CBSE Class 12 Physics

Sample Paper – 5

Duration: 180 Minutes **Maximum Marks: 70**

General Instructions

- This question paper contains **33 questions**. **All questions are compulsory**.
- The paper is divided into **five sections** – A, B, C, D and E.
- **Section A** (Q1–Q16) carries **1 mark** each: Q1–Q12 are multiple choice questions and Q13–Q16 are Assertion–Reason questions.
- **Section B** (Q17–Q21) carries **2 marks** each (Very Short Answer).
- **Section C** (Q22–Q28) carries **3 marks** each (Short Answer).
- **Section D** (Q29–Q30) carries **4 marks** each (case study based, with sub-parts).
- **Section E** (Q31–Q33) carries **5 marks** each (Long Answer).
- There is **no overall choice**, but an **internal choice** has been provided in some questions. Attempt only one of the alternatives in such questions.
- There is **no negative marking**. Use of a **calculator is not permitted**. You may use $c = 3 \times 10^8$ m/s, $h = 6.63 \times 10^{-34}$ J s, $e = 1.6 \times 10^{-19}$ C as required.

Section A (Q1–Q16) – 1 Mark Each

Q1. Two point charges separated by a fixed distance exert a force F on each other. If one of the charges is doubled and the other is tripled while the separation is kept unchanged, the new force between them is:

(A) $3F$

(B) $5F$

(C) $6F$

(D) $2F$

Q2. Three identical resistors, each of resistance R, are connected in parallel. The equivalent resistance of the combination is:

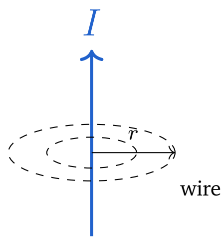
(A) $\frac{R}{3}$

(B) $3R$

(C) R

(D) $\frac{2R}{3}$

Q3. A long straight wire carries a steady current I. The magnitude of the magnetic field B at a perpendicular distance r from the wire varies with r as:



(A) $B \propto r$

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

(C) $B \propto \frac{1}{r^2}$

(D) $B \propto r^2$

Q4. The energy stored in an inductor of inductance L carrying a steady current I is:

(A) LI^2

(B) $\frac{1}{2}L^2I$

(C) $\frac{1}{2}LI$

(D) $\frac{1}{2}LI^2$

Q5. The inductive reactance of a coil is $X_L = 2\pi f L$. As the frequency f of the applied AC source is increased, the inductive reactance:

(A) increases

(B) decreases

(C) remains unchanged

(D) becomes zero

Q6. Which one of the following arranges the electromagnetic waves in order of *increasing* frequency?

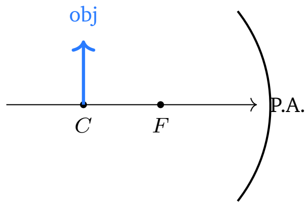
(A) X-rays, visible light, infrared, radio waves

(B) visible light, infrared, microwaves, radio waves

(C) radio waves, microwaves, infrared, ultraviolet

(D) gamma rays, X-rays, ultraviolet, visible light

Q7. An object is placed exactly at the centre of curvature C of a concave mirror, as shown. The image formed is:



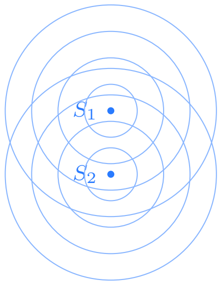
(A) virtual, erect and magnified

(B) real, inverted, of the same size and formed at C

(C) real, inverted and diminished

(D) real, inverted and magnified

Q8. For two light sources to produce a sustained (stationary) interference pattern, the two sources must be:



(A) of different amplitudes

(B) of different wavelengths

(C) incoherent, with a randomly varying phase difference

(D) coherent, maintaining a constant phase difference

Q9. The energy of a photon of light of frequency 5×10^{14} Hz is (take $h = 6.63 \times 10^{-34}$ J s):

(A) 1.6×10^{-19} J

(B) 6.63×10^{-34} J

(C) 5×10^{14} J

(D) 3.3×10^{-19} J

Q10. The spectral series of the hydrogen atom that lies in the *visible* region of the electromagnetic spectrum is the:

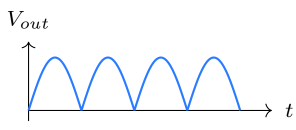
(A) Lyman series

(B) Paschen series

(C) Balmer series

(D) Brackett series

Q11. Compared with a half-wave rectifier using the same input, a full-wave rectifier (whose output is shown) has:



(A) lower efficiency and larger ripple

(B) higher efficiency and smaller ripple

(C) the same efficiency and the same ripple

(D) larger ripple and half the output frequency

Q12. A parallel-plate capacitor carrying a fixed charge is first disconnected from the battery, and a dielectric slab is then inserted to completely fill the gap between the plates. As a result:

(A) its capacitance decreases and the potential difference increases

(B) both its capacitance and its potential difference increase

(C) its capacitance decreases and the potential difference decreases

(D) its capacitance increases and the potential difference decreases

Q13. **Assertion (A):** An equipotential surface is everywhere perpendicular to the electric field.
Reason (R): No work is done in moving a charge from one point to another along an equipotential surface.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Q14. **Assertion (A):** An AC ammeter measures the root-mean-square (rms) value of the alternating current.
Reason (R): Such meters work on the heating effect of current, which depends on the square of the instantaneous current.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Q15. Assertion (A): A mirage in a desert is produced by the total internal reflection of light in layers of air of different densities.
Reason (R): Light travels in a straight line in an optically homogeneous medium.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Q16. Assertion (A): In Bohr's model of the hydrogen atom, the angular momentum of the electron is an integral multiple of $\frac{h}{2\pi}$.
Reason (R): According to Bohr's model, the revolving electron radiates electromagnetic energy continuously while in a stationary orbit.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Section B (Q17–Q21) – 2 Marks Each

