# CBSE Class 12 Physics

## Sample Paper – 6

**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 magnitude of the electric field on the axis of a short electric dipole, at a distance $r$ from its centre, varies with $r$ as:

(A) $\frac{1}{r}$

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

(C) $\frac{1}{r^3}$

(D) $\frac{1}{r^4}$

**Q2.** A resistor connected across a fixed voltage supply $V$ dissipates power $P = \frac{V^2}{R}$. If its resistance is reduced to half its original value, the power dissipated becomes:

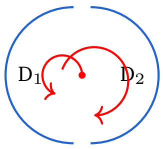
(A) half of $P$

(B) twice $P$

(C) unchanged

(D) four times $P$

**Q3.** In a cyclotron, a particle of charge $q$ and mass $m$ moves in a uniform magnetic field $B$ between two dees, as shown. Its cyclotron frequency is:




$B$ perpendicular to plane

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

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

(C) $\frac{qmB}{2\pi}$

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

**Q4.** The magnetic flux through a coil of resistance $R$ changes by an amount $\Delta\phi$. The total charge that flows through the coil during this change is:

(A) $\Delta\phi\, R$

(B) $\frac{\Delta\phi}{R}$

(C) $\frac{R}{\Delta\phi}$

(D) $\frac{\Delta\phi^2}{R}$

**Q5.** In an AC circuit, the component of current that is $90^\circ$ out of phase with the applied voltage and consumes no average power over a complete cycle is called the:

(A) active current

(B) direct current

(C) peak current

(D) wattless (reactive) current

**Q6.** During the charging of a parallel-plate capacitor, the quantity that flows in the region between the plates and maintains the continuity of Ampère's circuital law is the:

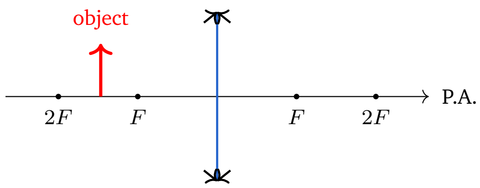
(A) conduction current

(B) eddy current

(C) displacement current

(D) drift current

**Q7.** An object is placed between $F$ and $2F$ of a thin convex lens, as shown. The image formed is:



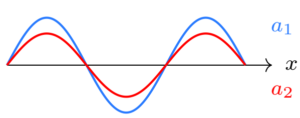

(A) real, inverted, magnified and beyond $2F$

(B) real, inverted, diminished and between $F$ and $2F$

(C) virtual, erect and magnified

(D) real, inverted and of the same size at $2F$

**Q8.** Two coherent light waves have amplitudes in the ratio $3 : 2$, as sketched below. The ratio of their intensities is:



(A) $3 : 2$

(B) $6 : 4$

(C) $4 : 9$

(D) $9 : 4$

**Q9.** The work function of a metal surface is $W$. The threshold wavelength $\lambda_0$ for photoelectric emission is given by:

(A) $\dfrac{hc}{W}$

(B) $\dfrac{W}{hc}$

(C) $\dfrac{hW}{c}$

(D) $\dfrac{c}{hW}$

**Q10.** Two nuclei have mass numbers $27$ and $64$. Using $R = R_0 A^{1/3}$, the ratio of their nuclear radii $R_1 : R_2$ is:

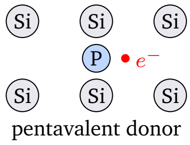
(A) $27 : 64$

(B) $9 : 16$

(C) $3 : 4$

(D) $4 : 3$

**Q11.** The figure shows a silicon crystal doped with a pentavalent (donor) impurity. In this n-type semiconductor, the majority charge carriers are:




(A) holes

(B) protons

(C) electrons

(D) positive ions

**Q12.** The energy stored per unit volume (energy density) in a region of vacuum where the electric field is $E$ is given by:

(A) $\varepsilon_0 E^2$

(B) $\frac{1}{2}\varepsilon_0 E^2$

(C) $\frac{1}{2}\varepsilon_0 E$

(D) $\frac{1}{2}\varepsilon_0^2 E$

**Q13. Assertion (A):** The terminal potential difference of a cell is always equal to its emf.

**Reason (R):** When a cell drives a current through an external circuit, a part of its emf is dropped across the internal resistance of the cell.

(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):** Magnetic field lines form closed continuous loops.

**Reason (R):** The magnetic field of a bar magnet is strongest near its poles.

(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 convex mirror is used as a rear-view mirror in vehicles because it forms a magnified image of the traffic behind.

**Reason (R):** A convex mirror has a wider field of view than a plane mirror of the same size.

(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):** The half-life of a radioactive sample is independent of the initial number of nuclei present.

**Reason (R):** The number of nuclei that decay per unit time is proportional to the number of nuclei present at that instant.

(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.** A parallel-plate capacitor is connected to a $100$ V supply, and the separation between its plates is $2$ mm. Calculate the magnitude of the uniform electric field between the plates. **[2]**

**Q18.** The resistance of a metal wire is $10\,\Omega$ at $20°$C. If the temperature coefficient of resistance is $4 \times 10^{-3}\ °\text{C}^{-1}$, find its resistance at $120°$C. **[2]**

**Q19.** An AC generator has a coil of $200$ turns and area $0.05\ \text{m}^2$ rotating at an angular speed of $50$ rad/s in a magnetic field of $0.4$ T. Calculate the peak emf produced. **[2]**

**OR**

A series LCR circuit has $L = 0.5$ H and $C = 8\,\mu$F. Find its resonant frequency $f_0$.

