CBSE Class 12 Physics

Sample Paper – 7

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 equal positive point charges $+q$ each are held a distance d apart. The net electric field at the midpoint of the line joining them is:

(A) $\frac{4kq}{d^2}$ directed towards the nearer charge

(B) zero

(C) $\frac{8kq}{d^2}$

(D) $\dfrac{2kq}{d^2}$

Q2. A cell of emf 6 V and internal resistance $0.5\,\Omega$ delivers a current of 2 A to an external circuit. The terminal voltage of the cell is:

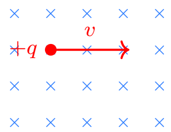
(A) 7 V

(B) 6 V

(C) 5 V

(D) 4 V

Q3. A positive charge $+q$ moves to the right with velocity v in a uniform magnetic field directed into the page, as shown. The magnetic force on the charge is directed:



(A) vertically upward (towards the top of the page)

(B) vertically downward

(C) into the page

(D) along the direction of v

Q4. A rectangular coil rotates with uniform angular speed in a uniform magnetic field. The induced emf in the coil is maximum when:

(A) the plane of the coil is perpendicular to the field

(B) the magnetic flux through the coil is maximum

(C) the coil is momentarily at rest

(D) the plane of the coil is parallel to the field

Q5. The average power dissipated in a purely resistive AC circuit is:

(A) $V_{rms} I_{rms}$

(B) $\frac{1}{2} V_{rms} I_{rms}$

(C) zero

(D) $V_{rms} I_{rms} \cos(90°)$

Q6. Which electromagnetic radiation is commonly used to detect fractures in bones?

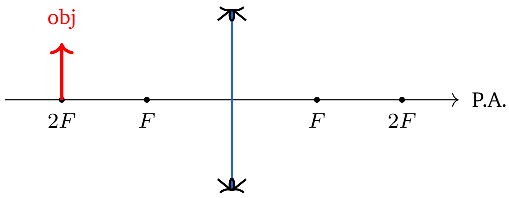
(A) Infrared rays

(B) X-rays

(C) Microwaves

(D) Radio waves

Q7. An object is placed at $2F$ (twice the focal length) in front of a convex lens, as shown. The image formed is:



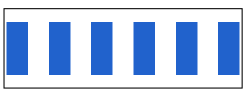
(A) virtual, erect and magnified

(B) real, inverted and magnified

(C) real, inverted and diminished

(D) real, inverted and of the same size as the object

Q8. In Young's double-slit experiment, if the wavelength of the light used is increased while everything else is kept fixed, the fringe pattern changes so that the fringe width:


interference fringes

(A) decreases

(B) remains unchanged

(C) increases

(D) becomes zero (fringes vanish)

Q9. The momentum of a photon of wavelength λ is:

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

(B) $h\lambda$

(C) $\frac{\lambda}{h}$

(D) $\frac{hc}{\lambda}$

Q10. The ionisation energy of a hydrogen atom in its ground state is:

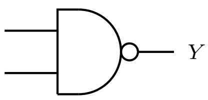
(A) 3.4 eV

(B) 1.51 eV

(C) 27.2 eV

(D) 13.6 eV

Q11. The logic gate whose symbol is shown below (an AND-shaped body with a small bubble at the output) is a:



(A) AND gate

(B) NOR gate

(C) NAND gate

(D) OR gate

Q12. When a number of capacitors are connected in series across a battery, the physical quantity that is the *same* for every capacitor is the:

(A) potential difference across it

(B) charge on it

(C) capacitance

(D) energy stored in it

Q13. Assertion (A): The total electric flux through a closed surface depends only on the net charge enclosed by it, and not on the size or shape of the surface.

Reason (R): By Gauss's law, the net flux through a closed surface equals $\frac{q_{enc}}{\varepsilon_0}$.

(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): A diamagnetic material is weakly repelled by a magnetic field.

Reason (R): The magnetic susceptibility of a diamagnetic material is nearly independent of temperature.

(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 interference of light does not violate the principle of conservation of energy.

Reason (R): In interference, energy is created at the bright fringes.

(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 stopping potential of a photoelectric cell increases when the intensity of the incident light is increased.
Reason (R): The maximum kinetic energy of the photoelectrons depends only on the frequency of the incident light and the work function, not on the intensity.