Q17. Two isolated conducting spheres of radii 3 cm and 6 cm carry charges of $2\,\mu$C and $4\,\mu$C respectively. They are then joined by a thin conducting wire. Find the common potential of the two spheres. (Take $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ SI units.) **[2]**

Q18. Two cells of emf 12 V and 6 V are connected in a single loop so that they oppose each other. If the total resistance of the loop is $3\,\Omega$, use Kirchhoff's voltage law to find the current in the loop. **[2]**

Q19. The magnetic flux linked with a coil of resistance $10\,\Omega$ changes by 5 Wb. Calculate the charge that flows through the coil. **[2]**

OR

A capacitor of capacitance $10\,\mu$F is connected to an AC source of frequency 50 Hz. Find the capacitive reactance of the capacitor. (Take $\pi = 3.14$.)

Q20. Two thin convex lenses of focal lengths 20 cm and 30 cm are placed in contact with each other. Find the focal length and the power of the combination. **[2]**

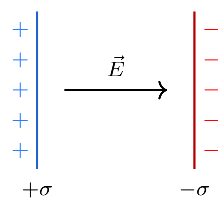
Q21. Calculate the de Broglie wavelength associated with a proton moving with a speed of 1×10^5 m/s. (Take $m_p = 1.67 \times 10^{-27}$ kg.) **[2]**

OR

A radioactive sample initially contains 8×10^{20} nuclei. How many nuclei remain undecayed after three half-lives?

Section C (Q22–Q28) – 3 Marks Each

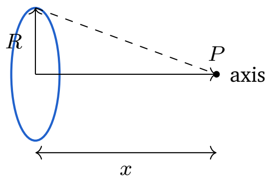
Q22. Using Gauss's law, derive an expression for the electric field in the region between two large parallel plane sheets carrying equal and opposite uniform surface charge densities $+\sigma$ and $-\sigma$. Also state the field in the regions outside the sheets.



[3]

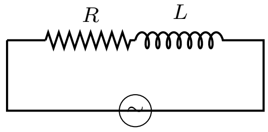
Q23. With the help of the working formula, explain how a potentiometer is used to measure the internal resistance of a cell. In such an experiment the balancing length is 100 cm with the cell in open circuit, and it falls to 80 cm when a resistance of $5\,\Omega$ is connected across the cell. Find the internal resistance of the cell. **[3]**

Q24. Using the Biot–Savart law, derive an expression for the magnetic field at a point on the axis of a circular current loop of radius R carrying current I, at a distance x from its centre.



[3]

Q25. A series RL circuit has $R = 30\,\Omega$ and an inductive reactance $X_L = 40\,\Omega$, and is connected to an AC source of rms voltage 100 V. Find the impedance of the circuit, the rms current, and the phase angle between the current and the voltage.

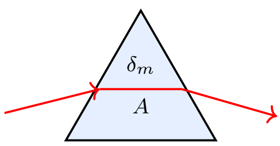


[3]

OR

Write the expression for the average power dissipated in an AC circuit and define the power factor. An AC circuit draws an rms current of 5 A at an rms voltage of 200 V with a power factor of 0.6. Calculate the average power consumed.

Q26. A ray of light passes symmetrically through a glass prism of refracting angle $A = 60^\circ$ and refractive index $\mu = \sqrt{2}$. Using the prism formula, calculate the angle of minimum deviation δ_m. (Take $\sin 45^\circ = 0.707$.)



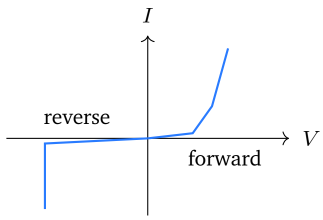
[3]

OR

Explain, with the help of the concept of total internal reflection, how light is transmitted along an optical fibre. If the core of a fibre has refractive index 1.5 and the surrounding cladding behaves like air, find the critical angle at the core–cladding boundary. (Take $\sin^{-1}(0.667) = 41.8^\circ$.)

Q27. A radioactive sample has a half-life of 2 hours and initially contains 4×10^{20} nuclei. Find the number of nuclei remaining after 6 hours, and the activity of the sample at that instant. (Take $\ln 2 = 0.693$.) **[3]**

Q28. With the help of suitable circuit ideas, explain the behaviour of a p-n junction diode under forward and reverse bias, and draw its complete V–I characteristic curve.

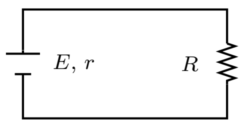


[3]

Section D (Q29–Q30) – 4 Marks Each (Case Study)

Q29. Case Study – Cell with Internal Resistance.

A cell of emf $E = 12$ V and internal resistance $r = 0.5\,\Omega$ is connected to an external resistance $R = 5.5\,\Omega$, as shown.



Based on the above, answer the following:

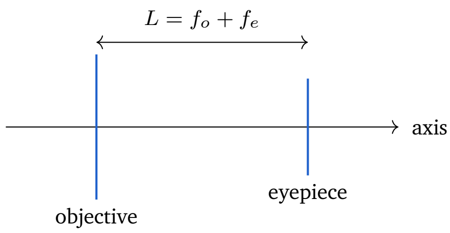
(i) Find the current drawn from the cell. (1)

(ii) Find the terminal voltage across the cell. (1)

(iii) Find the power delivered to the external resistance R and the power dissipated inside the cell. (2)

Q30. Case Study – Astronomical Telescope.

An astronomical telescope has an objective lens of focal length $f_o = 150$ cm and an eyepiece of focal length $f_e = 5$ cm. It is first used in normal adjustment (final image at infinity).



