CBSE Class 12 Physics

Sample Paper – 8

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

General Instructions

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

Section A (Q1–Q16) – 1 Mark Each

Q1. Two point charges $q_1 = +2\,\mu$C and $q_2 = +3\,\mu$C are held 6 cm apart in vacuum. The electric potential energy of this two-charge system is (take $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ SI units):

(A) 0.45 J

(B) 1.8 J

(C) 5.4 J

(D) 0.9 J

Q2. A resistance of $8\,\Omega$ is joined in series with the parallel combination of a $3\,\Omega$ and a $6\,\Omega$ resistor. The equivalent resistance of the whole combination is:

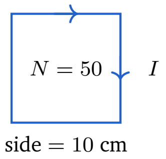
(A) $17\,\Omega$

(B) $10\,\Omega$

(C) $2\,\Omega$

(D) $4\,\Omega$

Q3. A square current loop of side 10 cm has $N = 50$ turns and carries a current $I = 2$ A, as shown. The magnitude of its magnetic dipole moment $m = NIA$ is:



(A) $0.5\ \mathrm{A\,m^2}$

(B) $2\ \mathrm{A\,m^2}$

(C) $1\ \mathrm{A\,m^2}$

(D) $10\ \mathrm{A\,m^2}$

Q4. A coil of 200 turns experiences a change in magnetic flux of 0.02 Wb through each turn in 0.1 s. The magnitude of the emf induced in the coil, $\varepsilon = N\dfrac{d\phi}{dt}$, is:

(A) 4 V

(B) 20 V

(C) 400 V

(D) 40 V

Q5. For an ideal transformer with N_p turns in the primary and N_s turns in the secondary, the correct relation between the voltages is:

(A) $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$

(B) $\dfrac{V_s}{V_p} = \dfrac{N_p}{N_s}$

(C) $\dfrac{V_s}{V_p} = \left(\dfrac{N_s}{N_p}\right)^2$

(D) $V_s V_p = N_s N_p$

Q6. In a plane electromagnetic wave travelling through free space, the electric field $\vec{E}$, the magnetic field $\vec{B}$ and the direction of propagation are:

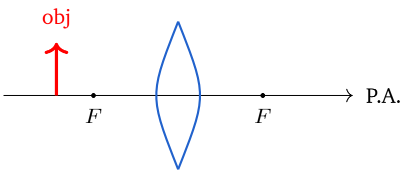
(A) all parallel to one another

(B) such that $\vec{E}$ is parallel to $\vec{B}$

(C) such that $\vec{E}$ and $\vec{B}$ are parallel, both perpendicular to the propagation

(D) mutually perpendicular to one another

Q7. For a real object placed at any position in front of a concave (diverging) lens, as shown, the image formed is always:



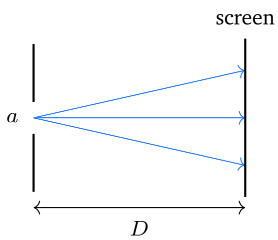
(A) real, inverted and magnified

(B) virtual, erect and diminished

(C) real, inverted and diminished

(D) virtual, erect and magnified

Q8. In single-slit diffraction with slit width a and slit-to-screen distance D, the width of the central bright maximum for light of wavelength λ is:



(A) $\dfrac{\lambda D}{a}$

(B) $\dfrac{\lambda D}{2a}$

(C) $\dfrac{2\lambda D}{a}$

(D) $\dfrac{aD}{2\lambda}$

Q9. In a photoelectric experiment the frequency of the incident light is kept fixed while its intensity is increased. The maximum kinetic energy of the emitted photoelectrons will:

(A) increase in proportion to the intensity

(B) decrease with the intensity

(C) increase because the stopping potential rises

(D) remain unchanged

Q10. The energy released when a mass defect of 0.1 u is completely converted into energy is (take 1 u $= 931.5$ MeV$/c^2$):

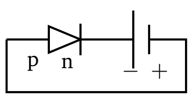
(A) 9.31 MeV

(B) 931 MeV

(C) 93.2 MeV

(D) 0.10 MeV

Q11. The p-n junction diode in the circuit below is connected in reverse bias. Compared with the unbiased junction, the width of the depletion region:



(A) increases

(B) decreases

(C) becomes zero

(D) remains unchanged

Q12. An isolated spherical conductor of radius $R = 9$ cm carries a charge. Its capacitance $C = 4\pi\varepsilon_0 R$ is (take $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ SI units):

(A) 5 pF

(B) 10 pF

(C) 1 pF

(D) 90 pF

Q13. Assertion (A): In the steady state a charged capacitor blocks a direct current.
Reason (R): The capacitive reactance $X_C = \frac{1}{\omega C}$ tends to infinity as the frequency $\omega \to 0$.

(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): At resonance the impedance of a series LCR circuit is minimum.
Reason (R): At resonance the current drawn from the source is maximum.

(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): Myopia (short-sightedness) is corrected by using a concave lens.
Reason (R): A concave lens diverges the incident rays so that the image of a distant object is formed on the retina.

(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):** Alpha particles are the least penetrating of the three common nuclear radiations.
Reason (R): Alpha particles are heavy, doubly charged, and travel faster than beta particles.

