CBSE Class 12 Physics

Sample Paper – 2

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. The electric field at a distance r from a point charge is E. If the distance is made three times as large while the charge is unchanged, the new field becomes:

(A) $3E$

(B) $\frac{E}{9}$

(C) $\dfrac{E}{3}$

(D) $9E$

Q2. A metallic conductor of cross-sectional area A has n free electrons per unit volume, each of charge e. If it carries a steady current I, the drift velocity v_d of the electrons is:

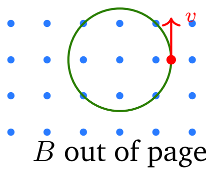
(A) $\dfrac{nAe}{I}$

(B) $nAeI$

(C) $\dfrac{I}{nAe}$

(D) $\dfrac{Ie}{nA}$

Q3. A charged particle of charge q and mass m moves in a circular path in a uniform magnetic field B directed out of the page, as shown. The time period of its circular motion is:



(A) $\dfrac{2\pi m}{qB}$

(B) $\dfrac{2\pi qB}{m}$

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

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

Q4. The north pole of a bar magnet is moved towards a nearby closed conducting loop. By Lenz's law, the induced current in the loop flows:

(A) clockwise, so that the face towards the magnet becomes a south pole

(B) zero, because the magnet does not touch the loop

(C) in a direction that helps the magnet move closer

(D) anticlockwise (as seen from the magnet), so that the face towards the magnet becomes a north pole

Q5. An alternating current has a peak value I_0. Its root-mean-square (rms) value is:

(A) I_0

(B) $\frac{I_0}{\sqrt{2}}$

(C) $\sqrt{2}\,I_0$

(D) $\frac{I_0}{2}$

Q6. Which of the following statements is true for all electromagnetic waves travelling through vacuum?

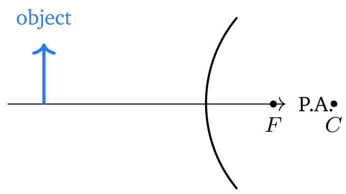
(A) They all travel with the same speed $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

(B) Their speed increases with frequency

(C) Longer wavelengths travel more slowly

(D) Their speed depends on the amplitude of the wave

Q7. An object is placed in front of a convex mirror, as shown. The image formed by a convex mirror is always:



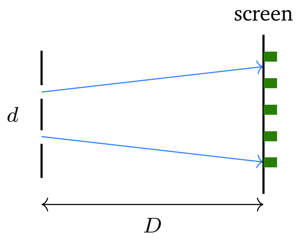
(A) real, inverted and magnified

(B) real, inverted and diminished

(C) virtual, erect and diminished

(D) virtual, erect and magnified

Q8. In Young's double-slit experiment, the separation of the slits and the wavelength are kept fixed. If the distance D of the screen from the slits is doubled, the fringe width β becomes:



(A) halved

(B) unchanged

(C) four times as large

(D) doubled

Q9. A particle moves with linear momentum p. The de Broglie wavelength associated with it is:

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

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

(C) hp

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

Q10. In the Bohr model of the hydrogen atom, the energy of the electron in the n-th level is proportional to:

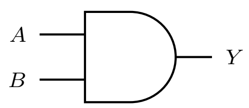
(A) $-n^2$

(B) $-\frac{1}{n^2}$

(C) $-\frac{1}{n}$

(D) $-n$

Q11. The logic gate whose symbol (a flat-backed D-shape with no output bubble) is shown below produces a HIGH output ($Y = 1$) only when *both* inputs are HIGH. This gate is a:



(A) NOR gate
(B) OR gate
(C) AND gate
(D) NAND gate

Q12. A capacitor of capacitance C is charged to a potential difference V and stores energy U. If the potential difference across it is now doubled (capacitance unchanged), the energy stored becomes:

(A) $\frac{U}{2}$
(B) $2U$
(C) U
(D) $4U$

Q13. **Assertion (A):** Two electric field lines can never intersect each other.
Reason (R): If they intersected, the electric field at the point of intersection would have two different directions, which is impossible.

(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):** Lenz's law is a consequence of the principle of conservation of energy.
Reason (R): The SI unit of magnetic flux is the weber.

(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):** Total internal reflection can occur only when light travels from a denser medium to a rarer medium.

Reason (R): For total internal reflection the angle of incidence must be *less* than the critical angle.

(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): There is a measurable time lag of a few seconds between the arrival of light and the emission of photoelectrons.
Reason (R): The maximum kinetic energy of photoelectrons is independent of the intensity of the incident light.

(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 capacitors of capacitance $4\,\mu$F and $6\,\mu$F are connected in parallel across a 12 V battery. Find the equivalent capacitance of the combination and the total charge drawn from the battery. **[2]**

Q18. A cell of emf 6 V is connected across an external resistance of $10\,\Omega$. The terminal voltage of the cell is found to be 5 V. Calculate the internal resistance of the cell. **[2]**

Q19. A metallic rod of length 0.2 m moves with a uniform velocity of 10 m/s at right angles to a uniform magnetic field of 0.5 T. Calculate the motional emf induced across the ends of the rod. **[2]**

OR

An ideal step-up transformer has 200 turns in the primary and 1000 turns in the secondary. If the current in the primary is 5 A, find the current in the secondary.

