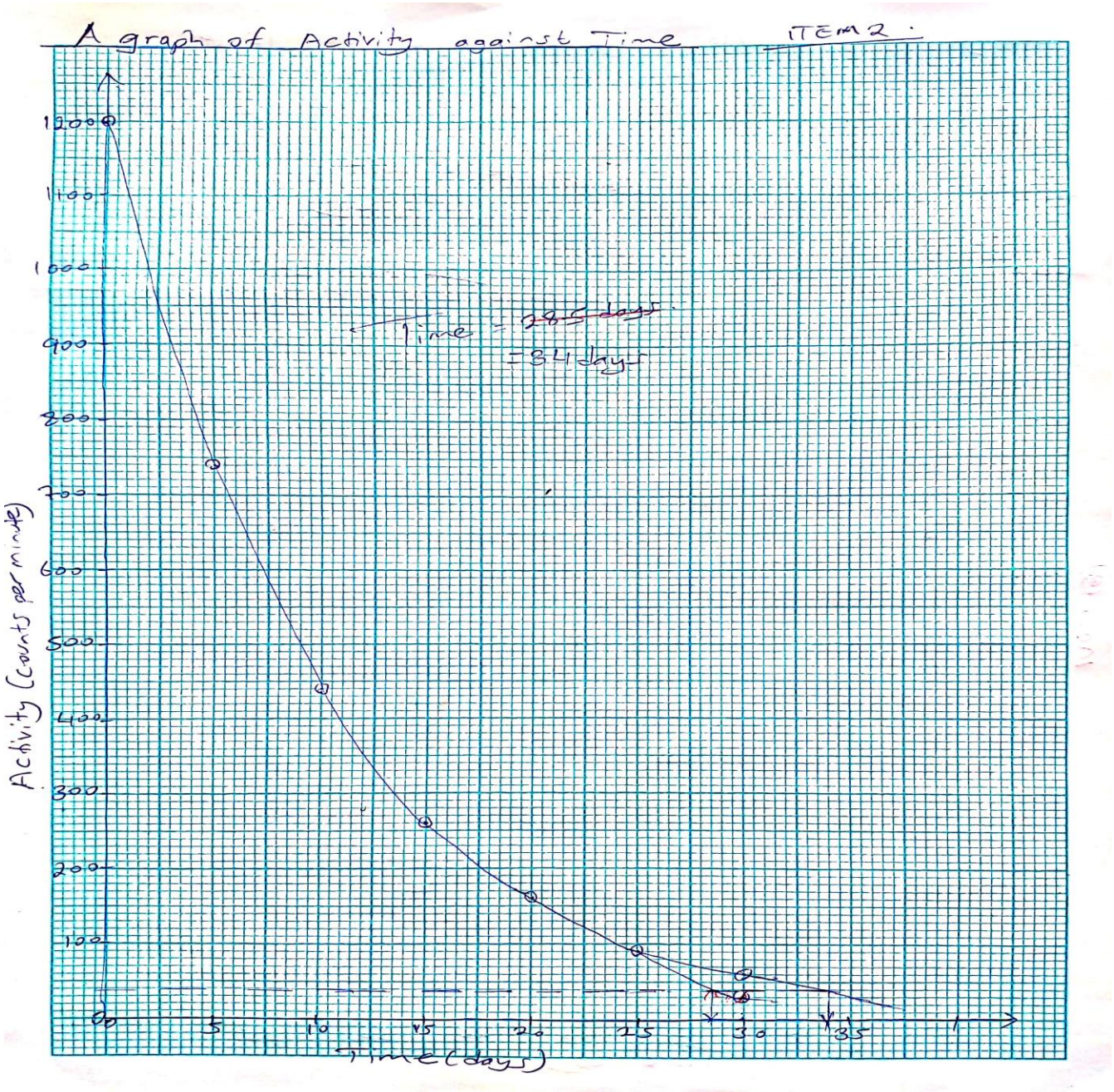
(b) Sensitize the members of the community about the risks associated with the materials contained in the water from the above mentioned lake and how such materials should be handled.

SOLUTION

(a) Advice to Chairperson LC1 About Time for Water to Be Safe:

To determine the time the community will have to wait for the water to become safe for use again, we need to understand the process of **radioactive decay** and how it reduces the **activity** of the water over time.

The water remains radioactive, but it is safe for use when its **activity** is less than 38 counts per minute (cpm).



(b) Sensitizing the Community About the Risks and Handling of Radioactive Water:

Radioactive contamination of water poses significant health risks, and it's important for the community to understand these risks and how to handle the situation safely. Here are some key points to help sensitize the community:

1. **Health Risks of Radioactive Materials in Water:**
    - **Cancer**: Prolonged exposure to radioactive materials increases the risk of developing cancer, particularly cancers of the bones, lungs, thyroid, and other organs.
    - **Radiation Poisoning**: High levels of radiation can lead to acute radiation sickness, which can cause nausea, vomiting, diarrhea, and in extreme cases, death.
    - **Genetic Mutations**: Exposure to radiation can also cause genetic mutations that may be passed on to future generations, leading to birth defects and hereditary diseases.
2. **How Radioactive Water Affects People:**
    - When people consume contaminated water, the radioactive substances enter the body, where they can continue to emit harmful radiation, affecting tissues and organs.
    - Drinking, bathing, or even coming into direct contact with contaminated water may lead to internal exposure to radiation, which is more harmful than external exposure.
3. **Proper Handling of Contaminated Water:**
    - **Avoid Direct Contact**: Until the water is confirmed to be safe, the community should avoid direct contact with the water. This means avoiding drinking, bathing, or even washing clothes with the water from the lake.
    - **Find Alternative Sources**: The community should look for alternative sources of clean water, such as bottled water, water from other nearby lakes, or water from distant sources not affected by contamination.
    - **Boiling the Water**: Boiling the water may not remove radioactive materials, so this method is not effective for decontaminating radioactive water.
    - **Filter the Water**: Special filtration systems may help reduce certain types of radioactive contaminants (like cesium or strontium), but these filters must be designed specifically for radioactive material removal.
    - **Monitor the Water**: It's important for the local government or authorities to continuously monitor the levels of radioactivity in the water. The community should be informed about any improvements and the timeline for when the water will be safe again.
4. **In Case of Exposure:**
    - If someone has been exposed to radioactive water, they should seek medical attention immediately, especially if they show symptoms like nausea, vomiting, or unusual tiredness. Hospitals and health clinics should be equipped to handle radiation-related issues.
    - It's important to inform the community about how to recognize symptoms of radiation exposure and what immediate steps to take if someone is affected.
5. **Future Precautions:**
    - The factory must be held accountable for ensuring that their waste does not continue to pollute the lake. Regular monitoring and proper disposal methods should be enforced to prevent future contamination.
    - The community should be educated on the importance of environmental protection and how to advocate for safer disposal practices in the future.

By spreading this awareness and taking appropriate actions, the community can minimize the risks of radioactive contamination and ensure the health and safety of its members.

ITEM 3

During a hospital tour, a liquid in a bottle spilled on one of the visitors. The visitor was told that the liquid that had spilled was a radioactive material of activity 450 counts per second with a half-life of two days. He was told to self-isolate in the hospital until the count rate drops to 6.25 counts per second. The relatives of the isolated person tasked the hospital administration to come up with better ways to keep such materials.

Support

Background radiation is 50 counts per second. Use your knowledge of physics to

(a) Determine how much time the patient would take in the hospital

(b) Explain to the relatives the dangers associated with radioactive materials.

(c) Explain to the hospital staff how such materials should be handled.

SOLUTION

(a) Determine How Much Time the Patient Would Take in the Hospital:

To determine the time the patient would need to stay in isolation until the activity drops from 450 counts per second to 6.25 counts per second, we can use the **exponential decay** formula for radioactive decay:

a) $450 - 50 = 400 counts$

$$400 \xrightarrow{t_{\frac{1}{2}}} 200 \xrightarrow{t_{\frac{1}{2}}} 100 \xrightarrow{t_{\frac{1}{2}}} 50 \xrightarrow{t_{\frac{1}{2}}} 25 \xrightarrow{t_{\frac{1}{2}}} 12.5 \xrightarrow{t_{\frac{1}{2}}} 6.25$$

$$t_{\frac{1}{2}} = 2 days$$

$$6t_{\frac{1}{2}} = t$$

$$time\ (t) = 6 \text{ x } 2$$

$$= 12 days$$

(b) Dangers Associated with Radioactive Materials:

Radioactive materials pose significant health risks, especially if a person is exposed to them for extended periods. Here are the main dangers:

1. **Radiation Exposure**:
   - Radioactive substances emit harmful radiation, which can be in the form of alpha, beta, or gamma radiation. This radiation can penetrate the body and damage cells, tissues, and organs.
   - **Gamma radiation** is particularly dangerous because it can penetrate deep into the body, potentially causing widespread damage to internal organs.
2. **Cancer Risk**:
   - Prolonged exposure to radiation increases the likelihood of developing various types of cancer. Ionizing radiation can damage the DNA in cells, leading to mutations that may result in the uncontrolled growth of cancerous cells.
3. **Radiation Poisoning**:
   - High doses of radiation in a short period can lead to **acute radiation sickness**. Symptoms include nausea, vomiting, fatigue, and in severe cases, damage to vital organs, and even death.
4. **Genetic Damage**:

- Radiation exposure can lead to genetic mutations in cells, which may be passed on to future generations. This can result in birth defects or inherited diseases.

5. **Environmental Contamination**:
   - If radioactive materials are not handled properly, they can contaminate the environment. This contamination can affect water, soil, and air quality, posing risks to both human health and wildlife.

In this case, the patient was advised to isolate themselves until the radioactive material decays to a safe level, as the radiation levels in the material may be harmful to their health.

(d) **How the Hospital Staff Should Handle Radioactive Materials:**

It is crucial for the hospital staff to be well-trained in handling radioactive materials to minimize the risks of exposure. Here are the steps they should follow:

1. **Proper Storage and Containment**:
   - Radioactive materials should be stored in secure, lead-lined containers that shield the radiation. Lead is an effective material for absorbing gamma radiation.
   - The storage area should be clearly marked with **radiation warning signs** and restricted to authorized personnel only.
   - The containers should be kept in a controlled environment with restricted access to prevent accidental exposure.
2. **Minimize Exposure**:
   - Staff should always aim to minimize their exposure to radiation by following the **ALARA principle** (As Low As Reasonably Achievable). This involves reducing the time spent near radioactive materials, increasing the distance from the source, and using appropriate shielding.
   - Protective gear such as lead aprons, gloves, and face shields should be worn by all staff members handling radioactive materials.
3. **Monitoring and Detection**:
   - The hospital should be equipped with **radiation detection instruments** like Geiger counters to monitor the radiation levels in areas where radioactive materials are handled.
   - Regular checks should be conducted to ensure that radiation levels are within safe limits.
4. **Safe Disposal**:
   - Radioactive waste should be disposed of according to **strict guidelines** to prevent contamination. This may involve storing waste in specialized containers or sending it to a licensed radioactive waste disposal facility.
   - The staff must ensure that any contaminated materials are securely sealed and transported for disposal as soon as possible.
5. **Training and Protocols**:
   - All hospital staff should be trained in **radiation safety protocols**. This includes understanding the risks of radiation, how to handle materials safely, and what steps to take in case of exposure or a spill.
   - Emergency response plans should be in place for situations such as spills, leaks, or accidental exposure. This includes providing medical care to affected individuals and reporting the incident to the relevant authorities.

By following these safety measures, hospital staff can prevent harmful exposure to radioactive materials and protect both themselves and the public.

ITEM 4

A patient who was suffering from liver cancer visited a hospital for treatment. He first checked in the radiographer's room. He was injected with Yttrium (Y-90) radioisotope dose of mass 6 mg into his bloodstream. The radiographer wrote a brief report.

He forgot to indicate the date of the next visit. The patient then went for X-ray photography. Unfortunately, he was told that the low voltage supply of the X-ray machine had mechanical issues and he was not worked on. The patient failed to understand the effect of that part of the machine on production of X-rays.

Using half-life of Y-90 as 5 days,

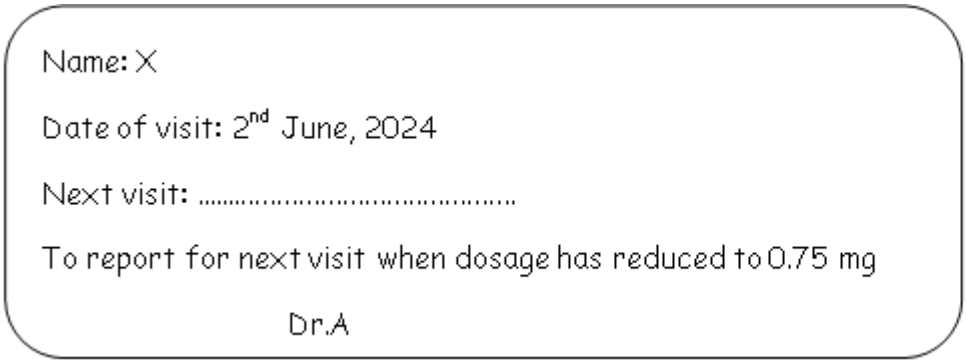
As a student of physics.

(a) Help the patient to determine the date for his next visit.

(b) Explain to the patient the effect of the faulty part of the X-ray machine on production of X-rays.

(c) Sensitise the patient on the dangers of such dosages in treatment of the disease.

HINT:



SOLUTION

(a) Determine the Date for the Next Visit:

a) $6 \xrightarrow{t_{\frac{1}{2}}} 3 \xrightarrow{t_{\frac{1}{2}}} 1.5 \xrightarrow{t_{\frac{1}{2}}} 0.75$

$$3t_{\frac{1}{2}} = t$$

But $t_{\frac{1}{2}} = 5$

$$3\ x\ 5 = \mathrm{t}$$

$$t = 15 days$$

$$2^{nd} + 15 = 17/june/2024$$

(b) Effect of the Faulty Part of the X-ray Machine on the Production of X-rays:

The X-ray machine has a **low voltage supply issue**, which means that the part of the machine responsible for producing X-rays is malfunctioning. To understand this, let's briefly explain how X-ray machines work:

1. **X-ray Production**:
   In an X-ray machine, electrons are accelerated to a very high speed using high voltage. These accelerated electrons then strike a target (typically made of tungsten) inside the X-ray tube. When the electrons hit the target, they interact with atoms in the material, causing the release of X-rays.
2. **Effect of Low Voltage**:
   - **Low voltage** means the electrons will not have enough energy to reach the necessary speed for effective X-ray production.
   - As a result, **the X-ray production will be inefficient or nonexistent** if the voltage is too low, even if the X-ray machine is switched on.
   - Therefore, the **X-ray images** cannot be produced properly because the electrons are not accelerated enough to create the necessary X-ray radiation.

In short, the **faulty low voltage supply** meant that the X-ray machine could not generate the high-energy electrons needed to produce X-rays, so the patient was not able to receive the X-ray photography as expected.

(c) Dangers of Radioactive Dosage in the Treatment of Liver Cancer:

While **Yttrium-90** (Y-90) is used in **radiation therapy** to treat liver cancer, it's important for the patient to understand the potential risks and dangers of such treatments:

1. **Exposure to Radiation**:
   - Yttrium-90 is a **beta emitter**, meaning it releases beta particles that can cause tissue damage. While it is effective in treating cancer by targeting cancerous cells, the radiation can also affect surrounding healthy tissues.
   - The radiation dose needs to be carefully controlled to avoid **damage to healthy organs** or causing secondary cancers.
2. **Acute Radiation Effects**:
   - After the administration of a radioactive dose, the patient may experience symptoms of radiation exposure such as **fatigue**, **nausea**, or **skin irritation**. These symptoms usually subside as the body processes the radiation and the isotope decays.
   - Overexposure or improper administration of radioactive substances can cause **radiation burns** or **tissue damage**, which can lead to complications in the healing process.
3. **Long-Term Effects**:
   - If the radiation dose is too high or not carefully monitored, it can lead to **long-term effects** such as **increased risk of cancer**. The body's cells can be damaged at the genetic level, increasing the likelihood of mutations and possibly leading to cancers years after treatment.
4. **Safety Protocols**:
   - The Yttrium-90 treatment is typically localized (targeting the liver in this case), but precautions must still be taken. The patient should **isolate** themselves briefly after receiving the injection to limit the exposure of others to radiation.
   - The patient should also avoid close contact with pregnant women or young children for a period of time after receiving the treatment.
5. **Monitoring and Follow-Up**:
   - Regular follow-ups are essential to ensure that the radiation therapy is effective and that the side effects are being managed. The radiation levels in the patient's body will decrease over time as the Yttrium-90 decays, but continuous monitoring is important to assess both the therapeutic effects and potential side effects.

In conclusion, while Yttrium-90 therapy is an important treatment option for liver cancer, the patient should be aware of the potential risks associated with radiation exposure and ensure they follow medical advice and safety guidelines to minimize these risks.

ITEM 5

A government has constructed an underground pipe to transport its oil over long distances. When tested, the pipe is suspected to leak in a 100 m section and the leakage point is not easy to identify since the pipe is underground. An engineer has proposed mixing some radioactive substance of short half-life in the oil and using a detector to find the spot where the oil is leaking. The radioactive substance to be used should diminish activity to less than 10 s^{-1} within 1 hour. The engineer has identified one substance to be used and found out that its activity when mixed with the oil, reduced from 480 s^{-1} to 60 s^{-1} in 30 minutes. The engineer has not yet drawn conclusions about this choice of substance and may need your help.

Assit the engineer to:

(a) Determine:

(i) the half-life of the radioactive substance he is about to use.

(ii) the substance should now be mixed in the oil and start tracing the leakage.

(b) Explain:

(i) how the leakage is traced using this method.

(ii) why the substance to be used should have a short half-life.

SOLUTION

(a) Determine:

(i) The Half-Life of the Radioactive Substance

480 $\xrightarrow{t_{\frac{1}{2}}}$ 240 $\xrightarrow{t_{\frac{1}{2}}}$ 120 $\xrightarrow{t_{\frac{1}{2}}}$ 60

$3t_{\frac{1}{2}} = t$

$$t_{\frac{1}{2}} = \frac{30}{3} = 10minutes$$

Halflife is 10minutes

(iii) *The Substance Should Now Be Mixed in the Oil and Start Tracing the Leakage*

Where halflife is 10minutes and time is 60minutes

480 $\xrightarrow{10}$ 240 $\xrightarrow{10}$ 120 $\xrightarrow{10}$ 60 $\xrightarrow{10}$ 30 $\xrightarrow{10}$ 15 $\xrightarrow{10}$ 7.5

The substance should be 7.5s^{-1}

(b) Explain:

(i) How the Leakage is Traced Using This Method

The leakage is traced by introducing the radioactive substance into the oil flowing through the pipe. Since the substance is radioactive, it will emit radiation, which can be detected by radiation detectors placed on the

surface of the ground above the pipeline. The oil leaks out of the pipe at the leakage point, and the radioactive substance will come out with it. The detector will register the radiation intensity, and by locating the area with the highest radiation, the engineer can pinpoint the location of the leak.

(ii) Why the Substance to Be Used Should Have a Short Half-Life

A short half-life is important for the following reasons:

1. **Minimize Environmental Impact**: A short half-life means the radioactive substance decays quickly, reducing the time it remains in the environment. This minimizes the potential for environmental contamination and ensures that the radioactive material does not persist long after the leakage has been repaired.
2. **Effective Detection**: A substance with a short half-life ensures that its activity decreases rapidly, making it easier to trace the leak in real-time. If the half-life were too long, the substance might still be detectable for a long period, which could lead to difficulty in identifying the exact moment the leakage occurred.
3. **Safety**: A short half-life ensures that the radiation exposure to workers and the environment is minimized, as the substance decays quickly after its use in the oil pipeline.

In summary, a short half-life is essential for rapid decay, effective detection, and minimal environmental and safety concerns.

ITEM 6

During charity work in the hospital by Red Cross Society of one school, a certain liquid containing a radioactive material spilled on one student accidentally, having been placed on an open place by a medical intern. The hospital authorities immediately took the student for a mandatory self-isolation within the hospital premises. The parents accused the hospital of negligence and demanded to see their child in a weeks' time. **Hint:**

- The liquid had an activity of 250 counts per second when tested immediately, with a half-life of 2 days.
- The back ground count rate in the laboratory was 50 counts per second.
- The student can be safe to re-join the public if the count rate falls below 10 counts per second.

Task:

Use your knowledge of physics to:-

(a) Determine how long the student will be self-isolated.

(b) Enlighten the parents on the dangers of having their child at home without medical monitoring.

(c) Explain to the medical intern how such materials should be handled.

SOLUTION

(a) Determine How Long the Student Will Be Self-Isolated:

$$250 - 50 = 200 counts$$

$$200 \xrightarrow{t_{\frac{1}{2}}} 100 \xrightarrow{t_{\frac{1}{2}}} 50 \xrightarrow{t_{\frac{1}{2}}} 25 \xrightarrow{t_{\frac{1}{2}}} 12.5 \xrightarrow{t_{\frac{1}{2}}} 6.25$$

$$5t_{\frac{1}{2}} = t$$

$$t_{\frac{1}{2}} = 2$$

$$time\ , t, = 2\ x\ 5 = 10 days$$

(b) Enlighten the Parents on the Dangers of Having Their Child at Home Without Medical Monitoring:

It's important for the parents to understand that radiation exposure can have serious health risks, and monitoring is essential to ensure their child's safety. Here are the main dangers of having the child at home without medical supervision:

1. **Radiation Exposure**:
   - Radioactive materials emit ionizing radiation, which can penetrate tissues and cause damage to cells, particularly in organs like the bone marrow, digestive system, and reproductive organs. Prolonged exposure can lead to cancer and other health problems.
2. **Acute Radiation Effects**:
   - Depending on the level of exposure, the child could experience symptoms like nausea, fatigue, and skin irritation. These effects may not be immediately visible but can worsen over time if not properly managed.
3. **Internal Contamination**:
   - If the radioactive material is not properly managed, it could continue emitting radiation inside the child's body. This could lead to internal radiation exposure and damage to vital organs.
4. **Increased Risk of Secondary Cancer**:
   - Even if the child appears healthy at first, exposure to radiation can increase the risk of developing cancer later in life. This is particularly important for growing children whose cells are dividing more rapidly.
5. **Monitoring and Treatment**:
   - Continuous monitoring is important to track the activity of the radioactive material in the body, as its decay follows an exponential pattern. The child should be monitored for signs of radiation sickness and to ensure the radiation levels are decreasing safely.

Therefore, medical monitoring is crucial to ensure that the child does not experience health complications and that the radiation levels are dropping to safe levels. The child should remain under observation until the radiation exposure is sufficiently low to prevent harm.

(b) Explain to the Medical Intern How Such Materials Should Be Handled:
Handling radioactive materials requires strict safety protocols to protect both the individuals working with the material and the public. Here are the key safety guidelines that the medical intern should follow:

1. **Proper Storage**:
   - Radioactive materials should always be stored in **secure, shielded containers** designed to prevent radiation leakage. Lead containers or lead-lined storage rooms are often used to provide adequate shielding.
   - The storage area must be clearly marked with radiation warning signs to alert others to the presence of radioactive materials.
2. **Minimizing Exposure**:
   - The intern should follow the **ALARA principle** (As Low As Reasonably Achievable) to minimize exposure to radiation. This includes minimizing the time spent near radioactive materials, maintaining a safe distance, and using appropriate shielding.
   - **Protective equipment** such as lead aprons, gloves, and safety goggles should be worn when handling radioactive materials.

3. **Use of Safety Devices**:
    - The intern should use radiation detectors, such as **Geiger counters**, to monitor radiation levels in the area. This helps ensure that exposure remains below safe limits.
4. **Handling Spills**:
    - In case of a spill, the intern should have a clear procedure in place to contain the spill and prevent contamination. This may involve using absorbent materials and placing the contaminated items in lead containers for disposal.
    - The area should be immediately **isolated** and decontaminated following the hospital's emergency protocols for radioactive spills.
5. **Training and Awareness**:
    - The intern must receive proper training on how to safely handle, store, and dispose of radioactive materials. They should be aware of the risks involved and the steps to take in case of exposure or emergencies.
6. **Disposal of Radioactive Waste**:
    - Radioactive waste should be disposed of through **licensed disposal services** that specialize in handling radioactive materials. The intern should never attempt to dispose of radioactive waste without following the appropriate legal and safety protocols.

By adhering to these safety practices, the intern can help prevent accidents and ensure that radioactive materials are handled in a way that minimizes health risks to themselves and others

ITEM 7

In a certain family, a child got an accident while playing with his friends and it was suspected to be broken leg. The family was referred by nearby health facility to go for X-ray radiography. The family already had some false information about how X-rays are produced and the related dangers to their child, therefor they were unwilling to go for it. The X-ray machine requires a voltage of about 4 kV to operate but the available main voltage supply is 10 kV.

Hint: *Available resistors are 300 Ω and 200 Ω*

Task

As physics learner,

(a) Help the family to:

(i) Clear the false information about the X-rays.

(ii) Understand how X-rays can be used to solve the problem of the family.

(b) Using the knowledge of digital electronics, help your friends understand how a 10 kV voltage would be used to operate the machine.

SOLUTION

(a) Clearing the False Information About X-rays and Their Use in Medical Imaging

(i) Clearing the False Information About X-rays:

The family may have heard some misconceptions about X-rays, so it is important to clarify these points based on physics:

1. **What Are X-rays?**
   - **X-rays** are a form of electromagnetic radiation, just like visible light, but with much higher energy. X-rays are produced when high-energy electrons are directed at a metal target, typically made of tungsten, inside an X-ray tube. The high-energy electrons are decelerated rapidly, which causes the release of energy in the form of X-rays.
2. **X-ray Production**:
   - When a high voltage (usually between 30 kV and 150 kV) is applied to an X-ray tube, it accelerates electrons to high speeds. When these electrons hit the target (often tungsten), they release energy in the form of X-rays.
3. **Misconception About Radiation Dangers**:
   - It is true that X-rays involve radiation, but **the dose used in medical X-ray imaging is very small** and is controlled carefully to minimize risks. The amount of radiation used for diagnostic imaging, such as checking a broken bone, is far below the levels that could cause harm.
   - **Precautions**: While radiation exposure is associated with some risks, healthcare providers ensure that X-ray doses are kept as low as possible (following the ALARA principle: "As Low As Reasonably Achievable"). Shielding and protective clothing (e.g., lead aprons) are also used to protect parts of the body that are not being imaged.
4. **X-ray Safety**:
   - Medical X-rays are a **valuable tool** used to visualize bones and internal structures in the body. X-ray exposure is typically brief and does not lead to significant harm when used appropriately. In fact, diagnostic X-rays have been essential in treating injuries like broken bones by helping doctors assess the situation accurately and make informed decisions.

(ii) How X-rays Can Be Used to Solve the Problem of the Family:

In the case of the child with a suspected broken leg, **X-rays** can help doctors confirm the diagnosis. Here's how:

1. **Imaging the Injury**:
   - **X-rays** are especially useful for **visualizing bones**. If the child's leg is suspected to be broken, an X-ray can provide a clear image of the bone structure, showing whether there is a fracture and its severity.
2. **Guiding Treatment**:
   - An X-ray helps the doctor determine the **type** of fracture (e.g., simple, complex, or compound) and the **location** of the break. This is crucial for deciding the appropriate treatment, such as whether the leg needs to be set in a cast or if surgery is required.

3. **Speed and Accuracy**:
    - The X-ray process is quick and non-invasive, which allows for a **rapid diagnosis**. The images can be captured in seconds, allowing the medical team to make a timely decision about how best to treat the injury.

By using X-ray imaging, doctors can ensure that the child receives the most appropriate care for a broken leg, leading to faster healing and better outcomes.

(b) How a 10 kV Voltage Can Be Used to Operate the X-ray Machine:

The X-ray machine requires a voltage of **4 kV** to operate, but the available voltage supply is **10 kV**. In this situation, the voltage supply is higher than required, so it must be reduced to the necessary level using a **step-down transformer**.

1. **Step-down Transformer**:
    - A **step-down transformer** is an electrical device used to reduce the input voltage to a lower output voltage. The 10 kV supplied to the machine will be too high for the X-ray tube, so it needs to be reduced to the required 4 kV.
2. **Working of a Step-down Transformer**:
    - A transformer works on the principle of electromagnetic induction and consists of two coils of wire: the **primary coil** (connected to the power supply) and the **secondary coil** (connected to the X-ray machine).
    - The **turns ratio** of the coils determines how much the voltage is increased or decreased. For a step-down transformer, the number of turns in the secondary coil is fewer than the number of turns in the primary coil, which results in a lower voltage on the secondary side.
3. **How the Voltage is Reduced**:
    - The 10 kV voltage from the main supply will be fed into the primary coil of the step-down transformer.
    - Through the transformer's turns ratio, the voltage will be reduced to the required 4 kV, which will then be supplied to the X-ray tube.
4. **Maintaining Control Over X-ray Exposure**:
    - The step-down transformer ensures that the X-ray tube operates at a safe, controlled voltage level (4 kV), which is sufficient to generate the X-rays needed for medical imaging without excess energy.
5. **Precise Control**:
    - Modern X-ray machines often have additional electronics, such as **voltage regulators** and **control circuits**, to ensure that the voltage stays stable and within the required range for consistent and safe X-ray production.

In summary, while the main supply voltage is 10 kV, a **step-down transformer** is used to reduce it to the required 4 kV. This ensures that the X-ray machine operates efficiently and safely within its specified voltage range.

ITEM 8

After research work, your group has presented the following article that was collected from a journal on nuclear science….

"Nuclear energy is the energy in the nucleus of any atom. An atom is a tiny unit that makes up matter; it consists of a small positively charged nucleus with negatively charged electrons rotating around. Nuclear energy can be used in generation of electricity but it must be released from an atom during the process of nuclear fission. A radioactive isotope of Uranium $^{92}_{235}U$ *is commonly in the production of nuclear energy. If the uranium sample of mass 64 kg decays to 4 kg in 96 days by emission of 2 alpha particles and 1 beta particle to form thorium (Th), then the large amounts of nuclear energy released can be trapped and used to power very big manufacturing industries and factories without directly affecting the environment. Also, the discoveries on radioactivity have led to significant advancements in sectors of agriculture, medicine, industries and archeology."*

At the end of your presentation, some classmates have not understand the ideas in it, and have requested you on behalf of the group to give them more details.

