CBSE Class 12 Physics

Sample Paper – 9

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. A large uniformly charged infinite plane sheet has surface charge density σ. The magnitude of the electric field at a perpendicular distance from the sheet is:

(A) $\dfrac{\sigma}{2\varepsilon_0}$, independent of the distance

(B) $\dfrac{\sigma}{\varepsilon_0}$, independent of the distance

(C) $\dfrac{\sigma}{2\varepsilon_0}$, decreasing as $1/r$

(D) $\dfrac{\sigma}{2\varepsilon_0 r}$, decreasing with distance

Q2. A steady current of 2 A flows through a resistor of $5\,\Omega$ for 10 s. The heat produced in the resistor is:

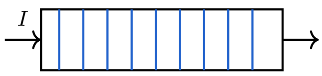
(A) 100 J

(B) 200 J

(C) 400 J

(D) 50 J

Q3. A long solenoid has $n = 1000$ turns per metre and carries a current $I = 2$ A. The magnetic field inside it is: (Take $\mu_0 = 4\pi \times 10^{-7}$ T m/A.)



long solenoid, n turns/m

(A) 1.25×10^{-3} T

(B) 5.0×10^{-3} T

(C) 2.5×10^{-3} T

(D) 4.0×10^{-3} T

Q4. Eddy currents are put to practical use in which of the following?

(A) Producing X-rays

(B) Charging a capacitor

(C) Increasing the resistance of a wire

(D) Electromagnetic braking in trains

Q5. At resonance, the impedance of a series LCR circuit is:

(A) maximum and equal to X_L

(B) zero

(C) equal to $X_L + X_C$

(D) minimum and equal to R

Q6. An electromagnetic wave falling on a surface exerts a radiation pressure on it because the wave:

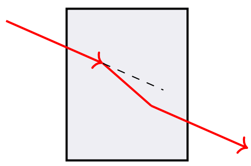
(A) carries both energy and momentum

(B) carries only energy

(C) has zero momentum

(D) has no electric field

Q7. A ray of light passes obliquely through a parallel-sided glass slab, as shown. Compared with the incident ray, the emergent ray is:



glass slab

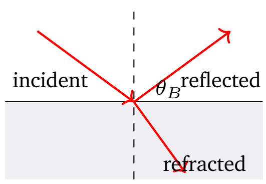
(A) bent towards the normal and deviated in direction

(B) parallel to the incident ray but laterally displaced

(C) totally internally reflected inside the slab

(D) reversed in direction

Q8. Unpolarised light is incident at the Brewster (polarising) angle θ_B on the surface of a medium of refractive index μ. Then:



(A) $\sin \theta_B = \mu$

(B) $\cos \theta_B = \mu$

(C) $\tan \theta_B = \mu$

(D) $\cot\theta_B = \mu$

Q9. The momentum p of a photon of energy E travelling in vacuum is:

(A) Ec

(B) $\frac{E}{c^2}$

(C) $\frac{E}{c}$

(D) $\frac{c}{E}$

Q10. A radioactive nuclide has a decay constant $\lambda = 0.0693\ \text{s}^{-1}$. Its half-life is: (Take $\ln 2 = 0.693$.)

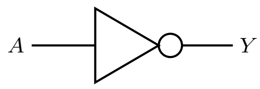
(A) 5 s

(B) 20 s

(C) 6.93 s

(D) 10 s

Q11. The logic gate shown below has a single input A and gives an output $Y = \overline{A}$. It is a:



(A) NOT gate

(B) AND gate

(C) OR gate

(D) NAND gate

Q12. A charged parallel-plate capacitor is disconnected from the battery so that its charge stays constant. A dielectric slab of dielectric constant K is now inserted to fill the gap. The electric field between the plates becomes:

(A) KE

(B) $\dfrac{E}{K}$

(C) E (unchanged)

(D) K^2E

Q13. Assertion (A): The electric potential everywhere inside a charged conductor is zero.
Reason (R): The electric field inside a conductor in electrostatic equilibrium is zero.

(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): When a bar magnet is moved towards a closed coil, an emf is induced in the coil.
Reason (R): A change in the magnetic flux linked with a coil induces an emf in it.

(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 phenomenon of polarisation establishes the transverse nature of light.
Reason (R): Light waves are longitudinal in nature.

(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 work function is a characteristic property of a given metal.
Reason (R): Photoelectric emission occurs only when the frequency of the incident light exceeds the threshold frequency.

(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 capacitor of capacitance $5\,\mu$F is charged to a potential difference of 100 V. Calculate the energy stored in the capacitor. **[2]**

Q18. A wire of length 2 m and uniform cross-sectional area 1×10^{-6} m^2 has a resistance of $0.1\,\Omega$. Calculate the resistivity of the material of the wire. **[2]**

Q19. A coil of 200 turns experiences a change in magnetic flux of 4×10^{-3} Wb through each turn in a time of 0.1 s. Calculate the magnitude of the induced emf. **[2]**

OR

A series resonant circuit has $L = 4$ H, $C = 1\,\mu$F and $R = 20\,\Omega$. Calculate its quality factor Q.