(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. Three capacitors $C_1 = 6\,\mu$F, $C_2 = 3\,\mu$F and $C_3 = 4\,\mu$F are connected such that C_1 and C_2 are in series, and this series combination is in parallel with C_3. Find the equivalent capacitance of the network. **[2]**

Q18. In a balanced Wheatstone bridge the four arms carry resistances $P = 10\,\Omega$, $Q = 20\,\Omega$, $R = 15\,\Omega$ and an unknown S. Using the balance condition, find the value of S. **[2]**

Q19. The current through a coil changes from 0 to 4 A in 0.2 s and induces an emf of 10 V across it. Calculate the self-inductance of the coil. **[2]**

OR

An ideal transformer has 200 turns in the primary and 50 turns in the secondary. If the primary carries a current of 2 A, find the current in the secondary.

Q20. A coin lies at the bottom of a tank containing water ($\mu = 4/3$) to a real depth of 8 cm. Find the apparent depth of the coin as seen by an observer looking normally from above. **[2]**

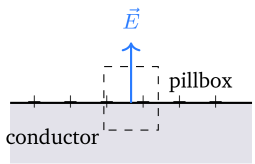
Q21. Calculate the momentum of a photon of light of wavelength 5000 Å. (Take $h = 6.63 \times 10^{-34}$ J s.) **[2]**

OR

The total binding energy of a nucleus of mass number 56 is 490 MeV. Find its binding energy per nucleon.

Section C (Q22–Q28) – 3 Marks Each

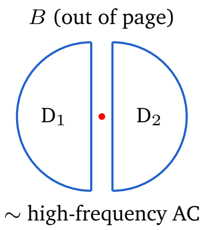
Q22. Using a Gaussian pillbox, derive the expression for the electric field just outside the surface of a charged conductor carrying a surface charge density σ.



[3]

Q23. Explain, with the relevant expression, how a galvanometer is converted into an ammeter using a shunt. A galvanometer of resistance 100 Ω gives a full-scale deflection for a current of 1 mA. Find the shunt resistance required to convert it into an ammeter of range 1 A. **[3]**

Q24. With the help of a labelled diagram, state the principle and describe the working of a cyclotron. Write the expression for the cyclotron frequency.



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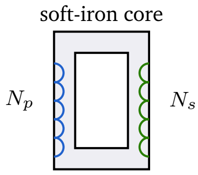
Q25. A step-down transformer has 1000 turns in the primary and 100 turns in the secondary. The primary is connected to a 220 V AC supply and draws a current of 0.5 A. Assuming the transformer is ideal, find the secondary voltage and the secondary current.



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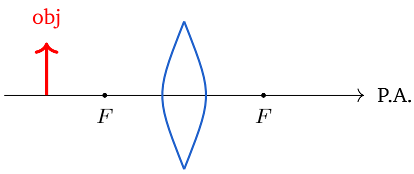
OR

Derive the expression for the energy stored in an inductor carrying a steady current. A coil of self-inductance 2 H carries a steady current of 3 A. Find the energy stored in its magnetic field.

Q26. Draw a ray diagram to show the image formed by a concave lens for a real object. An object is placed 30 cm in front of a concave lens of focal length 15 cm. Using the lens formula, find the position and nature of the image.



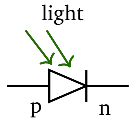
[3]

OR

Define critical angle and state the conditions for total internal reflection. The refractive index of a certain glass is 1.5. Calculate the critical angle for a glass-air interface. (Take $\sin^{-1}(0.667) \approx 41.8°$.)

Q27. In a nuclear reaction the total rest mass of the reactants exceeds that of the products by a mass defect $\Delta m = 0.0186$ u. Calculate the Q-value of the reaction in MeV and state whether energy is released or absorbed. (Take 1 u $= 931.5$ MeV$/c^2$.) **[3]**

Q28. With the help of a labelled symbol, explain the working of a photodiode (including its mode of biasing) and state one application of it.



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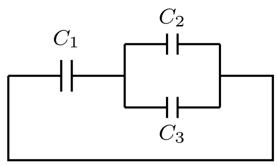
Section D (Q29–Q30) – 4 Marks Each (Case Study)

Q29. Case Study – Series–Parallel Capacitor Network.

A student connects three capacitors $C_1 = 2\,\mu\text{F}$, $C_2 = 2\,\mu\text{F}$ and $C_3 = 4\,\mu\text{F}$. First C_2 and C_3 are joined in parallel, and this parallel combination is then joined in series with C_1 across a 12 V battery, as shown.



Based on the above, answer the following:

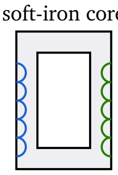
(i) Find the equivalent capacitance of C_2 and C_3 in parallel. (1)

(ii) Find the total equivalent capacitance of the circuit. (1)

(iii) Find the total charge drawn from the battery and the total energy stored. (2)

Q30. Case Study – The Transformer.

An ideal transformer used in a laboratory has 1000 turns in the primary and 200 turns in the secondary. The primary is connected to a 240 V AC mains, and the secondary supplies a device that draws a current of 2 A.



