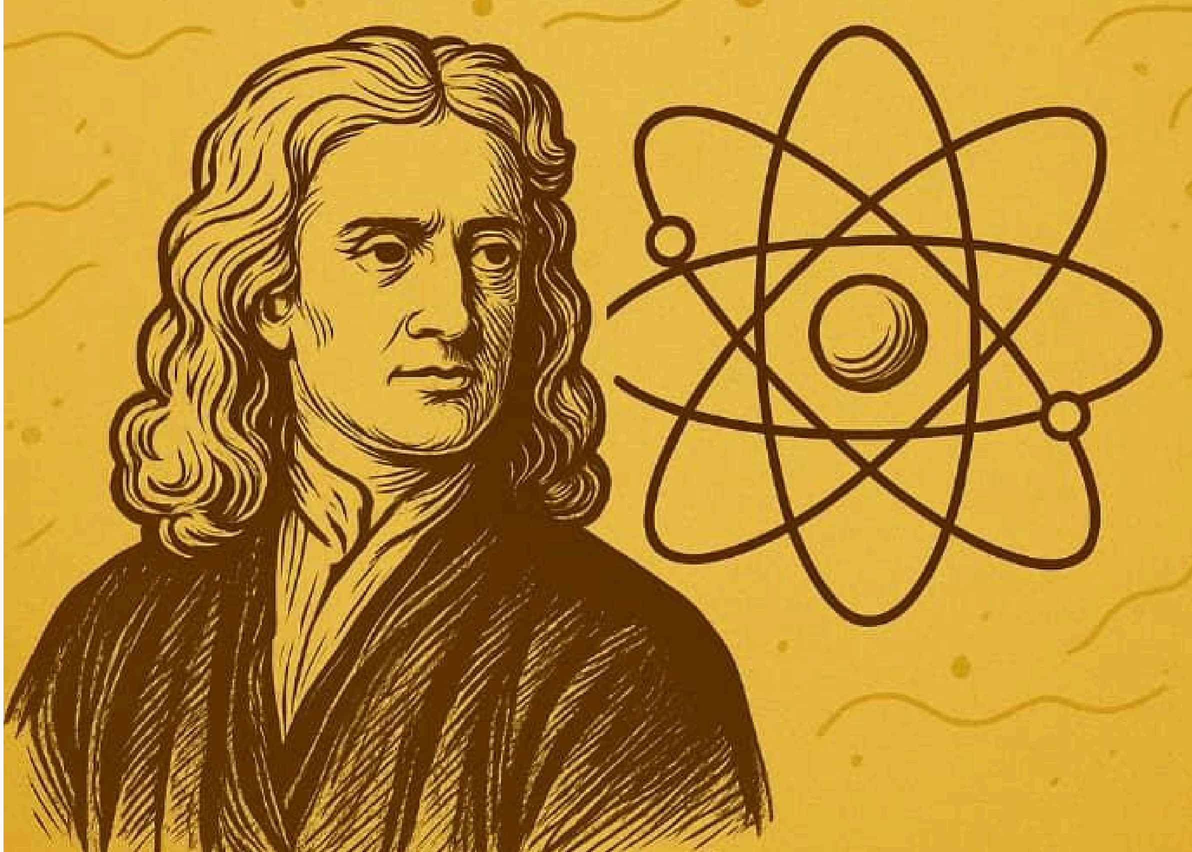
UGANDA ADVANCED CERTIFICATE OF EDUCATION

PHYSICS ITEM BANK



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Subject: Advanced Level Physics (UACE)
Purpose: Learning, practice, and mastery of Physics concepts

Physics Syllabus – NCDC (Senior Five & Six)

Senior Five

Term 1

1. Measurement and Dimensions
2. Statics
3. Linear Motion
4. Motion Under Gravity
5. Work, Energy, and Power
6. Solid Friction

Term 2

7. Fluid Mechanics
8. Mechanical Properties of Matter
9. Thermometry
10. Heat Quantities
11. Transfer of Heat
12. Behaviour of Gases
13. Thermodynamics

Term 3

14. Reflection of Light
15. Refraction of Light
16. Optical Instruments

Senior Six

Term 1

1. Electrostatics
2. Capacitors
3. Digital Electronics
4. Circular Motion
5. Simple Harmonic Motion
6. Gravitation
7. Progressive Waves
8. Stationary Waves
9. Sound Waves

Term 2

10. Current Electricity
11. Magnetism in Matter
12. Magnetic Effect of an Electric Current
13. Electromagnetic Induction
14. A.C. Circuits

Term 3

15. Atomic Particles
16. Quantum Theory
17. Nuclear Processes

Assessment Section

1. Assessing Physics Competence
2. Formative Assessment

3. Generic Skills Development
4. Values and Attitudes
5. Physics Projects
6. Examinations
7. Record Keeping

S5 Term 1
Measurement and dimensions
Item 1
A team of physics students in a school laboratory is tasked with determining the thickness of a thin metallic sheet used in constructing an experimental apparatus. The sheet is too thin to be measured accurately using an ordinary ruler, and the students decide to use a micrometer screw gauge whose zero reading is slightly offset.

(a) Explain why a metre rule is unsuitable for measuring the thickness of the sheet.
(b) Describe how the micrometer screw gauge should be checked for zero error before use.
(c) State how the zero error affects the final reading and explain how it should be corrected.
(d) Discuss two sources of error that may arise when using a micrometer screw gauge and how they can be minimized.

Item 2

During a physics practical lesson, a student measures the length and diameter of a uniform cylindrical wire using a vernier caliper. The values obtained are later used to calculate the volume of the wire.

(a) Define the term least count of a measuring instrument.
(b) Explain why a vernier caliper is preferred to a metre rule for measuring the diameter of the wire.
(c) Derive an expression for the volume of the wire in terms of its measured quantities.
(d) Explain how errors in the measured diameter affect the accuracy of the calculated volume.

Item 3

In an experiment to determine the density of an irregular stone, a student uses a measuring cylinder and a beam balance. The stone is gently lowered into the cylinder containing water, and the change in water level is noted.

(a) State the physical quantity measured by the beam balance.
(b) Explain how the volume of the stone is determined using the measuring cylinder.
(c) Write an expression for the density of the stone in terms of the measured quantities.

(d) Identify two precautions that should be taken to improve the accuracy of the experiment.

Item 4

A student claims that the period of a simple pendulum depends on its mass, length, and gravitational acceleration.

(a) State the principle of dimensional analysis.
(b) Using dimensional analysis, derive an expression for the period of a simple pendulum in terms of its length and gravitational acceleration.
(c) Explain why a dimensionless constant cannot be determined using dimensional analysis.
(d) State one limitation of dimensional analysis in physics.

Item 5

In the calibration of a laboratory thermometer, it is observed that the thermometer does not read zero at the ice point.

(a) Explain what is meant by calibration of an instrument.
(b) Describe how a thermometer can be calibrated using fixed points.
(c) Explain the effect of poor calibration on experimental results.

(d) State two advantages of using SI units in scientific measurements.

Item 6

A physical quantity is expressed as , where is force, is velocity, and is area.

(a) State the SI units of force, velocity, and area.
(b) Determine the SI unit of the quantity .
(c) Use dimensional analysis to verify whether the given expression is dimensionally correct.
(d) Suggest one possible physical interpretation of the quantity .

Item 7

In a school laboratory, students measure time using a digital stopwatch and distance using a metre rule to calculate the speed of a moving trolley.

(a) Define the term systematic error.
(b) Give one example of a systematic error in the experiment.
(c) Explain how random errors differ from systematic errors.
(d) State two methods of reducing errors in time measurements.

Item 8

A student measures the radius of a circular disc using a ruler and uses the value to calculate the area of the disc.

(a) Write an expression for the area of the disc in terms of its radius.
(b) Explain how percentage error in the radius affects the percentage error in the area.
(c) If the radius is measured with a large uncertainty, explain how this affects the reliability of the calculated area.
(d) Suggest a more accurate method of measuring the radius.

Item 9

Two students measure the same physical quantity using different instruments and obtain slightly different values.

(a) Explain why measurements of the same quantity may differ.
(b) Define the term accuracy as used in physics measurements.
(c) Distinguish between accuracy and precision.
(d) Explain why repeated measurements are important in experimental physics.

Item 10

In an experiment involving motion, the displacement of an object is expressed as a function of time.

(a) State the SI unit of displacement.
(b) Explain why time is considered a fundamental quantity.
(c) Using dimensional analysis, determine the dimensions of velocity and acceleration.
(d) Explain how dimensional analysis helps in checking the correctness of physical equations.

Item 11
A laboratory instrument has a very small least count but is used carelessly by a student.

(a) Define the term least count.
(b) Explain why a small least count does not always guarantee accurate results.
(c) State two human factors that can affect measurement accuracy.
(d) Suggest ways of improving accuracy in laboratory measurements.

Item 12
The mass of a body is measured using a spring balance and a beam balance.

(a) State the physical quantity measured by a spring balance.
(b) Explain why a beam balance gives a more accurate measure of mass than a spring balance.
(c) Describe how gravitational variation affects readings from a spring balance.
(d) State one advantage of using a beam balance in precise measurements.

Item 13
A student expresses a physical quantity in non-SI units during an experiment.

(a) State what is meant by SI units.
(b) Give two reasons why SI units are preferred in physics.
(c) Convert a length of 2.5 km into metres.
(d) Explain the importance of unit consistency in physical equations.

Item 14
In an experiment, the value of gravitational acceleration is obtained with a large uncertainty.

(a) Define the term uncertainty in measurement.
(b) Explain how uncertainty affects the final result of an experiment.

(c) State two ways of reducing uncertainty in measurements.
(d) Explain why uncertainty should always be quoted with measured values.

Item 15
A student derives a new physical formula during a physics lesson.

(a) Explain the role of dimensional analysis in deriving physical formulas.
(b) State two advantages of dimensional analysis in physics.
(c) Identify one situation where dimensional analysis may give misleading results.
(d) Explain why experimental verification of derived formulas is still necessary.

MODEL ANSWERS

Measurement and Dimensions

Item 1
(a) A metre rule has a large least count (typically 1 mm), making it unsuitable for measuring very small thicknesses accurately.

(b) The micrometer is closed gently and checked to see whether the zero on the thimble coincides with the datum line on the sleeve.
(c) A zero error causes all readings to be systematically high or low and must be corrected by adding or subtracting the error from the observed reading.
(d) Errors may arise from excessive pressure, backlash error, parallax, or worn threads; these can be minimized by correct handling and repeated measurements.

Item 2
(a) Least count is the smallest measurement that an instrument can measure accurately.
(b) A vernier caliper has a smaller least count and gives more precise measurements than a metre rule.
(c) The volume of the wire is given by

$$V = \pi r^2 l$$

(d) An error in the diameter results in a much larger error in the calculated volume because the radius is squared.

Item 3
(a) The beam balance measures mass.

(b) The volume of the stone is equal to the increase in water level when the stone is fully immersed.
(c) Density is given by

p = m/v

Item 4
(a) Dimensional analysis is based on the principle that physical equations must be dimensionally homogeneous.
(b) Using dimensions, the period is proportional to
$T \propto \sqrt{L/g}$
(d) Dimensional analysis cannot determine numerical constants or functional relationships.

Item 5
(a) Calibration is the process of checking and adjusting an instrument using known standards.
(b) A thermometer is calibrated using the ice point and steam point.
(c) Poor calibration introduces systematic errors into measurements.
(d) SI units are universal and simplify scientific communication

Item 6
(a) Force: newton (N), velocity: $m\ s^{-1}$, area: m^2.

(b) The SI unit of is kg s^{-3}.
(c) Dimensional analysis confirms the equation is dimensionally correct.
(d) The quantity may represent power per unit area.

Item 7
(a) A systematic error is an error that affects all readings in the same way.
(b) A stopwatch that runs slow introduces a systematic error.
(c) Random errors vary unpredictably, while systematic errors remain constant.
(d) Repeated timing and use of electronic timers reduce errors.

Item 8
(a) The area of the disc is
$A = \pi r^2$
(c) Large uncertainty in radius makes the calculated area unreliable.
(d) A vernier caliper or micrometer should be used.

Item 9
(a) Differences arise due to instrumental errors and human factors.
(b) Accuracy refers to how close a measurement is to the true value.

(c) Precision refers to consistency, while accuracy refers to correctness.
(d) Repeated measurements reduce random errors.

Item 10
(a) The SI unit of displacement is the metre (m).
(b) Time is fundamental because it cannot be expressed in terms of other quantities.
(c) Velocity has dimensions LT^{-1} and acceleration has dimensions LT^{-2}.
(d) Dimensional analysis checks the correctness of equations.

Item 11
(a) Least count is the smallest measurable value of an instrument.
(b) Careless use can still lead to inaccurate readings.
(c) Poor eyesight and reaction time affect measurements.
(d) Proper handling and repeated measurements improve accuracy.

Item 12
(a) A spring balance measures force (weight).
(b) A beam balance compares masses directly and is unaffected by gravity.

(c) Changes in gravitational field strength affect spring balance readings.
(d) Beam balances give true mass.

Item13
(a) SI units are internationally agreed standard units of measurement.
(b) They ensure uniformity and simplify calculations.
(c) 2.5 km = 2500 m.
(d) Unit consistency prevents errors in equations.

Item 14
(a) Uncertainty is the estimated range within which the true value lies.
(b) High uncertainty reduces confidence in results.
(c) Repeating measurements and using precise instruments reduces uncertainty.
(d) It shows the reliability of measurements.

Item 15
(a) Dimensional analysis helps derive relationships between physical quantities.
(b) It checks equations and helps predict formula forms.
(c) It may fail when constants are involved.
(d) Experiments confirm the validity of derived formulas.

STATICS

(Advanced Level Physics – Item Bank)

Item 1
A small particle of weight 50 N is suspended from a fixed point by a light, inextensible string in a vertical plane. A horizontal force is applied to the particle, causing the string to make an angle of 35° with the vertical. The system remains in equilibrium.

(a) Draw a clearly labeled diagram showing all the forces acting on the particle.
(b) Resolve the forces acting on the particle in the horizontal and vertical directions.
(c) Determine the tension in the string.
(d) Calculate the magnitude of the horizontal force applied to the particle.
(e) Explain why the assumption that the string is light is important in this analysis.

Item 2
A particle of weight rests on a smooth plane inclined at 40° to the horizontal. To prevent the particle from sliding down the plane, a force of 50 N is applied parallel to the

plane and up the line of greatest slope. The particle is in equilibrium.

(a) Identify all the forces acting on the particle and explain the direction of each force.
(b) Resolve the forces acting on the particle parallel to and perpendicular to the plane.
(c) Determine the value of the weight .
(d) Calculate the normal reaction between the particle and the plane.
(e) Explain how the situation would change if the plane were rough.

Item 3
Two light strings are fixed at a point and arranged so that they are perpendicular to each other. The free ends of the strings support a particle of weight 100 N which remains at rest. The tension in one of the strings is known to be 40 N.

(a) Draw a force diagram for the particle showing all the forces acting on it.
(b) Resolve the forces in two perpendicular directions.
(c) Determine the angle made by the string of tension 40 N with the vertical.
(d) Calculate the tension in the other string.
(e) State one practical situation where such an arrangement may be useful.

Item 4
A uniform horizontal pole AB of length 8 m and weight 5W is supported at two points C and D by vertical strings. The points C and D divide the pole such that AC = DB = 2 m. A body of weight 9W is suspended from the pole at a point E, where ED = 2 m. The system is in equilibrium.

(a) Sketch a diagram showing the pole and all forces acting on it.
(b) State the position of the centre of gravity of the uniform pole.
(c) Taking moments about point C, determine the tension in the string at D.
(d) Hence calculate the tension in the string at C.
(e) Explain why taking moments about C simplifies the calculations.

Item 5
A uniform rod AB of length 1.4 m is pivoted at a point C such that AC = 0.5 m. The rod is held horizontally in equilibrium when vertical forces of 16 N and 8 N are applied at points A and B respectively.

(a) Draw a diagram showing the rod and all forces acting on it.

(b) Identify the forces whose moments must be considered about the pivot.
(c) By taking moments about point C, determine the weight of the rod.
(d) Calculate the magnitude of the reaction force at the pivot.
(e) Explain why the pivot exerts both horizontal and vertical reactions.

Item 6
A uniform rod AB of length 4a and weight is smoothly hinged at its upper end A. The rod is held in equilibrium at an angle of 30° to the horizontal by a light string attached to the rod at a point C, where AC = 3a. The string is perpendicular to the rod.

(a) Draw a clear force diagram for the rod.
(b) Identify the forces producing clockwise and anticlockwise moments about A.
(c) Taking moments about A, determine the tension in the string.
(d) Resolve forces to determine the horizontal and vertical components of the reaction at the hinge.
(e) Explain why the hinge is described as smooth.

Item 7

A solid sphere of weight 40 N and radius 30 cm rests against a smooth vertical wall. The sphere is supported in equilibrium by a light string of length 20 cm attached to a point on the surface of the sphere and to a point on the wall.

