CBSE Class 12 Physics

Sample Paper – 10

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 E and the electric potential V in a region are related. For a field directed along the radial direction r, the correct relation is:

(A) $E = +\dfrac{dV}{dr}$

(B) $E = -\dfrac{dV}{dr}$

(C) $E = V\,r$

(D) $E = -\int V\,dr$

Q2. The drift velocity v_d of the free electrons in a conductor is related to their mobility μ and the applied electric field E by:

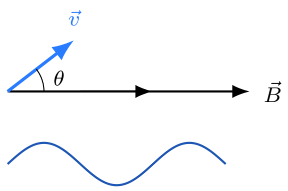
(A) $v_d = \dfrac{\mu}{E}$

(B) $v_d = \dfrac{E}{\mu}$

(C) $v_d = \mu E^2$

(D) $v_d = \mu E$

Q3. A charged particle (charge q, mass m) enters a uniform magnetic field B with speed v at an angle θ to the field, so it moves along a helix as shown. The pitch of the helix is:



(A) $\dfrac{2\pi m\, v\cos\theta}{qB}$

(B) $\dfrac{2\pi m\, v\sin\theta}{qB}$

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

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

Q4. During the growth of current in a circuit containing an inductor L and a resistor R in series, the time constant of the circuit is:

(A) LR

(B) $\dfrac{R}{L}$

(C) $\dfrac{L}{R}$

(D) $\dfrac{1}{LR}$

Q5. For a series resonant circuit of resonant angular frequency ω_0 and bandwidth $\Delta\omega$, the quality factor Q is:

(A) $\dfrac{\omega_0}{\Delta\omega}$

(B) $\dfrac{\Delta\omega}{\omega_0}$

(C) $\omega_0\,\Delta\omega$

(D) $\dfrac{1}{\omega_0\,\Delta\omega}$

Q6. Among the following electromagnetic radiations, the one having the *highest* frequency is:

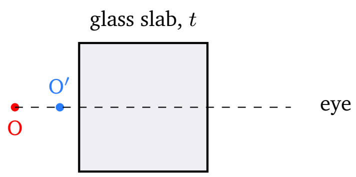
(A) Microwaves

(B) Infrared rays

(C) Visible light

(D) Ultraviolet rays

Q7. An object O is viewed normally through a glass slab of thickness t and refractive index μ, as shown. The apparent (normal) shift of the object towards the observer is:



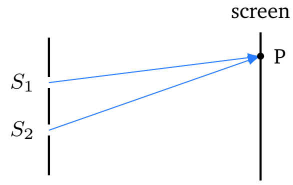
(A) $t\,(1-\mu)$

(B) $t\left(1-\dfrac{1}{\mu}\right)$

(C) $t\left(1+\dfrac{1}{\mu}\right)$

(D) $t\,\mu$

Q8. In Young's double-slit experiment, the point P on the screen is a *bright* fringe when the path difference between the two interfering waves equals ($n = 0, 1, 2, \dots$):



(A) $\left(n + \frac{1}{2}\right)\lambda$

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

(C) $n\lambda$

(D) $\frac{n\lambda}{2}$

Q9. An electron is accelerated from rest through a potential difference of 100 V. Using $\lambda = \frac{12.27}{\sqrt{V}}$ Å, its de Broglie wavelength is approximately:

(A) 12.27 Å

(B) 0.123 Å

(C) 122.7 Å

(D) 1.23 Å

Q10. In the radioactive decay ${}^{238}_{92}\text{U} \longrightarrow {}^{206}_{82}\text{Pb}$, the numbers of α and β^- particles emitted are, respectively:

(A) $8\,\alpha$ and $6\,\beta$

(B) $6\,\alpha$ and $8\,\beta$

(C) $8\,\alpha$ and $8\,\beta$

(D) $6\,\alpha$ and $6\,\beta$

Q11. The truth table shown below (inputs A, B; output Y) represents which logic gate?

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

(A) OR gate

(B) AND gate

(C) NAND gate

(D) NOR gate

Q12. Two capacitors of capacitance $2\,\mu$F and $4\,\mu$F are connected in series across a 12 V battery. The potential difference across the $2\,\mu$F capacitor is:

(A) 4 V

(B) 6 V

(C) 8 V

(D) 2 V

Q13. **Assertion (A):** Two electric field lines can never intersect each other.
Reason (R): The electric field has a unique direction at every point in space.

(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 inductor opposes any change in the current flowing through it.
Reason (R): An inductor stores energy in its magnetic field, given by $\frac{1}{2}LI^2$.

(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): The objective lens of an astronomical telescope is made of large aperture.

Reason (R): A large aperture increases the magnifying power of the telescope.

(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 an insulator the forbidden energy gap is very small (of the order of 0.1 eV).

Reason (R): In an insulator the electrons cannot easily jump from the valence band to the conduction band.