Q20. A convex lens has a focal length of 25 cm. Calculate its power in dioptres. **[2]**

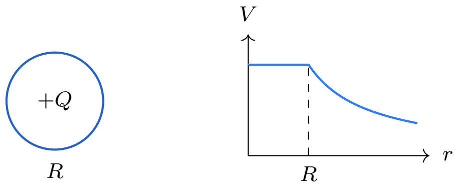
Q21. Calculate the de Broglie wavelength associated with an alpha particle moving with a speed of 1×10^5 m/s. (Take the mass of the alpha particle $= 6.4 \times 10^{-27}$ kg.) **[2]**

OR

The half-life of a radioactive substance is 10 s. Calculate its mean life. (Take $\ln 2 = 0.693$.)

Section C (Q22–Q28) – 3 Marks Each

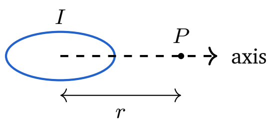
Q22. A thin spherical shell of radius R carries a total charge Q distributed uniformly on its surface. Obtain expressions for the electric potential at a point (i) inside the shell and (ii) outside the shell, and sketch the variation of potential V with distance r from the centre.



[3]

Q23. Explain how a galvanometer can be converted into a voltmeter. A galvanometer of resistance $50\,\Omega$ shows full-scale deflection for a current of 2 mA. Calculate the value of the series resistance required to convert it into a voltmeter reading up to 10 V. **[3]**

Q24. Define the magnetic dipole moment of a current-carrying loop and write the expression for the magnetic field on its axis at a far point. A circular coil of 10 turns and radius 5 cm carries a current of 2 A. Calculate its magnetic dipole moment.



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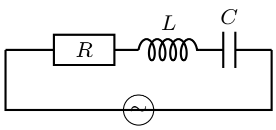
Q25. A series LCR circuit containing $R = 20\,\Omega$ is connected to a 220 V AC source and is operating at resonance. Find (i) the impedance of the circuit and (ii) the current in the circuit at resonance.



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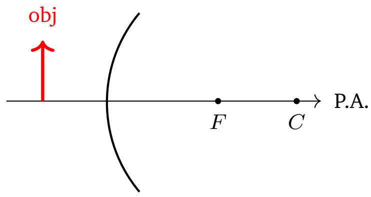
OR

A series RL circuit has $R = 30\,\Omega$ and inductive reactance $X_L = 40\,\Omega$. Find the impedance of the circuit and the phase angle between the current and the applied voltage.

Q26. Draw a ray diagram to show image formation by a convex mirror for an object placed in front of it. An object is placed 20 cm in front of a convex mirror of focal length 15 cm. Using the mirror formula, find the position of the image.



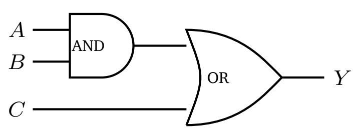
[3]

OR

Two thin lenses of powers $+4$ D and $+6$ D are placed in contact with each other. Calculate the power and the focal length of the combination.

Q27. The energy of an electron in the n-th orbit of a hydrogen atom is $E_n = -\frac{13.6}{n^2}$ eV. Calculate (i) the energy of the electron in the first excited state and (ii) the energy required to ionise a hydrogen atom that is already in the first excited state ($n = 2$). **[3]**

Q28. Using one AND gate and one OR gate, draw a logic circuit that realises the Boolean expression $Y = A \cdot B + C$. Also write its truth table.



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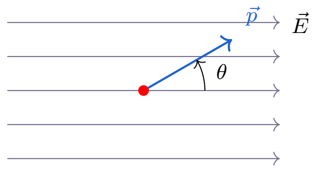
Section D (Q29–Q30) – 4 Marks Each (Case Study)

Q29. Case Study – Electric Dipole in a Uniform Field.

An electric dipole of moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$ so that $\vec{p}$ makes an angle θ with $\vec{E}$. The field exerts a torque that tends to align the dipole with the field, and the dipole possesses a potential energy that depends on its orientation.



Based on the above, answer the following:

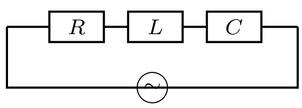
(i) Write the expression for the torque acting on the dipole. (1)

(ii) For what orientation θ is the torque maximum? (1)

(iii) Given $p = 2 \times 10^{-9}$ C m, $E = 1 \times 10^5$ N/C and $\theta = 30°$, calculate the torque and the potential energy of the dipole. (Take $\cos 30° = 0.866$.) (2)

Q30. Case Study – Series LCR AC Circuit.

In a series LCR circuit connected to a 20 V AC source, the resistance is $R = 6\,\Omega$, the inductive reactance is $X_L = 12\,\Omega$ and the capacitive reactance is $X_C = 4\,\Omega$.