Task

As a learner of Physics assist them by:

(a) (i) Explaining how the discoveries on radioactivity have played a great role in enhancing the different sectors.

(ii) Explaining how harmful the discoveries can be, in the field of medicine.

(b) Showing, using a well-balanced equation, how uranium reduced to thorium.

(c) Determining the time taken by the uranium isotope to reduce to half its original size.

SOLUTION

(a) Role of Discoveries on Radioactivity in Enhancing Different Sectors

(i) How Discoveries on Radioactivity Have Played a Great Role in Enhancing Different Sectors

The discovery of radioactivity has led to significant advances in many sectors. Here's how it has contributed to various fields:

1. **Medical Field (Radiology and Cancer Treatment)**:
    - **Medical Imaging**: Radioactive isotopes, such as **Technetium-99m**, are widely used in **nuclear medicine** for **diagnostic imaging** (e.g., PET scans and MRIs). These isotopes help doctors observe the internal structures of the body, detect diseases, and identify health conditions like cancer or heart disease.
    - **Cancer Treatment**: Radiation therapy uses controlled amounts of radiation to **shrink tumors** or kill cancer cells. **Cobalt-60** and **Radium-226** are examples of radioactive isotopes used in treating certain types of cancers, such as prostate cancer, breast cancer, and brain tumors.
    - **Sterilization**: Radioactivity is used to sterilize medical instruments, ensuring they are free of bacteria and other pathogens without heat or chemicals.
2. **Energy Sector (Nuclear Power Generation)**:
    - **Nuclear Power**: Radioactive isotopes like **Uranium-235** and **Plutonium-239** are used as fuel in nuclear reactors. These materials undergo **nuclear fission**, producing large amounts of energy. This energy is harnessed to generate electricity for homes, industries, and cities.
    - **Cleaner Energy**: Nuclear energy is considered a low-carbon alternative to fossil fuels, reducing greenhouse gas emissions and helping to mitigate climate change.
3. **Industrial Applications**:

- **Radiography**: Radioactive materials are used for **non-destructive testing (NDT)** in industries like construction and manufacturing. For example, X-rays or gamma rays can inspect the integrity of metal welds or the internal structure of components without damaging them.
- **Thickness Gauging**: Radioactive sources are used in industries like paper, plastic, and metal manufacturing to measure the thickness of materials during production.

4. **Scientific Research**:
   - Radioactive tracers are used in **biological and environmental research** to track the movement of substances within living organisms or ecosystems. Researchers use these isotopes to study how elements behave in chemical reactions or in the environment.

(ii) How Harmful the Discoveries Can Be in the Field of Medicine

While radioactivity has many positive applications, there are also risks, especially in medical settings:

1. **Overexposure to Radiation**:
   - **Radiation Exposure**: While medical procedures like X-rays and radiation therapy use controlled doses of radiation, overexposure can damage tissues, cells, or DNA, leading to harmful effects like **radiation burns**, **acute radiation sickness**, or increased risk of cancer.
   - **Cumulative Effect**: Repeated exposure to radiation, especially at high doses, can increase the risk of developing cancers, such as leukemia, thyroid cancer, or lung cancer. This is why it's important to limit radiation exposure to only necessary medical procedures.
2. **Radiation Therapy Side Effects**:
   - While radiation therapy is used to treat cancer, it can have side effects. Healthy tissues surrounding the cancerous cells can also be affected, leading to side effects such as **fatigue**, **nausea**, **hair loss**, and damage to organs near the treatment area (e.g., lungs, digestive system, or skin).
   - **Long-term Effects**: Sometimes, even after successful cancer treatment, patients may experience long-term side effects from radiation therapy, including damage to normal cells and an increased risk of developing secondary cancers years later.
3. **Need for Proper Safety Protocols**:
   - The use of radioactive materials in medicine requires strict safety measures to avoid accidental exposure. For example, medical personnel working with radioactive materials must wear protective clothing, use shielding, and monitor radiation levels to minimize risks. Patients also need to be informed of the potential risks associated with radiation treatments.

(b) How Uranium Reduces to Thorium

The process of uranium decay to thorium involves a nuclear decay process known as **alpha decay**, in which uranium (U) loses an alpha particle (which consists of 2 protons and 2 neutrons). Here's the balanced equation for the decay of uranium to thorium:

$$\text{Uranium-238} \rightarrow \alpha\text{Thorium-234} + \text{Alpha particle}$$

This equation shows that **Uranium-238 (U-238)** undergoes alpha decay to become **Thorium-234 (Th-234)** and releases an **alpha particle (helium nucleus)** in the process. The thorium-234 isotope has 90 protons, while uranium-238 has 92 protons, reflecting the loss of two protons and two neutrons in the alpha decay.

(c) Determining the Time Taken by the Uranium Isotope to Reduce to Half Its Original Size (Half-Life)

c) 64kg to 4kg for 96days

64 $\xrightarrow{t_{\frac{1}{2}}}$ 32 $\xrightarrow{t_{\frac{1}{2}}}$ 16 $\xrightarrow{t_{\frac{1}{2}}}$ 8 $\xrightarrow{t_{\frac{1}{2}}}$ 4

$$4t_{\frac{1}{2}} = t$$

$$\frac{4t_{\frac{1}{2}}}{4} = \frac{96}{4}$$

$$t_{\frac{1}{2}} = 24hours$$

$$\therefore half\ life\ t_{\frac{1}{2}} = 24hours$$

ITEM 9

In a certain school, a student carried an experiment to determine the penetrating power of a radioactive nuclide **X** using Geiger muller tube radiation detector connected to the speaker. The speaker was used to give sound whenever nuclide X was radiating. He used different materials which were placed in front of the detector. One material was placed in front of the detector one at a time and sound was heard from the speaker.

Task: As a physics learner, describe how different radiations penetrate materials used in the experiment. (**5 scores**)

Hint: Materials are; thick sheet of paper, aluminum foil, and Lead shield.

(a) Mr. Titus is yet to graduate from the department of Physics at Kyambogo University and the University requires him to carry out research in order to graduate. This made Mr. Titus to look at the areas where he can carry out his research and, in the process, he discovered that rays can be emitted from the metal surfaces when metals are subjected to a source of energy. During his research, he read published research papers by other authors and found out that rays are produced by two processes from the metal surfaces. These processes include **thermionic emission** and **photoelectric effect**. This made Mr. Titus took key interest on how to produce rays using the thermionic process during his research study. If he read many articles and found out that the device, he needs is Cathode Ray Oscilloscope for his experiment to study how rays can be produced. Unfortunately, Mr. Titus does not know how the **Cathode ray oscilloscope** looks like and this has made his research very difficult that made him fail to submit it for marking yet the graduation day is drawing near. As Mr. Titus continued to read other different articles, he found out that the rays produced by the photoelectric effects are very important in our life.

Tasks: As a physics learner, help Mr. Titus come up with a clear diagram of a cathode ray oscilloscope so that he can build in your absent. Also support him to know how this device works such that when he is presenting his work for marking, he does not fail. **(7 scores)**

SOLUTION

(a) Penetrating Power of Different Types of Radiation (Geiger-Muller Tube Experiment)

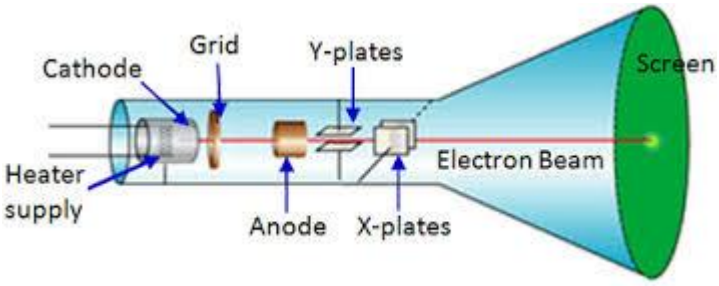
In the experiment, the student is using a Geiger-Muller tube connected to a speaker to detect the radiation emitted by a radioactive nuclide X. Different materials were placed in front of the detector, and the sound from the speaker indicates the intensity of the radiation reaching the detector.

Different types of radiation have different abilities to penetrate materials. The three common types of radiation are **alpha radiation (α)**, **beta radiation (β)**, and **gamma radiation (γ)**. Here's how each radiation type interacts with materials:

1. **Alpha Radiation (α)**:
   - **Penetrating Power**: Alpha particles are the least penetrating of the three types of radiation. They are heavy and positively charged particles consisting of 2 protons and 2 neutrons. Alpha particles can be stopped by a **sheet of paper** or even by the outer layer of human skin.
   - **Effect on Materials**: If a thick sheet of paper is placed in front of the Geiger-Muller tube, the alpha particles will be completely absorbed, and the sound from the speaker will stop. This is because alpha particles cannot penetrate the paper.
2. **Beta Radiation (β)**:
   - **Penetrating Power**: Beta particles are electrons (or positrons) and are much lighter and faster than alpha particles. Beta radiation can penetrate materials more effectively than alpha radiation, but it is still not as penetrating as gamma radiation. Beta particles can pass through a thin sheet of paper but will be stopped by materials like **aluminum foil**.
   - **Effect on Materials**: When an aluminum foil is placed in front of the detector, beta particles will be partially absorbed by the foil, and the sound from the speaker will decrease or stop, depending on the thickness of the aluminum foil. If the foil is thin enough, some beta particles may still reach the detector, but thicker foil will stop them.
3. **Gamma Radiation (γ)**:
   - **Penetrating Power**: Gamma rays are electromagnetic waves (photons) and have the highest penetrating power of all the types of radiation. Gamma radiation can pass through many materials, including paper and aluminum, but can be stopped by **thick lead shielding**.
   - **Effect on Materials**: When a **lead shield** is placed in front of the detector, it will block gamma radiation effectively, and the sound from the speaker will stop or decrease significantly, depending on the thickness of the lead. Lead is a very dense material and is ideal for shielding gamma radiation

(b) Diagram and Working of a Cathode Ray Oscilloscope (CRO)

Diagram of a Cathode Ray Oscilloscope (CRO)



Below is a simplified diagram of a **Cathode Ray Oscilloscope (CRO)**:

The **Cathode Ray Oscilloscope (CRO)** consists mainly of the following components:

1. **Cathode Ray Tube (CRT)**: This is the main component where the electron beam is generated and manipulated. The electrons are emitted from a **cathode**, and then accelerated towards an **anode**. The electron beam is directed towards the screen (phosphorescent display), where it can produce visible patterns (such as waveforms).
2. **Deflection Plates**: These plates (horizontal and vertical) control the path of the electron beam by applying electric fields. They help to display the waveform on the screen.

3. **Screen**: The screen of the CRT is coated with a phosphorescent material that lights up when struck by the electron beam, creating a visible trace (or waveform) on the screen.
4. **Control Knobs**: These are used to adjust the settings of the CRO, such as **brightness**, **focus**, and **time base**. The time base controls how fast the electron beam moves across the screen, and the intensity controls how bright the displayed trace is.
5. **Power Supply**: The power supply provides the necessary voltage for the operation of the CRO, including accelerating the electrons and powering the deflection plates.

How a Cathode Ray Oscilloscope Works

A Cathode Ray Oscilloscope (CRO) works by using a **stream of electrons** generated from a heated **cathode** (electron source). Here's a step-by-step explanation of how it works:

1. **Electron Emission**: The cathode is heated, and this causes it to emit electrons through **thermionic emission**. The emitted electrons are accelerated by an electric field towards an anode, which allows the electrons to pass through and form a beam.
2. **Electron Beam Acceleration**: The electrons are accelerated by the high voltage applied between the cathode and the anode. The electron beam is then directed towards the phosphorescent screen of the CRT.
3. **Deflection of Electron Beam**: The electron beam is deflected both horizontally and vertically by the **deflection plates**. The horizontal deflection controls the movement of the beam across the screen (X-axis), and the vertical deflection controls the movement of the beam up and down the screen (Y-axis). The deflection is controlled by applying electric fields to these plates.
4. **Display of Waveform**: As the electron beam strikes the phosphorescent screen, it causes the screen to light up, creating a visible trace or waveform on the screen. This waveform corresponds to the signal that is being observed. The time base setting controls how fast the waveform moves across the screen, allowing the user to view different time intervals.
5. **Signal Observation**: By adjusting the time base and vertical controls, the user can examine the signal in detail, measuring aspects such as amplitude, frequency, and waveform shape. The oscilloscope is used to study **AC signals** and **waveforms**.

Application of the CRO in Mr. Titus's Research

Mr. Titus can use the **CRO** to study the behavior of **thermionic emission** and the **photoelectric effect**. Here's how:

- **Thermionic Emission**: Mr. Titus can study the current produced by the cathode ray tube by heating the cathode. The CRO will allow him to visualize the voltage and current waveforms on the screen. By varying the temperature of the cathode, he can study how the current changes with temperature, providing insights into thermionic emission.
- **Photoelectric Effect**: Mr. Titus can use the CRO to observe the effect of different light intensities or wavelengths on the emission of electrons from a metal surface. The CRO can be used to measure the resulting current and visualize how it changes with the intensity of the light, demonstrating the photoelectric effect.

Summary of Solutions**:**

- **(a)** Different types of radiation (alpha, beta, and gamma) have different penetrating powers:
    - **Alpha radiation** is blocked by a sheet of paper.

    - **Beta radiation** is blocked by aluminum foil.
    - **Gamma radiation** is blocked by a lead shield.
- **(b)** The **Cathode Ray Oscilloscope (CRO)**:
    - **Diagram**: The CRO consists of a cathode ray tube (CRT), deflection plates, and control knobs.
    - **Working**: Electrons are emitted from a heated cathode, accelerated by a voltage, and deflected by plates to form a trace on the phosphorescent screen. This trace can display waveforms corresponding to various signals.
    - **Application**: Mr. Titus can use the CRO to study thermionic emission and the photoelectric effect by observing the voltage and current waveforms.

By following these instructions, Mr. Titus can better understand how to use the CRO in his research and present his findings effectively.

ITEM 10

The government has discovered a precious and rare mineral in a certain part of the country. A team of men picked samples and kept them in a store of one of the hospitals where photographic plates are also stored. The mineral was checked on regularly and they made the following observations; All photographic plates had darkened.

 Its mass reduced spontaneously with time as shown below

Mass (g)	200	150	70	35	25
Time (days)	0	4	16	28	30

As a physics learner,

(a) Support the view that the mineral is radioactive.

(b) Use the graph to estimate its half-life

(c) Explain the best way of storing this rare mineral.

(d) What are the dangers of exposing this mineral to the public

SOLUTION

(a) Support the View that the Mineral is Radioactive

The observations made about the mineral strongly suggest that it is radioactive. Here are the key points that support this:

1. **Darkening of Photographic Plates**: Photographic plates darken when exposed to radiation. The fact that the photographic plates were darkening indicates that the mineral is emitting ionizing radiation, which is characteristic of radioactive substances. When the radioactive material emits radiation, it can interact with the photographic material and cause the darkening effect.
2. **Reduction in Mass with Time**: The mineral's mass is reducing spontaneously with time. This is typical behavior for radioactive materials, as they undergo radioactive decay, where a fraction of the material is lost over time due to the emission of radiation (such as alpha, beta, or gamma radiation). The loss of mass is a result of the decay process, where atoms of the mineral break down into more stable forms, releasing radiation in the process.

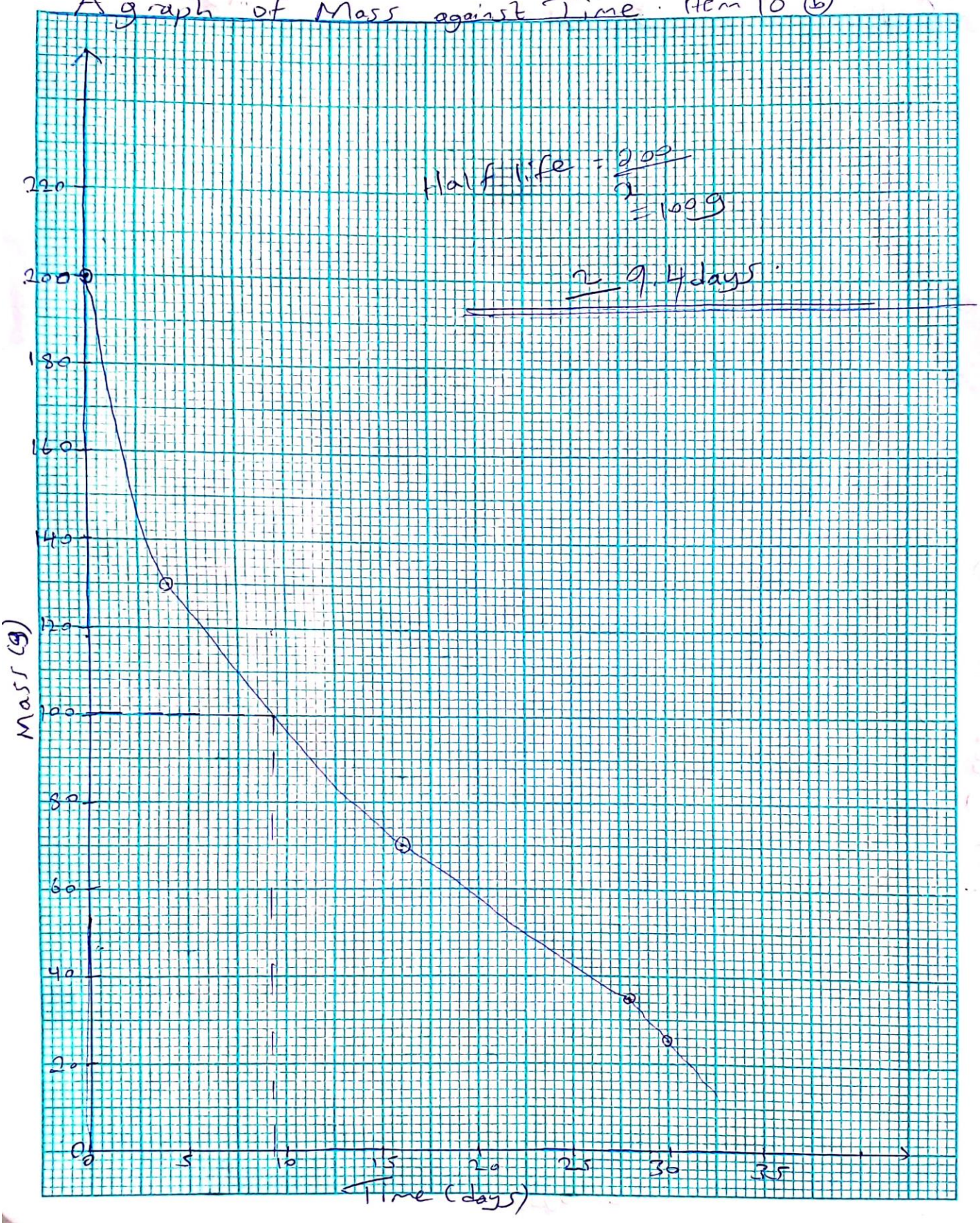
3. **Spontaneous Nature**: Radioactive decay is spontaneous and does not require any external energy or influence. The fact that the mineral's mass reduced spontaneously over time further supports the idea that it is radioactive.

Thus, based on the darkening of photographic plates and the reduction of mass over time, it is reasonable to conclude that the mineral is radioactive.

(b) Use the Graph to Estimate Its Half-life

To estimate the half-life of the mineral from the given data, we can plot a graph of **mass vs. time** and use the concept of half-life.

A graph of Mass against Time. Item 10 (b)



(c) Explain the Best Way of Storing This Rare Mineral

Since the mineral is radioactive, it must be stored in a safe manner to prevent exposure to harmful radiation. The following precautions should be taken when storing the mineral:

1. **Shielding**: The mineral should be stored in a **shielded container** to protect people from radiation exposure. This container should be made of materials that can absorb or block the radiation emitted by the mineral. Lead or thick concrete are commonly used to shield gamma radiation, while other materials like plastic or aluminum can shield alpha and beta radiation effectively.
2. **Storage in Isolated Areas**: The mineral should be kept in a **secure, isolated area** to ensure that no unauthorized personnel come into contact with it. The storage area should be well-ventilated and located away from places where people frequently gather, such as public areas or living quarters.
3. **Signage and Warnings**: Clear warning signs should be placed around the storage area to indicate that it contains radioactive material. These signs should inform people about the potential hazards of radiation exposure.
4. **Temperature and Humidity Control**: The storage area should be kept at a stable temperature and humidity to prevent any external environmental factors from affecting the stability of the mineral or its radiation emission.
5. **Monitoring**: Regular radiation monitoring should be conducted in and around the storage area to ensure that radiation levels are within safe limits. This can be done using radiation detectors or Geiger counters.

(d) Dangers of Exposing this Mineral to the Public

Exposing radioactive materials to the public can lead to significant health and environmental dangers. Some of the key risks include:

1. **Radiation Exposure**: Radioactive materials emit ionizing radiation, which can damage living cells and tissues. Prolonged exposure to high levels of radiation can lead to serious health issues such as:
    - **Cancer**: Ionizing radiation can cause mutations in DNA, which may lead to the development of cancer, particularly leukemia, thyroid cancer, and other types of tumors.
    - **Radiation Burns**: High doses of radiation can cause immediate damage to tissues, leading to radiation burns and other forms of physical damage.
    - **Genetic Mutations**: Exposure to radiation can cause genetic mutations in reproductive cells, leading to birth defects in future generations.
2. **Environmental Contamination**: If radioactive materials are released into the environment, they can contaminate soil, water, and air. This can affect ecosystems and lead to long-term environmental damage, including the contamination of food and water sources.
3. **Increased Risk for Vulnerable Groups**: Certain groups, such as pregnant women, children, and people with compromised immune systems, are more vulnerable to the harmful effects of radiation. Exposure to radiation can be more damaging to these individuals.
4. **Accidental Exposure**: If radioactive materials are mishandled or stored improperly, there is a risk of accidental exposure. This could happen if the mineral is accidentally released into public spaces or if individuals come into direct contact with the material.

To minimize these dangers, the mineral should be carefully controlled, stored securely, and monitored regularly to ensure that it does not pose a risk to public health and safety.

ITEM 11

At a major airport, X—ray machines are used to screen luggage and chcck for weapons and other prohibited items. Recently, a suspicious item was detected in a passenger's bag, but the X—ray image was unclear, causing confusion among security personnel. Furthcr investigation revealed that the X—ray machine's performance was affected by a nearby source of unknown radiation from a shipment containing isotopes of uranium with a known half-life. The security team was concerned about the incidence but couldn't understand how the machine operates, the type of radiation being produced by the radioactive substance, and the likely impact on their health and environment. Hint:

- The nearby shipment contains isotopes of Uranium of half-life 4.5 billion years.
- The radioactive decay equation for Uranium atom is:

$\longrightarrow$ 238Th 90 $+ {}^{A}_{Z}X$

Task:

Using the knowledge of physics, help the airport security team understand;

(a) The principle of X-ray imaging and why it is used for checking weapons at the airport.

(b) Which radiation was being produced and what percentage of the radioactive substance will remain after 22.5 billion years.

(c) How to mitigate the impact of the radioactive material on the X-ray machine's operation and ensure accurate luggage screening.

SOLUTION

(a) The Principle of X-ray Imaging and Why It Is Used for Checking Weapons at the Airport

X-ray imaging works on the principle that X-rays can penetrate materials to varying extents, depending on the material's density and atomic composition. When an object is exposed to X-rays, some of the X-rays pass through the object, and some are absorbed by it. These differences in absorption create a shadow or an image on a detector (such as a photographic plate or digital sensor) placed behind the object.

- **How it works**:
    1. **X-ray Source**: An X-ray machine generates a beam of X-rays by accelerating electrons and then striking them against a metal target (usually tungsten). This causes the emission of X-rays, which are directed toward the object being examined.
    2. **Penetration**: X-rays are a form of electromagnetic radiation, similar to light but with much higher energy. They can penetrate many materials, but different materials absorb X-rays differently. Denser materials, such as metals, absorb more X-rays and appear darker on the image, while less dense materials, like plastic, let more X-rays pass through and appear lighter.
    3. **Detection**: The X-rays that pass through the object strike a detector, which creates an image based on the varying intensities of X-rays that passed through. This is displayed on a monitor as a radiographic image. In luggage screening, the machine helps distinguish between materials of different densities to identify potential threats (such as weapons, explosives, or contraband).
- **Why it is used for checking weapons**: X-ray imaging is used at airports because it is a non-invasive and efficient method to inspect luggage. It allows security personnel to examine the contents of a bag without opening it. The different densities of materials inside the luggage can be clearly distinguished, making it easier to identify weapons or other prohibited items.

(b) Which Radiation Was Being Produced and What Percentage of the Radioactive Substance Will Remain After 22.5 Billion Years

The shipment contains **uranium isotopes**, specifically uranium-238 , which decays over time to form other elements through a process called **radioactive decay**.

The equation for the decay of uranium-238 is as follows:

$238U \rightarrow 234Th + \alpha$ (alpha decay)

- **Type of Radiation**: Uranium-238 undergoes **alpha decay**, emitting alpha particles (α\alpha) in the process. Alpha radiation consists of two protons and two neutrons, and it has a low penetrating power. It can be stopped by a sheet of paper or the outer layer of human skin, but it is harmful if inhaled or ingested.
- **Percentage Remaining After 22.5 Billion Years**: Given that the half-life of uranium-238 is **4.5 billion years**,
- $Time = 22.5 billion\ years$

Half-life = 4.5billion years

From the formula

$$\frac{M_o}{M_t} = 2^{\frac{t}{t_{\frac{1}{2}}}}$$

Where M_o is original mass, t is time

M_t is mass left, $t_{\frac{1}{2}}$ is half-life

$$\frac{M_o}{M_t} = 2^{\frac{22.5}{4.5}}$$

$$\frac{M_o}{M_t} = 2^5 = 32$$

Mass left $M_t = \frac{1}{32} M_o (Original\ mass)$

$$= \frac{1}{32} \times 100 = 3.125\%$$

Therefore, after 22.5 billion years, **1/32** of the original uranium-238 will remain. This means that only approximately **3.125%** of the original radioactive substance will be left after 22.5 billion years.

(c) How to Mitigate the Impact of the Radioactive Material on the X-ray Machine's Operation and Ensure Accurate Luggage Screening

The presence of nearby radioactive materials can potentially affect the operation of sensitive equipment like X-ray machines. Here's how to mitigate the impact:

1. **Shielding**:

    - The radioactive material emitting **alpha radiation** will not affect the machine as much due to its low penetration power, but if the material is emitting **gamma radiation** (which is possible in uranium decay), gamma rays could interfere with the X-ray machine's detectors.
    - To mitigate this, the radioactive shipment should be **shielded properly**. Using **lead shielding** or other dense materials around the shipment can absorb gamma rays and prevent them from interfering with the X-ray machine's performance. The shielding should be designed based on the intensity of the radiation and the specific materials involved.
2. **Distance**:
    - The intensity of radiation decreases with the square of the distance from the source. Keeping the radioactive shipment **far away** from the X-ray machines and other sensitive equipment can reduce the impact of radiation on the X-ray image quality.
    - The shipment should be stored in a **separate, controlled area** away from any operational machinery.
3. **Monitoring and Calibration**:
    - The X-ray machine should be **regularly calibrated** to ensure accurate imaging. If interference from radiation is suspected, the machine's detectors and sensitivity settings can be adjusted to compensate.
    - **Radiation monitors** can be placed near the X-ray machines to continuously measure ambient radiation levels. If excessive radiation is detected, the equipment can be shut down for safety purposes or recalibrated.
4. **Radiation Hazard Signs**:
    - The area where the radioactive materials are stored should be clearly marked with **radiation hazard signs** to alert personnel about potential radiation exposure. This ensures that everyone is aware of the risk and can take appropriate precautions.
5. **Enhanced X-ray Imaging**:
    - To ensure the X-ray machine provides clearer images, it may be beneficial to use **multiple energy levels** of X-rays. This technique, known as **dual-energy X-ray scanning**, can improve the contrast between different materials and may help reduce any interference from the nearby radiation source.

Summary of Solutions:

- **(a)** X-ray imaging works by using X-rays to penetrate objects, with denser materials absorbing more X-rays. It is used for screening luggage because it can distinguish between different materials, allowing security to detect weapons and other prohibited items.
- **(b)** The radiation being produced by the uranium isotopes is **alpha radiation**. After **22.5 billion years** (5 half-lives), only approximately **3.125%** of the uranium-238 will remain.
- **(c)** To mitigate the impact of the radioactive material on the X-ray machine:
    - **Shield the radioactive shipment** with lead or dense materials.
    - **Increase the distance** between the radioactive material and the X-ray machine.
    - **Calibrate** the X-ray machine regularly and use radiation monitoring.
    - Store the radioactive material in a **separate, controlled area** and place **radiation hazard signs**.
    - Use **dual-energy X-ray scanning** to improve image clarity and reduce interference.

By taking these precautions, the security team can ensure that the X-ray machines continue to operate effectively and that luggage screening remains accurate and safe.

LIGHT AND WAVES SOLUTIONS FROM ITEM 1 TO 25

ITEM 1

a) Two people stood in the middle of two cliffs at an unknown distance between them. The woman calls the boy and she hears herself 5 seconds later and the boy hears the second sound after 4 seconds. The two discovered that their sound was clearer at night than during the day. The scenarios left them confused without understanding the magic in the hall.

TASK:

As a physics student;

i) What is the scientific name is given to this second sound? (1 score)

ii) Help the two people understand why the sound was clearer at night than that during the day. (5 scores)

b) Light from air is made to strike the surface of alcohol of refractive index of 1.36 such that the incident light makes an angle of 20 º with the normal at the point of incidence.

TASK:

i) What physics term is given to these phenomena and state the laws that govern them.

ii) What is the angle of refraction as light passes the air-alcohol interface. (3 scores)

SOLUTION

i) What is the scientific name given to this second sound?

The second sound is known as **echo**. An echo occurs when sound waves reflect off a surface or obstacle and return to the listener after a delay.

ii) Why was the sound clearer at night than during the day?