(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 $2\,\mu$F and $4\,\mu$F are connected across a 100 V supply. Find the energy stored by the combination when the capacitors are joined (a) in series and (b) in parallel. **[2]**

Q18. Two cells, each of emf 2 V and internal resistance $0.5\,\Omega$, are connected in series with an external resistance of $3\,\Omega$. Calculate the current in the circuit. **[2]**

Q19. A current of 2 A flows through an inductor of inductance 5 H. Calculate the energy stored in its magnetic field. **[2]**

OR

A series LC circuit has $L = 2$ H and $C = 8\,\mu$F. Find its resonant frequency f_0. (Take $\pi = 3.14$.)

Q20. A ray of light travels from air into a glass medium of refractive index 1.5, striking the surface at an angle of incidence of $30°$. Find the angle of refraction. (Take $\sin^{-1}(0.333) \approx 19.5°$.) **[2]**

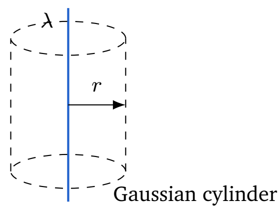
Q21. Light of wavelength 400 nm is incident on a metal of work function 2.0 eV. Find the maximum kinetic energy of the emitted photoelectrons (in eV). (Take $hc = 1240$ eV nm.) **[2]**

OR

A radioactive sample has a half-life of 10 years. What fraction of its nuclei will have *decayed* after 30 years?

Section C (Q22–Q28) – 3 Marks Each

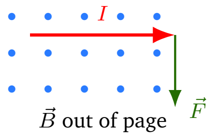
Q22. Using Gauss's law, derive an expression for the electric field at a distance r from the axis of an infinitely long, uniformly charged straight wire of linear charge density λ.



[3]

Q23. Four identical cells, each of emf 2 V and internal resistance $1\,\Omega$, are arranged in a mixed grouping of two parallel rows, each row containing two cells in series. This battery drives current through an external resistance of $3\,\Omega$. Find (a) the current in the circuit and (b) the terminal voltage of the battery. **[3]**

Q24. A straight wire of length 0.5 m carries a current of 4 A at right angles to a uniform magnetic field of 0.2 T directed out of the plane of the paper, as shown. Find the magnitude of the force on the wire and state its direction.



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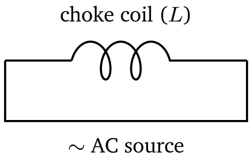
Q25. Explain, with the help of a diagram, why a choke coil is used to limit the current in an AC circuit with almost no power loss.

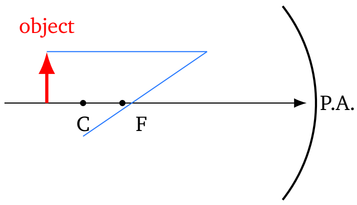


[3]

OR

Define the quality factor of a series resonant circuit and state how it decides the sharpness of resonance. A circuit has $L = 0.5$ H, $C = 2\,\mu$F and $R = 10\,\Omega$. Find its resonant angular frequency ω_0 and its quality factor Q.

Q26. Derive the mirror formula $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ for a concave mirror, using the ray diagram shown.



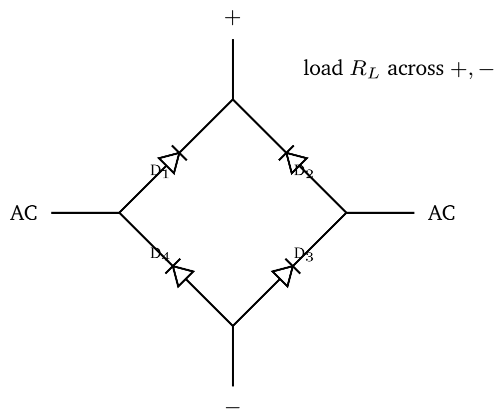
[3]

OR

Define refractive index in terms of real and apparent depth. A coin lies at the bottom of a beaker of water ($\mu = \frac{4}{3}$) at a real depth of 12 cm. Find its apparent depth and the apparent upward shift of the coin.

Q27. The work function of a metal is 2.0 eV. Find (a) the threshold wavelength for photoelectric emission and (b) the maximum kinetic energy of the photoelectrons when light of wavelength 400 nm falls on it. (Take $hc = 1240$ eV nm.) **[3]**

Q28. With the help of a labelled circuit diagram, explain the working of a full-wave bridge rectifier using four diodes, and draw the output waveform.



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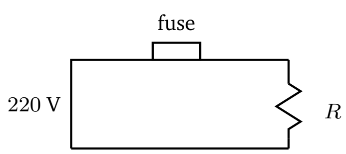
Section D (Q29–Q30) – 4 Marks Each (Case Study)

Q29. Case Study – Household Wiring and the Fuse.

A household mains supply of 220 V is connected to an electric heater of resistance $44\,\Omega$ through a fuse. The copper connecting wire has a free-electron density $n = 8.5 \times 10^{28}$ m^{-3} and a cross-sectional area $A = 1 \times 10^{-6}$ m^2.



Based on the above, answer the following:

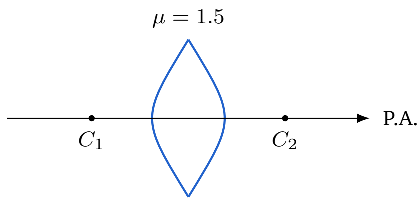
(i) Find the current drawn by the heater. (1)

(ii) State the function of a fuse in the circuit. (1)

(iii) Find the drift velocity of the electrons in the wire and the power dissipated in the heater. (2)

Q30. Case Study – The Lens Maker's Formula.