**Q20.** An object is placed $30$ cm in front of a thin convex lens of focal length $20$ cm. Using the lens formula, find the position of the image. **[2]**

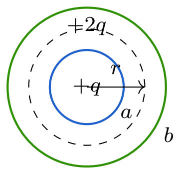
**Q21.** Using $E_n = -\dfrac{13.6}{n^2}$ eV, calculate the energy of the electron in the second excited state ($n = 3$) of the hydrogen atom. **[2]**

**OR**

In the radioactive decay of $^{238}_{92}U$ into $^{206}_{82}Pb$, find the number of $\alpha$-particles and $\beta$-particles emitted.

## Section C (Q22–Q28) – 3 Marks Each

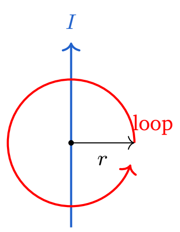
**Q22.** Two concentric thin spherical conducting shells of radii $a$ and $b$ ($a < b$) carry charges $+q$ and $+2q$ respectively. Using Gauss's law, find the electric field at a point (i) in the region between the shells ($a < r < b$) and (ii) outside both shells ($r > b$).




**[3]**

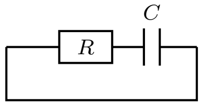
**Q23.** Explain how identical cells should be grouped (series or parallel) to obtain the maximum current through an external resistance. A battery of $n = 4$ identical cells, each of emf $2$ V and internal resistance $0.5\,\Omega$, is connected in series to an external resistance of $8\,\Omega$. Find the current in the circuit. **[3]**

**Q24.** Using Ampère's circuital law, derive an expression for the magnetic field at a perpendicular distance $r$ from a long straight conductor carrying a steady current $I$.




**[3]**

**Q25.** A series RC circuit has $R = 30\,\Omega$ and a capacitive reactance $X_C = 40\,\Omega$, connected to an AC source. Calculate the impedance of the circuit and the phase angle between the current and the voltage.

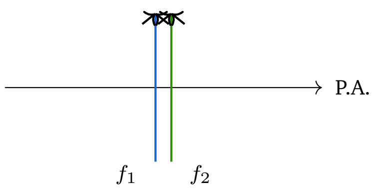



**[3]**

**OR**

What is meant by wattless current? Show that the average power consumed by an ideal (pure) inductor over a complete AC cycle is zero.

**Q26.** Two thin convex lenses of focal lengths 20 cm and 30 cm are placed in contact coaxially, as shown. Find the focal length and the power of the combination.



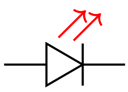

**[3]**

**OR**

An object of height 4 cm is placed 20 cm in front of a convex mirror of focal length 20 cm. Find the position, nature and size of the image.

**Q27.** When light of wavelength 400 nm falls on a metal surface, the stopping potential is found to be 1.1 V. Using Einstein's photoelectric equation, calculate the work function of the metal in eV. (Take $hc = 1240$ eV nm.) **[3]**

**Q28.** Explain the working of a light-emitting diode (LED). Draw its circuit symbol and state the condition on the energy gap for it to emit visible light.

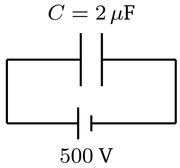



**[3]**

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

**Q29. Case Study – Charging a Capacitor.**

A parallel-plate air capacitor of capacitance $2\,\mu$F is connected to a $500$ V battery until it is fully charged. The separation between its plates is $1$ mm.




Based on the above, answer the following:

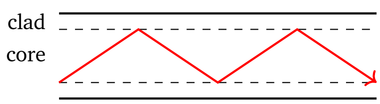
(i) Find the charge stored on the capacitor. (1)

(ii) Find the energy stored in the capacitor. (1)

(iii) Find the electric field between the plates and the energy density in that field. (Take $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m.) (2)

**Q30. Case Study – Optical Fibre.**

An optical fibre has a core of refractive index $1.5$ surrounded by a cladding of refractive index $1.4$. Light travelling in the core strikes the core–cladding boundary and can be guided along the fibre.




Based on the above, answer the following:

(i) State the condition for total internal reflection to occur. (1)

(ii) Write the relation between the critical angle $\theta_c$ and the two refractive indices. (1)

(iii) Calculate $\sin\theta_c$ for the core–cladding interface, and explain how total internal reflection guides the light along the fibre. (2)

## Section E (Q31–Q33) – 5 Marks Each

**Q31.** (a) Derive an expression for the energy stored in a charged capacitor of capacitance $C$ carrying a charge $Q$.

(b) A $10\,\mu$F capacitor is charged to $100$ V. Calculate the energy stored in it and the charge on it. **[5]**

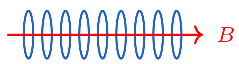
**OR**

(a) $n$ identical cells, each of emf $\varepsilon$ and internal resistance $r$, are connected in series across an external resistance $R$. Derive the expression for the current through $R$.

