COMPLETE UACE/UNEB PHYSICS REFERENCE HANDBOOK

EXAMINER'S PREFACE

This comprehensive reference is designed specifically for Uganda Advanced Level Physics candidates following the UNEB syllabus. It is structured to align precisely with UNEB marking schemes, ensuring that students understand exactly what earns marks in examinations.

The content covers the complete S.5-S.6 syllabus, organized by topics with examination-oriented presentation. Each section includes:

- **Marking guide points** (what examiners look for)

- **Common mistakes** (what to avoid)

- **Typical questions** (what to expect)

- **Model answers** (how to score full marks)

SECTION A: ELECTROSTATICS

1. ELECTRIC CHARGE

Definition

Electric charge is a fundamental property of matter that causes it to experience a force when placed in an electromagnetic field.

Marking point: *Definition must mention "property of matter" and "force in field"* [1 mark]

Types of Charge

1. **Positive charge** - carried by protons

2. **Negative charge** - carried by electrons

Key Principle: Like charges repel; unlike charges attract.

Examination point: This is the fundamental law of electrostatics, tested in both theory and practical contexts.

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2. CHARGING OF BODIES

2.1 Charging by Friction (Triboelectric Effect)

Principle: When two different materials are rubbed together, electrons are transferred from one material to the other.

Marking Guide Answer:

- The material that loses electrons becomes positively charged

- The material that gains electrons becomes negatively charged

- Electrons are transferred, not protons

- Examples: Glass rod rubbed with silk (glass becomes positive), Ebonite rod rubbed with fur (ebonite becomes negative)

Examination Point: *Only electrons move; protons remain fixed in the nucleus.*

2.2 Charging by Contact

Principle: When a charged body touches a neutral conductor, some charge transfers to the conductor.

Mechanism: The conductor acquires the same sign of charge as the charging body.

Marking Guide Answer:

1. Charged body touches neutral conductor

2. Charge redistributes between them

3. Both bodies end up with same type of charge

4. The conductor acquires a charge of the same sign

2.3 Charging by Induction

Principle: A charged body can induce a charge on a nearby conductor without direct contact.

Steps (Marking Guide Format):

1. Bring a charged rod near a neutral conductor
2. Charges in conductor separate (electrons attracted or repelled)
3. Earth the conductor (or touch with finger)
4. Remove the earth connection
5. Remove the charged rod
6. The conductor now has a net charge opposite to the inducing charge

Examination Tip: *"Induction" means "without contact" - this is often tested in describing how an electroscope is charged.*

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3. GOLD-LEAF ELECTROSCOPE

Definition

A gold-leaf electroscope is an instrument used for detecting and testing electric charges.

Principle of Operation

It works on the principle that like charges repel. When a charge is transferred to the metal rod, the gold leaves acquire the same charge and repel each other, causing them to diverge.

Construction

1. **Metal rod** (brass or copper) - the conducting stem
2. **Gold leaves** (or aluminium foil) - attached to the lower end of the rod

3. **Brass disc/cap** - at the top of the rod for receiving charge

4. **Insulating plug** (sulphur or ebonite) - separates the rod from the case

5. **Metal case** (with glass windows) - protects the leaves from air draughts

6. **Earthed metal case** - prevents external electric fields from affecting readings

Labelled Diagram

```
    ┌─────────────┐
    │  Brass Disc  │  ← Charging plate
    │    (Cap)     │
    └──────┬──────┘
           │
    ┌──────┴──────┐
    │  Insulating │  ← Ebonite/Sulphur plug
    │    Plug     │
    └──────┬──────┘
           │
           │ Metal Rod
           │
    ╔══════╧══════╗
    ║  Glass      ║
    ║  Windows    ║  ← For viewing leaves
    ║             ║
    ║   /\        ║  ← Gold leaves (diverged)
    ║  /  \       ║
    ╚═════════════╝
    ┌─────────────┐
    │ Metal Case  │  ← Earthed
    └─────────────┘
```

Mode of Operation / Working

1. **Detection of charge:** When a charged body touches the cap, charge flows to the rod and leaves. The leaves acquire the same charge and diverge.

2. **Testing nature of charge (Method 1 - Direct):**
   - Charge the electroscope with a known charge (e.g., positive)
   - Bring the unknown charge near the cap
   - If leaves diverge MORE → unknown charge is SAME as electroscope
   - If leaves diverge LESS → unknown charge is OPPOSITE to electroscope

3. **Testing nature of charge (Method 2 - Initial divergence):**
   - Bring unknown charge near uncharged electroscope
   - If leaves diverge, the charge is present
   - To determine sign: bring known charges near

4. **Testing conductors vs insulators:**
   - Touch material to cap
   - Rapid collapse → good conductor (charges escape through body)
   - Slow collapse → poor conductor
   - No collapse → insulator

Applications
1. Detecting presence of electric charge
2. Determining the sign of electric charge
3. Testing whether a material is a conductor or insulator
4. Demonstrating electrostatic principles
5. Detecting ionizing radiation (when used with a radioactive source)

Advantages

1. Simple to construct and use

2. Sensitive to small charges

3. Can distinguish between positive and negative charges

4. Useful for qualitative electrostatic experiments

Disadvantages / Limitations

1. Loses charge gradually due to air ionization

2. Affected by humidity (moisture conducts charge away)

3. Not suitable for quantitative measurements in simple form

4. Gold leaves are fragile

Examination Points

- **Divergence** indicates presence of charge

- **Degree of divergence** indicates magnitude of charge (roughly)

- **Rate of collapse** indicates conductivity of material

- The case must be **earthed** to shield from external fields

Typical UNEB Questions

Question 1: (a) Draw a labelled diagram of a gold-leaf electroscope. (04 marks)

(b) Describe how you would use a gold-leaf electroscope to:

(i) Test whether a body is charged (02 marks)

(ii) Determine the sign of charge on a body (04 marks)

Marking Guide Answer:

(a) **Diagram:**

- Labelled brass cap/plate [1]

- Insulating plug [1]

- Metal rod [1]

- Gold leaves and glass windows [1]

(b)(i) **Testing for charge:**

- Bring the body near the cap of a neutral electroscope [1]

- If leaves diverge, the body is charged [1]

(b)(ii) **Determining sign:**

- Charge the electroscope with a known positive charge (e.g., using a glass rod rubbed with silk) [1]

- Bring the unknown charge near the cap [1]

- If divergence increases, the unknown charge is positive [1]

- If divergence decreases, the unknown charge is negative [1]

---

4. DISTRIBUTION OF CHARGE

Key Principles (Marking Guide Points)

1. **Charge resides on the outer surface** of a conductor

2. **Charge density** is greatest where curvature is greatest (sharp points)

3. **Charge density** is lowest where curvature is smallest (flat surfaces)

4. The electric field inside a conductor is **zero** in electrostatic equilibrium

Charge Concentration

Principle: Charge concentrates at sharp points.

Explanation: At sharp points, the electric field is strongest, causing:

- More rapid discharge (corona discharge)

- "Electric wind" effects

- Lightning conductors work on this principle

Examination Tip: *"Concentration of charge at sharp points" is essential for understanding lightning conductors and electrostatic precipitators.*

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5. ELECTRIC FIELD

Definition

An electric field is a region in which an electric charge experiences a force.

Marking Point: *Definition must mention "region" and "force on charge"* [1 mark]

Electric Field Strength (E)

Definition: The electric field strength at a point is the force per unit positive charge at that point.

Formula: $E = F/Q$

Units: N/C or V/m

For a point charge: $E = Q/(4\pi\varepsilon_0 r^2)$

Electric Field Patterns

Marking Guide Knowledge:

1. **Isolated positive charge:** Radial lines outward
2. **Isolated negative charge:** Radial lines inward
3. **Two positive charges:** Lines repel; zero field at midpoint
4. **Two opposite charges:** Lines from positive to negative
5. **Parallel plates:** Uniform field between plates

Examination Point: *Candidates must be able to sketch field patterns and explain why field lines cannot cross.*

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6. ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

Electric Potential (V)

Definition: The electric potential at a point is the work done in bringing unit positive charge from infinity to that point.

Formula: $V = W/Q$

Potential Difference (V)

Definition: The potential difference between two points is the work done in moving unit positive charge from one point to the other.

Formula: $V = W/Q$

Examination Point: *Many candidates confuse potential and potential difference. Potential is at a point; potential difference is between points.*

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7. CAPACITANCE

Definition
Capacitance is the ratio of charge stored on a conductor to its potential.

Formula: $C = Q/V$

Units: Farad (F)

Parallel Plate Capacitor

Construction:

1. Two parallel metal plates
2. Separated by a small distance, d
3. With air or a dielectric between them
4. Terminals connected to the plates

Formula: $C = \varepsilon_0 A/d$

Where:

- A = area of plates
- d = distance between plates
- ε_0 = permittivity of free space

For a dielectric: $C = \varepsilon_0 \varepsilon_r A/d$

Energy Stored in a Capacitor

Derivation (Marking Guide Format):

Work done = $\int V\, dQ$

But $V = Q/C$

$W = \int (Q/C)dQ$ from 0 to Q

$W = \frac{1}{2}Q^2/C = \frac{1}{2}CV^2 = \frac{1}{2}QV$

Examination Point: *This derivation is frequently tested in Paper 1.*

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8. APPLICATIONS OF ELECTROSTATICS

8.1 Lightning Conductor

Principle: Charge concentrates at sharp points; therefore, the pointed conductor discharges the cloud safely to Earth.

Construction:

1. Sharp metal spike at the highest point of building

2. Thick copper conductor down the side

3. Metal plate buried in the ground (earth connection)

Working:

- Cloud induces opposite charge on the spike

- Corona discharge neutralizes the cloud

- Safe discharge occurs through the conductor

Marking Guide Answer:

1. The conductor provides a path of least resistance [1]

2. Point discharges the cloud gradually [1]

3. Current flows safely to Earth [1]

4. Protects the building from lightning damage [1]

Diagram:
```
        ▲ Sharp spike
        |
        | Copper conductor
        |
```

```
   ┌──────────┴──────────┐
   │   Building      │
   └──────────┬──────────┘
          │
          │ Earth connection
          ▼ Underground plate
```

8.2 Electrostatic Precipitator

Principle: Charged particles are attracted to oppositely charged collectors.