A biconvex lens is ground from glass of refractive index $\mu = 1.5$. Both faces are made spherical, each with a radius of curvature of magnitude 20 cm.



Based on the above, answer the following:

(i) Write the lens maker's formula relating f, μ, R_1 and R_2. (1)

(ii) State the signs of R_1 and R_2 for this biconvex lens by the sign convention. (1)

(iii) Calculate the focal length of the lens. (2)

Section E (Q31–Q33) – 5 Marks Each

Q31. (a) Establish the relation $E = -\dfrac{dV}{dr}$ between the electric field and the electric potential, and obtain the expression for the potential energy of an electric dipole placed at an angle θ in a uniform electric field.

(b) An electric dipole of moment $p = 2 \times 10^{-9}$ C m is placed in a uniform field $E = 1 \times 10^{5}$ N/C. Find its potential energy when it is aligned with the field and when it is perpendicular to it, and hence the work done in rotating it from 0° to 90°. **[5]**

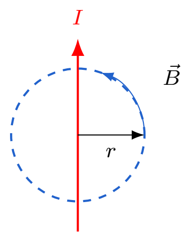
OR

(a) State and derive Joule's law of heating for a current-carrying resistor.

(b) A heater of resistance $44\,\Omega$ carries a current of 5 A for 2 minutes. Find the heat produced.

Q32. (a) Using Ampere's circuital law, derive the expression for the magnetic field at a distance r from a long straight wire carrying a steady current I.

(b) A long straight wire carries a current of 10 A. Find the magnetic field at a point 5 cm from the wire. (Take $\mu_0 = 4\pi \times 10^{-7}$ T m/A.)

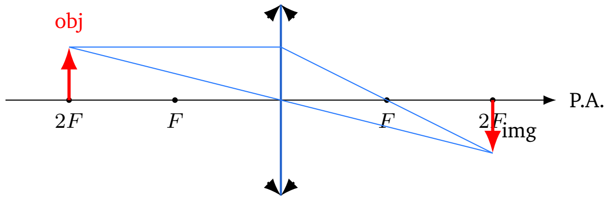


[5]

OR

(a) Explain the various energy losses in a transformer and how each is minimised, and define its efficiency.
(b) A transformer draws an input power of 1100 W and delivers an output power of 990 W. Find its efficiency.

Q33. (a) Draw a ray diagram for image formation by a convex lens and use it to derive the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, and define linear magnification.
(b) An object is placed 30 cm in front of a convex lens of focal length 20 cm. Find the position of the image and the magnification produced.



[5]

OR

(a) Draw the path of a ray through a triangular prism and derive the prism formula $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$.
(b) A prism of refracting angle $A = 60^\circ$ produces a minimum deviation of 30°. Find the refractive index of its material. (Take $\sin 45^\circ = 0.707$, $\sin 30^\circ = 0.5$.)

Detailed Solutions

Q1.

Solution

Concept — Field as the negative gradient of potential: The electric field points from high to low potential, so it equals the negative rate of change of V with distance.

Step 1 — Work-potential relation: The work done by the field in moving a unit charge through dr is

$$dW = E\,dr = -dV.$$

Step 2 — Solve for the field:

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

Why other options are wrong: (A) has the wrong sign, giving a field from low to high potential; (C) omits the gradient entirely; (D) integrates instead of differentiating.

Final Answer: $E = -\frac{dV}{dr} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept — Mobility: Mobility μ is defined as the drift speed acquired per unit electric field, so $\mu = \frac{v_d}{E}$.

Step 1 — Start from the definition:

$$\mu = \frac{v_d}{E}.$$

Step 2 — Rearrange for v_d:

$$v_d = \mu E.$$

Why other options are wrong: (A) and (B) invert the relation between v_d, μ and E; (C) wrongly makes v_d depend on E^2.

Final Answer: $v_d = \mu E \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q2

Q3.

Solution

Concept — Helical motion: The component $v\cos\theta$ along $\vec{B}$ is unaffected by the field, so the particle advances by this component in one revolution. The pitch is this parallel speed times the period.

Step 1 — Period of revolution: The perpendicular component gives circular motion with period

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

Step 2 — Parallel advance per turn (the pitch):

$$p = (v\cos\theta)\,T = \frac{2\pi m\,v\cos\theta}{qB}.$$

Why other options are wrong: (B) uses $\sin\theta$, which gives the radius factor, not the pitch; (C) drops the speed; (D) omits the $\cos\theta$ that selects the parallel component.

Final Answer: $p = \dfrac{2\pi m\,v\cos\theta}{qB} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q3

Q4.

Solution

Concept — LR growth of current: The current rises as $I = I_0\left(1 - e^{-t/\tau}\right)$, where τ is the time constant.

Step 1 — Identify the exponent: The exponent must be dimensionless, so τ has the dimension of time.