Q20. The speed of light in a certain transparent medium is 2×10^8 m/s. Find the refractive index of the medium. (Take $c = 3 \times 10^8$ m/s.) **[2]**

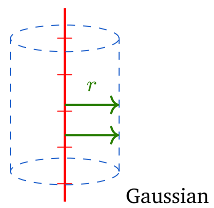
Q21. Calculate the energy (in joule and in eV) of a photon of light of frequency 5×10^{14} Hz. (Take $h = 6.63 \times 10^{-34}$ J s, 1 eV$= 1.6 \times 10^{-19}$ J.) **[2]**

OR

The half-life of a radioactive sample is 10 minutes. Calculate its decay constant λ.

Section C (Q22–Q28) – 3 Marks Each

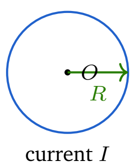
Q22. Using Gauss's law, derive an expression for the electric field at a perpendicular distance r from an infinitely long straight wire carrying a uniform linear charge density λ. Use a coaxial cylindrical Gaussian surface as shown.



[3]

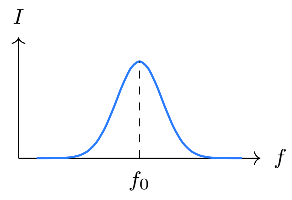
Q23. Explain, with the balance condition, how a potentiometer is used to compare the emfs of two cells. In an experiment, cell of emf ε_1 balances at a length of 300 cm and cell of emf ε_2 balances at 500 cm on the same potentiometer wire. If $\varepsilon_1 = 1.2$ V, find ε_2. **[3]**

Q24. Derive the expression for the magnetic field at the centre of a circular current loop of radius R carrying a current I. Hence find the field at the centre of a single circular loop of radius 0.1 m carrying a current of 2 A. (Take $\mu_0 = 4\pi \times 10^{-7}$ T m/A.)



[3]

Q25. Define resonance in a series LCR circuit. A series LCR circuit has $L = 0.5$ H and $C = 20\,\mu$F. Find its resonant frequency f_0. The resonance curve of current versus frequency is sketched below.

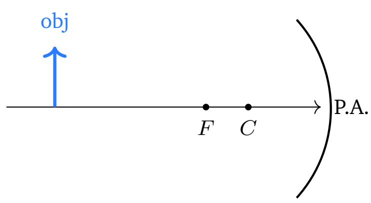


[3]

OR

Define the power factor of an AC circuit. A series RL circuit has resistance $R = 30\,\Omega$ and inductive reactance $X_L = 40\,\Omega$. Find the power factor of the circuit.

Q26. Draw a ray diagram to show the image formed by a concave mirror when the object is placed beyond the centre of curvature C. An object is placed 40 cm in front of a concave mirror of focal length 15 cm. Using the mirror formula, find the position of the image and its magnification.



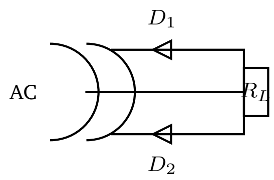
[3]

OR

Explain the dispersion of white light when it passes through a glass prism. Why does the violet colour deviate more than the red colour?

Q27. Using the Bohr model, calculate the wavelength of the photon emitted when the electron in a hydrogen atom makes a transition from the $n = 3$ level to the $n = 2$ level. Use $\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{9}\right)$ with the Rydberg constant $R = 1.097 \times 10^7\ \text{m}^{-1}$. **[3]**

Q28. With the help of a labelled circuit diagram, explain the working of a full-wave rectifier using two junction diodes and a centre-tapped transformer. Draw the output waveform.

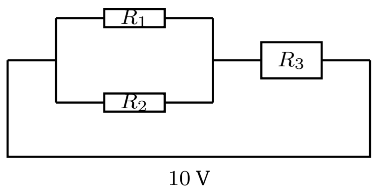


[3]

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

Q29. Case Study – A Resistor Network.

Two resistors $R_1 = 4\,\Omega$ and $R_2 = 4\,\Omega$ are connected in parallel. This parallel combination is then joined in series with a third resistor $R_3 = 3\,\Omega$, and the whole network is connected across a battery of emf 10 V (of negligible internal resistance), as shown.



Based on the above, answer the following:

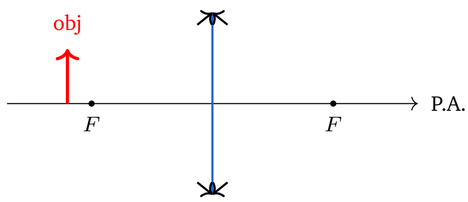
(i) Find the equivalent resistance of R_1 and R_2 in parallel. (1)

(ii) Find the total resistance of the network. (1)

(iii) Find the current drawn from the battery and the total power dissipated. (2)

Q30. Case Study – Image Formation by a Convex Lens.

A convex lens of focal length 20 cm is used to form the image of a small object placed on its principal axis at a distance of 30 cm from the lens, as shown.