Based on the above, answer the following:

(i) Find the turns ratio $\dfrac{N_s}{N_p}$ and state whether it is a step-up or step-down transformer. (1)

(ii) Find the secondary (output) voltage. (1)

(iii) Find the primary current and the power delivered to the load. (2)

Section E (Q31–Q33) – 5 Marks Each

Q31. (a) Three capacitors $C_1 = 1\,\mu$F, $C_2 = 2\,\mu$F and $C_3 = 3\,\mu$F are arranged so that C_2 and C_3 are in parallel and this combination is in series with C_1 across a 12 V battery. Find the charge on each capacitor and the total energy stored.

(b) State how the total charge is distributed between C_2 and C_3. **[5]**

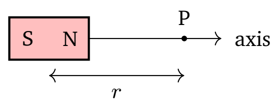
OR

(a) Explain the principle of a potentiometer and state why it 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. Find the emf of a cell that is balanced at a length of 250 cm on this wire.

Q32. (a) Show that a bar magnet behaves as a magnetic dipole and write the expression for the magnetic field on its axial line at a distance r from its centre.

(b) A short bar magnet of magnetic moment $0.4\,\text{A}\,\text{m}^2$ is placed on a table. Find the magnetic field at a point on its axis 0.2 m from its centre. (Take $\frac{\mu_0}{4\pi} = 10^{-7}$ SI units.)



[5]

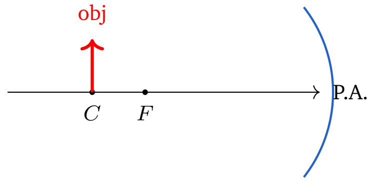
OR

(a) Define resonance in a series LCR circuit and derive the expression for the quality factor Q.

(b) A series LCR circuit has $L = 0.5$ H, $C = 2\,\mu$F and $R = 5\,\Omega$. Find its resonant angular frequency ω_0 and its quality factor Q.

Q33. (a) Draw a ray diagram and derive the mirror formula $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ for a concave mirror.

(b) An object is placed 30 cm in front of a concave mirror of focal length 15 cm. Find the position, nature and magnification of the image.



[5]

OR

(a) For refraction through a prism, derive the relation $A + \delta = i + e$ and hence obtain the prism formula $\mu = \dfrac{\sin\left(\dfrac{A+\delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$.

(b) State how the angle of deviation varies with the angle of incidence and mark the position of minimum deviation on the graph.

Detailed Solutions

Q1.

Solution

Concept — Potential energy of two point charges: The energy of the pair is $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$.

Step 1 — List the data:

$$q_1 = 2\times10^{-6}\ \text{C},\quad q_2 = 3\times10^{-6}\ \text{C},\quad r = 0.06\ \text{m}.$$

Step 2 — Product of the charges:

$$q_1q_2 = (2\times10^{-6})(3\times10^{-6}) = 6\times10^{-12}\ \text{C}^2.$$

Step 3 — Divide by the separation:

$$\frac{q_1q_2}{r} = \frac{6\times10^{-12}}{0.06} = 1\times10^{-10}.$$

Step 4 — Multiply by the constant:

$$U = (9\times10^{9})(1\times10^{-10}) = 0.9\ \text{J}.$$

Why other options are wrong: (A) 0.45 J halves the correct value; (B) 1.8 J doubles it; (C) 5.4 J uses r in cm.

Final Answer: $U = 0.9$ J $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q1

Q2.

Solution

Concept — Series and parallel resistances: Parallel resistors combine as $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$; series resistances add.

Step 1 — Parallel combination of $3\,\Omega$ and $6\,\Omega$:

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

$$R_p = 2\ \Omega.$$

Step 2 — Add the series $8\,\Omega$:

$$R_{eq} = 8 + 2 = 10\ \Omega.$$

Why other options are wrong: (A) $17\,\Omega$ adds all three in series; (C) $2\,\Omega$ is only the parallel part; (D) $4\,\Omega$ mis-adds.

Final Answer: $R_{eq} = 10\,\Omega \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q2

Q3.

Solution

Concept — Magnetic dipole moment of a loop: $m = NIA$, where A is the area of one turn.

Step 1 — Area of the square loop:

$$A = (0.1)^2 = 0.01\ \text{m}^2.$$

Step 2 — Substitute into $m = NIA$:

$$m = (50)(2)(0.01).$$

Step 3 — Multiply:

$$m = 50 \times 2 \times 0.01 = 1\ \text{A}\,\text{m}^2.$$

Why other options are wrong: (A) 0.5 uses $N = 25$; (B) 2 drops the area factor; (D) 10 takes the side in metres wrongly.

Final Answer: $m = 1\ \text{A}\,\text{m}^2 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q3

Q4.

Solution

Concept — Faraday's law with N turns: $|\varepsilon| = N\dfrac{d\phi}{dt}$.

Step 1 — Rate of change of flux per turn:

$$\frac{d\phi}{dt} = \frac{0.02}{0.1} = 0.2 \text{ Wb/s}.$$

Step 2 — Multiply by the number of turns:

$$|\varepsilon| = N\frac{d\phi}{dt} = 200 \times 0.2.$$
$$= 40 \text{ V}.$$

Why other options are wrong: (A) 4 V drops a factor of 10; (B) 20 V forgets the turns; (C) 400 V multiplies instead of dividing by time.

Final Answer: $|\varepsilon| = 40 \text{ V} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — Ideal transformer: The induced emf per turn is the same in both windings, so the voltages are in the ratio of the turns.