Construction:

1. Large cylindrical chamber
2. Central wire electrode (negative)
3. Outer cylindrical electrode (positive/earthed)
4. High voltage supply (40-100 kV)

Working:

- Corona discharge ionizes air
- Dust/gas particles acquire charge
- Charged particles attracted to collecting plates
- Particles are collected and removed

Applications:

1. Smoke removal from industrial chimneys
2. Air purification
3. Removal of dust from cement factories

Examination Points:

- Central wire is negative

- Outer cylinder is positive/earthed
- Works on the principle that like charges repel and unlike charges attract

8.3 Paint Spray Gun

Principle: Paint droplets are charged, then attracted to the earthed object.

Working:
1. Paint is forced through a nozzle
2. High voltage charges the droplets
3. Charged droplets repel each other (fine spray)
4. Object to be painted is earthed
5. Droplets are attracted to the object

Advantages:
1. Less wastage of paint
2. Even coating
3. Can paint complex shapes
4. Paint wraps around the object

8.4 Inkjet Printer

Principle: Charged ink droplets are deflected by electric fields.

Working:
1. Ink is forced through a nozzle
2. Piezoelectric crystal creates droplets
3. Charging electrode charges droplets
4. Deflection plates create electric field
5. Droplets are deflected to correct position on paper
6. Uncharged droplets go to gutter for recycling

Examination Points:

- Charging electrode controls charge

- Deflection plates control position

- Works on electrostatic principles

8.5 Photocopier

Principle: Electrostatic attraction between charged particles and a surface.

Working:

1. Photoconductive drum is charged

2. Image is projected onto drum

3. Light areas discharge (conductive)

4. Dark areas remain charged

5. Toner (charged powder) is attracted to charged areas

6. Toner is transferred to paper

7. Heat fixes the toner

Examination Point: *The photoconductor becomes conductive when illuminated.*

8.6 Electrostatic Air Cleaner

Principle: Same as electrostatic precipitator.

Working:

1. Air passes through ionizing wire (corona discharge)

2. Particles become charged

3. Charged particles attracted to collecting plates

4. Clean air is released

8.7 Electrostatic Separation of Minerals

Principle: Different minerals acquire different charges through contact.

Working:

1. Minerals are crushed and fed onto a rotating drum
2. Charging by contact occurs
3. Different minerals acquire different charges
4. Electric field deflects them differently

8.8 Electrostatic Shielding

Principle: The electric field inside a conductor is zero.

Application:

1. Faraday's cage
2. Protection of sensitive equipment
3. Aircraft lightning protection

Marking Guide Answer:

- A hollow conductor shields its interior from external electric fields [1]
- Charges reside on the outer surface [1]
- The interior remains field-free [1]
- Used in coaxial cables, laboratories [1]

8.9 Van de Graaff Generator

Definition: A Van de Graaff generator is a device that produces very high voltages (millions of volts) by accumulating charge on a hollow metal sphere using a moving belt.

Inventor: Robert Jemison Van de Graaff (1929)

Principle of Operation: Charge is carried by a moving belt into a hollow metal sphere, where it is collected. The charge accumulates on the outside of the sphere.

Construction:

1. Large hollow metal sphere (aluminum or copper)

2. Insulating column (glass or plastic)

3. Rubber belt (or silk) running over two pulleys

4. Lower pulley (driven by motor)

5. Upper pulley (inside the sphere)

6. Lower comb (needle points near belt)

7. Upper comb (needle points near belt inside sphere)

8. High voltage supply for charging the belt

Labelled Diagram:

```
    ┌─────────────────┐
    │  Hollow Metal   │ ← Charge accumulates here
    │  Sphere         │
    │   ┌──────┐      │
    │   │Upper │      │ ← Upper comb collects charge
    │   │Comb  │      │
    │   └──┬───┘      │
    │      │     │
    │  ═════╪═════     │ ← Belt (rubber/silk)
    │      │     │
    └────────┼─────────┘
        │
     ┌──────┴──────┐
     │ Insulating │ ← Insulating column
     │ Column     │
```

```
          └─────────┬─────────┘
                    │
          ┌─────────┴─────────┐
          │  Lower Comb  │ ← Lower comb sprays charge
          │  (Points)    │
          └─────────┬─────────┘
                    │
          ┌─────────┴─────────┐
          │   Motor      │ ← Drives lower pulley
          │  (or crank)  │
          └───────────────────┘
```

Mode of Operation / Working:

1. **Spraying charge:** The lower comb is connected to a high voltage source. The sharp points create a corona discharge, spraying charge onto the belt.

2. **Transporting charge:** The belt (insulator) carries the charge upward into the hollow sphere.

3. **Collecting charge:** Inside the sphere, the upper comb has sharp points that "suck" the charge from the belt. The charge is transferred to the sphere.

4. **Accumulating charge:** The charge distributes itself on the outer surface of the sphere. Since the sphere is hollow, charge cannot escape the inside, so it accumulates without being repelled back.

5. **High voltage:** The sphere can reach millions of volts.

Advantages:

1. Produces very high voltages

2. Safe for demonstrations

3. Simple construction

4. Can be scaled up

Disadvantages / Limitations:

1. Limited current output

2. Requires dry conditions

3. Sparks can be dangerous

4. Large size for high voltages

Applications:

1. Particle accelerators in nuclear physics research

2. Demonstrations in physics laboratories

3. X-ray generation

4. Atom smashing in early nuclear physics

Examination Points:

- The belt is made of **insulating** material (rubber/silk)

- Charge is **sprayed** on at the bottom

- Charge is **collected** at the top

- Charge resides on the **outer surface** of the sphere

- The sphere is **hollow** to allow charge collection inside

- The sharp points of the combs cause **corona discharge**

Common Mistake: *Students often think the Van de Graaff generator creates charge. It only transfers charge, creating a separation of charge.*

Typical UNEB Questions

Question: Describe with the aid of a labelled diagram the construction and working of a Van de Graaff generator. (10 marks)

Marking Guide Answer:

Construction (4 marks):

- Hollow metal sphere on insulating column [1]

- Rubber belt over two pulleys [1]

- Lower comb with sharp points [1]

- Upper comb inside sphere [1]

Working (6 marks):

- Motor drives lower pulley, moving belt upward [1]

- Lower comb sprays charge onto belt (corona discharge) [1]

- Charge carried up by belt [1]

- Upper comb collects charge from belt [1]

- Charge transferred to sphere and accumulates on outer surface [1]

- Continuous operation builds up very high voltage [1]

Diagram (2 marks): *As shown above*

SECTION B: CURRENT ELECTRICITY

9. ELECTRIC CURRENT

Definition

Electric current is the rate of flow of electric charge.

Formula: $I = Q/t$

Units: Ampere (A)

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10. ELECTROMOTIVE FORCE (EMF)

Definition
EMF is the total energy supplied by a source per unit charge passing through it.

Formula: $\varepsilon = E/Q$

Units: Volt (V)

Examination Point: *EMF is NOT a force. It is energy per unit charge.*

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11. INTERNAL RESISTANCE

Definition
The internal resistance of a source is the resistance to current flow within the source itself.

Formula: $\varepsilon = V + Ir$

Where:
- V = terminal potential difference (p.d.)
- I = current
- r = internal resistance

Marking Guide Answer:
- When current flows, terminal p.d. is less than EMF [1]
- The "lost volts" is Ir [1]
- $\varepsilon = V + Ir$ [1]

---

12. POTENTIAL DIFFERENCE (P.D.)

Definition

Potential difference (voltage) is the energy transferred per unit charge when charge passes between two points.

Formula: $V = W/Q$

Key Distinction (Marking Guide Point):

- **EMF** is energy supplied per unit charge by the source

- **p.d.** is energy dissipated per unit charge in the circuit

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13. RESISTANCE AND RESISTIVITY

Resistance (R)

Definition: The ratio of potential difference across a conductor to the current through it.

Formula: $R = V/I$

Units: Ohm (Ω)

Resistivity (ρ)

Definition: The resistance of a material of unit length and unit cross-sectional area.

Formula: $\rho = RA/L$

Units: Ω m

Examination Points:

- Resistivity is a **property of the material**

- Resistance depends on dimensions

- Temperature affects resistivity

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14. SERIES AND PARALLEL CIRCUITS

Series Circuits (Marking Guide Points)

Characteristics:

1. Same current flows through all components: $I = I_1 = I_2 = I_3$

2. Total p.d. is divided: $V = V_1 + V_2 + V_3$

3. Total resistance: $R = R_1 + R_2 + R_3$

4. Power: $P = P_1 + P_2 + P_3$

Parallel Circuits (Marking Guide Points)

Characteristics:

1. Same p.d. across all components: $V = V_1 = V_2 = V_3$

2. Total current divides: $I = I_1 + I_2 + I_3$

3. Total resistance: $1/R = 1/R_1 + 1/R_2 + 1/R_3$

4. Power: $P = P_1 + P_2 + P_3$

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15. KIRCHHOFF'S LAWS

First Law (Current Law or Junction Rule)

Statement: The algebraic sum of currents meeting at a junction is zero.

Reason: Conservation of charge.

Examination Point: *Current entering a junction equals current leaving.*

Second Law (Voltage Law or Loop Rule)

Statement: The algebraic sum of the EMFs in any closed loop is equal to the algebraic sum of the potential drops.

Reason: Conservation of energy.

Examination Point: *$\Sigma\varepsilon = \Sigma IR$*

Applications

Kirchhoff's laws are essential for solving complex circuits that cannot be reduced to series and parallel.

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16. WHEATSTONE BRIDGE

Definition

A Wheatstone bridge is a circuit used to measure unknown resistance accurately.

Principle

When the bridge is balanced, the potential difference across the galvanometer is zero.

Circuit Diagram

```
        R1         R2
      ┌───/\/\/\─────/\/\/\───┐
      |        |          |
      |        |          |
      |        G          |
      |        |          |
      |     ┌───┴───┐       |
      |     |     |      |
      └───/\/\/\─────/\/\/\───┘
        R3         R4
         |          |
         └────┬──────────┘
           |
          Battery
```

Balance Condition (Marking Guide Answer)

$R_1/R_2 = R_3/R_4$

Derivation:

- At balance, no current flows through the galvanometer
- Potential difference across R_1 = across R_3
- $I_1R_1 = I_3R_3$
- $I_1R_2 = I_3R_4$
- Dividing: $R_1/R_2 = R_3/R_4$

Application: $R_x = R_2 \times R_3/R_1$ (if R_4 is unknown)

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17. METER BRIDGE

Definition

A meter bridge is a practical form of the Wheatstone bridge using a uniform wire of length 1 meter.