Based on the above, answer the following:

(i) Find the magnifying power in normal adjustment. (1)

(ii) Find the length of the telescope tube. (1)

(iii) Find the magnifying power when the final image is formed at the least distance of distinct vision, $D = 25$ cm. (2)

Section E (Q31–Q33) – 5 Marks Each

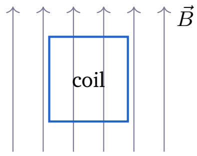
Q31. (a) Derive an expression for the capacitance of a parallel-plate capacitor when a dielectric slab of thickness t and dielectric constant K (with $t < d$) is introduced between its plates, the plates being separated by a distance d.
(b) A parallel-plate capacitor has plate area $A = 2 \times 10^{-2}$ m^2 and plate separation $d = 1$ cm. A dielectric slab of thickness $t = 0.5$ cm and $K = 4$ is placed inside it. Find the capacitance. (Take $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m.)
[5]

OR

(a) In the network below, resistances of $6\,\Omega$ and $3\,\Omega$ are joined in parallel, and this combination is in series with a $2\,\Omega$ resistor across a 12 V battery of negligible internal resistance. Find the equivalent resistance of the network and the main current drawn from the battery.
(b) Find how this main current is distributed between the $6\,\Omega$ and $3\,\Omega$ resistors.

Q32. (a) Derive an expression for the torque acting on a rectangular current-carrying loop placed in a uniform magnetic field, and explain how a radial field is used in a moving-coil galvanometer to make the deflection proportional to the current.

(b) A rectangular coil of 100 turns and area 2×10^{-4} m^2 carries a current of 2 A in a radial field of 0.5 T. Find the torque experienced by the coil.

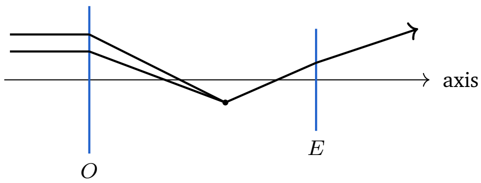


[5]

OR

(a) Derive the expression for the average power dissipated in a series LCR circuit driven by an AC source, and define the power factor of the circuit.
(b) A series LCR circuit has $R = 30\,\Omega$ and $(X_L - X_C) = 40\,\Omega$, connected to an AC source of rms voltage 200 V. Find the power factor and the average power consumed.

Q33. (a) Draw a labelled ray diagram of an astronomical telescope in normal adjustment and derive the expression for its magnifying power.
(b) The objective and eyepiece of such a telescope have focal lengths 120 cm and 3 cm respectively. Find its magnifying power and the length of the tube in normal adjustment.



[5]

OR

(a) In a single-slit diffraction experiment, derive the expression for the width of the central maximum on a screen at distance D from a slit of width a.
(b) A single slit of width 0.1 mm is illuminated by light of wavelength 500 nm, and the pattern is observed on a screen 1 m away. Find the width of the central maximum.

Detailed Solutions

Q1.

Solution

Concept — Coulomb's law: The force between two point charges is proportional to the product of the charges, $F \propto q_1q_2$, for a fixed separation.

Step 1 — Write the original force:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}.$$

Step 2 — Scale the charges: Replace q_1 by $2q_1$ and q_2 by $3q_2$, keeping r fixed:

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{(2q_1)(3q_2)}{r^2}.$$

$$= 6 \cdot \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}.$$

$$= 6F.$$

Why other options are wrong: (A) $3F$ and (D) $2F$ count only one of the two scalings; (B) $5F$ wrongly adds the factors $(2+3)$ instead of multiplying them.

Final Answer: New force $= 6F \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

Q2.

Solution

Concept — Resistors in parallel: For n equal resistances R in parallel, the equivalent resistance is R/n.

Step 1 — Add the reciprocals:

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R}.$$

$$= \frac{3}{R}.$$

Step 2 — Invert:

$$R_p = \frac{R}{3}.$$

Why other options are wrong: (B) $3R$ is the series result; (C) R ignores the parallel combination; (D) $\frac{2R}{3}$ does not follow from three equal branches.

Final Answer: Equivalent resistance $= \frac{R}{3} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept — Field of a long straight wire: By Ampere's law, the magnetic field around an infinitely long straight wire is $B = \frac{\mu_0 I}{2\pi r}$.

Step 1 — Write the field:

$$B = \frac{\mu_0 I}{2\pi r}.$$

Step 2 — Identify the dependence: With μ_0, I fixed, only r varies, so

$$B \propto \frac{1}{r}.$$

Why other options are wrong: (A) and (D) make B grow with distance; (C) $1/r^2$ is the dependence for a point magnetic dipole or a point charge's field, not a straight wire.

Final Answer: $B \propto \frac{1}{r} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q3

Q4.

Solution

Concept — Energy stored in an inductor: Building up a current I against the back-emf stores magnetic energy $U = \frac{1}{2}LI^2$.

Step 1 — Work done against the back-emf: The instantaneous power is $P = \varepsilon i = Li\frac{di}{dt}$, so

$$U = \int_0^I Li\, di.$$

Step 2 — Integrate:

$$U = L \cdot \frac{I^2}{2} = \frac{1}{2}LI^2.$$

Why other options are wrong: (A) LI^2 omits the factor $\frac{1}{2}$; (B) $\frac{1}{2}L^2I$ and (C) $\frac{1}{2}LI$ have the wrong powers of L and I.

Final Answer: $U = \frac{1}{2}LI^2 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — Inductive reactance: The opposition of an inductor to AC is $X_L = 2\pi f L = \omega L$, which is directly proportional to the frequency.

Step 1 — Write the relation:

$$X_L = 2\pi f L.$$

Step 2 — Vary the frequency: With L fixed, $X_L \propto f$, so raising f raises X_L.

Why other options are wrong: (B) decrease is the behaviour of capacitive reactance $X_C = \frac{1}{2\pi f C}$; (C) and (D) contradict the direct proportionality.