(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 by connecting it across a 12 V battery. Find the charge stored on the capacitor. **[2]**

Q18. Two cells of emf 2 V each and internal resistance $0.5\,\Omega$ each are connected in series (aiding) to an external resistance of $3\,\Omega$. Find the net emf of the combination and the current in the circuit. **[2]**

Q19. An inductor of inductance 2 H is connected in series with a resistor of $100\,\Omega$. Find the time constant of the LR circuit. **[2]**

OR

What is meant by wattless current? A pure inductor is connected across a 200 V AC source and carries an rms current of 2 A. Find the average power dissipated in it.

Q20. An object is placed 15 cm in front of a concave mirror of focal length 10 cm. Using the mirror formula, find the position of the image. **[2]**

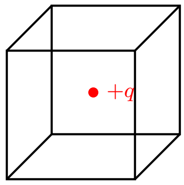
Q21. Photons of energy 5 eV are incident on a metal surface whose work function is 3 eV. Find the maximum kinetic energy of the emitted photoelectrons. **[2]**

OR

A radioactive sample decays to 25% of its initial number of nuclei in 10 years. Find the half-life of the sample.

Section C (Q22–Q28) – 3 Marks Each

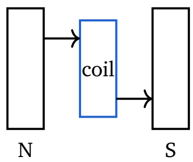
Q22. A point charge $q = 8.85\,\mu$C is placed at the exact centre of a cube. Using Gauss's law, find the total electric flux through the cube and the flux through one of its faces. (Take $\varepsilon_0 = 8.85 \times 10^{-12}$ C^{2}N^{-1}m^{-2}.)



[3]

Q23. What is meant by the end correction in a metre bridge, and why is it needed? In a metre bridge experiment with a known resistance of $4\,\Omega$ in the right gap, the balance (null) point is obtained at 60 cm from the left end. Find the value of the unknown resistance. **[3]**

Q24. State the principle of a moving-coil galvanometer and explain its working in brief. Define its current sensitivity and write its expression.



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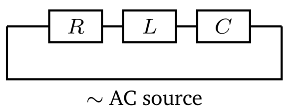
Q25. A series LCR circuit with $R = 40\,\Omega$, $X_L = 60\,\Omega$ and $X_C = 30\,\Omega$ is connected to an AC source of rms voltage 100 V. Find the impedance, the rms current and the average power dissipated in the circuit.

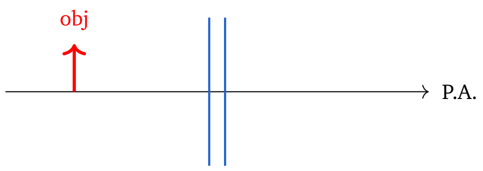


[3]

OR

Define the bandwidth and the sharpness of resonance of a series LCR circuit. A series resonant circuit has $R = 10\,\Omega$ and $L = 0.1$ H. Find its bandwidth.

Q26. Two thin convex lenses of focal lengths 20 cm and 30 cm are placed in contact. Find the equivalent focal length of the combination, and hence the image distance when an object is placed 18 cm from the combination.



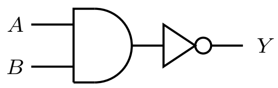
[3]

OR

An object is placed 30 cm in front of a concave mirror of focal length 20 cm. Find the position, nature and magnification of the image.

Q27. An electron in a hydrogen atom makes a transition from the $n = 3$ level to the $n = 2$ level. Find the energy of the emitted photon (in eV) and its wavelength (in nm). (Take ground-state energy $= -13.6$ eV and $\lambda(\text{nm}) = \dfrac{1240}{E(\text{eV})}$.) **[3]**

Q28. In the logic circuit shown below, inputs A and B are fed to an AND gate whose output is passed through a NOT gate. Write the Boolean expression for the output Y and draw its truth table.

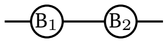


[3]

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

Q29. Case Study – Power in Bulbs.

Two identical incandescent bulbs are each rated $(60\text{ W},\ 120\text{ V})$. A student studies how the total power changes when the bulbs are connected in series and in parallel across the same 120 V supply.



series connection

Based on the above, answer the following:

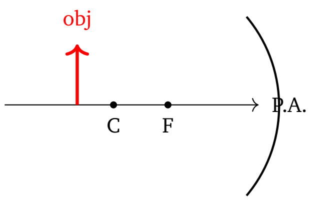
(i) Find the resistance of each bulb. (1)

(ii) Find the total power consumed when the two bulbs are connected in series across 120 V. (1)

(iii) Find the total power consumed in parallel across 120 V, and state which arrangement makes the bulbs glow brighter. (2)

Q30. Case Study – Concave Mirror Imaging.