(b) Six such cells, each of emf $1.5$ V and internal resistance $0.5\,\Omega$, are connected in series across a $7\,\Omega$ resistor. Find the current in the circuit.

**Q32.** (a) Using Ampère's circuital law, derive the expression for the magnetic field inside a long solenoid having $n$ turns per unit length carrying a current $I$, and write the expression for the field inside a toroid.

(b) A solenoid of length $0.5$ m has $1000$ turns and carries a current of $2$ A. Find the magnetic field at its centre. (Take $\mu_0 = 4\pi \times 10^{-7}$ T m/A.)




long solenoid, $n$ turns/m

**[5]**

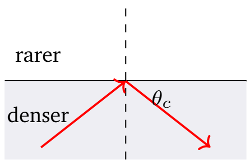
**OR**

(a) Define self-inductance and mutual inductance, and write the expression for the emf induced in terms of each.

(b) The current in a coil changes from $0$ to $5$ A in $0.2$ s, inducing an emf of $10$ V in a neighbouring coil. Find the mutual inductance of the pair.

**Q33.** (a) Explain total internal reflection and state the two conditions for it to occur. Derive the relation between the critical angle and the refractive index, and describe how an optical fibre makes use of it.

(b) The refractive index of a medium is $1.5$. Find its critical angle with respect to air. (Take $\sin^{-1}(0.667) = 41.8°$.)



**[5]**

**OR**

(a) State the conditions for constructive and destructive interference in Young's double-slit experiment and derive the expression for the fringe width $\beta$.
(b) In such an experiment the slit separation is $1$ mm, the screen is $1.5$ m away, and the wavelength of light is $500$ nm. Find the fringe width.

## Detailed Solutions

## Q1.

**Solution**

**Concept — Axial field of a short dipole:** For a short electric dipole, the field on the axial line falls off much faster than that of a single point charge.

**Step 1 — Write the axial field:**

$$E_{\text{axial}} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}.$$

**Step 2 — Identify the dependence:** With the dipole moment $p$ fixed, the numerator is constant, so

$$E_{\text{axial}} \propto \frac{1}{r^3}.$$

**Why other options are wrong:** (A) $1/r$ is a potential-like fall-off; (B) $1/r^2$ is a single point-charge field; (D) $1/r^4$ is faster than a dipole falls off.

**Final Answer:** $E_{\text{axial}} \propto \frac{1}{r^3} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q1

## Q2.

**Solution**

**Concept — Power at constant voltage:** With $V$ fixed, $P = \frac{V^2}{R}$, so power is inversely proportional to resistance.

**Step 1 — Original power:**

$$P = \frac{V^2}{R}.$$

**Step 2 — Halve the resistance:** Replace $R$ by $\frac{R}{2}$:

$$P' = \frac{V^2}{R/2} = \frac{2V^2}{R}.$$

$$= 2P.$$

**Why other options are wrong:** (A) half assumes $P \propto R$; (C) unchanged ignores the dependence; (D) four times uses a square dependence.

**Final Answer:** New power $= 2P \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q2

## Q3.

**Solution**

**Concept — Cyclotron frequency:** The time for one revolution follows from the magnetic force providing the centripetal force, and is independent of the particle's speed and radius.

**Step 1 — Force balance:**

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

**Step 2 — Period of revolution:**

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

**Step 3 — Frequency:**

$$f = \frac{1}{T} = \frac{qB}{2\pi m}.$$

**Why other options are wrong:** (B) is the period $T$, not the frequency; (C) and (D) misplace the factors of $2\pi$ and $m$.

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

Answer: (A) Go Back to Q3

## Q4.

**Solution**

**Concept — Induced charge:** The charge that flows equals the change in flux divided by the resistance, and does not depend on how fast the flux changes.

**Step 1 — Induced emf and current:**

$$\varepsilon = \frac{\Delta\phi}{\Delta t}, \qquad I = \frac{\varepsilon}{R} = \frac{\Delta\phi}{R\,\Delta t}.$$

**Step 2 — Charge over the interval:**

$$q = I\,\Delta t = \frac{\Delta\phi}{R\,\Delta t} \cdot \Delta t = \frac{\Delta\phi}{R}.$$

**Why other options are wrong:** (A) multiplies instead of divides by $R$; (C) inverts the ratio; (D) squares the flux, giving wrong dimensions.

**Final Answer:** $q = \frac{\Delta\phi}{R} \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q4

## Q5.

**Solution**

**Concept — Wattless current:** The average power in an AC circuit is $P = V_{\text{rms}} I_{\text{rms}} \cos\varphi$. The current component $90^\circ$ out of phase corresponds to $\cos\varphi = 0$.

**Step 1 — Resolve the current:** The current can be split into an in-phase (active) part $I\cos\varphi$ and a quadrature part $I\sin\varphi$.

**Step 2 — Power of the quadrature part:** For the $90^\circ$ component the phase difference is $\frac{\pi}{2}$, so $\cos\frac{\pi}{2} = 0$ and its average power is zero.

**Why other options are wrong:** (A) active current does deliver power; (B) direct current is not an AC concept here; (C) peak current is a magnitude, not a phase component.