Final Answer: Inductive reactance increases $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept — Electromagnetic spectrum: In order of increasing frequency (decreasing wavelength): radio $<$ microwave $<$ infrared $<$ visible $<$ ultraviolet $<$ X-rays $<$ gamma rays.

Step 1 — Test each option: Increasing frequency must start with radio waves and rise. Option (C) reads radio $<$ microwave $<$ infrared $<$ ultraviolet, which is correctly increasing.

Step 2 — Reject the reversed lists: Options (A), (B) and (D) begin with high-frequency waves and move to low-frequency ones, i.e. they are in *decreasing* order.

Why other options are wrong: (A) X-rays are much higher in frequency than radio waves; (B) visible light is higher than radio waves; (D) gamma rays are the highest, so listing them first is decreasing order.

Final Answer: radio $<$ microwave $<$ infrared $<$ ultraviolet $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

Q7.

Solution

Concept — Concave mirror with the object at C: When the object is at the centre of curvature, the image is formed at C itself, real, inverted and of the same size (magnification $= -1$).

Step 1 — Use the mirror formula: With $u = -2f$ (object at $C = 2f$),

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

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{-2f} \Rightarrow \text{taking } \frac{1}{v} = \frac{1}{f} - \frac{1}{2f}.$$

Step 2 — Solve:

$$\frac{1}{v} = \frac{2-1}{2f} = \frac{1}{2f} \Rightarrow v = 2f.$$

So the image is also at C; the magnification is $m = -\frac{v}{u} = -\frac{2f}{2f} = -1$.

Why other options are wrong: (A) virtual erect image needs the object within F; (C) diminished image needs the object beyond C; (D) magnified image needs the object between C and F.

Final Answer: Real, inverted, same size, formed at $C \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept — Coherence: A sustained (stationary) interference pattern requires two sources that emit waves of the same frequency and maintain a constant phase difference; such sources are called coherent.

Step 1 — Condition for a steady pattern: If the phase difference between the two waves stays fixed in time, the positions of the bright and dark fringes do not shift, so the pattern is stationary and observable.

Step 2 — Consequence of incoherence: If the phase difference varies randomly, the fringes wash out and no steady pattern is seen.

Why other options are wrong: (A) equal amplitudes only improve contrast, they are not the essential requirement; (B) different wavelengths destroy a single stationary pattern; (C) incoherent sources cannot give sustained interference.

Final Answer: Coherent sources with a constant phase difference $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q8

Q9.

Solution

Concept — Photon energy: The energy carried by a photon is $E = h\nu$.

Step 1 — Substitute the values:

$$E = (6.63 \times 10^{-34})(5 \times 10^{14}).$$

Step 2 — Multiply the mantissas:

$$6.63 \times 5 = 33.15.$$

Step 3 — Combine the powers of ten:

$$E = 33.15 \times 10^{-20} = 3.315 \times 10^{-19} \text{ J} \approx 3.3 \times 10^{-19} \text{ J}.$$

Why other options are wrong: (A) 1.6×10^{-19} J is the electronic charge in coulombs, not this photon's energy; (B) 6.63×10^{-34} J is just h without multiplying by ν; (C) 5×10^{14} J confuses the frequency value with the energy.

Final Answer: $E \approx 3.3 \times 10^{-19}$ J $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept — Hydrogen spectral series: The Lyman series lies in the ultraviolet, the Balmer series in the visible, and the Paschen, Brackett and Pfund series in the infrared.

Step 1 — Identify the visible series: Transitions ending at $n = 2$ form the Balmer series, whose lines (H_α, H_β, $\ldots$) fall in the visible band.

Step 2 — Conclusion: The visible-region series is the Balmer series.

Why other options are wrong: (A) Lyman is ultraviolet ($n \to 1$); (B) Paschen and (D) Brackett lie in the infrared ($n \to 3$ and $n \to 4$).

Final Answer: Balmer series $\Rightarrow \boxed{C}$

Answer: (C) Go Back to Q10

Q11.

Solution

Concept — Rectifier comparison: A full-wave rectifier uses both halves of each AC cycle, whereas a half-wave rectifier uses only one.

Step 1 — Efficiency: The full-wave rectifier delivers output during both half-cycles, so its rectification efficiency ($\approx 81.2\%$) is about twice that of the half-wave rectifier ($\approx 40.6\%$).

Step 2 — Ripple: Because the output pulses come twice as often (ripple frequency $2f$ instead of f), the gaps are smaller and the ripple factor is lower (1.21 for half-wave versus 0.48 for full-wave).

Why other options are wrong: (A) reverses both facts; (C) claims no improvement, which is false; (D) the output frequency is higher (doubled), not halved.

Final Answer: Higher efficiency and smaller ripple $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q11

Q12.

Solution

Concept — Dielectric at constant charge: An isolated (disconnected) capacitor keeps its charge Q fixed. Inserting a dielectric of constant K raises the capacitance to KC_0 and, since $V = Q/C$, lowers the voltage.

Step 1 — Capacitance change:

$$C = KC_0 > C_0 \quad (K > 1).$$

Step 2 — Voltage change: With Q constant,

$$V = \frac{Q}{C} = \frac{Q}{KC_0} = \frac{V_0}{K} < V_0.$$

Why other options are wrong: (A) and (C) claim the capacitance falls, but a dielectric always raises it; (B) says the voltage rises, but at constant charge it falls.

Final Answer: Capacitance increases, voltage decreases $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q12

Q13.

Solution

Concept — Assertion–Reason on equipotential surfaces: Judge each statement, then decide whether R explains A.

Step 1 — Assertion: An equipotential surface is everywhere perpendicular to $\vec{E}$. This is **true**.

Step 2 — Reason: Along an equipotential surface the potential is constant, so $W = q\,\Delta V = 0$; no work is done in moving a charge on it. This is **true**.