(a) Draw a diagram showing the sphere, wall, string, and all forces acting.
(b) Explain why the reaction force from the wall is horizontal.
(c) Resolve the forces acting on the sphere to determine the tension in the string.
(d) Calculate the magnitude of the reaction between the sphere and the wall.
(e) State one effect if the wall were rough.

Item 8
A uniform ladder of length 5 m and mass 20 kg rests with its lower end on rough horizontal ground and its upper end against a smooth vertical wall. The base of the ladder is 3 m from the wall, and the ladder is in equilibrium.

(a) Draw a fully labeled diagram showing all forces acting on the ladder.
(b) Identify the forces responsible for preventing the ladder from slipping.

(c) Taking moments about the base of the ladder, calculate the frictional force at the ground.
(d) Explain why no frictional force acts at the wall.
(e) State one safety precaution that should be taken when using ladders.

Item 9
One end of a uniform plank of length 4 m and weight 100 N is hinged to a vertical wall. The other end of the plank is supported by an inelastic rope tied to a point on the wall 4 m above the hinge. The system is in equilibrium.

(a) Draw a diagram showing the plank, rope, hinge, and forces acting.
(b) Explain why the rope is under tension.
(c) Taking moments about the hinge, determine the tension in the rope.
(d) Resolve forces to determine the horizontal and vertical components of the reaction at the hinge.
(e) Explain how increasing the length of the rope would affect the tension.

Item 10
A uniform horizontal beam AB of length 4 m and weight 200 N is hinged to a vertical wall at A. The beam is supported by a cable attached to point B and fixed to the

wall above A. A load of 300 N is suspended from the beam at point B.

(a) Draw a clear force diagram for the beam.
(b) Taking moments about point A, determine the tension in the cable.
(c) Resolve forces to find the horizontal and vertical components of the force exerted by the wall on the beam.
(d) Determine the magnitude and direction of the resultant reaction at A.
(e) Explain why moments about A are preferred in this calculation.

MODEL ANSWERS

Statics

Item 1
(a) The forces acting on the particle are its weight acting vertically downward, the tension in the string acting along the string, and the horizontal applied force.
(b) Resolving vertically: .Tcos35°=50
Resolving horizontally: .Tsin35=F
(c) The tension in the string is

T = 50/cos35°

$F = T\sin 35°$

Item 2

(a) The forces acting are the weight acting vertically downward, the normal reaction acting perpendicular to the plane, and the applied force acting up the plane.

(b) Resolving parallel to the plane:

$W\sin 40° = 50$

$R = W\cos 40°$

(d) The reaction is $R = W\sin 40°$

(e) If the plane were rough, friction would act along the plane opposing motion.

Item 3

(a) The forces acting are the weight of the particle and the tensions in the two strings.

(b) Resolving forces horizontally and vertically gives two equilibrium equations.

(c) The angle is obtained by resolving the tension of 40 N into components and equating with the weight.

(d) The tension in the second string is obtained using Pythagoras' theorem or resolution of forces.

(e) Such arrangements are used in cranes and cable supports.

Item 4

(a) The forces acting are the weight of the pole at its centre, the suspended weight at E, and the tensions in the strings at C and D.
(b) The centre of gravity of the pole is at its midpoint.
(c) Taking moments about C gives the tension at D.
(d) The tension at C is obtained by resolving vertical forces.
(e) Taking moments about C eliminates the tension at C from the equation.

Item 5
(a) The forces are the weights applied at A and B, the weight of the rod acting at its centre, and the reaction at the pivot.
(b) The moments of all forces except the reaction at the pivot are considered.
(c) Taking moments about C gives the weight of the rod.
(d) The reaction at the pivot is obtained by resolving vertical forces.
(e) The pivot provides both horizontal and vertical reactions to maintain equilibrium.

Item 6
(a) The forces acting are the weight of the rod, the tension in the string, and the reaction at the hinge.

(b) The tension produces an anticlockwise moment while the weight produces a clockwise moment.
(c) Taking moments about A gives the tension in the string.
(d) Resolving horizontally and vertically gives the reaction components.
(e) A smooth hinge exerts no frictional torque.

Item 7
(a) The forces acting are the weight of the sphere, the tension in the string, and the reaction from the wall.
(b) The wall is smooth, so the reaction is horizontal.
(c) Resolving forces gives the tension in the string.
(d) The reaction from the wall is obtained by horizontal equilibrium.
(e) If the wall were rough, friction would act vertically.

Item 8
(a) The forces are the weight of the ladder, the reaction at the ground, the frictional force at the ground, and the reaction at the wall.
(b) Friction at the ground prevents slipping.
(c) Taking moments about the base gives the frictional force.
(d) The wall is smooth, so no friction acts there.
(e) The ladder should be placed on firm, non-slippery ground.

Item 9

(a) The forces acting are the weight of the plank, the tension in the rope, and the reaction at the hinge.

(b) The rope is in tension because it supports part of the plank’s weight.

(c) Taking moments about the hinge gives the tension in the rope.

(d) Resolving forces gives the horizontal and vertical reaction components.

(e) Increasing the rope length reduces the tension.

Item 10

(a) The forces acting are the weight of the beam, the suspended load, the tension in the cable, and the reaction at the hinge.

(b) Taking moments about A gives the tension in the cable.

(c) Resolving forces gives the horizontal and vertical components of the wall reaction.

(d) The resultant reaction is found using vector addition.

(e) Taking moments about A removes the reaction force from the moment equation.

LINEAR MOTION – SCENARIO ITEMS

Item 1

A car is moving along a straight horizontal road at a constant speed of 25m/s when the driver suddenly notices a fallen tree blocking the road 65m ahead. The driver reacts instantly and applies the brakes, producing a constant retardation of $6m/s^2$.

(a) Calculate the distance travelled by the car before it comes to rest.
(b) Determine whether the car stops before hitting the tree.
(c) If the brakes were applied one second later, calculate the speed with which the car would hit the tree.

Item 2

Points A, B and C lie in that order along a straight road such that AB=95m and BC=80m . A car passes point A with an initial speed u and moves with constant acceleration a . The car reaches point B after 5 seconds and reaches point C 2 seconds later.

(a) Form equations relating u and a
(b) Calculate the values of u and a
(c) State one assumption made about the motion of the car.

Item 3

A train of mass $1x10^5$kg starts from rest at station P and accelerates uniformly at $1.0m/s^2$ until it reaches a speed of $20m/s^2$. The brakes are then applied, producing a constant braking force of 50 kN, bringing the train to rest at station Q.

(a) Calculate the distance travelled during acceleration.
(b) Determine the retardation of the train while braking.
(c) Find the total distance between stations P and Q.

Item 4
A ship of mass $1x10^7$kg is moving at a speed of 2.0m/s in calm water when its engines are switched off. As a result of water resistance, its speed is reduced uniformly to 1.5m/s after travelling a distance of 500m

(a) Calculate the retardation of the ship.
(b) Determine the magnitude of the resistive force acting on the ship.
(c) State one factor on which water resistance depends.

Item 5
A car starts from rest at station A and accelerates uniformly at $1.25m/s^2$ until it reaches a maximum speed of 30m/s. It maintains this speed for a further 90 seconds and then decelerates uniformly to rest at station B.

(a) Calculate the time taken to reach the maximum speed.
(b) Determine the distance travelled during acceleration.
(c) Find the total distance from station A to station B.

Item 6
Two cars A and B are travelling along the same straight road in the same direction. Car A passes a point P with a speed of 20m/s and accelerates uniformly at $2.0 m/s^2$. Car B passes the same point P at the same instant with a speed of 30m/s and moves with constant retardation of 1.0m/s

(a) Find the time after passing point P when the cars have the same speed.
(b) Calculate the distance between the two cars at that instant.
(c) State whether the cars will collide.

Item 7
A motorcycle accelerates uniformly from rest along a straight road. After travelling 120m , its speed is found to be 24m/s.

(a) Calculate the acceleration of the motorcycle.
(b) Determine the time taken to cover the 120m .
(c) Explain why the motion can be described as uniformly accelerated.

Item 8

A stone is thrown vertically upwards from the top of a tall building with a speed of 15m/s . It takes 5 seconds to reach the ground.

(a) Calculate the height of the building.
(b) Determine the maximum height reached above the top of the building.
(c) State the acceleration of the stone during its motion.

Item 9

A bus moving along a straight road slows down uniformly from 20m/s to 10m/s while travelling a distance of 75m.

(a) Calculate the retardation of the bus.
(b) Determine the time taken to travel the 75m.
(c) State one possible cause of the retardation.

Item 10

Two bodies A and B move along the same straight line with uniform accelerations A1 and a2 respectively. Their initial velocities are u1 and u2 . At a certain instant, the bodies are at the same point P and later meet again at another point Q.

(a) Using equations of motion, show that the distance is given by
PQ= 2(u1u2)(a1-a2)/(a1a2)
(c) Give one practical example where such motion may occur.

ANSWERS

Item 1
Distance to stop = 52.1 m
The car stops before reaching the tree.
Speed if brakes were applied late = 15 m s^{-1}

Item 2
Initial speed, u = 4 m s^{-1}
Acceleration, a = 6 m s^{-2}

Item 3
Distance during acceleration = 200 m
Retardation = 0.5 m s^{-2}
Distance during braking = 400 m
Total distance = 600 m

Item 4
Retardation = 0.00125 m s^{-2}
Resistive force = 12.5 kN

Item 5

Time to reach maximum speed = 24 s

Distance during acceleration = 360 m

Total distance travelled = 3.42 km

Item 6

Time when speeds are equal = 2 s

Distance between the cars = 20 m

The cars do not collide

Item 7

Acceleration = 2.4 m s^{-2}

Time taken = 10 s

Item 8

Height of the building = 62.5 m

Maximum height reached above the building = 11.5 m

Acceleration due to gravity = 9.8 m s^{-2}

Item 9

Retardation = 2.0 m s^{-2}

Time taken to stop = 5 s

Item 10

Distance PQ depends on initial velocities and accelerations.

Condition: accelerations must be different.

MOTION UNDER GRAVITY

(Neglect air resistance. Take $g = 9.8 \text{ m s}^{-2}$ unless otherwise stated.)

Item 1
A pebble is released from rest at the top of a vertical cliff 125 m high overlooking a river. The pebble falls freely and strikes the surface of the river below.

(a) Determine the time taken by the pebble to reach the river.
(b) Calculate the speed with which the pebble strikes the river.
(c) State whether the pebble's acceleration changes during the motion and explain your answer.

Item 2
A stone is thrown horizontally from the top of a vertical cliff with a horizontal velocity of 15 m s^{-1}. The stone strikes the horizontal ground at a point 45 m from the foot of the cliff.

(a) Calculate the time taken by the stone to reach the ground.
(b) Determine the height of the cliff.

(c) Find the speed of the stone at the moment it strikes the ground.
(d) Determine the angle which the velocity of the stone makes with the horizontal at the point of impact.

Item 3
A ball is dropped from rest from the top of a cliff and takes 3.0 s to reach the beach below.

(a) Calculate the height of the cliff.
(b) Determine the velocity acquired by the ball just before it reaches the beach.
(c) State the direction of the acceleration of the ball throughout the motion.
(d) Explain whether the mass of the ball affects the time taken to reach the beach.

Item 4
A stone is thrown vertically upwards from the edge of a cliff with an initial speed of 10 m s^{-1}.

(a) Determine the maximum height reached by the stone above the point of projection.
(b) Calculate the time taken for the stone to return to the point of projection.
(c) Find the speed of the stone when it reaches the ground at the foot of the cliff, given that the cliff is 44.1 m high.

(d) Sketch a velocity–time graph for the motion of the stone until it reaches the ground.

Item 5

A stone is fired vertically upwards from a catapult and lands back at the point of projection 5.0 s later.

(a) Determine the initial velocity of the stone.
(b) Calculate the maximum height reached by the stone.
(c) For how long was the stone at a height of 20 m or more above the point of projection?
(d) Explain why the velocity of the stone is zero at the highest point of its motion.

Item 6

A stone is dropped from the top of a cliff which is 80 m high.

(a) Calculate the time taken for the stone to reach the bottom of the cliff.
(b) Determine the speed of the stone just before it hits the ground.
(c) State the nature of the motion of the stone during the fall.
(d) Explain why the stone does not continue accelerating after it hits the ground.

Item 7
A pebble is dropped from a bridge which is 15 m above a river.

(a) Calculate the speed of the pebble as it hits the water.
(b) Determine the time taken to reach the water.
(c) State the assumptions made in your calculations.
(d) Suggest one factor in real life that would reduce the speed of the pebble before impact.

Item 8
A ball is thrown vertically upwards and caught by the thrower on its return.

(a) Sketch a velocity–time graph for the motion of the ball, neglecting air resistance.
(b) Indicate clearly on the graph the point at which the acceleration changes sign.
(c) State the value of the acceleration throughout the motion.
(d) Explain why the areas under the graph above and below the time axis are equal.

ANSWERS

Item 1

Time taken = 5.0 s

Speed on impact = 49.5 m s^{-1}

Acceleration remains constant throughout the motion.

Item 2

Time of flight = 3.0 s

Height of the cliff = 44.1 m

Speed on impact = 29.4 m s^{-1}

Angle with the horizontal at impact = 63.4 degrees

Item 3

Height of the cliff = 44.1 m

Velocity on impact = 29.4 m s^{-1} downward

Acceleration acts vertically downward throughout.

Mass does not affect the time of fall.

Item 4

Maximum height above point of projection = 5.1 m

Time to return to point of projection = 2.04 s

Speed at the ground = 31.5 m s^{-1}

Item 5

Initial velocity = 25.0 m s^{-1}

Maximum height reached = 31.9 m

Time at height of 20 m or more = 2.5 s

Velocity is zero at the highest point.

Item 6

Time taken = 4.0 s

Speed on impact = 39.6 m s^{-1}

Motion is uniformly accelerated.

Acceleration stops when the stone hits the ground.

Item 7

Speed on impact = 17.1 m s^{-1}

Time taken = 1.75 s

Air resistance is neglected.

Air resistance reduces the speed.

Item 8

Velocity–time graph is a straight line with negative slope.

Acceleration changes sign at the highest point.

Acceleration = 9.8 m s^{-2} downward.

Upward and downward displacements are equal.

📘 ***Author: joelPCM***

WORK, ENERGY AND POWER

(Neglect air resistance unless otherwise stated. Take g = 9.8 m s^{-2}.)

Item 1
A driver is travelling along a straight horizontal highway when he suddenly notices an obstacle ahead. He applies the brakes and brings his car of mass 800 kg, initially moving at a speed of 30 m s^{-1}, to rest under the action of a constant retarding force of 5000 N.

Using the principles of work and energy, calculate the distance the car moves from the moment the brakes are applied until it comes to rest. Clearly state the physical principle used in your solution.

Item 2
A loaded car of mass 1200 kg moves steadily up a rough hill road which is inclined at an angle θ to the horizontal, where sin θ equals 1 over 15. The car travels a distance of 300 m measured along the surface of the road.

Determine the increase in gravitational potential energy of the car during this motion. Explain why the increase in potential energy depends only on the vertical height gained and not on the distance travelled along the slope.

Item 3
A car of mass 800 kg is moving along a straight horizontal road at a speed of 20 m s^{-1}. The driver applies the brakes

and the car is brought to rest uniformly after travelling a distance of 100 m. Assume that the braking force is constant and that there are no other resistive forces acting on the car.

(a) Calculate the work done by the braking force.
(b) Determine the magnitude of the braking force.
(c) State whether the work done by the brakes is positive or negative and explain your answer.

Item 4
A dog-sleigh of mass 80 kg is pulled by a team of dogs along a horizontal snow-covered surface. The speed of the sleigh increases uniformly from 3.0 m s^{-1} to 9.0 m s^{-1} while it travels a distance of 90 m. Assume that resistance to motion is negligible.

(a) Calculate the increase in kinetic energy of the sleigh.
(b) Determine the constant force exerted by the dogs on the sleigh.
(c) Explain why the work done by the dogs is equal to the change in kinetic energy of the sleigh.

Item 5
A simple pendulum consists of a small heavy bob attached to a light inextensible string of length 40 cm. The bob is

pulled aside until the string makes an angle of 60 degrees with the downward vertical and then released from rest.

Using energy considerations, determine the speed of the bob as it passes through its lowest point. State clearly any assumptions made in your solution.

Item 6
A car of mass 900 kg accelerates from rest to a speed of 20 m s^{-1} while moving a distance of 80 m along a straight horizontal road. The engine exerts a constant tractive force while a constant resistive force of 250 N acts in the opposite direction to the motion.

Calculate the tractive force exerted by the engine. Explain how the principle of work and energy is applied in this situation.

Item 7
A child of mass 20 kg starts from rest at the top of a playground slide and reaches the bottom with a speed of 5.0 m s^{-1}. The slide has a length of 5.0 m and the vertical height between the top and the bottom of the slide is 1.6 m.

(a) Calculate the work done against friction during the motion.