**Final Answer:** Wattless (reactive) current $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q5

## Q6.

**Solution**

**Concept — Displacement current:** Maxwell proposed that a changing electric field between capacitor plates acts as a current, $I_d = \varepsilon_0 \frac{d\Phi_E}{dt}$, keeping Ampère's law consistent.

**Step 1 — The gap problem:** No conduction charge crosses the gap between the plates, yet a magnetic field exists there.

**Step 2 — Resolution:** The changing electric flux supplies a displacement current equal in magnitude to the conduction current in the wires, so the total current is continuous.

**Why other options are wrong:** (A) conduction current flows only in the wires; (B) eddy currents occur in bulk conductors; (D) drift current describes charge carriers in a conductor.

**Final Answer:** Displacement current $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q6

## Q7.

**Solution**

**Concept — Convex lens imaging:** For an object placed between $F$ and $2F$, a convex lens forms a real, inverted and magnified image beyond $2F$ on the far side.

**Step 1 — Locate the object:** The object lies between the focus $F$ and $2F$.

**Step 2 — Apply the standard result:** The refracted rays converge beyond $2F$, giving an enlarged real image.

**Why other options are wrong:** (B) diminished image needs the object beyond $2F$; (C) virtual erect image needs the object within $F$; (D) same-size image needs the object exactly at $2F$.

**Final Answer:** Real, inverted, magnified, beyond $2F \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q7

## Q8.

**Solution**

**Concept — Intensity and amplitude:** The intensity of a wave is proportional to the square of its amplitude, $I \propto a^2$.

**Step 1 — Write the ratio:**

$$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \left(\frac{a_1}{a_2}\right)^2.$$

**Step 2 — Substitute $a_1 : a_2 = 3 : 2$:**

$$\frac{I_1}{I_2} = \left(\frac{3}{2}\right)^2 = \frac{9}{4}.$$

**Why other options are wrong:** (A) $3 : 2$ is the amplitude ratio, not intensity; (B) $6 : 4$ simplifies to $3 : 2$; (C) $4 : 9$ is the inverse.

**Final Answer:** $I_1 : I_2 = 9 : 4 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q8

## Q9.

**Solution**

**Concept — Threshold wavelength:** Photoemission just begins when the photon energy equals the work function, $\frac{hc}{\lambda_0} = W$.

**Step 1 — Write the threshold condition:**

$$\frac{hc}{\lambda_0} = W.$$

**Step 2 — Solve for $\lambda_0$:**

$$\lambda_0 = \frac{hc}{W}.$$

**Why other options are wrong:** (B) $\frac{W}{hc}$ inverts the ratio; (C) and (D) misplace $h$, $c$ and $W$, giving wrong dimensions.

**Final Answer:** $\lambda_0 = \frac{hc}{W} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q9

## Q10.

**Solution**

**Concept — Nuclear radius:** The nuclear radius is $R = R_0 A^{1/3}$, so the ratio of radii equals the cube-root ratio of the mass numbers.

**Step 1 — Write the ratio:**

$$\frac{R_1}{R_2} = \frac{R_0(27)^{1/3}}{R_0(64)^{1/3}} = \left(\frac{27}{64}\right)^{1/3}.$$

**Step 2 — Evaluate the cube roots:**

$$(27)^{1/3} = 3, \qquad (64)^{1/3} = 4.$$

$$\frac{R_1}{R_2} = \frac{3}{4}.$$

**Why other options are wrong:** (A) $27 : 64$ ignores the cube root; (B) $9 : 16$ uses a square-root idea; (D) $4 : 3$ is the inverse.

**Final Answer:** $R_1 : R_2 = 3 : 4 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q10

## Q11.

**Solution**

**Concept — n-type semiconductor:** A pentavalent donor atom contributes one extra electron per atom, which becomes a free carrier.

**Step 1 — Doping effect:** Four of the donor's five valence electrons form covalent bonds; the fifth is loosely bound and easily freed.

**Step 2 — Majority carriers:** These extra free electrons vastly outnumber the thermally generated holes, so electrons are the majority carriers.

**Why other options are wrong:** (A) holes are the minority carriers here; (B) protons are bound in nuclei; (D) positive donor ions are fixed in the lattice and do not carry current.

**Final Answer:** Electrons $\Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q11

## Q12.

**Solution**

**Concept — Energy density of an electric field:** The energy stored per unit volume in an electric field in vacuum is $u = \frac{1}{2}\varepsilon_0 E^2$.

**Step 1 — Start from capacitor energy:** For a parallel-plate capacitor, $U = \frac{1}{2}CV^2$ with $C = \frac{\varepsilon_0 A}{d}$ and $V = Ed$.

**Step 2 — Divide by the volume $Ad$:**

$$u = \frac{U}{Ad} = \frac{\frac{1}{2}\frac{\varepsilon_0 A}{d}(Ed)^2}{Ad} = \frac{1}{2}\varepsilon_0 E^2.$$

**Why other options are wrong:** (A) omits the factor $\frac{1}{2}$; (C) and (D) have the wrong powers of $E$ or $\varepsilon_0$.

**Final Answer:** $u = \frac{1}{2}\varepsilon_0 E^2 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q12

## Q13.

**Solution**

**Concept — EMF versus terminal PD:** Assess each statement, then decide whether R explains A.

**Step 1 — Assertion:** The claim that the terminal PD is *always* equal to the emf is **false**; equality holds only when no current is drawn (open circuit).