Step 1 — emf per turn is common:

$$\frac{V_p}{N_p} = \frac{V_s}{N_s}.$$

Step 2 — Rearrange:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}.$$

Why other options are wrong: (B) inverts the turns ratio; (C) wrongly squares it; (D) is dimensionally incorrect.

Final Answer: $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept — Transverse nature of EM waves: In an electromagnetic wave $\vec{E}$, $\vec{B}$ and the direction of propagation $\hat{k}$ form a mutually perpendicular right-handed set.

Step 1 — Field orientation: $\vec{E} \perp \vec{B}$, and both are perpendicular to the direction of travel.

Step 2 — Right-hand rule: The wave propagates along $\vec{E} \times \vec{B}$, confirming all three are mutually perpendicular.

Why other options are wrong: (A) and (B) make the fields parallel; (C) wrongly makes $\vec{E}$ and $\vec{B}$ parallel.

Final Answer: $\vec{E}$, $\vec{B}$ and $\hat{k}$ mutually perpendicular $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept — Image in a concave (diverging) lens: A diverging lens always forms a virtual, erect and diminished image between the object and the lens, on the same side as the object.

Step 1 — Ray behaviour: Rays from the object diverge after passing through the lens; their backward extensions meet on the object side.

Step 2 — Nature of the image: The virtual image is upright and smaller than the object, for every real object position.

Why other options are wrong: (A) and (C) claim a real image, impossible for a concave lens with a real object; (D) claims magnification, which never occurs.

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

Answer: (B) Go Back to Q7

Q8.

Solution

Concept — Single-slit central maximum: The first minima on either side of the centre lie at $\sin\theta = \pm\frac{\lambda}{a}$, so the angular width of the central maximum is $\frac{2\lambda}{a}$.

Step 1 — Linear half-width: On a screen at distance D, the first minimum is at $y = \frac{\lambda D}{a}$.

Step 2 — Full width of the central maximum: It spans from $-y$ to $+y$:

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

Why other options are wrong: (A) gives only half the width; (B) halves it again; (D) inverts the roles of a and λ.

Final Answer: Width $= \frac{2\lambda D}{a} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q8

Q9.

Solution

Concept — Photoelectric effect: The maximum kinetic energy $K_{\max} = h\nu - W$ depends only on the frequency, not on the intensity.

Step 1 — Fixed frequency: With ν unchanged, $h\nu$ is fixed and W is a property of the metal, so $K_{\max}$ is unchanged.

Step 2 — Role of intensity: Higher intensity means more photons per second, so more photoelectrons per second, but each still gains the same maximum energy.

Why other options are wrong: (A),(B) tie $K_{\max}$ to intensity; (C) the stopping potential depends on frequency, not intensity.

Final Answer: $K_{\max}$ remains unchanged $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept — Mass-energy equivalence: A mass defect Δm releases energy $E = \Delta m\, c^2$; using 1 u $= 931.5$ MeV$/c^2$, $E = \Delta m$ (in u) $\times$ 931.5 MeV.

Step 1 — Insert the mass defect:

$$E = 0.1 \times 931.5 \text{ MeV}.$$

Step 2 — Multiply:

$$E = 93.15 \text{ MeV} \approx 93.2 \text{ MeV}.$$

Why other options are wrong: (A) 9.31 MeV divides by an extra 10; (B) 931 MeV uses $\Delta m = 1$ u; (D) 0.10 MeV omits the 931.5 factor.

Final Answer: $E \approx 93.2$ MeV $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q10

Q11.

Solution

Concept — Reverse-biased junction: In reverse bias the external field aids the barrier field, pulling majority carriers away from the junction and widening the depletion region.

Step 1 — Biasing: The p-side is at the lower potential and the n-side at the higher potential.

Step 2 — Effect on depletion width: Majority carriers are drawn towards the terminals, exposing more immobile ions, so the depletion layer becomes wider and the barrier potential increases.

Why other options are wrong: (B) decreasing width happens in forward bias; (C) it never becomes zero; (D) it does change.

Final Answer: The depletion region increases $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept — Capacitance of an isolated sphere: $C = 4\pi\varepsilon_0 R = \dfrac{R}{1/(4\pi\varepsilon_0)}$.

Step 1 — List the data:

$$R = 0.09\ \text{m}, \qquad \frac{1}{4\pi\varepsilon_0} = 9\times10^9.$$

Step 2 — Substitute:

$$C = \frac{R}{9\times10^9} = \frac{0.09}{9\times10^9}.$$

Step 3 — Simplify:

$$C = 1\times10^{-11}\ \text{F} = 10\ \text{pF}.$$

Why other options are wrong: (A) 5 pF halves the value; (C) 1 pF uses R in cm; (D) 90 pF misplaces the power of ten.

Final Answer: $C = 10$ pF $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept — Capacitor in a DC circuit: Evaluate the assertion and reason, then decide whether R explains A.

Step 1 — Assertion: Once a capacitor is fully charged, no steady current flows through it; it blocks DC. So A is **true**.

Step 2 — Reason: The capacitive reactance is $X_C = \dfrac{1}{\omega C}$. For DC the frequency $\omega \to 0$, so $X_C \to \infty$. So R is **true**.

Step 3 — Does R explain A? An infinite reactance means zero current, which is exactly why the capacitor blocks DC. So R correctly explains A.