Based on the above, answer the following:

(i) Write the expression for the impedance Z of a series LCR circuit. (1)

(ii) Calculate the impedance of this circuit. (1)

(iii) Find the current drawn from the source, and state the impedance and current if the circuit is tuned to resonance ($X_L = X_C$). (2)

Section E (Q31–Q33) – 5 Marks Each

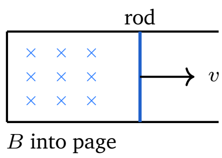
Q31. (a) Derive an expression for the capacitance of a parallel-plate capacitor of plate area A and plate separation d when a dielectric slab of thickness t ($t < d$) and dielectric constant K is introduced between the plates.

(b) A parallel-plate capacitor has plate area $A = 2 \times 10^{-2}$ m^2 and plate separation $d = 2$ mm. A dielectric slab of thickness $t = 1$ mm and dielectric constant $K = 5$ is inserted between the plates. Calculate the capacitance. (Take $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m.) **[5]**

OR

(a) Explain, with reasons, why a potentiometer is preferred over a voltmeter for measuring the emf of a cell.
(b) A potentiometer wire has a potential gradient of 0.2 V/m. A cell connected across a part of the wire is balanced at a length of 2.5 m. Calculate the emf of the cell.

Q32. (a) A conducting rod of length l moves with a uniform velocity v perpendicular to a uniform magnetic field B, sliding on two parallel conducting rails. Derive an expression for the motional emf induced in the rod.
(b) Such a rod of length 0.5 m moves at 4 m/s in a field of 0.2 T. If the rails and rod form a closed circuit of total resistance $2\,\Omega$, calculate the induced emf and the current in the circuit.

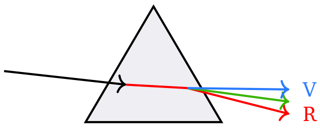


[5]

OR

(a) Compare a series RL circuit and a series RC circuit connected to an AC source: write the expression for the impedance in each case and state the phase relation between current and voltage.
(b) A series RL circuit has $R = 30\,\Omega$ and $X_L = 40\,\Omega$. Find the impedance and the phase angle. (Take $\tan^{-1}(4/3) = 53°$.)

Q33. (a) Explain the dispersion of white light by a glass prism and define the dispersive power of the prism material.
(b) For a certain prism, the refractive indices for violet, yellow and red light are $\mu_V = 1.53$, $\mu_y = 1.52$ and $\mu_R = 1.51$ respectively. Calculate the dispersive power of the prism material.



[5]

OR

(a) State Huygens' principle and use it to prove the law of reflection ($\angle i = \angle r$) for a plane wavefront incident on a plane reflecting surface.
(b) A plane wavefront is incident on a plane mirror at an angle of incidence of 25°. State the angle of reflection and justify your answer using Huygens' construction.

Detailed Solutions

Q1.

Solution

Concept — Field of an infinite charged sheet: By Gauss's law, an infinite plane sheet of surface charge density σ produces a uniform field on each side that does not depend on the distance from the sheet.

Step 1 — Apply Gauss's law: Take a cylindrical Gaussian pillbox of end-area S piercing the sheet:

$$2ES = \frac{\sigma S}{\varepsilon_0}.$$

Step 2 — Solve for E:

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

This result contains no r, so the field is the same at all distances.

Why other options are wrong: (B) σ/ε_0 is the field just outside a conductor, not a thin sheet; (C) and (D) wrongly introduce a distance dependence.

Final Answer: $E = \dfrac{\sigma}{2\varepsilon_0}$, independent of distance $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept — Joule heating: The heat produced in a resistor is $H = I^2Rt$.

Step 1 — List the data:

$$I = 2\ \text{A}, \quad R = 5\ \Omega, \quad t = 10\ \text{s}.$$

Step 2 — Substitute:

$$H = I^2Rt = (2)^2(5)(10).$$

$$= 4 \times 5 \times 10.$$

$$= 200\ \text{J}.$$

Why other options are wrong: (A) 100 J uses I instead of I^2; (C) 400 J doubles the result; (D) 50 J divides instead of multiplies.

Final Answer: $H = 200$ J $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q2

Q3.

Solution

Concept — Field inside a long solenoid: The magnetic field deep inside a long solenoid is uniform and given by $B = \mu_0 n I$.

Step 1 — List the data:

$$n = 1000\ \text{m}^{-1}, \quad I = 2\ \text{A}, \quad \mu_0 = 4\pi \times 10^{-7}.$$

Step 2 — Substitute:

$$B = (4\pi \times 10^{-7})(1000)(2).$$
$$= (4\pi \times 10^{-7})(2000).$$
$$= 8\pi \times 10^{-4}\ \text{T}.$$

Step 3 — Evaluate:

$$B \approx 8 \times 3.14 \times 10^{-4} = 25.1 \times 10^{-4} \approx 2.5 \times 10^{-3}\ \text{T}.$$

Why other options are wrong: (A) halves the current; (B) doubles the result; (D) drops the factor π.

Final Answer: $B \approx 2.5 \times 10^{-3}\ \text{T} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

Q4.