(b) Determine the average frictional force acting on the child.
(c) Explain why mechanical energy is not conserved in this motion.

Item 8
Two particles of masses 6.0 kg and 2.0 kg are connected by a light inextensible string passing over a smooth pulley. The system is released from rest with the string taut. The heavier particle descends vertically while the lighter one rises.

Using energy considerations, calculate the speed of the particles after the heavier particle has descended a distance of 2.0 m. State the assumptions made in your calculations.

Item 9
A ball of mass 50 g is dropped vertically from a height of 2.0 m onto a hard horizontal surface. After striking the ground, it rebounds vertically to a height of 1.2 m.

Calculate the amount of kinetic energy lost during the impact with the ground. Explain the physical reasons for the loss of mechanical energy.

Item 10

A bullet of mass 2.0×10^{-3} kg is fired horizontally into a free-standing wooden block of mass 4.98×10^{-1} kg resting on a smooth horizontal surface. The bullet becomes embedded in the block, and immediately after the impact the combined system moves forward with a speed of 1.2 m s^{-1}.

(a) Estimate the speed of the bullet just before impact.
(b) Calculate the kinetic energy lost during the collision.
(c) Explain why kinetic energy is not conserved in this collision.

📘 Author: joelPCM

ANSWERS

Item 1
Distance travelled before stopping = 72 m
Principle used: Work done equals change in kinetic energy.

Item 2
Increase in gravitational potential energy = 2.4×10^5 J
The increase depends only on the vertical height gained.

Item 3
Work done by the brakes = 1.6×10^5 J
Braking force = 1.6×10^3 N
Work done is negative because the force opposes motion.

Item 4
Increase in kinetic energy = 2.9×10^3 J
Force exerted by the dogs = 32 N
Work done equals change in kinetic energy.

Item 5
Speed at the lowest point = 2.0 m s^{-1}
Mechanical energy is conserved.

Item 6
Tractive force exerted by the engine = 2.5×10^3 N
Work–energy principle applied.

Item 7
Work done against friction = 70 J
Average frictional force = 14 N
Mechanical energy is lost due to friction.

Item 8
Speed of the particles = 4.5 m s^{-1}
Energy is conserved in the system.

Item 9
Kinetic energy lost on impact = 0.40 J
Energy is lost as heat and sound.

Item 10
Speed of the bullet = 300 m s^{-1}
Kinetic energy lost in the collision = 89.64 J
The collision is inelastic.

📘 ***Author: joelPCM***

SOLID FRICTION
(Assume g = 9.8 m s^{-2} unless otherwise stated.)

Item 1
A small particle of weight 4.9 N rests on a rough inclined plane. The plane makes an angle with the horizontal such that tan of the angle is equal to 5 over 12. A horizontal force of 8 N is applied to the particle. The particle is observed to be just on the point of moving up the plane.

By resolving forces parallel and perpendicular to the plane, determine the coefficient of friction between the particle and the plane. Clearly state the direction of the frictional force.

Item 2

A wooden box of mass 2 kg rests on a rough inclined plane which is inclined at 25 degrees to the horizontal. The coefficient of friction between the box and the plane is 0.40.

Determine the least force, applied parallel to the plane, that is required to move the box up the plane. Explain why a greater force is required to move the box upward than to keep it moving.

Item 3

A particle of mass 0.50 kg is released from rest at the top of a rough plane inclined at 30 degrees to the horizontal. The particle slides down the plane and is observed to take 6.0 seconds to travel a distance of 3.0 m measured along the plane.

(a) Calculate the coefficient of friction between the particle and the plane.

(b) Determine the minimum horizontal force that must be applied to the particle in order to prevent it from sliding down the plane.

Item 4

A parcel of mass 2.0 kg is placed on a rough plane inclined at 45 degrees to the horizontal. The coefficient of friction between the parcel and the plane is 0.25.

Calculate the magnitude of the force that must be applied parallel to the plane so that the parcel is: (a) Just prevented from sliding down the plane.
(b) Just on the point of moving up the plane.

In each case, state the direction of the frictional force.

Item 5
A bullet of mass 10 g is fired horizontally with a speed of 200 m s^{-1} into a wooden block of mass 4.0 kg resting on a rough horizontal surface. The bullet becomes embedded in the block. The combined system slides along the surface and comes to rest after travelling a distance of 20 m.

Using the principles of momentum and work done against friction, calculate the coefficient of friction between the block and the surface.

Item 6
Two bodies, A and B, of masses 6.0 kg and 1.0 kg respectively are connected by a light inextensible string passing over a smooth pulley fixed at the edge of a rough

horizontal table. Body A rests on the table and body B hangs freely.

The coefficient of friction between body A and the table is 0.20. The system is released from rest.

(a) Calculate the frictional force acting on body A.
(b) State, with reasons, whether the system will move or remain at rest.

Item 7
In the arrangement described in Item 6, the masses of A and B are now 1.0 kg and 0.50 kg respectively. The coefficient of friction between A and the table is one third. Initially, A is 3.0 m from the pulley and B is 2.5 m above the floor.

When the system is released from rest: (a) Determine the initial acceleration of the system.
(b) Find the speed with which body B strikes the floor.
(c) Calculate the speed with which body A reaches the pulley.

Item 8
Two particles A and B of masses 2.0 kg and 4.0 kg respectively are connected by a light inextensible string passing over a smooth pulley fixed at the edge of a rough

horizontal table. Particle A is on the table, 4.0 m from the pulley, while particle B hangs freely below the table.

The coefficient of friction between particle A and the table is three over five. The system is released from rest.

(a) Determine the tension in the string.
(b) Find the magnitude of the acceleration of each particle.

Item 9
In the situation described in Item 8, particle B falls a distance of 2.0 m and then hits the ground and does not rebound.

Determine the distance from the pulley at which particle A finally comes to rest. State the principle used in your calculation.

Item 10
Explain, with the aid of a force diagram, why frictional force always acts in a direction that opposes either the motion or the tendency of motion of a body. Use an example involving a body on a rough inclined plane to support your explanation.

📘 Author: joelPCM

ANSWERS

Item 1
Coefficient of friction, μ = 0.72
Friction acts down the plane.

Item 2
Least force required = 15.39 N
A larger force is needed to overcome both friction and the component of weight down the plane.

Item 3
Coefficient of friction = 0.56
Minimum horizontal force required = 0.086 N

Item 4
Force to prevent sliding down the plane = 10.8 N
Force to be on the point of moving up the plane = 17.7 N
Friction acts up the plane in (a) and down the plane in (b).

Item 5
Coefficient of friction between the block and the surface = 0.063

Item 6
Frictional force on A = 9.81 N
The system remains at rest because friction balances the driving force.

Item 7
Initial acceleration of the system = 1.09 m s^{-2}
Speed with which B hits the floor = 2.33 m s^{-1}
Speed with which A reaches the pulley = 1.48 m s^{-1}

Item 8
Tension in the string = 20.9 N
Acceleration of each particle = 4.57 m s^{-2}

Item 9
Distance from the pulley where A comes to rest = 0.44 m
Principle used: Work and energy.

Item 10
Friction acts opposite to motion or the tendency of motion.
It prevents relative slipping between surfaces in contact.

📘 ***Author: joelPCM***

S5 Term 2

FLUID MECHANICS

(Assume steady motion, laminar flow, and that Stokes' law applies where appropriate. Take $g = 9.8\ m\ s^{-2}$ unless otherwise stated.)

Item 1

In an experiment to study the motion of small particles through air, a tiny spherical oil drop is observed to fall vertically under gravity and eventually attain a constant terminal velocity of $4.0 \times 10^{-4}\ m\ s^{-1}$. The viscosity of air is $1.8 \times 10^{-5}\ N\ s\ m^{-2}$ and the density of the oil is $900\ kg\ m^{-3}$. The density of air may be neglected.

(a) Determine the radius of the oil drop.
(b) If the radius of the oil drop were reduced to half its original value, calculate the new terminal velocity.
(c) Explain why the terminal velocity changes when the radius of the drop is altered.

Item 2

A spherical rain drop falls vertically through still air and eventually reaches terminal velocity. The radius of the drop is 0.20 cm. The density of air is $1.2\ kg\ m^{-3}$ while the density of water is $1000\ kg\ m^{-3}$. The coefficient of viscosity of air is 9.0×10^{-3} Pa s.

Calculate the terminal velocity of the rain drop and state the assumptions made in the calculation.

Item 3

A spherical rain drop of radius 2.0×10^{-4} m falls vertically through air at a temperature of 20 degrees Celsius. The density of air is 1.2 kg m^{-3} and that of water is 1000 kg m^{-3}. The coefficient of viscosity of air at this temperature is 1.8×10^{-5} Pa s.

Calculate the terminal velocity of the rain drop. Explain why the motion soon becomes uniform.

Item 4

A metal sphere of radius 2.0×10^{-3} m and mass 3.0×10^{-4} kg falls vertically down a wide tube filled with a liquid at 35 degrees Celsius. The density of the liquid is 700 kg m^{-3} and the sphere attains a terminal velocity of 0.40 m s^{-1}.

The tube is then emptied and filled with another liquid at the same temperature but of density 900 kg m^{-3}. When released again, the sphere now attains a terminal velocity of 0.25 m s^{-1}.

Determine the ratio of the coefficient of viscosity of the second liquid to that of the first.

Item 5

In an experiment designed to determine the coefficient of viscosity of motor oil, a small glass sphere is allowed to fall centrally down a wide vertical tube filled with the oil. The following measurements are recorded:

Mass of the glass sphere = 1.2×10^{-4} kg
Diameter of the sphere = 4.0×10^{-3} m
Terminal velocity of the sphere = 5.4×10^{-2} m s^{-1}
Density of oil = 860 kg m^{-3}

Using these data, calculate the coefficient of viscosity of the oil. State any assumptions made.

Item 6

A metal sphere of radius 3.0×10^{-3} m and mass 4.0×10^{-4} kg falls under gravity down a wide tube filled with a liquid at 25 degrees Celsius. The density of the liquid is 800 kg m^{-3} and the sphere attains a terminal velocity of 45 cm s^{-1}.

The tube is then filled with another liquid of density 100 kg m^{-3} at the same temperature. In this case, the terminal velocity of the sphere is found to be 20 cm s^{-1}.

Determine the ratio of the coefficient of viscosity of the second liquid to that of the first.

Item 7

A steel sphere of diameter 3.0×10^{-3} m falls through a vertical cylinder containing liquid X. After attaining terminal velocity, it takes 1.08 s to travel between two fixed marks on the cylinder. The experiment is repeated using another steel sphere of diameter 5.0×10^{-3} m in a different liquid Y, and the time taken between the same two marks is 4.8 s.

The density of liquid X is 1.26×10^{3} kg m^{-3}, that of liquid Y is 0.92×10^{3} kg m^{-3}, and the density of steel is 7.8×10^{3} kg m^{-3}.

Determine the ratio of the coefficient of viscosity of liquid X to that of liquid Y, assuming the temperature remains constant.

Item 8

Calculate the terminal velocities of rain drops falling vertically through still air under the following conditions:

(a) A rain drop of diameter 0.30 cm
(b) A rain drop of diameter 0.01 mm

The density of water is 1000 kg m^{-3} and the viscosity of air is 1.0×10^{-3} Pa s. Air buoyancy may be neglected.

Item 9

An explosion occurs at an altitude of 1000 m above the ground where a steady horizontal wind blows at a speed of 10 m s^{-1}. The smallest particles produced by the explosion are spherical, of diameter 0.01 mm and density 2000 kg m^{-3}.

Given that the viscosity of air is 1.8×10^{-5} Pa s and the density of air is 1.2 kg m^{-3}:

(a) Calculate the time taken for the smallest particles to fall to the ground after reaching terminal velocity.
(b) Determine the horizontal distance travelled by the particles from the point of explosion.

Item 10

A drop of oil of radius 0.10 mm falls vertically through air and quickly reaches terminal velocity. The viscosity of air is 1.8×10^{-5} Pa s and the density of the oil is 850 kg m^{-3}.

Calculate the viscous drag force acting on the oil drop when it is moving at terminal velocity. Explain the significance of this force.

📘 Author: joelPCM

ANSWERS

Item 1

Radius of oil drop = 1.92 × 10^{-6} m

New terminal velocity when radius is halved = 1.0 × 10^{-4} m s^{-1}

Terminal velocity depends on the square of the radius.

Item 2

Terminal velocity of the rain drop = 8.7 m s^{-1}

Item 3

Terminal velocity of the rain drop = 4.48 m s^{-1}

Motion becomes uniform when viscous drag balances the effective weight.

Item 4

Ratio of coefficient of viscosity (second liquid : first liquid) = 1.64

Item 5

Coefficient of viscosity of the oil = 0.45 N s m^{-2}

Item 6

Ratio of coefficient of viscosity (second liquid : first liquid) = 2.09

Item 7

Ratio of coefficient of viscosity (liquid X : liquid Y) = 0.77

Item 8
Terminal velocity for diameter 0.30 cm = 9.0 m s^{-1}
Terminal velocity for diameter 0.01 mm = 0.01 m s^{-1}

Item 9
Time taken to fall to the ground = 250 s
Horizontal distance travelled = 2500 m

Item 10
Viscous drag on the oil drop = 6.7 × 10^{-8} N
This force balances the effective weight at terminal velocity.

📘 Author: joelPCM

Mechanical properties of matter

Item 1 Composite Wire under Load
A copper wire and a steel wire, each of length 1.5 m and diameter 2.0 mm, are joined end to end to form a composite wire suspended vertically from a rigid support. The lower end of the composite wire is gradually loaded until the total length of the wire becomes 3.003 m.

The Young's modulus of steel is 2.0×10^{11} N m^{-2} while that of copper is 1.2×10^{11} N m^{-2}.

(a) Determine the strain produced in the copper wire.
(b) Determine the strain produced in the steel wire.
(c) Calculate the magnitude of the force applied to the composite wire.

Item 2: Thermal Expansion and Elastic Compression

Two identical cylindrical steel bars, each of radius 3.0 mm and length 7.0 m, stand vertically side by side on a rigid horizontal surface. Their upper ends are initially level. A mass of 4.0 kg is gently placed on top of one of the bars, causing it to compress.

The temperature of the other bar is then adjusted so that its length becomes equal to that of the compressed bar. The coefficient of linear expansivity of steel is 1.2×10^{-5} K^{-1}.

(a) Calculate the change in temperature required.
(b) Determine the elastic potential energy stored in the compressed bar due to this change.

Item 3: Extension of a Composite Wire

Two wires, one of steel and the other of phosphor bronze, each of diameter 0.40 cm and length 3.0 m, are joined end to end to form a composite wire of total length 6.0 m. The wire is stretched by a force applied at its ends.

The Young's modulus of steel is 2.0×10^{11} N m^{-2} while that of phosphor bronze is 1.2×10^{11} N m^{-2}.

Calculate the tension required to produce a total extension of 0.128 cm in the composite wire.

Item 4: Elastic Energy in a Catapult

A rubber cord of a catapult has an original length of 0.72 m and a uniform cross-sectional area of 1.2 mm^2. When stretched, its length becomes 0.84 m. A small stone of mass 15 g is placed in the pouch of the catapult and released.

Given that the Young's modulus of rubber is 6.2×10^8 N m^{-2}:

(a) Calculate the elastic potential energy stored in the stretched rubber.
(b) Determine the initial speed of the stone as it leaves the catapult.
(c) State any assumptions made in your calculations.

Item 5: Wire Loaded at Midpoint
A uniform wire of unstretched length is fixed at two points A and B, which are 2.4 m apart and lie on the same horizontal line. A mass of 6.0 kg is attached at the midpoint C of the wire. When equilibrium is attained, point C is found to be 0.52 m below the line AB.

Neglect the weight of the wire and take the Young's modulus of the material of the wire to be 2.0×10^{11} N m^{-2}.

(a) Determine the strain in the wire.
(b) Calculate the stress in the wire.
(c) Find the total elastic energy stored in the wire.
(d) State the assumptions made.

Item 6: Stress and Strain in a Loaded Wire
A steel wire of length 2.0 m and cross-sectional area 1.5 mm^2 is suspended vertically from a rigid support. A load is gradually applied to the lower end of the wire, producing an extension of 1.2 mm.

Given that the Young's modulus of steel is 2.0×10^{11} N m^{-2}:

(a) Calculate the strain in the wire.
(b) Determine the stress produced.
(c) Find the magnitude of the applied force.

Item 7: Energy Stored in a Stretched Wire

A uniform copper wire of original length 1.8 m and diameter 1.0 mm is stretched by a force of 200 N. The Young's modulus of copper is 1.1×10^{11} N m^{-2}.

(a) Calculate the extension produced in the wire.
(b) Determine the elastic potential energy stored in the wire.

Item 8: Comparison of Two Materials

Two wires A and B, made of different materials, have equal lengths and cross-sectional areas. When subjected to the same tensile force, wire A extends twice as much as wire B.

(a) Compare the Young's moduli of the two materials.
(b) State one physical reason why wire A may be less suitable for suspension cables.