A concave mirror of focal length 15 cm is used to form images of an object placed at different distances along its principal axis.



Based on the above, answer the following:

(i) Find the radius of curvature of the mirror. (1)

(ii) Find the image distance when the object is at 30 cm and state the nature of the image. (1)

(iii) Find the image distance and magnification when the object is placed at 10 cm from the mirror. (2)

Section E (Q31–Q33) – 5 Marks Each

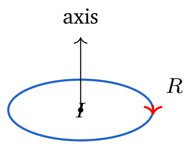
Q31. (a) Derive an expression for the potential energy of a system of two point charges, and extend it to a system of three point charges.

(b) Three equal point charges of $+1\ \mu$C each are placed at the corners of an equilateral triangle of side 10 cm. Find the total electrostatic potential energy of the system. (Take $k = 9 \times 10^9$ N m^{2}C^{-2}.) **[5]**

OR

(a) State Kirchhoff's junction rule and loop rule, and mention the conservation principle behind each.
(b) In a single-loop circuit two cells of emf 8 V and 2 V (aiding) with internal resistances $0.5\,\Omega$ each are joined to an external resistance of $3\,\Omega$. Using Kirchhoff's loop rule, find the current in the circuit.

Q32. (a) State the Biot–Savart law and use it to derive the expression for the magnetic field at the centre of a circular current loop of radius R carrying current I.
(b) A circular coil of 10 turns and radius 5 cm carries a current of 2 A. Find the magnetic field at its centre. (Take $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}.)

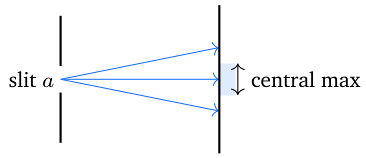


[5]

OR

(a) Describe LC oscillations and bring out their analogy with the simple harmonic motion of a mass on a spring.
(b) Write the expression for the frequency of LC oscillations, and find it for $L = 2$ H and $C = 8\,\mu$F. (You may use $\sqrt{1.6 \times 10^{-5}} = 4 \times 10^{-3}$.)

Q33. (a) Describe the diffraction pattern produced by a single slit and derive the expression for the width of the central maximum on a screen at distance D.
(b) A single slit of width 0.2 mm is illuminated by light of wavelength 600 nm. Find the width of the central maximum on a screen placed 1 m away.



[5]

OR

(a) With a labelled ray diagram, explain image formation by a convex lens for an object placed beyond $2F$, and write the thin-lens formula.
(b) An object is placed 30 cm in front of a convex lens of focal length 20 cm. Find the image distance and the magnification.

Detailed Solutions

Q1.

Solution

Concept — Superposition of fields: The net field at a point is the vector sum of the fields due to each charge.

Step 1 — Field of each charge at the midpoint: Each charge is a distance $d/2$ from the midpoint, so each produces a field of magnitude

$$E = \frac{kq}{(d/2)^2} = \frac{4kq}{d^2}.$$

Step 2 — Directions: The field of the left charge points to the right; the field of the right charge points to the left. The two fields are equal in magnitude and opposite in direction.

Step 3 — Add them:

$$E_{\text{net}} = \frac{4kq}{d^2} - \frac{4kq}{d^2} = 0.$$

Why other options are wrong: (A), (C) and (D) ignore that the two contributions point in opposite directions and cancel.

Final Answer: Net field $= 0 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q1

Q2.

Solution

Concept — Terminal voltage of a cell: On load, the terminal voltage is $V = E - Ir$, where Ir is the voltage drop across the internal resistance.

Step 1 — Internal voltage drop:

$$Ir = (2)(0.5) = 1\ \text{V}.$$

Step 2 — Subtract from the emf:

$$V = E - Ir = 6 - 1.$$

$$= 5\ \text{V}.$$

Why other options are wrong: (A) 7 V adds the drop; (B) 6 V ignores the drop; (D) 4 V doubles the drop.

Final Answer: Terminal voltage $= 5$ V $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q2

Q3.

Solution

Concept — Magnetic Lorentz force: The force on a moving charge is $\vec{F} = q\,\vec{v}\times\vec{B}$.

Step 1 — Assign directions: Take $\vec{v}$ along $+x$ (to the right) and $\vec{B}$ along $-z$ (into the page).

Step 2 — Evaluate the cross product:

$$\vec{v} \times \vec{B} = \hat{x} \times (-\hat{z}) = -(\hat{x} \times \hat{z}) = -(-\hat{y}) = +\hat{y}.$$

Step 3 — Include the sign of the charge: For a positive charge q, $\vec{F}$ is along $+\hat{y}$, i.e. vertically upward (towards the top of the page).