Step 3 — Does R explain A? Since $W = q\vec{E}\cdot\vec{dl} = 0$ for any displacement $\vec{dl}$ on the surface, $\vec{E}$ must be perpendicular to that displacement. So R is exactly the reason for A.

Why other options are wrong: (B) denies a genuine causal link; (C),(D) misjudge a truth value.

Final Answer: Both true, R explains A $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept — AC measuring instruments: Hot-wire and moving-iron AC meters respond to the heating (or torque) that depends on I^2, so their scale is graduated to read the rms value.

Step 1 — Assertion: An AC ammeter reads the rms value of the current. This is **true**.

Step 2 — Reason: The deflection is produced by the heating effect, and the heat generated is $\propto I^2$, whose time-average defines the rms value. This is **true**.

Step 3 — Does R explain A? Because the reading follows the mean of I^2, its square root (the rms current) is exactly what the scale shows, so R correctly explains A.

Why other options are wrong: (B) denies a real link; (C),(D) misjudge a truth value.

Final Answer: Both true, R explains A $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q14

Q15.

Solution

Concept — Assertion–Reason on a mirage: A mirage arises when light, passing through air layers of gradually changing density (and hence refractive index), bends progressively and finally undergoes total internal reflection.

Step 1 — Assertion: A mirage is produced by total internal reflection in air layers of different densities. This is **true**.

Step 2 — Reason: Light travels in a straight line in an optically homogeneous medium. This is **true** as a general statement.

Step 3 — Does R explain A? A mirage depends precisely on the air being *non-homogeneous* (its refractive index varies with height). The reason describes a homogeneous medium, so it does not account for the bending that causes the mirage.

Why other options are wrong: (A) wrongly links the two; (C),(D) misjudge a truth value.

Final Answer: Both true, but R does not explain A $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q15

Q16.

Solution

Concept — Bohr's postulates: Bohr assumed quantised angular momentum for the electron and, crucially, that the electron does *not* radiate while in a stationary orbit.

Step 1 — Assertion: Angular momentum is quantised, $mvr = \dfrac{nh}{2\pi}$. This is **true**.

Step 2 — Reason: The claim that the revolving electron radiates energy continuously is **false**; Bohr postulated exactly the opposite, that a stationary-orbit electron does not radiate.

Step 3 — Combine: A is true but R is false.

Why other options are wrong: (A),(B) require R true; (D) requires A false.

Final Answer: A true, R false $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q16

Q17.

Solution

Concept — Common potential: When two charged conductors are joined by a wire, charge flows until both reach the same potential. The common potential is $V = \frac{1}{4\pi\varepsilon_0}\frac{Q_1+Q_2}{r_1+r_2}$, because the total charge is conserved while each sphere satisfies $q/r =$ constant.

Step 1 — Total charge:

$$Q_1 + Q_2 = 2 + 4 = 6\ \mu\text{C} = 6 \times 10^{-6}\ \text{C}.$$

Step 2 — Sum of radii:

$$r_1 + r_2 = 3 + 6 = 9\ \text{cm} = 0.09\ \text{m}.$$

Step 3 — Common potential:

$$V = \frac{(9 \times 10^9)(6 \times 10^{-6})}{0.09}.$$

$$= \frac{5.4 \times 10^4}{0.09} = 6 \times 10^5\ \text{V}.$$

Final Answer: Common potential $= 6 \times 10^5$ V. Go Back to Q17

Q18.

Solution

Concept — Kirchhoff's voltage law: The algebraic sum of the emfs and the potential drops around a closed loop is zero. When two cells oppose, the net emf is their difference.

Step 1 — Net emf in the loop:

$$\varepsilon_{\text{net}} = 12 - 6 = 6\ \text{V}.$$

Step 2 — Apply KVL:

$$\varepsilon_{\text{net}} = I\,R_{\text{total}}.$$

$$6 = I \times 3.$$

Step 3 — Solve for the current:

$$I = \frac{6}{3} = 2 \text{ A}.$$

Final Answer: Current in the loop $= 2$ A (driven by the 12 V cell). **Go Back to Q18**

Q19.

Solution

Concept — Induced charge: The charge that flows during a flux change is $q = \frac{\Delta\phi}{R}$, independent of how fast the change occurs.

Step 1 — Write the relation:

$$q = \frac{\Delta\phi}{R}.$$

Step 2 — Substitute the values:

$$q = \frac{5}{10}.$$

$$= 0.5 \text{ C}.$$

Final Answer: Charge through the coil $= 0.5$ C.

OR — Capacitive reactance:

Step 1 — Formula: $X_C = \frac{1}{2\pi f C}$.

Step 2 — Denominator:

$$2\pi f C = 2(3.14)(50)(10 \times 10^{-6}) = 3.14 \times 10^{-3}.$$

Step 3 — Reactance:

$$X_C = \frac{1}{3.14 \times 10^{-3}} \approx 318.5 \ \Omega.$$

Final Answer (OR): $X_C \approx 318.5\,\Omega$. **Go Back to Q19**

Q20.

Solution

Concept — Lenses in contact: The reciprocals of the focal lengths add, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$, and the power is $P = \frac{1}{F}$ (with F in metres).

Step 1 — Add the reciprocals:

$$\frac{1}{F} = \frac{1}{20} + \frac{1}{30}.$$

$$= \frac{3+2}{60} = \frac{5}{60} = \frac{1}{12}.$$

Step 2 — Focal length:

$$F = 12 \text{ cm} = 0.12 \text{ m}.$$

Step 3 — Power:

$$P = \frac{1}{0.12} \approx +8.33 \text{ D}.$$

Final Answer: $F = 12$ cm; $P \approx +8.33$ D (converging). **Go Back to Q20**

Q21.

Solution

Concept — de Broglie wavelength: $\lambda = \frac{h}{mv}$.

