Bihar Board Class 12 Physics Set E 2026

Question Paper with Solutions

Conducted by the Bihar School Examination Board (BSEB)

Time Allowed: 3 hrs 15 min **Maximum Marks: 70**

General Instructions

(i) This question booklet is divided into two sections: **Section A** and **Section B**. The paper has **96 questions** (70 + 20 + 6) and carries **70 marks**.

(ii) In **Section A**, there are 70 objective type questions, out of which **any 35 questions** are to be answered, each carrying **1 mark**. If more than 35 questions are answered, only the first 35 answers are evaluated. The answers are marked on the OMR answer sheet.

(iii) In **Section B**, there are 20 short answer type questions, out of which **any 10 questions** are to be answered, each carrying **2 marks**.

(iv) Apart from these, Section B has 6 long answer type questions, out of which **any 3 questions** are to be answered, each carrying **5 marks**.

(v) Candidates must enter the 10-digit Question Booklet Serial No. on the OMR answer sheet and should give their answers in their own words as far as practicable.

(vi) Figures in the right-hand margin indicate full marks. 15 minutes of extra time have been allotted to read the questions carefully.

Section A: Objective Type Questions (any 35 to be answered, 1 mark each)

1. When an electric dipole $\vec{p}$ is placed in a uniform electric field $\vec{E}$, then at what angle between $\vec{p}$ and $\vec{E}$, the value of torque will be maximum ? [1 mark]

(A) 0°

(B) 45°

(C) 90°

(D) 180°

Correct Answer: (C) 90°

Solution:

Concept:

- An electric dipole of moment $\vec{p}$ placed in a uniform electric field $\vec{E}$ feels two equal and opposite forces.
- They do not push the dipole as a whole, but they form a couple that tries to rotate it.
- The moment of this couple is the torque.

Step 1: Key Formula or Approach The torque on the dipole is

$$\vec{\tau} = \vec{p} \times \vec{E}$$

Its magnitude is

$$\tau = pE \sin\theta$$

where θ is the angle between $\vec{p}$ and $\vec{E}$.

Step 2: Maximise the torque For fixed p and E, the torque depends only on $\sin\theta$. The value of $\sin\theta$ is largest, equal to 1, when $\theta = 90^\circ$. Then

$$\tau_{max} = pE$$

Step 3: Check each option. At 0°: $\sin 0^\circ = 0$, so torque is zero (stable equilibrium).
At 45°: $\tau = pE/\sqrt{2}$, about 0.71 of the maximum.
At 90°: $\tau = pE$, the maximum.
At 180°: $\sin 180^\circ = 0$, so torque is zero again (unstable equilibrium).

Step 4: Conclusion The torque is maximum when the dipole is perpendicular to the field, option (3).

Quick Tip to Solve: Use the torque on a dipole, $\tau = pE\sin\theta$, and ask when $\sin\theta$ is largest.

2. A circular loop of radius R carries a current I. Its magnetic dipole moment is [1 mark]

(A) IR^2

(B) IR

(C) $2\pi IR$

(D) πIR^2

Correct Answer: (D) πIR^2

Solution:

Concept:

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- A loop carrying current behaves like a tiny bar magnet.
- Its strength is measured by the magnetic dipole moment m.
- The direction of m is along the axis of the loop, given by the right-hand rule.

Step 1: Key Formula or Approach For a plane loop of area A carrying current I (one turn), the magnitude of the dipole moment is $m = IA$.

Step 2: Detailed Explanation The loop is circular with radius R, so its area is the area of a circle: $A = \pi R^2$.
Put this in the formula:

$$m = IA = I\,\pi R^2 = \pi I R^2$$

Unit check: current times area is ampere times metre squared, which is A m^2, the correct unit of magnetic moment.

Step 3: Why the other options are wrong Option (1) IR^2 leaves out the factor π, so it does not equal current times area.
Option (2) IR has the unit of A m, not A m^2.
Option (3) $2\pi IR$ uses the circumference $2\pi R$ in place of the area, and its unit is again A m.
Only option (4) matches I times πR^2.

Step 4: Conclusion The magnetic dipole moment of the loop is current times area, so option (4) is correct.

Quick Tip to Solve: Magnetic moment of a current loop is current times area. Area of a circle is πR^2.

3. When the tube length of microscope is increased, its magnifying power [1 mark]

(A) increases

(B) decreases

(C) becomes zero

(D) remains unchanged

Correct Answer: (A) increases

Solution:

Concept:

- A compound microscope has two lenses: an objective of small focal length f_o and an eyepiece of focal length f_e.
- The tube length L is the distance between the two lenses.
- It is about the distance of the first image from the objective.

Step 1: Key Formula or Approach For final image at the near point D, the magnifying power is

$$M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

For final image at infinity it is $M = \frac{L}{f_o} \cdot \frac{D}{f_e}$. In both cases M is directly proportional to L.

Step 2: Detailed Explanation The objective makes a real image at distance $v_o \approx L$ from it. The linear magnification of the objective is $m_o = v_o/u_o \approx L/f_o$. A longer tube makes this first image larger.
The eyepiece then magnifies that image by a factor that depends only on f_e and D, and does not change with L. So the total magnifying power $M = m_o \times m_e$ grows when L is increased, with f_o, f_e

and D fixed.

Step 3: Why the other options are wrong Option (2) says it decreases, but $M \propto L$ shows the opposite.
Option (3) says it becomes zero, which is not possible because L appears in the numerator.
Option (4) says it stays unchanged, which would be true only if M did not depend on L.

Step 4: Conclusion Increasing the tube length increases the magnifying power, so option (1) is correct.

Quick Tip to Solve: Magnifying power of a compound microscope is proportional to the tube length L.

4. Cathode rays are group of [1 mark]

(A) electrons

(B) protons

(C) neutrons

(D) none of these

Correct Answer: (A) electrons

Solution:

Concept:

- Cathode rays are the beams seen in a discharge tube at very low gas pressure and high voltage.
- They start at the negative plate (cathode) and travel toward the positive plate (anode).

Step 1: Key Facts J. J. Thomson (1897) showed that the rays are bent by electric and magnetic fields, and the bending shows that they carry negative charge.
He measured the ratio e/m and found the same value whatever gas or cathode material was used. This means the particles are a common constituent of all matter, the electron.

Step 2: Detailed Explanation The rays bend toward the positive plate in an electric field, so the particles are negative. Electrons are negative, so the rays are a stream of electrons.
The value $e/m \approx 1.76 \times 10^{11}$ C/kg is far larger than that of any ion, so the particles are very light.

Step 3: Why the other options are wrong. Option (2), protons: protons are positive and heavy. A beam of positive rays (canal rays) moves toward the cathode, which is the opposite direction.
Option (3), neutrons: neutrons carry no charge, so they would not bend in an electric or magnetic field.
Option (4) is wrong because option (1) is correct.

Step 4: Conclusion Cathode rays are a stream of electrons, option (1).

Quick Tip to Solve: Cathode rays bend toward the positive plate in an electric field. Which particle is negatively charged and very light?

5. When a soap bubble is charged, then its size [1 mark]

(A) increases

(B) decreases

(C) remains unchanged

(D) nothing can be said

Correct Answer: (A) increases

Solution:

Concept:

- A soap bubble is a thin film of liquid filled with air.
- Surface tension tries to shrink the bubble, and the excess air pressure inside holds it at a fixed radius.

Step 1: Key Formula or Approach Charge spread on a conducting surface repels itself. This gives an outward electrostatic pressure on the surface,

$$P_{el} = \frac{\sigma^2}{2\varepsilon_0}$$

where σ is the surface charge density. This pressure acts outward at every point of the surface.

Step 2: Detailed Explanation When the bubble is charged, all the charge on its surface is of the same sign, so each small part of the surface is pushed outward by the rest.
This outward push adds to the outward air pressure and works against the inward pull of surface tension. The old balance is broken, and the net force on the film is outward.
The bubble therefore expands, and it stops at a larger radius where the pressures balance again. For a bubble of radius r the balance is

$$P_{in} - P_{out} + \frac{\sigma^2}{2\varepsilon_0} = \frac{4T}{r}$$

and a larger electrostatic term needs a larger r in equilibrium.

Step 3: Why the other options are wrong Option (2) decreases: a decrease would need an inward force, but charge repulsion is outward.
Option (3) unchanged: the extra outward electrostatic pressure upsets the earlier balance, so the size must change.
Option (4) nothing can be said: the direction of the change is fixed by the physics above, so this is not correct.

Step 4: Conclusion A charged soap bubble expands because of the outward electrostatic pressure, so option (1) is correct.

Quick Tip to Solve: Charges of the same sign on the surface repel each other, which pushes the film outward.

6. If the area of plates of a capacitor is halved, then the capacitance will [1 mark]

(A) become double

(B) become half

(C) remain same

(D) become four times

Correct Answer: (B) become half

Solution:

Concept:

- A parallel plate capacitor stores charge on two plates separated by a small gap.
- The capacitance tells how much charge it holds per unit potential difference.
- It depends only on the geometry of the plates and the medium between them.

Step 1: Key Formula or Approach For a parallel plate capacitor with plate area A, separation d and medium of permittivity ε_0 (air),

$$C = \frac{\varepsilon_0 A}{d}$$

So C is directly proportional to A when d and the medium are fixed.

Step 2: Detailed Explanation The new area is half the old one: $A' = \frac{A}{2}$. The separation d and the medium are unchanged.

$$C' = \frac{\varepsilon_0 A'}{d} = \frac{\varepsilon_0 (A/2)}{d} = \frac{1}{2} \cdot \frac{\varepsilon_0 A}{d} = \frac{C}{2}$$

So the capacitance becomes half of its original value.

Step 3: Why the other options are wrong Option (1) double: this would need the area to be doubled, not halved.
Option (3) remain same: capacitance depends directly on the area, so it must change.
Option (4) four times: there is no square or higher power of A in the formula, so this is not possible.

Step 4: Conclusion Halving the plate area halves the capacitance, so option (2) is correct.

Quick Tip to Solve: For a parallel plate capacitor $C = \varepsilon_0 A/d$, so C is directly proportional to A.

7. Choke coil works on the principle of [1 mark]

(A) self induction

(B) transient current

(C) mutual induction

(D) wattless current

Correct Answer: (A) self induction

Solution:

Concept:

- A choke coil is a coil of thick copper wire with many turns wound on a soft iron core.
- It is used in AC circuits, for example in a tube light, to cut down the current without wasting much power.

Step 1: Key Formula or Approach When the current in a coil changes, the changing flux through the coil induces an emf in the same coil. This is self induction:

$$\varepsilon = -L \frac{dI}{dt}$$

The coil also offers inductive reactance $X_L = \omega L$ to alternating current.

Step 2: Detailed Explanation A choke has a large self inductance L and a very small resistance. In an AC circuit the current keeps changing, so a back emf $L\,dI/dt$ is always produced in the coil, and it opposes the change in current.
The average power used in a pure inductor is $P = V_{rms} I_{rms} \cos\phi$ with $\phi = 90^\circ$, so $P = 0$. The current is reduced by the reactance X_L and not by heating in a resistor, so almost no energy is lost.
So a choke coil works on the principle of self induction.

Step 3: Why the other options are wrong Option (2) transient current is the short-lived current in a circuit when it is switched on or off, and it is not a working principle.
Option (3) mutual induction is the principle of a transformer, where two coils are linked. A choke has

a single coil.
Option (4) wattless current is a result of a choke (current with no power loss), not the principle behind it.

Step 4: Conclusion A choke coil works on the principle of self induction, so option (1) is correct.

Quick Tip to Solve: A choke is a single coil of high inductance that opposes changes in AC current through its own induced emf.

8. If a bar magnet is cut into two equal pieces transverse to its length, then each piece will [1 mark]

(A) lose its magnetism

(B) become a single pole

(C) behave as a new magnet with a greater magnetic moment

(D) behave as a new magnet with reduced magnetic moment

Correct Answer: (D) behave as a new magnet with reduced magnetic moment

Solution:

Concept:

- A bar magnet has a north pole and a south pole of equal strength m at its two ends.
- Its magnetic moment is the pole strength times the distance between the poles.
- Magnetic poles always come in pairs, so they cannot be separated.

Step 1: Key Formula or Approach

$$M = m \times 2l$$

where $2l$ is the magnetic length of the magnet.

Step 2: Detailed Explanation Cutting the magnet across its length does not remove any poles. A new south pole appears at the cut face of the half that carries the original north pole. A new north pole appears at the cut face of the other half.
So each half is again a complete bar magnet with two opposite poles. The pole strength of each half stays m, but its length becomes l (half of $2l$). So the new moment is

$$M' = m \times \frac{2l}{2} = \frac{M}{2}$$

Option (A) is wrong because each piece is still a magnet.
Option (B) is wrong because an isolated single pole (monopole) does not exist.
Option (C) is wrong because the moment falls, it does not rise.
Option (D) agrees with $M' = M/2$.

Step 3: Conclusion Each piece is a new magnet with half the original moment, which is option (D).

Quick Tip to Solve: Poles cannot be separated, so each half has two poles of the same strength. Check what happens to the length in M = m x length.

9. In an ac circuit of capacitance the current from potential difference is [1 mark]

(A) forward

(B) backward

(C) both are in same phase

(D) none of these

Correct Answer: (A) forward

Solution:

Concept:

- In an ac circuit with only a capacitor, the voltage across the plates and the current in the wire do not rise and fall together.
- The capacitor stores charge, and the current is the rate at which that charge changes.
- So the two waves have a fixed phase gap.

Step 1: Key Formula or Approach Let the applied voltage be $V = V_0 \sin \omega t$. The charge on the capacitor is $q = CV$, and the current is the rate of change of charge:

$$I = \frac{dq}{dt} = C\frac{dV}{dt}$$

Step 2: Detailed Explanation Differentiate the voltage:

$$I = CV_0\omega \cos \omega t = CV_0\omega \sin\left(\omega t + \frac{\pi}{2}\right)$$

Compare this with $V = V_0 \sin \omega t$. The current has the same frequency, but its phase is larger by $\pi/2$. The current reaches its peak a quarter of a cycle before the voltage does. So the current is ahead of the potential difference (it leads it by 90°).

Step 3: Check the options Option (A), forward: the current is ahead of the potential difference, which matches the result. So (A) is TRUE.
Option (B), backward: this would mean the current lags the voltage. That happens in a pure inductor, not in a capacitor. So (B) is FALSE.
Option (C), same phase: this happens only in a pure resistor. So (C) is FALSE.
Option (D), none of these: not needed, because (A) is correct. So (D) is FALSE.

Step 4: Conclusion In a purely capacitive ac circuit the current leads the potential difference by 90°, so it is forward (ahead). This is option (A).

Quick Tip to Solve: Find the current as the rate of change of charge, $I = C\,dV/dt$, and compare its phase with the voltage.

10. A capacitor is a perfect insulator for [1 mark]

(A) alternating currents

(B) direct currents

(C) both (A) and (B)

(D) none of these

Correct Answer: (B) direct currents

Solution:

Concept:

- A capacitor has two plates separated by an insulator (dielectric) or by air.
- No charge carriers can cross the gap between the plates.
- So the behaviour of the capacitor depends on whether the source can keep pushing charge onto

the plates.

Step 1: Key Formula or Approach The opposition a capacitor offers to current is its reactance:

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

For dc the frequency is $f = 0$.

Step 2: Detailed Explanation For dc, $f = 0$, so $X_C \to \infty$. Once the plates are charged, the capacitor draws no more current. The steady current is zero, so for dc the capacitor acts like an open gap, a perfect insulator.
For ac, $f \neq 0$, so X_C is finite. The plates keep charging and discharging every cycle, so ac current flows in the wire (although no charge crosses the gap). So the capacitor passes ac easily.

Step 3: Check the options Option (A), alternating currents: a capacitor passes ac, so it is not an insulator for it. So (A) is FALSE.
Option (B), direct currents: a capacitor blocks dc after it has charged. So (B) is TRUE.
Option (C), both: this contradicts (A). So (C) is FALSE.
Option (D), none of these: (B) is correct. So (D) is FALSE.

Step 4: Conclusion A capacitor blocks steady (direct) current because its reactance becomes infinite at zero frequency. This is option (B).

Quick Tip to Solve: Put $f = 0$ for dc in $X_C = 1/(2\pi f C)$ and see what happens to the current.

11. The unit of displacement current is [1 mark]

(A) Am

(B) A

(C) $\Omega\mathrm{A}$

(D) $\Omega\mathrm{mA}$

Correct Answer: (B) A

Solution:

Concept:

- Displacement current is the term Maxwell added to Ampere's law. It is not a flow of charge.
- It comes from a changing electric flux, and it plays the same role in the law as ordinary conduction current. So it must have the same unit as current.

Step 1: Key Formula or Approach The displacement current is defined as

$$I_d = \varepsilon_0 \frac{d\Phi_E}{dt}$$

where Φ_E is the electric flux through the surface and ε_0 is the permittivity of free space.

Step 2: Detailed Explanation Check the units one by one. ε_0 is in $\mathrm{C^2\,N^{-1}\,m^{-2}}$. Electric flux $\Phi_E = EA$ is in $\mathrm{N\,C^{-1}\,m^2}$. So $\varepsilon_0 \Phi_E$ has unit

$$\frac{\mathrm{C^2}}{\mathrm{N\,m^2}} \times \frac{\mathrm{N\,m^2}}{\mathrm{C}} = \mathrm{C}$$

Dividing by time gives $\mathrm{C\,s^{-1}} = \mathrm{A}$. So the unit of displacement current is the ampere.

Step 3: Check the options Option (A), $\mathrm{A\,m}$: ampere metre is the unit of a current element $I\,dl$, not of

current. So (A) is FALSE.
Option (B), A: this matches. So (B) is TRUE.
Option (C), ΩA: ohm times ampere is a volt. So (C) is FALSE.
Option (D), ΩmA: this is also a voltage-type unit (milli volt or volt metre), not current. So (D) is FALSE.

Step 4: Conclusion Displacement current has the same unit as ordinary current, the ampere. This is option (B).

Quick Tip to Solve: Displacement current is added to conduction current in Ampere's law, so both must have the same unit.

12. The solar spectrum is [1 mark]

(A) continuous

(B) line spectrum

(C) spectrum of black lines

(D) spectrum of black bands

Correct Answer: (C) spectrum of black lines

Solution:

Concept:

- The sun has a very hot inner part (photosphere) that sends out light of all wavelengths, so it gives a continuous spectrum.
- This light then passes through the cooler gases in the outer layer of the sun (chromosphere) and in the earth's atmosphere.

Step 1: Key Idea A cool gas absorbs exactly those wavelengths that it would emit when hot. So the cool gases remove particular wavelengths from the continuous background. This is the absorption (Fraunhofer) spectrum.

Step 2: Detailed Explanation When the sunlight is passed through a spectrometer, the bright continuous band is crossed by many thin dark lines. These are the Fraunhofer lines, produced by absorption by elements such as hydrogen, sodium, calcium and iron in the sun's outer layer. So the solar spectrum is a continuous spectrum with dark lines on it, which is called a spectrum of black lines (an absorption line spectrum).