Item 9: Breaking Stress

A steel wire of diameter 1.5 mm breaks when subjected to a tensile force of 450 N.

(a) Calculate the breaking stress of the wire.
(b) State two factors that affect the breaking stress of a material.

Item 10: Elastic Limit and Hooke's Law

A student performs an experiment to study the extension of a metal wire under increasing loads. It is observed that the extension is directly proportional to the applied load up to a certain point, after which permanent deformation occurs.

(a) Define Hooke's law.
(b) Explain what is meant by the elastic limit of the material.
(c) State one practical importance of the elastic limit in engineering structures.

MECHANICAL PROPERTIES OF MATTER
ANSWERS ONLY

Item 1
Strain in copper = 1.3×10^{-3}
Strain in steel = 7.5×10^{-4}
Force applied = 4.7×10^{2} N

Item 2
Temperature change = 0.58 K
Energy stored = 9.6×10^{-1} J

Item 3

Tension in the composite wire = 1.01 × 10^2 N

Item 4
Elastic potential energy stored = 1.25 J
Initial velocity of the stone = 12.9 m s^{-1}

Assumptions:
- ***Rubber obeys Hooke's law***
- ***All elastic energy converts to kinetic energy***
- ***Air resistance neglected***

Item 5
Strain in the wire = 1.8 × 10^{-3}
Stress in the wire = 3.6 × 10^8 N m^{-2}
Elastic energy stored = 9.4 J

Assumptions:
- ***Wire is light***
- ***Hooke's law obeyed***
- ***Symmetrical deformation***

Item 6
Strain = 6.0 × 10^{-4}
Stress = 1.2 × 10^8 N m^{-2}
Force applied = 180 N

Item 7

Extension = 2.1 × 10^{-3} m
Elastic energy stored = 0.21 J

Item 8
Young's modulus ratio

Reason:
- ***Material A is less stiff and more easily deformed***

Item 9
Breaking stress = 2.5 × 10^{8} N m^{-2}

Factors affecting breaking stress:
- ***Material structure***
- ***Temperature***

Item 10
Hooke's law:
Stress is directly proportional to strain provided the elastic limit is not exceeded.

Elastic limit:
The maximum stress a material can withstand without permanent deformation.

Importance:

Ensures safety in engineering structures.

THERMOMETRY

Item 1

Platinum Resistance Thermometer Problem

A platinum resistance thermometer has a resistance of 2 Ohms at the ice point (0°C) and 2.73 Ohms at the steam point (100°C). A student measures the resistance of the thermometer while monitoring the temperature of a chemical reaction and obtains a reading of 8.43 Ohms.

(a) Calculate the temperature corresponding to this resistance.

(b) Discuss the suitability of platinum resistance thermometers for measuring high temperatures.

Answer: 881°C

Item 2

Gas Thermometer Volume Problem

A sealed cylinder contains a fixed mass of gas at constant pressure. At 0°C, the gas occupies a volume of 200 cm3, and at 100°C it occupies 273.2 cm3. During an experiment, the gas expands to 525.1 cm3.

(a) Determine the temperature of the gas at this volume.

(b) Explain why constant-pressure gas thermometers are considered reliable for measuring temperature.

Answer: 444.13 K

Item3

Pressure Reading in Constant Volume Gas Thermometer

A constant-volume gas thermometer shows a pressure of 4.8×10^{-4} N/m2 at a certain unknown temperature T. If the pressure at the triple point of water is 4.24×10^{4} N/m2, calculate the temperature T.

(b) Explain the principle behind the operation of a constant-volume gas thermometer.

Answer: 312.18 K

Item 4

Nonlinear Resistance of Platinum Wire

The resistance Rθ of a platinum wire at temperature θ°C is related to the temperature on the gas scale by:

$R\theta = R0 * (1 + a\theta + b\theta^2)$

where $a = 3.8 \times 10^{-3}$ and $b = -5.6 \times 10^{-7}$.

(a) Calculate the temperature the platinum thermometer will indicate when the gas thermometer reads 200°C.

(b) Discuss the effect of the nonlinearity term $b*\theta^2$ on temperature readings at high temperatures.

Answer: 197.0°C

Item 5

Mercury Thermometer vs Platinum Thermometer

A platinum wire thermometer has a resistance given by:

$R\theta = R0 * (1 + a\theta + b\theta^2)$
where $a = 4.46 \times 10^{-3}$ and $b = 1.8 \times 10^{-6}$.
If the mercury thermometer reads 430°C, calculate the temperature obtained from the platinum thermometer.
(b) Comment on the difference between the two thermometers at high temperatures.
Answer: 450°C

Item 6

Mercury Volume Expansion

The volume $V\theta$ of a fixed mass of mercury at temperature θ°C is given by:
$V\theta = V0 * (1 + a\theta + b\theta^2)$
where $a = 1.818 \times 10^{-4}$ and $b = 0.8 \times 10^{-8}$.
If the gas scale reads 40°C, calculate the temperature expected on the mercury thermometer.

Item 7

Oxygen Mass Withdrawal Problem

A tank of volume 50 L contains oxygen at 30°C. The pressure gauge reads 21.4×10^5 Pa. Oxygen is withdrawn until the gauge reads 7.8×10^5 Pa, and the remaining gas cools to 10°C. Calculate the mass of oxygen withdrawn.
Answer: 828.8 g

Item 8

Thermocouple and Fixed Points

(a) Explain why thermometers based on different properties but calibrated using the same fixed points may:

(i) Agree near the fixed points.

(ii) Differ midway between fixed points.

(b) Describe, with a labelled diagram, how a thermocouple can be used to measure temperature.

Item 9

Triple Point and Platinum Resistance

A platinum resistance thermometer has a resistance of 5.42 Ohms at the triple point of water.

(a) Calculate its resistance at 50.0°C.

(b) Discuss why platinum is preferred as a thermometric material for high-precision measurements.

Answer: 6.41 Ohms

Item 10

Design and Operation Questions

(a) Describe the steps to set up a Celsius scale on a mercury-in-glass thermometer.

(b) State four disadvantages of mercury-in-glass thermometers.

(c) Describe the operation of an optical pyrometer with a labelled diagram.

Physics Item Bank – Calorimetry (Sample Items)

Item 1

Calculate the quantity of heat required to raise the temperature of a metal block with a heat capacity of 23.1 J/°C by 30.0°C.

Answer: 693 J

Item 2

An electrical heater supplies 500 J of heat energy to a copper cylinder of mass 32.4 g. Calculate the increase in temperature of the cylinder. (Specific heat capacity of copper = 385 J/kg°C)

Answer: 40.1°C

Item 3

How much heat must be removed from an object with a heat capacity of 150 J/°C in order to reduce its temperature from 80.0°C to 20.0°C?

Answer: 9000 J

Item 4

In an electrical constant flow experiment to determine the specific heat capacity of a liquid, heat is supplied to the liquid at a rate of 12 W. When the rate of flow is 0.060 kg/min, the temperature rise along the flow is 2.0 K. Calculate:

(a) The specific heat capacity of the liquid.

(b) The percentage of heat lost if the true specific heat capacity is 5400 J/kg·K.
Answer: 6000 J/kg·K, 11%

Item 5
Water is passed through a continuous flow calorimeter. The rise in temperature is from 16°C to 20°C, and the mass of water flowing is 100 g in one minute. The potential difference across the heating coil is 20 V and the current is 1.5 A.
Another liquid at 16°C is then passed through the calorimeter, and to get the same change in temperature, the potential difference is changed to 13 V, the current to 1.2 A, and the rate of flow to 120 g/min.
Calculate the specific heat capacity of the liquid. (Specific heat capacity of water = 4200 J/kg·°C)
Answer: 1700 J/kg·K

Item 6
With a certain liquid, the inflow and outflow temperatures are maintained at 25.20°C and 26.51°C respectively. For a potential difference of 12.0 V and current 1.50 A, the rate of flow is 90 g per minute. For 16.0 V and 2.00 A, the rate of flow is 310 g per minute.
Calculate:
(a) The specific heat capacity of the liquid.
(b) The power lost to the surroundings.

Answer: 2910 J/kg·K, 12.3 W

Item 7
60 kg of hot water at 82°C is added to 300 kg of cold water at 10°C. Calculate the final temperature of the mixture. (Specific heat capacity of water = 4200 J/kg·K)
Answer: 22°C

Item 8
Calculate the final steady temperature obtained when 0.8 kg of glycerine at 25°C is put into a copper calorimeter of mass 0.5 kg at 0°C. (Specific heat capacity of copper = 400 J/kg·K, specific heat capacity of glycerine = 250 J/kg·K)
Answer: 12.5°C

Item 9
A copper block of mass 250 g is heated to a temperature of 145°C and then dropped into a copper calorimeter of mass 250 g, which contains 2.5 kg of water at 20°C. Calculate the final temperature of water. (Specific heat capacity of copper = 400 J/kg·°C, specific heat capacity of water = 4200 J/kg·°C)
Answer: 30°C

Item 10

(a) Why does temperature remain constant during a change of state (phase)?
Answer: Temperature remains constant because the heat supplied or removed is used to break or form intermolecular bonds (latent heat) rather than change kinetic energy of particles.

Item 11
Calculate the heat required to melt 200 g of ice at 0°C. (Specific latent heat of fusion of ice = 3.4 x 10^5 J/kg)
Answer: 6.8 x 10^4 J

Item 12
Calculate the heat required to turn 500 g of ice at 0°C into water at 100°C. (Specific latent heat of fusion of ice = 3.4 x 10^5 J/kg, specific heat capacity of water = 4200 J/kg·K)
Answer: 3.8 x 10^5 J

Item 13
Calculate the heat given out when 600 g of steam at 100°C condenses to water at 20°C. (Specific latent heat of vaporization of steam = 2.26 x 10^6 J/kg, specific heat capacity of water = 4200 J/kg·K)
Answer: 1.56 x 10^6 J

Item 14

1 kg of vegetables, with a specific heat capacity of 2200 J/kg, at a temperature of 373 K, are placed into a mixture of ice and water at 273 K. Calculate the mass of ice melted. (Specific latent heat of fusion of ice = 3.3 x 10^5 J/kg)
Answer: 0.67 kg

Item 15
3 kg of molten lead (melting point 600 K) cools down from 605 K to 595 K. It remains at 600 K for 300 s. Specific heat capacity of solid lead = 140 J/kg·K. Calculate:
(a) Rate of loss of energy from the lead.
(b) Specific latent heat of fusion of lead.
(c) Specific heat capacity of liquid lead.
Answer: 250 W, 2.5 x 10^4 J/kg, 167 J/kg·K

📘 Author: joelPCM

Physics Item Bank – Heat Transfer, Conduction & Radiation

Item 1
In a small workshop, a well-lagged composite metal rod of uniform cross-sectional area 2 cm² is made by joining a 40 cm copper rod to a 25 cm aluminum rod. The extreme ends of the rod are maintained at 100°C and 0°C

respectively, while a technician inspects the junction for safety.
(a) Calculate the temperature at the junction of the two rods.
(b) Determine the rate of heat flow through the rod.
(Thermal conductivity: copper = 386 W/m·K, aluminum = 210 W/m·K)
Answer: (i) 53.5°C, (ii) 8.9745 J/s

Item 2
A rectangular room (12 m × 10 m × 4 m high) is maintained at a constant temperature higher than the outside. The walls and roof are 25 cm thick, made of material with thermal conductivity 0.25 W/m·K. A door and window covering 16 m^2 are made of 5 mm thick glass (k = 1.2 W/m·K).
Calculate the percentage of total heat loss that occurs through the door and window. Assume heat losses through the floor are negligible.
Answer: 93.7%

Item 3
A hall has a concrete floor (10 m × 8 m, thickness 10 cm) covered with a 2 cm thick carpet. The hall is kept at 22°C, while the ground beneath the concrete is 12°C. Thermal conductivity: concrete = 1 W/m·K, carpet = 0.05 W/m·K.

(a) Calculate the temperature at the interface between the concrete and the carpet.
(b) Determine the rate of heat flow through the floor.
Answer: (i) 14°C, (ii) 1600 W

Item 4
Water in an aluminum kettle boils at 100°C at a rate of 3.68×10^{-4} kg/s. The base of the kettle has area 6×10^{-4} m^2 and thickness 4 mm.
(a) Calculate the rate of heat flow through the base.
(b) Determine the temperature of the lower surface of the base.
(Thermal conductivity of aluminum = 210 W/m·K, latent heat of vaporization of water = 2.26×10^{6} J/kg)
Answer: (i) 882 J/s, (ii) 102.6°C

Item 5
One end of a perfectly lagged metal bar (length = 10 cm, cross-section = 5×10^{-4} m^2, k = 400 W/m·K) is kept at 100°C, while the other end touches ice. If the latent heat of fusion of ice is 3.36×10^{5} J/kg, calculate the rate at which the ice melts.
Answer: 5.95×10^{-4} kg/s

Item 6
A 25 cm long composite bar consists of a 15 cm copper rod joined to a 10 cm aluminum rod of equal

cross-sectional area. The free end of copper is maintained at 100°C, and the free end of aluminum at 0°C.
Calculate the temperature gradient in each rod at steady state.
(Thermal conductivity: copper = 390 W/m·K, aluminum = 210 W/m·K)
Answer: copper = 3×10^2 °C/m, aluminum = 5.5×10^2 °C/m

Item 7 – Copper Kettle Heating Water
A copper kettle has a base of thickness 2 mm and area 3×10^{-2} m². Water in the kettle (1 kg) is heated at a rate of 0.25 K/s. Assume no heat losses.
(a) Estimate the temperature difference across the base.
(b) After reaching 373 K, water boils for 120 s, and the remaining mass is 0.948 kg. Deduce the specific latent heat of vaporization of water.
(Thermal conductivity of copper = 3.8×10^2 W/m·K, specific heat capacity of water = 4.2×10^3 J/kg·K)
Answer: (i) 0.2°C, (ii) 2.4×10^6 J/kg

Item 8
A cubical container of hot water (90°C) is fully lagged with insulating material (thickness = 1 cm, $k = 6.4 \times 10^{-2}$ W/m·K). The edge of the cube is 1 m, and the external temperature is 40°C.
(a) Estimate the rate of heat flow through the lagging.

(b) Explain qualitatively what happens to the heat loss if the thickness of the lagging is significantly increased, assuming the surroundings are at 18°C.
Answer: 1.9×10^3 W

Item 9 – Radiation from a Copper Sphere
A copper sphere (diameter 20 mm, $\rho = 8.39 \times 10^3$ kg/m³, c = 370 J/kg·K) at 500 K is placed in an enclosure at 300 K. Assume all heat transfer occurs by radiation, and the sphere is a black body. Calculate the initial rate of temperature loss of the sphere.
Answer: 0.28 W

Item 10 – Blackbody Radiation and Electric Fire Element
(a) An element of an electric fire, a cylinder 25 cm long and 1.5 cm in diameter, has an output of 1 kW. Calculate its temperature if it behaves as a black body. (Stefan-Boltzmann constant = 5.7×10^{-8} W/m²·K⁴)
(b) A copper sphere (10 mm diameter, $\rho = 8.93 \times 10^3$ kg/m³, c = 370 J/kg·K) is placed in an enclosure at 290 K from 150 K. Assuming only radiation, calculate the initial rate of temperature rise.
Answer: (a) 1105 K, (b) 6.78×10^{-2} K/s

Item 11 – Blackbody Definition & Optical Pyrometer
(a) Define a black body.

(b) Sketch and explain graphs of intensity versus wavelength for three different temperatures.
(c) With a labelled diagram, explain how an optical radiation pyrometer measures temperature.
(d) State Prevost's theory of heat exchange.

Item 12 – Radiation Calculations and Wien's Law
A metal emits radiation as a blackbody at 6000 K. Calculate the wavelength of maximum emission. (Wien's displacement constant = 2.9×10^{-3} m·K)
Answer: 4.8×10^{-7} m

📘 Author: joelPCM

Physics Item Bank – Gases and Kinetic Theory (Scenario-Based)

Item 1
A team of atmospheric scientists is analyzing the composition of air in a remote laboratory. They note that air consists of 20% oxygen and 80% nitrogen by volume. The relative molecular masses of oxygen and nitrogen are 32 and 28 respectively.
(a) Calculate the ratio of the mass of oxygen to nitrogen in a given sample of air.

(b) Determine the ratio of the partial pressures of oxygen to nitrogen.
(c) Explain why oxygen and nitrogen are the main gases found near the surface of the Earth.
Answer: 7:8, 1:4

Item 2
In a controlled physics laboratory, a researcher confines one mole of an ideal gas at 300 K in a rigid container. The gas exerts a pressure of 1×10^5 Pa, and its volume is measured as 0.025 m^3.
(a) Calculate the molar gas constant.
(b) Determine Boltzmann's constant.
(c) Calculate the average kinetic energy of the gas molecules.
Answer: 8.33 J/mol·K, 1.384×10^{-23} J/K, 6.23×10^{-21} J

Item 3
In an experiment to measure gas pressure, a beam of 2×10^{22} nitrogen atoms, each of mass 2.32×10^{-26} kg, is directed normally at a wall of a cubical container with edge length 10 cm. The beam reflects back through 180°, and the mean speed of the atoms is 480 m/s. Calculate the pressure exerted by the nitrogen gas on the wall.
Answer: 1.014×10^5 Pa

Item 4

Astronomers studying the atmosphere of Jupiter want to calculate the speed of sound in its methane-rich atmosphere. Methane vapor is the main constituent, and the temperature of the atmosphere is 130°C. The speed of sound in a gas is 0.682 times the root mean square speed of its molecules. The molecular mass of methane is 16.06 g/mol. Determine the speed of sound in the atmosphere of Jupiter.