Why other options are wrong: (B) is the direction for a negative charge; (C) forces cannot lie along $\vec{B}$; (D) the magnetic force is always perpendicular to $\vec{v}$.

Final Answer: Force is directed upward $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q3

Q4.

Solution

Concept — emf of a rotating coil: For a coil rotating in a field, $\varepsilon = NBA\omega \sin \omega t$, which is largest when $\sin \omega t = 1$.

Step 1 — Flux and its rate of change: The flux is $\phi = NBA \cos \omega t$, so the emf $\varepsilon = -d\phi/dt = NBA\omega \sin \omega t$.

Step 2 — When is ε maximum? It is maximum when the flux is changing fastest, i.e. when $\phi = 0$. This happens when the plane of the coil is parallel to the field (the coil's normal is perpendicular to $\vec{B}$).

Why other options are wrong: (A) and (B) describe the position of maximum flux, where the emf is zero; (C) with the coil at rest there is no changing flux and hence no emf.

Final Answer: Plane of coil parallel to the field ⇒ $\boxed{\text{D}}$

Answer: (D) Go Back to Q4

Q5.

Solution

Concept — Average AC power: The average power is $P = V_{rms}I_{rms}\cos\varphi$, where φ is the phase angle between voltage and current.

Step 1 — Phase in a pure resistor: In a purely resistive circuit the current is in phase with the voltage, so $\varphi = 0$.

Step 2 — Power factor: $\cos\varphi = \cos 0 = 1$, so

$$P = V_{rms}I_{rms}.$$

Why other options are wrong: (B) applies the peak-value factor incorrectly; (C) zero is the power for a purely reactive element; (D) $\cos 90^\circ = 0$ describes a purely inductive/capacitive case.

Final Answer: $P = V_{rms}I_{rms}$ ⇒ $\boxed{\text{A}}$

Answer: (A) Go Back to Q5

Q6.

Solution

Concept — Uses of the EM spectrum: X-rays have short wavelength and high penetrating power, so they pass through soft tissue but are absorbed by bone.

Step 1 — Requirement: To image bone, radiation must penetrate flesh yet be blocked by denser bone, giving a shadow image.

Step 2 — Identify the radiation: X-rays satisfy this and are used in radiography to detect fractures.

Why other options are wrong: (A) infrared is used in thermal imaging; (C) microwaves in ovens and radar; (D) radio waves in communication and MRI signalling, not fracture imaging.

Final Answer: X-rays ⇒ $\boxed{\text{B}}$

Answer: (B) Go Back to Q6

Q7.

Solution

Concept — Convex lens at $2F$: When an object is at $2F$, a convex lens forms an image at $2F$ on the other side that is real, inverted and of the same size.

Step 1 — Use the lens formula with $u = -2f$:

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

$$v = +2f.$$

Step 2 — Magnification:

$$m = \frac{v}{u} = \frac{2f}{-2f} = -1.$$

The negative sign shows the image is real and inverted; $|m| = 1$ shows it is the same size.

Why other options are wrong: (A) a virtual, erect image needs the object inside F; (B) magnified real image needs the object between F and $2F$; (C) diminished image needs the object beyond $2F$.

Final Answer: Real, inverted, same size $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q7

Q8.

Solution

Concept — Fringe width: In YDSE the fringe width is $\beta = \dfrac{\lambda D}{d}$, directly proportional to the wavelength λ.

Step 1 — Identify the dependence: With D and d fixed, $\beta \propto \lambda$.

Step 2 — Effect of increasing λ: A larger λ gives a larger β, so the fringes spread farther apart.

Why other options are wrong: (A) a decrease would require λ to fall; (B) unchanged ignores the proportionality; (D) fringes do not vanish, they merely widen.

Final Answer: Fringe width increases $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q8

Q9.

Solution

Concept — Photon momentum: A photon carries momentum $p = \frac{E}{c}$, and its energy is $E = \frac{hc}{\lambda}$.

Step 1 — Substitute the energy:

$$p = \frac{E}{c} = \frac{hc/\lambda}{c}.$$

Step 2 — Simplify:

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

Why other options are wrong: (B) $h\lambda$ has wrong dimensions; (C) inverts the ratio; (D) $\frac{hc}{\lambda}$ is the photon's energy, not its momentum.

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

Answer: (A) Go Back to Q9

Q10.