Step 1 — Denominator:

$$m_p v = (1.67 \times 10^{-27})(1 \times 10^{5}) = 1.67 \times 10^{-22}.$$

Step 2 — Divide:

$$\lambda = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-22}}.$$

$$= 3.97 \times 10^{-12} \text{ m}.$$

Final Answer: $\lambda \approx 3.97 \times 10^{-12}$ m.

OR — Nuclei after three half-lives:

Step 1 — Remaining fraction:

$$\left(\frac{1}{2}\right)^3 = \frac{1}{8}.$$

Step 2 — Number left:

$$N = \frac{8 \times 10^{20}}{8} = 1 \times 10^{20}.$$

Final Answer (OR): 1×10^{20} nuclei remain undecayed. Go Back to Q21

Q22.

Solution

Concept — Field of a charged sheet: A single infinite sheet of surface charge density σ produces a uniform field $E = \dfrac{\sigma}{2\varepsilon_0}$ on each side, directed away from a positive sheet.

Step 1 — Field of each sheet: From Gauss's law with a pill-box surface,

$$E_+ = \frac{\sigma}{2\varepsilon_0}, \qquad E_- = \frac{\sigma}{2\varepsilon_0}.$$

Step 2 — Between the sheets: Both fields point from the $+\sigma$ sheet towards the $-\sigma$ sheet, so they add:

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}.$$
$$= \frac{\sigma}{\varepsilon_0}.$$

Step 3 — Outside the sheets: On either outer side the two fields are equal and opposite, so they cancel:

$$E_{\text{outside}} = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0.$$

Final Answer: Between the sheets $E = \dfrac{\sigma}{\varepsilon_0}$ (uniform); outside, $E = 0$. Go Back to Q22

Q23.

Solution

Concept — Potentiometer internal resistance: The balancing length is proportional to the potential difference. In open circuit it measures the emf E ($\propto \ell_1$); with a resistance R across the cell it measures the terminal voltage V ($\propto \ell_2$). Hence $r = R\left(\dfrac{\ell_1 - \ell_2}{\ell_2}\right)$.

Step 1 — Ratio of readings:

$$\frac{E}{V} = \frac{\ell_1}{\ell_2} = \frac{100}{80} = \frac{5}{4}.$$

Step 2 — Internal resistance formula:

$$r = R\left(\frac{\ell_1 - \ell_2}{\ell_2}\right).$$

Step 3 — Substitute the values:

$$r = 5 \times \frac{100 - 80}{80} = 5 \times \frac{20}{80}.$$

$$= 5 \times 0.25 = 1.25\ \Omega.$$

Final Answer: Internal resistance of the cell $= 1.25\,\Omega$. **Go Back to Q23**

Q24.

Solution

Concept — Biot–Savart law on the axis of a loop: Each current element $I\,d\vec{l}$ contributes $dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{(R^2 + x^2)}$; the components perpendicular to the axis cancel in pairs, leaving only the axial components.

Step 1 — Magnitude from one element: Since $d\vec{l} \perp \vec{r}$,

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{R^2 + x^2}.$$

Step 2 — Take the axial component: Multiply by $\frac{R}{\sqrt{R^2 + x^2}}$:

$$dB_x = \frac{\mu_0}{4\pi}\frac{I\,dl}{R^2 + x^2} \cdot \frac{R}{\sqrt{R^2 + x^2}}.$$

Step 3 — Integrate around the loop ($\oint dl = 2\pi R$):

$$B = \frac{\mu_0}{4\pi}\frac{IR}{(R^2 + x^2)^{3/2}}(2\pi R).$$

$$= \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}.$$

Step 4 — At the centre ($x = 0$):

$$B = \frac{\mu_0 I}{2R}.$$

Final Answer: $B = \dfrac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$, directed along the axis. **Go Back to Q24**

Q25.

Solution

Concept — Series RL circuit: $Z = \sqrt{R^2 + X_L^2}$, $I = \dfrac{V}{Z}$, and $\tan\varphi = \dfrac{X_L}{R}$.

Step 1 — Impedance:

$$Z = \sqrt{30^2 + 40^2} = \sqrt{900 + 1600} = \sqrt{2500} = 50\ \Omega.$$

Step 2 — rms current:

$$I = \frac{V}{Z} = \frac{100}{50} = 2\text{ A}.$$

Step 3 — Phase angle:

$$\tan\varphi = \frac{40}{30} = \frac{4}{3}.$$

$$\varphi = \tan^{-1}\left(\frac{4}{3}\right) \approx 53^\circ \text{ (voltage leads current)}.$$

Final Answer: $Z = 50\,\Omega$, $I = 2$ A, $\varphi \approx 53^\circ$.

OR — Average power in an AC circuit:

Step 1 — Formula: $P_{\text{av}} = V_{\text{rms}} I_{\text{rms}} \cos\varphi$; the power factor is $\cos\varphi = \dfrac{R}{Z}$.

Step 2 — Substitute:

$$P_{\text{av}} = (200)(5)(0.6).$$

$$= 600\text{ W}.$$

Final Answer (OR): Average power $= 600$ W. **Go Back to Q25**

Q26.

Solution

Concept — Prism at minimum deviation: $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$.

Step 1 — Rearrange for the numerator:

$$\sin\left(\frac{A+\delta_m}{2}\right) = \mu\,\sin\left(\frac{A}{2}\right).$$

Step 2 — Substitute the values:

$$\sin\left(\frac{60^\circ+\delta_m}{2}\right) = \sqrt{2}\times\sin 30^\circ = \sqrt{2}\times 0.5 = 0.707.$$

Step 3 — Take the inverse sine ($\sin 45^\circ = 0.707$):

$$\frac{60^\circ+\delta_m}{2} = 45^\circ.$$

$$60^\circ+\delta_m = 90^\circ \;\Rightarrow\; \delta_m = 30^\circ.$$

Final Answer: Angle of minimum deviation $\delta_m = 30^\circ$.