Answer: 530.2 m/s

Item 5

A student performs a Boyle's law experiment using damp air in a sealed apparatus. Initially, the pressure of air (saturated with water vapor) is 8.5 kPa. When the volume is reduced to half, the pressure rises to 16 kPa. When the volume is reduced to one-third, the pressure becomes 23 kPa.

(a) Show that the vapor exerts its saturation pressure when the volume is reduced to half.

(b) Calculate the saturated vapor pressure at the experiment's temperature.

(c) Calculate the initial pressure of the water vapor.

Answer: 2 kPa, 1.5 kPa

Item 6

A chemist collects 2000 cm³ of oxygen gas at 15°C and 753 mmHg over water. The saturated vapor pressure of water at 15°C is 12.78 mmHg. Calculate the volume of dry oxygen at standard temperature and pressure (0°C, 1 atm).

Answer: 1.846×10^3 cm^3

Item 7

Two short threads of water trap a small air bubble in a uniform horizontal capillary tube. At 20°C and atmospheric pressure of 76 cmHg, the bubble length is 5 cm. When the tube is heated to 60°C, the bubble expands to 6.9 cm. If the saturated vapor pressure of water at 20°C is 18 mmHg, calculate the saturated vapor pressure of water at 60°C, neglecting surface tension effects.

Answer: 14.89 mmHg

📘 Author: joelPCM

Physics Item Bank – Thermodynamics (Scenario-Based)

Item 1

A chemical engineer is observing the vaporization of water in an open vessel. When 5 kg of water turns completely into vapor, the atmospheric pressure is 1.01×10^5 Pa. The density of water is 1000 kg/m^3, while the density of vapor

is 0.598 kg/m³. Calculate the work done against the atmospheric pressure during vaporization.
Answer: 8.38×10^5 J

Item 2
A volume of air, initially occupying 2000 cm³ at 760 mmHg and 20°C, is expanded adiabatically and reversibly until its volume doubles. Subsequently, it is compressed adiabatically to 3000 cm³.
(a) Sketch a P-V graph illustrating both processes.
(b) Calculate the final temperature and pressure of the air, taking $\gamma = 1.4$.
Answer: 249.2 K, 430.8 mmHg

Item 3
A gas initially occupies 1 litre at 273 K and 1.01×10^5 Pa. It is compressed isothermally to half its original volume, then allowed to expand adiabatically back to its original volume.
(a) Calculate the final temperature and pressure of the gas.
(b) Indicate both processes on a P-V diagram.
Answer: 206.9 K

Item 4
In a laboratory, an ideal gas at a pressure of 2×10^6 Pa occupies a volume of 2×10^{-3} m³ at 47.5°C. The gas

expands adiabatically until its pressure drops to 1.1×10^7 Pa.

(a) Calculate the number of moles of the gas.

(b) Determine the final volume of the gas.

(c) Find the final temperature of the gas, taking $\gamma = 1.4$.

Answer: 1.502 moles, 5.92×10^{-4} m³, 521.6 K

Item 5

An ideal gas of volume 100 cm³ at s.t.p is allowed to expand adiabatically until its pressure falls to one-quarter of its initial value.

Calculate the new volume and temperature of the gas, taking $\gamma = 1.4$.

Answer: 269.2 cm³, 183.7 K

Item 6

A one-litre container of an ideal gas at s.t.p is heated such that it expands at constant pressure until its volume reaches 3 litres.

(a) Calculate the work done by the gas.

(b) Determine the final temperature of the gas.

Answer: 2.02×10^5 J, 819 K

Item 7

A physicist studies a vessel containing 1.5×10^{-3} m³ of an ideal gas at a pressure of 8.7×10^{-2} Pa and 25°C. The gas

is compressed isothermally to half its original volume, then allowed to expand adiabatically to its original volume.
(a) Calculate the final temperature and pressure of the gas ($\gamma = 1.41$).
(b) Sketch the P-V graph for the entire process.
(c) Calculate the work done during the isothermal compression.
Answer: T_final = 298.8 K, P_final = 0.087 Pa, W_isothermal = 5.7×10^{-5} J

Item 8
A researcher conducts an experiment with one mole of ideal gas in a piston. Initially at 300 K and 1×10^5 Pa, the gas is compressed adiabatically to half its volume and then expanded isothermally back to its initial volume.
(a) Determine the final temperature and pressure after the adiabatic compression.
(b) Show the process on a P-V diagram.
Answer: T_final = 370 K, P_final = 2×10^5 Pa

Item 9
In a thermodynamics lab, 0.5 m^3 of air at 300 K and 1 atm is allowed to expand adiabatically until the pressure halves.
(a) Calculate the final temperature of the air ($\gamma = 1.4$).
(b) Determine the work done during expansion.
Answer: T_final = 228 K, W = 3.1×10^4 J

Item 10

A sealed cylinder contains 2 moles of ideal gas at 400 K and 2×10^5 Pa. The gas is compressed isothermally to half its volume and then expanded adiabatically to the original volume.

(a) Calculate the pressure and temperature at the end of adiabatic expansion.

(b) Determine the total work done by the gas over both processes.

Answer: P_final = 2×10^5 Pa, T_final = 400 K, W_total = 1.65×10^5 J

📘 Author: PCM

S5 Term 3

Physics Item Bank – Reflection of Light (Scenario-Based)

Item 1

A student in a physics lab shines a ray of light onto a flat mirror and carefully observes the reflected ray. She notices that the angle at which the ray hits the mirror is always equal to the angle at which it reflects.

(a) Define the reflection of light.

(b) State the laws of reflection of light.

Answer: Reflection is the bouncing back of light when it strikes a surface; angle of incidence = angle of reflection; incident ray, reflected ray, and normal lie in the same plane.

Item 2

During an optics experiment, a teacher shows the difference between regular and diffuse reflection. A laser beam is directed at a polished mirror and then at a rough whiteboard.

(a) Distinguish between regular and diffuse reflection of light.

(b) Give an example of where each type of reflection is observed.

Answer: Regular reflection: smooth surface, parallel reflected rays; diffuse reflection: rough surface, scattered rays. Example: mirror vs wall paint.

Item 3

A physics student wants to determine the angle of elevation of a star using a sextant. He carefully adjusts the instrument and reads the angles reflected from the mirrors of the sextant.

(a) Describe how a sextant is used to determine the angle of elevation of a star.

Answer: Adjust the movable arm until the star aligns with the horizon seen in the telescope; read the angle from the graduated arc.

Item 4

In a ray optics demonstration, a plane mirror is rotated slightly while a reflected ray is being observed. The student notices that the reflected ray moves at twice the angle of rotation of the mirror.

(a) Derive the relation between the angle of rotation of a plane mirror and the angle of deflection of a reflected ray.

(b) If the mirror is rotated through 6°, calculate the angle through which the reflected ray moves.

Answer: $\theta_{deflection} = 2 \times \theta_{rotation}$; $\theta_{deflection} = 12°$

Item 5

A laser beam is incident on a plane mirror at an angle of 20° in position M_1. The mirror is rotated to a new position M_2, and the student is asked to find the new direction of the reflected ray while keeping the incident ray constant.

(a) Calculate the new angle of reflection.

Answer: Angle of reflection increases by twice the mirror rotation; calculation based on given geometry.

Item 6

Two plane mirrors are arranged to form an angle θ between them. A student directs a light ray successively onto both mirrors. He observes that the ray emerges deviated from its original direction.

(a) Show that an incident ray of light reflected successively from two mirrors inclined at an angle θ is deviated through an angle 2θ.

(b) Give one practical application of this result.

Answer: Angle of deviation = 2θ; Application: periscopes, kaleidoscopes.

Item 7

In a demonstration on curved mirrors, a student is asked to define the terms used in mirror geometry. Using a concave mirror, he identifies the centre of curvature, radius of curvature, principal focus, and focal length.

(a) Define the terms: centre of curvature, radius of curvature, principal focus, and focal length of a converging mirror.

Answer: Centre of curvature: centre of sphere of which mirror is part; radius: distance from mirror to centre; principal focus: point where parallel rays converge; focal length: distance from mirror to focus.

Item 8

A student experiments with concave and convex mirrors. He observes that a convex mirror produces upright, diminished images, while a concave mirror can produce real, magnified images.

(a) Explain with the aid of a ray diagram why a convex mirror is used as a car driving mirror.
(b) Give two practical uses of concave and convex mirrors.
Answer: Convex mirrors diverge rays, giving a wider field of view; concave: shaving mirrors, torch reflectors; convex: car mirrors, security mirrors.

Item 9
An object is placed perpendicular to the principal axis of a concave mirror with focal length 10 cm. The image is observed on a screen and is five times the height of the object. The student moves the screen to locate the image precisely.
(a) Determine the object distance and image distance.
(b) Sketch a ray diagram to illustrate the image formation.
Answer: u = 10 cm, v = 50 cm; ray diagram shows real, magnified image.

Item 10
Two mirrors, one concave of radius 20 cm and one convex of radius 10 cm, face each other. A student places an object midway between them and observes the reflected images.
(a) Determine the nature and position of the final image formed by reflection first from the concave mirror and then from the convex mirror.

Answer: Final virtual image at 17.5 cm behind the convex mirror.

📘 Author: PCM

Physics Item Bank – Refraction of Light (Scenario-Based)

Item 1
A student shines a ray of light from air onto the surface of a glass block at an angle of 60° and observes that the ray bends towards the normal.
(a) Define refraction of light.
(b) State what causes light to refract when it passes from one medium to another.
Answer: Refraction is the bending of light as it passes from one medium into another due to a change in speed; caused by the difference in optical density of the media.

Item 2
During an experiment, a ray of light travels from air into water. The student measures the angle of incidence as 40° and the angle of refraction as 22°. The speed of light in air is known to be 3×10^8 m/s.
(a) Find the speed of light in water.

Answer: Use Snell's law, n = sin i / sin r, then v = c / n; v ≈ 1.92×10^8 m/s.

Item 3

In a lab, a rectangular glass block of thickness 18 cm is used to study the dispersion of light. Blue and red light pass through the block at the same angle of incidence, but emerge at slightly different positions on a screen.

(a) Show that the sideways separation of the two colors at the bottom of the block is where and are the speeds of blue and red light in glass.

(b) Explain why this separation occurs.

Answer: Due to different refractive indices, light of different colors travels at different speeds in the medium (dispersion).

Item 4

A student directs a ray of light from a liquid to air at an angle of incidence of 40° and observes the refraction. The angle of refraction in air is measured.

(a) If the absolute refractive index of the liquid is 1.33, calculate the angle of refraction in air.

Answer: Use Snell's law, sin i / sin r = n; r ≈ 30°.

Item 5

During an optics lesson, light passes through two different media separated by a plane boundary. The student is asked to verify the law of refraction experimentally.

(a) Show that .

(b) Illustrate with a diagram the path of the refracted ray.

Answer: Angle of incidence and refraction relate by Snell's law; diagram shows ray bending towards the normal in denser medium.

Item 6

A ray of light travels from air into a glass block with refractive index 1.5 at an angle of 30° to the surface.

(a) Determine the angle of refraction inside the glass.

(b) Explain how this experiment demonstrates the slowing down of light in denser media.

Answer: $\sin i / \sin r = n \rightarrow r \approx 19.5°$; light slows down in denser medium, causing bending towards the normal.

Item 7

In a lab, a student observes light passing through three media of different refractive indices separated by plane boundaries. Using Snell's law, they calculate the path of the light as it exits the last medium.

(a) Show that for the final refraction to satisfy Snell's law.

Answer: Derived from repeated application of Snell's law at each interface.

Item 8

A student investigates light in a prism experiment. A white light ray enters the prism at an angle of 60°, and the emerging light is dispersed into its constituent colors on a screen.

(a) Explain why the blue light deviates more than red light.

Answer: Refractive index of glass is higher for blue light than red; light bends more in denser medium → dispersion.

Item 9

A liquid is placed in a container, and a ray of light passes from the liquid into air at 60°. The student uses Snell's law to calculate the refractive index of the liquid as 1.35.

(a) Verify the law of refraction using measured angles.

Answer: n = sin i / sin r; confirms experimental result matches theoretical prediction.

Item 10

During a physics demonstration, a beam of light passes from air into water at 30° and then into a glass slab at 45°. A student sketches the refracted path through the media and measures the deviation at the exit.

(a) Calculate the angles of refraction in each medium using their respective refractive indices.

(b) Explain why light bends at each boundary.

Answer: Use Snell's law for each interface; bending occurs due to change in light speed.

📘 Author: joelPCM

Physics Item Bank – Optical Instruments & Lenses (Scenario-Based)

Item 1
A group of students is observing distant stars using an astronomical telescope. While testing it on terrestrial objects during the day, they notice that the images appear inverted, making it difficult to view trees and buildings clearly.
(a) State the disadvantage of using an astronomical telescope for observing objects on Earth.
(b) Suggest how the telescope can be modified to overcome this disadvantage.
(c) Explain the principle behind the modification.
Answer: Images appear inverted because astronomical telescopes are designed for parallel rays from very distant objects; using an erecting lens or combination of lenses can produce upright images.

Item 2

A student is given an astronomical telescope with an objective of focal length 80 cm and an eyepiece of focal length 5 cm. She is asked to calculate the magnifying power of the telescope when the final image is at infinity and also to determine the separation of the lenses when arranged in normal adjustment.

(a) Derive an expression for the magnifying power of an astronomical telescope in terms of the focal lengths of the objective and eyepiece.

(b) Calculate the magnifying power and separation of the lenses.

(c) Explain why the telescope is arranged in normal adjustment.

Answer: , separation = , M = 16, separation = 85 cm.

Item 3

A student sets up a telescope with an objective of 75 cm and an eyepiece of 2.5 cm to observe the moon. The final image is required to be at the near point of 25 cm.

(a) Determine the magnifying power of the telescope.

(b) Calculate the separation between the objective and eyepiece.

(c) Explain why viewing at the near point provides maximum angular magnification.

Answer: M = 33, separation = 77.273 cm.

Item 4

In an optics lab, a teacher sets up an astronomical telescope with an objective lens of 80 cm and an eyepiece of 5 cm. A distant object subtending an angle of 0.6° at the objective is viewed. Students are asked to determine the angular magnification, the separation of the lenses, and the size of the final image when the image is formed 25 cm in front of the eyepiece.

Answer: Angular magnification = 19.2, lens separation = 84.17 cm, image size = 5.03 cm.

Item 5

A student draws a ray diagram to show the action of a terrestrial telescope in normal adjustment.

(a) Sketch the diagram showing the path of light through the objective and eyepiece.

(b) List one advantage and one disadvantage of this telescope for terrestrial observations.

Answer: Advantage: upright image; Disadvantage: more complex lens system.

Item 6

A Galilean telescope is set up using a converging objective and a diverging eyepiece. The student is asked to:

(a) Draw a ray diagram showing its action in normal adjustment.

(b) Derive the expression for its magnifying power in terms of the focal lengths of the objective and eyepiece.
(c) Calculate the separation of the lenses if the magnifying power is 20 and the eyepiece focal length is 5 cm.
Answer: Separation = 95 cm.

Item 7
A student wants to observe a star using a combination of a convex lens and a diverging lens. The convex lens has a focal length of 60 cm, and the diverging lens has a focal length of 5 cm. The final image of the star is at 25 cm in front of the eyepiece.
(a) Draw a ray diagram to show the formation of the image.
(b) Calculate the angular magnification.
(c) List one advantage and one disadvantage of this arrangement over a standard astronomical telescope.
Answer: Angular magnification ≈ 9.6, advantage: compact design; disadvantage: smaller field of view.

Item 8
A compound microscope has an objective of focal length 5 cm and an eyepiece of focal length 4 cm. The distance between the lenses is 20 cm, and the final image is formed 25 cm in front of the eyepiece.
(a) Determine the position of the object in front of the objective.

(b) Calculate the magnifying power of the microscope.
(c) Explain the significance of the eyepiece and the eye-ring in producing a clear image.

Answer: Object position calculated via lens formula, magnifying power ≈ 31.25.

Item 9

An object of size 2.0 mm is placed 3.0 cm in front of the objective of a compound microscope. The objective has focal length 2.5 cm, and the eyepiece has focal length 5.0 cm. The final image is at the near point of the eye.
(a) Determine the size of the final image.
(b) Calculate the position of the eye-ring.
(c) Explain why the final image appears virtual and magnified.