Solution

Concept — Eddy currents: Changing magnetic flux through a bulk conductor induces circulating (eddy) currents whose magnetic effect opposes the motion; this is used for braking, damping and induction heating.

Step 1 — Identify a valid use: In electromagnetic braking, eddy currents set up in a metal drum or rail oppose the motion and bring the moving system to rest smoothly.

Step 2 — Conclusion: Option (D) describes a genuine application of eddy currents.

Why other options are wrong: (A) X-rays come from decelerating electrons, not eddy currents; (B) a capacitor is charged by conduction current; (C) eddy currents do not raise a wire's resistance.

Final Answer: Electromagnetic braking in trains $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — Series resonance: At resonance $X_L = X_C$, so the net reactance vanishes and the impedance is purely resistive.

Step 1 — Impedance formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}.$$

Step 2 — Put $X_L = X_C$:

$$Z = \sqrt{R^2 + 0} = R.$$

This is the minimum possible value of Z, so the current is maximum.

Why other options are wrong: (A) Z is not maximum at resonance; (B) Z is not zero since $R \neq 0$; (C) $X_L + X_C$ is never the impedance.

Final Answer: $Z = R$, minimum $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept — Momentum of EM waves: An electromagnetic wave transports energy U and also linear momentum $p = U/c$; when it is absorbed or reflected it transfers this momentum, producing radiation pressure.

Step 1 — Cause of pressure: A force is exerted only if the wave delivers momentum to the surface.

Step 2 — Conclusion: Since the wave carries both energy and momentum, it can push on the surface, giving radiation pressure.

Why other options are wrong: (B) energy alone without momentum would exert no pressure; (C) a wave with zero momentum could not push; (D) an EM wave always has an oscillating electric field.

Final Answer: Carries both energy and momentum $\Rightarrow$ A

Answer: (A) Go Back to Q6

Q7.

Solution

Concept — Refraction through a parallel slab: The two faces of a rectangular slab are parallel, so the ray bends towards the normal on entering and away on leaving by equal amounts.

Step 1 — Entry and exit: The net bending at the two parallel faces cancels in direction, so the emergent ray is parallel to the incident ray.

Step 2 — Effect: The ray is shifted sideways by a lateral displacement, but its direction is unchanged.

Why other options are wrong: (A) there is no net change of direction; (C) TIR needs an angle beyond the critical angle; (D) the ray is never reversed.

Final Answer: Parallel to the incident ray, laterally displaced $\Rightarrow$ B

Answer: (B) Go Back to Q7

Q8.

Solution

Concept — Brewster's law: When unpolarised light is incident at the polarising angle θ_B, the reflected light is completely plane polarised and the reflected and refracted rays are perpendicular; then $\tan\theta_B = \mu$.

Step 1 — Reflected and refracted rays perpendicular:

$$\theta_B + r = 90^\circ.$$

Step 2 — Apply Snell's law:

$$\mu = \frac{\sin\theta_B}{\sin r} = \frac{\sin\theta_B}{\sin(90^\circ - \theta_B)} = \frac{\sin\theta_B}{\cos\theta_B} = \tan\theta_B.$$

Why other options are wrong: (A), (B) and (D) do not follow from the perpendicularity of the reflected and refracted rays.

Final Answer: $\tan\theta_B = \mu \Rightarrow$ C

Answer: (C) Go Back to Q8

Q9.

Solution

Concept — Photon momentum: A photon of energy E has momentum $p = E/c$, since for a photon $E = pc$.

Step 1 — Energy–momentum relation:

$$E = pc.$$

Step 2 — Solve for p:

$$p = \frac{E}{c}.$$

Why other options are wrong: (A) Ec and (B) E/c^2 have the wrong dimensions for momentum; (D) c/E is inverted.

Final Answer: $p = \frac{E}{c} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept — Half-life and decay constant: They are related by $T_{1/2} = \frac{0.693}{\lambda}$.

Step 1 — Write the relation:

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

Step 2 — Substitute $\lambda = 0.0693$ s^{-1}:

$$T_{1/2} = \frac{0.693}{0.0693}.$$

$$= 10 \text{ s}.$$

Why other options are wrong: (A) 5 s halves the value; (B) 20 s doubles it; (C) 6.93 s omits the factor 10 in the arithmetic.

Final Answer: $T_{1/2} = 10 \text{ s} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept — NOT gate (inverter): A gate with a single input, drawn as a triangle with a small bubble at the output, inverts its input, giving $Y = \overline{A}$.

Step 1 — Read the symbol: There is one input line A and the triangular body ends in an inversion bubble.

Step 2 — Identify: A single-input inverter is the NOT gate; its output is the complement of the input.

Why other options are wrong: (B) AND and (C) OR are two-input gates without inversion; (D) NAND is a two-input gate.

Final Answer: NOT gate $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept — Dielectric at constant charge: With the battery disconnected, the charge Q is fixed. Inserting a dielectric of constant K reduces the field to E_0/K because the induced surface charges partly cancel the applied field.