**Step 2 — Reason:** When current $I$ flows, a voltage $Ir$ is dropped across the internal resistance, so terminal PD $= \varepsilon - Ir < \varepsilon$. This statement is **true**.

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

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

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

Answer: (D) Go Back to Q13

## Q14.

**Solution**

**Concept — Magnetic field lines:** Judge both statements, then test whether R is the reason for A.

**Step 1 — Assertion:** Magnetic field lines are continuous closed loops, since isolated magnetic poles (monopoles) do not exist. So A is **true**.

**Step 2 — Reason:** The field of a bar magnet is indeed strongest near its poles, where the lines are most crowded. So R is **true**.

**Step 3 — Does R explain A?** The crowding of lines near the poles is a statement about field strength, not about why the lines close on themselves. So R does *not* explain A.

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

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

Answer: (B) Go Back to Q14

## Q15.

**Solution**

**Concept — Convex mirror as rear-view mirror:** Check each statement carefully; a convex mirror forms a virtual, erect, diminished image.

**Step 1 — Assertion:** The stated reason "because it forms a magnified image" is **false**; a convex mirror always forms a *diminished* image.

**Step 2 — Reason:** A convex mirror does have a wider field of view than a plane mirror of the same size, which is the real reason it is used. 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 Q15

## Q16.

**Solution**

**Concept — Half-life and decay law:** Radioactive decay follows $N = N_0 e^{-\lambda t}$, and the half-life $T_{1/2} = \dfrac{\ln 2}{\lambda}$ depends only on $\lambda$.

**Step 1 — Assertion:** The half-life is fixed by the decay constant of the nuclide and does not depend on the initial number of nuclei. So A is **true**.

**Step 2 — Reason:** The decay rate obeys $\dfrac{dN}{dt} = -\lambda N$, i.e. the number decaying per unit time is proportional to the number present. So R is **true**.

**Step 3 — Does R explain A?** This proportionality is exactly what gives the exponential law and a constant half-life independent of $N_0$. 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 Q16

## Q17.

**Solution**

**Concept — Uniform field between plates:** The field between parallel plates is uniform and equals the potential difference divided by the separation, $E = \dfrac{V}{d}$.

**Step 1 — Convert the separation:**

$$d = 2\ \text{mm} = 2 \times 10^{-3}\ \text{m}.$$

**Step 2 — Apply $E = \dfrac{V}{d}$:**

$$E = \frac{100}{2 \times 10^{-3}}.$$
$$= 5 \times 10^{4}\ \text{V/m}.$$

**Final Answer:** $E = 5 \times 10^4$ V/m (or $5 \times 10^4$ N/C). **Go Back to Q17**

## Q18.

**Solution**

**Concept — Temperature dependence of resistance:** $R_T = R_0[1 + \alpha\,\Delta T]$, where $\Delta T$ is the temperature rise from the reference temperature.

**Step 1 — Temperature rise:**

$$\Delta T = 120 - 20 = 100\ ^{\circ}\text{C}.$$

**Step 2 — Substitute the values:**

$$R_T = 10\,[\,1 + (4 \times 10^{-3})(100)\,].$$

**Step 3 — Simplify:**

$$R_T = 10\,[\,1 + 0.4\,] = 10 \times 1.4.$$
$$= 14\ \Omega.$$

**Final Answer:** Resistance at $120°\text{C} = 14\,\Omega$. **Go Back to Q18**

## Q19.

**Solution**

**Concept — Peak emf of an AC generator:** The peak emf is $\varepsilon_0 = NBA\omega$.

**Step 1 — List the data:** $N = 200$, $B = 0.4$ T, $A = 0.05$ m$^2$, $\omega = 50$ rad/s.

**Step 2 — Substitute:**

$$\varepsilon_0 = (200)(0.4)(0.05)(50).$$

**Step 3 — Multiply step by step:**

$$(200)(0.4) = 80, \quad 80 \times 0.05 = 4, \quad 4 \times 50 = 200.$$

$$\varepsilon_0 = 200 \text{ V}.$$

**Final Answer:** Peak emf $= 200$ V.

**OR — Resonant frequency:**

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

**Step 2 — Compute $LC$:**

$$LC = (0.5)(8 \times 10^{-6}) = 4 \times 10^{-6}.$$

**Step 3 — Square root and evaluate:**

$$\sqrt{LC} = 2 \times 10^{-3}, \qquad f_0 = \frac{1}{2\pi(2 \times 10^{-3})} \approx 79.6 \text{ Hz}.$$

**Final Answer (OR):** $f_0 \approx 79.6$ Hz. **Go Back to Q19**

## Q20.

**Solution**

**Concept — Lens formula:** $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$, with $u$ negative for a real object.

**Step 1 — Assign values:** $u = -30$ cm, $f = +20$ cm.

**Step 2 — Substitute:**

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

**Step 3 — Take the common denominator:**

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

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

**Final Answer:** The image forms 60 cm behind the lens; it is real and inverted. **Go Back to Q20**

## Q21.

**Solution**

**Concept — Bohr energy levels:** The energy of the $n$-th level of hydrogen is $E_n = -\frac{13.6}{n^2}$ eV. The second excited state is $n = 3$.