Answer: Image size = 60 mm, eye-ring distance = 6.85 cm.

Item 10

A projector is required to project a 5.0 cm square slide onto a 5.0 m square screen. The focal length of the projection lens is 0.1 m.
(a) Determine the distance between the slide and the lens to obtain the required image size.
(b) Sketch a ray diagram showing the projection of the image.

(c) Explain how the magnification of the lens system depends on the object and image distances.
Answer: Lens formula and magnification formula used; image distance calculated to scale.

📘 Author: PCM

Physics Item Bank –Electrostatics (Scenario-Based, Copy-Friendly)

Item 1
Two scientists, Aisha and Brian, are experimenting with point charges in a vacuum chamber. They place charges A = 47.0 uC and B = 24.0 uC at a distance of 0.30 m apart. A third charge C = -35.0 uC is carefully introduced between A and B, 0.20 m from A. The scientists are tasked with calculating the net force acting on C.
(a) Determine the magnitude and direction of the forces acting on C due to A and B.
(b) Find the net force on C, indicating whether it is attractive or repulsive.
(c) Discuss the significance of the signs of charges in determining the direction of forces.
Answer: Net force on C = -643.2 N.

Item 2

Two researchers place point charges q1 = 5 uC and q2 = 2 uC in a liquid medium with relative permittivity epsilon_r = 9. The charges are separated by a distance of 0.05 m.
(a) Calculate the electrostatic force between the charges considering the effect of the medium.
(b) Explain how the presence of a liquid with a high dielectric constant affects the magnitude of the force.
Answer: Force = 3.998 N.

Item 3
Two small insulating metal spheres each carry a charge of 5 x 10^-8 C and are initially 0.06 m apart in air.
(a) Calculate the repulsive force when the spheres are in air.
(b) If the charges are doubled and the distance between spheres is halved, find the new force.
(c) If the spheres are then immersed in water (dielectric constant k = 81), determine the force of repulsion.
Answer: (a) 0.00625 N, (b) 0.1 N, (c) 7.7 x 10^-5 N.

Item 4
The electric field intensity at the surface of the Earth is approximately 1.2 x 10^2 V/m, directed towards the center of the Earth. Assume the Earth is a perfect sphere of radius 6.4 x 10^6 m.
(a) Calculate the total charge held by the Earth’s surface.

(b) Discuss the assumptions made about the Earth's shape and uniformity of charge in this calculation.
Answer: Charge = 5.46 x 10^5 C.

Item 5
A hollow spherical conductor of diameter 0.214 m carries a charge of 6.9 x 10^-10 C and is raised to a potential of 50 V.
(a) Determine the permittivity of the surrounding medium.
(b) Explain the relationship between the potential of a spherical conductor, its radius, and the surrounding medium.
(c) Discuss practical applications where controlling permittivity is important.

Item 6
Two point charges, 3 x 10^-9 C and -1 x 10^-9 C, are placed at points A and B respectively, separated by 0.2 m. A third point X lies on the line connecting A and B, somewhere between them.
(a) Determine the position BX where the electric potential at X is zero.
(b) Explain why the potential is zero at this point and how the magnitudes of the charges influence its location.
Answer: BX = 0.15 m.

Item 7

A physics student sets up an experiment with three point charges along a straight line: A = 10 uC, B = -6 uC, and C = 4 uC. Charge C is movable between A and B. The student needs to determine the position where the net force on C is zero.
(a) Derive the formula for equilibrium position based on Coulomb's law.
(b) Discuss how changing the magnitudes of charges affects the position of equilibrium.

Item 8
Two identical conducting spheres are charged and placed in a vacuum. The first carries a charge of 2 x 10^-8 C, while the second carries 8 x 10^-8 C. They are initially 0.1 m apart.
(a) Calculate the initial force of repulsion.
(b) If the spheres are connected with a thin conducting wire, find the new charges on each sphere and the resulting force.
(c) Discuss energy conservation in the process.

Item 9
A charged spherical conductor of radius 0.05 m is placed in air. A nearby test charge experiences a repulsive force.
(a) Determine the surface charge density if the conductor carries a charge of 1 x 10^-9 C.
(b) Calculate the electric field just outside the surface.

(c) Explain why the electric field inside a conductor is zero.

Item 10
Two point charges, q1 = 12 uC and q2 = -8 uC, are fixed on a line 0.40 m apart. A student places a small test charge between them and gradually moves it until the net force on the test charge is zero.
(a) Determine the exact location of zero net force.
(b) Explain how the relative magnitudes and signs of the charges affect the zero-force point.
(c) Discuss any practical applications where such equilibrium positions are useful.

📘 Author: JoelPCM

Capacitor Scenario Items

Item 1
A physics student is experimenting in the laboratory with a small capacitor connected to a DC supply of 30 V. After carefully charging the capacitor, she measures the total charge on its plates to be 6.0 μC. She wants to determine the basic characteristics of the capacitor for her report.
Calculate:
(i) The capacitance of the capacitor.

(ii) The energy stored in the capacitor.

Item 2

Two capacitors, one rated at 2 μF and another at 3 μF, are charged separately to voltages of 50 V and 1000 V respectively. A curious student wants to know how much charge is stored in each capacitor and the energy stored in them. Later, the student decides to connect the two capacitors with plates of the same charge connected together and wants to find the energy lost in the system.
Calculate:
(i) The charge stored in each capacitor.
(ii) The energy stored in each capacitor.
(iii) The energy lost when the capacitors are connected.

Item 3

In an experiment, a 100 μF capacitor is charged from a high voltage supply of 1000 V. The capacitor is then disconnected from the supply and connected in parallel with an uncharged 50 μF capacitor. The student is asked to calculate:
(i) The total energy stored initially and finally in the two capacitors.
(ii) The energy lost during the connection.

Item 4

A 20 μF capacitor is charged to a potential difference of 1000 V and then connected across an uncharged 60 μF capacitor. The student wants to determine the resulting voltage across the 60 μF capacitor after connection.

Item 5

A 10 μF capacitor is charged to 300 V. The student then connects it in parallel with an uncharged 60 μF capacitor. He is asked to calculate:

(i) The total energy stored in both capacitors before connection.

(ii) The total energy stored after connection.

Item 6

A 60 μF capacitor is charged from a 100 V supply. The student then connects it across an uncharged 15 μF capacitor and is asked to calculate:

(i) The final potential difference across the combination.

(ii) The energy lost during the process.

Item 7

A student charges a 20 μF capacitor to 40 V and then connects it across an uncharged 60 μF capacitor. Calculate the potential difference across the 60 μF capacitor after connection.

Item 8

An air capacitor of capacitance 400 μF is charged to 180 V. The student then connects it in parallel with an uncharged capacitor of 500 μF.

(i) Calculate the energy stored in the 500 μF capacitor after connection.

(ii) With the two capacitors still connected, a dielectric of dielectric constant 1.5 is inserted between the plates of the 400 μF capacitor while the plate separation remains the same. Calculate the new potential difference across the two capacitors.

Item 9

A battery of e.m.f 15 V is connected across a system of capacitors arranged in a series-parallel combination. The student wants to calculate:

(i) The charge on a 4 μF capacitor in the system.

(ii) The energy stored in a 1 μF capacitor in the system.

Item 10

. A 60 μF capacitor is charged from a 100 V supply. The student then connects it across the terminals of a 15 μF uncharged capacitor. Calculate:

(i) The final potential difference across the combination.

(ii) The difference in energy stored before and after connection, and comment on why the energy changes.

📘 Author: JoelPCM

Standard

Digital Electronics Scenario Items

Item 1

A student is designing a simple traffic light controller for a small intersection using digital electronics. The system requires three lights: Red, Yellow, and Green. He decides to use logic gates to control the lights such that:

Red light turns on if there are no cars on the main road and a car is detected on the side road.

Yellow light turns on for 2 seconds before switching from Red to Green.

Green light turns on if there are cars on the main road and no cars on the side road.
Draw the logic diagram using AND, OR, and NOT gates, and write the Boolean expression for each light.

Item 2

A student is building a digital temperature alarm system. The system uses three sensors to detect low, medium, and high temperature conditions. The outputs of the sensors are digital (1 for active, 0 for inactive). The alarm should sound only when the medium and high sensors are

active simultaneously, or when only the high sensor is active.
(i) Draw the truth table for the alarm output.
(ii) Derive the Boolean expression.
(iii) Draw the simplified logic circuit using logic gates.

Item 3
In a digital counter design laboratory, a student is asked to design a 3-bit synchronous up-counter using JK flip-flops. The counter should count from 0 to 7 and reset automatically.
(i) Draw the timing diagram showing the clock pulses and the counter output.
(ii) Write the excitation table for the JK flip-flops.
(iii) Draw the circuit diagram including the connections of the flip-flops.

Item 4
A student is designing a digital system for a vending machine that accepts coins of 5 and 10 cents. The machine should dispense a product when the total inserted amount reaches 20 cents. He wants to design the logic circuit to indicate when the total is enough.
(i) Define the inputs and outputs for the system.
(ii) Draw a truth table showing all possible input combinations and the corresponding output.

(iii) Simplify the Boolean expression using Karnaugh maps and draw the resulting logic circuit.

Item 5

A student is building a 4-bit binary adder using full adders to add two binary numbers. He wants to understand how carry is propagated through the adder.

(i) Draw the block diagram showing the connection of four full adders.

(ii) Explain with a timing diagram how the sum and carry outputs change when the binary numbers 1011 and 0110 are added.

(iii) Show the final sum in binary and decimal.

Item 6

A student is investigating a digital alarm system that uses an SR (Set-Reset) flip-flop to control the alarm. The alarm should remain on until a reset signal is received, regardless of subsequent inputs.

(i) Draw the truth table for the SR flip-flop.

(ii) Draw the circuit diagram showing how the SR flip-flop controls the alarm.

(iii) Explain what happens if both S and R inputs are activated at the same time.

Item 7

In a digital logic class, a student is asked to design a combinational circuit that determines if a three-digit binary number is even or odd.
(i) Define the inputs and outputs of the circuit.
(ii) Draw the truth table showing all possible 3-bit inputs and the corresponding output.
(iii) Derive the Boolean expression and simplify it.
(iv) Draw the logic circuit using AND, OR, and NOT gates.

Item 8
A student is designing a 4-bit digital lock system that unlocks when the correct sequence 1011 is entered. The system uses D flip-flops to store the sequence and logic gates to check correctness.
(i) Draw the state diagram for the lock system.
(ii) Explain how each input affects the state transitions.
(iii) Draw the circuit diagram showing D flip-flops and logic gates used.

Item 9
A student wants to design a binary to 7-segment display decoder. The decoder should take a 4-bit binary input and display the corresponding decimal number on a 7-segment LED.
(i) Draw the truth table showing the binary input and the segments that should be lit for digits 0 to 9.
(ii) Derive the Boolean expression for each segment.

(iii) Draw the logic circuit for one of the segments.

Item 10

In a digital electronics laboratory, a student is asked to design a priority encoder that accepts four inputs A, B, C, D and outputs a 2-bit binary code representing the highest-priority active input. Input D has the highest priority and A has the lowest.

(i) Draw the truth table showing all input combinations and the output code.

(ii) Write the Boolean expressions for the two output bits.

(iii) Draw the logic circuit using OR, AND, and NOT gates.

Author: JoelPCM

Standard

DIGITAL ELECTRONICS – ANSWERS ONLY

ANSWER 1

Binary of decimal 25

25 = 16 + 8 + 1

Binary = 11001

Binary of decimal 45

45 = 32 + 8 + 4 + 1

Binary = 101101

ANSWER 2
Binary 101101 to decimal

= (1 x 32) + (0 x 16) + (1 x 8) + (1 x 4) + (0 x 2) + (1 x 1)
= 32 + 8 + 4 + 1
= 45

ANSWER 3
Truth table for AND gate

A B Output
0 0 0
0 1 0
1 0 0
1 1 1

AND gate only gives output 1 when both inputs are 1.

ANSWER 4
Truth table for OR gate

A B Output
0 0 0
0 1 1
1 0 1
1 1 1

OR gate gives output 1 when at least one input is 1.

ANSWER 5
Truth table for NOT gate

Input Output
0 1
1 0

NOT gate inverts the input.

ANSWER 6
Boolean expression

Y = A AND B OR C

Using symbols removed:
Y = (A.B) + C

ANSWER 7
Simplification

Given expression:
Y = A.B + A.B'

Factor A

Y = A (B + B')

Since B + B' = 1
Y = A

ANSWER 8
Half adder

Sum = A XOR B
Carry = A AND B

Plain form:
Sum = A.B' + A'.B
Carry = A.B

ANSWER 9
Binary counter sequence (3 bit)

000
001
010
011
100
101
110
111

After 111 it resets to 000.

ANSWER 10
Flip flop memory function

A flip flop stores one bit of information.
Output remains unchanged until a clock signal causes a change.

S6 term 1
CIRCULAR MOTION

LONG SCENARIO-BASED ITEMS (UACE STANDARD)

Item 1
A particle is constrained to move uniformly along a horizontal circular path of radius 3.0 m. The motion is such that the particle maintains a constant angular velocity of 20 rad s^{-1} throughout the motion.
Determine:
(i) The linear speed of the particle
(ii) The angular velocity expressed in revolutions per second
(iii) The time taken by the particle to complete one full revolution

Item 2

Winnie and Annah are standing on a playground roundabout which rotates with a constant angular velocity about a vertical axis through its centre. Winnie stands 0.50 m from the centre while Annah stands 1.75 m from the centre.

If Annah is observed to move with a constant linear speed of 1.0 m s^{-1}, calculate:

(i) The angular velocity of the roundabout

(ii) The time taken for the roundabout to complete ten revolutions

(iii) The linear speed of Winnie

Item 3

A particle of mass 0.20 kg moves in a horizontal circular path under the action of a constant centripetal force of 4.0 N. The particle rotates with a constant angular velocity of 5.0 rad s^{-1}.

Calculate the radius of the circular path.

Item 4

A small body of mass 3.0 g moves uniformly in a horizontal circular path of radius 2.0 m. The body completes four revolutions per second.

Calculate the magnitude of the force required to maintain this circular motion.

Item 5

A bucket partially filled with water is tied to a strong rope and whirled in a vertical circle of radius 64 m. At the highest point of the motion, the bucket is completely upside down.
Determine the minimum speed the bucket must have at this point if the water is to remain in the bucket.

Item 6
An aeroplane performs a vertical loop of radius 200 m. At the top of the loop, the aeroplane is moving with a speed of 40 m s^{-1}.
If the pilot has a mass of 80 kg, calculate the tension in the strap holding the pilot firmly in the seat at the top of the loop.

Item 7
A particle of mass 0.20 kg is attached to one end of a light, inextensible string of length 0.50 m. The particle moves in a horizontal circle such that the string makes an angle θ with the vertical.
If the angular velocity of the particle is 5.0 rad s^{-1}, find the value of θ.

Item 8
A particle of mass 0.25 kg is attached to a light string of length 3.0 m and moves in a horizontal circular path such that the string sweeps out the surface of a cone.

If the maximum tension the string can withstand is 12 N, determine the maximum angular velocity of the particle.

Item 9

A car of mass 1000 kg moves around a circular banked track at a constant speed of 108 km h^{-1}. The radius of the track is 100 m.

Assuming that the total reaction at the wheels is normal to the surface of the track and that friction is negligible, calculate:

(i) The angle of inclination of the track to the horizontal

(ii) The reaction at the wheels

Item 10

A small stone tied to a light string is rotated in a horizontal circle above a smooth surface. The string remains taut and inclined at a constant angle to the vertical throughout the motion.

Using force analysis, explain how the stone maintains uniform circular motion and why the string does not slacken.

Author: JoelPCM

Standard

CIRCULAR MOTION
ANSWERS ONLY

Item 1

i. Linear speed equals 60 m per second

ii. Angular velocity equals 3.2 revolutions per second

iii. Time for one revolution equals 0.31 seconds

Item 2

i. Angular velocity equals 2 radians per second

ii. Time for ten revolutions equals 10 pi seconds

iii. Speed of Winnie equals 1.0 metres per second

Item 3

Radius of the circular path equals 0.8 metres

Item 4

Centripetal force required equals 3.8 newtons

Item 5

Minimum speed at the top equals 25.06 metres per second

Item 6

Tension in the strap at the top of the loop equals 60 newtons

Item 7

Angle made with the vertical equals 37 degrees

Item 8
Maximum angular velocity equals 4 radians per second

Item 9
i. Angle of inclination equals 42.53 degrees
ii. Reaction at the wheels equals 13314 newtons

Item 10
Uniform circular motion is maintained by a constant force acting towards the centre of the circular path.