Why other options are wrong: (B) denies the genuine 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 — Series resonance: At resonance $X_L = X_C$, so $Z = R$ is minimum and the current is maximum.

Step 1 — Assertion: At resonance the net reactance is zero, so the impedance $Z = R$ is minimum. So A is **true**.

Step 2 — Reason: Because Z is minimum, the current $I = \dfrac{V}{Z}$ is maximum. So R is **true**.

Step 3 — Does R explain A? The maximum current is a *consequence* of the minimum impedance, not its cause. So R does not explain A; the true cause is $X_L = X_C$.

Why other options are wrong: (A) claims R explains A, but it only follows from it; (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 — Correction of myopia: A myopic eye focuses distant objects in front of the retina; a diverging (concave) lens is used to correct it.

Step 1 — Assertion: Myopia is corrected using a concave lens. So A is **true**.

Step 2 — Reason: A concave lens diverges the incoming rays before they enter the eye, so the eye lens then focuses them exactly on the retina. So R is **true**.

Step 3 — Does R explain A? The diverging action shifting the image onto the retina is precisely why the concave lens corrects myopia. So R correctly explains A.

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

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

Answer: (A) Go Back to Q15

Q16.

Solution

Concept — Penetrating power of radiations: Alpha particles are heavy and doubly charged, so they ionise strongly and lose energy rapidly, giving them the least penetrating power.

Step 1 — Assertion: Alpha particles are the least penetrating of α, β and γ. So A is **true**.

Step 2 — Reason: Alpha particles are indeed heavy and doubly charged, but the claim that they "travel faster than beta particles" is **false**; alpha particles are much slower than beta particles.

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

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

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

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

Q17.

Solution

Concept — Mixed capacitor network: Series capacitors follow reciprocal addition; parallel capacitors add directly.

Step 1 — Series of C_1 and C_2:

$$\frac{1}{C_{12}} = \frac{1}{6} + \frac{1}{3} = \frac{1+2}{6} = \frac{3}{6} = \frac{1}{2}.$$

$$C_{12} = 2\ \mu\text{F}.$$

Step 2 — Parallel with C_3:

$$C_{eq} = C_{12} + C_3 = 2 + 4 = 6\ \mu\text{F}.$$

Final Answer: Equivalent capacitance $= 6\,\mu$F. **Go Back to Q17**

Q18.

Solution

Concept — Balanced Wheatstone bridge: At balance the galvanometer current is zero and $\frac{P}{Q} = \frac{R}{S}$.

Step 1 — Write the balance condition:

$$\frac{P}{Q} = \frac{R}{S}.$$

Step 2 — Substitute the known values:

$$\frac{10}{20} = \frac{15}{S}.$$

Step 3 — Solve for S:

$$S = 15 \times \frac{20}{10} = 15 \times 2 = 30\ \Omega.$$

Final Answer: Unknown resistance $S = 30\,\Omega$. **Go Back to Q18**

Q19.

Solution

Concept — Self-induced emf: The magnitude of the back-emf is $\varepsilon = L\frac{dI}{dt}$.

Step 1 — Rate of change of current:

$$\frac{dI}{dt} = \frac{4-0}{0.2} = 20\ \text{A/s}.$$

Step 2 — Solve for L:

$$L = \frac{\varepsilon}{dI/dt} = \frac{10}{20}.$$
$$= 0.5\ \text{H}.$$

Final Answer: Self-inductance $L = 0.5$ H.

OR — Secondary current of an ideal transformer:

Step 1 — Current ratio: For an ideal transformer $\frac{I_s}{I_p} = \frac{N_p}{N_s}$.

Step 2 — Substitute:

$$I_s = I_p \times \frac{N_p}{N_s} = 2 \times \frac{200}{50} = 2 \times 4 = 8\ \text{A}.$$

Final Answer (OR): Secondary current $= 8$ A. **Go Back to Q19**

Q20.

Solution

Concept — Apparent depth: For normal viewing, apparent depth $= \dfrac{\text{real depth}}{\mu}$.

Step 1 — List the data:

$$\text{real depth} = 8\ \text{cm}, \qquad \mu = \frac{4}{3}.$$

Step 2 — Substitute:

$$\text{apparent depth} = \frac{8}{4/3} = 8 \times \frac{3}{4}.$$

Step 3 — Simplify:

$$= \frac{24}{4} = 6\ \text{cm}.$$

Final Answer: Apparent depth $= 6$ cm (the coin appears raised by 2 cm). **Go Back to Q20**

Q21.

Solution

Concept — Momentum of a photon: $p = \dfrac{h}{\lambda}$.

Step 1 — Convert the wavelength:

$$\lambda = 5000\ \text{Å} = 5000 \times 10^{-10}\ \text{m} = 5 \times 10^{-7}\ \text{m}.$$

Step 2 — Substitute:

$$p = \frac{6.63 \times 10^{-34}}{5 \times 10^{-7}}.$$

Step 3 — Divide:

$$p = 1.326 \times 10^{-27}\ \text{kg m/s}.$$

Final Answer: $p \approx 1.33 \times 10^{-27}$ kg m/s.

OR — Binding energy per nucleon:

Step 1 — Recall the definition: BE per nucleon $= \dfrac{\text{total BE}}{A}$.