At night, sound appears clearer and travels further than during the day due to differences in temperature and air density. Here's a detailed explanation:

1. **Temperature Gradient:** During the day, the air near the ground tends to be warmer due to sunlight, and the air higher up is cooler. This creates a temperature gradient in the atmosphere, where sound waves travel faster in warmer air and slower in cooler air. As sound waves pass through different temperature layers, they refract (bend), causing the sound to scatter and become less clear.

At night, the ground cools more quickly than the air above it, creating an inverted temperature gradient. In this case, sound waves travel more directly because the air near the ground is cooler, causing sound waves to bend toward the ground. This allows sound to travel further with less distortion and more clarity.

2. **Air Density:** Cooler air is denser than warmer air, and denser air conducts sound waves better. At night, the denser cooler air allows sound waves to travel with less scattering and attenuation, making the sound clearer.

In summary, the clarity of sound at night is due to the cooler air and inverted temperature gradient, which causes sound to travel more directly and with less distortion.

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b) Refraction Problem:

i) What physics term is given to these phenomena and state the laws that govern them.

The phenomenon is called **refraction**. Refraction occurs when light passes from one medium to another (in this case, from air to alcohol) and changes direction due to a change in its speed.

The laws that govern refraction are known as **Snell's Law**. Snell's Law is given by the equation:

$$n_1\sin(\theta_1)=n_2\sin(\theta_2)$$

Where:

- n_1 is the refractive index of the first medium (air in this case, with $n_1\approx1.00$)
- θ_1 is the angle of incidence (the angle between the incident ray and the normal),
- n_2 is the refractive index of the second medium (alcohol in this case, with $n_2=1.36$)
- θ_2 is the angle of refraction (the angle between the refracted ray and the normal).

ii) What is the angle of refraction as light passes the air-alcohol interface?

Given:

- $n_1=1.00$ (refractive index of air),
- $n_2=1.36$ (refractive index of alcohol),
- $\theta_1=20^\circ$ (angle of incidence).

We can use Snell's Law to find the angle of refraction (θ^2):

$1.00\times\sin(20\circ)=1.36\times\sin(\theta_2)$

First, calculate $\sin(20\circ)\approx0.342$

Now, substitute into the equation:

$0.342=1.36\times\sin(\theta^2)$

Solve for $\sin(\theta^2)$:

$\sin(\theta^2)= 0.342/1.36\approx0.251$

Now, calculate θ^2:

$\theta2=\sin^{-1}(0.251)\approx14.5^\circ$

Thus, the angle of refraction is approximately **14.5°**.

ITEM 2

During a science project, learners are given two devices; a pinhole camera of length50 cm and a concave mirror of focal length 50 cm. As a learner of Physics, help the students determine which instrument forms a bigger image of the man of height 1.8 m standing 2m away from each of the instruments.

Write a report about the nature of the images formed by each of the devices and what would happen if the size of the pinhole was enlarged. (12 scores)

A group of hunters are told that the distant hill in the north of their village has very many wild animals which they can kill for meat. The hunters agree to meet and set off at night fall so that they reach the hill

by morning. They started off the journey with some holding solar bulbs and the others hand torches. When they had grouped together to start the journey, some feared that the distance might be longer than expected. Their leader resolved that if the distance is more than 12Km then it is not safe to go but the problem is that no one in the group was sure of the distance. One of the hunters decides makes a loud sound and they are surprised to hear a loud and clear sound come back later after 30s.

When the hunters who had solar bulbs switched them on, they could not the distant hill but those who switched on their torches could see part of the hill and this puzzled the hunters.

Hint: speed of sound in air=330ms-1

Task:

As a student of Physics, help the hunters to clearly understand;

a) whether it was safe to go or not.

b) Why a clear and loud sound came back after some time.

c) Why hunters who used the solar bulbs couldn't see the hill while those who used the torch light could see part of the hill.

SOLUTION

1. Pinhole Camera vs. Concave Mirror

Pinhole Camera:

- **Nature of Image:** The pinhole camera forms an inverted image due to the principle of rectilinear propagation of light. The image is formed at the focal length of the pinhole (50 cm in this case) on the opposite side of the pinhole from the object.
- **Image Size:** The size of the image formed by a pinhole camera depends on the distance of the object from the pinhole. In this case, the man of height 1.8 m standing 2 m away would form a relatively small inverted image on the screen placed behind the pinhole.

Concave Mirror:

- **Nature of Image:** A concave mirror can form both real and inverted images (when the object is beyond the focal point) or virtual and erect images (when the object is within the focal point). For an object placed beyond the focal point (2 m in this case), the concave mirror will form a real and inverted image.
- **Image Size:** The size of the image formed by a concave mirror depends on the object distance and the focal length of the mirror. Given a focal length of 50 cm and an object distance of 2 m, the image formed would typically be larger compared to the pinhole camera due to the reflective properties and focal length of the mirror.

2. Effect of Enlarging the Pinhole

If the size of the pinhole in the pinhole camera is enlarged:

- **Image Brightness:** The image formed would become brighter because more light would pass through the larger aperture.
- **Image Sharpness:** However, the sharpness of the image would decrease due to increased diffraction effects. This means the image would be less distinct or clear.

Part 2: Physics of the Hunters' Situation

a) Safety of the Journey

The hunters conducted a sound test and heard the echo after 30 seconds. The speed of sound in air is approximately 330 m/s.

- **Calculating Distance:** Distance to the object = Speed of sound × Time taken for echo / 2 Distance = 330 m/s × 30 s / 2 = 4950 meters = 4.95 km

Since the distance is less than 12 km (which is approximately 12000 meters), it is safe for the hunters to proceed to the hill.

b) Reason for Echo

- **Echo Formation:** The echo is caused by the reflection of sound waves from a distant object (the hill) back to the hunters after some time delay. This delay corresponds to the time taken for the sound to travel to the object and back.

c) Visibility with Solar Bulbs vs. Torches

- **Solar Bulbs:** Solar bulbs produce diffuse light, which may not be focused or strong enough to illuminate distant objects clearly. Hence, the hunters using solar bulbs couldn't see the distant hill clearly.
- **Torches:** Torches produce a more focused beam of light, which is directed towards the hill, allowing the hunters to see part of it despite the darkness.

In summary, the report covers the principles of image formation by different optical instruments (pinhole camera and concave mirror) and explains the acoustic principles involved in determining the distance to the hill, as well as the optical properties of light sources (solar bulbs and torches) affecting visibility in the dark.

ITEM 3

The mother developed a dental challenge but could not identify the exact tooth that should be extracted even after checking using her phone mirror. She decides to go the dental clinic. In the dental clinic, a small mirror was used and the tooth was easily identified. This made the mother to be more interested in the mirror and on checking, it had the following writings.

Radius of curvature = 20 cm

When she placed her face about 6.0 cm in front of the mirror, her face appeared different with bigger eyes and nose which left her wondering.

TASK

As a physics student,

(a) Make use of a ray diagram to explain how the mirror in the clinic is different from the one at home and how it works.

(b) Use a graph to support your explanation to the mother about the nature of the image of her face when she tried to look through it.

SOLUTION

In the clinic, the mirror described has a **radius of curvature of 20 cm**. From this, we can deduce that it is a **concave mirror**.

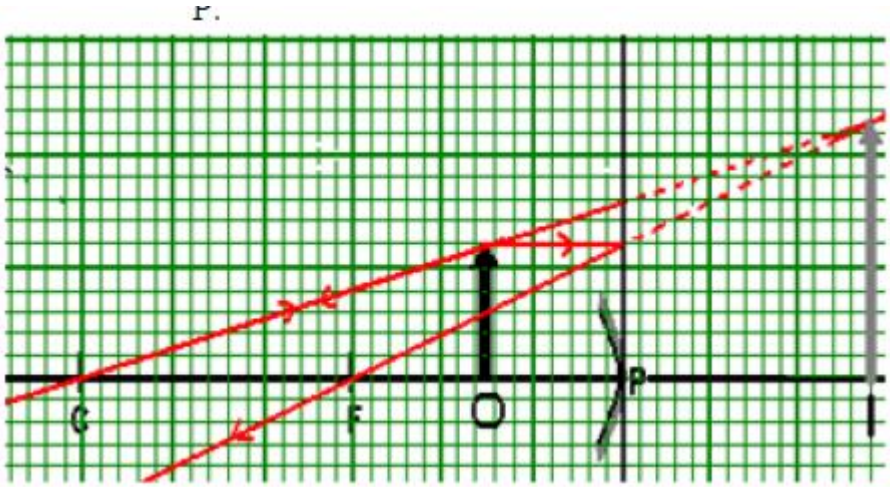
Concave Mirror:

A **concave mirror** is a spherical mirror with an inward-curved reflecting surface. The main properties of this type of mirror are:

- **Radius of curvature (R)**: This is the distance from the center of curvature to the mirror's surface. Given that R=20cm, the **focal length (f)** of the mirror is half of the radius:

  F = R/2 = 20/2 =10 cm

- **Object Distance (u)**: The mother placed her face about **6.0 cm** in front of the mirror. This is the **object distance**.
- **Image Formation**: When an object is placed in front of a concave mirror, it forms an **enlarged, virtual, and upright image** if the object is placed closer to the mirror than its focal point (in this case, the focal length is 10 cm, and the object is at 6 cm).



b. The mirror formula relates the object distance (u), the image distance (v), and the focal length (f):

$1/f = 1/v + 1/u$

- **Given**: f=10cm (as calculated from the radius of curvature),
- **Object distance**: u=6.0 cm
- We need to calculate the image distance (v).

Rearranging the mirror equation to solve for v:

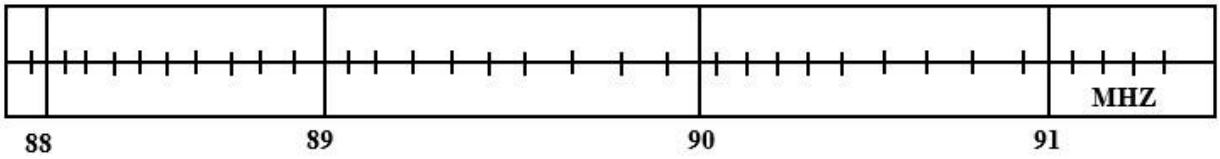
$1/v = 1/f - 1/u$
$1/v = 1/10 - 1/6$

$1/v = 3/30 - 5/30 = -2/30$
$V = -15cm$

This negative value of v indicates that the image is **virtual** and formed behind the mirror.

ITEM 4

An NGO is giving out radio and TV sets to people living in a valley surrounded by hills. The radio sets have a special antenna in form of a curved mirror. These people in this area listen to majorly three FM radio stations namely A-FM, B-FM and C-FM. These radio sets have a frequency bar as indicated below.



Both the radio and TV signals are weak in this area but TV signals are weaker compared to those of the radio set. The people find it difficult to manually locate the FM stations using the knob on the radio set. When you move very close to this curved mirror like antenna, a scaring image is formed in the mirror.

Hint

A-FM, B-FM and C-FM signals are broadcast at wavelengths of 3.40 m, 3.37 m and 3.33 m respectively and the speed of electromagnetic waves

is $3 \times 10^8 ms^{-1}$.

As a learner

(a) Help these people to mark the 3 radio stations on the frequency bar shown in the figure above.

(b) Explain to these people why the TV signals are weaker than the radio signals.

(c) Comment on the nature and formation of the scaring images in the curved mirror.

(d) Suggest ways of improving on the strength of the radio and TV signals.

SOLUTION

Part (a) Marking the Three Radio Stations on the Frequency Bar

To mark the radio stations (A-FM, B-FM, and C-FM) on the frequency bar, we need to first calculate the frequencies of the three FM stations based on their given wavelengths. The relationship between the wavelength (λ), frequency (f), and the speed of electromagnetic waves (v) is given by:

$V = f\lambda$

Where:

- $v=3\times10^8$ m/s(speed of electromagnetic waves),
- λ is the wavelength,
- f is the frequency of the wave.

Step 1: Calculate the frequencies for each radio station.

- **For A-FM (wavelength = 3.40 m):**

  $F_A = v/\lambda_A = 3\times10^8/3.40 = 8.82\times10^7$ Hz

- **For B-FM (wavelength = 3.37 m):**

  $f_B = v/\lambda_B = 3\times10^8/3.37 = 8.90\times10^7$ Hz

- **For C-FM (wavelength = 3.33 m):**

  $f_C = v/\lambda_C = 3\times10^8/3.33 = 9.00\times10^7$ Hz

Step 2: Convert frequencies to more common units (MHz):

- **A-FM**: 8.82×10^7 Hz=88.2 MHz
- **B-FM**: 8.90×10^7 Hz=89.0 MHz
- **C-FM**: 9.00×107 Hz=90.0 MHz

Step 3: Marking on the frequency bar.

If the frequency bar is scaled appropriately, the three radio stations will be marked as follows:

- **A-FM** at 88.2 MHz,
- **B-FM** at 89.0 MHz,
- **C-FM** at 90.0 MHz.

These frequencies will be close to each other, with the stations located in the FM radio band (87.5–108 MHz).

Part (b) Why TV Signals are Weaker than Radio Signals

TV signals are weaker than radio signals in this area for several reasons:

1. **Frequency Range**: TV signals are typically transmitted at higher frequencies than radio signals. Higher frequencies tend to experience greater attenuation due to the atmosphere and other obstacles. Radio signals (in the FM range) are relatively less affected by this attenuation, especially in valleys and hills, which is why they tend to be stronger.
2. **Wavelength of Signals**: Higher frequency signals have shorter wavelengths. Shorter wavelengths are more easily blocked or scattered by physical obstructions such as hills, buildings, and trees. Radio waves, having longer wavelengths, are less likely to be obstructed and can travel further, allowing better reception.
3. **Power of Transmission**: TV stations may not always transmit with as much power as radio stations, leading to weaker signals. In areas like valleys, the signal strength can diminish significantly due to the physical geography blocking or reflecting the signals.
4. **Line-of-Sight Propagation**: TV signals often require a line-of-sight path from the transmitter to the receiver. In a valley surrounded by hills, the lack of direct line-of-sight to the transmission tower can cause the signal to weaken or be blocked entirely, making TV reception difficult.

Part (c) Nature and Formation of the Scaring Images in the Curved Mirror

The curved mirror in the radio antenna is likely a **concave mirror**, which has the ability to focus radio waves to enhance reception. However, the people experience "scaring images" when they move too close to the mirror.

Nature of the Image:

- **Virtual and Upright**: When the object (the person's face or their position) is placed between the focal point and the mirror's surface, a **virtual** and **upright** image is formed. The image appears larger than the actual object (which is why it may look "scary").
- **Magnification**: Concave mirrors can produce an enlarged, virtual image when the object is close enough. The closer the object is to the mirror, the larger and more distorted the image becomes.

Formation of the Image:

- Rays coming from the object (such as the person's face) are reflected by the concave mirror. If the object is within the focal point, the reflected rays diverge, but the brain interprets them as coming from a larger, virtual image behind the mirror.

The "scaring image" is likely caused by the **magnification** effect, where the image appears unnaturally large and distorted when the person is too close to the mirror. This is common with concave mirrors when the object is within the focal point.

Part (d) Suggestions to Improve the Strength of the Radio and TV Signals

To improve the strength of both radio and TV signals in this valley, several approaches can be considered:

1. **Install Repeaters or Boosters**: Install repeaters or signal boosters on higher ground or hills to help transmit stronger signals to the valley. These devices amplify weak signals and extend the coverage area.
2. **Use Directional Antennas**: A **parabolic** or **directional antenna** can be used to focus radio and TV signals more effectively, reducing signal loss from obstacles like hills. These antennas can focus on a specific direction, improving signal reception from a distant transmitter.
3. **Increase Transmitter Power**: Increasing the power of the radio and TV transmitters can help broadcast stronger signals that can overcome the challenges posed by the hilly geography.
4. **Install More Transmitters**: Placing additional radio and TV transmitters at strategic locations within the valley can help improve coverage and signal strength. Multiple smaller transmitters can provide better service to people spread across the valley.
5. **Upgrade Antennas on Radio/TV Sets**: People can also be encouraged to upgrade their personal antenna systems to improve reception. For example, a more efficient antenna on the radio or TV can help in capturing weaker signals more effectively.
6. **Cable or Satellite TV/Radio**: In areas where electromagnetic signal reception is extremely poor, introducing satellite TV and radio or using cable systems could be an alternative to provide a consistent and strong signal.

By combining these strategies, the strength of both radio and TV signals in the valley could be significantly improved, offering better reception for the people in the area.

ITEM 5

One hot afternoon some learners walked along a tarmac road in the west ward direction to check on a new swimming pool. On the road, they saw a speeding car at a distance and its engine sounds kept on reducing as it moved further away. They also saw what looked like water near the car; but the water disappeared when they

reached the spot where they had seen it and it reappeared to another spot ahead. Later on, the weather changed and there was a light drizzle though the sun was still bright. In the Eastern direction, they observed a semi-circular distribution of colours in the sky. They finally reached the swimming pool; however the pool-attendant warned them to be careful when they are to use the swimming pool because it may appear shallow when filled with water. The adventure ended in arguments because the learners had different views about the observations and experiences they had that day.

Task

Use your knowledge of physics to assist the learners to understand:

(a) why the sounds they heard from the car kept on reducing?

(b) the process that leads to what they observed on the tarmac road.

(c) the process that leads to what they observed in the sky.

(d) why swimming pool appears the way the attendant told them?

Part (a): Why the Sounds They Heard from the Car Kept on Reducing

The phenomenon the learners observed, where the sound from the car kept reducing as it moved further away, is a result of the **Doppler Effect**.

- **Doppler Effect** refers to the change in the frequency (or pitch) of a wave in relation to an observer who is moving relative to the source of the wave.
- When the car is moving towards the learners, the sound waves are compressed, leading to a higher frequency (or pitch). This is why the car would sound louder and higher-pitched as it approached.
- However, as the car moves away from them, the sound waves are stretched out, leading to a lower frequency (or pitch). As a result, the learners hear the sound decrease in both volume and pitch as the car moves further away.

This is an everyday example of the Doppler Effect, which can be experienced with sound waves (like a passing car), light waves (like a passing airplane), and even electromagnetic waves.

Part (b): The Process that Leads to the Water-Like Appearance on the Tarmac Road

What the learners observed—an appearance of water on the tarmac road that disappeared as they reached it and reappeared ahead—is a phenomenon known as **superficial mirage**.

- **Mirage** occurs due to the refraction of light, where light rays bend as they pass through layers of air at different temperatures.
- On a hot day, the tarmac road heats the air directly above it, creating a gradient of air temperatures. The ground air near the road is much hotter than the air above it, causing the light rays to refract (bend) upward as they pass through this hot air.
- This bending causes the sky to appear as though it is reflected on the road, creating the illusion of a puddle of water. When the learners approached the spot, they no longer saw the "water" because their perspective changed, and the light was no longer refracted in such a way that it created the illusion.

This optical illusion is a result of **refraction** caused by the difference in air temperature, and it's more common on hot roads during bright sunny days.

Part (c): The Process that Leads to the Observed Colors in the Sky

The learners observed a semi-circular distribution of colors in the sky to the east, which suggests they were witnessing a **rainbow**.

- A rainbow forms when light from the sun is **refracted**, **reflected**, and **dispersed** inside water droplets in the atmosphere.
    - **Refraction** occurs when sunlight enters a water droplet, causing the light to bend.
    - The light is then **reflected** off the inside surface of the droplet.
    - Finally, as the light exits the droplet, it is **dispersed** into its component colors, creating the visible spectrum (red, orange, yellow, green, blue, indigo, violet).

The **semi-circular shape** of the rainbow comes from the angle at which the light is refracted (usually about 42° for the red light), and the curved distribution occurs because the observer is viewing the light at a specific angle from the water droplets in the sky.

The drizzle, in this case, was likely composed of small water droplets that caused the light to scatter and form the rainbow in the eastern part of the sky. This is why the learners could see the colors even though it was still sunny — the sunlight was interacting with the water droplets in the air to form the rainbow.

Part (d): Why the Swimming Pool Appears Shallow

The swimming pool appears shallow when filled with water due to **refraction** at the interface between air and water.

- When you look at an object underwater, the light rays coming from the object are refracted (bent) as they pass from the water (denser medium) into the air (less dense medium). This bending causes the object to appear shallower than it actually is.
- The refracted light rays make it appear as though the bottom of the pool is at a higher position than it actually is.

This effect happens because light travels more slowly in water than in air, so when you observe the pool from above, the rays of light from the bottom of the pool bend away from the normal (the imaginary line perpendicular to the surface), making the pool appear less deep than it really is.

This phenomenon is why the pool attendant warned the learners that the pool may appear shallower when viewed from the surface than it actually is. The refractive effect causes the bottom of the pool to look closer to the surface than it really is, creating an optical illusion.

ITEM 6

During the music gala in a hall, one of the adjudicators observed the following;

- On entering the stage, the colour of dress of one presenter changed from a yellow dress with red dots to a red dress with black dots.
- The sound from the nearest loud speaker reached him after 0.05s.
- She kept on hearing voices of two people singing on stage, yet there was only one person on the stage.

Hint: *Speed of sound in air =320 ms^{-1}*

Task

Using the knowledge of Physics, help the adjudicator to understand;

(a) Why the colour of the dress changed.

(b) Why the sound was reaching her after 0.05s.

(c) The origin of the second voice and how it can be minimized.

SOLUTION

Part (a): Why the Colour of the Dress Changed

The change in the colour of the dress observed by the adjudicator could be explained by the phenomenon of **light diffraction** or **interference** due to the lighting in the hall.

- **Light diffraction and interference**: If the hall had specific lighting effects, such as colored lights shining at the presenter's dress, light waves could interfere with each other as they pass through different layers or materials in the lighting. This could cause the color of the dress to change under different lighting conditions.
- **Angle-dependent effects**: If the presenter's dress had a reflective or iridescent fabric, the observed color could shift depending on the angle of the light and the observer's position. This effect is due to the way light is refracted and scattered by the fabric, which could cause a color shift.
- **Colored lights**: If the lighting on stage was changing (e.g., the lights switched from yellow to red), this would change the appearance of the dress color as well, making yellow appear red under specific light conditions.

In summary, the change in dress color was likely caused by lighting effects, possibly through **interference**, **diffraction**, or a change in the color of the lights illuminating the presenter's outfit.

Part (b): Why the Sound Reached Her After 0.05s

The time it took for the sound to reach the adjudicator was 0.05 seconds. Using the speed of sound in air, we can calculate the distance to the loudspeaker.

- **Given**:
  - Speed of sound in air = 320 m/s
  - Time delay = 0.05 s

We can use the equation $d = v \times t$ where:

- d is the distance,

- v is the speed of sound,
- t is the time delay.

Substituting the values:

$d = 320 \text{ m/s} \times 0.05 \text{ s} = 16 \text{ m}$

So, the loudspeaker was **16 meters away** from the adjudicator. The time delay of 0.05 seconds was simply the time it took for the sound to travel from the speaker to the adjudicator, which is a normal phenomenon considering the speed of sound in air.

Part (c): The Origin of the Second Voice and How It Can Be Minimized

The adjudicator was hearing the voices of two people singing, even though there was only one person on stage. This could be due to **echo** or **sound reflection**.

- **Echo and sound reflection**: The hall likely has reflective surfaces (such as walls, ceilings, or floors) that cause the sound to bounce back. When sound waves are reflected from these surfaces, the reflected sound can reach the observer slightly after the direct sound. This creates the perception of multiple voices (one direct and one reflected).
- **Origin of the second voice**: The second "voice" is the **reflected sound** that reaches the adjudicator after a slight delay. This happens when the sound waves reflect off surfaces (like walls or other objects) and travel a longer path to the listener.
- **Minimizing the echo**: To minimize the echo and ensure clearer sound, the following steps could be taken:
    1. **Soundproofing the hall**: Adding sound-absorbing materials (like foam panels, carpeting, or acoustic tiles) to the walls and ceiling can reduce the reflections and control the reverberation time.
    2. **Adjusting the speaker placement**: Placing the speakers in positions where the sound is less likely to reflect back towards the adjudicator could reduce unwanted echoes.
    3. **Using directional microphones and speakers**: Directional sound systems, where sound is focused in a particular direction, can help prevent sound from bouncing off surfaces and reaching the listener at multiple angles.

In summary, the second voice was the reflected sound or echo. It can be minimized by improving the acoustics of the hall and controlling the reflections of sound waves.

ITEM 7

A tycoon is to construct a first-class hotel and as he consulted from the technical personnel, the following guidelines on facilities he wanted to set up were given;

- The swimming pool should have a label of its depths at different points to avoid relying on a deceptive look.
- The multipurpose hall must have a soft wall or it must use curtains along the walls.
- Each entrance should strictly have white lights as the inside of the hall may have other LED lights for decoration.
- The security personnel should have devices to check under the cars entering the hotel, as a way of ensuring hotel security.

The tycoon is not knowledgeable about the importance of such guidelines in his upcoming investment and is seeking for explanations.

Task

Using the knowledge of physics, help the business man understand;

(a) the cause of deceptive look.

(b) the reason behind multipurpose hall having a soft wall and curtains.

(c) why the entrance must have white lights and how decoration on individuals is attained from inside the hall.

(d) which kind of ***materials*** are needed in making the devices to be used while checking ***under*** the cars entering the hotel.

Part (a): The Cause of the Deceptive Look in the Swimming Pool

The **deceptive look** of a swimming pool, where the pool appears shallower than it really is, is caused by **refraction**.

- **Refraction** is the bending of light as it passes from one medium to another. In this case, light passes from the air (less dense) into the water (denser).
- When you look at an object underwater, such as the bottom of a pool, the light rays coming from the object are refracted as they pass from the water into the air. The bending of these light rays causes the object to appear closer to the surface than it actually is.
- This is why the swimming pool may appear to be shallower than its true depth when viewed from above the surface. The visual illusion is due to the refraction of light at the air-water boundary.

Thus, to prevent any misunderstandings, the hotel should label the pool depths clearly at different points, as relying on visual appearance alone can be misleading.

Part (b): The Reason Behind the Multipurpose Hall Having a Soft Wall and Curtains

The **soft wall** and **curtains** in the multipurpose hall are likely intended to control **sound reflection** and **reverberation**.

- **Sound reflection and reverberation**: In large halls, sound waves can bounce off hard surfaces like concrete or brick walls, creating echoes and long-lasting sounds (reverberation). This can make it difficult for people to hear clearly or can distort sound, especially in large spaces like multipurpose halls used for speeches, concerts, or events.
- **Absorbing sound**: Soft materials like curtains, foam panels, or soft walls are effective at **absorbing sound**. They reduce the reflection of sound waves, helping to control the acoustics in the room. This leads to better sound clarity and prevents echo, ensuring that the sound remains clear and direct.
- **Versatility**: Using curtains is also practical because they are **adjustable**—they can be drawn open or closed depending on the need for sound absorption or aesthetics. Soft walls can provide a similar function by controlling how sound behaves in the hall.

In summary, the multipurpose hall uses soft walls and curtains to **improve acoustics**, ensuring clear sound without disturbing echoes.

Part (c): Why the Entrance Must Have White Lights and How Decoration on Individuals Is Attained from Inside the Hall

The use of **white lights** at the entrance and **decorative LED lights** inside the hall is related to the **color temperature** of light and its effects on perception.

- **White lights at the entrance**: White light is a combination of all visible light colors, and it provides a **neutral and uniform illumination**. This is important at entrances because it helps create a welcoming, clear, and easy-to-see environment for guests. White light also ensures that any security features (like identification) are visible.
    - Additionally, white light is less likely to cause any color distortion, which is important for safety and clarity, especially when people are entering a large building.
- **LED lights inside the hall**: Inside the hall, **decorative LED lights** in different colors are used to create an ambiance or mood. LED lights are energy-efficient and can be customized to emit different colors, making them ideal for creating decorative effects.
    - **Color temperature** plays a role in the atmosphere of the hall. For instance, warm white or red LED lights can make the space feel cozy or romantic, while blue or green LED lights can create a calming effect.
    - **Color rendering**: Inside the hall, the LED lights can be chosen to enhance the appearance of individuals, their clothing, and decorations, making the interior visually attractive.

In short, white lights at the entrance ensure clarity and security, while the decorative LED lights inside help set the mood and enhance the visual appeal of the space.

Part (d): Materials Needed for Devices to Check Under Cars Entering the Hotel

The **devices used to check under cars** for security purposes are typically **X-ray scanners** or **infrared cameras**. These technologies are useful for detecting hidden objects or security threats under the car.

- **X-ray Scanners**: These scanners use high-energy electromagnetic radiation (X-rays) to pass through the car and create an image of what is under the car. X-rays are good for penetrating solid objects like metal, allowing security personnel to detect objects that are hidden underneath.
    - **Materials for X-ray devices**:
        - **Lead shielding** is used to protect individuals from the harmful effects of X-ray radiation.
        - **Specialized detectors** (like scintillation detectors or CCD cameras) are used to capture the X-rays that pass through the car and create an image.
- **Infrared Cameras**: Infrared cameras detect heat emitted by objects. These cameras can help identify warm objects that may be hidden under the car, such as explosives or other security threats.
    - **Materials for infrared devices**:
        - **Infrared sensors** (e.g., thermographic sensors) detect radiation in the infrared spectrum.
        - **Optical lenses** made from **germanium** or **sapphire** are used to focus infrared light onto the detector since these materials transmit infrared light well.

In summary, the devices used for checking under the cars need to be made from materials that can safely handle X-ray or infrared radiation, such as **lead** for shielding in X-ray systems and **germanium or sapphire** for infrared sensors. Both technologies help ensure that the hotel remains secure by detecting hidden threats before they enter the premises.

ITEM 8

In a town, there is a woman who uses loud horn speakers to broadcast various information to the community. She has received the following concerns from the members of her community;

- Listeners at different locations have noticed a difference in time in which the sound reaches them.
- People who are at far distances are unable to receive the information broadcast by the speakers.
- People are complaining about too much noise from the speakers, some of whom are not interested at all in what is being broadcast.

Because of those concerns, the town council leadership has advised the woman to set up a radio broadcasting station and the broadcasting authorities allocated her a radio frequency of 87.8 MHz. She is ready to take up the advice, only that she lacks enough knowledge to guide her more.