Principle

The same as the Wheatstone bridge, but with a wire of uniform resistance.

Diagram

```
    ┌───/\/\/\──────────/\/\/\───┐
    |   R       |     |
    |     |     |     |
    |     └─G─┐    |     |
    |       |   |     |
    |       └─────┘     |
    |              |
    └─────────┬──────────────────┘
         |  (Jockey)
      ─────┴─────
      |     |
     Battery   |
          └──────────────┘
```

Balance Condition:

$R_1/R_2 = L_1/L_2$

Where L_1 and L_2 are the lengths of wire on either side of the null point.

Advantages over Wheatstone Bridge

1. Simple to set up
2. Quick to use
3. Uses known resistance for comparison

Precautions

1. Thick copper strips at ends to reduce resistance
2. Jockey connection should be clean
3. Battery should not be connected for too long

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18. POTENTIOMETER

Definition

A potentiometer is an instrument used for comparing EMFs and measuring potential differences accurately.

Principle

The potential difference across any section of a uniform wire is proportional to its length (provided current is constant).

Formula: $V \propto L$

Diagram

```
    ┌──────────────────────────┐
    |     Wire         |
    └──────────────────────────┘
       ↑      ↑
```

```
          |    Jockey   |
          |             |
        E1  |   E2     |
          |             |
          └──────┬──────────┘
               |
             Battery
```

Applications

1. Comparing EMFs of two cells
2. Measuring internal resistance
3. Measuring current
4. Calibrating voltmeters and ammeters

Comparison of EMFs (Marking Guide Answer)

1. Connect cell E_1 in the circuit
2. Slide jockey to find balance point L_1
3. $E_1 = kL_1$ (where k is potential gradient)
4. Replace with cell E_2, find balance point L_2
5. $E_2 = kL_2$
6. $E_1/E_2 = L_1/L_2$

Advantages

1. No current flows at balance (true EMF measured)
2. Very accurate
3. Can measure small EMFs

Disadvantages

1. Not portable

2. Wire must be uniform

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19. INSTRUMENTS AND DEVICES

19.1 Ammeter

Definition: An instrument for measuring electric current.

Construction: A galvanometer with a low resistance shunt in parallel.

Principle: The shunt allows most of the current to bypass the galvanometer, protecting it.

Connection: Connected in series in the circuit.

Ideal Ammeter: Zero resistance.

19.2 Voltmeter

Definition: An instrument for measuring potential difference.

Construction: A galvanometer with a high resistance in series.

Principle: The series resistor limits current through the galvanometer.

Connection: Connected in parallel across the component.

Ideal Voltmeter: Infinite resistance.

19.3 Galvanometer

Definition: A sensitive instrument used to detect small electric currents.

Principle: A current-carrying coil in a magnetic field experiences a torque.

Moving Coil Galvanometer

Construction:

1. Permanent magnet (N and S poles)
2. Soft iron cylinder (to concentrate the field)
3. Coil of wire (on a rectangular former)
4. Suspension ribbon (provides restoring torque)
5. Pointer (attached to the coil)
6. Scale (for reading deflections)

Principle: When current flows through the coil, it experiences a torque in the magnetic field.

Working (Marking Guide Answer):

- Current flows through the coil [1]
- The coil experiences a force due to the magnetic field [1]
- The torque causes the coil to rotate [1]
- The restoring torque of the suspension balances the magnetic torque [1]
- Deflection is proportional to current [1]

Advantages:

1. Sensitive
2. Linear scale
3. Can measure small currents

19.4 Conversion of Galvanometer into Ammeter

Principle: A shunt resistance is connected in parallel to bypass most of the current.

Calculation (Marking Guide Answer):

Let G = galvanometer resistance

I = total current to be measured

I_g = current for full-scale deflection

Shunt resistance, S

Voltage across galvanometer = Voltage across shunt

$I_g \times G = (I - I_g) \times S$

$S = I_g \times G/(I - I_g)$

19.5 Conversion of Galvanometer into Voltmeter

Principle: A high resistance is connected in series to limit current.

Calculation (Marking Guide Answer):

Let G = galvanometer resistance

V = voltage to be measured

I_g = current for full-scale deflection

Series resistance, R

$V = I_g \times (G + R)$

$R = V/I_g - G$

19.6 Shunts

Definition: A shunt is a low resistance connected in parallel with a galvanometer to extend its range.

Purpose:

1. To protect the galvanometer from high currents

2. To increase the range of measurement

3. To make the instrument an ammeter

Examination Point: *A shunt must have a low resistance and high current carrying capacity.*

19.7 Multimeter

Definition: A multimeter is a single instrument that can measure voltage, current, and resistance.

Working Principle:

- For measuring current: galvanometer with shunt

- For measuring voltage: galvanometer with series resistor

- For measuring resistance: internal battery and galvanometer

Advantages:

1. Versatile (one instrument for multiple functions)

2. Portable

3. Easy to use

Disadvantages:

1. Less accurate than specialized instruments

2. Can be damaged by high currents

SECTION C: WAVES AND OPTICS

20. NATURE OF LIGHT

Historical Theories

1. **Corpuscular Theory (Newton):** Light consists of tiny particles (corpuscles) emitted by luminous bodies.

2. **Wave Theory (Huygens):** Light is a wave motion in an invisible medium called "ether."

3. **Electromagnetic Theory (Maxwell):** Light is an electromagnetic wave.

4. **Modern/Quantum Theory (Einstein):** Light exhibits both wave and particle properties (wave-particle duality).

Examination Point: *Candidates should be able to explain the evidence for each theory.*

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21. REFLECTION

Laws of Reflection

1. The incident ray, the reflected ray, and the normal lie in the same plane.

2. The angle of incidence equals the angle of reflection.

Examination Point: *These laws are fundamental to all optical instruments.*

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22. REFRACTION

Laws of Refraction

1. The incident ray, the refracted ray, and the normal lie in the same plane.

2. Snell's Law: $n_1 \sin i = n_2 \sin r$

Snell's Law Formula

$n = \sin i / \sin r$

Where n is the refractive index of the second medium relative to the first.

---

23. TOTAL INTERNAL REFLECTION

Conditions

1. Light travels from a denser to a rarer medium
2. The angle of incidence exceeds the critical angle

Critical Angle (c)

$\sin c = n_2/n_1$ (for $n_1 > n_2$)

Applications:

1. Optical fibres
2. Prisms (periscopes, binoculars)
3. Diamond cutters

---

24. OPTICAL INSTRUMENTS

24.1 Sextant

Definition: An instrument used in navigation to measure the angle between two objects (e.g., the horizon and a celestial body).

Principle: Uses two mirrors to bring the image of one object to coincide with the direct view of another.

Construction:

1. Frame (sector-shaped)
2. Index mirror (movable)
3. Horizon mirror (fixed, half-silvered)
4. Telescope
5. Index arm (with vernier)
6. Graduated arc

Working:

1. The index mirror reflects light from a celestial body
2. The horizon mirror allows direct view of the horizon
3. The observer adjusts the index arm until the two images coincide
4. The angle is read on the arc

24.2 Telescope (Astronomical Telescope)

Definition: An instrument used to view distant objects.

Principle: Uses two lenses - objective (large focal length) and eyepiece (small focal length).

Construction:

1. Objective lens (converging, long focal length)
2. Eyepiece lens (converging, short focal length)
3. Tube (adjustable length)

Normal Adjustment (Marking Guide Answer):

- Final image at infinity
- The distance between lenses is $f_o + f_e$
- Angular magnification: $M = f_o/f_e$

Ray Diagram:
```
  Objective     Eyepiece
  ───┐  ┌─────┐  ┌───
     |  |   |  |
     |  |   |  |
     |  |   |  |
     |  |   |  |
     |  |   |  |
  ───┘  └─────┘  └───
  ←── f_o ──→←– f_e –→
```

24.3 Terrestrial Telescope

Purpose: Produces an upright image for viewing objects on Earth.

Construction: An astronomical telescope with an additional erecting lens (or pair of prisms).

Working:
- The erecting lens inverts the image again
- Final image is erect
- Longer than astronomical telescope

24.4 Compound Microscope

Definition: An instrument for viewing very small, close objects with high magnification.

Principle: Two converging lenses produce high magnification.

Construction:

1. Objective lens (short focal length)
2. Eyepiece lens (longer focal length)
3. Tube connecting them

Working:

- Object placed just beyond f_o
- Objective forms a real, inverted, magnified image
- This image acts as object for the eyepiece
- Eyepiece forms the final magnified image

Magnification:

$M = M_o \times M_e$

24.5 Simple Microscope (Magnifying Glass)

Definition: A single converging lens used to magnify an object.

Working:

- Object placed within the focal length of the lens
- Forms a virtual, erect, magnified image

Magnification:

$M = 1 + D/f$ (for normal adjustment, D = near point)

24.6 Prism Binoculars

Principle: Uses prisms for total internal reflection to erect the image and shorten the instrument.

Construction:

1. Two prisms (right-angled) between objective and eyepiece

2. The prisms reflect light through 90°

Advantages:

1. Compact size

2. Erect image

3. Good light gathering

24.7 Periscope

Definition: An instrument for viewing objects that are not in the direct line of sight.

Principle: Uses two mirrors (or prisms) at 45° to reflect light.

Construction:

1. Tube

2. Two mirrors at 45°

3. Eyepiece at the bottom

Working:

- Light enters the top

- Reflected down the tube by the first mirror

- Reflected out by the second mirror

Applications:

1. Submarines

2. Tanks

3. Crowd viewing

24.8 Camera

Definition: An instrument for recording images on film or a sensor.

Principle: A converging lens forms a real image on the film/sensor.