Based on the above, answer the following:

(i) Write the lens formula relating v, u and f. (1)

(ii) Find the image distance v. (1)

(iii) Find the magnification and state the nature of the image. (2)

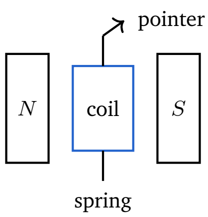
Section E (Q31–Q33) – 5 Marks Each

Q31. (a) Derive an expression for the electric field at a point on the equatorial line of an electric dipole at a distance r from its centre ($r \gg a$).
(b) A short dipole of dipole moment $p = 3\times10^{-9}$ C m is placed in vacuum. Find the magnitude of the electric field at a point on its equatorial line at a distance of 0.1 m from its centre. (Take $\dfrac{1}{4\pi\varepsilon_0} = 9\times10^{9}\ \mathrm{N\,m^2/C^2}$.) **[5]**

OR

(a) Three capacitors each of capacitance $3\,\mu$F are available. Two of them are joined in series and this series combination is joined in parallel with the third capacitor. Find the equivalent capacitance of the arrangement.
(b) This combination is connected across a 10 V battery. Calculate the total energy stored in it.

Q32. (a) With the help of a labelled diagram, explain the principle and working of a moving-coil galvanometer, and show that the deflection is proportional to the current.
(b) State one way of increasing the current sensitivity of a galvanometer.



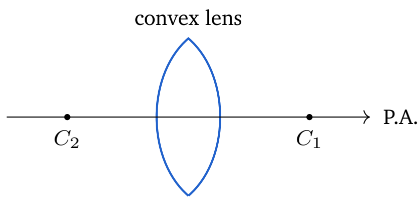
[5]

OR

(a) Explain the principle and working of a transformer, and derive the relation between the primary and secondary voltages of an ideal transformer.

(b) An ideal transformer has 100 turns in the primary and 400 turns in the secondary. If the primary is connected to a 220 V AC supply, find the secondary voltage.

Q33. (a) With the help of a ray diagram, derive the lens maker's formula for a thin convex lens.
(b) A thin biconvex lens is made of glass of refractive index 1.5; the radii of curvature of its two surfaces are 20 cm and 20 cm. Find its focal length.



[5]

OR

(a) Draw a labelled ray diagram of a compound microscope in normal adjustment and define its magnifying power.
(b) A compound microscope has an objective of focal length 2 cm and an eyepiece of focal length 5 cm. If the tube length is 20 cm and the least distance of distinct vision is 25 cm, estimate its magnifying power.

Detailed Solutions

Q1.

Solution

Concept — Field of a point charge: The electric field of a point charge is inversely proportional to the square of the distance, $E \propto \frac{1}{r^2}$.

Step 1 — Write the original field:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}.$$

Step 2 — Triple the distance: Replace r by $3r$:

$$E' = \frac{1}{4\pi\varepsilon_0}\frac{q}{(3r)^2}.$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{9r^2}.$$

$$= \frac{E}{9}.$$

Why other options are wrong: (A) $3E$ and (D) $9E$ assume the field grows with distance; (C) $\frac{E}{3}$ uses a $1/r$ dependence instead of $1/r^2$.

Final Answer: New field $= \frac{E}{9} \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept — Current and drift velocity: The steady current is $I = nAev_d$, where n is the free-electron density, A the area, e the electronic charge and v_d the drift velocity.

Step 1 — Write the current relation:

$$I = nAe\,v_d.$$

Step 2 — Solve for v_d:

$$v_d = \frac{I}{nAe}.$$

Why other options are wrong: (A) inverts the ratio; (B) multiplies instead of dividing; (D) misplaces e and drops A incorrectly.

Final Answer: $v_d = \dfrac{I}{nAe} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept — Time period in a magnetic field: The magnetic force provides the centripetal force, $qvB = \dfrac{mv^2}{r}$, and the time period is $T = \dfrac{2\pi r}{v}$.

Step 1 — Radius of the path:

$$qvB = \frac{mv^2}{r}.$$

$$r = \frac{mv}{qB}.$$

Step 2 — Time period:

$$T = \frac{2\pi r}{v} = \frac{2\pi}{v} \cdot \frac{mv}{qB}.$$

$$T = \frac{2\pi m}{qB}.$$

Step 3 — Observe: The speed v cancels, so T is independent of the particle's speed.

Why other options are wrong: (B) inverts the ratio; (C) still contains v, which cancels; (D) is the frequency, not the period.

Final Answer: $T = \dfrac{2\pi m}{qB} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q3

Q4.

Solution

Concept — Lenz's law: The induced current opposes the change that produces it; it flows so as to oppose the approaching magnet.

Step 1 — Identify the change: As the north pole approaches, the flux through the loop increases.

Step 2 — Apply Lenz's law: To oppose this increase, the face of the loop towards the magnet must become a *north* pole, so as to repel the incoming magnet.

Step 3 — Deduce the current direction: Making the near face a north pole requires the current, as seen from the side of the magnet, to flow *anticlockwise*.

Why other options are wrong: (A) a south near-face would attract, aiding the motion; (B) a changing flux does induce a current without contact; (C) aiding the motion violates conservation of energy.

Final Answer: Anticlockwise; near face becomes a north pole $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — RMS value of AC: The rms value is the square root of the mean of the square of the instantaneous current over one cycle.

Step 1 — Instantaneous current: For $i = I_0 \sin \omega t$, the mean of $\sin^2 \omega t$ over a full cycle is $\frac{1}{2}$.