Use: *Speed of light in air = 3 x 10^8 ms^{-1}*

Task:

Using your knowledge of Physics, assist the woman to;

(a) Differentiate between the type of waves produced by her current system and those to be produced in the system proposed by the town council leadership.

(b) Understand why the new method of broadcasting will not cause a problem of noise pollution.

(c) Understand why the new system of broadcasting is able to reach those who are far away and they get the broadcast almost instantly.

(d) Determine wavelength of the waves used in broadcasting in the new system.

SOLUTION

Part (a): Differentiating Between the Types of Waves Produced by the Current System and the Proposed Radio Broadcasting System

- **Current System (Loud Horn Speakers)**:
  - The **current system** uses **sound waves**. These are **mechanical waves** that require a medium (such as air) to propagate. Sound waves are **longitudinal waves**, where the particles of the medium oscillate parallel to the direction of wave propagation.
  - Sound waves travel through the air at a speed determined by the properties of the medium (typically around 340 m/s in air, depending on temperature and humidity).
  - As the sound waves travel, they experience issues such as **attenuation** (decrease in intensity) and are **subject to environmental obstacles**, which is why listeners at distant locations may have trouble hearing clearly or at all.
- **Proposed System (Radio Broadcasting)**:

- The **proposed system** uses **electromagnetic waves**. These waves are **transverse waves**, meaning that the electric and magnetic fields oscillate perpendicular to the direction of wave propagation.
- Unlike sound waves, electromagnetic waves do not require a medium to propagate; they can travel through a vacuum, air, or other media.
- These waves travel at the **speed of light** in air ($3 \times 10^8 \, \text{m/s}$), which is much faster than sound waves. Electromagnetic waves can travel long distances without significant attenuation and can pass through obstacles such as walls and buildings, making them much more effective for long-range communication.

Part (b): Why the New Method of Broadcasting Will Not Cause a Problem of Noise Pollution

- **Electromagnetic waves** (radio waves) used in the new broadcasting system do not generate noise pollution in the same way that sound waves do. Here's why:
  - **Radio waves** propagate through the air without causing physical vibrations in the medium. The waves carry information without producing harmful sound vibrations that could be considered noise pollution.
  - The **radio signal** is directed and can be received through a radio receiver tuned to a specific frequency (in this case, 87.8 MHz). People who are not interested in the broadcast can simply turn off their radio receivers, effectively preventing unwanted noise.
  - Unlike the loud horn system, where sound is broadcasted indiscriminately to everyone within range, **radio waves** are more **targeted** and can be tuned to specific frequencies, ensuring that only those who want to listen to the broadcast are exposed to it.
  - This method does not lead to environmental noise pollution because the radio waves themselves do not cause disturbances in the atmosphere, unlike loudspeakers that broadcast sound to a wide area.

Part (c): Why the New System of Broadcasting is Able to Reach Those Who Are Far Away and They Get the Broadcast Almost Instantly

- **Electromagnetic waves** (radio waves) travel at the speed of light ($3 \times 10^8 \, \text{m/s}$), which is vastly faster than sound waves. Because of this:
  - **Radio signals can travel long distances without significant loss of signal strength**. Even though the signal may attenuate slightly with distance, the drop in intensity is far less significant compared to the decay of sound waves, which lose energy much faster.
  - **Radio waves can propagate through the atmosphere**, overcoming obstacles like buildings and terrain. They can also be **reflected, refracted, or diffracted** by the Earth's surface and the ionosphere, allowing them to travel vast distances. This is why radio signals can reach listeners who are far away from the transmitter, even in remote areas.
  - The **broadcast reaches almost instantly** because radio waves travel at the speed of light. This is a huge improvement over sound waves, which travel much slower and are affected by environmental factors.

Part (d): Determining the Wavelength of the Waves Used in Broadcasting in the New System

To calculate the wavelength (λ) of the radio waves used for broadcasting, we can use the formula that relates the speed of a wave, its frequency, and its wavelength:

$V = f\lambda$

Where:

- v is the speed of the wave (speed of light in air = 3×10^8 m/s),
- f is the frequency of the wave (given as 87.8 MHz, which is 87.8×10^6 Hz),
- λ is the wavelength (the quantity we are solving for).

Rearranging the formula to solve for λ:

$\lambda = v/f$

Substituting the known values:

$\lambda = 3\times10^8$ m/s/87.8×10^6 Hz=3.42 m

So, the **wavelength** of the radio waves used for broadcasting at a frequency of 87.8 MHz is approximately **3.42 meters**.

Summary of Answers:

- **(a)** The current system uses sound waves (mechanical waves), while the proposed system uses electromagnetic waves (radio waves).
- **(b)** The new broadcasting method avoids noise pollution because radio waves don't generate physical vibrations, and listeners can easily tune in or out by adjusting their radios.
- **(c)** Radio waves can reach far distances and travel almost instantly due to their high speed (the speed of light), and they can propagate through obstacles.
- **(d)** The wavelength of the radio waves at 87.8 MHz is approximately **3.42 meters**.

ITEM 9

During a science project, learners are given two mirrors; a concave mirror of focal length 20cm and a convex mirror of focal length 20cm.

Task:

As a learner of physics;

(a) help the students to determine which mirror forms a bigger image of a man of height 4cm standing 25 cm a way from each of the mirror.

(b) write a brief report about the nature of image formed by each mirror (c) advise which mirror is suitable for use as driving mirror

Part (a): Determining Which Mirror Forms a Bigger Image

To determine which mirror forms a bigger image, we can use the **mirror equation** and the **magnification formula**.

Mirror Equation:
$1/f = 1/d_o + 1/d_i$

Where:

- f is the focal length of the mirror,
- d_o is the object distance (distance from the object to the mirror),
- d_i is the image distance (distance from the image to the mirror).

Magnification Formula:

$M = h_i/h_o = -di/do$

Where:

- M is the magnification (the ratio of the image height h_i to the object height h_o),
- h_i is the image height,
- h_0 is the object height,
- d_i is the image distance, and
- d_o is the object distance.

Given:

- Object height h_o=4 cm
- Object distance d_o=25 cm
- Focal length f=20 cm for both mirrors.

For the Concave Mirror:

- The concave mirror has a **positive focal length**. We can use the mirror equation to calculate the image distance d_i :

$1/20 = 1/25 + 1/d_i$

Solving for d_i:

$1/d_i = 1/20 – 1/25$

$1/d_i = 5/100 – 4/100 = 1/100$

d_i=100cm

Now, using the magnification formula:

$M = -d_i/d_o = -100/25 = -4$

This means the image is **inverted** (since the magnification is negative) and **4 times larger** than the object.

For the Convex Mirror:

- The convex mirror has a **negative focal length**. Again, using the mirror equation:

$1/-20 = 1/25 + 1/d_i$

Solving for d_i:

$1/d_i = 1/-20 – 1/25$

$1/d_i = -5/100 – 4/100$

$= -9/100$

di=−9/100≈−11.1cm

Now, using the magnification formula:

$M = -di/d_o = -11.1/25 = 0.444$

This means the image is **upright** (since the magnification is positive) and **smaller** than the object by a factor of approximately 0.444.

Comparison:

- **Concave Mirror**: The image is 4 times larger than the object and inverted.
- **Convex Mirror**: The image is smaller than the object by a factor of approximately 0.444 and upright.

Conclusion: The **concave mirror** forms a **bigger image** of the man than the convex mirror.

Part (b): Nature of the Image Formed by Each Mirror

- **Concave Mirror**:
  - **Type of Image**: Real and inverted.
  - **Size**: The image is magnified, approximately 4 times the size of the object.
  - **Location**: The image is formed **behind** the mirror at a distance of 100 cm (real image).
  - **Characteristics**: Since the image is real and inverted, it can be projected onto a screen.
- **Convex Mirror**:
  - **Type of Image**: Virtual and upright.
  - **Size**: The image is smaller than the object by a factor of 0.444.
  - **Location**: The image is formed **behind** the mirror, at approximately 11.1 cm (virtual image).
  - **Characteristics**: The image cannot be projected onto a screen because it is virtual. It is always upright and diminished in size.

Part (c): Which Mirror is Suitable for Use as a Driving Mirror

- A **driving mirror**, such as a **side-view mirror** or a **rear-view mirror**, needs to provide a wide field of view and show objects that are far away in a way that allows drivers to see vehicles or obstacles behind them.
- **Concave Mirror**: While a concave mirror can form a magnified image, it also produces an **inverted image**, which is not ideal for a driving mirror. It could lead to confusion, as the driver would not get a proper orientation of objects behind the vehicle.
- **Convex Mirror**: A convex mirror is **ideal for use as a driving mirror** because:
  - It forms a **virtual, upright, and diminished image**, making objects appear smaller but providing a wider field of view.
  - The **virtual image** allows the driver to see more of the area behind the vehicle, which is crucial for safe driving.
  - The image produced is **always upright**, which makes it easier for the driver to interpret.

Conclusion: The **convex mirror** is more suitable for use as a driving mirror because it provides a wider field of view and does not invert the image.

Final Summary:

- **(a)** The **concave mirror** forms a **larger image** (4 times the size of the object), while the **convex mirror** forms a smaller image.
- **(b)** The **concave mirror** forms a real, inverted, and magnified image, while the **convex mirror** forms a virtual, upright, and diminished image.
- **(c)** The **convex mirror** is more suitable for use as a driving mirror due to its wider field of view and upright image.

A brass band was invited to play during a celebration near a tall building, a distance slightly more than 17 m away. Two friends standing in the same direction and in line with the playing band, heard the sound from the band at different intervals of time which attracted them to go and attend the celebration.

On arrival, the sound they heard was unclear, confused and indistinct. Later in the night during the cerebration, coloured lights flashing red, blue and green made the colours of their clothes look different from the original colours which puzzled them. The two friends heard sound after 4 s and 5 s, respectively and were originally wearing yellow clothes.

Task:

As a physics student, help the two friends to understand why;

(a) They heard the sound at different intervals.

(b) The sound they heard was unclear, confused and indistinct.

(c) The colour of their clothes kept changing when coloured lights flashed on them.

HINT: Speed of sound in air = 330 ms^{-1}

SOLUTION

(a) Why did they hear the sound at different intervals?

The two friends heard the sound at different intervals of time because sound travels at a finite speed, and they were positioned at different distances from the brass band.

- The speed of sound in air is given as 330 m/s.
- The distance from the brass band to the friends is slightly more than 17 m.

Since the speed of sound is constant, the time it takes for the sound to reach each friend depends on their distance from the sound source. The closer a person is to the source, the shorter the time it takes for the sound to reach them.

- If Friend 1 heard the sound after 4 seconds, this means they were at a certain distance from the band.
- Friend 2 heard the sound after 5 seconds, so they must be farther from the band.

Using the formula for time:

$t = d/v$

where:

- t is the time it takes for sound to travel,
- d is the distance,

- v is the speed of sound (330 m/s).

For Friend 1:

$4 = d_1/330 \Rightarrow d_1 = 4 \times 330 = 1320$ meters

For Friend 2:

$5 = d_2/330 \Rightarrow d_2 = 5 \times 330 = 1650$ meters

Thus, Friend 1 is at a distance of 1320 meters, while Friend 2 is at 1650 meters. This explains why they heard the sound at different intervals.

(b) Why was the sound they heard unclear, confused, and indistinct?

The unclear, confused, and indistinct nature of the sound could be explained by several factors:

1. **Echoes and Reflections:** In an environment near a tall building, sound can reflect off the building's surface. These reflections cause the sound to be delayed, causing the friends to hear multiple versions of the sound from slightly different times. The combination of direct sound and reflected sound creates an effect known as *reverberation*, which makes the sound less clear and more difficult to distinguish.
2. **Doppler Effect (if they were moving):** If the friends were moving towards the sound source or away from it, the frequency of the sound they heard could have changed. This is known as the Doppler Effect. This would make the sound more distorted, adding to the confusion and indistinct nature of the sound they experienced.
3. **Environmental Noise:** If there were other sounds in the environment (wind, crowd noise, etc.), they could have further drowned out or distorted the sound from the band, making it harder to understand.

(c) Why did the colour of their clothes keep changing when coloured lights flashed on them?

The changing colours of their clothes are due to the **properties of light** and how coloured light interacts with the surface of the clothes.

1. **Reflected Light:** The coloured lights (red, blue, green) are shining on the clothes. The colour of an object is determined by the light it reflects. When the lights are shining on the clothes, the colour of the clothes may appear different because the clothes are reflecting the colours of the lights.
2. **The Three Primary Colours of Light:** When coloured lights (red, blue, and green) shine on the clothes, the combination of these primary colours can produce various new colours. The clothes might appear yellow in normal white light (which is a mix of all colours), but under the flashing coloured lights, they might reflect the lights in such a way that they look red, blue, or green, or even combinations of these colours.

Thus, the changing appearance of their clothes is a result of how the coloured lights interact with the surface of the clothes and how the human eye perceives those interactions.

Summary of Answers:

- **(a)** They heard the sound at different intervals because they were at different distances from the sound source, and sound travels at a constant speed, taking different amounts of time to reach them.
- **(b)** The sound was unclear, confused, and indistinct due to echoes and reflections from the building, possible Doppler effects, and environmental noise.

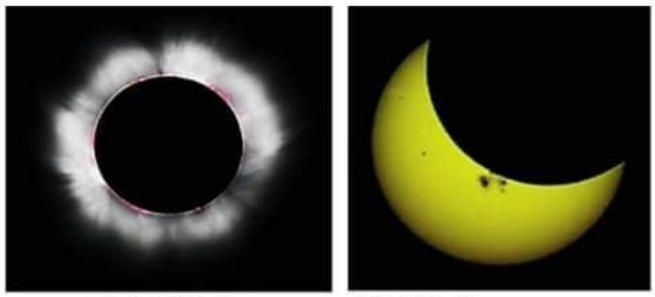
- **(c)** The colour of their clothes changed under the coloured lights due to the way the clothes reflected the light of different colours, altering the perceived colour of the clothes.

ITEM 11

Long time ago eclipses were considered as a message from the gods sine the people in that age dwelt so much in the spiritual realm than the scientific word. But with the development of science and technology, eclipses can now easily be explained scientifically instead of spiritually. Whenever eclipses occur many people gather out in open places to watch the beautiful view of the heavenly bodies as they align themselves in a beautiful display.

However, in most remote areas of Uganda some people still observe the eclipse directly using naked eyes not aware of the risk they are exposing their eyes to in the long run.

SUPPORT MATERIAL



(a) Total eclipse (b)Partial eclipse

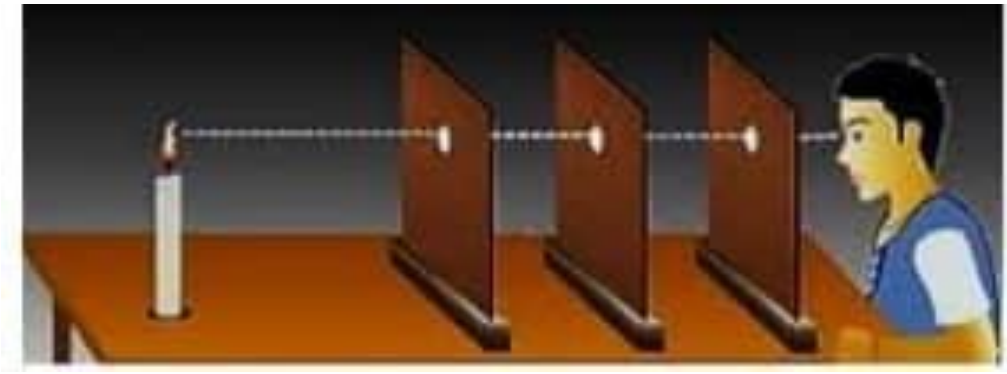
Task:

As a learner of physics;

(a) Explain the difference between total and partial eclipse.

(b) Using illustrations, explain the differences between solar eclipse and lunar eclipse.

(c) In a certain experiment to investigate nature of light, the set up below was arranged.



(i) State the property of light being investigated and explain its implications in daily life.

Explain what would happen when one of the cardboards is displaced slightly

SOLUTION

(a) Difference between total and partial eclipse:

- **Total Eclipse:** A total eclipse occurs when the Sun, Moon, and Earth align perfectly so that the Moon completely covers the Sun's disk from the viewpoint of Earth. This creates a period of darkness during the day at the location on Earth that falls under the Moon's shadow. Total solar eclipses are rare and only visible from specific regions on Earth during each event.

- **Partial Eclipse:** A partial eclipse happens when the alignment of the Sun, Moon, and Earth is such that the Moon only partially covers the Sun's disk from the viewpoint of Earth. This means observers in some regions see the Moon appearing to take a bite out of the Sun, but it never fully covers it. Partial solar eclipses are more common than total eclipses and can be visible over a broader geographic area.

(b) Differences between solar and lunar eclipse with illustrations:

- **Solar Eclipse:**
  - Occurs when the Moon passes between the Sun and Earth.
  - The Moon blocks the sunlight reaching Earth, casting a shadow on Earth's surface.
  - There are different types: total, partial, and annular (where the Sun appears as a ring around the Moon).

- **Lunar Eclipse:**
  - Occurs when Earth passes between the Sun and the Moon.
  - Earth's shadow falls on the Moon, causing it to darken.
  - There are two main types: total (where the Moon turns red or coppery) and partial (where only part of the Moon enters Earth's shadow).

(c) Experiment setup for investigating light:

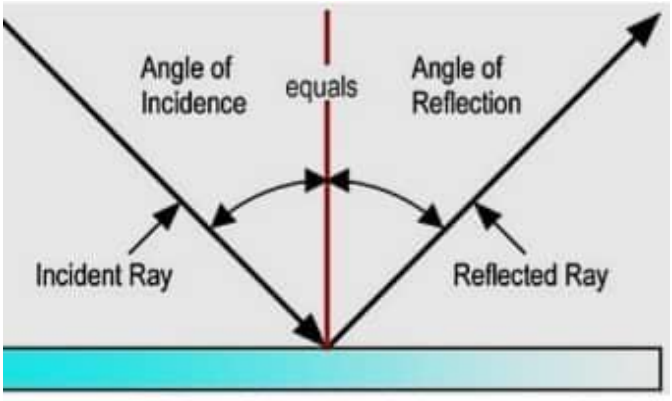
- **Property of light being investigated:** The property being investigated could be the reflection of light.
  - **Implications in daily life:** Understanding reflection helps in designing mirrors, lenses, and optical devices used in everyday items like cameras, telescopes, and eyeglasses. It also explains phenomena like how we see objects in mirrors or how light bounces off surfaces.
- **What happens when one cardboard is displaced slightly:**
  - If one of the cardboards is displaced slightly:

- Shadow will be formed on the cardboard
- The reflected light direction changes.
- The position of the reflected spot on the screen (or another surface) will move.
- This demonstrates the principle that the angle of incidence equals the angle of reflection, crucial in understanding how light behaves when it interacts with surfaces.

These explanations should help clarify the concepts and their significance in both scientific understanding and practical applications.

ITEM 12

We normally see the images of our faces when we look into the mirror. This is due to reflection of light.



Task:

As the learner of physics;

(a) State the laws of reflection of light and use them to find the glancing angle if the angle of reflection is 35^0.

(b)

(i) Describe the nature of the images formed by plane mirrors.

(ii) State the real-life applications of plane mirrors.

(c) With the aid ray diagrams, describe the differences between images formed by plane mirrors and a pin hole camera.

SOLUTION

(a) Laws of Reflection of Light:

The **laws of reflection** are:

1. **First Law:** The angle of incidence (i) is equal to the angle of reflection (r). i = r
2. **Second Law:** The incident ray, the reflected ray, and the normal (perpendicular line) to the surface at the point of incidence all lie in the same plane.

Now, let's find the glancing angle when the angle of reflection is 35°.

- From the first law of reflection, we know that the angle of incidence is equal to the angle of reflection.
  - Given: Angle of reflection = 35°.
  - So, the angle of incidence = 35°.

Now, if by "glancing angle" you mean the angle the incident ray makes with the surface (or the angle with the horizontal plane), this would be:

- The **glancing angle** (or angle with the surface) = 90° − Angle of reflection.
- Thus: Glancing angle=90°−35°=55°.

(b) (i) Nature of Images Formed by Plane Mirrors:

- The images formed by **plane mirrors** are:
  1. **Virtual**: The image cannot be projected on a screen because light rays do not actually converge to form the image. Instead, the image is formed where light rays appear to diverge from.
  2. **Upright**: The image is upright, meaning it has the same orientation as the object (not inverted).
  3. **Same size as the object**: The image formed is of the same size as the object.
  4. **Laterally inverted**: The image is a mirror image, meaning left and right are reversed.
  5. **Equidistant**: The image is located the same distance behind the mirror as the object is in front of it.

(b) (ii) Real-life Applications of Plane Mirrors:

- **Plane mirrors** have several practical applications, including:
    1. **Personal grooming:** Mirrors in bathrooms and dressing rooms allow us to see our reflection for shaving, combing hair, applying makeup, etc.
    2. **Vehicle mirrors:** Side and rearview mirrors in vehicles help drivers see behind and on the sides of their vehicles.
    3. **Optical instruments:** Mirrors are used in instruments like microscopes and telescopes for better focus and clarity.
    4. **Interior design:** Mirrors are used in homes and offices to create the illusion of more space and light.
    5. **Safety and security:** Mirrors are used in stores, hallways, and parking lots for surveillance and safety.

(c) Differences between Images Formed by Plane Mirrors and a Pin-Hole Camera with Ray Diagrams:

Plane Mirror Image:

- The image formed by a **plane mirror** is virtual, upright, and laterally inverted. The image appears to be the same size as the object and is located at the same distance behind the mirror as the object is in front of it.

  Ray Diagram:

    - An object is placed in front of a plane mirror. The rays of light reflect off the mirror. The reflected rays diverge but appear to come from a point behind the mirror, where the virtual image is formed.

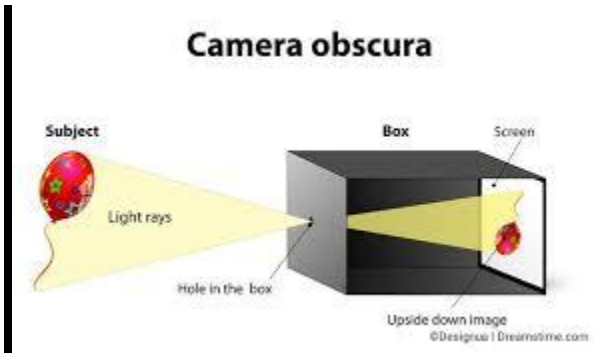
    - The image formed here is virtual (because the reflected rays don't actually meet but only appear to meet), upright, and the same size as the object.

Pin-Hole Camera Image:

- A **pin-hole camera** forms a real, inverted image. Light from the object passes through a small pinhole and projects an inverted image on the screen inside the camera. The image size depends on the distance between the pinhole and the screen and the distance of the object from the pinhole.

  Ray Diagram:

  - Light from an object passes through the small hole in the camera and projects an inverted image on the screen inside the camera.



  - The image formed here is real (since the rays actually converge to form the image), inverted, and its size is smaller or larger depending on the object's distance from the pinhole.

Key Differences between Plane Mirror and Pin-Hole Camera Images:

1. **Nature of Image:**
   - Plane Mirror: **Virtual** image (cannot be projected).
   - Pin-Hole Camera: **Real** image (can be projected onto a screen).
2. **Orientation of Image:**
   - Plane Mirror: Image is **upright** (same orientation as the object).
   - Pin-Hole Camera: Image is **inverted** (upside down compared to the object).
3. **Size of Image:**
   - Plane Mirror: Image is **same size** as the object.
   - Pin-Hole Camera: Image size can be **smaller or larger**, depending on the distance from the pinhole.
4. **Image Location:**
   - Plane Mirror: Image is located **behind** the mirror, at the same distance as the object is in front of the mirror.
   - Pin-Hole Camera: Image is formed **on the screen** inside the camera.

These concepts should help clarify how reflections and image formation work both in everyday life and in more experimental settings!

ITEM 13

While in your literature lesson, your teacher asks your friend to stand up and read for the class a book of Oliver Twist, however your friend always tells your literature teacher that she is unable to see the letters in the books and even when she sits near the board, she's unable to see but your teacher and other fellow literature students

think she's bewitched. On the s.4 leavers party, a boy of height 120cm stands in front of a lens camera with a lens of focal length 40cm at a distance 160cm from camera.

Task

As a learner of physics,

(a) By scale drawing find the; nature size and position of the image of the boy on the camera
(b) explain to your fellow students and the literature teacher the cause of the problem and the would-be possible solution to the above problem

(a) Nature, Size, and Position of the Image of the Boy on the Camera:

To determine the nature, size, and position of the image of the boy on the camera using the lens, we need to use the lens formula and the magnification formula.

1. **Lens Formula:**

   $1/f = 1/v - 1/u$

   Where:

   - f is the focal length of the lens,
   - v is the image distance (distance from the lens to the image),
   - u is the object distance (distance from the lens to the object).

   Given:

   - The focal length f=40 cm,
   - The object distance u=−160 cm (the negative sign indicates the object is on the left side of the lens, as per sign conventions).

   We can now calculate the image distance v:

   $1/40 = 1/v - 1/-160$

   $1/v = 4/160 - 1/160 = 3/160$

   $v = 1603 \approx 53.33$ cm

   Nature of the Image:

   - The image distance v=53.33 cm is positive, meaning the image is formed on the opposite side of the object (real image).
   - The image is **real**, **inverted**, and located **53.33 cm** from the lens.
2. **Magnification:** The magnification formula is given by:

   Magnification = Image Height/Object Height = v/u

   - Object height (the boy's height) = 120 cm.
   - From earlier, v=53.33 cm and u=−160 cm

Magnification = 53.33/160 ≈ 0.333

Image Size:

- The image size is:

Image Height = Object Height×Magnification

Image Height = 120×0.333 ≈ 40 cm

So, the image is approximately **40 cm** tall, **inverted**, and located **53.33 cm** away from the lens.

(b) Explanation of the Problem and Solution for Your Friend:

Problem: Your friend is likely experiencing a **vision problem**, where she is unable to clearly see the letters in books or the board, even when sitting near the board. This condition could be a result of **nearsightedness** (myopia), a common refractive error of the eye. In myopia, the image of distant objects is formed **in front** of the retina, which makes faraway objects appear blurry. Near objects, however, are seen clearly because the image is formed on the retina.

In this case, your literature teacher and fellow students might mistakenly think she is "bewitched" because they don't understand that her difficulty in seeing is related to a refractive error in the eye.

Possible Solution: The problem can be corrected with **glasses** or **contact lenses** that have a **concave lens** (divergent lens) prescription. The concave lens will help to diverge the light entering her eyes, making the image formed on the retina clearer and improving her vision of distant objects.

Additionally, a visit to an **optometrist** or **ophthalmologist** is necessary for a professional diagnosis and prescription.

Explanation to your Fellow Students and Teacher:

- Explain that the problem is due to **myopia**, a condition where the eye has difficulty focusing on distant objects because the image forms in front of the retina.
- The condition is **correctable** with the use of glasses or contact lenses designed for myopia correction.
- Reassure the class that it's a common vision issue and can be resolved through proper corrective lenses.

ITEM 14

A certain student was puzzled that the shallow end of the swimming pool at his school appeared to be about 1.5m deep when in the actual sense it was 2.0 m.

(a)

(i) Use a ray diagram to illustrate student's puzzle and explain why the swimming pool appeared shallower than it is actually is.

(ii) Determine the refractive index of the water in the swimming pool at school

(b) A barber was given a curved mirror of focal length 30 cm so that he could use it as a shaving mirror in his salon.

(i) Identify the type of curved mirror given to the barber and using a ray diagram explain how the selected curved mirror is used as a shaving mirror.

(ii) State the properties of the image formed above?

(c) Which type of curved mirror is suitable to be used as a side mirror and why?

SOLUTION

(a) Ray Diagram and Explanation of the Student's Puzzle

(i) Ray Diagram and Explanation

The student observed that the shallow end of the swimming pool appeared to be 1.5 m deep, even though it was actually 2.0 m deep. This is a result of **refraction** of light as it passes from the water (denser medium) to air (less dense medium).

- **Ray diagram:**
  1. Draw the water surface as a boundary between two media: water (denser) and air (less dense).
  2. A ray of light originates from a point below the water surface (say the bottom of the shallow end of the pool).
  3. This ray of light refracts as it passes from water to air, bending away from the normal (because the refractive index of water is higher than that of air).
  4. The brain perceives the ray as coming from a point that is higher than the actual position because of the bending of light rays. Hence, the bottom of the pool appears to be at a shallower depth than it really is.
- **Reason for the phenomenon:**
  The apparent depth is less than the actual depth because of **light refraction**. When light rays travel from the water (refractive index = 1.33) into air (refractive index ≈ 1), they bend away from the normal, making the bottom of the pool seem closer to the surface.

(ii) Determining the Refractive Index

To determine the refractive index of the water in the pool, we use the formula:

n = actual depth/apparent depth

Where:

- The actual depth is 2.0 m (the real depth).
- The apparent depth is 1.5 m (the depth the student perceives).

n = 2.0 m/1.5 m = 1.33

Thus, the refractive index of the water in the swimming pool is approximately **1.33**.

(b) Shaving Mirror and Image Properties

(i) Type of Curved Mirror and its Use as a Shaving Mirror

The mirror given to the barber has a **focal length of 30 cm**, which is a positive value. This means it is a **concave mirror** (curved inward).

- **Ray diagram explanation for shaving mirror:**
    1. The object (the face of the person shaving) is placed **between the focal point (F)** and the mirror's surface.
    2. Rays from the face reflect off the concave mirror.
    3. The reflected rays diverge and, when extended backward, appear to converge at a point **behind the mirror** (virtual image).
    4. This results in a **magnified, upright, and virtual image** of the face, which is ideal for shaving since it allows the person to see fine details more clearly.
- **Why this works for shaving:**
  Concave mirrors have the ability to form **magnified virtual images** when the object is located within the focal length. This magnification helps the person shave more accurately.

(ii) Properties of the Image Formed

The image formed by the concave mirror under these conditions has the following properties:

- **Upright:** The image appears the right side up (not inverted).
- **Magnified:** The image is larger than the object, which is helpful for tasks like shaving.
- **Virtual:** The image cannot be projected onto a screen because the light rays do not actually converge in reality; they only appear to do so behind the mirror.
- **Located behind the mirror:** The image forms behind the mirror.