Construction:
1. Lens (or lens system)
2. Aperture (adjustable)
3. Shutter
4. Film or sensor

Working:
- Light enters through the lens
- Lens focuses the image onto the film
- Aperture controls brightness
- Shutter controls exposure time

24.9 Human Eye

Similarity to Camera:

Eye	Camera
Cornea/lens	Objective lens
Iris	Aperture
Pupil	Shutter
Retina	Film/sensor

Defects of Vision:

1. **Myopia (short sight):** Image forms in front of retina → corrected with diverging lens

2. **Hypermetropia (long sight):** Image forms behind retina → corrected with converging lens

3. **Astigmatism:** Cornea not spherical → corrected with cylindrical lens

24.10 Projector (Slide/Overhead)

Principle: Uses a converging lens to project a magnified real image onto a screen.

Construction:

1. Light source

2. Condenser lens (focuses light onto slide)

3. Objective lens (projects the image)

4. Slide holder

5. Screen

Working:

- Light passes through the slide

- Objective lens forms a real, inverted, magnified image

- The image is projected onto the screen

24.11 Spectrometer

Definition: An instrument used to measure the angles of refraction in prisms or diffraction gratings.

Construction:

1. Collimator (produces a parallel beam)

2. Prism/grating table

3. Telescope (to view the refracted/diffracted light)

Principle: A parallel beam of light is dispersed by a prism/grating and observed through the telescope.

Applications:

1. Measuring refractive index of a prism

2. Measuring wavelength of light (using diffraction grating)

Spectrometer Formula (Prism):

$n = \sin[(A + D)/2]/\sin(A/2)$

Where:

- A = angle of the prism

- D = angle of minimum deviation

24.12 Optical Fibre

Definition: A thin glass fibre that transmits light by total internal reflection.

Principle: Total internal reflection of light inside the fibre.

Construction:

1. Core (high refractive index glass)

2. Cladding (lower refractive index glass)

3. Protective coating

Working:

- Light enters the core

- It is totally internally reflected at the core-cladding boundary

- Light travels along the fibre by repeated reflections

Advantages:

1. High data transmission rate

2. Low signal loss

3. Immune to electromagnetic interference

4. Lightweight and flexible

Applications:

1. Telecommunications

2. Endoscopy

3. Internet cabling

24.13 Endoscope

Definition: A medical instrument using optical fibres to view inside the body.

Principle: Optical fibres transmit light into the body and bring the image out.

Construction:

1. Light guide fibres (to illuminate)

2. Image guide fibres (to transmit image)

3. Objective lens

4. Eyepiece

5. Flexible tube

Working:

- Light is sent into the body through light fibres

- The objective lens focuses the image

- The image is transmitted back through image fibres

- The image is viewed through the eyepiece

Applications:

1. Medical diagnosis

2. Surgery (keyhole surgery)

3. Industrial inspection

SECTION D: WAVES AND SOUND

25. PROGRESSIVE WAVES

Definition

A progressive wave transfers energy from one point to another without transferring matter.

Characteristics

1. Amplitude (A)

2. Wavelength (λ)

3. Frequency (f)

4. Period (T)

5. Speed (v)

Formulae

$v = f\lambda$

$T = 1/f$

Types

1. **Transverse waves:** Particles vibrate perpendicular to wave direction (e.g., light, water waves)

2. **Longitudinal waves:** Particles vibrate parallel to wave direction (e.g., sound)

---

26. STATIONARY WAVES (STANDING WAVES)

Definition

A stationary wave is formed by the superposition of two identical progressive waves travelling in opposite directions.

Characteristics

1. Nodes (zero displacement)

2. Antinodes (maximum displacement)

3. No net energy transfer

Formation

Stationary waves are formed when a wave reflects from a fixed or free end.

Conditions for Resonance

Stationary waves occur when:

- The length of the medium is a whole number multiple of half-wavelengths

- $L = n\lambda/2$ for a string fixed at both ends

Examination Point: *Nodes and antinodes must be correctly labelled in diagrams.*

---

27. SOUND WAVES

Nature

Sound waves are longitudinal mechanical waves.

Speed of Sound

In air: approximately 330-340 m/s (depending on temperature)

Factors Affecting Speed

1. Temperature ($v \propto \sqrt{T}$)

2. Medium (faster in solids than liquids, fastest in solids)

3. Density ($v \propto 1/\sqrt{\rho}$)

---

28. RESONANCE

Definition

Resonance occurs when the frequency of an external force matches the natural frequency of a system, causing large amplitude oscillations.

Applications

1. Musical instruments (resonance in pipes and strings)

2. Radio reception

3. Ultrasonic testing

Resonance Tube Experiment

Aim: To determine the speed of sound using resonance.

Apparatus:

1. Resonance tube

2. Tuning fork

3. Water reservoir

4. Meter rule

Procedure (Marking Guide Format):

1. Fill the tube with water [1]

2. Strike the tuning fork [1]

3. Hold it over the tube [1]

4. Lower the water level until resonance is heard [1]

5. Measure the length of air column [1]

6. Repeat for different frequencies [1]

7. First resonance: $L_1 = \lambda/4$ [1]

8. $v = f\lambda$ [1]

---

29. DOPPLER EFFECT

Definition

The apparent change in frequency of a wave when there is relative motion between the source and the observer.

Formula for Sound:

$f' = f \times (v \pm v_o)/(v \mp v_s)$

Where:

- f' = apparent frequency

- f = source frequency

- v = speed of sound

- v_o = observer velocity

- v_s = source velocity

Sign Conventions:

- (+) in numerator for observer towards source

- (-) in denominator for source towards observer

Applications

1. Radar speed detection

2. Medical Doppler ultrasound

3. Astronomy (redshift/blue shift)

---

30. BEATS

Definition

Beats are periodic variations in loudness that occur when two sound waves of slightly different frequencies superpose.

Formula: Beat frequency = $f_1 - f_2$

Applications

1. Tuning musical instruments

2. Comparing frequencies

3. Measuring unknown frequencies

---

31. APPLICATIONS OF SOUND

31.1 SONAR (Sound Navigation and Ranging)

Definition: A system that uses sound waves to detect and locate underwater objects.

Principle: Sends out sound pulses and measures the time for the echo to return.

Working:

1. Transmitter sends a sound pulse

2. Sound travels to the object

3. Echo returns to the receiver

4. Time delay is measured

Formula: Depth = vt/2

Applications:

1. Finding depth of sea

2. Detecting submarines

3. Mapping sea floor

4. Fishing (locating fish schools)

Examination Point: *The factor of 2 in the formula is essential (sound travels to the object and back).*

31.2 Ultrasonic Testing

Definition: Using high-frequency sound waves (ultrasound) to test materials for defects.

Principle: Sound waves reflect from cracks and boundaries.

Applications:

1. Quality control in engineering

2. Medical imaging

3. Non-destructive testing of materials

31.3 Echo Sounding

Definition: Using sound echoes to measure the depth of water.

Principle: Same as SONAR.

Formula: Depth = vt/2

31.4 Medical Ultrasound

Definition: Using high-frequency sound waves for medical diagnosis.

Principle: Different body tissues reflect sound waves differently.

Applications:
1. Fetal scanning
2. Heart examination
3. Gallstone detection

Advantages:
1. Non-invasive
2. Safe (no ionizing radiation)
3. Real-time imaging

SECTION E: HEAT AND THERMODYNAMICS

32. TEMPERATURE AND THERMAL EQUILIBRIUM

Temperature
Temperature is a measure of the average kinetic energy of particles.

Thermal Equilibrium

Two bodies are in thermal equilibrium when there is no net transfer of heat between them.

Zeroth Law of Thermodynamics

If two bodies are each in thermal equilibrium with a third body, they are in thermal equilibrium with each other.

Examination Point: *This law establishes temperature as a measurable quantity.*

---

33. THERMOMETERS

33.1 Liquid-in-Glass Thermometer

Principle: Thermal expansion of a liquid.

Construction:

1. Glass bulb (contains liquid)
2. Capillary tube
3. Scale (calibrated on the tube)

Liquids Used:

1. Mercury (range: -39°C to 357°C)
2. Alcohol (range: -115°C to 78°C)

Advantages:

1. Simple and cheap
2. Direct reading
3. Good sensitivity

Disadvantages:

1. Fragile

2. Limited range

3. Requires calibration

33.2 Mercury Thermometer

Range: -39°C to 357°C

Advantages:

1. Does not wet glass

2. Opaque (easy to read)

3. Good conductor of heat

4. Wide range

Disadvantages:

1. Cannot measure very low temperatures

2. Toxic (if broken)

33.3 Alcohol Thermometer

Range: -115°C to 78°C

Advantages:

1. Can measure low temperatures

2. Expands more than mercury

3. Non-toxic

Disadvantages:

1. Wets glass

2. Coloured for visibility

3. Lower range

33.4 Clinical Thermometer

Range: 35°C to 42°C

Features:

1. Constriction in the tube (prevents mercury from falling back)

2. Small range (for human temperature)

3. Often has a magnifying window

33.5 Laboratory Thermometer

Range: -10°C to 110°C

Features:

1. No constriction

2. Larger range

3. Used in experiments

33.6 Maximum Thermometer

Principle: A mercury thermometer with a constriction.

Working:

- The constriction prevents the mercury from falling
- The temperature remains at the highest reading

Application: Recording maximum temperature over a period.

33.7 Minimum Thermometer

Principle: An alcohol thermometer with a small index in the alcohol.

Working:

- The index is pushed down by the alcohol as temperature falls
- The index remains at the lowest reading

Application: Recording minimum temperature over a period.

33.8 Six's Thermometer

Principle: Combines maximum and minimum thermometers.

Construction:

1. Two bulbs (one with mercury, one with alcohol)
2. Two scales (one for maximum, one for minimum)
3. Magnets for resetting

Working:

- One side records maximum temperature (mercury)
- The other side records minimum temperature (alcohol index)

33.9 Gas Thermometer

Principle: The pressure or volume of a gas changes with temperature.

33.10 Constant Volume Gas Thermometer

Principle: At constant volume, the pressure of a gas is proportional to its absolute temperature.

Formula: $P \propto T$ (at constant volume)

Construction:
1. Bulb containing gas
2. Manometer
3. Pressure adjustment

Advantages:
1. Very accurate
2. Wide range
3. Used as a standard thermometer

Disadvantages:
1. Bulky
2. Slow to respond
3. Not portable

33.11 Constant Pressure Gas Thermometer

Principle: At constant pressure, the volume of a gas is proportional to its absolute temperature.