Step 3: Check the options Option (A), continuous: the background is continuous, but the dark lines are present, so this is not the best description. So (A) is not the answer.
Option (B), line spectrum: a line spectrum means bright lines on a dark background (emission). The sun does not show this. So (B) is FALSE.
Option (C), spectrum of black lines: this matches the Fraunhofer absorption lines. So (C) is TRUE.
Option (D), spectrum of black bands: bands come from molecules, which is not the case for the solar spectrum. So (D) is FALSE.

Step 4: Conclusion The solar spectrum is an absorption spectrum with dark Fraunhofer lines. This is option (C).

Quick Tip to Solve: Sunlight passes through cooler gases of the sun's atmosphere, which absorb particular wavelengths and leave dark lines.

13. The field of view is maximum for [1 mark]

(A) plane mirror

(B) convex mirror

(C) concave mirror

(D) cylindrical mirror

Correct Answer: (B) convex mirror

Solution:

Concept:

- The field of view of a mirror is the region of space whose objects a person can see in the mirror when the eye is held in a fixed position.
- A bigger field of view means more of the surroundings fit in the image.

Step 1: Key Formula or Approach For a spherical mirror the mirror formula is

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

For a convex mirror f is positive and the image is always virtual, erect and smaller than the object.

Step 2: Detailed Explanation A convex mirror curves outwards, so it spreads parallel rays apart. Rays from a wide range of directions reach the eye after reflection. All the images lie close behind the mirror, between the pole and the focus, and are diminished. So a large area of surroundings is squeezed into the small image. This is why a convex mirror is used as a rear-view mirror in vehicles. A plane mirror gives an image of the same size, so the field of view equals the angle subtended by the mirror itself at the eye. A concave mirror converges rays, and for objects beyond the focus its field of view is narrower than that of a plane mirror.

Step 3: Check the options Option (A), plane mirror: field of view is moderate. So (A) is FALSE.
Option (B), convex mirror: it gives the widest field of view. So (B) is TRUE.
Option (C), concave mirror: field of view is the smallest of the three. So (C) is FALSE.
Option (D), cylindrical mirror: a cylindrical mirror is not the standard mirror in this comparison and is not the best choice. So (D) is FALSE.

Step 4: Conclusion A convex mirror has the maximum field of view. This is option (B).

Quick Tip to Solve: A mirror that spreads the reflected rays outwards and forms diminished images covers the widest region.

14. The ratio of the refractive index of red light to blue light in air is [1 mark]

(A) less than unity

(B) greater than unity

(C) equal to unity

(D) none of these

Correct Answer: (A) less than unity

Solution:

Concept:

- The refractive index of a transparent material is not the same for all colours.

- It depends on the wavelength of the light.
- This effect is called dispersion, and it is the reason a prism splits white light into a spectrum.

Step 1: Key Formula or Approach Cauchy's relation gives the refractive index as

$$n = A + \frac{B}{\lambda^2}$$

where A and B are positive constants for the medium. So a longer wavelength gives a smaller refractive index.

Step 2: Detailed Explanation Red light has the longest wavelength in the visible range, about 700 nm. Blue light has a much shorter wavelength, about 450 nm.
Since $\lambda_{red} > \lambda_{blue}$, the term B/λ^2 is smaller for red. So $n_{red} < n_{blue}$.
For example, with $A = 1.5$ and $B = 5000$ nm^2, we get $n_{red} \approx 1.510$ and $n_{blue} \approx 1.525$.
The ratio is therefore

$$\frac{n_{red}}{n_{blue}} = \frac{1.510}{1.525} < 1$$

Step 3: Check each option Option (1), less than unity: correct, because the numerator n_{red} is smaller than the denominator n_{blue}.
Option (2), greater than unity: wrong, it would need red light to bend more than blue, but in a prism blue bends more than red.
Option (3), equal to unity: wrong, it would mean no dispersion at all, and a prism would then give no spectrum.
Option (4), none of these: wrong, because option (1) is correct.

Step 4: Conclusion The refractive index of red light is smaller than that of blue light, so the ratio is less than 1. This is option (1).

Quick Tip to Solve: Refractive index falls as wavelength rises (Cauchy's relation). Red has the longer wavelength, so compare the two indices.

15. The nuclear density is approximately [1 mark]

(A) independent of mass number

(B) directly proportional to mass number

(C) inversely proportional to mass number

(D) directly proportional to $A^{1/3}$

Correct Answer: (A) independent of mass number

Solution:

Concept:

- The nuclear density is the mass of a nucleus divided by its volume. We want to know how this ratio changes when the mass number A changes.
- The mass number A is the number of nucleons (protons and neutrons) in the nucleus.

Step 1: Key Formula or Approach 1. Mass of the nucleus: $M \approx A\,u$, where $u = 1.66 \times 10^{-27}$ kg is the mass of one nucleon.
2. Radius of the nucleus: $R = R_0 A^{1/3}$, where $R_0 \approx 1.2 \times 10^{-15}$ m.
3. Volume of the nucleus (a sphere): $V = \frac{4}{3}\pi R^3$.

Step 2: Find the volume Put the radius formula in the volume formula.

$$V = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 = \frac{4}{3}\pi R_0^3 A$$

So the volume of a nucleus is directly proportional to A.

Step 3: Find the density Divide the mass by the volume.

$$\rho = \frac{M}{V} = \frac{A\,u}{\frac{4}{3}\pi R_0^3 A} = \frac{3u}{4\pi R_0^3}$$

The factor A cancels from the top and the bottom. Everything left is a constant, so the density does not depend on A.

Putting in the numbers gives $\rho \approx \dfrac{3 \times 1.66 \times 10^{-27}}{4\pi(1.2 \times 10^{-15})^3} \approx 2.3 \times 10^{17}$ kg m^{-3}. This is about the same for every nucleus, light or heavy.

Step 4: Check each option Option (A): the density is the same constant for all nuclei, so it is independent of mass number. This is correct.
Option (B): the mass grows with A but so does the volume, so the density does not grow with A. Wrong.
Option (C): the density does not fall as A rises. Wrong.
Option (D): $A^{1/3}$ is the way the radius changes, not the density. Wrong.

Step 5: Conclusion The nuclear density is the same for all nuclei, about 2.3×10^{17} kg m^{-3}, so it is independent of the mass number. This is option (A).

Quick Tip to Solve: Mass is proportional to A and volume $\frac{4}{3}\pi R^3$ with $R = R_0 A^{1/3}$ is also proportional to A.
See what happens to the ratio.

16. In a transistor [1 mark]

(A) concentration of impurities in the collector is minimum

(B) concentration of impurities in the emitter is minimum

(C) concentration of impurities in the base is minimum

(D) concentrations of impurities in all the three regions are same

Correct Answer: (C) concentration of impurities in the base is minimum

Solution:

Concept:

- A junction transistor has three regions: the emitter, the base and the collector.
- They are made from the same semiconductor but each region is doped (given impurity atoms) to a different level, because each region does a different job.

Step 1: Key Formula or Approach 1. The emitter must supply a large number of charge carriers, so it is heavily doped.
2. The base must pass almost all of these carriers on to the collector without losing them, so it is thin and lightly doped.
3. The collector must collect the carriers and handle more power, so it is larger and doped moderately,

less than the emitter but more than the base.

Step 2: Compare the doping levels Emitter: heavily doped, so many carriers are injected into the base.
Base: very thin (a few micrometres) and lightly doped. Fewer carriers here means fewer electron-hole recombinations in the base, so most of the emitter current reaches the collector.
Collector: moderately doped and physically the widest region, so it can dissipate the heat produced.
In order, the impurity concentration is: emitter > collector > base.

Step 3: Check each option Option (A): the collector is doped less than the emitter, but it is doped more than the base, so its concentration is not the minimum. Wrong.
Option (B): the emitter has the largest doping, so it cannot be the minimum. Wrong.
Option (C): the base has the smallest impurity concentration. This is correct.
Option (D): the three regions have different doping, and a transistor would not work with equal doping. Wrong.

Step 4: Conclusion The base is the lightly doped region, so its impurity concentration is the minimum. This is option (C).

Quick Tip to Solve: The base must be thin and lightly doped so that carriers from the emitter reach the collector without recombining.

17. Coulomb's law is valid for [1 mark]

(A) Point charges only

(B) Dispersed charges only

(C) Both point charges and dispersed charges

(D) Neutral particles

Correct Answer: (A) Point charges only

Solution:

Concept:

- Coulomb's law gives the force between two charges.
- The law is written for a pair of charges whose size is very small compared with the distance between them.
- Such charges are called point charges.

Step 1: Key Formula or Approach

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

Here r is the distance between the two charges. This only has a clear meaning if each charge sits at one single point, so that one value of r can be given.

Step 2: Apply to the options A body of finite size carries charge spread over its volume or surface. Different parts of it are at different distances from the second charge, so one value of r does not exist. For such a distributed charge we split it into tiny point-like pieces, apply Coulomb's law to each piece and add the results (superposition, or integration). The law itself is still stated only for point charges. If one body is neutral, the charge q is zero and the formula gives no force. It does not describe the neutral body's behaviour.

Step 3: Check each option Option (A): point charges only. This is the condition under which the law is stated. Correct.

Option (B): dispersed charges only. Wrong, since the law is not stated directly for spread-out charge.
Option (C): both. Wrong for the same reason. Dispersed charges need extra work with integration.
Option (D): neutral particles. Wrong, because $q = 0$ means zero force.

Step 4: Conclusion Coulomb's law is valid directly for point charges only. This is option (A).

Quick Tip to Solve: The distance r in the law must be a single number, which needs each charge to sit at one point.

18. S.I. unit of electric flux is [1 mark]

(A) Vm

(B) Vm^2

(C) Jm

(D) NC^{-1}

Correct Answer: (A) Vm

Solution:

Concept:

- Electric flux through a surface measures how much electric field passes through it.
- For a uniform field E crossing a flat area A at right angles, the flux is $\Phi = EA$.

Step 1: Key Formula or Approach 1. $\Phi = EA\cos\theta$, so the unit of flux is the unit of E times the unit of area.
2. Unit of electric field: $\mathrm{N\,C^{-1}}$, which is the same as $\mathrm{V\,m^{-1}}$.
3. Unit of area: $\mathrm{m^2}$.

Step 2: Find the unit Multiply the units.

$$[\Phi] = \mathrm{N\,C^{-1}} \times \mathrm{m^2} = \mathrm{N\,m^2\,C^{-1}}$$

Now use $\mathrm{V} = \mathrm{J\,C^{-1}} = \mathrm{N\,m\,C^{-1}}$. Then $\mathrm{N\,m^2\,C^{-1}} = (\mathrm{N\,m\,C^{-1}}) \times \mathrm{m} = \mathrm{V\,m}$.
The same answer comes from $\mathrm{V\,m^{-1}} \times \mathrm{m^2} = \mathrm{V\,m}$.

Step 3: Check each option Option (A): Vm is what we found. Correct.
Option (B): Vm^2 has one extra power of metre, so it is wrong.
Option (C): $\mathrm{Jm} = \mathrm{N\,m^2}$ has no $\mathrm{C^{-1}}$ in it, so it is wrong.
Option (D): $\mathrm{N\,C^{-1}}$ is the unit of the electric field itself, not of flux. Wrong.

Step 4: Conclusion The SI unit of electric flux is the volt metre. This is option (A).

Quick Tip to Solve: Flux is field times area, so multiply $\mathrm{N\,C^{-1}}$ by $\mathrm{m^2}$ and then rewrite $\mathrm{N\,m\,C^{-1}}$ as a volt.

19. A cell of internal resistance r is connected to an external resistance R. The current will be maximum in R, if [1 mark]

(A) $R = \dfrac{r}{2}$

(B) $R = r$

(C) $R > r$

(D) $R < r$

Correct Answer: (D) $R < r$

Solution:

Concept:

- A cell has an EMF E and an internal resistance r. It drives a current through an outside resistance R. The question asks for the condition on R that gives the largest current. The EMF and r stay fixed, only R is changed.
- The printed question is ambiguous, because the exact largest current needs $R \to 0$, which is not one of the choices. We pick the option that gives a larger current than the others, which is $R < r$.

Step 1: Key Formula or Approach The cell and R form a series circuit, so the total resistance is $R + r$. By Ohm's law:

$$I = \frac{E}{R + r}$$

Step 2: Compare the cases Take E and r as fixed and try values of R in terms of r.
$R = r/2$: $I = \dfrac{E}{1.5\,r} = 0.67\,\dfrac{E}{r}$.
$R = r$: $I = \dfrac{E}{2r} = 0.5\,\dfrac{E}{r}$.
$R = 2r$ (an example of $R > r$): $I = \dfrac{E}{3r} = 0.33\,\dfrac{E}{r}$.
The current becomes larger as R becomes smaller. The denominator $R + r$ shrinks, so I rises.

Step 3: Check each option Option (A): $R = r/2$ is one particular value that lies below r. It is a special case of option (D), and it is not the largest current, since R can be made smaller still.
Option (B): $R = r$ gives $I = E/2r$. This is the current at which power in R is maximum, not the current.
Option (C): $R > r$ gives a current less than $E/2r$, the weakest of the cases.
Option (D): $R < r$ gives a current greater than $E/2r$, and the current keeps rising as R falls. This is the best match.

Step 4: Conclusion The current in the circuit increases as the external resistance decreases, so it is largest when $R < r$. This is option (D).

Quick Tip to Solve: The current is $I = E/(R + r)$. Ask which choice of R makes the denominator smaller.

20. If L and R represent inductance and resistance respectively, then the unit of L/R will be [1 mark]

(A) ohm

(B) second

(C) volt

(D) ampere

Correct Answer: (B) second

Solution:

Concept:

- The question asks for the SI unit of the ratio of inductance L to resistance R.
- We can get it by writing the unit of each quantity from its defining relation.

Step 1: Key Formula or Approach 1. Induced emf in a coil: $\varepsilon = L\dfrac{dI}{dt}$.

2. Ohm's law: $V = IR$.

Step 2: Detailed Explanation From the first relation, $L = \frac{\varepsilon\, dt}{dI}$. So the unit of L is volt-second per ampere (this is the henry).
From Ohm's law, the unit of R is volt per ampere (this is the ohm).
Now divide the two units:

$$\frac{L}{R} \rightarrow \frac{\text{V s / A}}{\text{V / A}} = \text{s}$$

The volt and the ampere both cancel, and only the second is left. This is why L/R is called the time constant of an LR circuit.

Step 3: Check the options (A) ohm is the unit of R itself, not of L/R, so it is wrong.
(B) second is what we obtained, so it is correct.
(C) volt is the unit of emf, which is $L\, dI/dt$, not L/R, so it is wrong.
(D) ampere is the unit of current, so it is wrong.

Step 4: Conclusion The unit of L/R is the second, which is option (B).

Quick Tip to Solve: Write the unit of L from emf = L dI/dt and the unit of R from Ohm's law, then divide.

21. In a metallic conductor, the current is carried by [1 mark]

(A) free electrons

(B) protons

(C) free electrons and protons

(D) bound electrons

Correct Answer: (A) free electrons

Solution:

Concept:

- Electric current is the flow of charge carriers.
- The question asks which particles move through a metal when a potential difference is applied.

Step 1: Key Formula or Approach A metal is a lattice of positive ions (nuclei with their tightly bound electrons) sitting at fixed positions. Only the outermost electrons are loosely held and can wander through the whole lattice. These are called free electrons.

Step 2: Detailed Explanation When an electric field is applied across the conductor, the free electrons drift slowly in the direction opposite to the field. This drift is what we call the current.
The protons are inside the nuclei, which are fixed in the lattice. They cannot move through the metal.
The bound electrons stay attached to their own atoms, so they cannot carry current across the wire either.

Step 3: Check the options (A) free electrons: correct, they are the only mobile carriers in a metal.
(B) protons: wrong, they are locked in nuclei.
(C) free electrons and protons: wrong, because the protons do not move.
(D) bound electrons: wrong, they are held by their atoms.

Step 4: Conclusion Current in a metallic conductor is carried by free electrons, which is option (A).

Quick Tip to Solve: Ask which charged particles in a metal are free to move through the lattice.

22. 'World Wide Web' was invented by [1 mark]

(A) Tim Berner-Lee

(B) John Logie Baird

(C) Alexander Bain

(D) G. Marconi

Correct Answer: (A) Tim Berner-Lee

Solution:

Concept:

- This is a general knowledge question from the chapter on communication systems.
- It asks who invented the World Wide Web, which is the system of linked web pages that we open in a browser.

Step 1: Key Fact The World Wide Web was proposed in 1989 by the British scientist Tim Berners-Lee while he worked at CERN in Switzerland. He wrote the first web browser and web server in 1990 to 1991. (The printed option spells the name as Berner-Lee, but the person meant is Berners-Lee.)

Step 2: Check each option Option (A), Tim Berners-Lee, is the inventor of the Web.
Option (B), John Logie Baird, built one of the first working television systems in the 1920s.
Option (C), Alexander Bain, a Scottish inventor, patented an early form of the fax machine in 1843.
Option (D), G. Marconi (Guglielmo Marconi), is known for wireless telegraphy and early radio.
None of the last three had anything to do with the Web.

Step 3: Conclusion The World Wide Web was invented by Tim Berners-Lee, which is option (A).

Quick Tip to Solve: The Web was proposed at CERN in 1989 by a British computer scientist.

23. Which of the following expressions represents electrical energy ? [1 mark]

(A) $V \cdot I \cdot t$

(B) $V \cdot I$

(C) $I \cdot R^2 \cdot t$

(D) $\frac{V^2}{R}$

Correct Answer: (A) $V \cdot I \cdot t$

Solution:

Concept:

- Electrical energy is the work done by the source in pushing charge through a circuit.
- It is measured in joule (J).
- We must pick the expression that has the dimensions and meaning of energy.

Step 1: Key Formula or Approach Work done in moving a charge q through a potential difference V is $W = qV$. For a steady current I flowing for time t, the charge is $q = It$.

Step 2: Detailed Explanation Put $q = It$ into $W = qV$:

$$W = VIt$$

Using Ohm's law $V = IR$, this can also be written as $W = I^2Rt$ or $W = \frac{V^2}{R}t$.

Option (A), VIt, is exactly this expression. So (A) is correct.

Step 3: Why the other options are wrong Option (B), VI, is electrical power, the energy per second, measured in watt.
Option (D), V^2/R, is also power. To get energy it must be multiplied by t.
Option (C), as printed, is IR^2t. Check its units: $\text{A} \cdot \Omega^2 \cdot \text{s}$ is not joule. The correct heating formula has I^2 and R, that is I^2Rt, so (C) as printed does not represent energy.

Step 4: Conclusion Electrical energy is VIt, option (A).

Quick Tip to Solve: Energy = power times time = V I t. Check the units of the other options.

24. When an alpha-particle is brought towards another alpha-particle, the potential energy of the system [1 mark]

(A) increases

(B) decreases

(C) remains unchanged

(D) none of these

Correct Answer: (A) increases

Solution:

Concept:

- An alpha particle is a helium nucleus. It carries a charge of $+2e$.
- Two alpha particles therefore repel each other. The question asks what happens to the potential energy of the pair when we push them closer.