Step 1 — Original field:

$$E_0 = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}.$$

Step 2 — With the dielectric: The bound charges reduce the net field by a factor K:

$$E = \frac{E_0}{K}.$$

Why other options are wrong: (A) KE increases the field; (C) unchanged ignores the dielectric; (D) K^2E has no physical basis.

Final Answer: $E \to \dfrac{E}{K} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept — Potential inside a conductor: Judge each statement, then decide whether R explains A.

Step 1 — Assertion: "The potential everywhere inside a charged conductor is zero" is **false**. The potential inside is constant and equals the (generally non-zero) surface potential, not zero.

Step 2 — Reason: "The electric field inside a conductor in electrostatic equilibrium is zero" 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 Q13

Q14.

Solution

Concept — Electromagnetic induction: A changing flux through a coil induces an emf (Faraday's law).

Step 1 — Assertion: Moving a magnet towards a coil changes the flux linked with it and induces an emf. So A is **true**.

Step 2 — Reason: A change in magnetic flux linked with a coil induces an emf. So R is **true**.

Step 3 — Does R explain A? The approaching magnet is exactly what changes the flux, so R is the correct explanation of A.

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

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

Answer: (A) Go Back to Q14

Q15.

Solution

Concept — Polarisation and the nature of light: Only transverse waves can be polarised, so the fact that light can be polarised proves it is transverse.

Step 1 — Assertion: Polarisation demonstrates the transverse nature of light. This is **true**.

Step 2 — Reason: "Light waves are longitudinal in nature" is **false**; light is a transverse electromagnetic wave.

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 — Work function and threshold: Both statements are correct facts of the photoelectric effect, but one need not explain the other.

Step 1 — Assertion: The work function is a characteristic property that differs from metal to metal. So A is **true**.

Step 2 — Reason: Photoemission occurs only above the threshold frequency. So R is **true**.

Step 3 — Does R explain A? R is a separate correct statement about the emission condition; it does not explain *why* the work function is characteristic of the metal. So R is not the correct explanation of A.

Why other options are wrong: (A) claims a link that is not there; (C), (D) misjudge a truth value.

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

Answer: (B) Go Back to Q16

Q17.

Solution

Concept — Energy stored in a capacitor: $U = \frac{1}{2}CV^2$.

Step 1 — List the data:

$$C = 5\ \mu\text{F} = 5 \times 10^{-6}\ \text{F}, \quad V = 100\ \text{V}.$$

Step 2 — Substitute:

$$U = \frac{1}{2}(5 \times 10^{-6})(100)^2.$$
$$= \frac{1}{2}(5 \times 10^{-6})(10^4).$$

Step 3 — Evaluate:

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

Final Answer: $U = 2.5 \times 10^{-2}\ \text{J} = 0.025\ \text{J}$. **Go Back to Q17**

Q18.

Solution

Concept — Resistivity: From $R = \rho\frac{\ell}{A}$, the resistivity is $\rho = \frac{RA}{\ell}$.

Step 1 — List the data:

$$R = 0.1\ \Omega, \quad A = 1 \times 10^{-6}\ \text{m}^2, \quad \ell = 2\ \text{m}.$$

Step 2 — Substitute:

$$\rho = \frac{RA}{\ell} = \frac{(0.1)(1 \times 10^{-6})}{2}.$$

Step 3 — Evaluate:

$$\rho = \frac{1 \times 10^{-7}}{2} = 5 \times 10^{-8}\ \Omega\,\text{m}.$$

Final Answer: $\rho = 5 \times 10^{-8}\ \Omega\,\text{m}$. **Go Back to Q18**

Q19.

Solution

Concept — Induced emf: The magnitude of the emf induced in an N-turn coil is $\varepsilon = N\dfrac{\Delta\phi}{\Delta t}$.

Step 1 — List the data:

$$N = 200, \quad \Delta\phi = 4\times10^{-3}\ \text{Wb}, \quad \Delta t = 0.1\ \text{s}.$$

Step 2 — Substitute:

$$\varepsilon = 200\times\frac{4\times10^{-3}}{0.1}.$$
$$= 200\times(4\times10^{-2}).$$
$$= 8\ \text{V}.$$

Final Answer: Induced emf $= 8$ V.

OR — Quality factor:

Step 1 — Formula: $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$.

Step 2 — Substitute $L = 4$ H, $C = 1\,\mu$F, $R = 20\,\Omega$:

$$Q = \frac{1}{20}\sqrt{\frac{4}{1\times10^{-6}}}.$$
$$= \frac{1}{20}\sqrt{4\times10^{6}}.$$
$$= \frac{1}{20}(2\times10^{3}) = 100.$$

Final Answer (OR): $Q = 100$. **Go Back to Q19**

Q20.

Solution

Concept — Power of a lens: $P = \dfrac{1}{f}$, with f in metres and P in dioptres.

Step 1 — Convert the focal length:

$$f = 25\ \text{cm} = 0.25\ \text{m}.$$

Step 2 — Substitute:

$$P = \frac{1}{0.25}.$$
$$= +4 \text{ D}.$$

Final Answer: $P = +4$ D (converging lens). Go Back to Q20

Q21.