**Step 1 — Substitute $n = 3$:**

$$E_3 = -\frac{13.6}{3^2} = -\frac{13.6}{9}.$$

**Step 2 — Divide:**

$$E_3 = -1.51 \text{ eV}.$$

**Final Answer:** $E_3 \approx -1.51$ eV.

**OR — Number of $\alpha$- and $\beta$-particles:**

**Step 1 — Count $\alpha$-particles from the mass number:** Each $\alpha$ decay reduces $A$ by 4:

$$\text{number of } \alpha = \frac{238 - 206}{4} = \frac{32}{4} = 8.$$

**Step 2 — Balance the atomic number:** 8 alphas alone would reduce $Z$ by 16, giving $92 - 16 = 76$. The final $Z$ is 82, so

$$\text{number of } \beta = 82 - 76 = 6.$$

**Final Answer (OR):** 8 $\alpha$-particles and 6 $\beta$-particles. **Go Back to Q21**

## Q22.

**Solution**

**Concept — Gauss's law with shells:** The field at radius $r$ depends only on the charge enclosed within that radius, $\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\varepsilon_0}$.

**Step 1 — Region between the shells ($a < r < b$):** Only the inner shell's charge $+q$ is enclosed by a Gaussian sphere of radius $r$:

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

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

**Step 2 — Region outside both shells ($r > b$):** Now both charges are enclosed, $q_{\text{enc}} = q + 2q = 3q$:

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

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

**Final Answer:** Between shells $E = \frac{q}{4\pi\varepsilon_0 r^2}$; outside $E = \frac{3q}{4\pi\varepsilon_0 r^2}$ (both radially outward). **Go Back to Q22**

## Q23.

**Solution**

**Concept — Grouping of cells:** Cells are joined in *series* when the external resistance is much larger than the internal resistance, and in *parallel* when it is much smaller; a general mixed grouping maximises current when the external resistance equals the total internal resistance.

**Step 1 — Total emf in series:**

$$\varepsilon_{\text{total}} = n\varepsilon = 4 \times 2 = 8\,\text{V}.$$

**Step 2 — Total internal resistance in series:**

$$r_{\text{total}} = nr = 4 \times 0.5 = 2\,\Omega.$$

**Step 3 — Apply Ohm's law to the loop:**

$$I = \frac{\varepsilon_{\text{total}}}{R + r_{\text{total}}} = \frac{8}{8+2}.$$

$$= \frac{8}{10} = 0.8 \text{ A}.$$

**Final Answer:** Current $= 0.8$ A. **Go Back to Q23**

## Q24.

### Solution

**Concept — Ampère's circuital law:** $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}}$. By symmetry, the field around a long straight wire is circular and constant in magnitude at fixed distance.

**Step 1 — Choose an Amperian loop:** Take a circle of radius $r$ centred on the wire, in a plane perpendicular to it. Here $\vec{B}$ is tangential and of constant magnitude $B$.

**Step 2 — Evaluate the line integral:**

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

**Step 3 — Apply the law:** The current enclosed is $I$:

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

**Step 4 — Solve for $B$:**

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

**Final Answer:** $B = \frac{\mu_0 I}{2\pi r}$, directed along circles around the wire (right-hand rule).
**Go Back to Q24**

## Q25.

### Solution

**Concept — Impedance of series RC:** $Z = \sqrt{R^2 + X_C^2}$ and the current leads the voltage with $\tan\varphi = \frac{X_C}{R}$.

**Step 1 — Substitute the reactances:**

$$Z = \sqrt{R^2 + X_C^2} = \sqrt{30^2 + 40^2}.$$

**Step 2 — Evaluate:**

$$Z = \sqrt{900 + 1600} = \sqrt{2500} = 50\ \Omega.$$

**Step 3 — Phase angle:**

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

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

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

**OR — Wattless current:**

**Step 1 — Definition:** A wattless current is the component of AC current that is $90^\circ$ out of phase with the voltage; over a full cycle it transfers no net energy.

**Step 2 — Power in a pure inductor:** For a pure inductor the current lags the voltage by $\varphi = 90^\circ$, so

$$P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos\varphi = V_{\text{rms}} I_{\text{rms}} \cos 90^\circ = 0.$$

**Final Answer (OR):** The average power in a pure inductor is zero; its current is wattless. **Go Back to Q25**

## Q26.

**Solution**

**Concept — Lenses in contact:** For thin lenses in contact, $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$, and the power $P = \frac{1}{f}$ (with $f$ in metres).

**Step 1 — Combine the focal lengths:**

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

**Step 2 — Add the fractions:**

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

$$f = 12 \text{ cm}.$$

**Step 3 — Power of the combination:** Convert $f = 0.12$ m:

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

**Final Answer:** $f = 12$ cm; $P \approx +8.33$ D.

**OR — Convex mirror image:**

**Step 1 — Assign values:** For a convex mirror $f = +20$ cm, and $u = -20$ cm.

**Step 2 — Mirror formula:**

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{v} = \frac{1}{20} - \frac{1}{-20} = \frac{1}{20} + \frac{1}{20} = \frac{2}{20} = \frac{1}{10}.$$

$$v = +10 \text{ cm (behind the mirror, virtual).}$$

**Step 3 — Magnification and image height:**

$$m = -\frac{v}{u} = -\frac{10}{-20} = +0.5, \qquad h' = m\,h = 0.5 \times 4 = 2 \text{ cm}.$$

**Final Answer (OR):** Image is virtual, erect, $10$ cm behind the mirror, height $2$ cm (diminished). **Go Back to Q26**

## Q27.

**Solution**

**Concept — Photoelectric equation:** $E_{\text{photon}} = W + K_{\max}$, where $K_{\max} = eV_0$ and $V_0$ is the stopping potential.