Step 2 — Substitute:

$$\frac{490}{56} = 8.75 \text{ MeV}.$$

Final Answer (OR): Binding energy per nucleon $= 8.75$ MeV. **Go Back to Q21**

Q22.

Solution

Concept — Gauss's law at a conductor surface: Just outside a charged conductor the field is normal to the surface; a small pillbox gives its magnitude.

Step 1 — Choose a pillbox: Take a small cylinder (pillbox) of cross-sectional area ΔS with one flat face just outside the surface and the other just inside the conductor.

Step 2 — Flux through the pillbox: Inside the conductor $\vec{E} = 0$, and along the curved side $\vec{E}$ is parallel to the surface. Only the outer face contributes:

$$\oint \vec{E} \cdot d\vec{A} = E\,\Delta S.$$

Step 3 — Charge enclosed: The charge on the patch of surface is

$$q_{\text{enc}} = \sigma\,\Delta S.$$

Step 4 — Apply Gauss's law:

$$E\,\Delta S = \frac{\sigma\,\Delta S}{\varepsilon_0}.$$

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

Final Answer: The field just outside a charged conductor is $E = \dfrac{\sigma}{\varepsilon_0}$, directed normal to the surface. **Go Back to Q22**

Q23.

Solution

Concept — Ammeter from a galvanometer: A low resistance (shunt) S is connected in parallel with the galvanometer so that most of the current bypasses it.

Step 1 — Current split: At full-scale deflection the galvanometer carries I_g; the remaining $(I - I_g)$ passes through the shunt. Equal voltage across both:

$$I_g G = (I - I_g) S.$$

Step 2 — Expression for the shunt:

$$S = \frac{I_g G}{I - I_g}.$$

Step 3 — Substitute the numbers: $G = 100\,\Omega$, $I_g = 1 \times 10^{-3}$ A, $I = 1$ A:

$$S = \frac{(1 \times 10^{-3})(100)}{1 - 1 \times 10^{-3}}.$$

$$= \frac{0.1}{0.999} \approx 0.1\ \Omega.$$

Final Answer: A shunt of about $0.1\,\Omega$ (in parallel) is required. **Go Back to Q23**

Q24.

Solution

Concept — Cyclotron: It accelerates charged particles to high energies using a perpendicular magnetic field and an alternating electric field.

Step 1 — Principle: A charged particle moving perpendicular to a uniform magnetic field travels in a circular arc; the time for a half-circle is independent of the speed, so a fixed-frequency alternating voltage can repeatedly accelerate it.

Step 2 — Working: Two hollow D-shaped electrodes (dees) are kept in the field. Each time the particle crosses the gap between the dees, the alternating voltage accelerates it; inside a dee it moves in a semicircle of increasing radius.

Step 3 — Cyclotron frequency: From $qvB = \frac{mv^2}{r}$, the period is $T = \frac{2\pi m}{qB}$, so

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

Final Answer: The cyclotron frequency is $f = \dfrac{qB}{2\pi m}$, independent of the particle's speed and radius. Go Back to Q24

Q25.

Solution

Concept — Ideal transformer relations: $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$ and, from power conservation, $V_p I_p = V_s I_s$.

Step 1 — Secondary voltage:

$$V_s = V_p \times \frac{N_s}{N_p} = 220 \times \frac{100}{1000}.$$

$$= 220 \times 0.1 = 22 \text{ V}.$$

Step 2 — Secondary current (power conservation):

$$V_p I_p = V_s I_s.$$

$$I_s = \frac{V_p I_p}{V_s} = \frac{220 \times 0.5}{22}.$$

$$= \frac{110}{22} = 5 \text{ A}.$$

Final Answer: $V_s = 22$ V and $I_s = 5$ A.

OR — Energy stored in an inductor:

Step 1 — Derivation: The power delivered against the back-emf is $P = \varepsilon I = LI\dfrac{dI}{dt}$. The energy is

$$U = \int_0^I LI\, dI = \frac{1}{2}LI^2.$$

Step 2 — Substitute $L = 2$ H, $I = 3$ A:

$$U = \frac{1}{2}(2)(3)^2 = \frac{1}{2}(2)(9) = 9 \text{ J}.$$

Final Answer (OR): $U = \dfrac{1}{2}LI^2 = 9$ J. Go Back to Q25

Q26.

Solution

Concept — Lens formula for a concave lens: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, with f negative for a concave lens.

Step 1 — Assign signs: $u = -30$ cm, $f = -15$ cm.

Step 2 — Substitute:

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-15} + \frac{1}{-30}.$$

Step 3 — Simplify:

$$\frac{1}{v} = -\frac{2}{30} - \frac{1}{30} = -\frac{3}{30} = -\frac{1}{10}.$$

$$v = -10 \text{ cm}.$$

The negative sign shows the image is virtual, on the same side as the object; it is erect and diminished.

Final Answer: $v = -10$ cm; image is virtual, erect and diminished.

OR — Critical angle:

Step 1 — Definition and conditions: The critical angle θ_c is the angle of incidence in the denser medium for which the refracted ray grazes the surface (90°). Total internal reflection needs (i) light going from denser to rarer medium and (ii) angle of incidence $> \theta_c$.

Step 2 — Relation with refractive index:

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

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

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

Q27.

Solution

Concept — Q-value from mass defect: The energy released is $Q = \Delta m\, c^2 = \Delta m$ (in u) $\times 931.5$ MeV.