(c) Curved Mirror for Side Mirror

The most suitable type of curved mirror for use as a **side mirror** in a vehicle is a **convex mirror**.

- **Reason:**
    1. **Wide field of view:** Convex mirrors diverge light rays, which results in a smaller, upright, and virtual image that appears farther away, providing a broader view of the area behind and to the side of the vehicle.
    2. **Reduction of image size:** Convex mirrors produce smaller images, which allows for a larger area to be visible, thus increasing safety by minimizing blind spots.
    3. **Always upright:** The image formed is upright, making it easier for the driver to interpret the reflection accurately.

Thus, **convex mirrors** are preferred for side mirrors because of their ability to show a wider area with a clear, safe view.

ITEM 15

During a science project, learners are given two devices; a pin hole camera of length 50cm and a concave mirror of focal length 50cm.

As a learner of physics;

(a) Help the students to determine which instrument forms a bigger image of a man of height 1.8m standing 2m away from each of the instruments.

(b) Explain the difference in the properties of the images formed by the two instruments and identify the practical applications of the instruments.

(a) Determining Which Instrument Forms a Bigger Image

To determine which instrument forms a bigger image of the man, we need to consider how each device works and use the appropriate formulas.

1. **Pin Hole Camera**: A pinhole camera forms an image using a **real image** that is inverted. The size of the image depends on the ratio of the object's distance and the camera's length. The formula for the magnification of a pinhole camera is:

   Magnification (m) =Image height (I)/Object height (O)

   Where:

   - Object height O=1.8 m
   - Object distance u=2.0 m
   - Camera length v=50 cm=0.5 m

   So, the magnification mm for the pinhole camera is:

   m = vu =0.5 m/2.0 m=0.25

   The image height formed by the pinhole camera is:

   Image height (I) = m×O =0.25×1.8 m=0.45 m

   So, the image formed by the pinhole camera is **0.45 m** in height.

2. **Concave Mirror**: The concave mirror forms an image according to the mirror formula and magnification formula. The mirror formula is:

   1/f = 1/v + 1/u

   Where:

   - Focal length f=50 cm=0.5 m
   - Object distance u=−2.0 m

   Using the mirror formula:

   1/0.5 = 1/v + 1/−2.0

   1/v = 1/0.5 + ½ =2+0.5=2.5

   v = 1/2.5=0.4 m

   So, the image distance is v=0.4 m.

Now, we calculate the magnification using the magnification formula for mirrors:

$m = -v/u = -0.4/-2.0 = 0.2m$

The image height formed by the concave mirror is:

Image height (I) = $m \times O = 0.2 \times 1.8\ m = 0.36\ m$

So, the image formed by the concave mirror is **0.36 m** in height.

Comparison of Image Sizes:

- The image formed by the **pinhole camera** is **0.45 m** in height.
- The image formed by the **concave mirror** is **0.36 m** in height.

Therefore, **the pinhole camera** forms a **bigger image** of the man than the concave mirror.

(b) Explanation of the Differences in Properties of the Images Formed and Practical Applications

1. **Pin Hole Camera**:
    - **Image Type**: The pinhole camera forms a **real, inverted image**.
    - **Size and Clarity**: The size of the image is smaller compared to the object, and it may not be as clear or sharp as other optical instruments, but the image is projected on a screen.
    - **Properties**:
        - The image is **inverted** (upside down).
        - The image is **real** (can be captured on a screen).
        - The image formed is smaller in size.
    - **Practical Applications**:
        - **Photography**: The basic principle of a pinhole camera is used in photography. It's used for simple image capture without any lenses.
        - **Scientific demonstrations**: It is used for demonstrating the basic concepts of optics, like image formation and the nature of light rays.
2. **Concave Mirror**:
    - **Image Type**: The concave mirror forms a **real or virtual, inverted or upright image** depending on the object's position relative to the focal point. In this case, since the object is beyond the focal point, the image is **real** and **inverted**.
    - **Size and Clarity**: The image size depends on the object's distance from the focal point. The image formed is more focused and clearer than the pinhole camera image.
    - **Properties**:
        - The image is **inverted** (because the object is beyond the focal point).
        - The image is **real** (but can also be virtual if the object is between the focal point and the mirror).
        - The image formed is magnified or reduced depending on the object's position.
    - **Practical Applications**:
        - **Shaving mirrors**: Concave mirrors are used in shaving mirrors for magnification of the face.
        - **Telescopes**: Concave mirrors are used in telescopes to focus light from distant objects.
        - **Headlights of vehicles**: Concave mirrors are used to focus light into a beam.

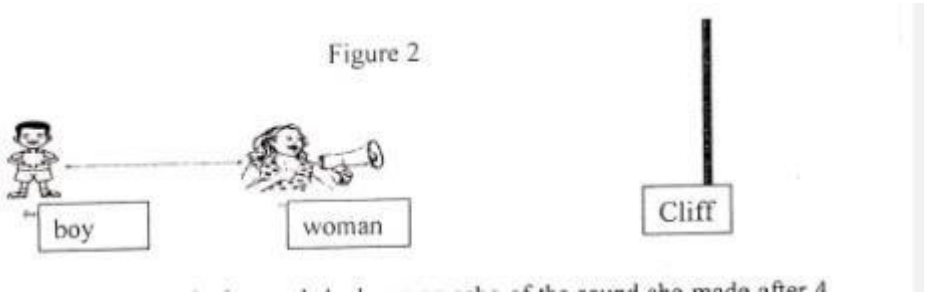
Summary of Differences:

- **Image type**: Pinhole camera forms a real, inverted image; Concave mirror forms a real, inverted image (in this case).
- **Image size**: The pinhole camera forms a bigger image (0.45 m), while the concave mirror forms a smaller image (0.36 m).
- **Applications**: Pinhole cameras are mainly used for educational purposes and basic photography, while concave mirrors are used in various optical devices for magnification and focusing light.

ITEM 16

Two people stand in front of a cliff at an unknown distance between them as shown below.

Figure 2



The woman calls out the boy, she hears an echo of the sound she made after 4 seconds while the boy hears the same echo 3.5 seconds later.

Task:

As a learner of physics;

(a) Help these people to determine the distance between them.

(b)

(i) Write a report about the factors that increase the rate of movement of sound.

(ii) Explain why it would be easier for the sound to travel from the girl to the cliff at night than during the day.

SOLUTION

(a) Determining the Distance Between the Woman and the Boy

To determine the distance between the two people, we need to use the **speed of sound** and the **time delay** for the echo to return.

- Let d_1 be the distance from the woman to the cliff, and d_2 be the distance from the boy to the cliff.
- The total time for the echo to return for the woman is 4 seconds, while the total time for the boy is 3.5 seconds.

We know that the sound travels to the cliff and back, so the **distance traveled by sound** in the given times is the **total distance** to the cliff and back. The formula for the total distance traveled by sound is:

Distance = Speed of sound×Time

The speed of sound in air at standard temperature (20°C) is approximately **343 m/s**.

- For the woman, the total distance $2d_1$ is traveled in 4 seconds, so:

  $2d_1 = 343 \text{ m/s} \times 4 \text{ s} = 1372 \text{ m}$

  $d_1 = 1372 \text{ m}/2 = 686 \text{ m}$

- For the boy, the total distance $2d_2$ is traveled in 3.5 seconds, so:

  $2d_2 = 343 \text{ m/s} \times 3.5 \text{ s} = 1200.5 \text{ m}$

  $d_2 = 1200.5 \text{ m}/2 = 600.25 \text{ m}$

Now, to find the **distance between the woman and the boy**:

Distance between the woman and the boy = $|d_1 - d_2| = |686 \text{ m} - 600.25 \text{ m}| = 85.75 \text{ m}$

So, the distance between the woman and the boy is approximately **85.75 meters**.

(b) Factors Affecting the Speed of Sound

(i) Report on the Factors that Increase the Rate of Movement of Sound

The speed of sound depends on several factors that affect the rate of its movement:

1. **Medium**:
   Sound travels at different speeds in different mediums. It travels fastest in **solids**, slower in **liquids**, and slowest in **gases**. This is because the particles in solids are more tightly packed, allowing sound waves to travel faster through them compared to gases.
2. **Temperature**:
   The speed of sound increases with an increase in temperature. As the temperature rises, the particles in the medium (such as air) vibrate faster, facilitating quicker transmission of sound waves. For example, the speed of sound in air at 0°C is about 331 m/s, while at 20°C it increases to about 343 m/s.
3. **Humidity**:
   Higher humidity (i.e., more water vapor in the air) can increase the speed of sound. Water vapor is less dense than dry air, so sound waves can travel more easily through moist air, leading to a slight increase in speed.
4. **Pressure (for gases)**:
   At a constant temperature, the speed of sound is generally unaffected by changes in atmospheric pressure because pressure and density tend to change proportionally in the air. However, in a specific, controlled environment where density changes significantly, sound speed can be influenced by pressure.

(ii) Why Sound Travels More Easily at Night Than During the Day

The speed and behavior of sound can be influenced by **temperature** and **air conditions** during the day and night, affecting how far and clearly sound travels:

1. **Temperature at Night**:
    - **At night**, the air tends to be cooler, which means the temperature gradient (difference in temperature between the ground and higher altitudes) is steeper. Colder air near the ground causes sound waves to bend downward, increasing their range. This phenomenon is called **temperature inversion**.
    - **During the day**, the sun heats the air near the ground, and the air higher up is cooler. This creates a situation where sound waves tend to bend upward and dissipate quickly, reducing the distance over which they travel.
2. **Less Disturbance at Night**:
    - During the night, there are fewer disturbances such as wind, traffic noise, and other environmental factors that can scatter sound waves, allowing them to travel more effectively and with less interference.
    - **At night**, the more stable atmosphere allows sound to travel farther and more directly to the listener (the woman and the boy), making the echo more noticeable and clearer.

Therefore, the sound would travel **more easily and with greater clarity** from the woman to the cliff at night than during the day due to cooler temperatures and a more stable atmosphere that facilitates better transmission of sound waves.

ITEM 17

A science exhibition organized by a university drew the attention of government officials, secondary schools and universities. Among the showcased instruments were:

- A device developed by university's physics department students capable of converting low frequency vibrations ($< 60HZ$) into electrical signals. It could measure the speed of the vibrations and visualize their characteristics on an attached screen.

- Secondary school students presented a black box measuring 40cm in length, featuring a small hole at one end and a translucent screen at the other end.

When an official peered through the box, he observed a large tree appearing small and inverted, sparkling curiosity. The official questioned why there was only one small hole in the box. Additionally, he wondered if the machine could effectively transmit vibrations to electrical signals, particularly in comparison to a nearby road roller.

Hint:

The screen displayed the velocity as $12.96kmhr^{-1}$

The screen of the machine displayed a sine curve and the distance between three successive tops of the curve was $9cm$.

The tree was of height $8m$ *and positioned* $16m$ *from the hole of the box.*

Task:

As a physics student help the official understand;

a) the reason as to why the tree appeared

i) inverted

ii) Small and also help him to know its size as observed on the screen.(5 scores)

b) Why there's one small hole in the box.(5scores)

c) Whether the machine could effectively convert the vibrations into electrical signals, addressing the official's concerns regarding its functionality compared to a nearby road roller. (5 marks)

SOLUTION

(1) Explanation of Why the Tree Appeared Inverted and Small:

The box described in the secondary school project is essentially a **pinhole camera**. Here's an explanation of the observations made by the official:

- **Inverted Image**: A **pinhole camera** works on the principle of light traveling in straight lines. When light from the tree passes through the small hole at one end of the box, it projects an image on the translucent screen at the other end. Due to the nature of how light rays converge after passing through the hole, the image formed on the screen is **inverted** (upside down). This is a standard feature of pinhole cameras, where the light rays from the top of the object (the tree) are directed to the bottom of the screen, and vice versa.
- **Small Image**: The tree appears small on the screen because the **image formed by a pinhole camera is a reduced version of the object**. The size of the image depends on the **distance between the tree, the hole, and the screen**. Since the distance from the tree to the hole is much larger than the distance between the hole and the screen, the image is reduced in size.

(2) Explanation of Why There is Only One Small Hole in the Box:

The reason for having only one small hole in the box is fundamental to the working of the **pinhole camera**.

- **Single Small Hole Principle**: A small hole allows light to pass through it and project an image on the screen. A larger hole would lead to multiple light rays entering the box from different angles, resulting in a blurry image. The small hole ensures that only a single ray of light from each point on the tree enters the box and projects an image on the screen, maintaining clarity.
- **Why It's Called a Pinhole**: The small hole ensures that only **light rays from specific parts of the object** contribute to the formation of the image. This results in a **sharp and clear image**, and is why only one small hole is used in the device.

---

(3) Evaluating Whether the Machine Could Effectively Convert Vibrations Into Electrical Signals (in comparison to a Road Roller):

The device mentioned by the university's physics department is capable of converting **low-frequency vibrations (<60 Hz) into electrical signals**. This is most likely a **vibration sensor** or **accelerometer**.

Vibrations Conversion to Electrical Signals:

- The device seems capable of converting vibrations into electrical signals, possibly through the use of a **piezoelectric material** or **electromagnetic sensors**. These materials generate an electric charge when subjected to vibrations. The device might be using such materials to convert mechanical vibrations into corresponding electrical signals that can then be displayed on the screen.

- **Road Roller and Vibrations**: A **road roller** generates very powerful vibrations (often much higher than 60 Hz). These vibrations are likely outside the sensitivity range of the device designed to measure low-frequency vibrations. Therefore, a road roller's vibrations would be **too strong and high-frequency** for this particular machine to measure effectively, especially since it is designed for **low-frequency vibrations (<60 Hz)**.
- **Comparing the Two**:
    - The device is **designed for low-frequency vibrations**, such as those produced by machinery or natural systems that vibrate at lower rates (such as earthquakes, machinery, etc.).
    - The **road roller** produces high-energy vibrations that may either be too large for the device to measure accurately, or may even damage the sensors if the machine is not calibrated for higher-intensity signals.

Therefore, **the machine could effectively convert low-frequency vibrations into electrical signals**, but it would not be suitable for measuring the powerful vibrations produced by the road roller. The road roller's vibrations are likely too intense and may fall outside the operational range of the sensor.

Calculation

ITEM 19

The students in a particular class visited a laboratory with a white bulb and a red one, to observe a glass tank filled with water with a white base at the bottom. Modifications were made to create a shallow end on one side of the tank using glass material. To their surprise, when they struck the water's surface at the shallow end with a long rectangular rod at a frequency of 80 Hz, they noticed that the spacing between successive crests changed from 2.5cm to 5cm. Additionally, they were disturbed by the distortion of ripples as they struck the tank walls. They were also surprised to see the base turning black when it was replaced with a yellow sheet and the red lights switched on.

Hint; the glass tank would break if the velocity of the waves that hit it is greater than 20 ms^{-1}

Use your knowledge of physics to:

a. Determine if the ripple tank will break.

b. Explain the reason for the change in the distance between the ripples and its impact on the velocity of the ripples.

c. Explain what distorted the waves and how it could have been reduced.

d. Explain why the yellow sheet changed color when the red lights were switched on.

(a) Determining if the Ripple Tank Will Break

To determine if the ripple tank will break, we need to consider the velocity of the ripples in the water. The glass tank will break if the **velocity of the waves exceeds 20 m/s**. We can calculate the velocity of the waves in the tank using the formula for wave velocity:

$v = f \times \lambda$

Where:

- v is the velocity of the wave (in meters per second).
- f is the frequency of the wave (in Hz).
- λ is the wavelength (in meters).

From the problem:

- The frequency of the waves is given as **80 Hz**.
- Initially, the spacing between the crests is 2.5 cm, which we need to convert to meters: $\lambda 1 = 2.5 \text{ cm} = 0.025 \text{ m}$
- After some change, the spacing between the crests increases to **5 cm**, which we convert to meters: $\lambda_2 = 5 \text{ cm} = 0.05 \text{ m}$

Now we calculate the velocity of the ripples for both scenarios:

1. **For the initial wavelength of 2.5 cm (0.025 m):**

   $v_1 = f \times \lambda_1 = 80 \text{ Hz} \times 0.025 \text{ m} = 2 \text{ m/s}$

2. **For the new wavelength of 5 cm (0.05 m):**

   $v_2 = f \times \lambda_2 = 80 \text{ Hz} \times 0.05 \text{ m} = 4 \text{ m/s}$

In both cases, the wave velocities ($v_1 = 2$ m/s and $v_2 = 4$ m/s are well below the **critical velocity of 20 m/s** at which the tank would break. Therefore, **the ripple tank will not break** as the velocities are too low.

(b) Reason for the Change in the Distance Between the Ripples and Its Impact on the Velocity of the Ripples

The spacing between the crests of the waves (also called the wavelength) changes due to a change in the **medium's properties** or **wave velocity**.

- **Wavelength Change**: The increase in the distance between the crests from 2.5 cm to 5 cm indicates that the wavelength has doubled.
- **Impact on the Velocity**: According to the wave equation $v = f \times \lambda$, if the frequency remains constant and the wavelength increases, the **velocity of the waves must also increase**. This is confirmed by the fact that the wave velocity increased from 2 m/s to 4 m/s when the wavelength doubled, while the frequency remained at 80 Hz.

Thus, the change in the wavelength is a result of **increased wave velocity**. This can be due to a change in the properties of the water, such as temperature, which affects the wave speed.

(c) Explanation of Distortion of Waves and How It Could Have Been Reduced

The distortion of the waves could be caused by **interference with the tank walls** or **refraction**. Here are some likely causes:

1. **Reflection and Interference**: When the waves hit the walls of the tank, they reflect back and interact with incoming waves. This causes **constructive and destructive interference**, which can distort the smooth propagation of the ripples. The reflected waves might also interfere with each other and cause irregular patterns.
2. **Refraction**: The shallow end of the tank could have altered the speed of the waves, leading to refraction. The change in depth (shallow to deep) would cause the waves to bend and change direction, distorting their pattern.

How to Reduce Distortion:

- **Ensure uniform water depth**: Maintaining a consistent water depth can reduce refraction and interference from walls.
- **Use barriers or waveguides**: Placing barriers along the walls or using a **waveguide** can prevent the waves from reflecting off the walls and reduce interference.
- **Smaller waves or dampening**: Reducing the intensity of the waves or using some form of damping material on the walls may help minimize the reflection and subsequent distortion.

(d) Explanation of Why the Yellow Sheet Changed Color When the Red Lights Were Switched On

When the red light is switched on, the yellow sheet changes color due to the **color filtering properties** of the sheet and the nature of light absorption.

- **Yellow Sheet and Color Mixing**: A yellow sheet reflects both **red** and **green** light, but absorbs other colors. When **red light** is shined on it, the sheet reflects the red light and still appears **yellow** because red light is a component of yellow light. However, since there is no other light in the spectrum (such as blue or green) to mix with the red, the yellow appearance is more pronounced or may appear slightly different based on the intensity of the red light.
- **Effect of Red Light**: When the yellow sheet is illuminated with **red light**, the primary reflected color remains red because the sheet reflects red wavelengths more than other colors. The result could be that the yellow sheet appears **brighter red** or slightly altered in color when only red light is available, especially if the sheet was initially reflecting a mixture of light colors.

This effect occurs due to the interaction of the red light with the sheet's ability to reflect certain wavelengths and absorb others.

ITEM 20

During the construction of a multipurpose hall of size 70m by 40m in a school, the students have been asked to raise challenges that could arise after the hall's construction. They are listed below; There could be a distortion of sound as a result of two sounds being heard.

- The hall could be dimly lit because of the paint color used to paint the walls.

- There could be disturbance of the neighbors in the community. During the day, the neighbors that would be disturbed wouldn't be very far but at night, even those outside the school would be disturbed.
- Complaints could arise from the wrong type of mirrors installed in the bathrooms
- Complaints would have arisen from fears due to insecurity from not checking under cars.

TASK

Use your knowledge of Physics to;

a) Identify the cause of the distortion of sound and structural adjustments that can be made to ensure the distortion is minimized.

b) Identify the paint color to use to increase the amount of light in the room.

c) Establish how the sound would reach the community, how it can be reduced, and the difference in the distance that the sound from the hall reaches.

d) Identify the type of mirrors that should be installed in the bathrooms and those that should be used to check under the cars.

SOLUTION

(a) Cause of Sound Distortion and Structural Adjustments to Minimize It

Cause of Sound Distortion:

- The **distortion of sound** in the hall could be caused by **sound reflections** or **echoes**. When sound waves are reflected off large, flat surfaces like walls and the ceiling, they can interfere with each other and cause undesirable effects such as **reverberation** (continuous reflection of sound) or **echo** (sound reflecting back to the listener after a delay). This occurs particularly in large, empty halls where sound waves travel long distances before reflecting back.

Structural Adjustments to Minimize Distortion:

1. **Acoustic Panels**: Installing **sound-absorbing materials** (such as foam panels, fabric, or perforated materials) on the walls, ceiling, and floors will absorb sound waves and reduce echo and reverberation.
2. **Curved or Irregular Shaped Surfaces**: Having **curved or irregularly shaped surfaces** in the hall can help redirect sound waves in multiple directions, reducing direct reflections and helping to avoid echo.
3. **Sound Baffles**: Hanging **sound baffles** or **diffusers** from the ceiling can help scatter sound waves in different directions, reducing unwanted reflections and echoes.
4. **Carpet or Soft Flooring**: Installing **carpet or other soft flooring** materials can reduce the reflection of sound waves from the floor, further helping to control sound distortion.

(b) Paint Color to Increase Light in the Room

To increase the amount of light in the room, the choice of **paint color** is critical. The paint should have a **high reflectivity** to bounce more light around the room.

- **Light colors** such as **white** or **light pastel colors (e.g., light yellow, light cream, or soft blue)** are the best options because they reflect a significant amount of light. These colors will **reflect natural or artificial light** throughout the hall, making the room brighter.
- **Darker colors** (e.g., dark brown, dark green, or deep red) would absorb more light and make the room appear **dimmer**.

Thus, the best choice for painting the walls would be **white** or a **light pastel color** to maximize light reflection.

(c) How Sound Reaches the Community and How It Can Be Reduced

How Sound Reaches the Community:

- **During the day**, the sound from the hall may be audible to neighbors nearby because sound waves travel easily through the air. The hall's size, combined with potentially poor sound insulation, could lead to significant sound leakage, especially if the windows and doors are not soundproof.
- **At night**, sound can travel further because there is generally **less background noise** in the environment, and sound travels more effectively through the cooler and denser air at night. This makes it easier for sound to carry over long distances.

How to Reduce Sound Transmission:

1. **Soundproofing the Hall**:
    - Install **soundproof doors** and **windows** to minimize the amount of sound escaping the hall.
    - Use **thicker walls**, **double glazing**, and **soundproof materials** to reduce noise transmission to the outside.
2. **Landscaping**:
    - Planting **dense shrubs or trees** around the hall can help absorb some of the sound waves, especially at the perimeter of the property. Trees can act as a **natural sound barrier**.
3. **Distance and Barriers**:
    - Ensure there are **distance barriers** between the hall and the surrounding neighborhood, or use **physical barriers** (e.g., walls or fences) to block the direct path of sound.

Difference in Distance That Sound Reaches:

- During the day, sound travels a shorter distance because there is more background noise, which interferes with the propagation of the sound.
- At night, the absence of background noise and cooler, denser air allows the sound to travel **further distances**. In cooler conditions, sound waves travel more efficiently through the air, especially at lower frequencies.

(d) Type of Mirrors to Install in the Bathrooms and to Check Under Cars

Mirrors for Bathrooms:

- For bathrooms, **flat mirrors** (plane mirrors) are typically installed. These mirrors provide a **true-to-life reflection**, which is essential for personal grooming, shaving, and other tasks where accuracy is important. A **flat mirror** will reflect light and show the exact image of the person, making it ideal for use in bathrooms.

Mirrors to Check Under Cars:

- For checking under cars, a **concave mirror** is more suitable. Concave mirrors **magnify objects**, allowing a clearer view of areas underneath the car. The concave shape of the mirror **focuses the light** onto a specific point, which can help in examining details that would otherwise be difficult to see.

  Additionally, a concave mirror provides **enhanced visibility**, especially in low-light conditions, and allows a person to see more clearly under the car.

ITEM 21

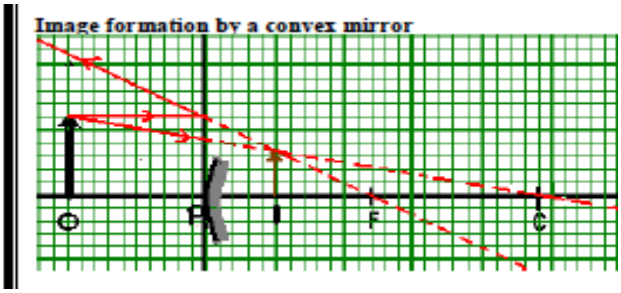
Your uncle operates one of the largest supermarkets in Hoima city. However he has been having some challenges especially theft of his goods in his supermarket.

TASK

Using the knowledge of reflection of light, what advice would you offer him to overcome such losses due to theft of his goods?

To help your uncle overcome theft in his supermarket, I would advise him to take advantage of the **principle of reflection of light** by incorporating **mirrors** in strategic locations within the store. Here's how:

1. **Install Convex Mirrors for Surveillance**



Convex mirrors are widely used in stores, supermarkets, and other public places because of their ability to **provide a wide field of view**. These mirrors are effective in surveillance because they allow **security personnel** or **cameras** to monitor areas that would otherwise be difficult to see.

Benefits of Convex Mirrors:

- **Wide Field of View**: Convex mirrors diverge light rays, making it possible to observe a larger area with a single mirror. They can cover corners, aisles, and spaces that are not in the direct line of sight of security cameras or staff.
- **Deterrent for Theft**: The presence of convex mirrors in areas such as aisles, near exits, or high-traffic zones can serve as a **deterrent to potential thieves**, as they know they are being observed from multiple angles.
- **Low Cost and Easy Installation**: Convex mirrors are relatively inexpensive and easy to install, making them an accessible solution for a supermarket owner.

2. Use Mirrors to Enhance the Effectiveness of CCTV Cameras

Mirrors can be strategically placed to **reflect light** onto areas that may be poorly lit or out of view of cameras, helping to improve visibility for **CCTV systems**. In areas where cameras have blind spots or limited coverage, mirrors can **redirect light and images** toward cameras, improving their ability to capture clear footage.

For example:

- **Place mirrors to reflect light on poorly lit aisles**: Thieves may be encouraged to operate in poorly lit areas where they are less likely to be caught on camera. Installing mirrors in these areas can help illuminate those parts of the store, and increase the likelihood of capturing clear video footage.

ITEM 22

A night swimming pool cleaner accidentally dropped his torch into the pool while on duty after a heavy rain that left the whole place logged with storm water and attempted to retrieve it as he was seeing light from the torch appearing closer to the water surface. Unfortunately, he fell into the water in an attempt to remove the torch as his hands couldn't reach the bottom of the pool. He screamed for help when about to drown in water but was surprised to hear his own voice after drowning in water 0.5 s later. After getting out of the water he tried to understand why he heard his own voice by shouting again but this time round the sound came little a bit later than while drowned in water after 0.16 s later and ended up getting confused the more.

Supporting Information:

- Sound travels at different rate in air and water
- The swimming pool is surrounded with a perimeter wall at a distance of 54 m in all directions.
- The distance from where he fell to the tall boundary wall of the swimming pool is

Task:

As a student of physics, help the cleaner,

(a) Understand why he was unable to reach his phone with his hand, even though it seemed close to the water's surface.

(b) (i) Understand why he heard himself at different time intervals after screaming.

(ii) Explain how he was able to hear the while drowned in water

(c) Compare the rate at which sound waves travel in air and water.

(a) Why He Was Unable to Reach His Phone with His Hand, Even Though It Seemed Close to the Water's Surface

The cleaner perceived the torch (or phone) as appearing closer to the surface of the water due to **refraction**. This phenomenon occurs when light travels from one medium (air) to another (water), causing the light to change speed and direction. This makes objects submerged in water appear **shallower** than they actually are.

- **Refraction and Apparent Depth**: When light travels from water (denser) to air (less dense), it bends away from the normal (perpendicular) line. This bending of light causes the image of the torch to appear closer to the surface of the water than it actually is. Therefore, the cleaner thought he could easily reach the torch, but in reality, the torch was deeper than it seemed due to the refraction of light.

(b) (i) Why He Heard Himself at Different Time Intervals After Screaming

The time it takes for sound to travel through a medium depends on the **speed of sound** in that medium. The cleaner heard his voice at different intervals due to the difference in the **speed of sound in air and in water**.

- **In Water**: Sound travels faster in water because water is denser than air. When the cleaner was in the water, the sound of his scream traveled faster through the water, reaching his ears almost instantly. This is why he heard himself 0.5 seconds after shouting while submerged.
- **In Air**: Sound travels more slowly in air compared to water. After the cleaner got out of the water and shouted again, the sound had to travel through air, which is less dense than water. This caused a **delay of 0.16 seconds** between his scream and hearing it, which is slower than when he was submerged in water.

Therefore, the difference in time intervals is due to the fact that sound travels faster in water than in air.

(b) (ii) Why He Was Able to Hear His Own Voice While Drowned in Water

When the cleaner screamed underwater, he heard his voice because **sound waves can travel through water**. The speed of sound in water is much higher than in air, which means sound travels faster and more efficiently underwater.

- **Sound Transmission in Water**: When he screamed underwater, the sound waves generated by his voice would travel through the water and be **picked up by his ears** either through direct conduction through the skull or through the water itself. The cleaner heard his voice because his body was submerged in the water, and the sound was transmitted directly through the medium (water) and his body.
- **Why the Delay Was Shorter in Water**: The **higher speed of sound in water** (compared to air) resulted in the sound reaching him faster, which caused him to hear his voice 0.5 seconds after he screamed while submerged.