Step 2 — Time constant: Solving the LR loop equation gives

$$\tau = \frac{L}{R}.$$

Why other options are wrong: (A) LR and (B) R/L do not have the dimension of time; (D) $1/(LR)$ is dimensionally a rate, not a time.

Final Answer: $\tau = \dfrac{L}{R} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q4

Q5.

Solution

Concept — Quality factor: Q measures the sharpness of resonance and equals the resonant frequency divided by the bandwidth.

Step 1 — Definition:

$$Q = \frac{\omega_0}{\Delta\omega}.$$

Step 2 — Meaning: A larger Q means a narrower bandwidth $\Delta\omega$ and a sharper resonance peak.

Why other options are wrong: (B) inverts the ratio; (C) and (D) are dimensionally incorrect products.

Final Answer: $Q = \frac{\omega_0}{\Delta\omega} \Rightarrow \boxed{A}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept — Electromagnetic spectrum: In order of increasing frequency: microwave $<$ infrared $<$ visible $<$ ultraviolet.

Step 1 — Compare the options: Ultraviolet lies beyond the violet end of the visible band, so it has the shortest wavelength here.

Step 2 — Conclusion: Since frequency $\nu = c/\lambda$, the shortest wavelength gives the highest frequency, which is ultraviolet.

Why other options are wrong: (A) microwaves and (B) infrared have the lowest frequencies; (C) visible light is lower in frequency than ultraviolet.

Final Answer: Ultraviolet rays $\Rightarrow \boxed{D}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept — Normal shift through a slab: When viewed normally, an object seen through a slab of thickness t appears raised by $t\left(1 - \frac{1}{\mu}\right)$.

Step 1 — Apparent depth reduction: The slab makes the object appear at depth t/μ instead of t.

Step 2 — Net shift:

$$\text{shift} = t - \frac{t}{\mu} = t\left(1 - \frac{1}{\mu}\right).$$

Why other options are wrong: (A) uses μ instead of $1/\mu$; (C) adds instead of subtracts; (D) is not a shift at all.

Final Answer: $t\left(1 - \frac{1}{\mu}\right) \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q7

Q8.

Solution

Concept — Constructive interference: A bright fringe forms where the two waves arrive in phase, i.e. their path difference is a whole number of wavelengths.

Step 1 — Condition for a bright fringe:

$$\Delta x = n\lambda, \qquad n = 0, 1, 2, \ldots$$

Step 2 — Reason: An integer multiple of λ gives a phase difference of $2n\pi$, so the amplitudes add.

Why other options are wrong: (A) and (B) are the dark-fringe (destructive) conditions; (D) $\frac{n\lambda}{2}$ mixes bright and dark cases.

Final Answer: $\Delta x = n\lambda \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q8

Q9.

Solution

Concept — de Broglie wavelength of an accelerated electron: $\lambda = \frac{12.27}{\sqrt{V}}$ Å, with V in volts.

Step 1 — Substitute $V = 100$ V:

$$\lambda = \frac{12.27}{\sqrt{100}}.$$

Step 2 — Evaluate:

$$\lambda = \frac{12.27}{10} = 1.227\ \text{Å} \approx 1.23\ \text{Å}.$$

Why other options are wrong: (A) forgets to divide by $\sqrt{V}$; (B) and (C) misplace the decimal by a factor of ten.

Final Answer: $\lambda \approx 1.23\ \text{Å} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept — Counting α and β decays: Each α decay lowers A by 4 and Z by 2; each β^- decay raises Z by 1 and leaves A unchanged.

Step 1 — Number of α from the mass change:

$$n_\alpha = \frac{238 - 206}{4} = \frac{32}{4} = 8.$$

Step 2 — Charge after the α decays:

$$Z = 92 - 2(8) = 92 - 16 = 76.$$

Step 3 — Number of β to reach $Z = 82$:

$$n_\beta = 82 - 76 = 6.$$

Why other options are wrong: (B) swaps the two counts; (C) and (D) do not balance both A and Z.

Final Answer: $8\,\alpha$ and $6\,\beta \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept — Reading a truth table: Identify the gate by the input combination that makes $Y = 1$.

Step 1 — Inspect the table: The output is 1 only for the row $A = 1,\ B = 1$; every other combination gives 0.

Step 2 — Match to a gate: An output that is high only when *both* inputs are high is the AND operation, $Y = A \cdot B$.

Why other options are wrong: (A) OR would give 1 for 01 and 10; (C) NAND and (D) NOR would give 1 for the 00 input, contradicting the table.

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

Answer: (B) Go Back to Q11

Q12.

Solution

Concept — Series capacitors: In series the charge Q is the same on each capacitor, so the voltage across a capacitor is $V = Q/C$; the smaller capacitor takes the larger voltage.

Step 1 — Equivalent capacitance:

$$C_{eq} = \frac{2 \times 4}{2 + 4} = \frac{8}{6} = \frac{4}{3}\ \mu\text{F}.$$

Step 2 — Common charge:

$$Q = C_{eq}V = \frac{4}{3} \times 12 = 16\ \mu\text{C}.$$

Step 3 — Voltage across the $2\,\mu$F:

$$V_1 = \frac{Q}{C_1} = \frac{16}{2} = 8\ \text{V}.$$

Why other options are wrong: (A) 4 V is the drop across the $4\,\mu$F; (B) and (D) do not satisfy $V_1 + V_2 = 12$ V with equal charge.