Step 1: Key Formula or Approach The electrostatic potential energy of two point charges q_1 and q_2 at separation r is

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

Step 2: Detailed Explanation Here $q_1 = q_2 = 2e$, so $q_1q_2 = 4e^2$ is positive. So

$$U = \frac{1}{4\pi\varepsilon_0}\frac{4e^2}{r}$$

The value of U is positive and it is proportional to $1/r$. When the particles are brought closer, r becomes smaller, so U becomes larger.
We can also see this from work and energy. The particles repel, so we must push against the repulsive force to bring them closer. The work we do is stored as potential energy, and the energy of the system goes up.

Step 3: Why the other options are wrong Option (B), decreases, would be true for opposite charges, which attract each other.
Option (C), unchanged, is wrong because U depends on r.
Option (D), none of these, is wrong because option (A) is correct.

Step 4: Conclusion The potential energy of the system increases, option (A).

Quick Tip to Solve: Two alpha particles are both positive, so they repel. Work must be done to bring them closer.

25. Dielectric constant of water is [1 mark]

(A) 80

(B) 1

(C) 0

(D) ∞

Correct Answer: (A) 80

Solution:

Concept:

- The dielectric constant K of a material is the ratio of its permittivity ε to the permittivity of free space ε_0.
- It also tells us how many times the capacitance of a capacitor grows when the gap between the plates is filled with that material.

Step 1: Key Formula or Approach

$$K = \frac{\varepsilon}{\varepsilon_0} = \frac{C_{\text{with dielectric}}}{C_{\text{vacuum}}}$$

For vacuum $K = 1$, and for every other insulating material $K > 1$.

Step 2: Detailed Explanation Water molecules are polar, so they turn strongly along an applied electric field. This partly cancels the field inside the water and gives a very large value of K.
At room temperature (about 20°C) the measured value for water is close to 80.
Option (B), $K = 1$, is the value for vacuum (air is almost the same), so it is wrong for water.
Option (C), $K = 0$, is impossible, because K can never be less than 1.
Option (D), $K = \infty$, is the idealised value used for a metallic conductor, not for water, which is an insulator.
So only option (A) fits.

Step 3: Conclusion The dielectric constant of water is 80, which is option (A).

Quick Tip to Solve: Water is a highly polar liquid, so its dielectric constant is far above 1. Recall the standard value at room temperature.

26. The relationship between current density $\vec{J}$, specific conductance σ and electric field intensity $\vec{E}$ is [1 mark]

(A) $\vec{E} = \sigma\vec{J}$

(B) $\vec{E} = \dfrac{\sigma}{\vec{J}}$

(C) $\vec{J} = \dfrac{\vec{E}}{\sigma}$

(D) $\vec{J} = \sigma\vec{E}$

Correct Answer: (D) $\vec{J} = \sigma\vec{E}$

Solution:

Concept:

- Current density $\vec{J}$ is the current flowing per unit area of cross-section.
- It is the point form of Ohm's law and links $\vec{J}$ to the electric field $\vec{E}$ inside the conductor.
- Specific conductance σ is the same as conductivity, the reciprocal of resistivity ρ.

Step 1: Key Formula or Approach Start from the usual Ohm's law $V = IR$ with $R = \rho\frac{l}{A}$, and rewrite it using $J = I/A$ and $E = V/l$.

Step 2: Detailed Explanation Take a uniform wire of length l and area A. Then

$$I = \frac{V}{R} = \frac{VA}{\rho l}$$

Divide both sides by A:

$$\frac{I}{A} = \frac{1}{\rho}\frac{V}{l}$$

Now $I/A = J$, $V/l = E$ and $1/\rho = \sigma$, so

$$J = \sigma E$$

Both $\vec{J}$ and $\vec{E}$ point the same way in an ohmic conductor, so the vector form is $\vec{J} = \sigma\vec{E}$.
Option (A) has $\vec{E}$ and $\vec{J}$ swapped. Its units are wrong, because σJ does not have the units of a field.
Option (B) divides a scalar by a vector, which has no meaning.
Option (C) puts σ in the denominator, which is the form for resistivity ($\vec{E} = \rho\vec{J}$), not for $\vec{J}$.

Step 3: Conclusion The relation is $\vec{J} = \sigma\vec{E}$, option (D).

Quick Tip to Solve: This is Ohm's law in point form. Write R = rho l / A in V = IR and divide by the area.

27. The yellow colour code value of carbon resistance is [1 mark]

(A) 4

(B) 2

(C) 3

(D) 5

Correct Answer: (A) 4

Solution:

Concept:

- A carbon resistor carries coloured rings.
- Each colour stands for a digit from 0 to 9, and the rings together give the resistance value and its tolerance.

Step 1: Key Formula or Approach The standard colour code, in order of digits, is:
Black 0, Brown 1, Red 2, Orange 3, Yellow 4, Green 5, Blue 6, Violet 7, Grey 8, White 9.
A common memory line is B B ROY of Great Britain had a Very Good Wife.

Step 2: Detailed Explanation Counting along the code, yellow is the fifth colour starting from black = 0, so its value is 4.
Option (B), 2, is the value for red.
Option (C), 3, is the value for orange.
Option (D), 5, is the value for green.
Only option (A) matches yellow.

Step 3: Conclusion The colour code value of yellow is 4, option (A).

Quick Tip to Solve: Recall the digit sequence of the resistor colour code starting from black = 0. Yellow comes right after orange.

28. Relative permeability is equal to [1 mark]

(A) $\mu_r = \mu_o \cdot \mu$

(B) $\mu_r = \dfrac{\mu}{\mu_o}$

(C) $\mu_r = \dfrac{\mu_o}{\mu}$

(D) $\mu_r = \sqrt{\mu \cdot \mu_o}$

Correct Answer: (B) $\mu_r = \dfrac{\mu}{\mu_o}$

Solution:

Concept:

- The permeability μ of a material tells how easily magnetic field lines pass through it.
- The permeability of free space is μ_o.
- Relative permeability compares the material with free space, so it is a pure number without units.

Step 1: Key Formula or Approach Relative permeability is defined as the ratio of the permeability of the medium to the permeability of free space.

$$\mu_r = \frac{\mu}{\mu_o} = 1 + \chi_m$$

where χ_m is the magnetic susceptibility.

Step 2: Detailed Explanation Option (A), $\mu_o\mu$, carries the unit $(\text{T m A}^{-1})^2$, so it is not dimensionless and cannot be a relative quantity.
Option (C), μ_o/μ, is the inverse of the correct ratio.
Option (D), $\sqrt{\mu\mu_o}$, is a geometric mean and also has units.
Option (B), μ/μ_o, is dimensionless and matches the definition. For vacuum it gives $\mu_r = 1$, as it should.

Step 3: Conclusion Relative permeability is μ/μ_o, option (B).

Quick Tip to Solve: Relative means compared with free space. Write it as a ratio of the medium's permeability to that of vacuum.

29. Who first explained electromagnetic waves mathematically ? [1 mark]

(A) Einstein

(B) Faraday

(C) Maxwell

(D) Hertz

Correct Answer: (C) Maxwell

Solution:

Concept:

- This is a history of physics question.

- Electricity and magnetism were first studied separately.
- A mathematical theory that joined them and predicted waves of electric and magnetic fields came later.

Step 1: Key Formula or Approach James Clerk Maxwell gave a set of four equations (Maxwell's equations) in the 1860s. He added the displacement current term to Ampere's law. From the equations he derived the wave equation for the electric and magnetic fields and found that the wave speed is $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$, the speed of light.

Step 2: Detailed Explanation Maxwell's calculation of the speed gave a value equal to the measured speed of light. So he proposed that light itself is an electromagnetic wave. This was the first mathematical explanation of electromagnetic waves.

Option (1), Einstein: he explained the photoelectric effect and relativity. He did not first describe electromagnetic waves.

Option (2), Faraday: he found electromagnetic induction by experiment and introduced field lines. His work was experimental, not a full mathematical theory of waves.

Option (4), Hertz: in 1887 he produced and detected electromagnetic waves in the laboratory. This was an experimental proof of Maxwell's prediction, which came after it.

Step 3: Conclusion Maxwell first explained electromagnetic waves mathematically, option (3).

Quick Tip to Solve: Think of the scientist whose four equations predicted electromagnetic waves. Hertz only detected them later.

30. Which factor of the following does not affect resistance of a conducting wire ? [1 mark]

(A) Length

(B) Temperature

(C) Material

(D) Voltage applied

Correct Answer: (D) Voltage applied

Solution:

Concept:

- The resistance of a conducting wire is a property of the wire itself.
- It depends on the size of the wire, the material it is made of and its temperature.
- It is not changed by the circuit connected to it.

Step 1: Key Formula or Approach For a wire of length l, cross-sectional area A and resistivity ρ:

$$R = \rho \frac{l}{A}$$

The resistivity ρ depends on the material and on the temperature. For a metal, $\rho_T = \rho_0 [1 + \alpha(T - T_0)]$.

Step 2: Detailed Explanation Option (1), length: $R \propto l$, so a longer wire has more resistance. This affects R.

Option (2), temperature: for a metal, ρ rises with temperature, so R rises too. This affects R.

Option (3), material: different materials have different ρ, so copper and nichrome wires of the same size have different resistances. This affects R.

Option (4), applied voltage: by Ohm's law $V = IR$, a larger voltage drives a larger current, and the

ratio $V/I = R$ stays the same for an ohmic wire. The voltage does not appear in $R = \rho l/A$. So it does not affect R.

Step 3: Conclusion The applied voltage does not change the resistance of the wire, option (4).

Quick Tip to Solve: Resistance is given by $R = \rho l/A$. See which option does not appear in it.

31. When a dielectric is placed in an external electric field, the effective electric field inside the dielectric [1 mark]

(A) Decreases

(B) Increases

(C) Becomes zero

(D) Remains same

Correct Answer: (A) Decreases

Solution:

Concept:

- A dielectric is an insulator. It has no free charges, but its atoms or molecules can be polarised by an electric field.
- When an external field $\vec{E}_0$ is applied, the positive and negative charges of each molecule are pulled slightly in opposite directions. The molecules line up like small dipoles.

Step 1: Key Formula or Approach The aligned dipoles leave a layer of bound (induced) charge on each face of the slab. This bound charge creates an induced field $\vec{E}_{ind}$ inside the slab, pointing opposite to $\vec{E}_0$.
The effective field is $E = E_0 - E_{ind} = \dfrac{E_0}{K}$, where K is the dielectric constant.

Step 2: Detailed Explanation For every dielectric, $K > 1$. So $E = E_0/K$ is smaller than E_0.
Example: if $E_0 = 1000\ \text{V/m}$ and $K = 5$, the field inside is $1000/5 = 200\ \text{V/m}$, which is less than before.
So the effective field inside the dielectric decreases.

Step 3: Check each option Option (A) Decreases: correct, because the induced field opposes the applied field and reduces it by the factor K.
Option (B) Increases: wrong, because that would need $K < 1$, which never happens for a material.
Option (C) Becomes zero: wrong. The field becomes zero inside a conductor (as if $K \to \infty$), but a dielectric only reduces it.
Option (D) Remains same: wrong, because this holds only for vacuum or air where $K = 1$.

Step 4: Conclusion The induced charges on the dielectric weaken the field inside it, so the effective field decreases. This is option (A).

Quick Tip to Solve: The dielectric gets polarised and its induced field opposes the applied field. Recall $E = E_0/K$ with $K > 1$.

32. A capacitor of capacitance $1\ \mu\text{F}$ is kept at $1\ \text{V}$ potential difference between the plates. The charge on the charged capacitor will be [1 mark]

(A) $1\ \text{C}$

(B) zero

(C) 1 μC

(D) none of these

Correct Answer: (C) 1 μC

Solution:

Concept:

- A capacitor stores charge on its plates.
- The charge is directly proportional to the potential difference across it, and the constant of proportionality is the capacitance.

Step 1: Key Formula or Approach

$$Q = CV$$

Here Q is the charge in coulomb, C is the capacitance in farad and V is the potential difference in volt.

Step 2: Detailed Explanation Given $C = 1\ \mu\text{F} = 1 \times 10^{-6}$ F and $V = 1$ V.

$$Q = (1 \times 10^{-6}\ \text{F})(1\ \text{V}) = 1 \times 10^{-6}\ \text{C} = 1\ \mu\text{C}$$

Step 3: Check each option Option (A) 1 C: wrong. This would need a capacitance of 1 F, which is a million times larger.
Option (B) zero: wrong. The charge would be zero only if the potential difference were zero.
Option (C) 1 μC: correct, as calculated above.
Option (D) none of these: wrong, because option (C) is correct.

Step 4: Conclusion The charge on the capacitor is 1 μC. This is option (C).

Quick Tip to Solve: Use $Q = CV$ and remember that micro means 10^{-6}.

33. If a charged particle of mass m and charge q enters a uniform magnetic field B at an angle θ in the direction of field with velocity v, then the path of the particle is helical. The radius of circular path of the helix will be [1 mark]

(A) $\dfrac{mv}{qB}$

(B) $\dfrac{mv\cos\theta}{qB}$

(C) $\dfrac{mv\sin\theta}{qB}$

(D) $\dfrac{2\pi mv}{qB}$

Correct Answer: (C) $\dfrac{mv\sin\theta}{qB}$

Solution:

Concept:

- The angle θ is measured between the velocity $\vec{v}$ and the field $\vec{B}$. Split the velocity into two parts: one along $\vec{B}$ and one perpendicular to it.
- The part along $\vec{B}$ feels no magnetic force, because $\vec{F} = q\,\vec{v} \times \vec{B}$ is zero for velocity parallel to the field. This part carries the particle forward and makes the path a helix.

- The part perpendicular to $\vec{B}$ gets a sideways force and makes the particle go round in a circle.

Step 1: Key Formula or Approach $v_{\parallel} = v\cos\theta$ and $v_{\perp} = v\sin\theta$.

The magnetic force supplies the centripetal force for the circular part: $qv_{\perp}B = \dfrac{mv_{\perp}^2}{r}$.

Step 2: Detailed Explanation

$$r = \frac{mv_{\perp}}{qB} = \frac{mv\sin\theta}{qB}$$

So the radius of the circular path of the helix is $\dfrac{mv\sin\theta}{qB}$.

Step 3: Check each option Option (A) mv/qB: wrong. This is the radius only when $\theta = 90°$, that is for motion perpendicular to the field.
Option (B) $mv\cos\theta/(qB)$: wrong. It uses the component along the field, which does not take part in the circular motion.
Option (C) $mv\sin\theta/(qB)$: correct.
Option (D) $2\pi mv/(qB)$: wrong. The factor $2\pi m/(qB)$ is the time period of revolution, not a radius.

Step 4: Conclusion The radius of the circular part of the helix is $\dfrac{mv\sin\theta}{qB}$. This is option (C).

Quick Tip to Solve: Only the velocity component perpendicular to B makes the circle. With theta measured from B, that component is $v\sin\theta$.

34. An ideal ammeter has [1 mark]

(A) zero resistance

(B) infinite resistance

(C) high resistance

(D) negative resistance

Correct Answer: (A) zero resistance

Solution:

Concept:

- An ammeter measures the current in a circuit.
- It is always connected in series with the part of the circuit whose current we want.

Step 1: Key Formula or Approach In series, the ammeter resistance R_A adds to the circuit resistance R, so the current becomes $I = \dfrac{E}{R + R_A}$.
The reading is the true current only if R_A does not change I, that is $R_A \to 0$.

Step 2: Detailed Explanation A real ammeter is a moving coil galvanometer with a small shunt resistance S in parallel. Its total resistance is

$$R_A = \frac{GS}{G+S} \approx S \quad (S \ll G)$$

which is very small. The ideal limit of this is $R_A = 0$. An ideal ammeter therefore has zero resistance, and it causes no voltage drop and no change in the current.

Step 3: Check each option Option (A) zero resistance: correct.
Option (B) infinite resistance: wrong. This describes an ideal voltmeter, which is joined in parallel and must draw no current.

Option (C) high resistance: wrong. A high resistance in series would cut down the current and the reading would be false.
Option (D) negative resistance: wrong. An ordinary measuring instrument is a passive device and does not have negative resistance.

Step 4: Conclusion An ideal ammeter has zero resistance. This is option (A).

Quick Tip to Solve: An ammeter is joined in series and must not change the current, so its resistance should be as small as possible.

35. Remote control for televisions uses [1 mark]

(A) infrared waves

(B) ultraviolet waves

(C) radio waves

(D) microwaves

Correct Answer: (A) infrared waves

Solution:

Concept:

- A television remote control sends a signal to the set without any wire.
- It does this with a beam of electromagnetic radiation sent out by a small light emitting diode on the front of the remote.

Step 1: Key Formula or Approach We match the use with the part of the electromagnetic spectrum. The infrared region has wavelengths from about 700 nm to 1 mm, just longer than visible red light. The remote uses infrared pulses of around 940 nm, which the sensor of the TV can detect.

Step 2: Detailed Explanation Infrared is used because it is low in energy and harmless for the user. It is easy to produce with a cheap LED and easy to detect with a photodiode.
It also stays inside the room, since it does not pass through walls, so your remote does not change the channel on your neighbour's TV.

Step 3: Check each option Option (A) infrared waves: correct.
Option (B) ultraviolet waves: wrong. They carry high energy and are harmful to skin and eyes, and they are used for sterilisation, not for remotes.
Option (C) radio waves: wrong. They are used for radio and TV broadcasting. They go through walls and would act on other sets too.
Option (D) microwaves: wrong. They are used in radar, satellite links and microwave ovens.

Step 4: Conclusion A TV remote control works with infrared waves. This is option (A).

Quick Tip to Solve: Think of the small LED on the front of a remote. It emits light that the eye cannot see, just beyond red.

36. The momentum (p) of photon is [1 mark]

(A) $\frac{\lambda}{h}$

(B) $\frac{h}{\lambda}$

(C) $\frac{hc}{\lambda}$

(D) $h\lambda$

Correct Answer: (B) $\frac{h}{\lambda}$

Solution:

Concept:

- A photon is a packet of light energy.
- It has no rest mass, but it still carries energy and momentum.
- We need a relation between its momentum and its wavelength.

Step 1: Key Formula or Approach 1. Energy of a photon: $E = h\nu = \frac{hc}{\lambda}$.
2. For a massless particle moving at the speed of light, $E = pc$.

Step 2: Detailed Explanation Equate the two expressions for energy:

$$pc = \frac{hc}{\lambda}$$

Divide both sides by c:

$$p = \frac{h}{\lambda}$$

This is the same as the de Broglie relation $\lambda = h/p$ applied to a photon.

Step 3: Check each option Option (1), λ/h: wrong, it is the inverse of the correct result and has the wrong units.
Option (2), h/λ: correct, units of h/λ are J s / m = kg m/s, which is the unit of momentum.
Option (3), hc/λ: wrong, this is the energy of the photon, in joules, not its momentum.
Option (4), $h\lambda$: wrong, its units are J s m, which are not those of momentum.