(c) Comparison of the Rate at Which Sound Waves Travel in Air and Water

The speed of sound is influenced by the medium through which it travels. In general:

- **In Water**: Sound travels much faster in water than in air because water is denser and has molecules that are closer together, which makes it easier for sound waves to propagate. The typical speed of sound in water is about **1,500 m/s**.
- **In Air**: Sound travels more slowly in air because air is less dense than water. The speed of sound in air at room temperature (20°C) is around **343 m/s**.

Thus, the sound waves travel **significantly faster in water** (around 1,500 m/s) than in air (around 343 m/s).

Summary:

(a) The cleaner was unable to reach his phone even though it seemed close to the surface due to **refraction**, which caused the torch to appear **shallower** than it actually was.

(b) (i) He heard himself at different time intervals because **sound travels faster in water** (0.5 s delay when submerged) compared to **air** (0.16 s delay when out of the water).

(b) (ii) He was able to hear his voice underwater because **sound travels faster through water**, allowing the sound to reach his ears more quickly while submerged.

(c) The speed of sound in **water** is about **1,500 m/s**, much faster than in **air**, where it is around **343 m/s**.

This explanation of how the speed of sound varies in different media helps the cleaner understand the timing differences in hearing his voice while submerged and after getting out of the water.

ITEM 23

In a certain music concert that took place at night, a man played a guitar on a floating stage surrounded by disco lights flashing red, blue and green in the middle of the lake. The audience on the boats and shores were wearing white clothes with yellow spots on them. The audience was surprised about the new appearance of the colour of their clothes. The sound waves from the guitar travel through the air with a frequency of $\mathbf{440}\boldsymbol{Hz}$. The organizers also projected laser light, that travels through air with a frequency of $\mathbf{4.7}\times\mathbf{8}\boldsymbol{Hz}$ illuminating waves on the lake surface to aid visibility. On the shores of a lake was a tall storeyed building a distance of $\boldsymbol{x\ metres}$ away from the floating cruise. A lady on the floating boat cruise bearing the floating stage noticed that the guitar sound was heard twice every time the guitar was played. Using a stop watch, she got the time interval between the first and second sound heard to be 2s.

Hint: $Speed\ of\ sound\ in\ air$ = $\mathbf{330}\boldsymbol{ms}\mathbf{-1}$, $Speed\ of\ light\ in\ air$ = $\mathbf{3.0}\times\mathbf{10^8}\boldsymbol{ms}\mathbf{-1}$

Task:

As a physics student;

(a) Help the lady understand why she heard the sound of the guitar twice. And help her know the distance between the lake shore and the boast cruise.

(b) Clearly explain why the colour of the clothes of the audience kept on changing when coloured lights flashed on them.

(c) Why was laser source of light preferred to provide laser light that enhanced visibility in the late hours of the night.

(d) Compare the wave lengths of the sound waves and laser light waves in air medium

SOLUTION

(a) Why She Heard the Sound of the Guitar Twice and the Distance Between the Shore and the Boat

Why She Heard the Sound Twice: The lady on the floating boat cruise heard the guitar sound twice due to the phenomenon of **echo**. This occurs when sound waves are reflected off a surface, such as a building or the shore, and travel back to the listener. The sound heard directly from the guitar is the **direct sound**, while the sound that reaches the listener after reflecting off the building or shore is the **reflected sound**. The two sounds are heard at different times, with the second sound being the echo, which arrives after a delay based on the distance it traveled.

The time between hearing the first and second sound is the time it takes for the sound to travel to the building and back. From the problem, the time interval between the first and second sound is given as **2 seconds**.

To calculate the distance between the boat cruise and the shore, we can use the formula for the speed of sound:

Speed of sound = Distance traveled/Time taken

The time taken for the sound to travel to the building and back is **2 seconds**, so the time for the sound to travel one way is:

Time for one way = 2 seconds/2 = 1 second

Now, using the speed of sound in air, which is **330 m/s**, the distance from the boat cruise to the shore is:

Distance = Speed of sound×Time for one way

Distance=330 m/s×1 second=330 meters

So, the distance between the shore and the boat cruise is **330 meters**.

(b) Why the Colour of the Clothes Kept Changing When Coloured Lights Flashed on Them

The changing colours of the clothes worn by the audience when coloured lights flashed on them can be explained by the **principle of light absorption and reflection**.

- **Absorption and Reflection**: The white clothes reflect almost all of the light that hits them, but when the coloured lights (red, blue, green) flash on the clothes, the colours of the clothes are influenced by the colour of the light shining on them. The **yellow spots** on the clothes are a combination of the red and green parts of the visible light spectrum. When the different coloured lights (red, blue, green) are flashed onto the white clothes, the spots change colour because:
    - **Red light**: The yellow spots reflect both red and green light, so they appear more intense or vivid under red light.
    - **Green light**: Under green light, the yellow spots would reflect green light as well as some red, but the visual effect would be different.
    - **Blue light**: When blue light is flashed, the yellow spots might appear to be less vivid because blue light doesn't have a strong component in the yellow wavelength range, affecting the perception of the yellow spots.

Thus, the **changing colours** are due to the **different wavelengths of light** being reflected by the clothes in response to the flashing coloured lights.

(c) Why Laser Light Was Preferred to Enhance Visibility in the Late Hours of the Night

Laser light is preferred for enhancing visibility at night for several reasons:

1. **Monochromatic Light**: Laser light is **monochromatic**, meaning it consists of light of a single wavelength or colour. This property makes laser light very **intense** and **focused**, which helps it to travel long distances without spreading out or scattering significantly.
2. **Coherent Light**: Laser light is **coherent**, meaning that the light waves are in phase with each other. This allows the laser to be directed in a narrow beam, making it very **efficient** at illuminating specific areas, like the surface of the lake, even from a distance.
3. **Minimal Scattering**: Unlike ordinary light sources, laser light undergoes very little scattering as it travels through air. This is important for **long-range visibility** at night, especially in the presence of fog, mist, or dust particles, where normal light sources might lose intensity.
4. **High Intensity and Focused Beam**: Laser light is much more focused and has a **higher intensity** than regular lights, making it perfect for use in low-light conditions, like at night, to provide clear visibility.

Therefore, **laser light** was preferred in the concert to **illuminate the waves on the lake** and provide clear, visible beams over long distances in the dark.

(d) Comparison of the Wavelengths of Sound Waves and Laser Light Waves in Air

- **Sound Waves**: Sound is a mechanical wave that requires a medium (such as air) to propagate. The wavelength of sound depends on its frequency and the speed of sound in the medium. The frequency of the guitar sound is given as **440 Hz** (which is a typical A note in music). Using the speed of sound in air (330 m/s), we can calculate the wavelength of the sound:

Wavelength of sound = Speed of sound/Frequency of sound=3 30 m/s/440 Hz ≈ 0.75 m

So, the wavelength of the sound waves is approximately **0.75 meters**.

- **Laser Light Waves**: Laser light has a very high frequency compared to sound waves. The frequency of the laser light is given as **4.7 × 10^8 Hz**. The speed of light in air is approximately **3.0 × 10^8 m/s**. We can calculate the wavelength of the laser light as:

Wavelength of laser light = Speed of light/Frequency of light =3.0×108 m/s/4.7×108 Hz ≈ 0.64 m

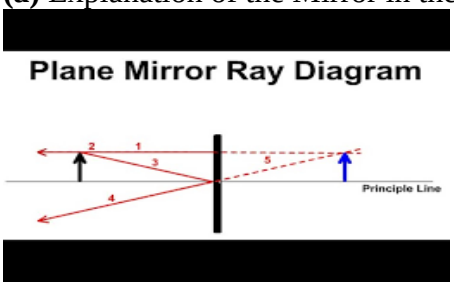
So, the wavelength of the laser light waves is approximately **0.64 meters**.

Summary:

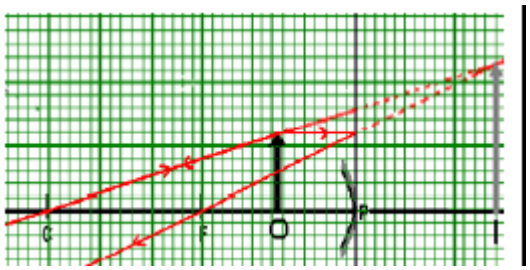
- **(a)** The lady heard the guitar sound twice due to an **echo** from the shore or building. The distance between the boat cruise and the shore is **330 meters**.
- **(b)** The changing colours of the audience's clothes were caused by the different wavelengths of the coloured lights reflecting off the white clothes and the yellow spots.
- **(c) Laser light** was preferred because it is **monochromatic**, **coherent**, and travels long distances with minimal scattering, providing better visibility at night.
- **(d)** The **wavelength of sound** is approximately **0.75 meters**, and the **wavelength of laser light** is approximately **0.64 meters**, showing that the sound and light waves are of comparable wavelength in air but have vastly different frequencies and propagation characteristics.

ITEM 24
The mother developed a dental challenge but could not identify the exact tooth that should be extracted even after checking using her phone mirror. She decides to go the dental clinic. In the dental clinic, a small mirror was used and the tooth was easily identified. This made the mother to be more interested in the mirror and on checking, it had the following writings.
Radius of curvature = 20 cm
When she placed her face about 6.0 cm in front of the mirror, her face appeared different with bigger eyes and nose which left her wondering. As a physics student,
(a) Make use of a ray diagram to explain how the mirror in the clinic is different from the one at home and how it works.
(b) Use a graph to support your explanation to the mother about the nature of the image of her face when she tried to look through it.
SOLUTION

(a) Explanation of the Mirror in the Clinic and How It Works Using a Ray Diagram



plane mirrior



Concave mirrior

The **small mirror** used in the clinic is a **concave mirror**, and it is different from the flat mirror she used at home. Here's an explanation of how it works:

1. **Concave Mirror vs. Plane Mirror**:
    - A **plane mirror** (the one she used at home with her phone) produces an image that is **virtual**, **upright**, and **same size** as the object, but it is laterally reversed (the left-right inversion).
    - A **concave mirror** (the one in the clinic) is **curved inward** (like the inside of a bowl). It has a **focal point** where parallel light rays converge after reflection. This type of mirror creates a **magnified** and **virtual image** of the face when the object (in this case, the face) is placed between the mirror's surface and its focal point.

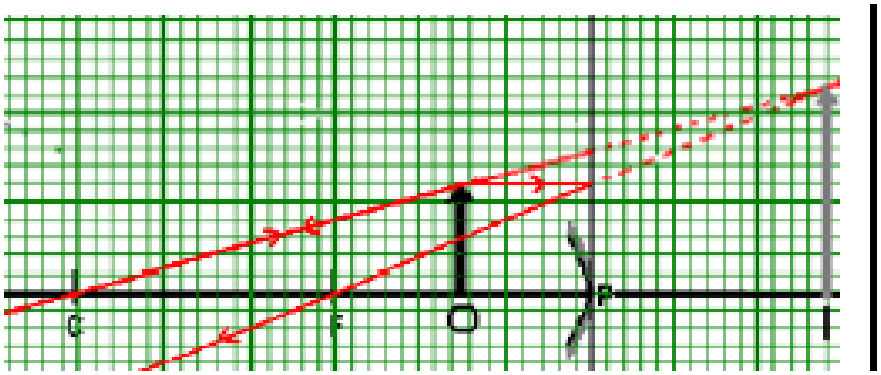
In the case of the mother's face:

- The **radius of curvature** of the concave mirror is given as **20 cm**, so the **focal length (f)** of the mirror can be calculated as half the radius of curvature:

  $f = R/2 = 20\ cm/2 = 10\ cm$

- When she placed her face about **6.0 cm in front** of the mirror, it was **closer than the focal point (10 cm)**. In this case, the mirror forms a **virtual image** that is **magnified**, **upright**, and **located behind the mirror**. This is why her face appeared with **bigger eyes and nose**.

(c) Graph Supporting the Explanation of the Image Nature



To support the explanation about the nature of the image (when the face is placed at 6 cm from the mirror), we can use a **graph** showing the relationship between the **object distance (u)** and the **image distance (v)**.

The **mirror equation** is:

$1/f = 1/v + 1/u$

Where:

- **f** is the focal length (10 cm),
- **v** is the image distance (behind the mirror),
- **u** is the object distance (6 cm).

To solve for the image distance (v), we rearrange the mirror equation:

$1/v = 1/f - 1/u$

Substitute the values:

$1/v = 1/10 - 1/6$

Find a common denominator:

$1/v = 3/30 - 5/30 = -2/30 = -1/15$

Thus, the image distance is:

$V = -15$ cm

The negative sign indicates that the image is **virtual** and formed behind the mirror.

Now, to explain the magnification, we can calculate the **magnification (M)** using the formula:

$M = \text{image height}/\text{object height} = v/u$

Substitute the known values:

$M = -15/6 = -2.5$

This means the image is **magnified** by a factor of 2.5 times and **upright** (because the magnification is negative, indicating no inversion).

ITEM 25

During the music gala in a hall, one of the adjudicators observed the following;
 On entering the stage, the colour of dress of one presenter changed from a yellow dress with red dots to a red dress with black dots.

 The sound from the nearest loud speaker reached him after 0.05s.

 She kept on hearing voices of two people singing on stage, yet there was only one person on the stage.

Hint: *Speed of sound in air =320 ms-1*
Task
Using the knowledge of Physics, help the adjudicator to understand;
(a) Why the colour of the dress changed.

(b) Why the sound was reaching her after 0.05s.

(c) The origin of the second voice and how it can be minimized.
SOLUTION

(a) Why the Colour of the Dress Changed

The change in the colour of the dress can be explained by the **lighting** used during the music gala, which likely involved **different coloured lights** being projected onto the dress. When the presenter entered the stage, the **colour of the lights** changed, which caused the colour of the dress to appear different due to **colour absorption and reflection**.

- The **yellow dress with red dots** would reflect both yellow and red wavelengths of light when illuminated by white light.
- However, when **red lights** were projected onto the dress, the dress would appear **red** because red light is reflected by both the red part of the dress and the yellow portion. The **dots** that were previously yellow may appear darker or black because red light does not interact with yellow in the same way as white light does.
- The **red dress with black dots** could be the result of the **lighting colour** (red lights) causing the overall reflection to appear as red, while the black dots are the result of light being absorbed or not reflected at all by the areas where the black dots are located.

Thus, the dress colour changed due to the **type of light illuminating the dress**. The dress was likely **yellow** under normal lighting, but when exposed to **red lighting**, it appeared **red** with **black dots**.

(b) Why the Sound Was Reaching the Adjudicator After 0.05s

The reason the sound from the nearest loudspeaker reached the adjudicator after 0.05 seconds can be explained by the **speed of sound in air** and the **distance between the adjudicator and the loudspeaker**.

The speed of sound in air is given as **320 m/s**. The time it takes for the sound to travel from the loudspeaker to the adjudicator is given as **0.05 seconds**.

Using the equation:

Distance = Speed×Time

Substitute the given values:

Distance=320 m/s×0.05 s=16 meters.

So, the adjudicator is **16 meters** away from the nearest loudspeaker. The sound takes **0.05 seconds** to reach the adjudicator because it travels this distance at the speed of **320 m/s**.

(c) The Origin of the Second Voice and How It Can Be Minimized

The second voice that the adjudicator heard, even though there was only one person singing on stage, is likely due to a phenomenon known as **echo** or **sound reflection**. Here's why this could have happened:

1. **Sound Reflection**: In the hall, the sound from the singer may have reflected off the **walls** or other surfaces, causing the adjudicator to hear **multiple instances of the sound**. The reflected sound would travel a longer distance, creating a delayed version of the original sound. This could be perceived as a **second voice**.
2. **Reverberation**: The hall itself might have **high reverberation** (the persistence of sound due to multiple reflections), which causes the sound to bounce off various surfaces. This can result in a **blurred or confusing** auditory experience where the adjudicator perceives two voices instead of one.

How It Can Be Minimized:

To minimize the effect of the second voice (echo or reverberation), the following measures could be taken:

- **Acoustic Treatment**: The hall could be treated with **sound-absorbing materials** (like acoustic panels, carpets, curtains, etc.) to reduce the amount of sound that reflects off the walls and ceilings.
- **Proper Speaker Placement**: Speakers should be strategically placed to direct sound towards the audience rather than allowing it to reflect off surfaces where it can interfere.
- **Use of Delay Systems**: In larger halls, a delay system could be used to ensure that the sound from multiple speakers reaches the audience in sync, minimizing the perception of multiple voices.

In summary, the second voice is caused by the **echo** or **reverberation** of sound within the hall, and it can be minimized through **sound absorption** and **better speaker placement**.

SPACE PHYSICS ITEMS

ITEM 1

One of the most misunderstood branches of physics for years has been space physics (Astronomy). Some of the examples of such misunderstandings include the following.

- While watching the world cup which took place in Brazil in 2014 at 9:00 pm East African time, the football fans watching the game in E. Africa realized that it was still day time in Brazil, some of them were puzzled by this.
- The NASA (National Aeronautic and Space Administration) tells us that the only planet that supports life is earth.

TASK:

a) How can you explain the above statement in **case one** to your classmates, siblings or friends about the astronomical events in order to promote deeper understanding of physics in the school and community at large. **(6scores)**

b) The solar system is composed of big, small and much smaller objects including planets. All planets move around the sun in elliptical paths. The motion is both rotational and revolution. Rotation motion involves the planets spinning about a fixed axis and revolution motion involves planet moving around the sun.

TASK:

i) Identify the other components of the solar system. **(3 scores)**

ii) Which name is given to the path in which planets move. **(1 score)**

iii) Draw diagrams to show rotational motion and revolution motion. **(2 scores)**

SOLUTION

(a) Explanation of the First Statement about Daytime in Brazil during the World Cup (9:00 PM EAT)**:**

The confusion about the time of day in Brazil during the World Cup match can be explained by understanding how time zones and the Earth's rotation work.

- **Time Zones**: The Earth is divided into 24 time zones, with each time zone generally corresponding to one hour of the Earth's 24-hour rotation. East Africa Time (EAT) is **UTC +3**, while Brazil operates on several time zones, with the most commonly used being **Brasília Time (BRT)**, which is **UTC -3**. This means that there is a **6-hour difference** between East Africa and Brazil (EAT is 6 hours ahead of BRT).
- **Why It Was Still Daytime in Brazil**: When it is **9:00 PM in East Africa (EAT)**, it is only **3:00 PM in Brazil (BRT)**. Therefore, in Brazil, it is still the afternoon, and there is plenty of daylight. The time difference is a key factor in why it seemed like it was still daytime in Brazil while it was already evening in East Africa.
- **Earth's Rotation**: The Earth's rotation causes different parts of the Earth to experience daylight and night at different times. As the Earth rotates, different areas experience different times of the day. Since Brazil is much further west of East Africa, the Sun sets later in Brazil.

So, this situation arises because of the **time zone differences** and the **Earth's rotation**, which causes different regions of the Earth to experience daylight at different times.

(b) Solar System Components and Planetary Motion**:**

(i) Other Components of the Solar System:

The **solar system** is composed of the following components in addition to the planets:

1. **The Sun**: The central star of the solar system that provides light and energy to all the objects in the solar system.
2. **Moons**: Natural satellites that orbit planets. For example, the Moon orbits Earth, and Jupiter has over 70 moons.
3. **Dwarf Planets**: These are celestial bodies that orbit the Sun but do not clear their orbits of other objects. An example is **Pluto**, which was reclassified as a dwarf planet in 2006.
4. **Asteroids**: Small rocky bodies that mostly exist in the **Asteroid Belt** between Mars and Jupiter. These objects are made of metal and rock.

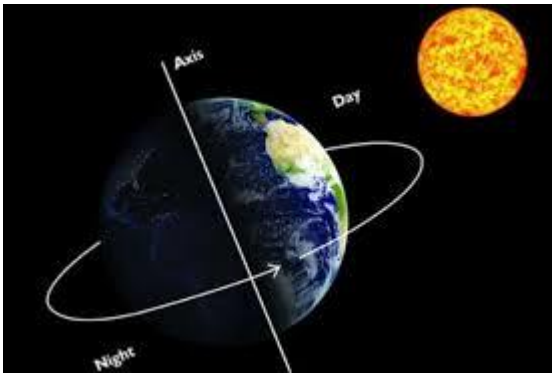
5. **Comets**: Icy bodies that originate from the outer solar system (such as the **Kuiper Belt** and **Oort Cloud**). When comets get close to the Sun, they form bright tails due to the Sun's heat vaporizing the ice.
6. **Kuiper Belt**: A region beyond Neptune that contains many icy objects and dwarf planets, including Pluto.
7. **Oort Cloud**: A distant, spherical shell of icy bodies surrounding the solar system. It is thought to be the origin of long-period comets.

(ii) The Name Given to the Path in Which Planets Move:

The path that planets follow as they move around the Sun is called an **orbit**. The orbit of the planets is elliptical in shape, meaning it is oval, rather than perfectly circular.

(iii) Diagrams Showing Rotational Motion and Revolution Motion:

1. **Rotational Motion**:
    - **Rotation** refers to the spinning of a planet about its own axis. For example, Earth spins on its axis, which gives us day and night.

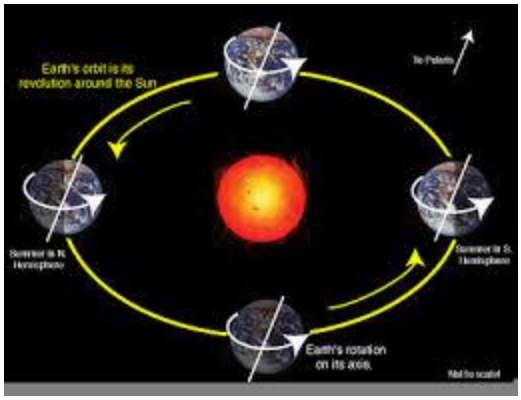


In the above diagram, the Earth spins on its **axis**, which is an imaginary line passing from the North Pole to the South Pole. This rotation causes the cycle of **day and night** as different parts of the Earth face toward or away from the Sun.

2. **Revolution Motion**:
    - **Revolution** refers to the movement of a planet around the Sun. This is what causes the year, with the planet taking approximately one year to complete one orbit around the Sun.

Diagram:

Sun



In the above diagram, **Earth** moves along an elliptical path around the **Sun**. This revolution takes one year, and the Earth's tilt and orbit around the Sun give rise to the changing seasons.

Summary**:**

1. The World Cup game being in the daytime in Brazil and nighttime in East Africa is due to the **6-hour time zone difference** between the two locations, and the **Earth's rotation** causing different parts of the Earth to experience day and night at different times.
2. The solar system contains **the Sun**, **planets**, **moons**, **dwarf planets**, **asteroids**, **comets**, **the Kuiper Belt**, and **the Oort Cloud**.
3. The path in which planets move around the Sun is called an **orbit**.
4. **Rotational motion** refers to a planet spinning on its own axis, and **revolution motion** refers to the planet moving around the Sun.

ITEM 2

On April 8, 2024, an eclipse was scheduled to occur, generating excitement worldwide. However, despite preparations and anticipation, observers in Uganda were left disappointed when the eclipse was not visible from their location. Meanwhile, reports emerged from the United States of America indicating that the eclipse had indeed occurred, causing momentary complete daytime darkness. Additionally, observers in the USA were seen using glasses to enhance their viewing experience.

Hint: • Support your explanation with a diagram where necessary

• Assume the speed of sound in air is approximately $340 ms^{-1}$

TASK:

As a student of physics, a national television station has requested you to explain to Ugandans:

i) The occurrence of the eclipse and why it was not visible from Uganda. (05 scores)

ii) Why the observers were using glasses for viewing the eclipse? (02 scores)

iii) If an eclipse viewer wants to shout a message to another 500 metres away to share her excitement about the eclipse, how long will it take for her message to reach the friend? (03 scores)

SOLUTION

(i) The Occurrence of the Eclipse and Why It Was Not Visible from Uganda:

An **eclipse** occurs when one celestial body (such as the Moon) passes in front of another (such as the Sun), blocking its light either partially or completely. There are two types of eclipses:

- A **solar eclipse**, where the Moon blocks the Sun's light from reaching the Earth, creating darkness during the day.
- A **lunar eclipse**, where the Earth blocks the Sun's light from reaching the Moon, causing the Moon to appear dark or reddish.

In this case, the **solar eclipse** that occurred on April 8, 2024, was a **total solar eclipse** in some regions of the Earth, meaning the Moon completely covered the Sun for a brief period. However, solar eclipses are **local events**, meaning they are visible only from specific areas on Earth.

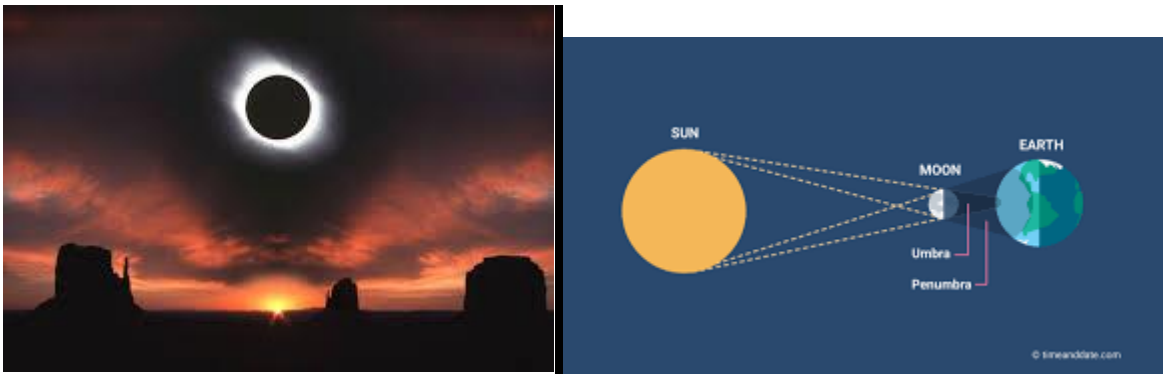
Why the Eclipse Was Not Visible from Uganda:

- The **path of totality** for this eclipse was confined to certain regions, including parts of **North America** (USA, Mexico, and Canada). The **path of totality** is the narrow strip on Earth where the Moon will completely block the Sun.
- Uganda, located in **East Africa**, lies outside this path. In Uganda, people would have seen either a **partial eclipse** (where only part of the Sun is covered by the Moon) or no eclipse at all, depending on the exact location within Uganda.

The eclipse's **visibility** is determined by the specific alignment of the Sun, Moon, and Earth, and the region's position within the path of totality. The path of totality is narrow, typically only about 100-150 km wide, and does not cover every part of the Earth. Uganda, being far outside this path, was unable to see the complete darkness or the total eclipse.

Diagram:

Here’s a simple diagram to illustrate the eclipse and the path of totality:



(ii) Why the Observers Were Using Glasses for Viewing the Eclipse:

Observers used **special eclipse glasses** for viewing the eclipse to protect their eyes from the **damaging effects of solar radiation**. Looking directly at the Sun without proper eye protection can cause severe damage to the eyes, especially during an eclipse, when the Sun's brightness is diminished, making it difficult to recognize the danger.

- During a solar eclipse, the **Sun's light** is partially or fully blocked by the Moon, but the Sun's rays are still extremely intense, especially when looking directly at the Sun's corona (the outer atmosphere). This intense light can cause **retinal burns** or permanent blindness.
- **Eclipse glasses** are designed to filter out harmful ultraviolet (UV) and infrared radiation and reduce the visible light to safe levels, making it safe to look at the Sun during the eclipse. These glasses typically have a special coating that blocks the harmful rays and allows safe viewing of the event.

(iii) How Long Will It Take for the Message to Reach a Friend 500 Metres Away?

The speed of sound in air is approximately **340 meters per second** (m/s).

To calculate the time it takes for the sound of a shout to travel 500 meters, we can use the formula for time:

Time = Distance/Speed

Given:

- Distance = 500 meters
- Speed of sound = 340 m/s

Time = 500 m/340 m/s =1.47 seconds

Thus, it would take approximately **1.47 seconds** for the sound of the shout to travel 500 meters and reach the friend.

Summary:

1. The eclipse occurred along a specific **path of totality** and was not visible from Uganda because Uganda lies outside this path.
2. Observers used special **eclipse glasses** to protect their eyes from the harmful rays of the Sun during the eclipse.
3. The time for the sound of a shout to travel 500 meters would be approximately **1.47 seconds**.

ITEM 3

A boy was listening to a science program on BBC radio. The radio presenters opening remarks were;

(i) Human beings are born and later die, so is the sun

(ii) The death of the sun will automatically translate into death of the earth

Immediately the radio went off due to power black out

TASK

Using the knowledge of physics, help the boy to understand the two remarks

SOLUTION

(i) "Human beings are born and later die, so is the Sun"

This remark is referring to the **life cycle of stars**, particularly the **Sun**. In physics, stars, including our Sun, are not eternal; they go through a process of birth, life, and death, just like living organisms.

- **The Birth of the Sun**: The Sun was formed around 4.6 billion years ago from a cloud of gas and dust in space. Over time, this cloud collapsed under its gravity, forming a dense core that began nuclear fusion—this is the "birth" of a star.
- **The Life of the Sun**: The Sun is currently in the **main sequence phase** of its life cycle, which is the longest phase of a star's life. During this phase, the Sun fuses hydrogen atoms into helium in its core, releasing huge amounts of energy. This energy is what we see as sunlight. The Sun has been in this phase for around 4.6 billion years, and it will continue in this phase for about another 5 billion years.
- **The Death of the Sun**: Eventually, the Sun will run out of hydrogen fuel in its core. At this point, it will no longer be able to maintain the balance between gravity pulling inward and pressure from nuclear fusion pushing outward. The Sun will then expand into a **red giant** and, after shedding its outer layers, will become a **white dwarf**. The core of the Sun will cool and fade over billions of years.

So, just like human beings are born and die, the Sun also has a life cycle with a beginning, middle, and an eventual end. The "death" of the Sun will occur after it exhausts its fuel and undergoes the changes described above.