Step 1 — Insert the mass defect:

$$Q = 0.0186 \times 931.5 \text{ MeV}.$$

Step 2 — Multiply:

$$Q = 17.33 \text{ MeV}.$$

Step 3 — Interpret the sign: Since the reactants are heavier than the products, mass is lost, so energy is *released*; the reaction is exothermic.

Final Answer: $Q \approx 17.3$ MeV; energy is released (exothermic reaction). **Go Back to Q27**

Q28.

Solution

Concept — Photodiode: A photodiode is a p-n junction operated in *reverse bias*, used to detect light by converting it into an electrical current.

Step 1 — Biasing: It is connected in reverse bias, with light allowed to fall on the junction through a transparent window.

Step 2 — Working: Photons of energy greater than the band gap create additional electron-hole pairs near the junction. The reverse field sweeps these carriers across, increasing the reverse (photo) current in proportion to the light intensity.

Step 3 — Why reverse bias: The fractional change in reverse current with illumination is easily measured, making detection sensitive and nearly linear with intensity.

Step 4 — Application: Photodiodes are used in light detectors, optical communication receivers, and light-operated switches (e.g. in cameras and smoke detectors).

Final Answer: A reverse-biased photodiode produces a photocurrent proportional to the incident light intensity; it is used as a fast light detector. **Go Back to Q28**

Q29.

Solution

Concept — Series/parallel capacitors, charge and energy: Parallel capacitances add; series follow reciprocal addition; charge $Q = CV$ and energy $U = \frac{1}{2}CV^2$.

(i) C_2 and C_3 in parallel:

$$C_{23} = C_2 + C_3 = 2 + 4 = 6\ \mu\text{F}.$$

(ii) Total (series of C_1 with C_{23}):

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_{23}} = \frac{1}{2} + \frac{1}{6} = \frac{3+1}{6} = \frac{4}{6} = \frac{2}{3}.$$

$$C_{eq} = \frac{3}{2} = 1.5\ \mu\text{F}.$$

(iii) Charge and energy at $V = 12$ V:

$$Q = C_{eq}V = (1.5 \times 10^{-6})(12) = 1.8 \times 10^{-5}\ \text{C}.$$

$$U = \frac{1}{2}C_{eq}V^2 = \frac{1}{2}(1.5 \times 10^{-6})(12)^2.$$
$$= \frac{1}{2}(1.5 \times 10^{-6})(144) = 1.08 \times 10^{-4}\ \text{J}.$$

Final Answer: $C_{23} = 6\,\mu$F; $C_{eq} = 1.5\,\mu$F; $Q = 1.8 \times 10^{-5}$ C; $U = 1.08 \times 10^{-4}$ J. **Go Back to Q29**

Q30.

Solution

Concept — Ideal transformer: $\frac{V_s}{V_p} = \frac{N_s}{N_p}$, and for an ideal transformer input power equals output power.

(i) Turns ratio:

$$\frac{N_s}{N_p} = \frac{200}{1000} = \frac{1}{5} = 0.2.$$

Since $N_s < N_p$, it is a **step-down** transformer.

(ii) Secondary voltage:

$$V_s = V_p \times \frac{N_s}{N_p} = 240 \times 0.2 = 48\ \text{V}.$$

(iii) Power and primary current: Output power delivered to the load:

$$P = V_sI_s = 48 \times 2 = 96\ \text{W}.$$

For an ideal transformer $P_p = P_s$, so

$$I_p = \frac{P}{V_p} = \frac{96}{240} = 0.4\ \text{A}.$$

Final Answer: Turns ratio $= 0.2$ (step-down); $V_s = 48$ V; power $= 96$ W; $I_p = 0.4$ A.

Go Back to Q30

Q31.

Solution

Concept — Charge sharing in a capacitor network: In series, each capacitor carries the same charge as the equivalent capacitor; in parallel, the common voltage divides the charge in the ratio of the capacitances.

(a) Step 1 — Parallel combination of C_2 and C_3:

$$C_{23} = 2 + 3 = 5\ \mu\text{F}.$$

Step 2 — Series with C_1:

$$\frac{1}{C_{eq}} = \frac{1}{1} + \frac{1}{5} = \frac{5+1}{5} = \frac{6}{5}.$$

$$C_{eq} = \frac{5}{6}\ \mu\text{F} \approx 0.83\ \mu\text{F}.$$

Step 3 — Total charge (this is the charge on C_1):

$$Q = C_{eq}V = \frac{5}{6} \times 10^{-6} \times 12 = 1.0 \times 10^{-5}\ \text{C} = 10\ \mu\text{C}.$$

So the charge on C_1 is $Q_1 = 10\,\mu$C.

Step 4 — Voltage across the parallel section:

$$V_1 = \frac{Q}{C_1} = \frac{10}{1} = 10\ \text{V}, \qquad V_{23} = 12 - 10 = 2\ \text{V}.$$

Step 5 — Charge on C_2 and C_3 (each at 2 V):

$$Q_2 = C_2V_{23} = 2 \times 2 = 4\ \mu\text{C}, \qquad Q_3 = C_3V_{23} = 3 \times 2 = 6\ \mu\text{C}.$$

Step 6 — Total energy stored:

$$U = \frac{1}{2}C_{eq}V^2 = \frac{1}{2}\left(\frac{5}{6} \times 10^{-6}\right)(12)^2 = 6 \times 10^{-5}\ \text{J}.$$

(b) The parallel charge $Q = 10\,\mu$C splits as $Q_2 : Q_3 = C_2 : C_3 = 2 : 3$, giving $4\,\mu$C and $6\,\mu$C.