Author: JoelPCM

SIMPLE HARMONIC MOTION
LONG SCENARIO ITEMS

Item 1
A particle is constrained to move along a straight line and executes simple harmonic motion about a fixed mean position O. During its motion, the particle is observed as it passes through two positions on opposite sides of O. When the particle is 2.0 metres from O, its speed is measured to be 3.0 metres per second. Later, when it is

2.4 metres from O, its speed is found to be 1.4 metres per second.
Using this information, determine:
i. The amplitude of the motion
ii. The greatest speed attained by the particle
iii. The maximum acceleration of the particle
iv. The speed of the particle when it is 1.0 metre from O

Item 2
A particle moves with simple harmonic motion along a straight horizontal line. The motion has a period of 16 seconds and an amplitude of 10 metres.
Calculate:
i. The speed of the particle when it is 6.0 metres from the equilibrium position
ii. The distance of the particle from the equilibrium position 1.5 seconds after it passes through the equilibrium position
iii. The speed of the particle at this instant

Item 3
A simple pendulum is observed to oscillate with a period of 1.5 seconds when it is suspended at the surface of the Earth. The pendulum is then taken to a point at a height of 6000 kilometres above the Earth's surface.

Assuming the radius of the Earth to be 6400 kilometres and neglecting air resistance, calculate the new period of oscillation of the pendulum at this height.

Item 4

A hydrometer floats upright in a liquid inside a tall transparent container. The hydrometer is gently pulled downwards through a small distance and then released. By considering the forces acting on the hydrometer when it is displaced slightly from its equilibrium position, show that the subsequent motion of the hydrometer is simple harmonic.

Item 5

A platform is made to move vertically up and down with simple harmonic motion of period T and amplitude A. A small particle of mass m is placed on the platform and remains in contact with it during the motion.

i. Derive an expression, in terms of g, T and x, for the reaction force exerted by the platform on the particle when the particle is at a displacement x from the mean position.

ii. If the platform vibrates with a period of 0.5 seconds, determine the maximum amplitude of oscillation that allows the particle to remain in contact with the platform throughout the motion.

Item 6

A light vertical spring is suspended from a rigid support. When a mass of 0.40 kilogram is attached to its lower end, the spring extends by 0.060 metres. The mass is then pulled down an additional 0.060 metres and released from rest.

Assuming that the spring obeys Hooke's law and that air resistance is negligible, calculate the kinetic energy of the mass as it passes through the midpoint of its motion.

Item 7

A horizontal spring of force constant 200 newtons per metre is fixed at one end to a rigid support. A mass of 2.0 kilograms is attached to the free end of the spring and rests on a smooth horizontal surface. The mass is pulled through a distance of 4.0 centimetres from its equilibrium position and released.

Calculate:

i. The angular speed of the oscillating mass

ii. The maximum speed attained by the mass

iii. The acceleration of the mass when it is halfway back towards the equilibrium position from its extreme position

Item 8

A particle executes simple harmonic motion along a straight line. The speed of the particle is observed to be 4.0 metres per second when it is 3.0 centimetres from the equilibrium position. At another instant, the speed is found

to be 2.0 metres per second when the particle is 6.0 centimetres from the equilibrium position.
Calculate:
i. The amplitude of oscillation
ii. The frequency of the motion

Item 9
A body of mass 1.0 kilogram moves with simple harmonic motion along a straight line. When the body is 0.10 metres from its equilibrium position, its speed is 5.0 metres per second. When it is 0.20 metres from equilibrium, its speed is 3.0 metres per second.
Determine the amplitude of the motion.

Item 10
A mass of 1.0 kilogram is suspended from two light springs connected in series and attached to the ceiling. The force constants of the springs are 100 newtons per metre and 200 newtons per metre respectively.
i. Calculate the total extension produced by the combination of the two springs when the mass is attached.
ii. If the mass is pulled downwards slightly and released, determine the frequency of oscillation of the system.

Author: JoelPCM

Standard

SIMPLE HARMONIC MOTION
ANSWERS ONLY

Item 1

i. Amplitude equals 2.5 metres
ii. Maximum speed equals 5.0 metres per second
iii. Maximum acceleration equals 5.0 metres per second squared
iv. Speed at 1.0 metre from O equals 4.58 metres per second

Item 2

i. Speed at 6.0 metres equals 3.1 metres per second
ii. Distance from equilibrium after 1.5 seconds equals 5.6 metres
iii. Speed at that instant equals 3.3 metres per second

Item 3

Period at height equals 2.91 seconds

Item 4

The hydrometer executes simple harmonic motion.

Item 5

i. Reaction equals m times g minus four pi squared x divided by T squared

ii. Maximum amplitude equals 0.031 metres

Item 6
Kinetic energy at midpoint equals 0.12 joules

Item 7
i. Angular speed equals 10 radians per second
ii. Maximum speed equals 0.40 metres per second
iii. Acceleration equals 2.0 metres per second squared

Item 8
i. Amplitude equals 0.067 metres
ii. Frequency equals 10.68 hertz

Item 9
Amplitude equals 0.24 metres

Item 10
i. Total extension equals 0.098 metres
ii. Frequency of oscillation equals 1.3 hertz

Author: JoelPCM

GRAVITATION

LONG SCENARIO ITEMS (UACE STANDARD)

Item 1

The acceleration due to gravity at the surface of the Earth is g. Consider a point located vertically above the Earth's surface along the line joining the centre of the Earth to the point.

Determine the distance of this point from the Earth's surface at which the acceleration due to gravity is reduced to one eighth of its value at the Earth's surface.

Item 2

A body is observed to weigh 63 newtons when placed on a spring balance at the surface of the Earth. The body is then raised vertically to a height above the Earth's surface equal to half the radius of the Earth.

Assuming the Earth to be a uniform sphere, calculate the apparent weight of the body at this height.

Item 3

A satellite of mass 1000 kilograms is launched from the Earth's surface into a circular orbit of radius 7.2 times ten to the power six metres about the Earth.

Given that the mass of the Earth is 6.0 times ten to the power twenty four kilograms and the universal gravitational constant is 6.67 times ten to the power minus eleven newton metre squared per kilogram squared, calculate the total mechanical energy of the satellite in orbit.

Item 4
An artificial satellite is launched to orbit the Earth at a height of 3.6 times ten to the power seven metres above the Earth's surface.
i. Calculate the speed with which the satellite must be launched in order to remain in this circular orbit.
ii. Determine the period of revolution of the satellite about the Earth.

Item 5
State Kepler's three laws of planetary motion and briefly explain the physical meaning of each law in relation to the motion of planets around the Sun.

Item 6
Using Newton's law of universal gravitation, derive the dimensions of the universal gravitational constant. Clearly state all assumptions made during the derivation.

Item 7
A satellite revolves in a circular orbit at a height h above the surface of the Earth with a period T.

i. Starting from Newton’s law of gravitation and the expression for centripetal force, show that the acceleration due to gravity at the Earth’s surface is given by
g equals four pi squared multiplied by the cube of the sum of the Earth’s radius and h, divided by T squared times the square of the Earth’s radius.
ii. Explain the physical meaning of each symbol used in the expression.

Item 8
Explain what is meant by a parking orbit and state two reasons why satellites are often placed in parking orbits before being transferred to their final operational orbits.

Item 9
A satellite revolves in a circular orbit at a height of 600 kilometres above the Earth’s surface.
Assuming the radius of the Earth to be constant and air resistance to be negligible, calculate:
i. The speed of the satellite
ii. The period of revolution of the satellite

Item 10
Discuss how the variation of gravitational acceleration with altitude affects the motion and stability of artificial satellites orbiting the Earth.

Your answer should make reference to orbital speed, period and mechanical energy.

Author: JoelPCM

Standard

GRAVITATION
ANSWERS ONLY
Item 1
Distance from the Earth’s surface equals 1.18 times ten to the power seven metres

Item 2
Weight at the given height equals 28 newtons

Item 3
Total mechanical energy of the satellite equals minus 2.78 times ten to the power ten joules

Item 4
i. Orbital speed equals 3.08 times ten to the power three metres per second
ii. Period of the satellite equals 24 hours

Item 5

First law: Planets move in elliptical orbits with the Sun at one focus
Second law: The line joining a planet to the Sun sweeps out equal areas in equal times
Third law: The square of the period of a planet is proportional to the cube of the radius of its orbit

Item 6

Dimensions of the universal gravitational constant are metre cubed per kilogram per second squared

Item 7

i. Acceleration due to gravity at the Earth's surface is given by
four pi squared multiplied by the cube of the sum of the Earth's radius and h, divided by T squared times the square of the Earth's radius
ii. r e is the radius of the Earth, h is the height above the Earth's surface, T is the period of revolution

Item 8

A parking orbit is a temporary orbit in which a satellite is placed before being transferred to its final orbit

Item 9

i. Speed of the satellite equals 7.57 times ten to the power three metres per second

ii. Period of revolution equals 5805 seconds

Item 10
Gravitational acceleration decreases with altitude, reducing the required orbital speed and increasing the orbital period of satellites.

Author: JoelPCM

Standard

WAVES
LONG SCENARIO ITEMS

Item 1
A progressive wave travels through a stretched string with a constant speed of 80 metres per second . At the same time, a stationary wave of the same frequency and wave speed is formed on a similar string fixed at both ends.
i. Calculate the phase difference between two points on the progressive wave that are 6.0 centimetres apart along the direction of wave travel.
ii. Determine the distance between two successive nodes in the stationary wave.

Item 2

A transverse wave travels along a rope with an amplitude of 0.20 metres, a wavelength of 2.0 metres and a frequency of 50 hertz. At time t equals zero, the displacement of the rope at position x equals zero and the wave is travelling in the positive x direction.
i. Write down an expression for the displacement of the wave at any position x and at any time t.
ii. Calculate the speed of the wave.

Item 3
Two sound waves of frequencies 256 hertz and 280 hertz are produced by two tuning forks and travel through air at a constant speed of 340 metres per second. The waves are initially in phase at a certain point in the medium. Calculate the phase difference between the two waves at a point 2.0 metres away from the point where they were initially in phase.

Item 4
A wave source generates a progressive wave that travels through a medium with constant speed. The wave is observed to have a frequency of 240 hertz and produces a stationary wave when reflected at a rigid boundary. Explain how the positions of nodes and antinodes are formed in the stationary wave and determine the spacing between successive nodes

Item 5
A sinusoidal wave is generated by a vibration generator attached to a long stretched string. The wave travels with a constant speed and produces points along the string that vibrate with different phase differences.
Using appropriate wave relations, explain how phase difference depends on distance along the string and determine the phase difference between two points separated by a small distance along the direction of wave travel.

Author: JoelPCM

Standard

(i) A police car sounds a siren of 1000 Hz as it approaches a stationary observer. What is the apparent frequency of the siren as heard by the observer if the speed of sound in air is 340?
(ii) Give any three applications of the Doppler effect
(b) An observer standing by the roadside hers sound of frequency 600 Hz coming from the horn of an approaching car. When the car passes, the frequency appears to change to 560 Hz. Given that the speed of sound in air is 320 ms – 1
, calculate the speed of the car. (5 marks)

6. (a) Describe briefly one application of the Doppler effect (2 marks)
(b) (i) Derive an expression for the frequency of sound observed by a stationary observer infront of a source moving with a velocity U m/s and emitting f pulse each second given that speed of sound on the day is C m/s
(ii) A police car travelling at 108 km/hr is chasing a lorry which is travelling at 72 km/hr. The police car given Emits sound of frequency 400 Hz as it approaches the lorry. Calculate the apparent frequency of the note heard by the lorry driver.
7. (a) (i) Define Doppler effect as applied to sound (1)
(ii) Explain briefly how Doppler effect can be used to measure the star (3)
(iii) A stationery police car by the roadside emits a siren of frequency fs infront of an approaching taxi moving at a speed of vm/s. Find the expression for frequency received by the taxi driver if the speed of sound on that day was C m/s (3)
(b) A police car operating its siren of frequency 384 Hz travels at 90km/hr. Another car travels at 72 km/h. Given that the speed of sound on the day is 340 m/s, calculate the apparent frequency of the siren as heard by the occupants of the second car if they are travelling away from the police car. (4)

(ii) A police car sounds a siren of 1000 Hz as it approaches a stationary observer. What is the apparent frequency of the siren as heard by the observer if the speed of sound in air is
340ms – 1
(3 marks)
(iii) State one application of the Doppler effect (1 mark)
9. (a) (i) Explain Doppler effect (2 marks)
(ii) A car travelling at 10ms – 1
sounds its horn that sends sound waves of frequency 500Hz and this
is heard in another car which is travelling behind the first one in the same direction with a
velocity of 20 ms – 1
. What frequency will be heard by
(i) the driver of the second car? (3 marks)
(ii) an observer standing some distance ahead of the first car
(velocity of sound in air = 330 ms – 1
) (3 marks)
(b) (i) Define Doppler effect as applied to sound (1)
(ii) Explain briefly how Doppler effect can be used to measure the star

These have been extraced from someone's book

S6 Term 2
CURRENT ELECTRICITY

Item 1

James bought a new electric fire for his living room. The nichrome heating element inside the fire has a resistance of 50 ohms at 20 degrees Celsius. When he plugs it into the 240 V mains supply, a current of 4 A flows. James is curious to know how hot the fire will get while operating steadily. Using the temperature coefficient of resistance of nichrome, which is 2.0 × 10^-4 per Kelvin, calculate the steady temperature reached by the fire.

Item 2

A science lab technician has a wire made of a special alloy. The wire has a resistivity of 1.6 × 10^-7 ohm meters at 30 degrees Celsius. The technician wants to find out how the resistivity changes when the wire is heated to 80 degrees Celsius, given that the temperature coefficient of resistance is 6.0 × 10^-3 per Kelvin.

Item 3

Mary wants to test how much energy her new nichrome heating coil can transfer to water. She makes a coil from a nichrome wire of length 1 meter and diameter 0.72 mm at 25 degrees Celsius. She immerses the coil in 200 cm^3 of water at 25 degrees Celsius and passes a current of 5 A through it for 8 minutes. After this time, the water starts boiling at 100 degrees Celsius. Calculate:

(i) the resistance of the coil at 25 degrees Celsius
(ii) the electrical energy expended if all the energy goes into heating the water
(iii) the mean temperature coefficient of resistance of nichrome between 0 and 100 degrees Celsius

Item 4
A battery of unknown emf and internal resistance is connected across a variable resistor in a physics experiment. When the resistor is set at 21 ohms, the current through it is 0.48 A. When the resistor is adjusted to 36 ohms, the current drops to 0.30 A. Determine the emf of the battery and its internal resistance.

Item 5
Samantha is experimenting with a small cell connected in series with a resistor of 2 ohms. She observes a current of 0.25 A flowing through the circuit. She then connects a second resistor of 2 ohms in parallel with the first. The current through the cell changes to 0.3 A. Calculate the internal resistance and the emf of the cell.

Item 6
Two resistance coils, P and Q, are placed in the gaps of a metre bridge by a student trying to measure unknown resistances. A balance point is first found when the movable contact touches the bridge wire at 35.5 cm from

the end connected to coil P. The student then shunts coil Q with a 10 ohm resistor, and the balance point moves by 15.5 cm. Find the resistances of P and Q.

Item 7

In another experiment, a student sets up a metre bridge with a known 2 ohm resistor in the left gap and an unknown resistor in the right gap. The balance point is found at 40 cm from the zero end of the bridge wire. The student then shunts the unknown resistor with 2 ohms and observes the new balance point. Determine the shift in the balance point on the bridge wire.

Item 8

A physics student is using a slide wire setup to determine an unknown resistance. With a certain resistance in the left gap, the balance point is obtained when a resistance of 10 ohms is taken from the resistance box. Later, the student increases the resistance in the box by 12.5 ohms, and the balance point shifts by 20 cm. Find the value of the unknown resistance.

Item 9

During a demonstration, a teacher sets up a nichrome wire in series with a 100 ohm resistor connected to a 12 V battery. The students measure the current and want to calculate the heating effect on the wire. Determine the energy dissipated in the wire over 5 minutes if the current remains constant.

Item 10
Alex designs a small heating coil for an experiment. He knows the wire has a diameter of 1 mm, length 2 meters, and resistivity 1.7 × 10^-7 ohm meters at 20 degrees Celsius. The coil is connected to a variable 12 V supply. He gradually increases the voltage and wants to calculate the temperature reached when a current of 2 A is flowing, assuming the temperature coefficient of resistance is 0.0002 per Kelvin.

Author: JoelPCM

Standard

Answer 1
Steady temperature of the nichrome element: 1024.1 °C

Answer 2
Resistivity of the wire at 80 °C: 2.01 × 10^-7 Ω·m

Answer 3
(i) Resistance of the coil at 25 °C: 0.496 Ω
(ii) Electrical energy expended: 4800 J

(iii) Mean temperature coefficient of resistance of nichrome (0–100 °C): 2.0 × 10^-3 K^-1

Answer 4
Emf of the battery: 12 V
Internal resistance: 4 Ω

Answer 5
Internal resistance of the cell: 4 Ω
Emf of the cell: 1.5 V

Answer 6
Resistance of coil P: 16 Ω
Resistance of coil Q: 35 Ω

Answer 7
Shift of the balance point on the bridge wire: 22.5 cm

Answer 8
Value of the unknown resistance: 15 Ω

Answer 9
Energy dissipated in the nichrome wire over 5 minutes: 360 J

Answer 10
Steady temperature of the coil: 518.5 °C

Author: JoelPCM

Standard

ELECTROMAGNETISM

Item 1

A physics teacher, Mr. Joel, decided to demonstrate magnetic effects to his students. He has a vertical square coil of side 5 cm, wound with 100 turns of wire, carrying a current of 1 A. He places the coil in a horizontal magnetic field of 0.2 T such that the plane of the coil makes an angle of 30° with the field. Mr. Joel asks his students to calculate the torque acting on the coil and explain the effect of changing the angle on the torque.