Step 4: Conclusion The momentum of a photon is Planck's constant divided by its wavelength. This is option (2).

Quick Tip to Solve: Use $E = hc/\lambda$ for a photon and $E = pc$ for a massless particle, then solve for p.

37. The radius of the lowest Bohr's orbit in hydrogen atom is r_0. The radius of Bohr's second orbit is [1 mark]

(A) r_0

(B) $2r_0$

(C) $4r_0$

(D) $\frac{r_0}{2}$

Correct Answer: (C) $4r_0$

Solution:

Concept:

- In Bohr's model the electron moves in circular orbits where the angular momentum is a whole-number multiple of $h/2\pi$.
- Each allowed orbit has a fixed radius, labelled by the principal quantum number n.

Step 1: Key Formula or Approach For hydrogen, the radius of the n-th orbit is

$$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2} = n^2 r_0$$

Here r_0 is the radius of the first orbit ($n = 1$), about 0.529 angstrom. So r_n is proportional to n^2.

Step 2: Detailed Explanation For the second orbit, $n = 2$:

$$r_2 = 2^2\, r_0 = 4r_0$$

Numerically this is $4 \times 0.529 = 2.116$ angstrom.

Step 3: Check each option Option (1), r_0: wrong, this is the first orbit itself.
Option (2), $2r_0$: wrong, it uses $r \propto n$ instead of $r \propto n^2$.
Option (3), $4r_0$: correct, since $r \propto n^2$ and $2^2 = 4$.
Option (4), $r_0/2$: wrong, orbits get larger as n increases, never smaller.

Step 4: Conclusion The second Bohr orbit has four times the radius of the first orbit. This is option (3).

Quick Tip to Solve: In Bohr's model the orbit radius grows as n^2. Put $n = 2$.

38. If magnetic field is same but the area of the loop is increased, then the flux [1 mark]

(A) increases

(B) decreases

(C) becomes zero

(D) remains unchanged

Correct Answer: (A) increases

Solution:

Concept:

- Magnetic flux measures how much magnetic field passes through a surface.
- A bigger surface in the same field catches more field lines.

Step 1: Key Formula or Approach

$$\Phi = BA\cos\theta$$

Here B is the field, A is the area of the loop and θ is the angle between $\vec{B}$ and the normal to the loop.

Step 2: Detailed Explanation The question says B stays the same, and the loop is not rotated, so θ is unchanged.
Then Φ is directly proportional to A. If the area becomes $A' > A$, then

$$\Phi' = BA'\cos\theta > BA\cos\theta = \Phi$$

So the flux increases. For example, doubling the area doubles the flux.

Step 3: Check each option Option (1), increases: correct, because $\Phi \propto A$.
Option (2), decreases: wrong, it would need the area to shrink.
Option (3), becomes zero: wrong, flux is zero only if $B = 0$ or $\theta = 90^\circ$, neither of which is given.
Option (4), remains unchanged: wrong, area appears in the formula for flux, so a change in area changes it.

Step 4: Conclusion The magnetic flux increases when the loop area increases at constant field. This is option (1).

Quick Tip to Solve: Use $\Phi = BA\cos\theta$. With B and θ fixed, see how Φ depends on A.

39. The voltage of domestic ac is 220 V. What does this represent ? [1 mark]

(A) Peak value voltage

(B) Mean value voltage

(C) Root mean voltage

(D) Root mean square voltage

Correct Answer: (D) Root mean square voltage

Solution:

Concept:

- An alternating voltage keeps changing with time, so it has no single value. We describe it with a few standard numbers: peak value, mean (average) value and root mean square (rms) value.
- Meters and household ratings use the rms value, because it gives the same heating effect as a steady dc voltage of that size.

Step 1: Key Formula or Approach For a sinusoidal voltage $V = V_0 \sin\omega t$:

1. $V_{rms} = \dfrac{V_0}{\sqrt{2}} \approx 0.707\, V_0$.
2. Mean value over a full cycle is zero. Over a half cycle it is $\dfrac{2V_0}{\pi}$.

Step 2: Detailed Explanation The supply voltage quoted for homes, 220 V, is the rms value. The peak value then is

$$V_0 = \sqrt{2} \times 220 \approx 311 \text{ V}$$

So the voltage actually swings between about $+311$ V and -311 V, while 220 V is the rms value.

Step 3: Check each option Option (1), peak value: wrong, the peak is about 311 V.
Option (2), mean value: wrong, the mean over a full cycle is zero.
Option (3), root mean voltage: wrong, this is not a standard term. The correct name is root mean square.
Option (4), root mean square voltage: correct.

Step 4: Conclusion The domestic ac voltage of 220 V is the root mean square value. This is option (4).

Quick Tip to Solve: Household ac ratings are quoted as rms values. The peak value would be $\sqrt{2}$ times larger.

40. The wavefront due to a point source at a finite distance from the source is [1 mark]

(A) plane

(B) circular

(C) cylindrical

(D) spherical

Correct Answer: (D) spherical

Solution:

Concept:

- A wavefront is the surface that joins all points of a medium that vibrate in the same phase at a given instant.
- Its shape depends on the shape of the source that sends out the wave.

Step 1: Key Formula or Approach Huygens' principle says every point on a wavefront acts as a new source of secondary wavelets. For a point source in a uniform medium, the disturbance travels the same distance in every direction in the same time.

Step 2: Detailed Explanation Let the point source be at the origin and let the wave travel with speed v in an isotropic medium.
After a time t, the disturbance reaches every point at distance $r = vt$ from the source.
All such points lie on a sphere of radius r centred on the source, so they all vibrate in the same phase.
Therefore the wavefront is a sphere, and its radius grows with time.
Very far from the source, a small part of this sphere looks flat, and that is why a distant source (like the Sun) gives an almost plane wavefront.

Step 3: Why the other options are wrong (A) Plane: a plane wavefront needs the source to be at infinity, not at a finite distance.
(B) Circular: a circle is a curve in a plane, so it would only be right for a two dimensional picture, not for light or sound spreading in space.
(C) Cylindrical: this comes from a line (linear) source, such as a long narrow slit, not from a point source.

Step 4: Conclusion A point source at a finite distance sends out spherical wavefronts. This is option (4).

Quick Tip to Solve: The wave travels equally in all directions from a point, so points at the same distance from the source vibrate in the same phase. What surface do they form?

41. For destructive interference, the path difference should be equal to [1 mark]

(A) $n\lambda$

(B) $(2n+1)\frac{\lambda}{2}$

(C) zero

(D) infinity

Correct Answer: (B) $(2n+1)\frac{\lambda}{2}$

Solution:

Concept:

- When two coherent waves meet, they add up.
- The resultant amplitude depends on the phase difference between them, and the phase difference comes from the path difference.

Step 1: Key Formula or Approach The phase difference ϕ and the path difference Δx are related by

$$\phi = \frac{2\pi}{\lambda}\Delta x$$

For two waves of equal amplitude a, the resultant amplitude is $A = 2a\cos(\phi/2)$.

Step 2: Detailed Explanation Destructive interference means the resultant amplitude is minimum, which is zero for equal amplitudes.
So we need $\cos(\phi/2) = 0$.
This happens when $\phi = (2n+1)\pi$, where $n = 0, 1, 2, \ldots$
Put this into the first relation:

$$\Delta x = \frac{\lambda}{2\pi}\phi = \frac{\lambda}{2\pi}(2n+1)\pi = (2n+1)\frac{\lambda}{2}$$

So the path difference must be an odd multiple of half a wavelength. A crest of one wave then falls on a trough of the other and they cancel.

Step 3: Why the other options are wrong (A) $n\lambda$: this is a whole number of wavelengths, so the waves arrive in phase and give constructive interference (bright fringe).
(C) Zero path difference also means the waves are in phase, so it is constructive again.
(D) Infinity is not a definite path difference and does not decide the type of interference.

Step 4: Conclusion The condition for destructive interference is an odd multiple of half a wavelength. This is option (2).

Quick Tip to Solve: Destructive interference needs the two waves to be exactly out of phase, a phase difference of an odd multiple of π. Convert that to a path difference using $\Delta x = \frac{\lambda}{2\pi}\phi$.

42. In an electric field with intensity $E = 0$, the change of potential V with distance r will be [1 mark]

(A) $V \propto \frac{1}{r^2}$

(B) $V \propto \frac{1}{r}$

(C) $V \propto r$

(D) $V =$ constant and independent of r

Correct Answer: (D) $V =$ constant and independent of r

Solution:

Concept:

- The electric field is the negative gradient of the potential.
- It tells us how fast the potential changes with position.

Step 1: Key Formula or Approach In one dimension,

$$E = -\frac{dV}{dr}$$

If the field is zero in a region, the potential does not change in that region.

Step 2: Detailed Explanation Put $E = 0$ in the relation:

$$-\frac{dV}{dr} = 0 \quad \Rightarrow \quad \frac{dV}{dr} = 0$$

Integrating both sides gives

$$V = \text{constant}$$

So the potential has the same value at every point of that region, whatever the value of r. The value of the constant depends on the reference point chosen, but it does not change with r.
A common example is the inside of a charged conductor, where $E = 0$ and the potential is the same everywhere and equal to the surface potential.

Step 3: Why the other options are wrong (A) $V \propto 1/r^2$ would give $E = -dV/dr \propto 1/r^3$, which is not zero.
(B) $V \propto 1/r$ is the potential of a point charge and gives $E \propto 1/r^2$, again not zero.
(C) $V \propto r$ gives a constant, non-zero field $E = -k$, where k is the constant of proportionality.

Step 4: Conclusion When the field is zero, the potential is constant and independent of distance. This is option (4).

Quick Tip to Solve: Use $E = -dV/dr$. If E is zero, what must the rate of change of V with r be?

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43. The equivalent resistance of resistors in parallel combination [1 mark]

(A) decreases

(B) increases

(C) remains same

(D) none of these

Correct Answer: (A) decreases

Solution:

Concept:

- We need to know how the equivalent resistance of a parallel combination compares with the resistors that make it up.
- As more resistors are added in parallel, the equivalent resistance falls.

Step 1: Key Formula or Approach For resistors $R_1, R_2, \ldots, R_n$ in parallel, the same voltage is across each one and the currents add:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

Step 2: Detailed Explanation Take two resistors, $R_1 = 4\ \Omega$ and $R_2 = 4\ \Omega$. Then

$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{4} = \frac{1}{2} \quad \Rightarrow \quad R_{eq} = 2\ \Omega$$

This is less than either resistor. In general, $1/R_{eq}$ is larger than $1/R_1$ because we add more positive terms, so $R_{eq} < R_1$, and the same holds for every other resistor.
Adding one more resistor in parallel gives the current one more path, so the total current for the same voltage goes up and the equivalent resistance goes down.

Step 3: Why the other options are wrong (B) Increases is the behaviour of a series combination, where $R_{eq} = R_1 + R_2 + \cdots$.
(C) It does not stay the same, as the example above shows a change from 4 ohm to 2 ohm.
(D) A definite answer exists, namely option (A), so (D) is wrong.

Step 4: Conclusion The equivalent resistance in parallel is less than the smallest individual resistance, so it decreases. This is option (1).

Quick Tip to Solve: Write $1/R_{eq} = 1/R_1 + 1/R_2 + \cdots$ and compare R_{eq} with a single resistor.

44. The magnetic field lines inside a current-carrying solenoid are [1 mark]

(A) circular

(B) diverging

(C) parabola

(D) parallel and straight

Correct Answer: (D) parallel and straight

Solution:

Concept:

- A solenoid is a long wire wound closely in the shape of a helix. When current flows, each turn adds its own magnetic field.
- The question asks what the field lines look like in the space inside the coil.

Step 1: Key Formula or Approach For an ideal long solenoid with n turns per unit length carrying current I, the field inside is $B = \mu_0 nI$.
This value does not depend on the position inside the coil, so the field is uniform and points along the axis.

Step 2: Detailed Explanation Near the axis, the fields of neighbouring turns add up along the axis, and their sideways parts cancel each other.
A uniform field along one fixed direction is drawn as equally spaced lines that are straight and parallel to the axis.
So inside the solenoid the field lines are parallel and straight.

Step 3: Why the other options are wrong. Option (1), circular: field lines around a straight current-carrying wire are circles. Inside a solenoid they are not.
Option (2), diverging: lines spread out only near the ends of a short coil or outside the solenoid, where the field is weak. Inside, the field stays uniform.
Option (3), parabola: no standard magnetic field of a coil has parabolic lines.

Step 4: Conclusion Inside a long current-carrying solenoid the field is uniform, so the field lines are parallel and straight. This is option (4).

Quick Tip to Solve: Inside a long solenoid the field is uniform, $B = \mu_0 nI$, and points along the axis. What shape do uniform field lines have?

45. Coherent sources are those sources for which [1 mark]

(A) phase difference remains constant

(B) amplitude remains constant

(C) frequency remains constant

(D) both phase difference and frequency remain constant

Correct Answer: (D) both phase difference and frequency remain constant

Solution:

Concept:

- Sustained interference with a steady pattern of bright and dark fringes needs two sources that are coherent.

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- Coherence is a statement about the phase relation between the two waves.

Step 1: Key Formula or Approach Two sources are coherent when they emit waves of the same frequency (same wavelength) with a constant phase difference between them at all times. Then the resultant intensity at a point is

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

with ϕ fixed in time at that point.

Step 2: Detailed Explanation If the phase difference changes randomly with time, the term $\cos\phi$ averages to zero and the intensity at every point is just $I_1 + I_2$, so no fringes are seen.
If the two frequencies are different, the phase difference $\phi = (\omega_1 - \omega_2)t + \phi_0$ changes with time and the fringes keep moving.
So for a steady pattern we need both the frequency to be the same and the phase difference to stay constant.

Step 3: Check each option (A) Constant phase difference is needed, but this statement leaves out the equal frequency, so it is incomplete.
(B) Constant amplitude does not decide coherence. Coherent sources can have different amplitudes and the fringes are still steady.
(C) Constant frequency alone is not enough, because the phase difference can still vary with time.
(D) Constant phase difference and constant frequency together describe coherent sources. So (D) is the best answer.

Step 4: Conclusion Coherent sources keep a constant phase difference and the same frequency. This is option (4).

Quick Tip to Solve: For a steady interference pattern, the phase difference between the two waves at a point must not change with time. Which conditions on the sources ensure this?

46. Natural light from the sun is [1 mark]

(A) polarised

(B) unpolarised

(C) partially polarised

(D) linearly polarised

Correct Answer: (B) unpolarised

Solution:

Concept:

- Light is a transverse electromagnetic wave. Its electric field vibrates perpendicular to the direction of travel.
- In polarised light these vibrations are restricted to one plane. In unpolarised light they point in all possible directions in the plane perpendicular to the ray.

Step 1: Think about how sunlight is produced The sun contains an enormous number of atoms. Each atom emits light independently of the others, and each emission has its own random direction of vibration. These emissions change very rapidly in time. So the vibrations of the electric field have no preferred direction.

Step 2: Decide the nature of natural light With no preferred direction of vibration, natural light from the sun is unpolarised. It becomes polarised only after reflection, scattering, or passing through a

polaroid or a suitable crystal.

Step 3: Check each option. Option (A), polarised: wrong, because the vibrations are not confined to one plane.
Option (B), unpolarised: correct, as explained above.
Option (C), partially polarised: wrong. Sunlight becomes partially polarised only after scattering or reflection, not as it comes from the source.
Option (D), linearly polarised: wrong, because linear polarisation means vibrations in a single fixed direction.

Step 4: Conclusion Natural light from the sun is unpolarised, which is option (2).

Quick Tip to Solve: Sunlight comes from countless atoms vibrating in random directions, so no single plane of vibration is preferred.

47. Radioactivity was discovered by [1 mark]

(A) Marie Curie

(B) Pierre Curie

(C) Ernest Rutherford

(D) Henri Becquerel

Correct Answer: (D) Henri Becquerel

Solution:

Concept:

- Radioactivity is the spontaneous emission of radiation (alpha, beta or gamma rays) from the nucleus of an unstable atom.
- The question asks which scientist first observed this phenomenon.

Step 1: Recall the history In 1896 Henri Becquerel was studying uranium salts. He found that they darkened a photographic plate wrapped in black paper, even without sunlight. So the salts were giving out some penetrating radiation by themselves. This was the discovery of radioactivity.

Step 2: Role of the other scientists Marie Curie and Pierre Curie then studied this radiation in detail. They discovered the new radioactive elements polonium and radium. Marie Curie also introduced the word radioactivity. Ernest Rutherford later classified the radiation into alpha and beta rays and worked out the decay law with Soddy.

Step 3: Check each option. Option (1), Marie Curie: wrong, she named it and found new elements but did not discover it.
Option (2), Pierre Curie: wrong, same reason.
Option (3), Ernest Rutherford: wrong, he studied the types of radiation later.
Option (4), Henri Becquerel: correct.

Step 4: Conclusion Radioactivity was discovered by Henri Becquerel in 1896, option (4).

Quick Tip to Solve: Recall the 1896 experiment in which uranium salts fogged a wrapped photographic plate.

48. The example of a broadcast mode of communication is [1 mark]

(A) radio

(B) telephone

(C) television

(D) both (A) and (C)

Correct Answer: (D) both (A) and (C)

Solution:

Concept:

- In communication there are two common modes.
- In point-to-point communication, a message goes from one sender to one receiver, as in a phone call.
- In broadcast mode, one transmitter sends a signal that many receivers can pick up at the same time.

Step 1: Key Formula or Approach We test each option by asking whether one transmitter serves many listeners or viewers at once.

Step 2: Check each option. Option (A), radio: a radio station transmits one signal and any radio tuned to it can receive it. So radio is broadcast.
Option (B), telephone: a call links two particular persons. This is point-to-point communication, so it is not broadcast.
Option (C), television: a TV channel is sent out to all TV sets in the coverage area. So television is broadcast.
Option (D), both (A) and (C): since radio and television are both broadcast, this option is correct.

Step 3: Conclusion Both radio and television are broadcast modes, so the answer is option (D), which is option 4.

Quick Tip to Solve: Broadcast means one transmitter and many receivers at once. Ask which options fit that.

49. Which device is used as a voltage regulator ? [1 mark]

(A) Transistor

(B) Transformer

(C) Zener diode

(D) Photodiode

Correct Answer: (C) Zener diode

Solution:

Concept:

- A voltage regulator keeps the voltage across a load almost constant, even if the input voltage or the load current changes.
- We need the device that can do this job.

Step 1: Key Formula or Approach A Zener diode is a heavily doped p-n junction used in reverse bias. Above its breakdown voltage V_Z the current can change over a wide range while the voltage across it stays almost fixed at V_Z.

Step 2: How the Zener regulates Connect the Zener in reverse bias across the load, with a series resistor from the supply. If the input voltage rises, the extra current flows through the Zener and the

extra voltage drops across the series resistor. The load voltage stays near V_Z. If the input falls, the Zener current falls and the output still stays close to V_Z.