Step 2 — Take the root of the mean square:

$$I_{rms} = \sqrt{\langle i^2 \rangle} = \sqrt{I_0^2 \cdot \frac{1}{2}}.$$

$$= \frac{I_0}{\sqrt{2}}.$$

Why other options are wrong: (A) I_0 is the peak value; (C) $\sqrt{2} I_0$ inverts the factor; (D) $\frac{I_0}{2}$ forgets the square root.

Final Answer: $I_{rms} = \frac{I_0}{\sqrt{2}} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q5

Q6.

Solution

Concept — Speed of EM waves in vacuum: All electromagnetic waves travel through vacuum with the same speed $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$, independent of frequency, wavelength or amplitude.

Step 1 — Recall Maxwell's result: From Maxwell's equations the speed of an EM wave in free space is

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ m/s}.$$

Step 2 — Conclusion: Since μ_0 and ε_0 are constants of free space, the speed is the same for radio waves, light, X-rays and gamma rays alike.

Why other options are wrong: (B),(C) the vacuum speed does not depend on frequency or wavelength; (D) it does not depend on amplitude.

Final Answer: Same speed $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q6

Q7.

Solution

Concept — Convex mirror imaging: A convex mirror is a diverging mirror; for any real object it forms a virtual, erect and diminished image located between the pole and the focus behind the mirror.

Step 1 — Trace the rays: Rays from the object diverge after reflection; their backward extensions meet behind the mirror.

Step 2 — Nature of the image: The image is therefore virtual (behind the mirror), erect and smaller than the object, whatever the object position.

Why other options are wrong: (A),(B) a convex mirror never forms a real image; (D) the image is diminished, not magnified.

Final Answer: Virtual, erect and diminished $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept — Fringe width: In Young's double-slit experiment $\beta = \frac{\lambda D}{d}$, so $\beta \propto D$ when λ and d are fixed.

Step 1 — Write the fringe width:

$$\beta = \frac{\lambda D}{d}.$$

Step 2 — Double the screen distance: Replace D by $2D$:

$$\beta' = \frac{\lambda(2D)}{d}.$$

$$= 2 \cdot \frac{\lambda D}{d} = 2\beta.$$

Why other options are wrong: (A) halving needs D halved; (B) β does depend on D; (C) four times would need D quadrupled.

Final Answer: Fringe width doubles $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q8

Q9.

Solution

Concept — de Broglie hypothesis: A moving particle behaves like a wave of wavelength $\lambda = \frac{h}{p}$, where p is its momentum.

Step 1 — Write the de Broglie relation:

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

Step 2 — Interpretation: The wavelength is inversely proportional to the momentum; a heavier or faster particle has a shorter wavelength.

Why other options are wrong: (B) inverts the ratio; (C) has the wrong dimensions; (D) inserts an incorrect factor of 2.

Final Answer: $\lambda = \frac{h}{p} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q9

Q10.

Solution

Concept — Bohr energy levels: The energy of the n-th level of hydrogen is $E_n = -\frac{13.6}{n^2}$ eV, so $E_n \propto -\frac{1}{n^2}$.

Step 1 — Recall the result: Combining the quantisation of angular momentum with the Coulomb force gives

$$E_n = -\frac{me^4}{8\varepsilon_0^2 h^2 n^2}.$$

Step 2 — Extract the dependence: All the factors except n^2 are constants, so

$$E_n \propto -\frac{1}{n^2}.$$

Why other options are wrong: (A),(D) energy does not grow with n; (C) the dependence is $1/n^2$, not $1/n$.

Final Answer: $E_n \propto -\frac{1}{n^2} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept — Logic gate symbols: A flat-backed D-shaped body with two inputs and *no* output bubble is the AND gate, whose output is $Y = A \cdot B$.

Step 1 — Read the symbol: Two inputs A and B enter a D-shaped body; the output has no inversion bubble.

Step 2 — Truth table check: The output is HIGH only when both inputs are HIGH:

$$Y = A \cdot B \;\Rightarrow\; Y = 1 \text{ only for } A = B = 1.$$

Why other options are wrong: (A) NOR and (D) NAND both carry an output bubble; (B) OR gives HIGH when *either* input is HIGH.

Final Answer: AND gate $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q11

Q12.

Solution

Concept — Energy stored in a capacitor: $U = \frac{1}{2}CV^2$, so at fixed C the energy is proportional to V^2.

Step 1 — Original energy:

$$U = \frac{1}{2}CV^2.$$

Step 2 — Double the voltage: Replace V by $2V$:

$$U' = \frac{1}{2}C(2V)^2.$$

$$= \frac{1}{2}C \cdot 4V^2.$$

$$= 4\left(\frac{1}{2}CV^2\right) = 4U.$$

Why other options are wrong: (A),(C) energy cannot fall or stay the same when V rises; (B) $2U$ ignores the squaring of V.

Final Answer: New energy $= 4U \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q12

Q13.

Solution

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

Step 1 — Assertion: Two electric field lines never cross. So A is **true**.

Step 2 — Reason: The tangent to a field line gives the direction of $\vec{E}$. If two lines crossed, the field at that point would have two directions at once, which is impossible. So R is **true**.

Step 3 — Does R explain A? The impossibility of two field directions at one point is exactly why lines cannot intersect, so R correctly explains A.