Final Answer: $V_1 = 8\ \text{V} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q12

Q13.

Solution

Concept — Uniqueness of field direction: The tangent to a field line gives the direction of $\vec{E}$ at that point.

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

Step 2 — Reason: At any point the electric field has a single, well-defined direction. So R is **true**.

Step 3 — Does R explain A? If two lines crossed, the field would have two directions at the crossing point, which is impossible; so the unique direction is exactly why lines cannot intersect. R correctly explains A.

Why other options are wrong: (B) denies the 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 — Why an inductor opposes change: The opposition comes from the self-induced back-emf $\varepsilon = -L\dfrac{dI}{dt}$, which by Lenz's law resists the change.

Step 1 — Assertion: An inductor opposes any change in current. So A is **true**.

Step 2 — Reason: An inductor does store energy $\dfrac{1}{2}LI^2$ in its magnetic field. So R is **true**.

Step 3 — Does R explain A? The opposition is caused by the induced back-emf, not by the fact that energy is stored. The energy statement is true but is not the reason for the opposition, so R does *not* correctly explain A.

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

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

Answer: (B) Go Back to Q14

Q15.

Solution

Concept — Role of the objective aperture: A large aperture collects more light and improves the resolving power; it does *not* change the magnifying power, which is $m = f_o/f_e$.

Step 1 — Assertion: A telescope objective is made with a large aperture. So A is **true**.

Step 2 — Reason: "A large aperture increases the magnifying power" is **false**; magnifying power depends only on the focal lengths, not on the aperture.

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 Q15

Q16.

Solution

Concept — Band gap of an insulator: An insulator has a *large* forbidden gap (typically several eV), which is why electrons cannot cross into the conduction band.

Step 1 — Assertion: "The forbidden energy gap is very small (~ 0.1 eV)" is **false**; for an insulator the gap is large (> 3 eV).

Step 2 — Reason: It is **true** that in an insulator electrons cannot easily jump from the valence band to the conduction band.

Step 3 — Combine: A is false but 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 — Stored energy: $U = \frac{1}{2}CV^2$; series and parallel give different equivalent capacitances at the same voltage.

Step 1 — Series capacitance:

$$C_s = \frac{2 \times 4}{2+4} = \frac{8}{6} = \frac{4}{3}\ \mu\text{F} = 1.33 \times 10^{-6}\ \text{F}.$$

Step 2 — Energy in series:

$$U_s = \frac{1}{2}C_sV^2 = \frac{1}{2}(1.33 \times 10^{-6})(100)^2.$$

$$= \frac{1}{2}(1.33 \times 10^{-6})(10^4) = 6.67 \times 10^{-3}\ \text{J}.$$

Step 3 — Parallel capacitance and energy:

$$C_p = 2 + 4 = 6\ \mu\text{F} = 6 \times 10^{-6}\ \text{F}.$$

$$U_p = \frac{1}{2}(6 \times 10^{-6})(10^4) = 3.0 \times 10^{-2}\ \text{J}.$$

Final Answer: $U_s \approx 6.67 \times 10^{-3}$ J (series); $U_p = 3.0 \times 10^{-2}$ J (parallel). **Go Back to Q17**

Q18.

Solution

Concept — Cells in series: The emfs add and the internal resistances add, so $I = \frac{\sum \varepsilon}{R + \sum r}$.

Step 1 — Total emf:

$$\varepsilon_{\text{net}} = 2 + 2 = 4\ \text{V}.$$

Step 2 — Total internal resistance:

$$r_{\text{net}} = 0.5 + 0.5 = 1\ \Omega.$$

Step 3 — Current:

$$I = \frac{4}{3+1} = \frac{4}{4} = 1\ \text{A}.$$

Final Answer: Current $= 1$ A. Go Back to Q18

Q19.

Solution

Concept — Energy in an inductor: $U = \frac{1}{2}LI^2$.

Step 1 — Substitute the values:

$$U = \frac{1}{2}(5)(2)^2.$$

Step 2 — Evaluate:

$$U = \frac{1}{2}(5)(4) = 10 \text{ J}.$$

Final Answer: Energy stored $= 10$ J.

OR — Resonant frequency:

Step 1 — Formula: $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$.

Step 2 — Compute $\sqrt{LC}$**:**

$$\sqrt{LC} = \sqrt{(2)(8 \times 10^{-6})} = \sqrt{1.6 \times 10^{-5}} = 4 \times 10^{-3}.$$

Step 3 — Substitute:

$$f_0 = \frac{1}{2(3.14)(4 \times 10^{-3})} = \frac{1}{2.512 \times 10^{-2}} \approx 39.8 \text{ Hz}.$$

Final Answer (OR): $f_0 \approx 39.8$ Hz. Go Back to Q19

Q20.