**Step 1 — Photon energy:** Using $hc = 1240$ eV nm and $\lambda = 400$ nm,

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

**Step 2 — Maximum kinetic energy:** The stopping potential gives

$$K_{\max} = eV_0 = 1.1 \text{ eV}.$$

**Step 3 — Work function:**

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

$$= 2.0 \text{ eV}.$$

**Final Answer:** Work function $W = 2.0$ eV. **Go Back to Q27**

## Q28.

### Solution

**Concept — Light-emitting diode:** An LED is a heavily doped p-n junction operated in *forward* bias, in which recombination of electrons and holes releases energy as light.

**Step 1 — Working:** When forward biased, electrons from the n-side and holes from the p-side are injected across the junction and recombine near it.

**Step 2 — Photon emission:** Each recombination releases energy approximately equal to the band gap as a photon:

$$h\nu \approx E_g.$$

**Step 3 — Energy-gap condition:** For the emitted light to be visible (wavelength about 400–700 nm), the band gap must satisfy

$$E_g \approx 1.8 \text{ eV to } 3 \text{ eV}.$$

**Symbol:** An ordinary diode symbol with two small arrows pointing *away* from the junction (indicating emitted light), as drawn in the question.

**Final Answer:** A forward-biased LED emits light of energy $h\nu \approx E_g$; for visible light $E_g \approx 1.8$–$3$ eV. **Go Back to Q28**

## Q29.

### Solution

**Concept — Capacitor charge, energy and energy density:** $Q = CV$, $U = \frac{1}{2}CV^2$, $E = \frac{V}{d}$ and $u = \frac{1}{2}\varepsilon_0 E^2$.

**(i) Charge stored:**

$$Q = CV = (2 \times 10^{-6})(500).$$
$$= 1 \times 10^{-3} \text{ C}.$$

**(ii) Energy stored:**

$$U = \frac{1}{2}CV^2 = \frac{1}{2}(2 \times 10^{-6})(500)^2.$$
$$= \frac{1}{2}(2 \times 10^{-6})(2.5 \times 10^5) = 0.25 \text{ J}.$$

**(iii) Field and energy density:**

$$E = \frac{V}{d} = \frac{500}{1 \times 10^{-3}} = 5 \times 10^5 \text{ V/m}.$$

$$u = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}(8.85 \times 10^{-12})(5 \times 10^5)^2.$$

$$= \frac{1}{2}(8.85 \times 10^{-12})(2.5 \times 10^{11}) \approx 1.11 \text{ J/m}^3.$$

**Final Answer:** $Q = 1 \times 10^{-3}$ C; $U = 0.25$ J; $E = 5 \times 10^5$ V/m; $u \approx 1.11$ J/m$^3$. **Go Back to Q29**

## Q30.

**Solution**

**Concept — Total internal reflection in a fibre:** Light travelling from the denser core towards the rarer cladding is totally reflected if it strikes the boundary beyond the critical angle.

**(i) Condition:** (a) The light must travel from a denser medium (core) to a rarer medium (cladding); (b) the angle of incidence must exceed the critical angle $\theta_c$.

**(ii) Relation for the critical angle:** At the core–cladding interface,

$$\sin\theta_c = \frac{n_{\text{clad}}}{n_{\text{core}}}.$$

**(iii) Numerical and explanation:**

$$\sin\theta_c = \frac{1.4}{1.5} \approx 0.933.$$

Rays that hit the boundary at more than $\theta_c$ are totally reflected each time, so the light zig-zags along the core with almost no loss and is guided from one end of the fibre to the other.

**Final Answer:** $\sin\theta_c \approx 0.933$ (so $\theta_c \approx 69°$); repeated total internal reflection guides the light along the fibre. **Go Back to Q30**

## Q31.

**Solution**

**Concept — Energy stored in a capacitor:** Work is done in transferring charge against the rising potential; this work is stored as electrostatic energy.