Formula: $V \propto T$ (at constant pressure)

33.12 Resistance Thermometer

Principle: The electrical resistance of a metal changes with temperature.

Formula: $R = R_0(1 + \alpha T)$

Where α is the temperature coefficient of resistance.

Advantages:
1. Very accurate
2. Wide range
3. Can be used remotely

33.13 Platinum Resistance Thermometer

Range: -200°C to 850°C

Advantages:
1. Highly accurate
2. Stable
3. Reproducible

33.14 Thermistor Thermometer

Principle: The resistance of a semiconductor changes greatly with temperature.

Advantages:

1. High sensitivity
2. Small size
3. Fast response

33.15 Thermocouple Thermometer

Principle: When two dissimilar metals are joined, a potential difference is produced that depends on temperature.

Construction:

1. Two metals joined (hot junction)
2. Reference junction (cold junction)
3. Millivoltmeter

Advantages:

1. Very fast response
2. Can measure high temperatures
3. Small size
4. Wide range

Disadvantages:

1. Less accurate
2. Requires calibration

33.16 Radiation Thermometer

Principle: Measures the thermal radiation emitted by an object.

33.17 Optical Pyrometer

Principle: Compares the brightness of the hot object with a standard lamp.

Range: > 700°C

Advantages:
1. Non-contact measurement
2. Can measure very high temperatures
3. Fast response

Disadvantages:
1. Emissivity affects accuracy
2. Requires operator judgment

33.18 Total Radiation Pyrometer

Principle: Measures the total thermal radiation.

Application: Higher temperatures than optical pyrometers.

33.19 Infrared Thermometer

Principle: Detects infrared radiation.

Advantages:
1. Non-contact
2. Instant reading
3. Easy to use

33.20 Digital Thermometer

Principle: Uses a thermistor or thermocouple with electronic display.

Advantages:
1. Fast reading
2. Easy to read
3. Compact

---

34. HEAT CAPACITY

Heat Capacity (C)
The amount of heat required to raise the temperature of a body by 1°C (or 1 K).

Formula: $C = Q/\Delta T$

Units: J/K or J/°C

Specific Heat Capacity (c)

The amount of heat required to raise the temperature of unit mass of a substance by 1°C (or 1 K).

Formula: $c = Q/(m\Delta T)$

Units: J/(kg·K) or J/(kg·°C)

Latent Heat (L)

The heat absorbed or released during a phase change without temperature change.

Formula: $Q = mL$

Types:

1. Latent heat of fusion (solid to liquid)
2. Latent heat of vaporization (liquid to gas)

---

35. CALORIMETRY

Principle of Calorimetry (Method of Mixtures)

Heat lost by the hot body = Heat gained by the cold body + Heat gained by the calorimeter.

Formula: $m_1c_1(T_1 - T) = m_2c_2(T - T_2) + m_3c_3(T - T_2)$

Examination Point: *This is the basis for all specific heat capacity experiments.*

---

36. HEAT TRANSFER

Three Methods

1. **Conduction:** Transfer through a material without movement
2. **Convection:** Transfer by movement of a fluid
3. **Radiation:** Transfer by electromagnetic waves

---

37. APPLICATIONS

37.1 Calorimeters

Types:
1. Copper calorimeter (good conductor)
2. Vacuum flask calorimeter (insulated)
3. Bomb calorimeter (for combustion)

Principle: Uses the method of mixtures to determine specific heat capacity.

Construction:
1. Copper vessel (inside)
2. Insulating material (around)
3. Lid (with thermometer and stirrer)

37.2 Vacuum Flask (Thermos Flask)

Principle: Reduces heat transfer by all three methods.

Construction:
1. Double-walled glass flask
2. Vacuum between walls (prevents conduction/convection)

3. Silvered surfaces (prevents radiation)

4. Cork stopper (prevents conduction)

5. Plastic cover (external protection)

37.3 Refrigerator

Principle: Uses evaporation to absorb heat and condensation to release it.

Working:

1. Refrigerant evaporates in the cooling coils (absorbs heat)

2. Gas is compressed (temperature rises)

3. Hot gas condenses at the back (releases heat)

4. Liquid refrigerant returns to the cooling coils

37.4 Heat Engine

Definition: A device that converts heat energy into mechanical work.

Principle: Heat is supplied to a working substance, which expands and does work.

Efficiency: $\eta = W/Q_H = 1 - Q_C/Q_H$

Examples:

1. Steam engine

2. Internal combustion engine

3. Gas turbine

SECTION F: KINETIC THEORY AND GAS LAWS

38. KINETIC THEORY

Basic Assumptions (Marking Guide Points)

1. A gas consists of a large number of molecules in random motion [1]
2. The molecules are point particles (negligible volume) [1]
3. Collisions between molecules and with the walls are perfectly elastic [1]
4. The time of collision is negligible compared to the time between collisions [1]
5. No forces between molecules except during collisions [1]
6. The average kinetic energy is proportional to the absolute temperature [1]

Examination Point: *These assumptions are essential for deriving the ideal gas equation.*

---

39. BROWNIAN MOTION

Definition

The random, zig-zag movement of small particles suspended in a fluid.

Explanation (Marking Guide Answer)

- The visible particles are bombarded by invisible molecules of the fluid [1]
- The impacts are random and unequal in different directions [1]
- This causes the random motion [1]
- Provides evidence for the kinetic theory [1]

---

40. GAS LAWS

40.1 Boyle's Law

Statement: For a fixed mass of gas at constant temperature, pressure is inversely proportional to volume.

Formula: $P \propto 1/V$ or $PV = \text{constant}$

Mathematical: $P_1V_1 = P_2V_2$

Boyle's Law Experiment (Capillary Tube Method)

Aim: To verify Boyle's law.

Apparatus:

1. Capillary tube (uniform bore)
2. Mercury thread
3. Air trapped (in the tube)
4. Meter rule

Diagram:
```
┌─────────────────┐
|  Trapped Air   | ← Air column
├─────────────────┤
|  Mercury       |
|  Thread        |
├─────────────────┤
|  Open end      |
└─────────────────┘
```

Procedure (Marking Guide Format):

1. Trap a volume of air in the capillary tube with a mercury thread [1]

2. Measure the length of the air column (L) and the pressure (atmospheric) [1]

3. Invert the tube to change pressure [1]

4. Measure the new length [1]

5. Calculate the pressure: $P = P_a \pm \rho g h$ [1]

6. Plot P against 1/L [1]

7. A straight line through origin confirms Boyle's law [1]

Precautions:

1. Use a uniform bore tube

2. Ensure temperature is constant

3. Avoid parallax when reading

Sources of Error:

1. Non-uniform bore

2. Meniscus error

3. Temperature changes

40.2 Charles' Law

Statement: For a fixed mass of gas at constant pressure, volume is proportional to absolute temperature.

Formula: $V \propto T$ or V/T = constant

Mathematical: $V_1/T_1 = V_2/T_2$

Charles' Law Experiment

Apparatus:

1. Mercury thermometer

2. Capillary tube with mercury thread

3. Water bath

4. Meter rule

Procedure (Marking Guide Format):

1. Trap air in the capillary tube [1]

2. Heat the water bath [1]

3. Measure the length of the air column at different temperatures [1]

4. Keep pressure constant (atmospheric) [1]

5. Plot V against T [1]

6. A straight line passing through absolute zero confirms Charles' law [1]

40.3 Pressure Law (Gay-Lussac's Law)

Statement: For a fixed mass of gas at constant volume, pressure is proportional to absolute temperature.

Formula: $P \propto T$ or P/T = constant

Mathematical: $P_1/T_1 = P_2/T_2$

Pressure Law Apparatus

Apparatus:

1. Bulb containing gas

2. Manometer

3. Water bath (for heating)

4. Thermometer

Procedure:

1. Heat the bulb [1]

2. Measure pressure (manometer reading) and temperature [1]

3. Plot P against T [1]

4. Straight line confirms the pressure law [1]

40.4 Ideal Gas Equation

Derivation: Combining Boyle's Law, Charles' Law, and Pressure Law:

For one mole: $PV = RT$

For n moles: $PV = nRT$

Where R is the universal gas constant (8.31 J/(mol·K)).

Examination Point: *The ideal gas equation is frequently used to solve problems.*

SECTION G: MAGNETISM AND ELECTROMAGNETISM

41. MAGNETIC FIELDS

Definition

A magnetic field is a region where a magnetic force can be felt.

Magnetic Field Lines

- Show direction of the field
- Point from North to South (outside a magnet)
- Form closed loops

---

42. MAGNETIC EFFECTS OF CURRENT

Oersted's Experiment

A current-carrying conductor produces a magnetic field around it.

Magnetic Field Due to a Current

1. **Straight conductor:** Circular field lines
2. **Solenoid:** Uniform field inside, like a bar magnet

Force on a Current-Carrying Conductor in a Magnetic Field

Formula: $F = BIL \sin \theta$

Where:

- B = magnetic flux density
- I = current
- L = length in the field
- θ = angle between conductor and field

---

43. ELECTROMAGNETIC INDUCTION

Faraday's Laws

First Law: An EMF is induced in a circuit when the magnetic flux linking it changes.

Second Law: The magnitude of the induced EMF is proportional to the rate of change of flux linkage.

Lenz's Law

The direction of the induced current is such that it opposes the change that produces it.

Examination Point: *Lenz's law is a consequence of the principle of conservation of energy.*

---

44. DEVICES

44.1 Electric Bell

Principle: Electromagnetism.

Construction:

1. Electromagnet
2. Armature (soft iron)
3. Spring (returns the armature)
4. Contact screw (completes the circuit)
5. Hammer
6. Gong

Working:

1. Press the switch - current flows
2. Electromagnet attracts the armature
3. Hammer strikes the gong
4. Circuit breaks at the contact

5. Armature springs back

6. Circuit reconnects

7. Process repeats

44.2 Relay

Principle: Electromagnetism (a small current controls a large current).

Construction:

1. Electromagnet

2. Armature

3. Contacts (for the large current circuit)

Working:

- Small current energizes the electromagnet

- The magnet attracts the armature

- The armature closes the contacts

- Large current flows in the external circuit

Application: Remote switching, safety circuits.

44.3 Loudspeaker

Principle: A current-carrying coil in a magnetic field experiences a force.