Solution

Concept — Snell's law: $\mu_1 \sin i = \mu_2 \sin r$, here $1 \cdot \sin i = \mu \sin r$.

Step 1 — Write Snell's law:

$$\sin i = \mu \sin r.$$

Step 2 — Solve for $\sin r$**:**

$$\sin r = \frac{\sin i}{\mu} = \frac{\sin 30^\circ}{1.5} = \frac{0.5}{1.5} = 0.333.$$

Step 3 — Take the inverse sine:

$$r = \sin^{-1}(0.333) \approx 19.5^\circ.$$

Final Answer: Angle of refraction $\approx 19.5^\circ$. **Go Back to Q20**

Q21.

Solution

Concept — Photoelectric equation: $K_{\max} = \dfrac{hc}{\lambda} - W$.

Step 1 — Photon energy:

$$E = \frac{hc}{\lambda} = \frac{1240\ \text{eV nm}}{400\ \text{nm}} = 3.1\ \text{eV}.$$

Step 2 — Subtract the work function:

$$K_{\max} = 3.1 - 2.0 = 1.1\ \text{eV}.$$

Final Answer: $K_{\max} = 1.1$ eV.

OR — Fraction decayed after 30 **years:**

Step 1 — Number of half-lives: $\dfrac{30}{10} = 3$.

Step 2 — Fraction remaining:

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

Step 3 — Fraction decayed:

$$1 - \frac{1}{8} = \frac{7}{8}.$$

Final Answer (OR): A fraction $\dfrac{7}{8}$ has decayed. **Go Back to Q21**

Q22.

Solution

Concept — Gauss's law with cylindrical symmetry: For a line charge the field is radial, so a coaxial cylinder is the natural Gaussian surface.

Step 1 — Choose the surface: Take a coaxial cylinder of radius r and length l. The field $\vec{E}$ is radial and has the same magnitude over its curved surface.

Step 2 — Flux through it: The flat ends contribute nothing (field is parallel to them), so

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

Step 3 — Charge enclosed:

$$q_{\text{enc}} = \lambda\,l.$$

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: $E = \dfrac{\lambda}{2\pi\varepsilon_0 r}$, directed radially, falling off as $1/r$. **Go Back to Q22**

Q23.

Solution

Concept — Mixed grouping of cells: Add cells in a row like a series battery, then combine identical rows in parallel.

Step 1 — One row (two cells in series):

$$\varepsilon_{\text{row}} = 2 + 2 = 4\ \text{V}, \qquad r_{\text{row}} = 1 + 1 = 2\ \Omega.$$

Step 2 — Two identical rows in parallel:

$$\varepsilon = 4\ \text{V}, \qquad r_{\text{int}} = \frac{2}{2} = 1\ \Omega.$$

Step 3 — Current in the circuit:

$$I = \frac{\varepsilon}{R + r_{\text{int}}} = \frac{4}{3+1} = 1\ \text{A}.$$

Step 4 — Terminal voltage:

$$V = I\,R = 1 \times 3 = 3\ \text{V}.$$

Final Answer: $I = 1$ A; terminal voltage $= 3$ V. **Go Back to Q23**

Q24.

Solution

Concept — Force on a current element: $\vec{F} = I\,\vec{L}\times\vec{B}$, magnitude $F = BIL\sin\theta$.

Step 1 — Note the geometry: The current is perpendicular to $\vec{B}$, so $\theta = 90^\circ$ and $\sin\theta = 1$.

Step 2 — Magnitude:

$$F = BIL\sin\theta = (0.2)(4)(0.5)(1).$$

$$= 0.4\ \text{N}.$$

Step 3 — Direction: With the current to the right ($+x$) and $\vec{B}$ out of the page ($+z$), $\vec{L}\times\vec{B}$ points in $-y$, i.e. vertically downward (as shown).

Final Answer: $F = 0.4$ N, directed downward in the plane of the page. **Go Back to Q24**

Q25.

Solution

Concept — Choke coil: A choke is an inductor of large L and negligible resistance used to limit AC current.

Step 1 — How it limits current: In AC it offers a large inductive reactance $X_L = \omega L$, so the current $I = \dfrac{V}{\sqrt{R^2 + X_L^2}}$ is kept small.

Step 2 — Why the power loss is small: The average power is $P = V_{rms}I_{rms}\cos\phi$. For a nearly pure inductor $\phi \approx 90^\circ$, so $\cos\phi \approx 0$ and very little power is dissipated.

Step 3 — Contrast with a resistor: A resistor would also limit current, but it wastes energy as heat (I^2R); a choke does not, which is its advantage.

Final Answer: A choke limits AC current through $X_L = \omega L$ while dissipating almost no power because $\cos\phi \approx 0$.

OR — Quality factor and ω_0:

Step 1 — Definition: $Q = \dfrac{\omega_0 L}{R} = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$; a larger Q gives a sharper (narrower) resonance.