Solution

Concept — Ionisation energy: It is the energy needed to remove the electron from the ground state ($n = 1$) to infinity ($n = \infty$).

Step 1 — Ground-state energy: For hydrogen $E_1 = -13.6$ eV.

Step 2 — Energy to free the electron:

$$E_{\text{ion}} = E_\infty - E_1 = 0 - (-13.6) = 13.6 \text{ eV}.$$

Why other options are wrong: (A) 3.4 eV is $|E_2|$ (first excited state); (B) 1.51 eV is $|E_3|$; (C) 27.2 eV is twice the ground-state magnitude.

Final Answer: Ionisation energy $= 13.6$ eV $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q10

Q11.

Solution

Concept — Logic gate symbols: An AND-shaped body (flat back, rounded front) with a small inversion bubble at the output is a NAND gate.

Step 1 — Read the body: The flat back with a semicircular front denotes an AND operation, giving $A \cdot B$.

Step 2 — Read the bubble: The bubble inverts the output, so $Y = \overline{A \cdot B}$, which is the NAND gate.

Why other options are wrong: (A) AND has no bubble; (B) NOR uses a curved (OR) back with a bubble; (D) OR uses a curved back and no bubble.

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

Answer: (C) Go Back to Q11

Q12.

Solution

Concept — Series capacitors: In series the same charge flows onto every plate because charge is pushed from one capacitor onto the next.

Step 1 — Charge conservation on the connecting plates: The isolated conductor between two capacitors must have zero net charge, so the two facing plates carry equal and opposite charge. Hence each capacitor stores the same charge Q.

Step 2 — Voltage differs: Since $V = \dfrac{Q}{C}$ and the capacitances differ, the potential differences are generally unequal; only Q is common.

Why other options are wrong: (A) voltages differ when capacitances differ; (C) capacitances need not be equal; (D) energy $= \frac{1}{2}QV$ differs because V differs.

Final Answer: The charge is the same $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept — Assertion–Reason on Gauss's law: Judge each statement, then decide whether R explains A.

Step 1 — Assertion: The total flux through a closed surface depends only on the enclosed charge, independent of the surface's size or shape. This is **true**.

Step 2 — Reason: Gauss's law states $\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$. This is **true**.

Step 3 — Does R explain A? The right-hand side of Gauss's law contains only q_{enc}, which is exactly why the flux is independent of shape or size. So R correctly explains A.

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

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

Answer: (A) Go Back to Q13

Q14.

Solution

Concept — Diamagnetism: Diamagnetic materials develop an induced magnetic moment opposite to the applied field, so they are weakly repelled.

Step 1 — Assertion: A diamagnetic material is weakly repelled by a magnetic field. This is **true**.

Step 2 — Reason: The susceptibility of a diamagnetic material is small, negative and nearly independent of temperature. This is **true**.

Step 3 — Does R explain A? The repulsion arises from the *induced* moment opposing the field, not from the temperature independence of the susceptibility. So R is true but does *not* explain A.

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

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

Answer: (B) Go Back to Q14

Q15.

Solution

Concept — Interference and energy conservation: Interference only redistributes light energy; it neither creates nor destroys energy.

Step 1 — Assertion: Interference does not violate conservation of energy. This is **true**: the energy missing from the dark fringes reappears in the bright fringes.

Step 2 — Reason: "Energy is created at the bright fringes" is **false**; energy is not created, only redistributed from dark to bright regions.

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

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

Final Answer: A true, R false ⇒ C

Answer: (C) Go Back to Q15

Q16.

Solution

Concept — Photoelectric effect: The stopping potential (hence the maximum kinetic energy) depends on frequency and work function, not on intensity.

Step 1 — Assertion: "Stopping potential increases with intensity" is **false**. Increasing intensity raises the number of photoelectrons (the current) but not their maximum energy, so the stopping potential is unchanged.

Step 2 — Reason: $K_{\max} = h\nu - W$ depends only on frequency and work function. This is **true**.

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

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

Final Answer: A false, R true ⇒ D

Answer: (D) Go Back to Q16

Q17.

Solution

Concept — Charge on a capacitor: $Q = CV$.

Step 1 — List the data:

$$C = 5\ \mu\text{F} = 5 \times 10^{-6}\ \text{F}, \qquad V = 12\ \text{V}.$$

Step 2 — Substitute:

$$Q = CV = (5 \times 10^{-6})(12).$$

$$= 60 \times 10^{-6}\ \text{C}.$$

$$= 60\ \mu\text{C}.$$

Final Answer: Charge stored $= 60\ \mu\text{C} = 6 \times 10^{-5}$ C. **Go Back to Q17**

Q18.