OR — Optical fibre and critical angle:

Step 1 — Principle: Light entering the denser core strikes the core–cladding boundary at more than the critical angle, so it undergoes repeated total internal reflection and is guided along the fibre.

Step 2 — Critical angle:

$$\sin\theta_c = \frac{1}{\mu} = \frac{1}{1.5} = 0.667.$$

$$\theta_c = \sin^{-1}(0.667) = 41.8^\circ.$$

Final Answer (OR): Critical angle $\theta_c \approx 41.8^\circ$. **Go Back to Q26**

Q27.

Solution

Concept — Radioactive decay: After n half-lives $N = \frac{N_0}{2^n}$, the decay constant is $\lambda = \frac{\ln 2}{T_{1/2}}$, and the activity is $A = \lambda N$.

Step 1 — Number of half-lives in 6 hours:

$$n = \frac{6}{2} = 3.$$

Step 2 — Nuclei remaining:

$$N = \frac{4 \times 10^{20}}{2^3} = \frac{4 \times 10^{20}}{8} = 5 \times 10^{19}.$$

Step 3 — Decay constant (in per second, $T_{1/2} = 2 \times 3600 = 7200$ s):

$$\lambda = \frac{0.693}{7200} = 9.63 \times 10^{-5}\ \text{s}^{-1}.$$

Step 4 — Activity:

$$A = \lambda N = (9.63 \times 10^{-5})(5 \times 10^{19}).$$

$$= 4.8 \times 10^{15}\ \text{decays/s}.$$

Final Answer: $N = 5 \times 10^{19}$ nuclei; activity $A \approx 4.8 \times 10^{15}$ Bq. **Go Back to Q27**

Q28.

Solution

Concept — p-n junction diode: A diode conducts easily under forward bias but only allows a tiny saturation current under reverse bias, until breakdown.

Step 1 — Forward bias: The p-side is joined to the positive terminal. This lowers the potential barrier, the depletion region narrows, and beyond a small "knee" voltage (≈ 0.7 V for Si) the current rises steeply.

Step 2 — Reverse bias: The p-side is joined to the negative terminal. The barrier widens, and only a very small reverse saturation current (due to minority carriers) flows, nearly independent of voltage.

Step 3 — Breakdown: At a large reverse voltage the current increases sharply (breakdown region).

Step 4 — V–I characteristic: The graph (shown above the question) is steeply rising in the forward region past the knee, and almost flat and small in the reverse region until breakdown.

Final Answer: The diode offers low resistance in forward bias and very high resistance in reverse bias, giving the characteristic asymmetric V–I curve. **Go Back to Q28**

Q29.

Solution

Concept — Cell with internal resistance: Current $I = \dfrac{E}{R+r}$; terminal voltage $V = E - Ir = IR$; power in a resistor $P = I^2R$.

(i) Current drawn:

$$I = \frac{E}{R+r} = \frac{12}{5.5+0.5} = \frac{12}{6} = 2\text{ A}.$$

(ii) Terminal voltage:

$$V = E - Ir = 12 - (2)(0.5).$$

$$= 12 - 1 = 11\text{ V}.$$

(iii) Power delivered and dissipated:

$$P_R = I^2R = (2)^2(5.5) = 4 \times 5.5 = 22\text{ W}.$$

$$P_r = I^2r = (2)^2(0.5) = 4 \times 0.5 = 2\text{ W}.$$

Final Answer: $I = 2$ A; $V = 11$ V; power to $R = 22$ W and power lost in the cell $= 2$ W. **Go Back to Q29**

Q30.

Solution

Concept — Astronomical telescope: In normal adjustment $m = \dfrac{f_o}{f_e}$ and tube length $L = f_o + f_e$. When the image is at the near point, $m = \dfrac{f_o}{f_e}\left(1 + \dfrac{f_e}{D}\right)$.

(i) Magnifying power (normal adjustment):

$$m = \frac{f_o}{f_e} = \frac{150}{5} = 30.$$

(ii) Tube length:

$$L = f_o + f_e = 150 + 5 = 155 \text{ cm}.$$

(iii) Image at the near point ($D = 25$ cm):

$$m' = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right) = 30\left(1 + \frac{5}{25}\right).$$

$$= 30(1 + 0.2) = 30 \times 1.2 = 36.$$

Final Answer: $m = 30$; $L = 155$ cm; magnifying power at the near point $= 36$. **Go Back to Q30**

Q31.

Solution

Concept — Capacitor with a partial dielectric slab: The field is $E_0 = \sigma/\varepsilon_0$ in the empty gap and E_0/K inside the slab; the plate voltage is the sum of the potential drops across each region.

(a) Derivation: With charge density $\sigma = Q/A$, the field in the air gap (thickness $d-t$) is $E_0 = \frac{\sigma}{\varepsilon_0}$, and inside the slab it is $\frac{E_0}{K}$. The total voltage is

$$V = E_0(d-t) + \frac{E_0}{K}t = \frac{\sigma}{\varepsilon_0}\left(d - t + \frac{t}{K}\right).$$

Since $C = \frac{Q}{V} = \frac{\sigma A}{V}$,

$$C = \frac{\varepsilon_0 A}{d - t + \dfrac{t}{K}}.$$

(b) Numerical: $A = 2 \times 10^{-2}$ m^2, $d = 0.01$ m, $t = 0.005$ m, $K = 4$:

$$d - t + \frac{t}{K} = 0.01 - 0.005 + \frac{0.005}{4} = 0.005 + 0.00125 = 0.00625 \text{ m}.$$

$$C = \frac{(8.85 \times 10^{-12})(2 \times 10^{-2})}{0.00625}.$$

$$= \frac{1.77 \times 10^{-13}}{6.25 \times 10^{-3}} = 2.83 \times 10^{-11} \text{ F}.$$

Final Answer: $C = \dfrac{\varepsilon_0 A}{d - t + t/K} \approx 2.83 \times 10^{-11}$ F $= 28.3$ pF.