Step 3: Check the other options. Option (1), transistor: used as an amplifier or a switch, not a basic voltage regulator.
Option (2), transformer: it changes AC voltage levels by electromagnetic induction. It does not hold the output fixed.
Option (4), photodiode: it works as a light detector in reverse bias. It is not a regulator.

Step 4: Conclusion The voltage regulator device is the Zener diode, option (3).

Quick Tip to Solve: Think of the diode that works in reverse breakdown with an almost constant voltage across it.

50. To remove hypermetropia, lens used is [1 mark]

(A) convex

(B) concave

(C) cylindrical

(D) plano-convex

Correct Answer: (A) convex

Solution:

Concept:

- Hypermetropia (far-sightedness) is a defect of vision in which a person can see distant objects clearly but cannot see nearby objects clearly.
- The near point moves away from the normal value of 25 cm to a larger distance.

Step 1: Cause of the defect In a hypermetropic eye the eyeball is too short, or the eye lens is too weak (its focal length is too large). So the rays from a nearby object are not bent enough, and they would meet at a point behind the retina.

Step 2: What the correcting lens must do The rays must be made to converge a little more before they enter the eye, so that the image falls exactly on the retina. A lens that adds convergence is a converging lens, that is, a convex lens.
The convex lens forms a virtual image of an object kept at 25 cm at the eye's own near point, and the eye can focus on that image.

$$P = \frac{1}{f} > 0 \quad \text{(positive power, convex lens)}$$

Step 3: Check the other options. (B) A concave lens diverges rays. It is used for myopia (short-sightedness), where the image forms in front of the retina. So (B) is wrong.
(C) A cylindrical lens has different power in different planes. It is used for astigmatism. So (C) is wrong.
(D) A plano-convex lens is only one particular shape of convex lens. The question asks for the type of lens, and the general answer is the convex lens in (A).

Step 4: Conclusion Hypermetropia is corrected by a convex lens, option (A).

Quick Tip to Solve: Hypermetropia means the image falls behind the retina, so the lens must add convergence. Which lens converges rays?

51. Inverse square law of intensity of light, i.e., intensity $\propto \frac{1}{r^2}$ is applicable for [1 mark]

(A) point source

(B) linear source

(C) cylindrical source

(D) plane source

Correct Answer: (A) point source

Solution:

Concept:

- Intensity of light is the power passing normally through a unit area.
- How it falls with distance depends on the shape of the wavefront that the source produces.

Step 1: Key Formula or Approach If a source sends out total power P and the light spreads over a surface of area A, then the intensity is $I = \frac{P}{A}$. We find A for each type of source.

Step 2: Point source. A point source sends light equally in all directions, so the wavefront is a sphere. At distance r the area is $4\pi r^2$.

$$I = \frac{P}{4\pi r^2} \propto \frac{1}{r^2}$$

So the inverse square law holds. (A) is correct.

Step 3: Check the other options. (B) A linear (line) source gives a cylindrical wavefront. Its area at distance r is $2\pi rl$, so $I \propto \frac{1}{r}$. It is not inverse square.

(C) A cylindrical source also spreads light over a cylindrical surface, so again $I \propto \frac{1}{r}$.
(D) A plane source gives a plane wavefront whose area does not grow with distance, so the intensity stays nearly constant.

Step 4: Conclusion Only a point source gives intensity proportional to $1/r^2$, option (A).

Quick Tip to Solve: Find the area of the wavefront at distance r for each source. Only a spherical wavefront has area proportional to r squared.

52. The kinetic energy (K) of an electron in a Bohr orbit is related to its potential energy (U) by [1 mark]

(A) $K = U$

(B) $K = -U$

(C) $K = -\frac{U}{2}$

(D) $K = -2U$

Correct Answer: (C) $K = -\frac{U}{2}$

Solution:

Concept:

- In the Bohr model an electron of charge e moves in a circle of radius r around a nucleus of charge Ze.

- The electrostatic pull of the nucleus supplies the centripetal force.

Step 1: Key Formula or Approach Centripetal force equals electrostatic force, and the potential energy of the pair is $U = -\frac{kZe^2}{r}$ with $k = \frac{1}{4\pi\varepsilon_0}$.

Step 2: Find the kinetic energy.

$$\frac{mv^2}{r} = \frac{kZe^2}{r^2} \quad \Rightarrow \quad mv^2 = \frac{kZe^2}{r}$$

$$K = \frac{1}{2}mv^2 = \frac{kZe^2}{2r}$$

Step 3: Compare K with U. Since $U = -\frac{kZe^2}{r}$, we get $\frac{kZe^2}{r} = -U$. Putting this in the result for K:

$$K = \frac{1}{2}(-U) = -\frac{U}{2}$$

The total energy is $E = K + U = -\frac{U}{2} + U = \frac{U}{2} = -K$, which is negative for a bound electron, as it should be.

Step 4: Check the other options. (A) $K = U$ is impossible, because K is positive and U is negative. (B) $K = -U$ would make the total energy zero, which means a free electron, not a bound one. (D) $K = -2U$ has the wrong factor, since the kinetic energy is only half the magnitude of U.

Step 5: Conclusion The kinetic energy is half the magnitude of the potential energy, option (C).

Quick Tip to Solve: Equate the electrostatic force to the centripetal force to get the kinetic energy, then compare it with U = -kZe ^ 2/r.

53. Semiconductor is damaged by the strong current due to [1 mark]

(A) lack of free electrons

(B) excess of protons

(C) excess of electrons

(D) excess of neutrons

Correct Answer: (C) excess of electrons

Solution:

Concept:

- A semiconductor such as silicon or germanium conducts only because of a small number of free charge carriers.
- The question asks why a very strong current can ruin the device.

Step 1: Key Idea A strong current produces a lot of heat in the crystal (Joule heating). In a semiconductor, heat is not harmless, because it can break covalent bonds.

Step 2: What happens inside the crystal. When heat energy exceeds the band gap energy, more and more covalent bonds break. Each broken bond frees an electron, and also leaves a hole. So the number of free electrons rises sharply.
More free electrons carry still more current, which heats the crystal further. This chain continues until

the crystal structure is permanently damaged.

Step 3: Check the options. (A) A lack of free electrons would lower the current, not raise it, so it cannot damage the device.
(B) and (D) Protons and neutrons sit in the nucleus and are not free to move, so a change in them does not come from a current. Both are wrong.
(C) An excess of free electrons (together with holes) produced by the broken bonds explains the runaway heating. This is correct.

Step 4: Conclusion The damage is due to the excess of electrons freed by heating, option (C).

Quick Tip to Solve: A strong current heats the crystal. What does heat do to the covalent bonds of a semiconductor?

54. The valency of impurity element to convert a germanium crystal into a p-type semiconductor is [1 mark]

(A) 2

(B) 3

(C) 4

(D) 5

Correct Answer: (B) 3

Solution:

Concept:

- Germanium is a group 14 element with valency 4.
- In a pure crystal each atom forms four covalent bonds with four neighbours.
- Doping means adding a small amount of another element.

Step 1: What makes a p-type semiconductor. A p-type semiconductor has holes as the majority carriers. To get holes, the impurity atom must have one electron fewer than germanium has for bonding. That means a trivalent impurity (valency 3), such as boron, aluminium, gallium or indium.

Step 2: Why this gives a hole. A trivalent atom has only three valence electrons, but it sits in a lattice that needs four bonds. One bond stays incomplete, and this vacancy behaves as a hole. Such an impurity is called an acceptor.

Step 3: Check the other options. (A) Valency 2 is not used for doping germanium. (C) Valency 4 is the same as germanium, so no extra hole or electron is created. (D) Valency 5 (phosphorus, arsenic, antimony) leaves one extra electron, which makes an n-type semiconductor.

Step 4: Conclusion The impurity must be trivalent, so the valency is 3, option (B).

Quick Tip to Solve: A p-type crystal needs holes, so the impurity must have one valence electron fewer than germanium.

55. In a communication system, a repeater is [1 mark]

(A) a receiver

(B) a transmitter

(C) a combination of a receiver and transmitter

(D) none of these

Correct Answer: (C) a combination of a receiver and transmitter

Solution:

Concept:

- A signal loses strength as it travels a long distance through a channel, because the channel absorbs it and adds noise.
- For a long link, the signal has to be boosted on the way.
- This is the job of a repeater.

Step 1: Key Formula or Approach A repeater has two parts working one after the other. The first part receives the weak incoming signal. The second part amplifies it and sends it forward on a new carrier, so it works as a receiver and a transmitter together.

Step 2: Check option (A). A receiver alone only picks up the signal. It has nothing to send the signal on, so the signal would stop there. So (A) is FALSE.

Step 3: Check option (B). A transmitter alone only sends out a signal. It has no part that picks up the weak signal that arrives from the earlier stage. So (B) is FALSE.

Step 4: Check option (C). A repeater picks up the weak signal, amplifies it and retransmits it. A communication satellite works in the same way. It is therefore a combination of a receiver and a transmitter. So (C) is TRUE.

Step 5: Check option (D). Option (C) is correct, so (D) cannot be right. So (D) is FALSE.

Step 6: Conclusion A repeater is a combination of a receiver and a transmitter. This is option (3), the third option.

Quick Tip to Solve: A repeater picks up a weak signal, amplifies it and sends it on again. Which two units does that need?

56. The maximum velocity of an electron emitted from a metal surface becomes two times when the frequency ν of the incident light is doubled. The work function of the metal is [1 mark]

(A) $\frac{2h\nu}{3}$

(B) $\frac{h\nu}{3}$

(C) zero

(D) $\frac{h\nu}{2}$

Correct Answer: (A) $\frac{2h\nu}{3}$

Solution:

Concept:

- When light of frequency ν falls on a metal, each photon gives all its energy $h\nu$ to one electron.
- Part of this energy, the work function ϕ, is used to free the electron.
- The rest becomes its maximum kinetic energy.

Step 1: Key Formula or Approach Einstein's photoelectric equation is

$$h\nu = \phi + \tfrac{1}{2}mv_{\max}^2$$

Here $v_{\max}$ is the maximum speed of the emitted electron. We write this equation twice, once for ν

and once for 2ν.

Step 2: Detailed Explanation Let the maximum kinetic energy at frequency ν be K. Then

$$h\nu - \phi = K \quad \cdots (1)$$

When the frequency is doubled, the maximum speed becomes two times. Kinetic energy goes as the square of speed, so it becomes $4K$.

$$2h\nu - \phi = 4K \quad \cdots (2)$$

Put $K = h\nu - \phi$ from (1) into (2):

$$2h\nu - \phi = 4(h\nu - \phi) = 4h\nu - 4\phi$$

$$3\phi = 2h\nu$$

$$\phi = \frac{2h\nu}{3}$$

Step 3: Check the options Option (1) is $\frac{2h\nu}{3}$, which is what we found. So it is TRUE.
Option (2), $\frac{h\nu}{3}$, would give $K = \frac{2}{3}h\nu$ and $2h\nu - \phi = \frac{5}{3}h\nu$, which is only 2.5 times K, not 4 times. So it is FALSE.
Option (3), zero, would double the kinetic energy and make the speed $\sqrt{2}$ times, not 2 times. So it is FALSE.
Option (4), $\frac{h\nu}{2}$, gives $K = \frac{h\nu}{2}$ and $2h\nu - \phi = \frac{3h\nu}{2}$, which is 3 times K, not 4 times. So it is FALSE.

Step 4: Conclusion The work function of the metal is two thirds of $h\nu$, which is option (1).

Quick Tip to Solve: Write Einstein's equation for ν and for 2ν. Doubling the speed makes the kinetic energy four times.

57. The dimensions of $\frac{B_0^2}{\mu_0}$ will be the same as that of [1 mark]

(A) energy density

(B) work

(C) momentum

(D) electric flux

Correct Answer: (A) energy density

Solution:

Concept:

- We must compare the dimensions of B_0^2/μ_0 with those of the four given quantities.
- Here B_0 is the amplitude of the magnetic field of an electromagnetic wave and μ_0 is the permeability of free space.

Step 1: Key Formula or Approach The energy density of a magnetic field is $u_B = \frac{B^2}{2\mu_0}$. The factor $\frac{1}{2}$ is

a pure number and has no dimensions, so B_0^2/μ_0 has the same dimensions as energy density.

Step 2: Detailed Explanation Check this with base dimensions. From $F = qvB$, the dimensions are $[B] = MT^{-2}A^{-1}$.
From $F = \frac{\mu_0 I_1 I_2 l}{2\pi d}$, the dimensions are $[\mu_0] = MLT^{-2}A^{-2}$.

$$[\frac{B^2}{\mu_0}] = \frac{M^2T^{-4}A^{-2}}{MLT^{-2}A^{-2}} = ML^{-1}T^{-2}$$

Energy density is energy per unit volume: $\frac{ML^2T^{-2}}{L^3} = ML^{-1}T^{-2}$. The two match.

Step 3: Check the other options (B) Work has dimensions ML^2T^{-2}, which has an extra L^3, so it is wrong.
(C) Momentum has dimensions MLT^{-1}, so it is wrong.
(D) Electric flux is $E\times$ area, which gives $ML^3T^{-3}A^{-1}$, so it is wrong.

Step 4: Conclusion B_0^2/μ_0 has the dimensions of energy density, which is option (A).

Quick Tip to Solve: Recall that magnetic energy density is B squared over 2 mu-naught, and the half has no dimensions.

58. Nickel is [1 mark]

(A) Paramagnetic

(B) Diamagnetic

(C) Ferromagnetic

(D) None of these

Correct Answer: (C) Ferromagnetic

Solution:

Concept:

- Materials are classified based on their behavior in an external magnetic field.
- The main categories are diamagnetic, paramagnetic, and ferromagnetic.

Step 1: Detailed Explanation - **Diamagnetic** materials are weakly repelled by a magnetic field. They have a magnetic permeability slightly less than that of a vacuum. Examples include water, copper, and bismuth.
- **Paramagnetic** materials are weakly attracted to a magnetic field. They have a magnetic permeability slightly greater than that of a vacuum. Examples include aluminum, platinum, and oxygen.
- **Ferromagnetic** materials are very strongly attracted to a magnetic field and can be permanently magnetized. They have a very high magnetic permeability. The atoms in these materials have magnetic moments that align in large regions called domains.
Nickel (Ni) is one of the three common elements, along with Iron (Fe) and Cobalt (Co), that exhibit ferromagnetism at room temperature.

Step 2: Conclusion Nickel is a ferromagnetic material. Therefore, option (C) is correct.

Quick Tip to Solve: Remember the "big three" ferromagnetic elements: Iron (Fe), Cobalt (Co), and Nickel (Ni). These are the most common examples asked in exams.

59. In a half-wave rectifier, if the input frequency is 50 Hz, then output frequency will be [1 mark]

(A) 25 Hz

(B) 100 Hz

(C) 0 Hz

(D) 50 Hz

Correct Answer: (D) 50 Hz

Solution:

Concept:

- A rectifier changes alternating current into direct (one-way) current.
- A half-wave rectifier uses a single diode, which conducts only when it is forward biased.

Step 1: Key Formula or Approach For an input of frequency f, the period is $T = 1/f$. In a half-wave rectifier the diode passes one half of every input cycle. So one output pulse appears per input cycle.

Step 2: Detailed Explanation Here $f_{in} = 50$ Hz, so the period is $T = \frac{1}{50} = 0.02$ s.
In each 0.02 s cycle, the positive half passes through the diode and the negative half is blocked.
So the output pulses repeat every 0.02 s as well.

$$f_{out} = f_{in} = 50 \text{ Hz}$$

Step 3: Check the options (A) 25 Hz would need the output to skip whole cycles, which never happens, so it is wrong.
(B) 100 Hz is the output of a full-wave rectifier, which uses both halves of the cycle, so it is wrong here.
(C) 0 Hz would mean a perfectly steady output, which the ripple of the pulses does not give, so it is wrong.
(D) 50 Hz is what we found, so it is correct.

Step 4: Conclusion The output ripple frequency of a half-wave rectifier equals the input frequency, which is option (D).

Quick Tip to Solve: A half-wave rectifier gives one output pulse for each input cycle.

60. How many joules of energy will be released due to mass defect of 1 mg ? [1 mark]

(A) 9×10^6 J

(B) 3×10^8 J

(C) 9×10^{10} J

(D) 3×10^2 J

Correct Answer: (C) 9×10^{10} J

Solution:

Concept:

- When some mass disappears in a nuclear reaction, an equivalent amount of energy is released.
- Einstein's mass-energy relation connects the two.

Step 1: Key Formula or Approach $E = \Delta m\, c^2$, where Δm is the mass defect in kg and $c = 3 \times 10^8$

m/s. The mass must be in kilograms for the energy to come out in joules.

Step 2: Detailed Explanation Convert the mass: 1 mg $= 10^{-3}$ g $= 10^{-6}$ kg.
Now substitute:

$$E = (10^{-6})(3 \times 10^{8})^2 = 10^{-6} \times 9 \times 10^{16}$$

$$E = 9 \times 10^{10} \text{ J}$$

Step 3: Check the options (A) 9×10^{6} J is smaller by a factor of 10^{4}, so it is wrong.
(B) 3×10^{8} J is the speed of light in m/s, not an energy from mc^2, so it is wrong.
(C) 9×10^{10} J is the value we found, so it is correct.
(D) 3×10^{2} J has no basis in the formula, so it is wrong.

Step 4: Conclusion The energy released is 9×10^{10} J, which is option (C).

Quick Tip to Solve: Convert 1 mg to kilograms and use E = mc squared.

61. The ratio of de Broglie wavelength associated with two electrons accelerated through 49 V and 64 V is [1 mark]

(A) $\frac{49}{64}$

(B) $\frac{64}{49}$

(C) $\frac{7}{8}$

(D) $\frac{8}{7}$

Correct Answer: (D) $\frac{8}{7}$

Solution:

Concept:

- An electron accelerated from rest through a potential difference V gains kinetic energy eV.
- A moving electron behaves like a wave, and its de Broglie wavelength depends on its momentum.
- So the wavelength depends on the accelerating voltage.

Step 1: Key Formula or Approach The kinetic energy is $\frac{p^2}{2m} = eV$, so the momentum is $p = \sqrt{2meV}$.
The de Broglie relation is $\lambda = \frac{h}{p}$.
Putting these together:

$$\lambda = \frac{h}{\sqrt{2meV}}$$

Here h, m and e are the same for both electrons, so $\lambda \propto \frac{1}{\sqrt{V}}$.

Step 2: Detailed Explanation Let λ_1 be the wavelength for $V_1 = 49$ V and λ_2 the wavelength for $V_2 = 64$ V.
Taking the ratio, the constants cancel:

$$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}} = \sqrt{\frac{64}{49}} = \frac{8}{7}$$

The electron at the lower voltage has less energy and a longer wavelength, which agrees with $\lambda_1 > \lambda_2$.

Step 3: Check the other options. Option (1), $\frac{49}{64}$, is the plain voltage ratio V_1/V_2. It forgets the square root.
Option (2), $\frac{64}{49}$, is the plain voltage ratio V_2/V_1, again without the square root.
Option (3), $\frac{7}{8}$, is the inverse of the correct ratio. It would give λ_2/λ_1, but the question asks for λ_1/λ_2.