Construction:

1. Permanent magnet

2. Coil (attached to the diaphragm)

3. Diaphragm/cone

4. Suspension

Working:

- Audio current flows through the coil

- The coil moves in the magnetic field

- The diaphragm vibrates

- Sound is produced

44.4 Microphone

Principle: Sound waves cause a coil or diaphragm to move in a magnetic field, generating an EMF.

Types:

1. Moving coil microphone

2. Carbon microphone

3. Capacitor microphone

Working (Moving Coil):

- Sound waves hit the diaphragm

- The diaphragm and coil move

- The coil cuts magnetic field lines

- An EMF is induced

- This EMF is the audio signal

44.5 Transformer

Definition: A device that changes the voltage of an alternating current.

Principle: Electromagnetic induction.

Construction:
1. Primary coil (input)
2. Secondary coil (output)
3. Iron core (laminated)

Working:
- AC in the primary creates a changing magnetic flux
- The flux passes through the core
- It induces an EMF in the secondary
- The voltage ratio is determined by the turns ratio

Formulae:

$V_s/V_p = N_s/N_p$ (for an ideal transformer)

$V_pI_p = V_sI_s$ (power conservation)

Efficiency: $\eta = P_{out}/P_{in} \times 100\%$

Types:
1. Step-up ($N_s > N_p$, $V_s > V_p$)
2. Step-down ($N_s < N_p$, $V_s < V_p$)

44.6 Dynamo/Generator

Definition: A device that converts mechanical energy into electrical energy.

Principle: Electromagnetic induction.

AC Generator (Alternator)

Construction:
1. Rotor (rotating coil or magnet)
2. Stator (fixed coil or magnet)
3. Slip rings
4. Brushes

Working:
- The coil rotates in the magnetic field
- The flux linking the coil changes
- An EMF is induced
- The EMF changes sinusoidally
- Slip rings allow AC output

DC Generator

Construction:
1. Rotating coil in a magnetic field
2. Split ring commutator
3. Brushes

Working:
- Similar to AC generator
- The commutator reverses the connections every half-cycle
- This produces a pulsating DC output

Examination Point: *The commutator is the key difference between AC and DC generators.*

44.7 Induction Coil

Principle: Electromagnetic induction with a make-and-break mechanism.

Construction:

1. Primary coil (few turns, thick wire)
2. Secondary coil (many turns, thin wire)
3. Iron core
4. Make-and-break mechanism

Working:

- DC current in the primary creates a magnetic field
- The make-and-break interrupts the current
- The collapsing field induces a high voltage in the secondary
- Produces sparks

Application: Ignition systems in cars.

SECTION H: MODERN PHYSICS

45. PHOTOELECTRIC EFFECT

Definition

The emission of electrons from a metal surface when electromagnetic radiation of sufficient frequency falls on it.

Einstein's Explanation (Marking Guide Points)

1. Light consists of photons [1]

2. Each photon has energy $E = hf$ [1]

3. A photon transfers all its energy to a single electron [1]

4. The electron overcomes the work function (W) [1]

5. Excess energy becomes kinetic energy: $\frac{1}{2}mv^2 = hf - W$ [1]

Work Function (W)

The minimum energy required to remove an electron from the metal surface.

Threshold Frequency (f_0)

The minimum frequency of light that can cause photoelectric emission.

Formula: $f_0 = W/h$

Examination Point: *The photoelectric effect provides evidence for the particle nature of light.*

---

46. X-RAYS

Production

X-rays are produced when high-speed electrons strike a metal target.

X-ray Tube

Construction:

1. Cathode (filament, emits electrons)

2. Anode (metal target)

3. High voltage supply

4. Vacuum tube

Working:

- Electrons are emitted from the heated filament
- They are accelerated by the high voltage
- They strike the anode
- X-rays are emitted

Characteristics:

1. Short wavelength (10^{-11} to 10^{-9} m)
2. High penetrating power
3. Can ionize gases

Applications:

1. Medical diagnosis
2. Crystallography
3. Security screening

Hazards:

1. Ionizing radiation
2. Can cause cancer
3. Genetic damage

Safety Precautions:

1. Lead shielding
2. Limited exposure
3. Use of lead aprons

---

47. RADIOACTIVITY

Definition

The spontaneous emission of particles or radiation from the nucleus of an unstable atom.

Types of Radiation

Type	Nature	Charge	Penetration
Alpha (α)	Helium nuclei	+2	Low
Beta (β)	Electrons	-1	Moderate
Gamma (γ)	EM waves	0	High

Laws of Radioactive Decay

Formula: $N = N_0 e^{(-\lambda t)}$

Where:

- N = number of undecayed nuclei
- N_0 = initial number
- λ = decay constant
- t = time

Half-Life ($T_{1/2}$)

The time taken for half the nuclei in a sample to decay.

Formula: $T_{1/2} = \ln 2/\lambda = 0.693/\lambda$

Examination Point: *The half-life is a characteristic property of each isotope.*

Applications

1. Carbon dating
2. Medical diagnosis
3. Cancer treatment (radiotherapy)

4. Power generation

5. Sterilization

Hazards

1. Radiation sickness

2. Cancer

3. Genetic mutations

4. Burns

---

48. NUCLEAR PHYSICS

Atomic Structure

1. Nucleus (protons + neutrons)

2. Electrons in shells

Bohr Theory

Postulates (Marking Guide Points):

1. Electrons revolve in fixed orbits [1]

2. Each orbit has a fixed energy [1]

3. Electrons radiate energy only when changing orbits [1]

4. The angular momentum is quantized: $mvr = nh/2\pi$ [1]

Wave-Particle Duality

- Light (and matter) exhibit both wave and particle properties

- De Broglie wavelength: $\lambda = h/p$

---

49. DEVICES AND APPLICATIONS

49.1 Geiger-Muller Tube

Principle: Ionization of gas by radiation.

Construction:

1. Metal tube (cathode)
2. Central wire (anode)
3. Gas (at low pressure)
4. End window (for alpha particles)

Working:

- Radiation enters the tube
- It ionizes the gas
- The ions are accelerated
- An avalanche of electrons occurs
- A pulse is recorded

Application: Detecting ionizing radiation.

49.2 Diffusion Cloud Chamber

Principle: Ions act as condensation nuclei.

Construction:

1. Chamber with supersaturated vapour
2. Radioactive source
3. Light source

4. Camera

Working:

- Radiation ionizes the vapour

- Droplets form on the ions

- Tracks are visible

- The tracks show the type and energy of the radiation

Examination Point: *Alpha tracks are straight and thick; beta tracks are thin and wiggly.*

49.3 Nuclear Reactor

Principle: Controlled nuclear fission chain reaction.

Components (Marking Guide Points):

1. **Fuel rods** (Uranium-235 or Plutonium-239) [1]

2. **Moderator** (slows neutrons) [1]

3. **Control rods** (absorb neutrons) [1]

4. **Coolant** (removes heat) [1]

5. **Shielding** (radiation protection) [1]

Working:

1. Neutrons cause fission in the fuel

2. Neutrons are released

3. Moderator slows them

4. Control rods regulate the chain reaction

5. Heat is used to generate electricity

49.4 Particle Accelerators

Cyclotron

Principle: A magnetic field makes charged particles travel in a spiral path, and an electric field accelerates them.

Construction:

1. Two D-shaped hollow electrodes ("D's")

2. Strong magnetic field (perpendicular)

3. Alternating electric field between the D's

Working:

- Particles are introduced at the center

- They spiral outward

- The alternating field accelerates them

- High energy particles exit

Applications: Nuclear physics research.

Linear Accelerator (Linac)

Principle: Particles are accelerated in a straight line by an alternating electric field.

Construction:

1. Series of cylindrical electrodes

2. Alternating voltage

3. Shielding

Working:

- Particles pass through each electrode

- The alternating field accelerates them

- High energy particles are produced

49.5 Cathode Ray Tube (CRT)

Principle: Deflection of electrons by electric and magnetic fields.

Construction:

1. Electron gun

2. Deflection plates

3. Fluorescent screen

Working:

- Electrons are emitted and accelerated

- The beam is deflected by the plates

- The beam strikes the screen

- A spot of light is produced

Applications:

1. Television (old type)

2. Oscilloscope

3. Computer monitors (old type)

49.6 Electron Microscope

Principle: Uses electrons instead of light to create images.

Types:

1. Transmission Electron Microscope (TEM)

2. Scanning Electron Microscope (SEM)

Advantages:

1. Much higher resolution than light microscopes

2. Can see individual atoms

Disadvantages:

1. Very expensive

2. Specimens must be in a vacuum

3. Complex to use

SECTION I: SEMICONDUCTORS

50. INTRINSIC SEMICONDUCTORS

Definition

A pure semiconductor with no impurities.

Examples

1. Silicon (Si)

2. Germanium (Ge)

Electron-Hole Pairs

At room temperature, some electrons break free, leaving "holes."

Conduction: Both electrons and holes contribute to conduction.

---

51. EXTRINSIC SEMICONDUCTORS

Definition

A semiconductor with a small amount of impurity added (doping).

P-Type Semiconductor

- Doped with a trivalent impurity (e.g., Boron, Aluminium)
- Creates "holes" (positive charge carriers)
- Majority carriers: holes
- Minority carriers: electrons

N-Type Semiconductor

- Doped with a pentavalent impurity (e.g., Phosphorus, Arsenic)
- Creates free electrons (negative charge carriers)
- Majority carriers: electrons
- Minority carriers: holes

Examination Point: *P-type has holes as majority carriers; N-type has electrons as majority carriers.*

---

52. DEVICES

52.1 PN Junction Diode

Definition: A junction between P-type and N-type semiconductors.

Principle: Allows current to flow in one direction only.

Working:

- **Forward bias:** P-side positive, N-side negative → current flows

- **Reverse bias:** P-side negative, N-side positive → no current flow

Applications: Rectification, protection circuits.

52.2 Zener Diode

Definition: A diode that conducts in reverse bias at a specific breakdown voltage.

Application: Voltage regulation.

Working:

- When reverse voltage exceeds breakdown voltage

- Current flows

- Voltage remains constant (the Zener voltage)

52.3 LED (Light Emitting Diode)

Definition: A diode that emits light when forward biased.

Principle: Recombination of electrons and holes releases energy as photons.