Why other options are wrong: (B) denies a real 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 — Assertion–Reason on Lenz's law: Judge each statement independently, then test the explanation.

Step 1 — Assertion: Lenz's law states the induced current opposes the change; the work done against this opposition appears as electrical (and then heat) energy, so the law follows from conservation of energy. So A is **true**.

Step 2 — Reason: The SI unit of magnetic flux is indeed the weber (Wb). So R is **true**.

Step 3 — Does R explain A? The name of the unit of flux has nothing to do with why Lenz's law conserves energy, so R does *not* explain A.

Why other options are wrong: (A) claims a false link; (C),(D) misjudge a truth value.

Final Answer: Both true, R not the explanation $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q14

Q15.

Solution

Concept — Total internal reflection (TIR): TIR needs light going from a denser to a rarer medium and an angle of incidence *greater* than the critical angle.

Step 1 — Assertion: TIR occurs only when light travels from a denser medium to a rarer medium. This is **true**.

Step 2 — Reason: The condition on the angle is $i > \theta_c$, not $i < \theta_c$. So R, which says the angle must be *less* than θ_c, is **false**.

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

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

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

Answer: (C) Go Back to Q15

Q16.

Solution

Concept — Photoelectric emission: Emission is essentially instantaneous (within about 10^{-9} s); the maximum kinetic energy depends on frequency, not intensity.

Step 1 — Assertion: The claim of a time lag of a *few seconds* is **false**; experiment shows the emission is instantaneous.

Step 2 — Reason: The maximum kinetic energy $K_{\max} = h\nu - W$ depends on frequency and work function, not on intensity. So R is **true**.

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

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

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

Answer: (D) **Go Back to Q16**

Q17.

Solution

Concept — Capacitors in parallel: In parallel, capacitances add directly, $C_p = C_1 + C_2$, and the charge is $Q = C_pV$.

Step 1 — Equivalent capacitance:

$$C_p = C_1 + C_2 = 4 + 6.$$

$$= 10\ \mu\text{F}.$$

Step 2 — Total charge at 12 V:

$$Q = C_pV = (10 \times 10^{-6})(12).$$

$$= 1.2 \times 10^{-4}\ \text{C} = 120\ \mu\text{C}.$$

Final Answer: $C_p = 10\,\mu$F; total charge $Q = 120\,\mu$C. **Go Back to Q17**

Q18.

Solution

Concept — Internal resistance: For a cell of emf ε and terminal voltage V on load, $r = \dfrac{\varepsilon - V}{I}$, where I is the current.

Step 1 — Current in the circuit: The terminal voltage drives the external resistance,

$$I = \frac{V}{R} = \frac{5}{10} = 0.5\ \text{A}.$$

Step 2 — Lost volts across r:

$$\varepsilon - V = 6 - 5 = 1\ \text{V}.$$

Step 3 — Internal resistance:

$$r = \frac{\varepsilon - V}{I} = \frac{1}{0.5}.$$

$$= 2\ \Omega.$$

Final Answer: Internal resistance $r = 2\,\Omega$. Go Back to Q18

Q19.

Solution

Concept — Motional emf: A rod of length l moving with speed v perpendicular to a field B develops an emf $\varepsilon = Blv$.

Step 1 — Substitute the values:

$$\varepsilon = Blv = (0.5)(0.2)(10).$$

Step 2 — Evaluate:

$$= (0.5)(0.2)(10) = 1\ \text{V}.$$

Final Answer: Motional emf $\varepsilon = 1$ V.

OR — Secondary current of an ideal transformer:

Step 1 — Ideal transformer relation: For an ideal transformer, power is conserved, so $I_p N_p = I_s N_s$, giving

$$\frac{I_s}{I_p} = \frac{N_p}{N_s}.$$

Step 2 — Substitute:

$$I_s = I_p \frac{N_p}{N_s} = 5 \times \frac{200}{1000} = 5 \times 0.2 = 1 \text{ A}.$$

Final Answer (OR): Secondary current $= 1$ A. Go Back to Q19

Q20.

Solution

Concept — Refractive index: The refractive index of a medium is the ratio of the speed of light in vacuum to the speed of light in the medium, $\mu = \frac{c}{v}$.

Step 1 — Write the definition:

$$\mu = \frac{c}{v}.$$

Step 2 — Substitute the values:

$$\mu = \frac{3 \times 10^8}{2 \times 10^8}.$$

$$= 1.5.$$

Final Answer: Refractive index $\mu = 1.5$. Go Back to Q20

Q21.

Solution

Concept — Energy of a photon: $E = h\nu$; to convert joule to eV, divide by 1.6×10^{-19}.

Step 1 — Energy in joule:

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

$$= 3.315 \times 10^{-19} \text{ J}.$$

Step 2 — Convert to eV:

$$E = \frac{3.315 \times 10^{-19}}{1.6 \times 10^{-19}}.$$

$$= 2.07 \text{ eV}.$$

Final Answer: $E \approx 3.32 \times 10^{-19}$ J ≈ 2.07 eV.

OR — Decay constant from half-life:

Step 1 — Relation: The decay constant is $\lambda = \frac{0.693}{T_{1/2}}$.