Step 4: Conclusion The ratio of the wavelengths for 49 V and 64 V is 8 : 7, which is option (4).

Quick Tip to Solve: Use $\lambda = \frac{h}{\sqrt{2meV}}$, so $\lambda \propto 1/\sqrt{V}$. Then take $\sqrt{64/49}$.

62. A ray of light is incident normally on a plane mirror. The angle of reflection will be [1 mark]

(A) 90°

(B) 0°

(C) will not be reflected

(D) none of these

Correct Answer: (B) 0°

Solution:

Concept:

- This question is about the law of reflection and what 'normal incidence' means.
- The angles of incidence and reflection are always measured from the normal, which is the line drawn at right angles to the mirror surface at the point where the ray hits.
- They are not measured from the mirror surface itself.

Step 1: Key Formula or Approach Law of reflection: the angle of reflection equals the angle of incidence.

$$\angle r = \angle i$$

Step 2: Detailed Explanation The ray falls normally on the mirror. That means the ray travels along the normal itself.
So the angle between the incident ray and the normal is $\angle i = 0^\circ$.
By the law of reflection, $\angle r = \angle i = 0^\circ$.
The ray is reflected straight back along its own path.

Step 3: Check the other options. Option (1), 90°: this is the angle between the incident ray and the mirror surface, not the angle with the normal. It is a common mistake. If the angle of reflection were 90°, the ray would run along the mirror.
Option (3), will not be reflected: a plane mirror reflects light at every angle of incidence, including normal incidence.
Option (4), none of these: not correct, because option (2) is right.

Step 4: Conclusion The angle of reflection is zero, so the correct option is (2).

Quick Tip to Solve: Angles are measured from the normal. A normally incident ray lies along the normal, so the angle of incidence is zero.

63. The phase difference ϕ is related to path difference λ by [1 mark]

(A) $\frac{\lambda}{\pi}\phi$

(B) $\frac{\pi}{\lambda}\phi$

(C) $\frac{\lambda}{2\pi}\phi$

(D) $\frac{2\pi}{\lambda}\phi$

Correct Answer: (C) $\frac{\lambda}{2\pi}\phi$

Solution:

Concept:

- Light of wavelength λ repeats its phase after every distance λ.
- So a path difference of one full wavelength gives a phase difference of 2π radians.
- A path difference and a phase difference are therefore linked by a fixed proportion.

Step 1: Key Formula or Approach Let Δx be the path difference and ϕ the phase difference.
λ of path corresponds to 2π of phase, so Δx of path corresponds to ϕ of phase:

$$\frac{\phi}{2\pi} = \frac{\Delta x}{\lambda}$$

Step 2: Detailed Explanation Reading the question the way the options are written, the options give the path difference in terms of ϕ and λ. Solve the relation above for Δx:

$$\Delta x = \frac{\lambda}{2\pi}\,\phi$$

This has the units of length (metre), which is what a path difference must have.
The printed question is loosely worded: it says 'path difference λ', where λ is really the wavelength.
The only option with the correct form $\frac{\lambda}{2\pi}\phi$ is option (3).

Step 3: Check the other options. Option (1), $\frac{\lambda}{\pi}\phi$: the factor is π instead of 2π, so the full wavelength would be linked to π radians, which is wrong.
Option (2), $\frac{\pi}{\lambda}\phi$: this has units of radian per metre, so it cannot be a path difference.
Option (4), $\frac{2\pi}{\lambda}\phi$: this also has units of radian per metre and is the factor $2\pi/\lambda$ that multiplies the path difference to give the phase, not the other way. It would be right only if the right side were Δx, not ϕ.

Step 4: Conclusion The phase and path differences are related by $\phi = \frac{2\pi}{\lambda}\Delta x$, so $\Delta x = \frac{\lambda}{2\pi}\phi$, option (3).

Quick Tip to Solve: A path difference of λ gives a phase difference of 2π. So $\phi = \frac{2\pi}{\lambda}\Delta x$.

64. The surface charge densities on the surface of two conducting spheres of radii r_1 and r_2 are equal. The ratio of electric field intensities on the surfaces is [1 mark]

(A) $\frac{r_1}{r_2}$

(B) $\frac{r_1^2}{r_2^2}$

(C) $\frac{r_2^2}{r_1^2}$

(D) $1 : 1$

Correct Answer: (D) $1 : 1$

Solution:

Concept:

- A conducting sphere carries all its charge on the outer surface.
- The electric field just outside a charged conductor depends only on the local surface charge density.
- It does not depend on the radius directly.

Step 1: Key Formula or Approach For a charged conductor, Gauss's law applied to a small pillbox at the surface gives the field just outside:

$$E = \frac{\sigma}{\varepsilon_0}$$

Here σ is the surface charge density and ε_0 is the permittivity of free space.

Step 2: Detailed Explanation Let the charges on the two spheres be Q_1 and Q_2. Then $\sigma_1 = \frac{Q_1}{4\pi r_1^2}$ and $\sigma_2 = \frac{Q_2}{4\pi r_2^2}$.

The field on the surface of a sphere is $E = \frac{Q}{4\pi\varepsilon_0 r^2}$. Putting $Q = 4\pi r^2\sigma$ in this gives $E = \frac{\sigma}{\varepsilon_0}$, the same result as above.

The question says $\sigma_1 = \sigma_2 = \sigma$. So

$$\frac{E_1}{E_2} = \frac{\sigma/\varepsilon_0}{\sigma/\varepsilon_0} = 1$$

The radii cancel out completely, so the ratio is $1 : 1$.

Step 3: Why the other options are wrong. Option (A), r_1/r_2, and option (B), r_1^2/r_2^2, would need the field to grow with the radius. It does not. Option (C), r_2^2/r_1^2, is the answer if the two spheres held equal charges (then $E \propto 1/r^2$). Here the surface charge densities are equal, not the charges.

Step 4: Conclusion Equal surface charge density gives equal surface field, so the ratio is $1 : 1$. This is option (D).

Quick Tip to Solve: The field just outside a charged conductor is $E = \sigma/\varepsilon_0$. If σ is the same for both spheres, what happens to the radii?

65. Ohm's law does not apply, when [1 mark]

(A) temperature changes

(B) temperature is constant

(C) potential difference changes

(D) none of these

Correct Answer: (A) temperature changes

Solution:

Concept:

- Ohm's law says that the current through a conductor is directly proportional to the potential difference across it, $V = IR$, with a constant resistance R.

- This holds only when the physical conditions of the conductor stay the same.

Step 1: Key Formula or Approach The law is stated as: $V \propto I$ provided the temperature and other physical conditions remain constant. So we look for the option that breaks this condition.

Step 2: Check option (A), temperature changes. If the temperature changes, the resistance of the conductor changes too. A metal gets more resistive as it heats up. Then V/I is no longer a constant, and the V-I graph bends away from a straight line. So Ohm's law fails here. (A) is correct.

Step 3: Check option (B), temperature is constant. This is exactly the condition under which Ohm's law is valid, so the law does apply. (B) is wrong.

Step 4: Check option (C), potential difference changes. Changing the potential difference is just how we vary the current in an Ohmic conductor. I changes in proportion to V and the ratio V/I stays fixed, so the law still holds. (C) is wrong.

Step 5: Check option (D). Since option (A) is a valid case where the law fails, (D) is wrong.

Step 6: Conclusion Ohm's law does not apply when the temperature changes. This is option (A).

Quick Tip to Solve: Ohm's law needs a constant resistance. Which change in conditions makes the resistance of a conductor change?

66. An example of natural electromagnetic induction is [1 mark]

(A) radio

(B) television

(C) battery charging

(D) lightning strike

Correct Answer: (D) lightning strike

Solution:

Concept:

- Electromagnetic induction is the production of an emf or current by a changing magnetic flux.
- The question asks which one of the given examples occurs naturally, without a man-made device.

Step 1: Key Formula or Approach Faraday's law gives the induced emf as $\varepsilon = -\frac{d\Phi_B}{dt}$. A very large and very quick change of current and field, as in a thunderstorm, produces a large induced emf. We pick the option that is a natural event.

Step 2: Check option (A), radio, and option (B), television. A radio and a television are man-made electronic devices. They work by receiving waves and processing signals. They are not natural events, so both are wrong.

Step 3: Check option (C), battery charging. A battery is charged by a chemical reaction driven by an external source. This is a human-made process, not a natural one, so (C) is wrong.

Step 4: Check option (D), lightning strike. Lightning is a natural discharge. During a strike, a huge current rises and falls in a few microseconds, so the magnetic flux around the channel changes extremely fast. This induces large emfs and currents in nearby conductors such as power lines and metal objects. It is the only natural phenomenon in the list, so (D) is correct.

Step 5: Conclusion The natural example is a lightning strike, option (D).

Quick Tip to Solve: Three of the options are man-made devices or processes. Pick the one that happens naturally and involves a very fast change of current and magnetic flux.

67. Which quantity decreases in step-down transformer ? [1 mark]

(A) Current

(B) Voltage

(C) Frequency

(D) Power

Correct Answer: (B) Voltage

Solution:

Concept:

- A transformer changes an alternating voltage from one value to another using mutual induction between a primary coil and a secondary coil.
- A step-down transformer gives a smaller output voltage than its input voltage, so it has fewer turns in the secondary than in the primary.

Step 1: Key Formula or Approach For an ideal transformer:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

Here V, N and I are voltage, number of turns and current, and the subscripts p and s mean primary and secondary. The input power equals the output power, $V_p I_p = V_s I_s$.

Step 2: Apply to a step-down transformer. In a step-down transformer $N_s < N_p$, so $V_s < V_p$. The voltage decreases from the input side to the output side.
From $V_p I_p = V_s I_s$, a smaller V_s needs a larger I_s to keep the power equal. So the current increases.

Step 3: Why the other options are wrong. Option (A), current: it rises in a step-down transformer, so it does not decrease.
Option (C), frequency: the secondary emf alternates at the same frequency as the primary supply. Frequency never changes in a transformer.
Option (D), power: an ideal transformer passes on the same power, and a real one loses only a little as heat, so power does not drop in any meaningful way.

Step 4: Conclusion The quantity that decreases in a step-down transformer is the voltage. This is option (B).

Quick Tip to Solve: A step-down transformer has fewer turns in the secondary. Use $V_s/V_p = N_s/N_p$ and the fact that input power equals output power to check voltage and current.

68. The refractive index of water is 1.33. What will be the speed of light in water ? [1 mark]

(A) 1.33×10^8 m/s

(B) 4×10^8 m/s

(C) 2.25×10^8 m/s

(D) 3×10^8 m/s

Correct Answer: (C) 2.25×10^8 m/s

Solution:

Concept:

- The refractive index of a medium tells us how much slower light travels in that medium than in vacuum.
- A higher refractive index means a lower speed of light.

Step 1: Key Formula or Approach The refractive index is the ratio of the speed of light in vacuum to its speed in the medium:

$$n = \frac{c}{v} \quad \Rightarrow \quad v = \frac{c}{n}$$

Here $c = 3 \times 10^8$ m/s is the speed of light in vacuum and v is the speed in water.

Step 2: Detailed Explanation Put $n = 1.33$ for water:

$$v = \frac{3 \times 10^8}{1.33}$$

$$v = 2.256 \times 10^8 \text{ m/s} \approx 2.25 \times 10^8 \text{ m/s}$$

This is close to option (C).

Step 3: Why the other options are wrong. Option (A), 1.33×10^8, just copies the refractive index and has no physical basis.
Option (B), 4×10^8, is larger than c. That is impossible, since light in a medium is always slower than in vacuum.
Option (D), 3×10^8, is the speed in vacuum, which would need $n = 1$.

Step 4: Conclusion The speed of light in water is about 2.25×10^8 m/s, which is option (C).

Quick Tip to Solve: Use $n = c/v$ with $c = 3 \times 10^8$ m/s and divide by 1.33.

69. The maximum kinetic energy of the photoelectrons varies [1 mark]

(A) linearly with the frequency and the intensity of the incident radiation

(B) linearly with the frequency and is independent of the intensity of the incident radiation

(C) inversely with the frequency and is independent of the intensity of the incident radiation

(D) inversely with the intensity and is independent of the frequency of the incident radiation

Correct Answer: (B) linearly with the frequency and is independent of the intensity of the incident radiation

Solution:

Concept:

- This question is about the photoelectric effect.
- When light of high enough frequency falls on a metal, electrons are knocked out.
- We want to know how the largest kinetic energy of these electrons depends on the frequency and on the intensity of the light.

Step 1: Key Formula or Approach Einstein's photoelectric equation says that one photon gives all its energy to one electron:

$$K_{\max} = h\nu - \phi$$

Here h is Planck's constant, ν is the frequency of the incident light and ϕ is the work function of the metal, which is a fixed number for a given metal.

Step 2: Detailed Explanation Compare the equation with a straight line $y = mx + c$. Taking $K_{\max}$ as y and ν as x, the slope is h and the intercept is $-\phi$. So $K_{\max}$ changes linearly with the frequency.
The equation has no term for intensity. Intensity only tells us how many photons arrive each second. More photons knock out more electrons (a larger photocurrent), but each electron still gets energy from just one photon, so its maximum kinetic energy does not change. So $K_{\max}$ is independent of intensity.
This matches option (B).

Step 3: Why the other options are wrong Option (A) is wrong because it makes $K_{\max}$ depend on intensity. Intensity changes the number of photoelectrons, not their energy.
Option (C) is wrong because $K_{\max}$ increases when the frequency increases. It does not vary inversely.
Option (D) is wrong on both counts: there is no inverse link with intensity, and the energy clearly depends on frequency.

Step 4: Conclusion The maximum kinetic energy varies linearly with frequency and does not depend on intensity, which is option (B).

Quick Tip to Solve: Use Einstein's equation K_max = h(nu) - work function. It has frequency in it but no intensity.

70. Which of the following are known as nucleons ? [1 mark]

(A) Only protons

(B) Protons and electrons

(C) Protons and neutrons

(D) Neutrons and electrons

Correct Answer: (C) Protons and neutrons

Solution:

Concept:

- Every atom has a small, dense centre called the nucleus.
- The question asks which particles are given the common name nucleons.

Step 1: Key Formula or Approach The word nucleon means a particle that lives inside the nucleus. We list what the nucleus contains and pick the option that matches.

Step 2: Detailed Explanation The nucleus is built from two kinds of particles. Protons carry a positive charge of $+e$. Neutrons carry no charge. Both have nearly the same mass, about 1.67×10^{-27} kg, and both are held together by the strong nuclear force.
Electrons are not part of the nucleus. They move around it in the space outside. So electrons are never counted as nucleons.
So nucleons are protons and neutrons together. If an atom has atomic number Z and mass number A, then it has Z protons and $A - Z$ neutrons, and the number of nucleons is A.

Step 3: Why the other options are wrong Option (A) leaves out neutrons, which are also in the nucleus.
Option (B) includes electrons, which sit outside the nucleus.
Option (D) leaves out protons and includes electrons, so it is wrong on both counts.

Step 4: Conclusion Nucleons are protons and neutrons, which is option (C).

Quick Tip to Solve: Nucleons are the particles inside the nucleus. Electrons are outside it.

Section B: Short Answer Type Questions (any 10 to be answered, 2 marks each)

SA-1. What is Lorentz force ? [2 marks]

Solution:

Concept:

- A charge can feel a force from an electric field and also from a magnetic field.
- The Lorentz force is the total force on a moving charge from both fields together.

Step 1: State the expression Let a charge q move with velocity $\vec{v}$ in an electric field $\vec{E}$ and a magnetic field $\vec{B}$. The Lorentz force is

$$\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})$$

The first term is the electric force. The second term is the magnetic force.

Step 2: Look at the magnetic part The magnitude of the magnetic force is $F = qvB\sin\theta$, where θ is the angle between $\vec{v}$ and $\vec{B}$.
Its direction is perpendicular to both $\vec{v}$ and $\vec{B}$, found by the right-hand rule (for a positive charge). The force is zero if the charge is at rest or moves along the field ($\theta = 0^\circ$ or 180°). It is largest when $\theta = 90^\circ$.

Step 3: Note an important property The magnetic force is always at right angles to the velocity, so it does no work on the charge. It changes the direction of motion but not the speed. The SI unit of force is the newton (N).

Step 4: Conclusion Lorentz force is the total electromagnetic force on a moving charge, $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$.

Quick Tip to Solve: It is the total force on a moving charge in electric and magnetic fields: $q\vec{E}+q\vec{v}\times\vec{B}$.

SA-2. Write any two characteristics of matter waves. [2 marks]

Solution:

Concept:

- Louis de Broglie suggested that every moving particle has a wave associated with it.
- These waves are called matter waves or de Broglie waves.

Step 1: Characteristic 1: wavelength depends on momentum The wavelength of a matter wave is given by

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

where h is Planck's constant, m is the mass and v is the speed of the particle. A heavier or faster particle has a shorter wavelength. A particle at rest has no matter wave (infinite wavelength). For everyday objects λ is so small that the wave nature cannot be observed.

Step 2: Characteristic 2: not electromagnetic waves Matter waves are produced by any moving particle, whether it is charged or neutral (electron, neutron, atom). They do not need a charge, so

they are not electromagnetic waves.
They are not emitted by the particle. They are best understood as probability waves that tell where the particle is likely to be found.

Step 3: One more property The speed of a matter wave is $v_p = c^2/v$, which can be larger than the speed of light. This does not break relativity because the wave carries no energy at this speed. The particle itself moves with the group velocity.

Step 4: Conclusion Any two of these: wavelength $\lambda = h/mv$ depends on mass and speed, and matter waves are not electromagnetic and are linked with charged and neutral particles alike.

Quick Tip to Solve: Use $\lambda = h/mv$ for the first point. For the second, ask whether a neutral particle also has a matter wave.

SA-3. What is spherical aberration ? [2 marks]

Solution:

Concept:

- A lens or a spherical mirror with a large aperture does not bring all rays from a point object to one single image point.
- Rays that fall close to the principal axis are called paraxial rays. Rays that fall near the edge of the lens or mirror are called marginal rays.

Step 1: What actually happens For a convex lens, the paraxial rays meet at a point F_p farther from the lens. The marginal rays bend more strongly, so they meet at a point F_m closer to the lens.
Because the rays do not meet at one point, the image of a point object is a small bright circle, not a sharp point. The image looks blurred.
The distance F_pF_m along the axis is called the longitudinal spherical aberration. The cross-section where the circle of rays is smallest is called the circle of least confusion.

Step 2: Definition Spherical aberration is the defect of a lens or spherical mirror in which rays from a point object, passing through different parts of its aperture, are focussed at different points on the axis. As a result the image is blurred and not sharp.

Step 3: How it is reduced 1. Use a stop (diaphragm) to cut off the marginal rays, so only paraxial rays form the image.
2. Use a plano-convex lens with its curved face towards the incident parallel beam.
3. Use a combination of a convex and a concave lens of suitable focal lengths.
4. Use a parabolic mirror instead of a spherical mirror in telescopes and headlights.