Solution

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

Step 1 — List the data:

$$h = 6.63 \times 10^{-34} \text{ J s}, \quad m = 6.4 \times 10^{-27} \text{ kg}, \quad v = 1 \times 10^{5} \text{ m/s}.$$

Step 2 — Denominator:

$$mv = (6.4 \times 10^{-27})(1 \times 10^{5}) = 6.4 \times 10^{-22}.$$

Step 3 — Divide:

$$\lambda = \frac{6.63 \times 10^{-34}}{6.4 \times 10^{-22}} = 1.04 \times 10^{-12} \text{ m}.$$

Final Answer: $\lambda \approx 1.04 \times 10^{-12}$ m.

OR — Mean life:

Step 1 — Decay constant from half-life:

$$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{10} = 0.0693 \text{ s}^{-1}.$$

Step 2 — Mean life:

$$\tau = \frac{1}{\lambda} = \frac{1}{0.0693} \approx 14.4 \text{ s}.$$

Final Answer (OR): $\tau \approx 14.4$ s. Go Back to Q21

Q22.

Solution

Concept — Potential of a charged shell: Outside, the shell behaves like a point charge; inside, since $E = 0$, the potential stays constant at its surface value.

Step 1 — Outside the shell ($r \geq R$):

$$V_{\text{out}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}.$$

Step 2 — At the surface ($r = R$):

$$V_{\text{surface}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}.$$

Step 3 — Inside the shell ($r < R$): The field inside is zero, so no work is done in moving a charge inside; the potential is constant and equal to its surface value:

$$V_{\text{in}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} \quad \text{(constant)}.$$

Step 4 — Sketch: V is flat at $\frac{kQ}{R}$ for $r \leq R$, then falls off as $1/r$ for $r > R$ (see the graph in the question).

Final Answer: $V_{\text{in}} = \frac{kQ}{R}$ (constant) and $V_{\text{out}} = \frac{kQ}{r}$, with $k = \frac{1}{4\pi\varepsilon_0}$. **Go Back to Q22**

Q23.

Solution

Concept — Galvanometer to voltmeter: A high resistance R is connected in *series* with the galvanometer so that only its full-scale current I_g flows when the desired voltage V is applied. Then $V = I_g(G + R)$.

Step 1 — Rearrange for R:

$$R = \frac{V}{I_g} - G.$$

Step 2 — List the data:

$$V = 10\text{ V}, \quad I_g = 2\text{ mA} = 2 \times 10^{-3}\text{ A}, \quad G = 50\ \Omega.$$

Step 3 — Evaluate V/I_g:

$$\frac{V}{I_g} = \frac{10}{2 \times 10^{-3}} = 5000\ \Omega.$$

Step 4 — Subtract G:

$$R = 5000 - 50 = 4950\ \Omega.$$

Final Answer: A series resistance $R = 4950\,\Omega$ is required. **Go Back to Q23**

Q24.

Solution

Concept — Magnetic dipole moment: For a coil of N turns, each of area A, carrying current I, the magnetic dipole moment is $m = NIA$; on the axis at a far distance r, the field is $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$.

Step 1 — Area of the coil:

$$A = \pi r^2 = \pi(0.05)^2 = \pi(2.5 \times 10^{-3}) = 7.85 \times 10^{-3}\ \text{m}^2.$$

Step 2 — Magnetic moment:

$$m = NIA = (10)(2)(7.85 \times 10^{-3}).$$

$$= 20 \times 7.85 \times 10^{-3}.$$

$$= 0.157\ \text{A m}^2.$$

Step 3 — Axial field expression:

$$B_{\text{axial}} = \frac{\mu_0}{4\pi}\frac{2m}{r^3}.$$

Final Answer: $m \approx 0.157\ \text{A m}^2$; the far axial field is $B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$. **Go Back to Q24**

Q25.

Solution

Concept — LCR at resonance: At resonance $X_L = X_C$, so the impedance is minimum and equal to R.

(i) Impedance:

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 0} = R = 20\ \Omega.$$

(ii) Current:

$$I = \frac{V}{Z} = \frac{220}{20}.$$
$$= 11\text{ A}.$$

Final Answer: $Z = 20\,\Omega$ and $I = 11$ A at resonance.

OR — RL circuit:

Step 1 — Impedance:

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

Step 2 — Phase angle:

$$\tan\varphi = \frac{X_L}{R} = \frac{40}{30} = \frac{4}{3}.$$
$$\varphi = \tan^{-1}\left(\frac{4}{3}\right) \approx 53^\circ \text{ (voltage leads current)}.$$

Final Answer (OR): $Z = 50\,\Omega$, $\varphi \approx 53^\circ$. **Go Back to Q25**

Q26.

Solution

Concept — Convex mirror (mirror formula): $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$. For a convex mirror the focal length is positive; the image is always virtual, erect and diminished, formed behind the mirror.

Step 1 — Assign signs: $u = -20$ cm, $f = +15$ cm.