Solution

Concept — Cells in series (aiding): The emfs add and the internal resistances add.

Step 1 — Net emf:

$$E = E_1 + E_2 = 2 + 2 = 4\ \text{V}.$$

Step 2 — Total resistance:

$$R_{\text{total}} = r_1 + r_2 + R = 0.5 + 0.5 + 3 = 4\ \Omega.$$

Step 3 — Current:

$$I = \frac{E}{R_{\text{total}}} = \frac{4}{4}.$$
$$= 1\ \text{A}.$$

Final Answer: Net emf $= 4$ V and current $= 1$ A. **Go Back to Q18**

Q19.

Solution

Concept — Time constant of an LR circuit: $\tau = \dfrac{L}{R}$.

Step 1 — List the data:

$$L = 2\ \text{H}, \qquad R = 100\ \Omega.$$

Step 2 — Substitute:

$$\tau = \frac{L}{R} = \frac{2}{100}.$$
$$= 0.02\ \text{s} = 20\ \text{ms}.$$

Final Answer: Time constant $\tau = 0.02$ s (20 ms).

OR — Wattless current:

Step 1 — Definition: A wattless current is one that flows in a purely reactive (ideal inductive or capacitive) circuit; its phase differs from the voltage by 90°, so it dissipates zero average power.

Step 2 — Power in a pure inductor: Here $\varphi = 90°$, so

$$P = V_{rms} I_{rms} \cos 90° = (200)(2)(0) = 0.$$

Final Answer (OR): Average power dissipated $= 0$. Go Back to Q19

Q20.

Solution

Concept — Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, with the sign convention.

Step 1 — Assign values: For a concave mirror, $f = -10$ cm and $u = -15$ cm.

Step 2 — Rearrange:

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-10} - \frac{1}{-15}.$$

Step 3 — Simplify:

$$\frac{1}{v} = -\frac{1}{10} + \frac{1}{15} = \frac{-3+2}{30} = -\frac{1}{30}.$$

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

Final Answer: The image forms 30 cm in front of the mirror (real and inverted).
Go Back to Q20

Q21.

Solution

Concept — Einstein's photoelectric equation: $K_{\max} = E_{\text{photon}} - W$.

Step 1 — List the data:

$$E_{\text{photon}} = 5 \text{ eV}, \qquad W = 3 \text{ eV}.$$

Step 2 — Subtract:

$$K_{\max} = 5 - 3 = 2 \text{ eV}.$$

Final Answer: Maximum kinetic energy $= 2$ eV.

OR — Half-life from decay to 25%**:**

Step 1 — Fraction remaining:

$$\frac{N}{N_0} = 25\% = \frac{1}{4} = \left(\frac{1}{2}\right)^2.$$

Step 2 — Number of half-lives: This equals two half-lives, so

$$2T_{1/2} = 10 \text{ years}.$$

$$T_{1/2} = 5 \text{ years}.$$

Final Answer (OR): Half-life = 5 years. **Go Back to Q21**

Q22.

Solution

Concept — Gauss's law with symmetry: The total flux through any closed surface is $\Phi = \frac{q_{\text{enc}}}{\varepsilon_0}$; a cube has six identical faces.

Step 1 — Total flux through the cube:

$$\Phi = \frac{q}{\varepsilon_0} = \frac{8.85 \times 10^{-6}}{8.85 \times 10^{-12}}.$$

$$= 1.0 \times 10^6 \text{ N m}^2\text{C}^{-1}.$$

Step 2 — Symmetry argument: With the charge at the centre, each of the six faces receives an equal share of the flux.

Step 3 — Flux through one face:

$$\Phi_{\text{face}} = \frac{\Phi}{6} = \frac{1.0 \times 10^6}{6}.$$

$$= 1.67 \times 10^5 \text{ N m}^2\text{C}^{-1}.$$

Final Answer: Total flux = 1.0×10^6 N m^{2}C^{-1}; flux per face = 1.67×10^5 N m^{2}C^{-1}.
Go Back to Q22

Q23.

Solution

Concept — End correction: The metre-bridge wire does not begin exactly at the 0 cm mark and end at 100 cm; the small extra lengths at the copper strips introduce a systematic error. Adding a small constant (the end correction) to each measured length corrects for this. It is usually found by interchanging the known and unknown resistances.