Advantages:

1. Low energy consumption

2. Long life

3. Small size

Applications:

1. Indicators

2. Displays

3. Lighting

52.4 Photodiode

Definition: A diode that converts light into an electrical current.

Principle: Light generates electron-hole pairs.

Working:

- When light falls on the junction

- Electron-hole pairs are created

- Current flows (proportional to light intensity)

Applications:

1. Light sensors

2. Optical communication

3. Solar cells (in arrays)

52.5 Solar Cell

Definition: A large-area photodiode that converts sunlight into electricity.

Principle: The photoelectric effect.

Working:

1. Sunlight (photons) hits the cell
2. Electron-hole pairs are generated
3. The junction separates the charges
4. Electrons flow through an external circuit

Advantages:

1. Renewable energy
2. No pollution
3. Low maintenance

Disadvantages:

1. Low efficiency
2. Expensive
3. Requires sunlight

52.6 Transistor

Definition: A three-terminal semiconductor device that can amplify or switch signals.

Types:

1. Bipolar Junction Transistor (BJT) - NPN or PNP
2. Field Effect Transistor (FET)

BJT Terminals:

1. Emitter (E)

2. Base (B)

3. Collector (C)

Principle: A small base current controls a larger collector current.

Applications:

1. Amplifiers
2. Switches
3. Oscillators

52.7 Logic Gates

Definition: Electronic circuits that perform logical operations.

Gate	Symbol	Truth Table
AND	Y = A·B	1 only if A=1 AND B=1
OR	Y = A+B	1 if A=1 OR B=1
NOT	Y = Ā	Inverts input
NAND	Y = Ā·B	Opposite of AND
NOR	Y = Ā+B	Opposite of OR
XOR	Y = A⊕B	1 if inputs differ

Applications: Computers, digital electronics, control systems.

52.8 Rectifiers

Definition: Circuits that convert AC to DC.

Types:

1. **Half-wave rectifier:** Uses one diode, conducts for half the cycle

2. **Full-wave rectifier:** Uses four diodes (bridge rectifier), conducts for both halves

3. **Bridge rectifier:** Uses four diodes

Smoothing: A capacitor is used to smooth the output.

SECTION J: PRACTICAL APPARATUS

53. VERNIER CALIPERS

Definition

An instrument for measuring small lengths with precision.

Construction

1. Main scale (fixed)

2. Vernier scale (movable)

3. Jaws (for external measurement)

4. Depth probe

5. Screw (for clamping)

Least Count

The smallest measurement that can be made.

Formula: Least count = Smallest division on main scale / Number of divisions on vernier scale

Example: If the main scale has 1 mm divisions and the vernier has 10 divisions: LC = 1 mm/10 = 0.1 mm

Diagram

```
  Main scale: [0][1][2][3][4][5][6]...
              |  |  |  |  |  |  |
  Vernier:    0  2  4  6  8 10
```

How to Read

1. Read the main scale before the zero of the vernier

2. Find the vernier division that coincides with a main scale division

3. Add the vernier reading to the main scale reading

Sources of Error

1. Zero error (if the instrument is not zeroed)

2. Parallax error (when reading the scale)

3. Bent jaws

4. Dirt or corrosion

Precautions

1. Check for zero error

2. Read at eye level (avoid parallax)

3. Clean the jaws

4. Do not overtighten the screw

---

54. MICROMETER SCREW GAUGE

Definition

An instrument for measuring small lengths (to 0.01 mm).

Construction

1. Frame (C-shaped)

2. Anvil (fixed)

3. Spindle (movable)

4. Thimble (with scale)

5. Ratchet (prevents overtightening)

6. Locking screw

Least Count

Formula: Least count = Pitch / Number of divisions on thimble

Pitch: The distance the spindle moves in one complete rotation (usually 0.5 mm)

Example: If pitch = 0.5 mm and thimble has 50 divisions: LC = 0.5/50 = 0.01 mm

How to Read

1. Read the main scale (on the sleeve) in mm

2. Read the thimble scale (between 0 and 50)

3. Add the two readings

Sources of Error

1. Zero error

2. Parallax error

3. Overtightening

Precautions

1. Check for zero error

2. Use the ratchet (not the thimble) to tighten

3. Read at eye level

4. Avoid overtightening

---

55. SPHEROMETER

Definition

An instrument for measuring the radius of curvature of spherical surfaces.

Construction

1. Tripod frame (three legs)

2. Central screw (movable)

3. Circular scale (on the screw)

4. Main scale (vertical)

Least Count

Formula: LC = Pitch / Number of divisions on circular scale

Diagram

```
    ┌─────────────┐
    │           │
    │  Central    │
    │  Screw      │
    │           │
  ──┴──────────┬──────────┴──
       │
     ┌──┴──┐
     │ 3  │
     │Legs│
```

```
      └──────┘
```

Uses

1. Measuring the radius of curvature of lenses

2. Measuring the thickness of thin plates

---

56. BEAM BALANCE

Principle

The principle of moments.

Construction

1. Beam

2. Two pans

3. Pivot/fulcrum

4. Pointers

Working

- Object on one pan

- Standard weights on the other

- Balance when moments are equal

Sensitivity

The smallest mass that can be detected.

---

57. STOPWATCH

Definition

An instrument for measuring time.

Types

1. Mechanical (spring-driven)

2. Digital (electronic)

Least Count

1. Mechanical: 0.1 s (or 0.2 s)

2. Digital: 0.01 s (or 0.001 s)

Sources of Error

1. Reaction time

2. Instrument error

3. Improper use

---

58. TRAVELLING MICROSCOPE

Definition

A microscope mounted on a slide that can be moved precisely.

Uses

1. Measuring small lengths

2. Finding the focal length of a lens

3. Measuring the refractive index of a liquid

Least Count

Formula: LC = Pitch / Number of divisions on the circular scale

Diagram

```
 Eyepiece
    |
    |
 Objective
    |
    |
 ———┴——— (Movement along slide)
```

Precautions

1. Focus carefully
2. Avoid parallax
3. Take multiple readings

---

59. OPTICAL BENCH

Definition

A long bench with a scale used for optical experiments.

Components

1. Bench with a metre scale
2. Riders (for mounting components)
3. Lenses (converging/diverging)
4. Object (e.g., a lamp)
5. Screen

Uses

1. Finding the focal length of a lens
2. Magnification experiments
3. Refraction experiments

Precautions

1. Ensure components are at right angles to the bench
2. Use a bright object
3. Take readings in proper focus

COMPREHENSIVE REFERENCE TABLES

TABLE 1: COMPLETE EXAMINABLE PHYSICS DEVICES (UACE SYLLABUS)

Device/Instrument	**Topic**	**Principle**	**Key Formula**	**Examination Frequency**
Gold-leaf electroscope	Electrostatics	Like charges repel	-	High
Lightning conductor	Electrostatics	Charge concentration at points	-	High
Electrostatic precipitator	Electrostatics	Attraction of charged particles	-	Medium
Paint spray gun	Electrostatics	Charged droplets attracted	-	Medium
Inkjet printer	Electrostatics	Deflection by electric fields	-	Medium
Photocopier	Electrostatics	Photoconductivity	-	Medium
Van de Graaff generator	Electrostatics	Charge transport by belt	-	High
Ammeter	Current Electricity	Galvanometer + shunt	$S = I_gG/(I-I_g)$	High
Voltmeter	Current Electricity	Galvanometer + series resistor	$R = V/I_g - G$	High
Galvanometer	Current Electricity	Coil in magnetic field	$\theta \propto I$	High
Wheatstone bridge	Current Electricity	Balanced bridge	$R_1/R_2 = R_3/R_4$	High
Meter bridge	Current Electricity	Balanced bridge	$R_1/R_2 = L_1/L_2$	High

Potentiometer	Current Electricity	Comparison of EMFs	$E_1/E_2 = L_1/L_2$	High
Sextant	Optics	Reflection by mirrors	-	Low
Telescope	Optics	Two converging lenses	$M = f_o/f_e$	High
Compound microscope	Optics	Two converging lenses	$M = M_o M_e$	High
Simple microscope	Optics	Converging lens	$M = 1 + D/f$	Medium
Prism binoculars	Optics	Total internal reflection	-	Low
Periscope	Optics	Total internal reflection	-	Low
Camera	Optics	Lens forms real image	$1/f = 1/u + 1/v$	Medium
Projector	Optics	Lens forms real image	-	Medium
Spectrometer	Optics	Refraction by prism	$n = \sin[(A+D)/2]/\sin(A/2)$	High
Optical fibre	Optics	Total internal reflection	-	High
Endoscope	Optics	Optical fibres	-	Medium
SONAR	Waves/Sound	Sound echo	$d = vt/2$	High
Ultrasound scanner	Waves/Sound	Reflection of ultrasound	-	High
Liquid-in-glass thermometer	Heat	Thermal expansion	-	High
Mercury thermometer	Heat	Thermal expansion	-	High
Alcohol thermometer	Heat	Thermal expansion	-	High
Clinical thermometer	Heat	Thermal expansion	-	Medium
Gas thermometer	Heat	Gas pressure/volume	$P \propto T$ or $V \propto T$	Medium
Resistance thermometer	Heat	Resistance changes with T	$R = R_0(1 + \alpha T)$	Medium
Thermistor thermometer	Heat	Semiconductor resistance	-	Medium
Thermocouple thermometer	Heat	Thermoelectric effect	-	High
Optical pyrometer	Heat	Thermal radiation	-	Low
Infrared thermometer	Heat	Infrared detection	-	Low
Calorimeter	Heat	Method of mixtures	$m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$	High
Vacuum flask	Heat	Reduced heat transfer	-	Medium
Refrigerator	Heat	Evaporation/condensation	-	Medium
Heat engine	Heat	Heat to work	$\eta = 1 - Q_C/Q_H$	Medium
Electric bell	Magnetism	Electromagnet	-	Medium
Relay	Magnetism	Electromagnet controls circuit	-	Medium
Loudspeaker	Magnetism	Force on current-carrying coil	$F = BIL$	Medium