Step 2 — Substitute $T_{1/2} = 10$ **min**$= 600$ **s:**

$$\lambda = \frac{0.693}{600}.$$

$$= 1.155 \times 10^{-3}\ \text{s}^{-1}.$$

Final Answer (OR): $\lambda \approx 1.16 \times 10^{-3}$ s^{-1}. **Go Back to Q21**

Q22.

Solution

Concept — Gauss's law: The net flux through a closed surface is $\frac{q_{\text{enc}}}{\varepsilon_0}$.

Step 1 — Choose a Gaussian surface: Take a coaxial cylinder of radius r and length L around the wire. By symmetry $\vec{E}$ is radial and constant in magnitude over the curved surface.

Step 2 — Flux through the surface: The two flat ends contribute no flux (field parallel to them); only the curved surface contributes:

$$\oint \vec{E} \cdot d\vec{A} = E\,(2\pi r L).$$

Step 3 — Charge enclosed: For linear charge density λ,

$$q_{\text{enc}} = \lambda L.$$

Step 4 — Apply Gauss's law:

$$E\,(2\pi r L) = \frac{\lambda L}{\varepsilon_0}.$$

Step 5 — Solve for E:

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}.$$

Final Answer: $E = \frac{\lambda}{2\pi\varepsilon_0 r}$, directed radially; it falls off as $\frac{1}{r}$. **Go Back to Q22**

Q23.

Solution

Concept — Potentiometer: The potential drop along the wire is uniform, so the balancing length is proportional to the emf being balanced: $\frac{\varepsilon_1}{\varepsilon_2} = \frac{\ell_1}{\ell_2}$.

Step 1 — Balance condition: When a cell balances at length ℓ, its emf equals the potential drop across that length, $\varepsilon = k\ell$ (with k the potential gradient). Hence

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{\ell_1}{\ell_2}.$$

Step 2 — Substitute the lengths:

$$\frac{1.2}{\varepsilon_2} = \frac{300}{500}.$$

Step 3 — Solve for ε_2:

$$\varepsilon_2 = 1.2 \times \frac{500}{300}.$$

$$= 1.2 \times \frac{5}{3} = 2.0 \text{ V}.$$

Final Answer: $\varepsilon_2 = 2.0$ V. **Go Back to Q23**

Q24.

Solution

Concept — Biot–Savart law: Every current element $I\,d\vec{l}$ of the loop contributes a field at the centre; by symmetry all contributions add.

Step 1 — Field of one element: For an element at distance R from the centre, with $d\vec{l} \perp \hat{r}$,

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

Step 2 — Integrate around the loop: All dB point the same way, so

$$B = \frac{\mu_0 I}{4\pi R^2}\oint dl = \frac{\mu_0 I}{4\pi R^2}(2\pi R).$$

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

Step 3 — Numerical value: With $I = 2$ A, $R = 0.1$ m,

$$B = \frac{(4\pi \times 10^{-7})(2)}{2(0.1)}.$$

$$= \frac{8\pi \times 10^{-7}}{0.2} = 4\pi \times 10^{-6}.$$

$$= 1.26 \times 10^{-5} \text{ T}.$$

Final Answer: $B = \frac{\mu_0 I}{2R} \approx 1.26 \times 10^{-5}$ T. **Go Back to Q24**

Q25.

Solution

Concept — Resonance: A series LCR circuit is at resonance when $X_L = X_C$; the current is then maximum and the resonant frequency is $f_0 = \frac{1}{2\pi\sqrt{LC}}$.

Step 1 — Product LC:

$$LC = (0.5)(20 \times 10^{-6}).$$

$$= 1.0 \times 10^{-5} \text{ s}^2.$$

Step 2 — Square root:

$$\sqrt{LC} = \sqrt{1.0 \times 10^{-5}} = 3.16 \times 10^{-3} \text{ s}.$$

Step 3 — Resonant frequency:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi(3.16 \times 10^{-3})}.$$

$$= \frac{1}{1.99 \times 10^{-2}} \approx 50.3 \text{ Hz}.$$

Final Answer: $f_0 \approx 50$ Hz.

OR — Power factor of an RL circuit:

Step 1 — Definition: The power factor is $\cos\varphi = \frac{R}{Z}$, where Z is the impedance.

Step 2 — Impedance:

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

Step 3 — Power factor:

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

Final Answer (OR): Power factor $\cos\varphi = 0.6$. **Go Back to Q25**

Q26.

Solution

Concept — Concave mirror, object beyond C: The image is real, inverted and diminished, formed between F and C. Use the mirror formula $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ with the sign convention.

Step 1 — Assign values: For a concave mirror $f = -15$ cm; the object is real, $u = -40$ cm.

Step 2 — Mirror formula:

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-40}.$$

Step 3 — Common denominator (120):

$$\frac{1}{v} = -\frac{8}{120} + \frac{3}{120} = -\frac{5}{120}.$$

$$\frac{1}{v} = -\frac{1}{24}.$$

$$v = -24 \text{ cm}.$$

Step 4 — Magnification:

$$m = -\frac{v}{u} = -\frac{-24}{-40} = -0.6.$$

The image is real, inverted and diminished, 24 cm in front of the mirror.

Final Answer: $v = -24$ cm; $m = -0.6$ (real, inverted, diminished).

OR — Dispersion by a prism:

Step 1 — Cause: The refractive index of glass depends on the wavelength (colour) of light; it is largest for violet and smallest for red.