Step 1 — Balance condition: With the known resistance $S = 4\,\Omega$ in the right gap and null point $\ell = 60$ cm from the left,

$$\frac{R}{S} = \frac{\ell}{100 - \ell}.$$

Step 2 — Substitute:

$$\frac{R}{4} = \frac{60}{100 - 60} = \frac{60}{40} = \frac{3}{2}.$$

Step 3 — Solve for R:

$$R = 4 \times \frac{3}{2} = 6\ \Omega.$$

Final Answer: Unknown resistance $= 6\,\Omega$ (to be refined using the end correction).

Go Back to Q23

Q24.

Solution

Concept — Moving-coil galvanometer: A current-carrying coil placed in a magnetic field experiences a torque that deflects it.

Step 1 — Principle: When current I passes through a coil of N turns and area A in a radial magnetic field B, the deflecting torque is $\tau = NBIA$.

Step 2 — Working: A radial field (from concave pole pieces and a soft-iron core) keeps the coil's plane always parallel to B, so the torque is $NBIA$ for any deflection. The suspension provides a restoring torque $k\phi$. At equilibrium

$$NBIA = k\phi \;\Rightarrow\; \phi = \frac{NBA}{k} I,$$

so the deflection is proportional to the current, giving a linear scale.

Step 3 — Current sensitivity: It is the deflection produced per unit current:

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

Final Answer: Deflection $\phi = \frac{NBA}{k}I$; current sensitivity $= \frac{NBA}{k}$. **Go Back to Q24**

Q25.

Solution

Concept — Series LCR power: $Z = \sqrt{R^2 + (X_L - X_C)^2}$, $I_{rms} = \frac{V_{rms}}{Z}$, and $P = I_{rms}^2 R$.

Step 1 — Net reactance:

$$X_L - X_C = 60 - 30 = 30\ \Omega.$$

Step 2 — Impedance:

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

Step 3 — rms current:

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{100}{50} = 2\text{ A}.$$

Step 4 — Average power:

$$P = I_{rms}^2 R = (2)^2(40) = 160\text{ W}.$$

Final Answer: $Z = 50\,\Omega$, $I_{rms} = 2$ A, $P = 160$ W.

OR — Bandwidth and sharpness:

Step 1 — Definitions: The bandwidth $\Delta\omega = \frac{R}{L}$ is the width in angular frequency between the half-power points. The sharpness of resonance is measured by the quality factor $Q = \frac{\omega_0}{\Delta\omega} = \frac{\omega_0 L}{R}$; a larger Q means a sharper peak.

Step 2 — Numerical bandwidth:

$$\Delta\omega = \frac{R}{L} = \frac{10}{0.1} = 100\text{ rad/s}.$$

Final Answer (OR): Bandwidth $= 100$ rad/s. **Go Back to Q25**

Q26.

Solution

Concept — Lenses in contact: The equivalent focal length obeys $\dfrac{1}{F} = \dfrac{1}{f_1} + \dfrac{1}{f_2}$, then use the lens formula.

Step 1 — Equivalent focal length:

$$\frac{1}{F} = \frac{1}{20} + \frac{1}{30} = \frac{3+2}{60} = \frac{5}{60} = \frac{1}{12}.$$

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

Step 2 — Lens formula with $u = -18$ cm:

$$\frac{1}{v} = \frac{1}{F} + \frac{1}{u} = \frac{1}{12} + \frac{1}{-18}.$$

Step 3 — Simplify:

$$\frac{1}{v} = \frac{3}{36} - \frac{2}{36} = \frac{1}{36}.$$

$$v = +36 \text{ cm}.$$

Final Answer: $F = 12$ cm; image at $v = +36$ cm (real, inverted, magnified).

OR — Concave mirror:

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

Step 2 — Mirror formula:

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-20} - \frac{1}{-30} = -\frac{1}{20} + \frac{1}{30} = \frac{-3+2}{60} = -\frac{1}{60}.$$

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

Step 3 — Magnification:

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

Final Answer (OR): $v = -60$ cm; image real, inverted, magnified ($m = -2$). **Go Back to Q26**

Q27.

Solution

Concept — Hydrogen energy levels: $E_n = -\frac{13.6}{n^2}$ eV; the photon energy is $E = E_3 - E_2$ (magnitude of the level difference).