Final Answer: $Q_1 = 10\,\mu$C, $Q_2 = 4\,\mu$C, $Q_3 = 6\,\mu$C; total energy $U = 6 \times 10^{-5}$ J.

OR — Potentiometer:

(a) A potentiometer works on the principle that the potential drop across a uniform wire of constant current is proportional to its length ($V \propto \ell$). At the balance point it draws *no* current from the cell, so it measures the true emf. A voltmeter always draws some current, so it reads the terminal voltage (less than the emf); hence the potentiometer is preferred.

(b) Step 1 — Balance length in metres:

$$\ell = 250 \text{ cm} = 2.5 \text{ m}.$$

Step 2 — emf = potential gradient × balance length:

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

Final Answer (OR): $E = 0.5$ V. **Go Back to Q31**

Q32.

Solution

Concept — Bar magnet as a magnetic dipole: A short bar magnet with magnetic moment m behaves like a dipole; its axial field is $B_{axial} = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$.

(a) A bar magnet has two poles of equal strength separated by a small distance $2l$; the magnetic moment is $m = q_m(2l)$, directed from S to N. Treating the poles like point sources and adding their fields along the axis (with $r \gg l$) gives

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

directed along the magnetic moment. This is analogous to the axial field of an electric dipole, confirming the bar magnet acts as a magnetic dipole.

(b) Step 1 — List the data:

$$m = 0.4 \text{ A m}^2, \quad r = 0.2 \text{ m}, \quad \frac{\mu_0}{4\pi} = 10^{-7}.$$

Step 2 — Cube of the distance:

$$r^3 = (0.2)^3 = 0.008 \text{ m}^3.$$

Step 3 — Substitute:

$$B_{axial} = 10^{-7} \times \frac{2 \times 0.4}{0.008} = 10^{-7} \times \frac{0.8}{0.008}.$$

$$= 10^{-7} \times 100 = 1 \times 10^{-5}\ \text{T}.$$

Final Answer: $B_{axial} = \frac{\mu_0}{4\pi}\frac{2m}{r^3} = 1 \times 10^{-5}$ T.

OR — Resonance and quality factor of a series LCR circuit:

(a) Resonance occurs when $X_L = X_C$, i.e. $\omega_0 L = \frac{1}{\omega_0 C}$, giving $\omega_0 = \frac{1}{\sqrt{LC}}$. The quality factor measures the sharpness of resonance:

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = \frac{1}{R}\sqrt{\frac{L}{C}}.$$

(b) Step 1 — Resonant angular frequency:

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(0.5)(2 \times 10^{-6})}} = \frac{1}{\sqrt{1 \times 10^{-6}}} = \frac{1}{10^{-3}} = 1000\ \text{rad/s}.$$

Step 2 — Quality factor:

$$Q = \frac{\omega_0 L}{R} = \frac{1000 \times 0.5}{5} = \frac{500}{5} = 100.$$

Final Answer (OR): $\omega_0 = 1000$ rad/s; $Q = 100$. **Go Back to Q32**

Q33.

Solution

Concept — Mirror formula: For a concave mirror the object distance, image distance and focal length obey $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$.

(a) Derivation: Consider an object of height h placed beyond C. A ray parallel to the axis reflects through F, and a ray through C retraces its path; they meet to form a real inverted image. Using the two similar triangles formed at the pole P and at the focus F, and applying the sign convention (distances measured from P, real distances negative), one obtains

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

(b) Step 1 — Assign signs: $u = -30$ cm, $f = -15$ cm.

Step 2 — Substitute:

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-30}.$$

Step 3 — Simplify:

$$\frac{1}{v} = -\frac{2}{30} + \frac{1}{30} = -\frac{1}{30}.$$

$$v = -30 \text{ cm}.$$

Step 4 — Magnification:

$$m = -\frac{v}{u} = -\frac{-30}{-30} = -1.$$

The image is real, inverted, of the same size, formed at the centre of curvature.

Final Answer: $v = -30$ cm; real, inverted, same-size image ($m = -1$).

OR — Refraction through a prism:

(a) In the quadrilateral formed by the two normals and the two refracting faces, the angle of the prism satisfies $A = r_1 + r_2$. The total deviation is $\delta = (i - r_1) + (e - r_2)$, so

$$\delta = i + e - (r_1 + r_2) = i + e - A.$$

$$\Rightarrow A + \delta = i + e.$$

At minimum deviation the ray passes symmetrically, so $i = e$ and $r_1 = r_2 = \frac{A}{2}$, with $i = \frac{A + \delta_m}{2}$. Applying Snell's law at the first face:

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

(b) As the angle of incidence i increases, the deviation δ first decreases to a single minimum value δ_m and then increases; the δ–i graph is a curve with a minimum, where $i = e$ (the symmetric passage).

Final Answer (OR): $A + \delta = i + e$ and $\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$; deviation is minimum for symmetric passage. Go Back to Q33

Answer Key – Section A (Q1–Q16)

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

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