Step 2 — Rearrange:

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{15} - \frac{1}{-20} = \frac{1}{15} + \frac{1}{20}.$$

Step 3 — Add the fractions:

$$\frac{1}{v} = \frac{4}{60} + \frac{3}{60} = \frac{7}{60}.$$

Step 4 — Invert:

$$v = \frac{60}{7} \approx +8.6 \text{ cm.}$$

The positive sign shows the image is virtual and behind the mirror.

Final Answer: $v \approx +8.6$ cm (virtual, erect, diminished).

OR — Lens combination:

Step 1 — Add the powers:

$$P = P_1 + P_2 = (+4) + (+6) = +10 \text{ D.}$$

Step 2 — Focal length:

$$f = \frac{1}{P} = \frac{1}{10} = 0.1 \text{ m} = +10 \text{ cm.}$$

Final Answer (OR): $P = +10$ D; $f = +10$ cm. **Go Back to Q26**

Q27.

Solution

Concept — Hydrogen energy levels: $E_n = -\frac{13.6}{n^2}$ eV. The ionisation energy from a level is the energy needed to raise the electron from that level to $n = \infty$ (where $E = 0$).

(i) First excited state ($n = 2$):

$$E_2 = -\frac{13.6}{2^2} = -\frac{13.6}{4}.$$

$$= -3.4 \text{ eV.}$$

(ii) Ionisation energy from $n = 2$:

$$E_{\text{ion}} = E_\infty - E_2 = 0 - (-3.4).$$

$$= 3.4 \text{ eV.}$$

Final Answer: $E_2 = -3.4$ eV; energy to ionise from $n = 2$ is 3.4 eV. **Go Back to Q27**

Q28.

Solution

Concept — Combining gates: An AND gate first forms the product $A \cdot B$; an OR gate then adds C to give $Y = A \cdot B + C$.

Step 1 — Circuit logic: Feed A and B into the AND gate; its output $A \cdot B$ and the input C go into the OR gate, whose output is Y (see the diagram in the question).

Step 2 — Boolean output:

$$Y = (A \cdot B) + C.$$

Step 3 — Truth table:

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

Final Answer: $Y = A \cdot B + C$; output is 1 whenever $C = 1$ or both A and B are 1.
Go Back to Q28

Q29.

Solution

Concept — Dipole in a uniform field: Torque $\tau = pE \sin\theta$ and potential energy $U = -pE\cos\theta$.

(i) Torque expression:

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

(ii) Maximum torque: $\sin\theta$ is greatest at $\theta = 90^\circ$, so the torque is maximum when the dipole is perpendicular to the field.

(iii) Numerical values: With $p = 2 \times 10^{-9}$ C m, $E = 1 \times 10^{5}$ N/C, $\theta = 30^\circ$:

$$\tau = pE \sin 30^\circ = (2 \times 10^{-9})(1 \times 10^{5})(0.5).$$

$$= (2 \times 10^{-4})(0.5) = 1 \times 10^{-4} \text{ N m}.$$

$$U = -pE\cos 30^\circ = -(2\times 10^{-9})(1\times 10^{5})(0.866).$$
$$= -(2\times 10^{-4})(0.866) = -1.73\times 10^{-4}\ \text{J}.$$

Final Answer: $\tau = pE\sin\theta$; maximum at $\theta = 90^\circ$; here $\tau = 1\times 10^{-4}$ N m and $U = -1.73\times 10^{-4}$ J. Go Back to Q29

Q30.

Solution

Concept — Series LCR impedance: $Z = \sqrt{R^2 + (X_L - X_C)^2}$ and $I = \dfrac{V}{Z}$. At resonance $X_L = X_C$ so $Z = R$.

(i) Impedance formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}.$$

(ii) Impedance value:

$$X_L - X_C = 12 - 4 = 8\ \Omega.$$
$$Z = \sqrt{6^2 + 8^2} = \sqrt{36 + 64} = \sqrt{100} = 10\ \Omega.$$

(iii) Current and resonance:

$$I = \frac{V}{Z} = \frac{20}{10} = 2\ \text{A}.$$

At resonance $X_L = X_C$, so

$$Z_{\text{res}} = R = 6\ \Omega, \qquad I_{\text{res}} = \frac{20}{6} \approx 3.33\ \text{A}.$$

Final Answer: $Z = 10\,\Omega$, $I = 2$ A; at resonance $Z = 6\,\Omega$ and $I \approx 3.33$ A. Go Back to Q30

Q31.

Solution

Concept — Capacitor with a dielectric slab: The gap d splits into an air part $(d-t)$ and a dielectric part t; the slab reduces the effective field over its thickness.