Step 2 — Resonant angular frequency:

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(0.5)(2\times10^{-6})}} = \frac{1}{\sqrt{1\times10^{-6}}} = 10^3\ \text{rad/s}.$$

Step 3 — Quality factor:

$$Q = \frac{\omega_0 L}{R} = \frac{(10^3)(0.5)}{10} = 50.$$

Final Answer (OR): $\omega_0 = 1000$ rad/s, $Q = 50$. **Go Back to Q25**

Q26.

Solution

Concept — Mirror formula by similar triangles: Using the pole P, focus F and centre C, similar triangles relate object and image distances.

Step 1 — Set up the rays: A ray parallel to the axis reflects through F; a ray to the pole reflects symmetrically. Their intersection locates the image.

Step 2 — Similar triangles: From the geometry of the reflected rays,

$$\frac{\text{image size}}{\text{object size}} = \frac{PF - v}{PF} \quad \text{and} \quad = \frac{v}{u}.$$

Step 3 — Combine and use the sign convention: Eliminating the heights and substituting $PF = f$ gives

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

Final Answer: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ (mirror formula for the concave mirror).

OR — Real and apparent depth:

Step 1 — Definition: $\mu = \frac{\text{real depth}}{\text{apparent depth}}$.

Step 2 — Apparent depth:

$$\text{apparent depth} = \frac{\text{real depth}}{\mu} = \frac{12}{4/3} = 12 \times \frac{3}{4} = 9 \text{ cm}.$$

Step 3 — Apparent shift:

$$\text{shift} = 12 - 9 = 3 \text{ cm}.$$

Final Answer (OR): Apparent depth $= 9$ cm; the coin appears raised by 3 cm. **Go Back to Q26**

Q27.

Solution

Concept — Threshold and Einstein's equation: $\lambda_0 = \frac{hc}{W}$ and $K_{\max} = \frac{hc}{\lambda} - W$.

Step 1 — Threshold wavelength:

$$\lambda_0 = \frac{hc}{W} = \frac{1240 \text{ eV nm}}{2.0 \text{ eV}} = 620 \text{ nm}.$$

Step 2 — Photon energy for $\lambda = 400$ nm:

$$E = \frac{hc}{\lambda} = \frac{1240}{400} = 3.1 \text{ eV}.$$

Step 3 — Maximum kinetic energy:

$$K_{\max} = E - W = 3.1 - 2.0 = 1.1 \text{ eV}.$$

Final Answer: $\lambda_0 = 620$ nm and $K_{\max} = 1.1$ eV. **Go Back to Q27**

Q28.

Solution

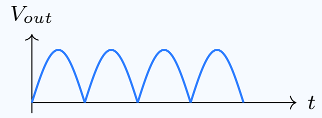
Concept — Full-wave bridge rectifier: Four diodes are arranged so that the load current flows in the same direction during *both* halves of the AC cycle.

Step 1 — Circuit: The AC input is applied to one pair of opposite corners; the load R_L is connected across the other pair, the $+$ and $-$ output nodes.

Step 2 — Positive half-cycle: Diodes D_1 and D_3 are forward biased and conduct, so current passes through R_L from $+$ to $-$.

Step 3 — Negative half-cycle: Now D_2 and D_4 conduct, and the current through R_L is again from $+$ to $-$, i.e. in the same direction as before.

Step 4 — Output waveform: Both halves appear as positive humps, so the output is a pulsating DC with no gaps.



Final Answer: Both half-cycles drive current the same way through R_L, giving a full-wave pulsating DC output. **Go Back to Q28**

Q29.

Solution

Concept — Household circuit: Use $I = V/R$, the fuse as a safety device, $v_d = I/(nAe)$ and $P = I^2R$.

(i) Current drawn:

$$I = \frac{V}{R} = \frac{220}{44} = 5 \text{ A}.$$

(ii) Function of the fuse: The fuse is a thin wire of low melting point placed in series; if the current exceeds its rated value it heats up and melts, breaking the circuit and protecting the wiring and appliances.

(iii) Drift velocity and power:

$$v_d = \frac{I}{nAe} = \frac{5}{(8.5 \times 10^{28})(1 \times 10^{-6})(1.6 \times 10^{-19})}.$$

$$= \frac{5}{1.36 \times 10^4} = 3.68 \times 10^{-4} \text{ m/s}.$$

$$P = I^2R = (5)^2(44) = 25 \times 44 = 1100 \text{ W}.$$

Final Answer: $I = 5$ A; the fuse melts on excess current; $v_d \approx 3.68 \times 10^{-4}$ m/s; $P = 1100$ W. **Go Back to Q29**

Q30.

Solution

Concept — Lens maker's formula: $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

(i) Formula:

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

(ii) Signs for a biconvex lens: Light meets the first surface (centre on the right) so $R_1 = +20$ cm; the second surface has its centre on the left so $R_2 = -20$ cm.

(iii) Focal length:

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

$$= (0.5)\left(\frac{1}{20} + \frac{1}{20}\right) = (0.5)\left(\frac{2}{20}\right).$$

$$= (0.5)(0.1) = 0.05 \text{ cm}^{-1}.$$

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

Final Answer: $R_1 = +20$ cm, $R_2 = -20$ cm; focal length $f = 20$ cm. Go Back to Q30

Q31.