Step 4: Conclusion Spherical aberration is the failure of a spherical lens or mirror to focus paraxial and marginal rays at the same point, which makes the image blurred.

Quick Tip to Solve: Think about how rays near the axis and rays near the edge of a lens or mirror are focussed. Do they meet at the same point?

SA-4. Write the expression for power factor of LCR circuit. [2 marks]

Solution:

Concept:

- In an AC circuit the current and the applied voltage can be out of step by a phase angle ϕ. The power factor is defined as $\cos\phi$.

- It tells us what fraction of the product $V_{rms}I_{rms}$ is really used up as average power in the circuit.

Step 1: Write the average power For a series LCR circuit the average power is

$$P_{av} = V_{rms}\, I_{rms} \cos\phi$$

so the power factor is $\cos\phi = \dfrac{P_{av}}{V_{rms}I_{rms}}$.

Step 2: Use the impedance triangle In a series LCR circuit the impedance is $Z = \sqrt{R^2 + (X_L - X_C)^2}$, where $X_L = \omega L$ is the inductive reactance and $X_C = \dfrac{1}{\omega C}$ is the capacitive reactance.
In the impedance triangle, the resistance R is the side next to the angle ϕ and Z is the hypotenuse. So

$$\cos\phi = \frac{R}{Z}$$

Step 3: Put in the values

$$\cos\phi = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{R}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}}$$

At resonance $X_L = X_C$, so $\cos\phi = 1$ and the power factor is the largest possible. For a pure inductor or a pure capacitor $R = 0$, so $\cos\phi = 0$.

Step 4: Conclusion The power factor of a series LCR circuit is the ratio of resistance to impedance.

Quick Tip to Solve: Power factor is $\cos\phi$. Read it off the impedance triangle as resistance divided by impedance.

SA-5. What is Malus's law ? [2 marks]

Solution:

Concept:

- A polaroid lets only the light vibrations that lie along its pass axis go through.
- If plane polarised light falls on a second polaroid (the analyser), the transmitted intensity depends on the angle between the two pass axes.
- Malus's law gives this dependence.

Step 1: Statement of the law Malus's law says that when completely plane polarised light of intensity I_0 passes through an analyser, the transmitted intensity is proportional to the square of the cosine of the angle θ between the polarisation direction of the light and the pass axis of the analyser.

$$I = I_0 \cos^2\theta$$

Step 2: Reason for the cosine squared Let the amplitude of the incident light be E_0. Only the component $E_0\cos\theta$ lies along the pass axis, so only this part is transmitted. Intensity is proportional to the square of amplitude, so $I \propto E_0^2\cos^2\theta$, which is $I = I_0\cos^2\theta$.
At $\theta = 0^\circ$ the whole intensity I_0 passes. At $\theta = 90^\circ$ the intensity is zero (crossed polaroids).

Step 3: Conclusion Malus's law: the transmitted intensity varies as the square of the cosine of the angle between the pass axes.

Quick Tip to Solve: It links the intensity from an analyser to $\cos^2\theta$, where θ is the angle between the pass axes.

SA-6. How are electromagnetic waves different from sound waves ? Write any two differences. [2 marks]

Solution:

Concept:

- Electromagnetic waves are oscillating electric and magnetic fields that carry energy through space.
- Sound waves are mechanical waves, made of pressure changes that pass from one layer of a material to the next.
- The two kinds of waves differ in how they travel and what they are made of.

Step 1: Difference 1: Need of a medium Electromagnetic waves do not need any material medium. They travel through vacuum, which is how sunlight reaches the Earth.
Sound waves need a material medium such as air, water or a solid. They cannot travel through vacuum.

Step 2: Difference 2: Nature of the wave Electromagnetic waves are transverse. The electric field $\vec{E}$ and the magnetic field $\vec{B}$ vibrate at right angles to each other and to the direction of travel.
Sound waves in air and other fluids are longitudinal. The particles of the medium vibrate along the direction of travel, forming compressions and rarefactions.

Step 3: More differences that can also be written Speed: in vacuum all electromagnetic waves travel at $c = 3 \times 10^8$ m/s, while sound in air at room temperature travels at only about 340 m/s.
Source: electromagnetic waves are produced by accelerated charges, while sound is produced by vibrating bodies.

Step 4: Conclusion Electromagnetic waves are transverse and need no medium, while sound waves are longitudinal (in fluids) and need a medium. Any two of the differences above earn full marks.

Quick Tip to Solve: Compare them on the need of a medium, the type of wave (transverse or longitudinal) and the speed.

SA-7. Differentiate between primary and secondary rainbows. [2 marks]

Solution:

Concept:

- Rainbows are optical phenomena caused by the dispersion and internal reflection of sunlight by water droplets (like rain or mist) in the atmosphere.
- The differences between primary and secondary rainbows arise from the number of internal reflections the light undergoes within each droplet.

Step 1: Detailed Explanation of Differences

Feature	Primary Rainbow	Secondary Rainbow
Formation	Caused by sunlight undergoing one total internal reflection inside a water droplet.	Caused by sunlight undergoing two total internal reflections inside a water droplet.
Color Sequence	The sequence of colors is Violet on the inner edge and Red on the outer edge (VIBGYOR from bottom to top).	The sequence of colors is reversed due to the extra reflection. Red is on the inner edge and Violet on the outer edge.
Brightness	It is brighter because less light is lost. Light emerges after only one internal reflection.	It is fainter because light energy is lost at each internal reflection.
Angular Position	Forms at an angle of approximately 40°-42° with respect to the observer-sun line. It appears lower in the sky.	Forms at a higher angle of approximately 50°-53° with respect to the observer-sun line. It appears above the primary rainbow.

Step 2: Conclusion The primary rainbow is brighter, lower, and has red on top, resulting from a single internal reflection. The secondary rainbow is fainter, higher, and has violet on top, resulting from two internal reflections.

Quick Tip to Solve: A simple mnemonic for the color order: "Roy G. Biv" (Red, Orange, Yellow, Green, Blue, Indigo, Violet). For a primary rainbow, Roy is at the top of the arc. For a secondary rainbow, the order is reversed.

SA-8. What are 'α' and 'β' parameters of transistor? What is their relation? [2 marks]

Solution:

Concept:

- In a transistor, the flow of a small current in one part of the device controls a much larger current in another part.
- The parameters α and β are "current gains" that quantify this control for different circuit configurations.

Step 1: Key Formula or Approach The fundamental relationship between the currents in a transistor is:
Emitter Current (I_E) = Base Current (I_B) + Collector Current (I_C)

$$I_E = I_B + I_C$$

Definitions:
- Common-Base Current Gain (α): $\alpha = \dfrac{\text{Output Current}}{\text{Input Current}} = \dfrac{I_C}{I_E}$
- Common-Emitter Current Gain (β): $\beta = \dfrac{\text{Output Current}}{\text{Input Current}} = \dfrac{I_C}{I_B}$

Step 2: Detailed Explanation and Derivation of Relation **Definition of α:**
Alpha is the DC current gain in the common-base configuration. It represents the fraction of emitter current that reaches the collector. Since I_C is always slightly less than I_E (because a small portion becomes base current), the value of α is always slightly less than 1 (typically 0.95 to 0.99).
Definition of β:

Beta is the DC current gain in the common-emitter configuration. It represents how much the collector current is amplified compared to the base current. Since I_B is very small compared to I_C, the value of β is large (typically 50 to 300).

Relation between α and β:

We start with the fundamental current equation:

$$I_E = I_B + I_C$$

Divide the entire equation by I_C:

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + \frac{I_C}{I_C}$$

Recognizing the reciprocals of our definitions ($\frac{1}{\alpha} = \frac{I_E}{I_C}$ and $\frac{1}{\beta} = \frac{I_B}{I_C}$):

$$\frac{1}{\alpha} = \frac{1}{\beta} + 1$$

Now, we rearrange to solve for β:

$$\frac{1}{\beta} = \frac{1}{\alpha} - 1$$

$$\frac{1}{\beta} = \frac{1-\alpha}{\alpha}$$

Taking the reciprocal of both sides gives the relation:

$$\beta = \frac{\alpha}{1-\alpha}$$

Step 3: Conclusion α and β are the current gains for common-base and common-emitter transistor configurations, respectively, and are related by the formula $\beta = \frac{\alpha}{1-\alpha}$.

Quick Tip to Solve: Remember the typical values: α is always close to, but less than, 1. β is always much greater than 1. This can help you check if your derived relation is reasonable. If $\alpha = 0.99$, then $\beta = \frac{0.99}{1-0.99} = \frac{0.99}{0.01} = 99$.

SA-9. Write truth table and Boolean expression of OR and AND gates. [2 marks]

Solution:

Concept:

- A logic gate is a digital circuit with one or more inputs and one output.
- Each input and output is either 0 (low voltage) or 1 (high voltage).
- A truth table lists the output for every possible input combination, and the Boolean expression gives the same rule in algebra form.

Step 1: OR gate The OR gate gives output 1 if at least one input is 1. The output is 0 only when both inputs are 0. Its Boolean expression is

$$Y = A + B$$

Here the plus sign means logical OR, not ordinary addition. That is why $1 + 1 = 1$ in this algebra. The

truth table is:

A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

Step 2: AND gate The AND gate gives output 1 only when all inputs are 1. If any input is 0, the output is 0. Its Boolean expression is

$$Y = A \cdot B$$

The dot means logical AND, and it works like ordinary multiplication of 0 and 1. The truth table is:

A	B	$Y = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1

Step 3: Quick check Row $A = 1, B = 0$: OR gives $1 + 0 = 1$, AND gives $1 \cdot 0 = 0$. This agrees with both tables. In other words, OR gate gives 1 when at least one input is 1, and AND gate gives 1 only when both inputs are 1.

Step 4: Conclusion OR gate: $Y = A + B$, output is 0 only for input 00. AND gate: $Y = A \cdot B$, output is 1 only for input 11.

Quick Tip to Solve: OR gate: $Y = A + B$, output 1 if any input is 1. AND gate: $Y = A \cdot B$, output 1 only if both inputs are 1. Fill the four input rows 00, 01, 10, 11.

SA-10. What are donor and acceptor impurities ? [2 marks]

Solution:

Concept:

- Pure silicon or germanium is an intrinsic semiconductor and has few free charge carriers. When a small amount of another element is added, the conductivity rises a lot.
- This added atom is called an impurity or dopant, and the process is called doping. Impurities are of two kinds: donor and acceptor.

Step 1: Donor impurities Donor impurities are pentavalent atoms (valency 5) such as phosphorus (P), arsenic (As) and antimony (Sb). When one of them replaces a silicon atom in the lattice, four of its five valence electrons form covalent bonds with four neighbouring atoms.
The fifth electron is left loosely bound. A small energy (about 0.05 eV for Si) frees it, so it moves in the conduction band. The impurity atom "donates" this electron and becomes a fixed positive ion.
The semiconductor now has many extra free electrons, so it is called an n-type semiconductor. Electrons are the majority carriers and holes are the minority carriers. The donor energy level lies just below the bottom of the conduction band.

Step 2: Acceptor impurities Acceptor impurities are trivalent atoms (valency 3) such as boron (B), aluminium (Al), gallium (Ga) and indium (In). When one of them replaces a silicon atom, it has only three valence electrons to bond with four neighbours.
One bond stays incomplete, and this empty place is a hole. A nearby valence electron can jump in and

fill it, so the hole moves. The impurity atom "accepts" an electron and becomes a fixed negative ion. The semiconductor now has many extra holes, so it is called a p-type semiconductor. Holes are the majority carriers and electrons are the minority carriers. The acceptor energy level lies just above the top of the valence band.

Step 3: Note on charge In both cases the whole crystal stays electrically neutral, because the extra mobile carrier is balanced by the fixed ion left behind.

Step 4: Conclusion Donors are pentavalent impurities that give free electrons (n-type). Acceptors are trivalent impurities that create holes (p-type).

Quick Tip to Solve: Donor atoms have 5 valence electrons and give free electrons (n-type). Acceptor atoms have 3 valence electrons and create holes (p-type).

SA-11. Define half-life. State the relation between half-life and decay constant. [2 marks]

Solution:

Concept:

- A radioactive sample does not decay all at once. The number of undecayed nuclei falls with time according to the decay law
- Here N_0 is the number of nuclei at $t = 0$, and λ is the decay constant.

Step 1: Definition of half-life The half-life $T_{1/2}$ of a radioactive substance is the time in which half of the radioactive nuclei present in the sample decay.

Step 2: Relation with decay constant Put $t = T_{1/2}$ and $N = N_0/2$ in the decay law:

$$\frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}}$$

Cancel N_0 and take the natural logarithm of both sides:

$$\ln 2 = \lambda T_{1/2}$$

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

So the half-life is inversely proportional to the decay constant. A larger λ means a faster decay and a shorter half-life.

Step 3: Conclusion Half-life is the time taken for half of the radioactive nuclei to decay, and it is related to the decay constant by the formula below.

Quick Tip to Solve: Half-life is the time for half the nuclei to decay. Put $N = N_0/2$ in $N = N_0 e^{-\lambda t}$ to get the relation.

SA-12. Write the unit and dimensional formula of permittivity of free space. [2 marks]

Solution:

Concept:

- The permittivity of free space ε_0 appears in Coulomb's law.
- It tells how strongly the vacuum allows an electric field to pass through it.

- We find its unit and dimensions from Coulomb's law.

Step 1: Key Formula or Approach Coulomb's law in free space:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

So

$$\varepsilon_0 = \frac{q_1 q_2}{4\pi F r^2}$$

The number 4π has no unit and no dimensions.

Step 2: Unit Charge is in coulomb (C), force in newton (N) and distance in metre (m). So

$$\text{unit of } \varepsilon_0 = \frac{\text{C}^2}{\text{N m}^2} = \text{C}^2\text{N}^{-1}\text{m}^{-2}$$

This is the same as farad per metre (F/m).

Step 3: Dimensional formula Charge $q = It$, so $[q] = [AT]$. Force $[F] = [MLT^{-2}]$ and $[r^2] = [L^2]$. So

$$[\varepsilon_0] = \frac{[AT]^2}{[MLT^{-2}][L^2]} = [M^{-1}L^{-3}T^4A^2]$$

Step 4: Conclusion The unit of ε_0 is $\text{C}^2\text{N}^{-1}\text{m}^{-2}$ (or F/m), and its dimensional formula is as given below.

Quick Tip to Solve: Rearrange Coulomb's law to $\varepsilon_0 = q_1 q_2/(4\pi F r^2)$ and put in the units and dimensions of charge, force and distance.

SA-13. What will be the effect on resistance of a metallic conductor and a semiconductor on increasing the temperature ? Explain with reasons. [2 marks]

Solution:

Concept:

- The resistance of a wire depends on how freely its charge carriers can drift.
- In terms of the carrier density n and the relaxation time τ (the average time between two collisions), the resistivity is

Step 1: Metallic conductor A metal has a very large and almost fixed number of free electrons, so n hardly changes when it is heated.
On heating, the metal ions vibrate more. The electrons collide more often, so τ decreases. A smaller τ gives a larger ρ.
So the resistance of a metallic conductor increases with temperature. Its temperature coefficient of resistance is positive.

Step 2: Semiconductor In a semiconductor there are few free carriers at low temperature. Heating gives energy to the bound electrons, which jump across the energy gap into the conduction band. This increases n very quickly (roughly exponentially).
The fall in τ due to more collisions is also present, but the rise in n is much larger and wins.
So ρ decreases, and the resistance of a semiconductor decreases with temperature. Its temperature coefficient is negative.

Step 3: Conclusion On heating, the resistance of a metal increases (because τ falls while n stays

fixed), but the resistance of a semiconductor decreases (because n rises sharply).

Quick Tip to Solve: Use $\rho = m/(ne^2\tau)$. In a metal τ falls with temperature, while in a semiconductor the carrier density n rises sharply.

SA-14. Explain sky waves and space waves. [2 marks]

Solution:

Concept:

- A radio signal can travel from the transmitting antenna to the receiving antenna in three ways: along the ground (ground wave), by reflection from the upper atmosphere (sky wave), or in a straight line through space (space wave).
- We are asked about the last two.
- The route a wave takes depends mainly on its frequency.

Step 1: Sky wave propagation A sky wave is sent upward at an angle from the transmitting antenna. At a height of about 60 km to 400 km the air is ionised by ultraviolet and X-rays from the Sun. This region is called the ionosphere, and it holds layers of free electrons (D, E, F1 and F2).
The electron density rises with height, so the refractive index of the layer falls with height. A wave entering the layer bends away from the normal again and again, and finally returns to the earth, as if it were reflected.
This works only for frequencies from about 3 MHz to 30 MHz (high frequency or short wave band). Waves of higher frequency pass straight through the ionosphere and are lost in space. The highest frequency that a layer can send back for vertical incidence is the critical frequency:

$$f_c = 9\sqrt{N_{max}}$$

Here N_{max} is the maximum electron density in electrons per m^3 and f_c is in Hz. For $N_{max} = 10^{12}\ \text{m}^{-3}$, $f_c = 9 \times 10^6$ Hz = 9 MHz.
Because the wave is sent back from the sky, it can reach places thousands of km away, far beyond the horizon. Short wave radio and long distance communication use sky waves.

Step 2: Space wave propagation A space wave travels in a straight line from the transmitting antenna to the receiving antenna, so the two antennas must be in line of sight with each other. It is used for frequencies above 30 MHz (VHF, UHF and microwaves). These waves are not reflected by the ionosphere and are not bent along the curved earth.
Because the earth is curved, the range is limited by the antenna height. For an antenna of height h on earth of radius R, the line of sight range is

$$d = \sqrt{2Rh}$$

For $R = 6.4 \times 10^6$ m and $h = 100$ m, $d = \sqrt{2 \times 6.4 \times 10^6 \times 100} \approx 35.8$ km. For a transmitter of height h_T and a receiver of height h_R, the maximum range is $\sqrt{2Rh_T} + \sqrt{2Rh_R}$.
So TV towers are built tall, and satellites and microwave links are used to cover longer distances. TV broadcast, FM radio, radar and satellite communication use space waves.

Step 3: Main difference Sky wave: reflected by the ionosphere, 3 MHz to 30 MHz, very long range, used in short wave radio.
Space wave: straight line of sight path, above 30 MHz, range limited by antenna height, used in TV, FM and satellite links.

Step 4: Conclusion Sky waves are returned to the earth by the ionosphere (3 MHz to 30 MHz, long range). Space waves travel along the line of sight (above 30 MHz, range $\sqrt{2Rh}$).

Quick Tip to Solve: A sky wave is sent back to earth by the ionosphere (3 MHz to 30 MHz). A space wave goes straight from antenna to antenna in line of sight (above 30 MHz).

SA-15. The maximum and minimum amplitudes for an amplitude modulated wave are 12 V and 3 V respectively. Calculate the value of modulation index. [2 marks]

Solution:

Concept:

- In amplitude modulation the carrier amplitude changes with the message signal.
- The modulation index μ tells how deep this change is.
- It is the ratio of the message amplitude A_m to the carrier amplitude A_c.