(ii) "The death of the Sun will automatically translate into death of the Earth"

This remark refers to the **dependence of Earth on the Sun for life**. The Earth and the Sun are closely linked in terms of energy, and the death of the Sun will indeed have catastrophic consequences for life on Earth. Here's why:

- **Energy Source**: The Sun provides the energy necessary for life on Earth. This energy is critical for maintaining Earth's temperature, weather systems, and for photosynthesis, which is the process by which plants produce oxygen and food. Without the Sun, Earth would become extremely cold and lifeless, and the atmosphere would eventually freeze.
- **Effect of the Sun's Death**:
    - When the Sun eventually becomes a **red giant** (after it exhausts its hydrogen fuel), it will expand and likely engulf the inner planets, including Earth, or at least cause extreme heating on Earth.
    - Even before the Sun reaches this phase, as it runs out of fuel and enters the **red giant phase**, the Earth will experience significant changes. The increasing luminosity (brightness) of the Sun will gradually raise Earth's temperature, making it uninhabitable long before the Sun's physical death.
    - The **loss of solar energy** will mean that the Earth will become increasingly cold and dark, leading to the collapse of ecosystems that depend on sunlight, such as plant life and the food chains that follow. Without solar energy, the Earth cannot support life as we know it.

Thus, **the death of the Sun** means the end of the primary source of energy for Earth. The Earth, in turn, will become inhospitable to life as the Sun progresses through its life cycle. The death of the Sun is not only an end for the Sun itself but also an end to the conditions necessary for life on Earth.

ITEM 4

An article in the newspaper gave information that on 2nd December 2022, Ugandan engineers with the help of Japanese engineers launched a satellite. The literature teacher who picked interest who picked interest in the

article found new words like artificial and natural satellites. He developed a number of un answered questions which could be answered by a physics learner like you.

(a) Explain the difference between the two types of satellites in the article.

(b) With reasons, justify why Uganda should spend all that much money to launch its own satellite.

(C) In case Uganda is to develop to a super rocket capable of reaching different planets. List with reasons the planets it can land on and planets it cannot land on.

SOLUTION

(a) Difference between Artificial and Natural Satellites:

1. **Natural Satellites:**
   - A **natural satellite** is a celestial body that orbits a planet or another larger body in space naturally, without human intervention.
   - The most common example of a natural satellite is **the Moon**, which orbits the Earth.
   - Other planets in the solar system, such as Jupiter and Saturn, also have moons, which are natural satellites.
   - **Key Characteristics**: They are formed through natural processes, like gravitational capture or formation alongside the planet they orbit.
2. **Artificial Satellites:**
   - An **artificial satellite** is a man-made object placed into orbit around a celestial body, usually Earth, by humans for various purposes.
   - These satellites are launched by rockets and include examples like communication satellites, weather satellites, and GPS satellites.
   - **Key Characteristics**: They are designed for specific purposes, such as gathering data, communication, or scientific research, and are built using technology and engineering by humans.

(b) Justification for Uganda Launching Its Own Satellite:

Launching its own satellite can be highly beneficial for Uganda in several ways:

1. **Improved Communication:**
   - **Reason**: A communication satellite would enhance the quality and reliability of communication networks in Uganda, especially in remote areas where terrestrial communication infrastructure is not feasible. It could also facilitate faster internet connectivity and provide access to global communication systems.
2. **Monitoring of Weather and Climate:**
   - **Reason**: An earth observation satellite can help in monitoring weather patterns, natural disasters, and climate change. This would enable Uganda to forecast weather more accurately, monitor agricultural conditions, and respond quickly to disasters like floods or droughts, which are critical for the country's agriculture-dependent economy.
3. **National Security:**
   - **Reason**: An artificial satellite can be used for surveillance, improving the security of the nation by monitoring activities within and outside the country. This can aid in border security and detecting threats or unusual activity in real-time.
4. **Scientific and Technological Advancement:**
   - **Reason**: Launching and operating a satellite would boost Uganda's scientific and technological capabilities. It could provide valuable data for research in fields like astronomy, meteorology,

and environmental science, as well as stimulate innovation in the country's engineering and technology sectors.

5. **Economic Growth and Development:**
    - **Reason**: A satellite can drive the growth of Uganda's space industry, creating jobs in science, technology, and engineering fields. Moreover, it may create opportunities for the country to collaborate with international organizations, bringing in new technologies and expertise.
6. **Education and Capacity Building:**
    - **Reason**: A satellite program would create opportunities for Ugandan students and young professionals to engage in space sciences, engineering, and satellite technology, fostering educational growth and inspiring future generations in STEM fields (science, technology, engineering, and mathematics).

(c) Planets Uganda's Super Rocket Could Land On and Those It Cannot Land On:

A super rocket capable of reaching different planets would face various challenges in landing on specific planets based on their environmental conditions. Here are the planets Uganda's rocket could potentially land on, and those it would not be able to land on:

Planets Uganda Could Land On:

1. **Mars**:
    - **Reason**: Mars has an atmosphere (though thin), and it is relatively similar to Earth in terms of day length and surface conditions, making it a prime candidate for exploration and potential landing. It also has gravity (about 38% of Earth's gravity) that could allow for safe landings with advanced technologies.
    - Mars has been the focus of several space missions, and with the right technology, a rocket could land on it, deploy rovers, and conduct scientific exploration.
2. **Venus** (with extreme caution):
    - **Reason**: Venus has a thick atmosphere and surface conditions that are extreme, with temperatures around 465°C and crushing pressure. However, certain technologies and materials are being developed that could withstand these conditions for limited exploration. Despite its harsh environment, landing missions have been attempted by other space agencies, such as the Soviet Union's Venera program.
3. **Earth's Moon**:
    - **Reason**: The Moon is the most accessible and feasible location for a landing. It has a lack of atmosphere, low gravity (about 1/6th of Earth's), and surface conditions that have already been studied extensively. The Moon is considered a stepping stone for further space exploration.

Planets Uganda Cannot Land On:

1. **Gas Giants (Jupiter, Saturn, Uranus, Neptune)**:
    - **Reason**: These planets are composed mostly of gases and lack solid surfaces, making it impossible to land on them in the traditional sense. They have very strong magnetic fields, extreme pressure, and high levels of radiation that would pose significant challenges to any landing or even sustained exploration.
    - Additionally, their gravity and intense atmospheric conditions (such as high-speed winds and storms) would make landing on or near them nearly impossible with current technology.
2. **Mercury**:
    - **Reason**: Mercury has extreme temperature fluctuations (from extremely hot to extremely cold), and while it has a solid surface, its proximity to the Sun makes landing and operating spacecraft

there very difficult. The lack of atmosphere also means there is no way to slow down a spacecraft for a safe landing.

3. **Pluto** (if considered as part of the plan):
    - **Reason**: Pluto is very distant from Earth, making a landing mission challenging due to the extreme cold, low gravity, and lack of a thick atmosphere to assist in landing. Although Pluto has a solid surface, it is not an ideal candidate for landing compared to closer, more hospitable bodies like Mars.

ITEM 5

As a man in Uganda was watching an educative TV show at 11:00 am, the program was interrupted to bring a live broadcast of some educative night time events in South Mexico. The live broadcast showed some children that who were viewing a dark sky on a cloudless, clear night. The dark sky had greyish areas and many bright twinkling spots of different extents of brightness and colours. Some of the bright spots appeared to be moving. The TV presenter reported that unlike night time, there was only one outstanding bright object in the sky during day time and that it is part of a continuously evolving universe. The man was unable to understand this TV production and wished to have a clear explanation.

Task:

As physics student, help the man to understand:

(a) (i) What the observed grey areas that the learners saw represent.

(ii) What the artificial bright spots represent and their significance in the universe.

(b) Why there are outstanding bright objects that the TV presenter mentioned, and their significance in the universe.

(c) why there existed:

(i) Different levels of brightness of the bright spots.

(ii) Differences in colour of the bright spots.

SOLUTION

(a) (i) What the observed grey areas that the learners saw represent:

The **greyish areas** in the sky that the children observed during the clear, dark night represent **nebulae** or **interstellar dust clouds**. These are regions in space that contain gas and dust particles which partially block the light from stars and other celestial objects.

- **Nebulae** are large clouds of gas and dust in space. Some nebulae are regions where new stars are being formed, while others are remnants of exploded stars (supernova remnants).

- The grey appearance comes from the dust scattering and absorbing light from distant stars or galaxies. Nebulae may look more diffuse or cloud-like because they reflect light from nearby stars or emit light at certain wavelengths.

(a) (ii) What the artificial bright spots represent and their significance in the universe:

The **bright twinkling spots** that the children saw represent **stars**, which are massive balls of hot, glowing gas, mostly hydrogen, that emit light and energy. These stars are the basic building blocks of the universe, and each one represents a distinct celestial object that undergoes nuclear fusion in its core to generate energy and light.

- **Significance**: Stars are crucial in the universe because they serve as the primary source of energy and light in the cosmos. They are also responsible for creating most of the elements in the universe through nucleosynthesis. When stars reach the end of their lives, they can explode in supernovae, dispersing these elements into space, which may later form new stars, planets, and other celestial bodies.
- The movement of the bright spots could represent **planets**, **satellites**, or **other celestial objects**, which might move relative to the background of fixed stars.

(b) Why there are outstanding bright objects that the TV presenter mentioned, and their significance in the universe:

The **outstanding bright object** that the TV presenter mentioned is likely referring to the **Sun**, the star that is the most prominent object in the sky during the day.

- **The Sun's significance**: The Sun is the central star in our solar system, and it provides the necessary light and energy for life on Earth. It is a massive ball of hydrogen and helium gas undergoing nuclear fusion in its core, releasing enormous amounts of energy.
- During the day, the Sun is visible as a bright object in the sky because it is closer to the Earth compared to other stars, and its light overwhelms the light from other stars due to its much higher intensity.

(c) Why there existed:

(i) Different levels of brightness of the bright spots:

The **different levels of brightness** of the bright spots in the sky can be attributed to several factors:

- **Distance**: Objects that are closer to Earth (such as the Sun or planets in our solar system) appear brighter than those that are far away (such as distant stars). The farther an object is, the dimmer it appears.
- **Size**: Larger stars or objects with greater surface area tend to appear brighter than smaller ones. Some stars are inherently much more massive and emit more light.
- **Intrinsic luminosity**: Some stars are much more luminous (i.e., they emit more light and energy) than others. This can cause a star to appear brighter even if it is distant, compared to a less luminous star at the same distance.
- **Atmospheric conditions**: The Earth's atmosphere can also affect how bright objects appear. For example, atmospheric turbulence (such as air movement or temperature differences) causes the twinkling effect (called **stellar scintillation**), which can make stars appear to vary in brightness.

(ii) Differences in colour of the bright spots:

The **different colors** of the bright spots are related to the temperature and composition of the stars:

- **Hotter stars** emit more blue or white light, while cooler stars emit red or orange light. This is due to **blackbody radiation**, where the color of a star is related to its surface temperature. Hotter stars (with surface temperatures above 10,000 K) emit blue or white light, while cooler stars (with surface temperatures around 3,000 K) emit red or orange light.
- **Star types**:
    - **Blue stars** are usually hotter, with temperatures greater than 10,000 K.
    - **Yellow stars** (like our Sun) are of medium temperature (around 5,500 K).
    - **Red stars** are cooler, with temperatures below 3,500 K.
- **Interstellar dust**: In addition to the temperature of stars, the color can also be influenced by the **interstellar medium**. Dust and gas between Earth and the star can scatter light, especially at shorter (blue) wavelengths, causing distant stars to appear redder (a phenomenon known as **reddening**).

ITEM 6

In some southern part of South Africa, people were ordered to vacate their areas and relocate to other parts of the country in anticipation of the heavy rains in the coming months, that are likely to cause flooding and landslides. The Local authorities have been requested by the Ministry of Disaster Preparedness to sensitize the people about the issues. However, they are finding difficulties in explaining to the people:-

- Why rains will be experienced in their area while other parts of the continent are experiencing dry season.
- How it is possible to predict accurately weather patterns before they occur.
- Why there are two seasons threatening them with high rainfall in a period of just a year.

Task

As a student of physics, help the Local authorities to understand:-

(a) The variations in seasons as realized by the locals at the same time of the year.

(b) How the weather is always accurately predicted before it happens.

(c) Why the community is experiencing that challenge twice in the same year.

(a) The Variations in Seasons as Realized by the Locals at the Same Time of the Year

The variations in seasons across the world, particularly in different regions of a continent like Africa, are primarily caused by the Earth's axial tilt and its orbit around the Sun. The Earth's axis is tilted at an angle of approximately 23.5°, which means that different parts of the Earth receive varying amounts of sunlight throughout the year. These variations result in the different seasons: summer, autumn, winter, and spring.

- **In the Southern Hemisphere**: The southern part of South Africa, where the locals are located, is experiencing summer during the period when other parts of Africa (mainly the Northern Hemisphere) are in winter. This is because as the Earth orbits the Sun, the Southern Hemisphere is tilted toward the Sun, making it warmer and leading to the rainy season in southern regions, especially in coastal areas and mountainous regions.
- **Local Weather Patterns**: Local variations in weather can occur due to factors like proximity to the ocean, altitude, and the movement of weather systems like low-pressure zones. Even when large areas of the continent experience dry conditions, localized factors such as ocean currents, mountain ranges, and wind patterns can cause southern areas to experience rain.

(b) How the Weather Is Always Accurately Predicted Before It Happens

Weather prediction is based on sophisticated technologies and scientific models that analyze a wide variety of factors:

- **Satellite Data**: Satellites provide real-time data on cloud formations, sea temperatures, and atmospheric pressure systems. This data helps meteorologists monitor weather patterns in different regions of the world.
- **Weather Stations**: Ground-based weather stations measure temperature, humidity, wind speed, and atmospheric pressure. This data is crucial for understanding and predicting short-term weather changes.
- **Numerical Weather Prediction Models**: Meteorologists use complex mathematical models to predict weather patterns. These models are based on the principles of fluid dynamics, thermodynamics, and atmospheric science. They take into account current weather conditions and predict how they will evolve over time, using high-performance computers to run simulations.
- **Historical Data**: Historical patterns and trends also help meteorologists predict weather. By studying past weather patterns in a region, meteorologists can identify cyclical or recurring patterns (such as the likelihood of rain in certain months).

Though it is impossible to predict the weather with 100% accuracy, advances in meteorology and the use of modern technology allow for relatively accurate weather predictions, especially in the short term (days to weeks ahead).

(c) Why the Community Is Experiencing That Challenge Twice in the Same Year

The reason the community is experiencing high rainfall twice in a single year, even though they are facing floods in one season, is likely related to the **cyclical weather patterns** that occur in the region, particularly **the El Niño and La Niña phenomena**, and the interaction between tropical weather systems.

- **Tropical Rainfall Patterns**: In southern Africa, the rainy season typically spans from October to April, with the peak occurring in the summer months (December to February). However, some years may experience unusually heavy rainfall during certain months due to weather systems like **tropical cyclones** or **low-pressure systems**. These systems can bring more intense rainfall to areas that typically have a dry season.
- **El Niño and La Niña**: These are phenomena that are linked to changes in sea surface temperatures in the Pacific Ocean. They influence weather patterns across the world, including in southern Africa.
    - **El Niño** (warmer than average sea surface temperatures) often leads to droughts and reduced rainfall in many parts of southern Africa.
    - **La Niña** (cooler than average sea surface temperatures) tends to increase rainfall in the region, potentially leading to heavy rains and flooding.
- **Shifts in Seasonal Weather**: Changes in atmospheric pressure systems, such as the movement of the Intertropical Convergence Zone (ITCZ), can lead to prolonged rainy periods in certain years. Normally, the region experiences its rains during the summer months, but shifts in atmospheric circulation patterns can bring a second season of high rainfall, resulting in two periods of heavy rainfall within the same year.

In conclusion, the local authorities should explain to the community that the rainy season in southern Africa is influenced by a variety of complex global and regional factors, such as Earth's tilt, seasonal patterns, atmospheric systems, and cyclical phenomena like El Niño and La Niña. While the weather can be predicted with reasonable accuracy, it’s the complex interaction of these factors that sometimes causes unusual or extreme weather events, such as two rainy seasons in one year.

ITEM 7

In recent times Uganda joined a number of countries that have launched an artificial satellite. When the satellite is in orbit, the sun is the major source energy needed for operation of devices on the satellite. Some Ugandans

think that the government is wasting res ources in such activities and are planning to make a protest. You have been invited to make a presentation that can answer these Ugandans.

Task:

In your presentation:

(a) Explain

(i) Why it is important for a country to have that type of technology.

(ii) Why that object is called "artificial".

(b) (i) Inform them about other bodies that are kept in this type of motion.

(ii) Explain why such bodies have this kind of motion.

(b) (i) Explain how the major source of energy produces energy.

(ii) Explain the other roles of the major source of energy, on earth.

SOLUTION

Presentation: The Importance of Artificial Satellites and the Role of the Sun's Energy

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(a) Why It Is Important for a Country to Have That Type of Technology

1. **(i) Why It Is Important for a Country to Have Satellite Technology**

   Artificial satellites have a wide range of benefits for a country, and here are some of the key reasons why Uganda, like many other nations, would invest in satellite technology:

   - **Improved Communication**: Satellites enable **global communication**, allowing for instant exchange of information, which is crucial for businesses, governments, and individuals. They provide television broadcasts, internet services, and telephone connectivity, even in remote areas where terrestrial networks are not available.

- **Weather Forecasting and Disaster Management**: Satellites play a crucial role in monitoring **weather patterns**, helping countries predict weather, climate changes, and natural disasters (such as floods or droughts). This allows for **early warnings** and better disaster management, saving lives and reducing economic damage.
- **Earth Observation**: Satellites provide valuable data for monitoring **agriculture**, **forests**, and **land use**. In Uganda, for example, satellites can be used to track deforestation, monitor crop health, and manage natural resources more efficiently.
- **National Security**: Satellites help monitor borders, assist in defense communication, and provide surveillance for national security. They can also be used for **geospatial intelligence** and tracking military movements.
- **Scientific Research**: Satellites help expand a country's capability in **space exploration** and contribute to global scientific knowledge, including **astronomy**, **climate science**, and **physics**.

In short, having satellite technology allows a country to improve its **infrastructure**, **economic growth**, and **international standing**.

2. **(ii) Why the Object Is Called "Artificial"**

The term **"artificial"** is used because the satellite is **human-made**. Unlike natural celestial bodies like the **Moon** or **planets**, which were formed through natural processes, artificial satellites are built and launched by humans for specific purposes, such as communication, weather monitoring, or scientific research. These satellites do not occur naturally in space; they are **designed, constructed**, and then sent into orbit.

(b) Bodies Kept in Motion by Artificial Satellites

1. **(i) Inform Them About Other Bodies Kept in This Type of Motion**

Several other objects besides satellites are kept in orbital motion around Earth or other celestial bodies:

- **The Moon**: Earth's natural satellite, which is kept in motion by the **gravitational attraction** between the Earth and the Moon.
- **Space Probes**: These are spacecraft sent to explore other planets, moons, and asteroids. Examples include the **Mars rovers** or the **Voyager probes**.
- **Space Stations**: The **International Space Station (ISS)**, which orbits Earth and serves as a habitat for astronauts conducting scientific experiments in space.
- **Debris**: There are numerous pieces of **space debris**, such as defunct satellites, rocket stages, and other objects left in orbit around Earth.

2. **(ii) Why Such Bodies Have This Kind of Motion**

The motion of objects like satellites, the Moon, and space stations in orbit is primarily governed by **gravity** and **inertia**:

- **Gravitational Force**: The Earth's **gravity** pulls objects towards it. Satellites and other objects in orbit are constantly being pulled toward Earth. However, they are also moving forward at high speeds (due to their initial launch), which causes them to **fall around the Earth** rather than directly toward it. This continuous forward motion combined with gravity results in **orbital motion**.
- **Inertia**: An object in motion will continue to move in a straight line unless acted upon by a force. The **inertia** of a satellite keeps it moving forward, while gravity pulls it towards Earth,

creating a stable orbit. This balance between the **centripetal force** (gravity) and **centrifugal force** (inertia) keeps the object in a steady orbit.

(c) The Sun as the Major Source of Energy

1. **(i) How the Major Source of Energy Produces Energy**

   The Sun is the primary source of energy for the Earth. Here's how it produces energy:

   - **Nuclear Fusion**: The Sun produces energy through a process called **nuclear fusion** that occurs in its core. During fusion, **hydrogen atoms** are fused together under extreme pressure and temperature to form **helium atoms**, releasing a tremendous amount of energy in the form of light and heat.
   - The energy produced by fusion radiates outward from the Sun and travels through space. A small fraction of this energy reaches Earth, providing the heat and light that sustain life on our planet.
   - The Sun's core temperature is around **15 million degrees Celsius**, and the energy produced in the form of light and heat takes about **8 minutes** to travel from the Sun to the Earth.

2. **(ii) The Other Roles of the Major Source of Energy on Earth**

   The Sun plays several crucial roles in sustaining life on Earth and maintaining the conditions necessary for life:

   - **Climate Regulation**: The Sun's energy drives the **Earth's climate system** by heating the Earth's surface and atmosphere. This heat affects **weather patterns**, ocean currents, and atmospheric circulation, contributing to the planet's overall climate.
   - **Photosynthesis**: Sunlight is essential for **photosynthesis**, the process by which **plants** convert light energy into chemical energy, producing food and oxygen. This is the foundation of the food chain and is crucial for the survival of all living organisms.
   - **Solar Power**: Humans have harnessed the Sun's energy through technologies like **solar panels**. These devices convert sunlight directly into electricity, providing a renewable and clean source of energy.
   - **Water Cycle**: The Sun's heat causes **evaporation** of water from oceans, lakes, and rivers, which forms clouds. The Sun's energy drives the **water cycle**, leading to precipitation that sustains life and replenishes water resources.
   - **Day and Night Cycle**: The Sun's position relative to Earth creates the **day-night cycle**. The Earth's rotation allows sunlight to illuminate different parts of the Earth at different times, enabling the rhythms of life.

Conclusion

In conclusion, launching and operating an **artificial satellite** brings numerous benefits to Uganda, including improved communication, weather forecasting, and scientific research. The Sun, as the major source of energy, powers satellites and plays vital roles in maintaining life on Earth, from regulating climate to supporting photosynthesis. Understanding these principles shows that investing in space technology is not a waste of resources but a step toward progress, scientific advancement, and economic growth.

Thank you for your attention, and I encourage you to embrace this exciting journey into space and its potential benefits for our country.

This presentation should help answer the concerns of the Ugandans and demonstrate the value of space exploration and satellite technology.

ITEM 8

An elder in a certain village was narrating to his family members his experience of a visit to London. He said that in London, day time was longer than night time with 16 hours of day and 8 hours of night, this was unique to family. He also added that stars were rare organisms that died at day time and resurrected at night. Furthermore, he stated that the shape of the moon kept changing over a month's cycle.

The family members, in comparison, said that some of the elder's experiences were equally observed in their village but unfortunately did not understand these occurrences.

Task

As a student of physics, help the elder and his family to understand;

a) How the unique observation in London came about.

b) The observation of stars at day time and night time.

c) Why the shape of the moon keeps on changing over that period.

SOLUTION

a) How the Unique Observation in London Came About

The elder observed that in London, the day was **longer** than the night, with 16 hours of daylight and 8 hours of night. This phenomenon is a result of **Earth's tilt and its position relative to the Sun** during different times of the year. Here's an explanation:

1. **Earth's Axial Tilt**:
    - The Earth is tilted on its axis by about **23.5 degrees**. As Earth orbits the Sun over the course of a year, different parts of the Earth are tilted towards or away from the Sun, leading to the **seasonal variation** in the length of day and night.
2. **Northern Hemisphere Summer**:
    - Since **London** is in the **Northern Hemisphere**, the elder's visit likely occurred during the **summer months** (around **June to September**). During this time, the Northern Hemisphere is tilted **towards** the Sun, causing the days to be **longer** than the nights.
    - At the **summer solstice** (around **June 21st**), the Northern Hemisphere experiences the longest day of the year, with daylight lasting up to **16–18 hours** in places like London, while night time is shorter.
3. **Daylight Length Variation**:
    - The **further north** you go from the Equator, the **longer** the days during summer and the **shorter** they are during winter. In London, this phenomenon results in longer days during the summer months, with **more daylight** and **shorter nights**.

b) The Observation of Stars at Daytime and Nighttime

The elder mentioned that stars "die" during the day and "resurrect" at night. This is actually a **misunderstanding** of how stars are observed and how they appear to us based on the Earth's rotation:

1. **Stars During the Day**:
    - Stars are always present in the sky, even during the **daytime**. However, we cannot see them because of the **brightness of the Sun**. The Sun's light scatters in the atmosphere, making the sky bright and washing out the faint light from the stars.
2. **Stars at Night**:

    - At night, the **Earth rotates** such that the side of the Earth facing away from the Sun is no longer illuminated by sunlight. This allows us to see the stars because there is no longer enough sunlight scattered in the atmosphere to block their light.
3. **Why We Can't See Stars During Daytime**:
    - During the day, although stars remain in the sky, their light is overwhelmed by the Sun's much stronger light. When the Earth rotates and we move into the night side, the absence of sunlight allows the stars to be visible.

In summary, **stars don't die or resurrect**. They are always there, but we can only see them during **nighttime** when the Sun's brightness is not dominating the sky.

c) Why the Shape of the Moon Keeps Changing Over the Month

The elder also observed that the shape of the Moon kept changing over the course of a month. This is because of the **phases of the Moon**, which occur as the Moon orbits around the Earth. Here's an explanation:

1. **Moon's Orbit Around Earth**:
    - The Moon takes about **29.5 days** to complete one full orbit around the Earth. As it orbits, the amount of sunlight it reflects changes, which causes the Moon to appear to change shape from our perspective on Earth.
2. **Phases of the Moon**:
    - The phases of the Moon are caused by the relative positions of the Earth, Moon, and Sun. There are **eight main phases** of the Moon that repeat in a cycle over the course of about a month:
        - **New Moon**: The Moon is between the Earth and Sun, and we can't see the illuminated side.
        - **Waxing Crescent**: A small sliver of the Moon starts to become visible.
        - **First Quarter**: Half of the Moon is illuminated.
        - **Waxing Gibbous**: More than half of the Moon is illuminated.
        - **Full Moon**: The entire illuminated side of the Moon is visible.
        - **Waning Gibbous**: The illuminated portion starts to shrink.
        - **Last Quarter**: Half of the Moon is illuminated again but in the opposite direction.
        - **Waning Crescent**: Only a small sliver remains visible before the cycle starts over.
3. **Why the Moon Changes Shape**:
    - The Moon's appearance changes because the angle at which sunlight strikes it changes as the Moon moves around the Earth. As the Moon completes its orbit, different portions of the Moon are illuminated by the Sun, and we see these changes as phases.

In short, the **changing shape of the Moon** is due to its **orbit around Earth**, which causes varying amounts of the Moon's surface to be illuminated by the Sun, creating the different phases.

Summary

- The unique observation of **longer daytime and shorter nighttime** in London occurs because of **Earth's axial tilt** during the **Northern Hemisphere summer**, leading to longer daylight hours.
- **Stars** are always present in the sky but are only visible at **night** because the brightness of the **Sun** during the day prevents us from seeing them.
- The **changing shape of the Moon** over a month is due to its **orbit around Earth**, which causes different portions of the Moon to be illuminated by the Sun, resulting in the **phases of the Moon**.

These explanations should help the elder and his family understand these natural phenomena based on the principles of physics.

ITEM 9

In a certain country, a Television (TV) reporter was reporting live near the ocean about the high tides during night time. Viewers in another country were watching the live broadcast of the news bulletin during day time. The viewers wondered how it could be day and night at the same time, and how the event in one country could be watched live on TV in another country.

Task

Using your knowledge of physics, help the viewers to understand;

(a) The possibility of it being day in one place and night in another place.

(b) The occurrence of High Ocean tides.

(c) How an event in one place can be broadcast live in another country.

SOLUTION

(a) The Possibility of It Being Day in One Place and Night in Another Place

This phenomenon is due to the **rotation of the Earth** on its axis. Here's an explanation:

1. **Earth's Rotation**:
   - The Earth rotates on its axis approximately once every **24 hours**. This rotation causes different parts of the Earth to face the Sun at different times, resulting in **daytime** in one region and **nighttime** in another region. As the Earth rotates, one half of the planet is exposed to the Sun (experiencing daylight), while the other half is in the shadow (experiencing nighttime).
2. **Time Zones**:
   - The Earth is divided into **24 time zones**, each corresponding to roughly one hour of the Earth's rotation. This division means that when it is daytime in one country (for example, **daytime in Uganda**), it can be nighttime in another country (for example, **nighttime in Japan**). This happens because different parts of the Earth are facing either the Sun or the shadow at any given moment.

In short, the **day-night cycle** is a result of the Earth rotating on its axis, causing different locations to experience daytime and nighttime at different times.

(b) The Occurrence of High Ocean Tides

Ocean tides are caused by the gravitational interactions between the **Earth**, **Moon**, and **Sun**. Here's how high tides occur:

1. **Gravitational Pull of the Moon**:
   - The **Moon's gravity** pulls on the Earth's oceans, causing the water to bulge out slightly on the side of the Earth closest to the Moon. This bulge is what we call a **high tide**. At the same time, the opposite side of the Earth also experiences a high tide due to the centrifugal force caused by the Earth-Moon system's rotation.
2. **Gravitational Pull of the Sun**:
   - The **Sun** also exerts a gravitational pull on the Earth's oceans, but it is less powerful than the Moon's pull because the Sun is much farther away. However, when the Sun, Moon, and Earth align (during **new moons** or **full moons**), the combined gravitational forces of the Sun and Moon create **extra-high tides**, known as **spring tides**.

3. **Tidal Cycles**:
    - Tides occur in a regular pattern: most coastal areas experience **two high tides** and **two low tides** every 24 hours and 50 minutes. This is due to the Earth's rotation relative to the Moon's position. High tides are typically about **12 hours apart**.

In summary, **high ocean tides** occur because of the **gravitational pull of the Moon** (and to a lesser extent the Sun) on Earth's oceans, causing bulges of water that result in high tides at different locations.

(c) How an Event in One Place Can Be Broadcast Live in Another Country

Broadcasting live events across long distances is made possible through the use of **satellites** and **communication technology**. Here's how it works:

1. **Use of Communication Satellites**:
    - Satellites orbiting the Earth can receive signals from ground-based stations and transmit them back to Earth, allowing for long-distance communication. A **television broadcast** can be sent from the location of the event (like the TV reporter near the ocean) to a satellite in space, which then relays the signal to receiving stations in another country.
2. **Global Transmission**:
    - Once the satellite receives the signal, it transmits it to ground stations located in different countries. These ground stations are connected to television networks, which then distribute the signal to viewers. This allows **live television broadcasts** to be seen almost instantaneously in other parts of the world.
3. **Cable and Internet Networks**:
    - Apart from satellites, cable networks and the **internet** also play a crucial role in transmitting live video feeds. TV signals can be routed through a network of cables or fiber optics, and the internet allows for live streaming, enabling viewers to watch the event on their devices, even if they are in different countries.