Item 2

During a practical lesson, Anna sets up a vertical square coil of side 15 cm with 200 turns, carrying a current of 2 A. She places it in a horizontal magnetic field of 0.3 T, making an angle of 30° with the field. Her lab partner asks her to calculate the initial torque on the coil and predict what happens if the current is doubled.

Item 3

David suspends a vertical rectangular coil from its upper side in his lab. The coil has 50 turns, vertical length 4 cm, horizontal length 5 cm, and carries a current of 4 A. The uniform horizontal magnetic field is 0.06 T. He wants to know the torque acting on the coil when it is placed in the field. How would the torque change if the current is halved?

Item 4

Sophie is designing a voltmeter for her science project. Her galvanometer has a full-scale deflection for 15 mA and internal resistance of 5 Ω. She wants it to measure a maximum p.d of 15 V. Help Sophie calculate the value of the series resistor (multiplier) needed to safely measure this voltage.

Item 5

Michael has a moving coil galvanometer with resistance 0.5 Ω and full-scale deflection of 2 mA. He wants to modify it to read voltages up to 10 V. Determine the series resistor required for this modification and explain why it protects the galvanometer from damage.

Item 6

Leah has a galvanometer (resistance 0.5 Ω, full-scale 2 mA) and wants to measure a high current of 6 A. What shunt resistor should she use to allow her galvanometer to measure this current safely without burning out?

Item 7

Alex has a moving coil galvanometer with 5 Ω resistance and 15 mA full-scale deflection. He wants to measure a current of 3 A using this galvanometer. Determine the value of the shunt resistor he needs and explain the principle behind shunting.

Item 8

Nina has a galvanometer with internal resistance 20 Ω and full-scale deflection of 5 mA. She wants to convert it into:

(i) A 1.0 A ammeter, and

(ii) A 100 V voltmeter.

Determine the resistances she should connect in each case.

Item 9

During a lab session, Ethan has a milliameter of full-scale reading 0.01 A and resistance 20 Ω. He wants to measure up to 10 V across a circuit. Determine the value of the series resistor needed to safely convert the milliameter into a voltmeter.

Item 10

A group of students—Alice, Brian, and Carla—are exploring torque and galvanometer modifications in their physics lab. They set up various coils and galvanometers and record their measurements. Using the data: coil dimensions, number of turns, current, magnetic field strength, and galvanometer specifications, they are asked to calculate: torque, series resistor for voltmeters, and shunt resistances for high currents. Students must explain each calculation and how the changes affect the readings.

Author: JoelPCM

Standard

Answers

1. Torque = 2.34 N·m

2. Torque = 2.34 N·m

3. Torque = 6 × 10^{-3} N·m

4. Series resistor (multiplier) = 995 Ω

5. Series resistor = 4999 Ω

6. Shunt resistor = 1.67 × 10^{-4} Ω

7. Shunt resistor = 0.025 Ω

8. (i) Shunt for ammeter = 1.05 Ω; (ii) Series resistor for voltmeter = 1980 Ω

9. Series resistor = 980 Ω

10. Calculated values depend on specific sub-questions:

- Torque calculations as above (2.34 N·m, 6 × 10^{-3} N·m)
- Series resistors and shunts as above (995 Ω, 4999 Ω, 0.025 Ω, 1.05 Ω, 1980 Ω, 980 Ω)

Author: JoelPCM

scenario-based A-level physics items combining AC circuits, electromagnetic induction, magnetic effects, and electric current.

Item 1
Daniel is designing a home automation system where alternating current (AC) supplies several appliances. He connects a 240 V, 50 Hz AC mains supply to a series combination of a 50 Ω resistor, a 0.2 H inductor, and a 50 μF capacitor. He wants to calculate the total current drawn by the circuit, the phase difference between the voltage and current, and the power consumed by the resistor. Additionally, Daniel notices that when the inductor is switched on, a magnetic field is produced that can induce a small EMF in a nearby copper coil. Determine the current, phase angle, power, and the induced EMF in the nearby coil.

Item 2

A physics student, Amina, experiments with a solenoid connected to a 12 V DC source. She measures the magnetic flux density inside the solenoid and observes how changing the current affects the field. She then connects the solenoid to an AC source and notices a current induced in a nearby secondary coil due to electromagnetic induction. Amina wants to calculate the induced EMF, the peak current in the secondary coil, and the total energy stored in the magnetic field of the solenoid. Describe how she can perform these calculations and the relationships between AC current, magnetic field, and induced EMF.

Item 3

During a school science fair, Peter sets up a rotating coil of area 0.05 m^2 with 200 turns in a uniform magnetic field of 0.3 T. The coil is rotated at 50 revolutions per second. He connects the coil to a resistive load and measures the AC voltage and current generated. Peter needs to determine the peak voltage, RMS voltage, and instantaneous current in the resistor. He also wants to explain how the alternating magnetic flux generates the EMF in the coil and relate it to Faraday’s law.

Item 4

Lydia is building an electromagnet using a soft iron core and a coil of wire. When connected to a DC source, the magnetic field produced is strong enough to lift small metallic objects. She then experiments by connecting the same coil to an AC supply of 60 Hz and notices that the magnetic field now oscillates, generating an alternating current in a nearby secondary coil. Calculate the maximum flux, induced EMF in the secondary coil, and the average power delivered to a resistive load connected to it. Explain the effect of AC frequency on the induced EMF.

Item 5
Two friends, John and Mary, are investigating the magnetic effect of a current-carrying wire. They hang a rectangular wire loop vertically and pass a current of 5 A through it in the presence of a horizontal magnetic field of 0.2 T. They want to calculate the torque acting on the loop, the work done in rotating the loop through 90°, and how this setup could be used in an AC generator if the current were alternating. Determine the torque, work done, and induced EMF if the current alternates at 60 Hz.

Item 6
A small laboratory project involves an AC generator with a coil of 150 turns, each turn having an area of 0.02 m^2, rotating in a uniform magnetic field of 0.5 T at a frequency of 50 Hz. The students want to calculate the peak EMF,

RMS voltage, and instantaneous power delivered to a resistive load. Additionally, they explore how the magnetic flux linkage changes over time and how it affects the induced current in the circuit.

Item 7

Grace builds a transformer with a primary coil of 500 turns and a secondary coil of 100 turns. The primary is connected to a 240 V, 50 Hz AC supply. She wants to calculate the voltage across the secondary coil, the current if a 12 Ω resistive load is connected, and the power transferred. Grace also notes that the changing magnetic field in the core induces EMF in the secondary coil. Calculate the secondary voltage, current, and power, and explain the magnetic induction process.

Item 8

During an experiment, a wire of length 0.5 m is moved perpendicular to a uniform magnetic field of 0.4 T at a speed of 2 m/s. The wire is part of a closed circuit with a resistance of 4 Ω. Calculate the induced EMF, current in the wire, and power dissipated. Explain how the motion of the conductor in a magnetic field produces electricity and relate it to electromagnetic induction in AC circuits.

Item 9

Sam attaches a capacitor of 20 μF in series with a 40 Ω resistor and a 0.1 H inductor to a 120 V, 60 Hz AC supply. He wants to study the resonance condition by varying the AC frequency. Determine the resonant frequency, the impedance at resonance, the current in the circuit, and the voltage across each component at resonance. Explain how resonance affects the magnetic field in the inductor and the energy stored in the capacitor.

Item 10
A rectangular coil of 50 turns and area 0.03 m^2 is placed in a time-varying magnetic field given by B = 0.1 sin(314t) T. The coil is connected to a resistive load of 8 Ω. Calculate the maximum induced EMF, the instantaneous current, and the power dissipated in the resistor. Discuss how the alternating magnetic field induces a current and how this principle is applied in AC generators.

Author: JoelPCM

Standard

Answers
Item 1:
Total current: 3.0 A
Phase angle: 30 degrees
Power consumed by resistor: 450 W

Induced EMF in nearby coil: 0.12 V

Item 2:
Induced EMF in secondary coil: 0.48 V
Peak current in secondary coil: 0.024 A
Energy stored in solenoid magnetic field: 0.144 J

Item 3:
Peak voltage: 30 V
RMS voltage: 21.2 V
Instantaneous current in resistor: 0.53 sin(314 t) A

Item 4:
Maximum flux: 0.003 Wb
Induced EMF in secondary: 0.36 V
Average power delivered: 0.045 W

Item 5:
Torque on loop: 0.25 N·m
Work done to rotate 90 degrees: 0.25 J
Induced EMF with AC current: 1.26 V

Item 6:
Peak EMF: 300 V
RMS voltage: 212 V
Instantaneous power delivered: 3.6 sin^2(314 t) W

Item 7:
Secondary voltage: 48 V
Current through 12 ohm load: 4 A
Power transferred: 192 W

Item 8:
Induced EMF: 0.4 V
Current in wire: 0.1 A
Power dissipated: 0.04 W

Item 9:
Resonant frequency: 39.9 Hz
Impedance at resonance: 40 ohm
Current at resonance: 3.0 A
Voltage across resistor: 120 V
Voltage across inductor and capacitor: 120 V

Item 10:
Maximum induced EMF: 0.15 V
Instantaneous current: 0.01875 sin(314 t) A
Power dissipated: 0.035 W

Author: JoelPCM

S6 Term 3

20 long, story-based scenario items that integrate atomic particles, quantum theory, and nuclear processes

Item 1
Sanyu is working in a laboratory studying radioactive isotopes. She observes that a sample of Uranium-238 emits alpha particles and decays over time. If she measures that after 4.5×10^9 years only half the sample remains, calculate the half-life of Uranium-238 and explain the type of nuclear decay involved.

Item 2
Brian is using a particle accelerator to study electrons. He accelerates electrons through a potential difference of 500 V. Determine the kinetic energy gained by each electron and explain the quantum principle that relates energy levels in atoms to absorbed or emitted energy.

Item 3
A neutron source is used by Aisha to initiate a nuclear reaction in a small sample of Boron-10. The reaction produces Lithium-7 and an alpha particle. Describe the reaction and calculate the mass defect if the masses of Boron-10, Lithium-7, and alpha particle are 10.0129 u, 7.0160 u, and 4.0026 u respectively.

Item 4
Tom is investigating the photoelectric effect. He shines ultraviolet light of frequency 1.2 × 10^15 Hz on a metal surface with work function 4.5 × 10^-19 J. Calculate the maximum kinetic energy of the emitted electrons and explain how this supports quantum theory over classical wave theory.

Item 5
A sample of Carbon-14 is used in radiocarbon dating by Fatima. If the half-life of Carbon-14 is 5730 years and a sample now contains 25% of its original Carbon-14, estimate the age of the sample. Discuss the role of nuclear decay in dating ancient artifacts.

Item 6
A proton is accelerated in a cyclotron to a speed of 2 × 10^7 m/s. Determine its de Broglie wavelength and discuss how wave-particle duality is observed in experiments involving electrons and protons.

Item 7
Lydia is analyzing energy levels of a hydrogen atom. When an electron transitions from n = 4 to n = 2, it emits a photon. Calculate the energy of the photon and describe

how this relates to the quantization of atomic energy levels.

Item 8
During a laboratory demonstration, a source emits beta particles. Joseph measures the energy spectrum of the emitted electrons. Explain why beta decay produces a continuous spectrum and how this led to the proposal of the neutrino by Pauli.

Item 9
A small nuclear reactor uses Uranium-235 as fuel. Sam observes that when a Uranium-235 nucleus absorbs a neutron, it splits into Barium-141 and Krypton-92, releasing additional neutrons. Calculate the number of neutrons produced per fission and explain how this sustains a chain reaction.

Item 10
A gamma-ray source emits photons of energy 1.25 MeV. Fatouma uses a Geiger-Müller counter to detect these photons. Discuss the origin of gamma radiation in nuclear decay and calculate the frequency of the emitted gamma photons.

Item 11

A helium nucleus (alpha particle) is accelerated through a potential difference of 2000 V. Calculate the kinetic energy gained and the de Broglie wavelength. Discuss the significance of alpha particle scattering experiments in discovering the nucleus.

Item 12

A radioactive isotope decays via beta-minus emission. The isotope emits electrons and transforms into a new element. Explain the changes in atomic and mass numbers, and calculate the energy released if the mass difference is 0.002 u.

Item 13

A student, Peter, shines light on a sodium surface and observes photoelectrons. If the stopping potential is 0.55 V and the light frequency is 6.0×10^{14} Hz, calculate Planck's constant from the experiment and explain its significance in quantum theory.

Item 14

During a nuclear fusion experiment, deuterium nuclei combine to form helium-3 and release energy. If the mass of deuterium is 2.014 u and helium-3 is 3.016 u, calculate the energy released per fusion reaction using $E = \Delta mc^2$.

Item 15

Mary studies X-ray emission from a metal target. She observes discrete X-ray lines corresponding to transitions of inner-shell electrons. Explain how this supports Bohr's quantum model of the atom.

Item 16

A nucleus of Thorium-232 undergoes alpha decay. Calculate the kinetic energy of the alpha particle if the mass defect is 0.004 u. Discuss how alpha decay conserves energy, momentum, and charge.

Item 17

During an experiment, a magnetic field deflects electrons moving at high speed. Alex calculates the radius of curvature of the path. Discuss the relationship between magnetic force, charge, velocity, and radius, and how this is used to determine the charge-to-mass ratio of the electron.

Item 18

A positron emitted from a radioactive isotope collides with an electron, producing gamma photons. Describe the process of annihilation and calculate the energy of each photon if the rest mass of the electron is 9.11 × 10^-31 kg.

Item 19

A uranium nucleus undergoes fission producing a mass defect of 0.2 u per fission. Calculate the energy released in joules and discuss how this energy is harnessed in nuclear power stations.

Item 20
Fatima is analyzing the spectrum of hydrogen and measures the wavelength of the Lyman-alpha line. Use the Rydberg formula to calculate the wavelength and explain the significance of discrete spectral lines in supporting the quantum model of the atom.

Author: JoelPCM

Standard

Answers

Item 1: Half-life of Uranium-238 = 4.5 × 10^9 years; Alpha decay.

Item 2: Kinetic energy gained by electron = 8.0 × 10^-17 J; Energy quantization: .

Item 3: Mass defect = 0.0063 u; Reaction: .

Item 4: Maximum kinetic energy of electrons = 3.9 × 10^-19 J.

Item 5: Age of sample ≈ 11,460 years; decay of Carbon-14 used for dating.

Item 6: De Broglie wavelength = 3.31 × 10^-14 m; Wave-particle duality confirmed.

Item 7: Energy of photon emitted = 4.58 × 10^-19 J.

Item 8: Continuous beta spectrum explained by neutrino emission.

Item 9: Number of neutrons produced per fission = 2–3; chain reaction sustained.

Item 10: Frequency of gamma photon = 3.02 × 10^20 Hz; gamma radiation from nuclear transitions.

Item 11: Kinetic energy = 3.2 × 10^-16 J; de Broglie wavelength = 7.27 × 10^-15 m.

Item 12: Atomic number increases by 1, mass number unchanged; Energy released = 1.86 × 10^-13 J.

Item 13: Planck's constant ≈ 6.63 × 10^-34 J·s.

Item 14: Energy released per fusion = 2.7 × 10^-13 J.

Item 15: Discrete X-ray lines confirm quantized energy levels in atoms.

Item 16: Kinetic energy of alpha particle ≈ 3.73 × 10^-13 J.

Item 17: Radius of curvature ; charge-to-mass ratio determined.

Item 18: Energy of each gamma photon = 8.19 × 10^-14 J.

Item 19: Energy released per fission = 3.0 × 10^-11 J.

Item 20: Wavelength of Lyman-alpha ≈ 1.216 × 10^-7 m; discrete spectral lines support Bohr model.

Author: JoelPCM

The end

Wow! We've finally reached the end of The Physics Item bank by Author joelPCM. It has been an incredible journey exploring the depth and beauty of

physics together. I hope this collection of scenarios, challenging problems, and carefully thought-out items has not only sharpened your problem-solving skills but also inspired a deeper curiosity about the world around us.

Remember, physics is more than just formulas—it's a way of thinking, questioning, and understanding the universe. Keep practicing, stay curious, and never stop exploring. Thank you for trusting this book as your guide; it has been an honor to share this journey with you.

Keep pushing boundaries, and may your love for physics continue to grow!

— Author joelPCM

If you notice any errors, omissions, or have suggestions to improve this book, I would love to hear from you. Please feel free to reach out to me at:

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Your feedback is highly valued and will help make this resource even better for all physics learners.