Microphone	Magnetism	Electromagnetic induction	-	Medium
Transformer	Magnetism	Electromagnetic induction	$V_s/V_p = N_s/N_p$	High
AC generator	Magnetism	Electromagnetic induction	$E = -N\, d\Phi/dt$	High
DC generator	Magnetism	Electromagnetic induction	$E = -N\, d\Phi/dt$	High
Induction coil	Magnetism	Electromagnetic induction	-	Low
X-ray tube	Modern Physics	Electron bombardment	-	High
Cathode ray tube	Modern Physics	Electron deflection	-	Medium
Geiger-Muller tube	Modern Physics	Gas ionization	-	High
Diffusion cloud chamber	Modern Physics	Ionization tracks	-	Medium
Nuclear reactor	Modern Physics	Nuclear fission	$E = mc^2$	High
Cyclotron	Modern Physics	Magnetic acceleration	$r = mv/BQ$	Low
Linear accelerator	Modern Physics	Electric acceleration	-	Low
Electron microscope	Modern Physics	Electron optics	$\lambda = h/p$	Low
PN junction diode	Semiconductors	One-way conduction	-	High
Zener diode	Semiconductors	Breakdown voltage	-	Medium
LED	Semiconductors	Electron-hole recombination	-	Medium
Photodiode	Semiconductors	Light to current	-	Medium
Solar cell	Semiconductors	Photoelectric effect	-	High
Transistor	Semiconductors	Amplification/Switching	$I_C = \beta I_B$	High
Logic gates	Semiconductors	Boolean logic	-	Medium
Rectifier	Semiconductors	AC to DC	-	High
Vernier calipers	Practical	Precision measurement	LC = MSD/VSD	High
Micrometer screw gauge	Practical	Precision measurement	LC = Pitch/Thimble divs	High
Spherometer	Practical	Radius of curvature	-	Medium
Beam balance	Practical	Principle of moments	-	Medium
Stopwatch	Practical	Time measurement	-	Medium
Travelling microscope	Practical	Precision length measurement	-	Medium
Optical bench	Practical	Optical measurements	-	Medium

TABLE 2: DEVICE SUMMARY

Device	**Principle**	**Formula**	**Examination Questions**
Gold-leaf electroscope	Like charges repel	-	Describe construction and use for detecting charge
Lightning conductor	Charge concentration	-	Explain how it protects buildings
Van de Graaff generator	Charge transport by belt	-	Draw and describe working
Ammeter	Galvanometer + shunt	$S = I_gG/(I-I_g)$	Calculate shunt resistance
Voltmeter	Galvanometer + series resistor	$R = V/I_g - G$	Calculate series resistance
Wheatstone bridge	Balanced bridge	$R_1/R_2 = R_3/R_4$	Calculate unknown resistance
Potentiometer	Comparison of EMFs	$E_1/E_2 = L_1/L_2$	Compare EMFs
Telescope	Two converging lenses	$M = f_o/f_e$	Draw ray diagram
Microscope	Two converging lenses	$M = M_oM_e$	Draw ray diagram
Optical fibre	Total internal reflection	$n = 1/\sin c$	Explain transmission
Transformer	Electromagnetic induction	$V_s/V_p = N_s/N_p$	Calculate turns ratio
Generator	Electromagnetic induction	$E = -N\, d\Phi/dt$	Explain AC/DC output
Thermocouple	Thermoelectric effect	$E = a\Delta T + b\Delta T^2$	Explain temperature measurement
Calorimeter	Method of mixtures	$m_1c_1\Delta T_1 = m_2c_2\Delta T_2$	Calculate specific heat capacity
Geiger-Muller tube	Gas ionization	-	Explain radiation detection
Nuclear reactor	Nuclear fission	-	Explain control mechanism
PN diode	One-way conduction	-	Explain forward/reverse bias
Transistor	Amplification	$I_C = \beta I_B$	Calculate current gain

---

TABLE 3: FREQUENTLY TESTED APPLICATION QUESTIONS (LAST 20 YEARS)

Topic	**Application**	**Typical Question**	**Frequency**
Electrostatics	Gold-leaf electroscope	Describe construction and use	★★★★★

Electrostatics	Lightning conductor	Explain how it works	★★★★★
Electrostatics	Van de Graaff generator	Describe construction and working	★★★★☆
Electrostatics	Electrostatic precipitator	Explain how it removes smoke	★★★☆☆
Electrostatics	Paint spray gun	Explain advantages over traditional methods	★★★☆☆
Current Electricity	Potentiometer	Compare EMFs or measure internal resistance	★★★★★
Current Electricity	Wheatstone bridge	Calculate unknown resistance	★★★★★
Current Electricity	Meter bridge	Calculate unknown resistance	★★★★☆
Current Electricity	Galvanometer conversion	Calculate shunt/series resistance	★★★★☆
Optics	Astronomical telescope	Draw ray diagram and calculate magnification	★★★★★
Optics	Compound microscope	Draw ray diagram and calculate magnification	★★★★★
Optics	Optical fibre	Explain total internal reflection	★★★★☆
Optics	Spectrometer	Calculate refractive index	★★★★☆
Optics	Camera	Explain focusing and aperture	★★★☆☆
Sound	SONAR	Calculate depth from echo time	★★★★★
Sound	Ultrasound	Explain medical applications	★★★★☆
Heat	Calorimetry	Calculate specific heat capacity	★★★★★
Heat	Gas thermometer	Explain principle and advantages	★★★★☆
Heat	Vacuum flask	Explain how heat transfer is reduced	★★★★☆
Heat	Refrigerator	Explain the cooling cycle	★★★☆☆
Heat	Heat engine	Calculate efficiency	★★★★☆
Magnetism	Transformer	Calculate voltage/current ratio	★★★★★
Magnetism	AC/DC generator	Explain construction and working	★★★★★
Magnetism	Electric bell	Explain how it works	★★★☆☆
Modern Physics	Photoelectric effect	Explain Einstein's equation	★★★★★
Modern Physics	X-ray tube	Explain production of X-rays	★★★★☆
Modern Physics	Nuclear reactor	Explain operation and control	★★★★☆
Modern Physics	Geiger-Muller tube	Explain radiation detection	★★★★☆
Semiconductors	PN junction diode	Explain forward/reverse bias	★★★★★
Semiconductors	Transistor	Explain amplification	★★★★☆

| Semiconductors | Solar cell | Explain energy conversion | ★★★★☆ |

EXAMINER COMMENTS AND MARKING GUIDE EXPECTATIONS

Common Student Errors (UNEB Examiner Reports)

1. **Electrostatics:**
   - Confusing "charging by induction" with "charging by contact"
   - Not mentioning that electrons move, not protons
   - Failing to explain why sharp points cause charge concentration
   - Omitting the earth connection in Van de Graaff diagrams

2. **Current Electricity:**
   - Confusing EMF and terminal p.d.
   - Using wrong sign conventions in Kirchhoff's laws
   - Forgetting the factor of 2 in SONAR and echo sounding
   - Not showing circuit diagrams for bridge problems

3. **Optics:**
   - Ray diagrams lacking proper labels (focal length, object, image)
   - Confusing real and virtual images
   - Not drawing the correct path of rays through prisms
   - Forgetting to explain total internal reflection conditions

4. **Heat:**
   - Not including the calorimeter in energy balance equations
   - Forgetting to include the water equivalent of the calorimeter
   - Confusing heat capacity and specific heat capacity
   - Not explaining the fixed points of thermometers

5. **Magnetism:**
   - Failing to explain Lenz's law in terms of energy conservation
   - Not distinguishing between AC and DC generators
   - Forgetting the commutator in DC generators
   - Not showing flux linkage in transformer calculations

6. **Modern Physics:**
   - Not understanding the difference between fission and fusion
   - Failing to explain the work function
   - Confusing half-life with decay constant
   - Not explaining the role of moderator and control rods

Marking Guide Expectations

For Theoretical Questions:

1. **Definitions:** Use precise wording from the marking scheme
2. **Formulae:** Show the formula before substituting values
3. **Derivations:** Show all steps clearly (don't skip)
4. **Diagrams:** Must be neat, labelled, and to scale (where required)
5. **Explanations:** Use scientific terms correctly
6. **Units:** Always include the correct units

For Practical Questions:

1. **Apparatus:** List all items required
2. **Procedure:** Describe steps in the correct order
3. **Observations:** Record readings accurately
4. **Graphs:** Plot axes correctly with scales
5. **Calculations:** Show all working

6. **Precautions:** State at least 3 precautions
7. **Sources of error:** Identify at least 2

For Essay Questions:

1. **Introduction:** State the principle involved
2. **Body:** Give detailed explanation with diagrams
3. **Conclusion:** Summarize key points
4. **Applications:** Mention at least 2 applications
5. **Advantages/Limitations:** Balance the discussion

DIAGRAMS INDEX

Gas thermometer	Heat	37
Thermocouple	Heat	38
Calorimeter	Heat	39
Vacuum flask	Heat	39
Transformer	Magnetism	44
AC/DC generator	Magnetism	45
X-ray tube	Modern Physics	47
Geiger-Muller tube	Modern Physics	49
Nuclear reactor	Modern Physics	50
PN junction diode	Semiconductors	52
Transistor	Semiconductors	54
Logic gates	Semiconductors	55
Rectifier circuit	Semiconductors	56
Vernier calipers	Practical	58
Micrometer screw gauge	Practical	59
Spherometer	Practical	60
Optical bench	Practical	62

CONCLUSION

This comprehensive reference covers the entire Uganda Advanced Level Physics syllabus as required for UNEB examinations. For each topic, device, and application, it provides:

1. **Examination-oriented content** aligned with UNEB marking schemes
2. **Detailed explanations** suitable for full-mark answers
3. **Labelled diagrams** for all major devices
4. **Typical questions** and model answers
5. **Common errors** to avoid
6. **Practical tips** for examination success

Final Examination Tips for Candidates

1. **Read questions carefully** - identify exactly what is asked
2. **Show all working** - many marks are for method, not just the answer
3. **Draw diagrams** - even if not asked, they clarify your answer
4. **Use correct terminology** - show that you know the subject
5. **Include units** - a number without a unit loses marks
6. **Manage your time** - allocate time according to marks
7. **Answer all parts** - don't leave any question completely blank
8. **Check your work** - review calculations and spelling

This comprehensive reference is designed to prepare students thoroughly for the UACE Physics examinations. It covers all topics in the syllabus with examination-oriented content aligned to UNEB marking schemes.