Thus, **live broadcasting** is made possible through advanced communication technologies like **satellites**, **fiber optics**, and **the internet**, which transmit signals in real-time across the globe.

ITEM 10

One of the most important components of our solar system is the sun. Another important component of our solar systems are the big masses called planets.

(a) Name all the planets found in our solar system.

(b) (i) Identify the planet that sustains life in our solar system.

(ii) How are the times and seasons of the year explained on the planet mentioned in (i) Above?

(c) Explain the statement "the sun has a life cycle".

SOLUTION

(a) All the Planets Found in Our Solar System

The eight planets in our solar system, listed in order of their distance from the Sun, are:

1. **Mercury**

2. **Venus**
3. **Earth**
4. **Mars**
5. **Jupiter**
6. **Saturn**
7. **Uranus**
8. **Neptune**

These planets orbit the Sun due to its gravitational pull.

(b) (i) The Planet that Sustains Life in Our Solar System

The only planet in our solar system that sustains life is **Earth**. Earth has the right conditions—such as the presence of liquid water, a breathable atmosphere, and a stable climate—that allow life to thrive.

(b) (ii) How Times and Seasons of the Year Are Explained on Earth

1. **Times of the Day (Day and Night)**:
    - The **rotation** of Earth on its axis causes the cycle of **day and night**. Earth rotates once every 24 hours, so one side of the Earth faces the Sun (experiencing daylight), while the other side faces away from the Sun (experiencing nighttime).
    - This rotation explains why different places on Earth experience day and night at different times.
2. **Seasons of the Year**:
    - The **tilt** of Earth's axis (about 23.5°) relative to its orbit around the Sun is what causes the different seasons. Earth orbits the Sun once every **365.25 days**, and as Earth moves around the Sun, the tilt of its axis means that different parts of the planet receive varying amounts of sunlight throughout the year.
    - In **summer**, the hemisphere tilted towards the Sun receives more direct sunlight and experiences longer days. In **winter**, the hemisphere tilted away from the Sun receives less direct sunlight, leading to shorter days and cooler temperatures.
    - **Spring** and **autumn** are the transitional periods when both hemispheres receive roughly equal amounts of sunlight, resulting in more moderate temperatures.

Thus, Earth's tilt and orbit around the Sun create the cycle of day and night, as well as the changing seasons over the course of the year.

(c) The Statement "The Sun Has a Life Cycle"

The Sun, like all stars, goes through a **life cycle**, which can be broken down into several stages:

1. **Formation**:
    - The Sun began as a cloud of gas and dust in space, known as a **nebula**. Over millions of years, gravity caused the gas and dust to collapse and form a dense core. As the core heated up, nuclear fusion began, and the Sun started to shine.
2. **Main Sequence**:
    - For about **90% of its life**, the Sun has been in the **main sequence phase**, where it fuses hydrogen into helium in its core. This is the stable phase of the Sun's life, during which it continuously emits energy in the form of light and heat. The Sun has been in this phase for approximately **4.6 billion years** and is expected to remain in this phase for about **5 billion more years**.
3. **Red Giant Phase**:

- Once the Sun's hydrogen fuel in its core is used up, it will enter the **red giant phase**. The core will contract while the outer layers expand, causing the Sun to become much larger and cooler. This phase will last for a few hundred million years. The Sun will begin to fuse heavier elements like helium into carbon and oxygen.

4. **Planetary Nebula and White Dwarf**:
   - After the red giant phase, the Sun will shed its outer layers, creating a cloud of gas and dust known as a **planetary nebula**. The remaining core will become a **white dwarf**—a dense, Earth-sized remnant that no longer undergoes fusion but slowly cools over billions of years.
5. **End of Life**:
   - After billions of years, the white dwarf will continue to cool and fade, and eventually, it will no longer emit light or heat.

Thus, the Sun has a life cycle that includes its birth, main sequence phase, red giant expansion, and eventual transformation into a white dwarf. This process takes billions of years.

ITEM 11

On November 7th 2022, Uganda launched its first satellite named PearlAfricaSat-I into space with the help of National Aeronautics and Space Administration (NASA). The purpose of the mission was to study weather patterns. Students of physics were availed with data collected over a certain of time and they noticed the following while some places were having day time. Other places were having night time. Various places were having different seasons.

Task:

As a learner of physics

(a) Explain why some places had daytime while it was night time at other places.

(b) Explain why different places had weather patterns and how world- wide communication is made possible through satellites.

SOLUTION

(a) Why Some Places Had Daytime While It Was Nighttime at Other Places

This phenomenon is due to the **rotation of the Earth** around its axis. The Earth is constantly rotating, and this rotation creates a cycle of day and night. Here's a breakdown of the process:

1. **Earth's Rotation**:
   - The Earth rotates on its axis once every **24 hours**, which causes different parts of the Earth to face the Sun at different times. As the Earth rotates, one half of the planet is exposed to sunlight (daytime), while the other half is in the shadow (nighttime).
2. **Day and Night Cycle**:
   - When a location on Earth is facing the Sun, it experiences **daytime**. As the Earth continues to rotate, the location moves out of the Sun's direct light and enters the shadow of the Earth, resulting in **nighttime**.
3. **Time Zones**:
   - Since the Earth is divided into **24 time zones**, each zone experiences daytime and nighttime at different times. This is why, for example, when it's daytime in Uganda, it might be nighttime in other parts of the world, such as in countries on the opposite side of the Earth.

In short, the changing positions of places on Earth relative to the Sun as the Earth rotates are responsible for the day-night cycle experienced around the world.

(b) Why Different Places Have Different Weather Patterns and How Worldwide Communication is Made Possible Through Satellites

1. Why Different Places Have Different Weather Patterns

Weather patterns vary across the globe due to several factors:

1. **Earth's Tilt and Orbit**:
    - The Earth is tilted at an angle of about **23.5°** relative to its orbit around the Sun. This tilt causes the **seasons**, which lead to variations in temperature, sunlight, and weather patterns. For example, when the Northern Hemisphere is tilted toward the Sun (around June), it experiences summer, while the Southern Hemisphere experiences winter, and vice versa around December.
2. **Latitude**:
    - The **latitude** (distance from the equator) plays a significant role in determining the climate of a region. Near the **equator**, the Sun's rays are more direct, leading to **hotter** and more consistent temperatures. At higher latitudes (closer to the poles), the Sun's rays are spread out over a larger area, resulting in **colder** temperatures.
3. **Air and Ocean Currents**:
    - Winds and ocean currents help to distribute heat and moisture around the planet. For example, warm ocean currents can bring higher temperatures and humidity to nearby coastal regions, influencing local weather patterns.
4. **Topography**:
    - The presence of **mountains** or other landforms can affect weather patterns by blocking or redirecting winds, causing **rain shadows** (areas on the leeward side of mountains that receive less rainfall) or influencing precipitation.

Thus, different geographical locations have varying amounts of sunlight, temperature, humidity, and precipitation, which results in different **weather patterns**.

2. How Worldwide Communication is Made Possible Through Satellites

Satellites play a crucial role in modern global communication. Here's how they make communication possible worldwide:

1. **Communication Satellites**:
    - Satellites in **geostationary orbits** (about 35,786 kilometers above Earth) are positioned to stay fixed relative to a specific point on the Earth's surface. These satellites can relay signals between Earth-based stations, allowing for **television broadcasts, phone calls, internet connections**, and **radio transmissions** across vast distances.
2. **Weather Satellites**:
    - Satellites like Uganda's **PearlAfricaSat-I**, which are equipped with specialized sensors, collect data on weather patterns and atmospheric conditions. This data can be sent back to Earth and used for weather forecasting, helping countries to better understand and predict weather changes.
3. **Global Positioning System (GPS)**:
    - GPS satellites orbit Earth and provide location data for navigation systems. These satellites enable precise location tracking for everything from smartphones to airplanes and ships, contributing to global communication and navigation.
4. **Data Transmission**:

- Satellites can transmit data over large distances, bypassing the need for long cables or physical infrastructure. This is essential for regions where it may be difficult or expensive to lay down wires (such as in remote or oceanic areas). Satellite communication connects countries, allowing people to communicate globally, share information, and even access the internet anywhere on Earth.

ITEM 12

In the space section of a certain newspaper, various articles were published, including statements about changes in the motion of the earth, moon and sun over time, the challenges facing the solar system and ongoing exploration for habitable places in the universe. However, the locals found it difficult to grasp the significance of these news items.

Utilizing your knowledge of physics, clarify the following points for them:

a) The changes in the motion of the earth, moon and the sun.(5scores)

b) The characteristics of the solar system(5 scores)

c) Why earth remains the only known habitat for humans.(5 scores)

SOLUTION

Clarifying Space Concepts Using Physics

In the space section of the newspaper, various complex topics about the motion of celestial bodies, characteristics of the solar system, and the uniqueness of Earth as a habitat for humans are discussed. Let's break down these ideas in simpler terms using basic physics principles to help the locals understand.

a) The Changes in the Motion of the Earth, Moon, and Sun

The motion of the Earth, Moon, and Sun has been studied for centuries, and physics explains how these motions change over time due to gravitational interactions and other forces.

1. **Earth's Motion**:
   - **Rotation**: The Earth rotates around its own axis, causing day and night. The rotation is slowing down gradually over time due to tidal friction, which is caused by the Moon's gravitational pull. This process is very slow, with Earth's day increasing by about **1.7 milliseconds per century**.
   - **Revolution**: The Earth revolves around the Sun in an elliptical orbit, taking about **365.25 days** to complete one full revolution. The Earth's orbit is slightly changing due to gravitational influences from other planets, but the effect is very small.
2. **Moon's Motion**:
   - The **Moon** orbits the Earth in an elliptical orbit, taking about **27.3 days** to complete one revolution. Over time, the Moon is moving away from the Earth at an average rate of about **3.8 cm per year**. This is a result of tidal interactions between the Earth and the Moon.
   - The **Moon's rotation** is synchronized with its orbit around the Earth, meaning that it always shows the same face to Earth, a phenomenon known as **tidal locking**.
3. **Sun's Motion**:
   - The **Sun** does not stay in one place. It is part of the **Milky Way Galaxy**, and as the galaxy rotates, the Sun also moves through space. The Sun, along with the solar system, orbits the center

of the Milky Way at a speed of about **828,000 km/h**, taking approximately **230 million years** to complete one full orbit.

The changes in the motion of these celestial bodies, while happening over long periods, influence everything from our calendars and the seasons to the length of days on Earth.

b) The Characteristics of the Solar System

The **solar system** consists of the Sun, planets, moons, and other smaller objects. These components interact through gravity, and they have unique characteristics that make our solar system an interesting place for exploration.

1. **The Sun**: The Sun is a star at the center of our solar system. It is the primary source of light and energy. The Sun's gravitational pull keeps the planets and other objects in orbit around it.
2. **The Planets**: There are eight recognized planets in the solar system, and they are divided into:
    - **Terrestrial planets** (Mercury, Venus, Earth, Mars): These are rocky planets with solid surfaces.
    - **Gas giants** (Jupiter, Saturn): These planets are made mostly of gases like hydrogen and helium and have no solid surface.
    - **Ice giants** (Uranus, Neptune): These are similar to gas giants but contain more ice (water, ammonia, and methane).
3. **Moons**: Many planets have natural satellites (moons). For example, Earth has one Moon, while Jupiter has over 70 known moons.
4. **Asteroids and Comets**: The solar system contains many small bodies like **asteroids** (rocky objects mostly found in the asteroid belt between Mars and Jupiter) and **comets** (icy bodies that have highly elliptical orbits).
5. **Kuiper Belt and Oort Cloud**: These are regions of space beyond Neptune that contain many small icy bodies and dwarf planets like Pluto. The Kuiper Belt is closer, while the Oort Cloud is much farther and is thought to be the source of long-period comets.

All these objects orbit the Sun due to its immense gravitational pull. The solar system is vast, with the planets and other objects moving in predictable orbits, but also subject to gradual changes over time due to gravitational interactions.

c) Why Earth Remains the Only Known Habitat for Humans

Earth is the only known planet capable of supporting human life due to a combination of physical and environmental factors. Here's why:

1. **Distance from the Sun**:
    - Earth is located in the **habitable zone** (also known as the "Goldilocks zone") of the Sun, where temperatures are just right for liquid water to exist on the surface. This is crucial for life as we know it. If Earth were too close to the Sun, it would be too hot, and if it were farther away, it would be too cold.
2. **Atmosphere**:
    - Earth has a **thick atmosphere** composed mostly of nitrogen and oxygen, which protects us from harmful solar radiation and helps regulate temperature. The atmosphere also contains **carbon dioxide**, which plays a role in maintaining the Earth's temperature through the **greenhouse effect**.
3. **Water**:
    - Earth has abundant liquid **water**, which is essential for all known forms of life. Water helps to regulate the planet's temperature and acts as a solvent for biochemical reactions that sustain life.
4. **Stable Climate**:

- Earth's climate is relatively stable compared to other planets, thanks to the **greenhouse effect** and the moderating effects of the oceans, which help distribute heat around the planet.

5. **Magnetic Field**:
   - Earth has a **magnetic field** generated by its molten iron core. This field protects the planet from harmful solar and cosmic radiation, which could otherwise strip away the atmosphere and make the planet uninhabitable.

In contrast, other planets do not have the right combination of factors that make Earth habitable. For example, Mars has a thin atmosphere and is too cold, Venus is too hot with a thick, toxic atmosphere, and other planets have extreme conditions (either too hot, too cold, or too high pressure) that are unsuitable for human life.

ITEM 13

David flew from Uganda to China for one month study trip. He started the journey during the day at around 09:15am. He reached China for 4hours (at 01:15pm) and found when the Chinese were sleeping because it was at night. He also slept till morning and started touring different areas in China. He found out that in China they were harvesting maize though in Uganda people were planting maize. During his tour, he visited one of the lakes in China for more research. He put a dip stick in the shores of the lake where he left it in at a level of 22m. After 2 days, he checked on the dip stick and found the water level at 15m. During his trip, he also investigated on the life of stars where he managed to study on only small stars. But unfortunately the doctor who was supposed to help in investigation was sick. So he never studied about the small stars and he had to go back to Uganda.

Task

a.) i) As a physics student, help David to know why China was in the Darkness by the time he landed there when Uganda was not? (3mks)

ii) David got disturbed to know why Ugandans were planting Maize when in China they were harvesting. Explain to him what caused that.

iv) .Explain why water levels of the lake changed from 22m to 15m?

b) As a physics student who studied stars and galaxies, help David to know the following;

i) .How small stars are formed ,their life cycle

ii) .Why stars are not seen during the day with naked eyes ,red giants are red and not any other colour

iii) .Why a star expands when it becomes red giant? (15 scores)

SOLUTION

(a) Understanding the Observations during David's Trip

i) Why was China in Darkness when David Landed, but Uganda was Not?

This phenomenon is due to **time zones** and the Earth's **rotation**. The Earth rotates around its axis, dividing the planet into 24 time zones. As the Earth rotates, one half faces the Sun (daytime), and the other half faces away from the Sun (nighttime).

- **Uganda** is located near the equator, and its time zone is UTC+3. At 09:15 AM Uganda time, the Sun would be up and visible in Uganda.
- **China** is located much farther east (UTC+8), meaning that when it is daytime in Uganda, it could already be nighttime in China due to the time difference.

- In the case of David's flight, when it was **09:15 AM in Uganda**, it was already **01:15 PM (next day)** in China, and thus **nighttime in China**, which is why David found the Chinese people sleeping.

This difference occurs because the Earth rotates on its axis, so different parts of the world experience day and night at different times.

ii) Why were Ugandans Planting Maize While the Chinese Were Harvesting?

The reason for this difference lies in the **seasons** and the **Earth's tilt**. The Earth is tilted at an angle of about 23.5° on its axis, which causes the changing seasons.

- **Uganda** is located near the equator, where the climate remains relatively consistent year-round, with two rainy seasons that are ideal for planting crops like maize. In Uganda, planting maize typically happens during the rainy seasons, which are either from March to May or from September to November, depending on the region.
- **China**, on the other hand, is located farther north, where the climate changes significantly with the seasons. Depending on the specific region of China David visited, they may be harvesting maize in the summer or early autumn months (typically around July to September) when the growing season ends and the crops are ready to be harvested.

So, the difference in planting and harvesting times is mainly due to the **difference in seasonal cycles** between the equatorial regions and temperate regions of the world.

iii) Why did the Water Levels in the Lake Change from 22m to 15m?

The change in the water level could be due to a number of natural factors:

1. **Evaporation**: Over time, the water in the lake could have evaporated due to high temperatures or dry conditions, causing a decrease in the water level. This is particularly true if the region experienced hot and dry weather conditions during David's visit.
2. **Water Usage**: The water level could have dropped if water was being withdrawn for purposes like irrigation, industry, or domestic use, which can lower the lake's water level.
3. **Seasonal Changes**: Depending on the time of year, lakes may experience fluctuations in water levels due to seasonal changes in rainfall or the inflow/outflow of water from rivers feeding into the lake.
4. **Geological or Tidal Factors**: In some areas, water levels can fluctuate due to the movement of underground water or tidal changes, especially if the lake is connected to larger bodies of water.

David should consider these natural processes to explain why the lake's water level decreased.

(b) Understanding Stars and Their Properties

i) How are Small Stars Formed and What is Their Life Cycle?

Formation of Small Stars: Small stars, like our Sun or smaller, begin as clouds of gas and dust in space, known as **nebulae**. These clouds contract due to gravitational forces, and as they collapse, they heat up, eventually forming a **protostar**.

- The pressure and temperature at the center of the protostar increase until nuclear fusion begins, where hydrogen is converted into helium, releasing energy. This marks the start of the star's **main sequence phase**.

Life Cycle of Small Stars:

- **Main Sequence**: A small star spends the majority of its life in this stable phase, where it fuses hydrogen into helium in its core. This phase can last billions of years.
- **Red Giant Phase**: When the hydrogen in the core is depleted, the core contracts, and the outer layers expand. The star becomes a **red giant**. During this phase, helium and other heavier elements are fused in the core.
- **Planetary Nebula**: After the red giant phase, small stars shed their outer layers, creating a beautiful cloud of gas and dust known as a **planetary nebula**.
- **White Dwarf**: The core of the star remains as a **white dwarf**, which is a dense remnant of the star. Over time, the white dwarf cools and fades.

ii) Why Are Stars Not Seen During the Day with Naked Eyes? Why Are Red Giants Red?

Stars Not Visible During the Day:

- Stars, including our Sun, emit light across the electromagnetic spectrum. However, during the daytime, the Sun's light is so bright that it **overpowers the light from other stars**, making them invisible to the naked eye. The **scattering of sunlight** in Earth's atmosphere also causes the blue sky, further masking the faint light from distant stars.

Why Red Giants Are Red:

- A **red giant** star appears red because of its **lower temperature** compared to other stars. A red giant has a surface temperature of around 3,000–5,000 K, which emits light predominantly in the **red** and **orange** regions of the spectrum, making it appear red to our eyes.
- In contrast, hotter stars, like blue giants, emit more light in the blue or white regions of the spectrum, making them appear blue or white.

iii) Why Does a Star Expand When it Becomes a Red Giant?

When a star exhausts the hydrogen in its core, the core contracts under gravity while the outer layers expand. This process occurs due to the changes in nuclear fusion inside the star:

- **Core Contraction**: The core of the star contracts as hydrogen is depleted, increasing the temperature and pressure at the center.
- **Outer Expansion**: The increased pressure causes the outer layers to expand and cool. As the core shrinks and heats up, the outer layers are pushed outward, making the star become much larger, reaching sizes up to hundreds of times that of the original star. This results in the star becoming a **red giant**.

This expansion is driven by the balance between gravitational forces pulling inward and the outward pressure created by the energy from nuclear fusion. When the star moves into the red giant phase, it is essentially in the final stages of its life before it sheds its outer layers.

ITEM 14

In a certain country, a Television (TV) reporter was reporting live near the ocean about the high tides during night time. Viewers in another country were watching the live broadcast of the news bulletin during day time.

On the same Television (TV), it was reported that people can reach new places without help from another person when they install Global Positioning System (**GPS)** application on their phones or tablets.

Task

Using your knowledge of physics to help the viewers to understand;

(a) The uses of **GPS** in our daily life. (**4 scores**)

(b) how an event in one place can be broadcast live in another country. (**4 scores**)

(c) the occurrence of high ocean tides. (**4 scores**)

SOLUTION

Understanding the Physics Behind Everyday Phenomena

As viewers of the television news bulletin, you may have encountered some fascinating topics—such as GPS technology, live broadcasts, and ocean tides. Let's break down these concepts and explore how they work using physics principles.

(a) Uses of GPS in Our Daily Life

The **Global Positioning System (GPS)** is an essential tool in our daily lives, providing location information through satellite technology. Here are some key uses of GPS:

1. **Navigation**: GPS allows us to navigate from one place to another using maps and directions on smartphones or car navigation systems. By calculating the time it takes for signals from satellites to reach a GPS receiver, it can pinpoint your location accurately.
2. **Tracking and Location Services**: GPS helps businesses track vehicles, shipments, and even people. For instance, delivery services or ride-hailing apps like Uber rely on GPS to find and track the exact location of vehicles and customers.
3. **Geocaching and Outdoor Activities**: GPS enables outdoor enthusiasts to find specific coordinates when hiking, biking, or engaging in geocaching—a modern-day treasure hunt that uses GPS coordinates to find hidden objects.
4. **Emergency Services**: In case of an emergency, GPS allows rescue teams to quickly locate people who may be in distress. It provides accurate coordinates to guide them to the exact location, saving valuable time.

Physics behind GPS: GPS uses the principles of **triangulation** and **satellite time signals**. The GPS satellites broadcast signals that include their location and the time the signal was sent. By measuring the time it takes for these signals to reach your device, the GPS system can calculate your distance from multiple satellites and determine your exact position on Earth.

(b) How an Event in One Place Can Be Broadcast Live in Another Country

When we watch a **live broadcast** of an event occurring in one country while we are in another, there is a fascinating combination of physics and technology at play. Here's how it works:

1. **Transmission of Signals**: A **television station** captures the live footage using cameras, and this footage is converted into an electronic signal. The signal travels via electromagnetic waves (radio waves, microwaves, or optical signals) to a transmitter, which sends the signal into space or to a satellite.

2. **Satellites**: The signal is received by a communication satellite orbiting the Earth. Satellites act as relay stations, receiving the signal from the transmitter on the ground and then sending it to another satellite or directly to receiving stations on Earth.
3. **Reception and Broadcasting**: The receiving stations on Earth pick up the signal, and it is transmitted via local TV networks to households, allowing people to view the event in real-time, regardless of their location.

Physics behind the broadcast: The key physics principle here is **electromagnetic wave propagation**. Electromagnetic waves can travel through space, allowing information to be transmitted over vast distances. These waves include radio waves, microwaves, and even light waves, which are used in fiber optic cables.

(c) The Occurrence of High Ocean Tides

Ocean tides are the regular rise and fall of sea levels caused by the gravitational forces between the Earth, the Moon, and the Sun. Here's how it works:

1. **Gravitational Pull of the Moon**: The primary cause of ocean tides is the gravitational pull of the **Moon** on the Earth's oceans. As the Moon orbits the Earth, its gravity pulls the water on the side of the Earth closest to it, causing a bulge of water—this is called the **high tide**.
2. **Centrifugal Force**: As the Earth and Moon rotate around their common center of mass (the **barycenter**), there is also a centrifugal force that causes water to bulge on the opposite side of the Earth. This creates a second high tide on the far side of the Earth.
3. **Effect of the Sun**: The **Sun's gravitational pull** also influences tides, though to a lesser extent than the Moon. When the Sun, Moon, and Earth align (during full moon and new moon), the Sun's gravity adds to the Moon's pull, creating **spring tides**—higher than usual high tides and lower than usual low tides.
4. **The Earth's Rotation**: As the Earth rotates, different coastal areas experience high and low tides at different times. In most places, high tides occur twice a day—once when the bulge caused by the Moon's gravity passes over, and again when the opposite bulge passes.

Physics behind tides: The **gravitational interaction** between the Earth, Moon, and Sun causes the ocean waters to deform. The combination of gravitational pull and centrifugal force creates the periodic rise and fall of ocean water levels, resulting in high and low tides.

Conclusion

By understanding the physics behind these everyday phenomena—GPS, live broadcasting, and ocean tides—we can gain a deeper appreciation of how interconnected the world is, and how science and technology continue to shape our daily lives. Whether navigating the streets with GPS, watching a live event thousands of miles away, or observing the natural rhythms of the ocean, physics plays a crucial role in making these experiences possible.

ITEM 15

Learners of a certain school were watching a documentary video by NASA who had recently launched the stellar surveyor mission to the ISS to study the solar system, life cycle of stars, as well as energy they evolve. The crew in the mission was equipped with the Hubble telescope and other equipment to collect data. The narrator said, that the mission marked a significant milestone in space exploration, demonstrating the ISS's potential as a platform for advanced space exploration. After the lesson, a leaner was asked to write an article

about the space mission so that it can be published in the school magazine but she couldn't provide enough information.

Task:

As a learner of Physics, help the learner come up with a write up to be published in the school magazine about the explanation of the;

(a) Components of the solar system.

(b) Life cycle of stars

(c) Relevancy of the Hubble Telescope and the ISS in the mission.

SOLUTION

Exploring the Wonders of Space: NASA's Stellar Surveyor Mission to the ISS

In the vastness of space, the mysteries of the solar system and the life cycle of stars have captivated scientists and curious minds alike. Recently, NASA launched the Stellar Surveyor mission to the International Space Station (ISS) to study these cosmic phenomena. Equipped with cutting-edge tools like the Hubble Space Telescope, the crew aboard the mission aims to gather vital data that will help humanity better understand the universe. Let's take a closer look at the mission and some of the key concepts it explores.

(a) Components of the Solar System

Our solar system is a fascinating collection of celestial objects, all bound by the gravity of the Sun. The Sun, a massive ball of burning gas, is at the center, providing light and heat to the planets and other objects around it. The major components of the solar system include:

1. **The Sun**: The heart of our solar system, a giant star that powers everything through nuclear fusion.
2. **The Planets**: There are eight planets, divided into two groups: the inner rocky planets (Mercury, Venus, Earth, and Mars) and the outer gas giants (Jupiter, Saturn, Uranus, and Neptune).
3. **Moons**: Many planets, like Earth, have natural satellites or moons. For example, Earth's Moon and Jupiter's moon, Europa.
4. **Asteroids and Comets**: These smaller objects are remnants from the early solar system. Asteroids are rocky objects, while comets are icy bodies that form spectacular tails when they approach the Sun.
5. **The Kuiper Belt and Oort Cloud**: These regions are home to many small icy objects and dwarf planets, like Pluto.

NASA's Stellar Surveyor mission seeks to gather more information about these components, particularly by studying the planets and the interactions between the Sun and other objects in the system.

(b) Life Cycle of Stars

Stars are born, live, and die in cycles, a process that takes millions or even billions of years. The life cycle of a star begins in a region of space filled with gas and dust, known as a nebula. Here's how the life cycle unfolds:

1. **Stellar Nebula**: Stars are born from the collapse of gas and dust in nebulae, forming protostars.
2. **Main Sequence**: A star enters this stable phase when nuclear fusion begins, turning hydrogen into helium. Our Sun is currently in this phase, and it will remain in it for about 10 billion years.

3. **Red Giant or Supergiant**: As the star exhausts its hydrogen, it expands into a red giant or supergiant, depending on its mass.
4. **Death**: The end of a star's life depends on its mass:
    - **Low-mass stars**: These stars shed their outer layers and become white dwarfs.
    - **High-mass stars**: These stars may explode in a supernova, leaving behind either a neutron star or a black hole.
5. **Remnants**: The remnants of stars, such as white dwarfs, neutron stars, or black holes, continue to evolve and can influence their surrounding space for millions of years.

The Stellar Surveyor mission is particularly focused on understanding the different stages of stellar evolution, especially how stars form and die, which will offer insights into the origins of elements and life.

(c) The Relevancy of the Hubble Space Telescope and the ISS in the Mission

Two essential tools that have significantly contributed to the Stellar Surveyor mission are the **Hubble Space Telescope** and the **International Space Station (ISS)**.

1. **Hubble Space Telescope**: Launched in 1990, the Hubble Space Telescope has been instrumental in revolutionizing our understanding of space. Positioned outside Earth's atmosphere, Hubble can capture incredibly detailed images of distant galaxies, nebulae, and stars without the distortion caused by the atmosphere. For the Stellar Surveyor mission, Hubble provides high-resolution images of stars and planets, helping scientists observe celestial phenomena in far greater detail than ever before.
2. **International Space Station (ISS)**: The ISS serves as a state-of-the-art research laboratory orbiting Earth. Equipped with advanced instruments, the ISS allows astronauts to conduct experiments in a microgravity environment. This makes it an ideal platform for studying how space affects materials, life forms, and even the processes of star formation. By sending experiments and telescopes like Hubble to the ISS, NASA can collect real-time data from space, enabling scientists to explore the solar system and stars without interference from Earth's atmosphere.

Together, the ISS and Hubble telescope form a powerful duo, enabling researchers to push the boundaries of space exploration. The Stellar Surveyor mission marks an important milestone, as it harnesses these technologies to deepen our understanding of space, from the birth of stars to the formation of planets.

Conclusion

NASA's Stellar Surveyor mission offers an exciting opportunity to explore the wonders of space, with a particular focus on the solar system, the life cycle of stars, and the crucial roles that the Hubble Space Telescope and the ISS play in advancing scientific knowledge. Through the mission's findings, we can expect to uncover more about the origins and evolution of our universe, pushing us closer to answering some of the most profound questions in astronomy. The work being done today is shaping the future of space exploration, ensuring that humanity will continue to look beyond the stars with ever-greater understanding.