Step 2 — Deviation: Since the deviation $\delta = (\mu - 1)A$ increases with μ, violet (larger μ) deviates more than red (smaller μ). White light therefore splits into its component colours, red at the top and violet at the bottom.

Final Answer (OR): Different colours have different μ, so they deviate by different amounts; violet deviates most, red least. Go Back to Q26

Q27.

Solution

Concept — Balmer series: The wavelength of the $n = 3 \to 2$ line is given by $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$.

Step 1 — Evaluate the bracket:

$$\frac{1}{4} - \frac{1}{9} = \frac{9-4}{36} = \frac{5}{36}.$$

$$= 0.1389.$$

Step 2 — Reciprocal of wavelength:

$$\frac{1}{\lambda} = (1.097 \times 10^7)(0.1389).$$

$$= 1.524 \times 10^6 \text{ m}^{-1}.$$

Step 3 — Wavelength:

$$\lambda = \frac{1}{1.524 \times 10^6}.$$

$$= 6.56 \times 10^{-7} \text{ m} = 656 \text{ nm}.$$

Final Answer: $\lambda \approx 656$ nm (the red Hα line). Go Back to Q27

Q28.

Solution

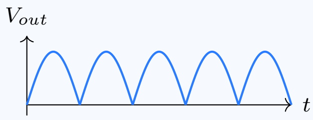
Concept — Full-wave rectifier: Two diodes fed by a centre-tapped transformer conduct on alternate half-cycles, so current flows through the load in the *same* direction during both halves of the AC input.

Step 1 — Circuit: The two ends of the secondary connect to diodes D_1 and D_2; the centre tap and the junction of the diodes are joined through the load R_L (as drawn).

Step 2 — Positive half-cycle: D_1 is forward biased and conducts while D_2 is reverse biased; current passes through R_L.

Step 3 — Negative half-cycle: Now D_2 is forward biased and conducts while D_1 is off; current again passes through R_L in the same direction.

Step 4 — Output waveform: Both half-cycles give output, so the output is a series of positive humps with no gaps.



Final Answer: A full-wave rectifier uses both half-cycles, giving a smoother pulsating DC output than a half-wave rectifier. **Go Back to Q28**

Q29.

Solution

Concept — Series and parallel resistors: Parallel resistances combine as $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$; series resistances add; power is $P = \frac{V^2}{R}$ or VI.

(i) Parallel combination of R_1 and R_2:

$$\frac{1}{R_p} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4} = \frac{1}{2}.$$

$$R_p = 2\ \Omega.$$

(ii) Total resistance (series with R_3):

$$R_{eq} = R_p + R_3 = 2 + 3 = 5\ \Omega.$$

(iii) Current and power:

$$I = \frac{V}{R_{eq}} = \frac{10}{5} = 2\ \text{A}.$$

$$P = VI = (10)(2) = 20\ \text{W}.$$

Final Answer: $R_p = 2\,\Omega$; $R_{eq} = 5\,\Omega$; $I = 2$ A; $P = 20$ W. **Go Back to Q29**

Q30.

Solution

Concept — Thin lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, with u negative for a real object; magnification $m = \frac{v}{u}$.

(i) Lens formula:

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

(ii) Image distance: With $u = -30$ cm, $f = +20$ cm,

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{-30}.$$

$$\frac{1}{v} = \frac{3}{60} - \frac{2}{60} = \frac{1}{60}.$$

$$v = +60 \text{ cm}.$$

(iii) Magnification and nature:

$$m = \frac{v}{u} = \frac{60}{-30} = -2.$$

The negative sign shows the image is inverted; $|m| = 2$ means it is twice the size of the object. Since v is positive, the image is real and formed on the far side of the lens.

Final Answer: $v = +60$ cm; $m = -2$ (real, inverted, magnified two times). **Go Back to Q30**

Q31.

Solution

Concept — Equatorial field of a dipole: On the equatorial line the components of the fields of $+q$ and $-q$ along the axis add while the perpendicular parts cancel, giving a net field antiparallel to $\vec{p}$ with magnitude $E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$ (for $r \gg a$).

(a) Derivation: Each charge is at distance $\sqrt{r^2 + a^2}$ from the point, giving field magnitude

$$E_+ = E_- = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r^2 + a^2)}.$$

The perpendicular components cancel; the components along the dipole axis add. Each contributes a factor $\cos\theta = \frac{a}{\sqrt{r^2 + a^2}}$:

$$E = 2E_+ \cos\theta = \frac{2q}{4\pi\varepsilon_0(r^2 + a^2)} \cdot \frac{a}{\sqrt{r^2 + a^2}}.$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q(2a)}{(r^2 + a^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2 + a^2)^{3/2}}.$$

For $r \gg a$, $(r^2 + a^2)^{3/2} \approx r^3$, so

$$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}.$$

(b) Numerical: With $p = 3 \times 10^{-9}$ C m, $r = 0.1$ m:

$$E = (9 \times 10^9)\frac{3 \times 10^{-9}}{(0.1)^3}.$$

$$= (9 \times 10^9)\frac{3 \times 10^{-9}}{10^{-3}}.$$

$$= (9 \times 10^9)(3 \times 10^{-6}) = 2.7 \times 10^4 \text{ N/C}.$$

Final Answer: $E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3} = 2.7 \times 10^4$ N/C.