(a) Derivation: The potential difference across the plates is the sum over the air and dielectric regions:

$$V = E_0(d-t) + \frac{E_0}{K}\,t, \qquad E_0 = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}.$$

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

Hence

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

(b) Numerical: $A = 2 \times 10^{-2}$ m^2, $d = 2 \times 10^{-3}$ m, $t = 1 \times 10^{-3}$ m, $K = 5$:

$$d - t + \frac{t}{K} = 2 \times 10^{-3} - 1 \times 10^{-3} + \frac{1 \times 10^{-3}}{5}.$$

$$= 1 \times 10^{-3} + 0.2 \times 10^{-3} = 1.2 \times 10^{-3}\ \text{m}.$$

$$C = \frac{(8.85 \times 10^{-12})(2 \times 10^{-2})}{1.2 \times 10^{-3}}.$$

$$= \frac{1.77 \times 10^{-13}}{1.2 \times 10^{-3}} = 1.48 \times 10^{-10}\ \text{F}.$$

Final Answer: $C = \dfrac{\varepsilon_0 A}{d - t + t/K} \approx 1.48 \times 10^{-10}$ F (≈ 148 pF).

OR — Potentiometer vs voltmeter:

(a) At balance the potentiometer draws *no* current from the cell, so it measures the true emf; a voltmeter draws some current and reads only the terminal voltage, which is less than the emf by the drop Ir. The potentiometer thus behaves like an ideal voltmeter of infinite resistance and is more accurate.

(b) emf = (potential gradient) × (balancing length):

$$\varepsilon = (0.2)(2.5) = 0.5\ \text{V}.$$

Final Answer (OR): The potentiometer measures true emf as it draws no current; $\varepsilon = 0.5$ V. **Go Back to Q31**

Q32.

Solution

Concept — Motional emf: As the rod sweeps out area, the flux through the circuit changes, inducing an emf $\varepsilon = Blv$.

(a) Derivation: In time dt the rod of length l moving at speed v sweeps an area $dA = l\,v\,dt$. The flux change is

$$d\phi = B\,dA = B\,l\,v\,dt.$$

By Faraday's law the magnitude of the induced emf is

$$\varepsilon = \frac{d\phi}{dt} = Blv.$$

(Equivalently, the magnetic force on a free charge q in the rod is qvB, giving a motional field vB and emf Blv.)

(b) Numerical: $B = 0.2$ T, $l = 0.5$ m, $v = 4$ m/s:

$$\varepsilon = Blv = (0.2)(0.5)(4).$$

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

With total resistance $R = 2\,\Omega$:

$$I = \frac{\varepsilon}{R} = \frac{0.4}{2} = 0.2\text{ A}.$$

Final Answer: $\varepsilon = Blv = 0.4$ V and $I = 0.2$ A.

OR — RL vs RC circuits:

(a) Series RL: $Z = \sqrt{R^2 + X_L^2}$; the voltage *leads* the current by $\varphi = \tan^{-1}(X_L/R)$. Series RC: $Z = \sqrt{R^2 + X_C^2}$; the current *leads* the voltage by $\varphi = \tan^{-1}(X_C/R)$.

(b) For $R = 30\,\Omega$, $X_L = 40\,\Omega$:

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

$$\varphi = \tan^{-1}\left(\frac{40}{30}\right) = 53^\circ\ \text{(voltage leads current)}.$$

Final Answer (OR): $Z = 50\,\Omega$, $\varphi = 53°$. Go Back to Q32

Q33.

Solution

Concept — Dispersion by a prism: A prism bends violet light more than red because the refractive index depends on wavelength, so white light spreads into a spectrum. The dispersive power is $\omega = \dfrac{\mu_V - \mu_R}{\mu_y - 1}$.

(a) Explanation: Since μ is largest for violet and smallest for red, the deviation is greatest for violet and least for red; the difference in deviation $(\delta_V - \delta_R)$ is the angular dispersion. Dispersive power measures the spreading relative to the mean deviation:

$$\omega = \frac{\delta_V - \delta_R}{\delta_y} = \frac{\mu_V - \mu_R}{\mu_y - 1}.$$

(b) Numerical: $\mu_V = 1.53$, $\mu_R = 1.51$, $\mu_y = 1.52$:

$$\mu_V - \mu_R = 1.53 - 1.51 = 0.02.$$

$$\mu_y - 1 = 1.52 - 1 = 0.52.$$

$$\omega = \frac{0.02}{0.52} \approx 0.0385.$$

Final Answer: $\omega = \dfrac{\mu_V - \mu_R}{\mu_y - 1} \approx 0.038.$

OR — Huygens' principle and reflection:

(a) Huygens' principle: every point on a wavefront acts as a source of secondary wavelets that spread out in the forward direction with the wave speed; the new wavefront is the forward tangent (envelope) of these wavelets. Applying it to a plane wavefront striking a plane mirror, the incident and reflected wavefronts and the surface form two congruent right triangles with a common hypotenuse and equal speeds, giving equal legs; hence the angle of incidence equals the angle of reflection, $\angle i = \angle r$.

(b) By this law, for an angle of incidence of 25° the angle of reflection is also

$$\angle r = \angle i = 25^\circ.$$

Final Answer (OR): Huygens' construction gives $\angle i = \angle r$, so the angle of reflection is 25°. Go Back to Q33

Answer Key – Section A (Q1–Q16)

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

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