Solution

Concept — Field-potential relation and dipole energy: $E = -\frac{dV}{dr}$; the dipole energy is $U = -\vec{p} \cdot \vec{E} = -pE\cos\theta$.

(a) Relation $E = -dV/dr$**:** The work done by the field on a unit charge over dr equals the drop in potential:

$$E\,dr = -dV \;\Rightarrow\; E = -\frac{dV}{dr}.$$

Dipole potential energy: The torque on the dipole is $\tau = pE\sin\theta$; the work to rotate it from $90°$ to θ is

$$U = \int_{90°}^{\theta} pE\sin\theta'\,d\theta' = -pE\cos\theta.$$

(b) Numerical values: With $p = 2 \times 10^{-9}$ C m and $E = 1 \times 10^5$ N/C:

$$U(0°) = -pE\cos 0° = -(2 \times 10^{-9})(1 \times 10^5)(1) = -2 \times 10^{-4} \text{ J}.$$

$$U(90°) = -pE\cos 90° = 0.$$

Work done in rotating $0° \to 90°$**:**

$$W = U(90°) - U(0°) = 0 - (-2 \times 10^{-4}) = 2 \times 10^{-4} \text{ J}.$$

Final Answer: $U(0°) = -2 \times 10^{-4}$ J, $U(90°) = 0$; work $= 2 \times 10^{-4}$ J.

OR — Joule's law of heating:

(a) The work done in time t by a source driving current I through resistance R at potential difference $V = IR$ is

$$W = VIt = (IR)It = I^2Rt.$$

This heat is $H = I^2Rt$ (Joule's law): the heat is proportional to I^2, to R and to t.

(b) With $I = 5$ A, $R = 44\,\Omega$, $t = 2$ min $= 120$ s:

$$H = I^2Rt = (5)^2(44)(120) = 25 \times 44 \times 120.$$

$$= 1.32 \times 10^5 \text{ J}.$$

Final Answer (OR): $H = I^2Rt = 1.32 \times 10^5$ J. **Go Back to Q31**

Q32.

Solution

Concept — Ampere's circuital law: $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}}$, applied on a circular loop around the wire.

(a) Derivation: By symmetry $\vec{B}$ is tangential and constant on a circle of radius r around the wire. Taking such a loop,

$$\oint \vec{B} \cdot d\vec{l} = B\,(2\pi r).$$

The current enclosed is I, so

$$B\,(2\pi r) = \mu_0 I.$$

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

(b) Numerical: With $I = 10$ A and $r = 5$ cm$= 0.05$ m:

$$B = \frac{(4\pi \times 10^{-7})(10)}{2\pi(0.05)}.$$

$$= \frac{(2 \times 10^{-7})(10)}{0.05} = \frac{2 \times 10^{-6}}{0.05}.$$

$$= 4 \times 10^{-5} \text{ T}.$$

Final Answer: $B = \dfrac{\mu_0 I}{2\pi r} = 4 \times 10^{-5}$ T.

OR — Transformer losses and efficiency:

(a) Energy losses: (i) *copper loss* — I^2R heating in the windings, reduced by using thick low-resistance wire; (ii) *iron/eddy-current loss* — reduced by using a laminated core; (iii) *hysteresis loss* — reduced by using a soft-iron core of low hysteresis; (iv) *flux leakage* — reduced by winding the coils over one another on the same core. Efficiency $\eta = \dfrac{\text{output power}}{\text{input power}}$.

(b) With input 1100 W and output 990 W:

$$\eta = \frac{990}{1100} = 0.9 = 90\%.$$

Final Answer (OR): $\eta = 90\%$. **Go Back to Q32**

Q33.

Solution

Concept — Lens formula from similar triangles: A parallel ray and a ray through the optical centre locate the image; similar triangles give the relation.

(a) Derivation: For a convex lens with the object beyond $2F$, a ray parallel to the axis refracts through F, and a ray through the optical centre goes straight. From the two pairs of similar triangles and the sign convention,

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

Linear magnification is $m = \frac{\text{image height}}{\text{object height}} = \frac{v}{u}$.

(b) Numerical: $u = -30$ cm, $f = +20$ cm.

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

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

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

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

The image is real, inverted and magnified two times.

Final Answer: $v = +60$ cm, $m = -2$ (real, inverted, magnified).

OR — Prism formula:

(a) For a ray through a prism, $A + \delta = i + e$ and $r_1 + r_2 = A$. At minimum deviation $i = e$ and $r_1 = r_2 = A/2$, so $i = \frac{A + \delta_m}{2}$. Snell's law at the first face gives

$$\mu = \frac{\sin i}{\sin r_1} = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}.$$

(b) With $A = 60°$ and $\delta_m = 30°$:

$$\mu = \frac{\sin\left(\frac{60° + 30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)} = \frac{\sin 45°}{\sin 30°} = \frac{0.707}{0.5}.$$

$$= 1.414.$$

Final Answer (OR): $\mu \approx 1.41$. **Go Back to Q33**

Answer Key – Section A (Q1–Q16)

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	D	3	A	4	C	5	A
6	D	7	B	8	C	9	D	10	A
11	B	12	C	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.