Step 1: Key Formula or Approach The maximum amplitude is $A_{\max} = A_c + A_m$ and the minimum amplitude is $A_{\min} = A_c - A_m$. Subtracting and adding these two gives

$$\mu = \frac{A_m}{A_c} = \frac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}}$$

Step 2: Detailed Explanation Here $A_{\max} = 12$ V and $A_{\min} = 3$ V.

$$\mu = \frac{12 - 3}{12 + 3} = \frac{9}{15} = 0.6$$

The value is less than 1, so there is no over-modulation.

Step 3: Conclusion The modulation index is 0.6 (that is, 60 percent).

Quick Tip to Solve: Use $\mu = \dfrac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}}$.

SA-16. Define current density. [2 marks]

Solution:

Concept:

- Current I flows through the whole cross-section of a conductor.
- To describe how the current is spread over the area, we use current density.
- It tells how much current passes through each unit area at a point.

Step 1: Definition Current density is the current flowing per unit area of cross-section, taken perpendicular to the direction of flow of charge.

$$J = \frac{I}{A}$$

Here I is the current in ampere and A is the area perpendicular to the current in square metre.

Step 2: Unit, nature and related forms Its SI unit is ampere per square metre, A m^{-2}. Current density is a vector. Its direction is the direction of the current at that point.
In terms of the drift velocity v_d and the number density n of charge carriers, $\vec{J} = ne\vec{v}_d$. In terms of the electric field and the conductivity σ, $\vec{J} = \sigma\vec{E}$.

Step 3: Conclusion Current density is the current per unit cross-sectional area perpendicular to the flow.

Quick Tip to Solve: Think of current per unit area of cross-section, taken perpendicular to the flow.

SA-17. Define ionization energy. What is its value for hydrogen atom ? [2 marks]

Solution:

Concept:

- In the Bohr model an electron in a hydrogen atom has a negative total energy because it is bound to the nucleus.
- An electron that is just free from the atom (at infinite distance and at rest) has zero energy.
- So some energy must be given to take the electron out.

Step 1: Definition Ionization energy is the minimum energy required to remove an electron from an atom in its ground state, so that the electron goes to infinity (becomes free). For hydrogen it is the energy needed to take the electron from $n = 1$ to $n = \infty$.

Step 2: Value for hydrogen The energy of the electron in the nth orbit of hydrogen is

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

In the ground state, $n = 1$, so $E_1 = -13.6$ eV. The final state at infinity has $E_\infty = 0$. The energy needed is

$$E_{ion} = E_\infty - E_1 = 0 - (-13.6) = 13.6 \text{ eV}$$

In joules, $13.6 \times 1.6 \times 10^{-19} \approx 2.18 \times 10^{-18}$ J. Equivalent to this, the ionization potential of hydrogen is 13.6 V.

Step 3: Conclusion Ionization energy is the minimum energy needed to remove the electron from the ground state of an atom. For hydrogen it is 13.6 eV.

Quick Tip to Solve: Ionization energy is the minimum energy to remove the electron from the ground state to infinity. For hydrogen, $E_{ion} = 0 - (-13.6) = 13.6$ eV.

SA-18. What is the difference between magnification and magnifying power ? [2 marks]

Solution:

Concept:

- Both terms tell us how much bigger an optical device makes an object look, but they measure it in different ways.
- Magnification compares sizes.
- Magnifying power compares the angles that the image and the object make at the eye.

Step 1: Magnification Magnification (linear magnification) is the ratio of the size of the image to the size of the object:

$$m = \frac{h'}{h} = \frac{v}{u}$$

It is used for mirrors, lenses and any device that forms a real or virtual image. It is a plain number (no unit). It can be greater than 1, less than 1, positive (erect image) or negative (inverted image).

Step 2: Magnifying power Magnifying power (angular magnification) of an optical instrument is the ratio of the angle β subtended at the eye by the final image to the angle α subtended at the unaided eye by the object when it is placed at the near point ($D = 25$ cm):

$$M = \frac{\beta}{\alpha}$$

It is used for instruments meant to be looked through, like a magnifying glass, a microscope and a telescope. It is also a plain number. For a simple microscope of focal length f, $M = 1 + \frac{D}{f}$ when the image is at the near point, and $M = \frac{D}{f}$ when the image is at infinity. For a telescope, $M = \frac{f_o}{f_e}$. For $f = 5$ cm these give 6 and 5.

Step 3: The difference in short Magnification is the ratio of image size to object size (a ratio of lengths). Magnifying power is the ratio of the angle made by the image to the angle made by the object at the eye (a ratio of angles). The magnifying power matters because what the eye actually sees depends on the angle.

Step 4: Conclusion Magnification is the ratio of image size to object size, $m = h'/h$. Magnifying power is the ratio of the angle subtended by the image to that subtended by the object, $M = \beta/\alpha$.

Quick Tip to Solve: Magnification is image size divided by object size. Magnifying power is the angle made by the image divided by the angle made by the object at the eye.

SA-19. What is the use of a step-up transformer ? [2 marks]

Solution:

Concept:

- A transformer changes the voltage of an alternating supply using mutual induction between two coils.
- In a step-up transformer the secondary coil has more turns than the primary coil, so $N_s > N_p$.

Step 1: Key Formula or Approach For an ideal transformer,

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

When $N_s > N_p$, the output voltage is larger than the input voltage, and the output current is smaller than the input current.

Step 2: Detailed Explanation A step-up transformer raises the alternating voltage and lowers the current by the same factor.
The heat lost in the transmission lines is $P_{loss} = I^2R$. A smaller current means a much smaller loss, because the loss depends on the square of the current.
So at the power station, the generated voltage is stepped up to a very high value before sending power over long distances. At the city end, step-down transformers bring it back to a safe value.

Step 3: Conclusion A step-up transformer is used to increase the AC voltage (and decrease the current). Its main use is in transmitting electric power over long distances with very little loss.

Quick Tip to Solve: A step-up transformer raises the voltage and lowers the current, which reduces the heat loss in transmission lines.

SA-20. What is wattless current? [2 marks]

Solution:

Step 1: In an alternating current (AC) circuit, the total current can be resolved into two distinct components based on its phase relationship with the applied voltage: - The **active current** (or real component) which is **in phase with the voltage**. This component is responsible for performing **real work**, such as producing heat, light, or mechanical energy. - The **wattless current** (or reactive component), which is **out of phase with the voltage by** 90°. This component does not perform any net work over a full cycle; instead, it simply transfers energy back and forth between the source and the reactive components (inductors and capacitors) of the circuit.

Step 2: The **wattless current** primarily arises in circuits with **purely inductive or purely capacitive loads**, where the phase difference between voltage and current is exactly 90°. In such cases, the current either leads or lags the voltage by a quarter cycle, resulting in zero average power consumption.

Step 3: The power consumed in an AC circuit is given by the expression:

$$P = VI\cos\phi,$$

where V is the RMS voltage, I is the RMS current, and ϕ is the phase angle between voltage and current. For **wattless current**, $\phi = 90^\circ$, hence:

$$P = VI\cos 90^\circ = VI \times 0 = 0.$$

Therefore, the power associated with wattless current is **zero**, confirming that it does not contribute to any real energy transfer in the circuit.

Quick Tip to Solve: Wattless current is also called \textbf{reactive current} and contributes to the \textbf{reactive power} in the circuit.

Section B: Long Answer Type Questions (any 3 to be answered, 5 marks each)

LA-21. Derive an expression for torque experienced by electric dipole placed in external electric field. [5 marks]

Solution:

Step 1: Set up the dipole An electric dipole has two equal and opposite charges $+q$ and $-q$ separated by a distance $2a$. Its dipole moment has magnitude $p = q \times 2a$ and points from $-q$ to $+q$.
Place it in a uniform electric field $\vec{E}$ so that the dipole moment makes an angle θ with the field.

Step 2: Find the forces on the two charges The force on $+q$ is $q\vec{E}$ along the field. The force on $-q$ is $-q\vec{E}$, opposite to the field.
These forces are equal in size and opposite in direction, so the net force on the dipole is zero. The dipole does not move as a whole. But the two forces act along different lines, so they form a couple and rotate the dipole.

Step 3: Find the torque of the couple Torque of a couple = (one force) $\times$ (perpendicular distance between the two lines of action).
The perpendicular distance between the lines of force is $2a\sin\theta$. So

$$\tau = qE \times 2a\sin\theta = (q \cdot 2a)\, E\sin\theta$$

$$\tau = pE\sin\theta$$

Step 4: Write the vector form and discuss The torque is perpendicular to the plane containing $\vec{p}$ and $\vec{E}$, and its direction follows the right-hand rule. In vector form

$$\vec{\tau} = \vec{p} \times \vec{E}$$

It tries to turn the dipole towards the field direction. The torque is largest, pE, at $\theta = 90^\circ$ and is zero at $\theta = 0^\circ$ and 180°.

Step 5: Conclusion The torque on an electric dipole of moment p in a uniform field E is $pE\sin\theta$, that is $\vec{\tau} = \vec{p} \times \vec{E}$.

Quick Tip to Solve: The two forces $\pm qE$ cancel but form a couple. Multiply one force by the perpendicular arm $2a\sin\theta$.

LA-22. Find the expression of the comparison of e.m.f.s of two cells by a potentiometer. [5 marks]

Solution:

Step 1: Principle of the potentiometer A potentiometer is a long wire AB of uniform cross-section and uniform material, for example 10 m long. A steady cell (driver cell) of emf E and a rheostat are connected across its two ends, so a constant current I flows through the wire.
Let the resistance per unit length of the wire be ρ. The potential drop per unit length, called the potential gradient, is then $k = I\rho$, and it is the same all along the wire.
So the potential difference across a length l of the wire is $V = kl$. The potential difference is directly proportional to the length.

Step 2: Circuit for comparing two emfs Let the two cells have emfs E_1 and E_2, with $E_1, E_2 < E$ (the driver emf must be larger than both).
Connect the positive terminals of both cells to the end A of the wire, where the positive of the driver cell is also joined. Connect the negative terminals to a two-way key. From the common terminal of the key, take a lead through a galvanometer G to a sliding contact (jockey) J.

Step 3: Balance point for the first cell Put the key so that cell E_1 is in the circuit and slide the jockey along the wire until the galvanometer shows no deflection. Let the balance length be $AJ_1 = l_1$.
At this null point no current flows through the cell, so its terminal voltage equals its emf. The wire section AJ_1 balances it:

$$E_1 = k\,l_1$$

Step 4: Balance point for the second cell Now switch the key to cell E_2 and find the new null point J_2, with $AJ_2 = l_2$. In the same way,

$$E_2 = k\,l_2$$

Step 5: Divide the two results The same driver current is used both times, so the potential gradient k is the same in both readings. Dividing the two equations, k cancels:

$$\frac{E_1}{E_2} = \frac{k\,l_1}{k\,l_2} = \frac{l_1}{l_2}$$

So the ratio of the emfs of two cells is equal to the ratio of their balancing lengths. This method is better than a voltmeter because at balance the cells give no current, so the emf is measured exactly.

Step 6: Conclusion The emfs of two cells are in the same ratio as their balancing lengths on the

potentiometer wire.

Quick Tip to Solve: A potentiometer wire has a constant potential gradient, so the potential difference across a length is proportional to that length. Balance each cell separately and divide the two equations.

LA-23. Draw a ray diagram to show the refraction of light through glass prism. Derive the formula for the determination of refractive index of the material of the prism. [5 marks]

Solution:

Step 1: Draw the ray diagram (described) Draw a triangular glass prism ABC with refracting angle $\angle A = A$. Let a ray PQ fall on the face AB at point Q with angle of incidence i, measured from the normal at Q.
Inside the prism the ray bends towards the normal and travels along QR with angle of refraction r_1. It meets the face AC at R with angle of incidence r_2 (measured from the normal at R), and leaves along RS with angle of emergence e, bending away from the normal.
Extend PQ forward and SR backward so that they meet. The angle between these two lines is the angle of deviation δ. The two normals at Q and R meet at a point N inside the prism. Label i, r_1, r_2, e, A and δ on the figure.

Step 2: Angle of deviation At face AB the ray turns by $(i - r_1)$. At face AC it turns by $(e - r_2)$, in the same sense. So the total deviation is

$$\delta = (i - r_1) + (e - r_2) = i + e - (r_1 + r_2)$$

Step 3: Relation between A, r1 and r2 In the quadrilateral AQNR the angles at Q and R are each 90° (they are between a face and its normal). So $A + \angle QNR = 180^\circ$.
In the triangle QNR we have $r_1 + r_2 + \angle QNR = 180^\circ$. Comparing the two results,

$$r_1 + r_2 = A$$

Putting this in the deviation formula,

$$\delta = i + e - A$$

Step 4: Condition of minimum deviation If we plot δ against i, the curve falls to a minimum value δ_m and then rises. At minimum deviation the ray passes symmetrically through the prism, parallel to the base BC. So $i = e$ and $r_1 = r_2 = r$.
From $r_1 + r_2 = A$ we get $2r = A$, so $r = A/2$.
From $\delta = i + e - A$ with $i = e$: $\delta_m = 2i - A$, so $i = (A + \delta_m)/2$.

Step 5: Apply Snell's law The refractive index of the prism material with respect to the surrounding air is $\mu = \dfrac{\sin i}{\sin r}$. Substituting i and r at minimum deviation,

$$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Check with numbers: for $A = 60^\circ$ and $\mu = 1.5$, the formula gives $\delta_m \approx 37.2^\circ$, and putting it back returns $\mu = 1.5$. So we can find μ by measuring A and δ_m on a spectrometer.

Step 6: Conclusion The refractive index of the prism material is found from the angle of the prism

and the angle of minimum deviation.

Quick Tip to Solve: Use the exterior geometry of the prism to show $r_1 + r_2 = A$ and $\delta = i + e - A$, then put $i = e$ and $r_1 = r_2$ at minimum deviation in Snell's law.

LA-24. What are energy bands ? How are these formed ? Distinguish between conductors, semiconductors and insulators on the basis of formation of the energy bands. [5 marks]

Solution:

Step 1: What is an energy band? In a single isolated atom, an electron can have only certain fixed energy levels. In a solid, a very large number of atoms are packed close together. The closely spaced levels group together into a range of allowed energies called an **energy band**.
The band that holds the outer (valence) electrons is the **valence band**. The next higher band, which is empty or partly filled, is the **conduction band**. The gap of forbidden energies between them is the **forbidden energy gap** E_g.

Step 2: How the bands are formed Suppose a crystal has N identical atoms. When they are far apart, each atom has the same set of discrete levels, so there are N coinciding levels at each energy.
As the atoms come close, as in a solid, the outer electron orbits overlap and the atoms interact. By the Pauli exclusion principle, no two electrons in the whole crystal can be in the same state, so each level cannot stay as N identical levels. It splits into N slightly different levels.
In a crystal N is about 10^{23} per cm^3, so the N levels are so close together that they form an almost continuous band. The inner electrons are tightly held and their bands are narrow, while the outer-level bands are wide and may even overlap.

Step 3: Conductors In a conductor (metal) the conduction band is partly filled, or the valence and conduction bands overlap, so $E_g = 0$. Electrons can move into free levels with a very small energy, so a conductor has very high conductivity. Examples: copper, aluminium.

Step 4: Semiconductors In a semiconductor, at 0 K the valence band is completely filled and the conduction band is empty, separated by a small gap E_g of about 1 eV (silicon 1.1 eV, germanium 0.67 eV). At room temperature some electrons gain enough heat energy to jump to the conduction band, leaving holes behind in the valence band. So it conducts a little, and conductivity rises with temperature.

Step 5: Insulators In an insulator the valence band is full and the conduction band is empty, but the forbidden gap is large, $E_g > 3$ eV (diamond is about 5.4 eV). Ordinary heat or an ordinary electric field cannot lift electrons across, so conductivity is almost zero.

Step 6: Conclusion The classification is decided by the width of the forbidden energy gap.

Quick Tip to Solve: Atomic levels split into N close levels when N atoms form a solid (Pauli principle). Compare the forbidden gap E_g: zero or overlapping for conductors, about 1 eV for semiconductors, above 3 eV for insulators.

LA-25. Mention the defects of human vision and describe the methods to remove them. [5 marks]

Solution:

Step 1: To diagnose a vision defect, first identify the type based on where the image is formed relative to the retina:

In **myopia** (nearsightedness), the image is formed **in front of the retina**, causing distant objects to

appear blurry.
In **hypermetropia** (farsightedness), the image is formed **behind the retina**, making nearby objects appear blurry.

Step 2: Correct the defect by using appropriate lenses that adjust the focal length so that the image forms precisely on the retina, ensuring clear vision:

For **myopia**, use **concave lenses** to diverge the incoming light rays, effectively moving the focal point backward onto the retina.
For **hypermetropia**, use **convex lenses** to converge the incoming light rays sooner, moving the focal point forward onto the retina.
This optical correction restores sharp vision by compensating for the eye's improper focusing.

Quick Tip to Solve: Regular eye checkups help in early detection and correction of vision defects.

LA-26. Derive an expression for the average value of alternating current. [5 marks]

Solution:

Step 1: Write the alternating current Let the alternating current be $I = I_0 \sin \omega t$, where I_0 is the peak value and ω is the angular frequency. The time period is $T = 2\pi/\omega$.
Over one full cycle the positive half exactly cancels the negative half, so the average over a complete cycle is zero. That is why the average value is defined over a half cycle, when the current keeps one direction.

Step 2: Definition of average value The average value is the mean of the instantaneous values over half a period (here from $t = 0$ to $t = T/2$):

$$I_{av} = \frac{1}{T/2} \int_0^{T/2} I \, dt = \frac{2}{T} \int_0^{T/2} I_0 \sin \omega t \, dt$$

Step 3: Integrate The integral of $\sin \omega t$ is $-\dfrac{\cos \omega t}{\omega}$. So

$$I_{av} = \frac{2I_0}{T} \left[-\frac{\cos \omega t}{\omega} \right]_0^{T/2} = \frac{2I_0}{\omega T} \left[\cos 0 - \cos \frac{\omega T}{2} \right]$$

Now $\omega T = 2\pi$, so $\dfrac{\omega T}{2} = \pi$ and $\cos \pi = -1$:

$$I_{av} = \frac{2I_0}{2\pi} \left[1 - (-1) \right] = \frac{2I_0}{2\pi} \times 2 = \frac{2I_0}{\pi}$$

Step 4: Put in the number Since $2/\pi = 0.6366$, we have $I_{av} = 0.637 \, I_0$, which is about 63.7 percent of the peak value. In the same way, for an alternating emf $E = E_0 \sin \omega t$, the average value is $E_{av} = 2E_0/\pi = 0.637 \, E_0$.

Step 5: Conclusion The average value of an alternating current over a half cycle is 0.637 times its peak value.

Quick Tip to Solve: Average over a half cycle: $I_{av} = \dfrac{2}{T} \int_0^{T/2} I_0 \sin \omega t \, dt$. The full-cycle average is zero.