OR — Resistor network:

(a) Parallel part:

$$\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3} = \frac{1+2}{6} = \frac{3}{6} \Rightarrow R_p = 2\ \Omega.$$

Equivalent resistance:

$$R_{\text{eq}} = R_p + 2 = 2 + 2 = 4\ \Omega.$$

Main current:

$$I = \frac{V}{R_{\text{eq}}} = \frac{12}{4} = 3\ \text{A}.$$

(b) The voltage across the parallel section is $V_p = IR_p = 3 \times 2 = 6$ V, so

$$I_{6\Omega} = \frac{6}{6} = 1\ \text{A}, \qquad I_{3\Omega} = \frac{6}{3} = 2\ \text{A}.$$

Final Answer (OR): $R_{\text{eq}} = 4\,\Omega$, $I = 3$ A; the branch currents are 1 A ($6\,\Omega$) and 2 A ($3\,\Omega$). **Go Back to Q31**

Q32.

Solution

Concept — Torque on a current loop: A loop of N turns, area A, carrying current I in a field B experiences a torque $\tau = NBIA\sin\theta$, where θ is the angle between $\vec{B}$ and the coil's normal.

(a) Derivation: The two sides of length L perpendicular to $\vec{B}$ carry equal and opposite forces $F = BIL$, forming a couple. With breadth b and $A = Lb$,

$$\tau = NBIL \times b\sin\theta = NBIA\sin\theta.$$

In a moving-coil galvanometer the field is made *radial* by a soft-iron core and concave pole pieces, so the plane of the coil is always parallel to $\vec{B}$ ($\theta = 90°$, $\sin\theta = 1$). Then $\tau = NBIA$, which balances the restoring torque $k\phi$ of the spring, giving $\phi \propto I$, a linear scale.

(b) Numerical: $N = 100$, $A = 2 \times 10^{-4}$ m^2, $I = 2$ A, $B = 0.5$ T, $\sin\theta = 1$:

$$\tau = NBIA = (100)(0.5)(2)(2 \times 10^{-4}).$$

$$= (100)(0.5)(2)(2 \times 10^{-4}) = 0.02\ \text{N m}.$$

Final Answer: $\tau = NBIA = 0.02\ \mathrm{N\,m}$.

OR — Average power and power factor:

(a) The instantaneous power averaged over a cycle gives

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

where the power factor is $\cos\varphi = \frac{R}{Z}$ and $Z = \sqrt{R^2 + (X_L - X_C)^2}$. Only the resistance dissipates energy.

(b) With $R = 30\,\Omega$, $(X_L - X_C) = 40\,\Omega$:

$$Z = \sqrt{30^2 + 40^2} = \sqrt{2500} = 50\ \Omega.$$

$$\cos\varphi = \frac{R}{Z} = \frac{30}{50} = 0.6.$$

$$I_{\mathrm{rms}} = \frac{V}{Z} = \frac{200}{50} = 4\ \mathrm{A}.$$

$$P_{\mathrm{av}} = (200)(4)(0.6) = 480\ \mathrm{W}.$$

Final Answer (OR): Power factor $= 0.6$; average power $= 480$ W. **Go Back to Q32**

Q33.

Solution

Concept — Astronomical telescope in normal adjustment: The objective forms a real image of a distant object at its focus; the eyepiece, acting as a magnifier, views this image with the final image at infinity.

(a) Magnifying power: The magnifying power is the ratio of the angle subtended at the eye by the final image to that subtended by the object:

$$m = \frac{\beta}{\alpha}.$$

If the intermediate image has height h at the common focal point, then $\alpha \approx \frac{h}{f_o}$ and $\beta \approx \frac{h}{f_e}$, so

$$m = \frac{h/f_e}{h/f_o} = \frac{f_o}{f_e}.$$

(Ray diagram: parallel rays from the objective converge at its focus, which coincides with the focus of the eyepiece, emerging as a parallel beam to the eye.)

(b) Numerical: $f_o = 120$ cm, $f_e = 3$ cm:

$$m = \frac{f_o}{f_e} = \frac{120}{3} = 40.$$

$$L = f_o + f_e = 120 + 3 = 123 \text{ cm}.$$

Final Answer: $m = \frac{f_o}{f_e} = 40$; tube length $= 123$ cm.

OR — Single-slit diffraction:

(a) The first minima on either side of the centre satisfy $a \sin\theta = \lambda$, so for small angles $\theta \approx \frac{\lambda}{a}$. The linear distance of a first minimum from the centre is $y = D\theta = \frac{\lambda D}{a}$, and the width of the central maximum (between the two first minima) is

$$W = 2y = \frac{2\lambda D}{a}.$$

(b) With $a = 0.1$ mm$= 1 \times 10^{-4}$ m, $D = 1$ m, $\lambda = 500$ nm$= 5 \times 10^{-7}$ m:

$$W = \frac{2(5 \times 10^{-7})(1)}{1 \times 10^{-4}}.$$

$$= \frac{1 \times 10^{-6}}{1 \times 10^{-4}} = 1 \times 10^{-2} \text{ m} = 1 \text{ cm}.$$

Final Answer (OR): $W = \frac{2\lambda D}{a} = 1$ cm. **Go Back to Q33**

Answer Key – Section A (Q1–Q16)

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	A	3	B	4	D	5	A
6	C	7	B	8	D	9	D	10	C
11	B	12	D	13	A	14	A	15	B
16	C								

Sections B–E are descriptive; refer to the Detailed Solutions above for full model answers and step marking.