**(a) Derivation:** When the charge on the capacitor is $q$, its potential is $V = \frac{q}{C}$. The work to add a further charge $dq$ is

$$dW = V\,dq = \frac{q}{C}\,dq.$$

Integrate from $0$ to the final charge $Q$:

$$U = \int_0^Q \frac{q}{C}\,dq = \frac{1}{C}\cdot\frac{Q^2}{2} = \frac{Q^2}{2C} = \frac{1}{2}CV^2.$$

**(b) Numerical:** With $C = 10\,\mu$F and $V = 100$ V,

$$U = \frac{1}{2}(10\times10^{-6})(100)^2 = \frac{1}{2}(10\times10^{-6})(10^4) = 0.05 \text{ J.}$$

$$Q = CV = (10\times10^{-6})(100) = 1\times10^{-3} \text{ C.}$$

**Final Answer:** $U = \frac{1}{2}CV^2 = 0.05$ J; $Q = 1\times10^{-3}$ C.

**OR — Series grouping of $n$ cells:**

**(a) Derivation:** With $n$ cells of emf $\varepsilon$ in series, the total emf is $n\varepsilon$ and the total internal resistance is $nr$. Applying Ohm's law to the loop with external resistance $R$,

$$I = \frac{n\varepsilon}{R+nr}.$$

**(b) Numerical:** With $n = 6$, $\varepsilon = 1.5$ V, $r = 0.5\,\Omega$, $R = 7\,\Omega$,

$$I = \frac{6\times1.5}{7+6\times0.5} = \frac{9}{7+3} = \frac{9}{10} = 0.9 \text{ A.}$$

**Final Answer (OR):** $I = \frac{n\varepsilon}{R+nr} = 0.9$ A. **Go Back to Q31**

## Q32.

**Solution**

**Concept — Solenoid and toroid fields:** Ampère's law $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{\text{enc}}$ gives a uniform field inside a long solenoid.

**(a) Solenoid derivation:** Take a rectangular Amperian loop of length $L$ with one side inside the solenoid (field $B$) and the opposite side outside (field $\approx 0$). Only the inner side contributes:

$$\oint \vec{B}\cdot d\vec{l} = BL.$$

The current enclosed is $(nL)I$, where $n$ is the number of turns per unit length:

$$BL = \mu_0 (nL) I \;\Rightarrow\; B = \mu_0 n I.$$

For a toroid of $N$ turns and mean radius $r$, a circular loop gives $B(2\pi r) = \mu_0 N I$, so

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

**(b) Numerical:** Turns per unit length:

$$n = \frac{1000}{0.5} = 2000\ \text{m}^{-1}.$$

$$B = \mu_0 n I = (4\pi \times 10^{-7})(2000)(2).$$

$$= (1.2566 \times 10^{-6})(4000) \approx 5.03 \times 10^{-3}\ \text{T}.$$

**Final Answer:** $B = \mu_0 n I \approx 5.03 \times 10^{-3}$ T.

**OR — Self- and mutual inductance:**

**(a) Definitions:** Self-inductance $L$ is the flux linkage per unit current in a coil, $N\phi = LI$, with induced emf $\varepsilon = -L\frac{dI}{dt}$. Mutual inductance $M$ relates the flux in a second coil to the current in the first, $N_2\phi_2 = MI_1$, with induced emf $\varepsilon_2 = -M\frac{dI_1}{dt}$.

**(b) Numerical:**

$$\frac{dI}{dt} = \frac{5-0}{0.2} = 25\ \text{A/s}.$$

$$M = \frac{\varepsilon}{dI/dt} = \frac{10}{25} = 0.4\ \text{H}.$$

**Final Answer (OR):** $M = 0.4$ H. Go Back to Q32

## Q33.

**Solution**

**Concept — Total internal reflection:** When light passes from a denser to a rarer medium, the refracted ray bends away from the normal; beyond a certain angle it is reflected entirely back into the denser medium.

**(a) Explanation and conditions:** The two conditions are: (i) light must travel from a denser to a rarer medium, and (ii) the angle of incidence must exceed the critical angle $\theta_c$. At $i = \theta_c$ the refraction angle is $90°$; applying Snell's law at the boundary (denser index $\mu$, rarer index 1):

$$\mu \sin\theta_c = 1 \times \sin 90° = 1 \;\Rightarrow\; \sin\theta_c = \frac{1}{\mu}.$$

In an optical fibre, light entering the denser core strikes the core–cladding boundary beyond $\theta_c$ and is totally reflected again and again, so it is guided along the fibre with negligible loss.

**(b) Numerical:** With $\mu = 1.5$,

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

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

**Final Answer:** $\sin\theta_c = \frac{1}{\mu}$; for $\mu = 1.5$, $\theta_c \approx 41.8°$.

**OR — Interference and fringe width:**

**(a)** For constructive interference the path difference must be $\Delta = n\lambda$ ($n = 0, 1, 2, \dots$); for destructive interference $\Delta = (n + \frac{1}{2})\lambda$. With slit separation $d$ and screen distance $D$, the path difference at height $y$ is $\Delta = \frac{yd}{D}$. Bright fringes lie at $y_n = \frac{n\lambda D}{d}$, so the fringe width is

$$\beta = y_{n+1} - y_n = \frac{\lambda D}{d}.$$

**(b)** With $d = 1$ mm$= 1 \times 10^{-3}$ m, $D = 1.5$ m, $\lambda = 500$ nm$= 5 \times 10^{-7}$ m,

$$\beta = \frac{(5 \times 10^{-7})(1.5)}{1 \times 10^{-3}} = \frac{7.5 \times 10^{-7}}{1 \times 10^{-3}} = 7.5 \times 10^{-4}\text{ m} = 0.75\text{ mm}.$$

**Final Answer (OR):** $\beta = \frac{\lambda D}{d} = 0.75$ mm. **Go Back to Q33**

## Answer Key – Section A (Q1–Q16)

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

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