OR — Capacitor combination and energy:

(a) Two $3\,\mu$F capacitors in series:

$$\frac{1}{C_s} = \frac{1}{3} + \frac{1}{3} = \frac{2}{3} \Rightarrow C_s = 1.5\ \mu\text{F}.$$

This in parallel with the third $3\,\mu$F capacitor:

$$C_{eq} = 1.5 + 3 = 4.5\ \mu\text{F}.$$

(b) Energy stored at $V = 10$ V:

$$U = \frac{1}{2}C_{eq}V^2 = \frac{1}{2}(4.5 \times 10^{-6})(10)^2.$$

$$= \frac{1}{2}(4.5 \times 10^{-6})(100) = 2.25 \times 10^{-4} \text{ J}.$$

Final Answer (OR): $C_{eq} = 4.5\,\mu$F; $U = 2.25 \times 10^{-4}$ J. Go Back to Q31

Q32.

Solution

Concept — Moving-coil galvanometer: A current-carrying coil in a radial magnetic field experiences a torque that is balanced by the restoring torque of a spring, so the steady deflection measures the current.

(a) Principle and working: A rectangular coil of N turns, area A, is suspended in a radial field B (produced by curved pole pieces and a soft-iron core), so that the plane of the coil is always parallel to B. When a current I flows, the deflecting torque is

$$\tau_{def} = NIAB.$$

The suspension provides a restoring torque proportional to the twist ϕ,

$$\tau_{rest} = k\phi.$$

At equilibrium the two are equal:

$$NIAB = k\phi.$$

$$\phi = \frac{NAB}{k} I.$$

Since N, A, B, k are constants, $\phi \propto I$; the deflection is directly proportional to the current, giving a linear scale.

(b) Increasing current sensitivity: Current sensitivity is $\frac{\phi}{I} = \frac{NAB}{k}$; it can be increased by using a larger number of turns N (or a stronger field B, larger area A, or a weaker suspension with smaller k).

Final Answer: $\phi = \frac{NAB}{k} I$, so $\phi \propto I$; increase N to raise current sensitivity.

OR — Transformer:

(a) A transformer works on mutual induction: an alternating current in the primary produces a changing flux that links the secondary through a common soft-iron core, inducing an emf in it. If the same flux ϕ links each turn, then for the primary and secondary

$$\varepsilon_p = -N_p \frac{d\phi}{dt}, \qquad \varepsilon_s = -N_s \frac{d\phi}{dt}.$$

Dividing,

$$\frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}.$$

For an ideal transformer $V_s/V_p = N_s/N_p$.

(b) With $N_p = 100$, $N_s = 400$, $V_p = 220$ V:

$$V_s = V_p \frac{N_s}{N_p} = 220 \times \frac{400}{100} = 220 \times 4 = 880 \text{ V}.$$

Final Answer (OR): $\frac{V_s}{V_p} = \frac{N_s}{N_p}$; $V_s = 880$ V (step-up). Go Back to Q32

Q33.

Solution

Concept — Lens maker's formula: Applying refraction at each of the two spherical surfaces of a thin lens and adding the results gives $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

(a) Derivation: For refraction at the first surface (radius R_1), forming an intermediate image at v_1,

$$\frac{\mu}{v_1} - \frac{1}{u} = \frac{\mu - 1}{R_1}.$$

This image acts as the object for the second surface (radius R_2), giving the final image at v,

$$\frac{1}{v} - \frac{\mu}{v_1} = \frac{1 - \mu}{R_2}.$$

Adding the two equations, the $\frac{\mu}{v_1}$ terms cancel:

$$\frac{1}{v} - \frac{1}{u} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right).$$

For an object at infinity, $v = f$, so

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right).$$

(b) Numerical: A biconvex lens has $R_1 = +20$ cm and $R_2 = -20$ cm, with $\mu = 1.5$:

$$\frac{1}{f} = (1.5 - 1)\left(\frac{1}{20} - \frac{1}{-20}\right).$$

$$= (0.5)\left(\frac{1}{20} + \frac{1}{20}\right).$$

$$= (0.5)\left(\frac{2}{20}\right) = (0.5)(0.1) = 0.05 \text{ cm}^{-1}.$$

$$f = \frac{1}{0.05} = 20 \text{ cm}.$$

Final Answer: $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$; $f = +20$ cm (converging).

OR — Compound microscope:

(a) In normal adjustment the final image forms at the least distance of distinct vision D. The magnifying power is the product of the linear magnification of the objective and the angular magnification of the eyepiece,

$$M = m_o m_e = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) \approx \frac{L}{f_o} \cdot \frac{D}{f_e}.$$

(b) With $f_o = 2$ cm, $f_e = 5$ cm, $L = 20$ cm, $D = 25$ cm:

$$M = \frac{L}{f_o} \cdot \frac{D}{f_e} = \frac{20}{2} \times \frac{25}{5}.$$

$$= 10 \times 5 = 50.$$

Final Answer (OR): $M = \frac{L}{f_o} \cdot \frac{D}{f_e} \approx 50.$ **Go Back to Q33**

Answer Key – Section A (Q1–Q16)

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

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