Step 1 — Energy of each level:

$$E_2 = -\frac{13.6}{4} = -3.4 \text{ eV}, \qquad E_3 = -\frac{13.6}{9} = -1.51 \text{ eV}.$$

Step 2 — Photon energy emitted:

$$E = E_3 - E_2 = -1.51 - (-3.4) = 1.89 \text{ eV}.$$

Step 3 — Wavelength:

$$\lambda = \frac{1240}{E(\text{eV})} = \frac{1240}{1.89}.$$
$$\approx 656 \text{ nm}.$$

Final Answer: Photon energy ≈ 1.89 eV; wavelength ≈ 656 nm (the H_α line). **Go Back to Q27**

Q28.

Solution

Concept — Cascaded gates: An AND gate followed by a NOT gate gives the NAND operation.

Step 1 — Output of the AND gate: The AND output is $A \cdot B$.

Step 2 — Pass it through the NOT gate: The NOT gate inverts it, so

$$Y = \overline{A \cdot B}.$$

Step 3 — Truth table:

A	B	$A \cdot B$	$Y = \overline{A \cdot B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

Final Answer: $Y = \overline{A \cdot B}$; the output is 0 only when both inputs are 1 (a NAND gate). Go Back to Q28

Q29.

Solution

Concept — Power ratings: From the rating, $R = \frac{V^2}{P}$; then use $P = \frac{V^2}{R_{\text{eq}}}$ for the network.

(i) Resistance of each bulb:

$$R = \frac{V^2}{P} = \frac{(120)^2}{60} = \frac{14400}{60} = 240\ \Omega.$$

(ii) Series across 120 **V:**

$$R_{\text{series}} = 240 + 240 = 480\ \Omega.$$

$$P_{\text{series}} = \frac{V^2}{R_{\text{series}}} = \frac{14400}{480} = 30\ \text{W}.$$

(iii) Parallel across 120 **V:** Each bulb gets the full 120 V, so each dissipates its rated 60 W:

$$P_{\text{parallel}} = 60 + 60 = 120\ \text{W}.$$

Since $P_{\text{parallel}} = 120$ W $> P_{\text{series}} = 30$ W, the bulbs glow *brighter in parallel*.

Final Answer: $R = 240\,\Omega$; $P_{\text{series}} = 30$ W; $P_{\text{parallel}} = 120$ W (brighter in parallel). Go Back to Q29

Q30.

Solution

Concept — Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ with $f = -15$ cm for a concave mirror; $R = 2f$ and $m = -\frac{v}{u}$.

(i) Radius of curvature:

$$R = 2f = 2 \times 15 = 30\ \text{cm}.$$

(ii) Object at 30 **cm (**$u = -30$ **cm):**

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-30} = -\frac{1}{15} + \frac{1}{30} = \frac{-2+1}{30} = -\frac{1}{30}.$$

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

The image is real, inverted and of the same size (object is at the centre of curvature).

(iii) Object at 10 cm ($u = -10$ cm):

$$\frac{1}{v} = \frac{1}{-15} - \frac{1}{-10} = -\frac{1}{15} + \frac{1}{10} = \frac{-2+3}{30} = \frac{1}{30}.$$

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

$$m = -\frac{v}{u} = -\frac{30}{-10} = +3.$$

The image is virtual, erect and magnified three times.

Final Answer: $R = 30$ cm; at 30 cm image is real and same size; at 10 cm image is virtual, erect, $m = +3$. **Go Back to Q30**

Q31.

Solution

Concept — Electrostatic potential energy: The energy of a pair of charges is $U = \frac{kq_1q_2}{r}$; for several charges, sum over all distinct pairs.

(a) Two charges: The work done in bringing q_2 from infinity to a distance r from q_1 is

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}.$$

Three charges: Add the energies of all three pairs:

$$U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_1q_3}{r_{13}}\right).$$

(b) Numerical (equilateral triangle): Here all charges are $q = 1\,\mu$C and all separations are $r = 0.1$ m. There are three equal pairs, so

$$U = 3 \times \frac{kq^2}{r} = 3 \times \frac{(9\times 10^9)(1\times 10^{-6})^2}{0.1}.$$

$$= 3 \times \frac{(9\times 10^9)(1\times 10^{-12})}{0.1}.$$

$$= 3 \times \frac{9\times 10^{-3}}{0.1} = 3 \times 0.09 = 0.27 \text{ J}.$$

Final Answer: $U = 0.27$ J.

OR — Kirchhoff's rules:

(a) *Junction rule:* the algebraic sum of currents at a junction is zero ($\sum I = 0$), a statement of conservation of charge. *Loop rule:* the algebraic sum of potential changes around any closed loop is zero ($\sum \Delta V = 0$), a statement of conservation of energy.

(b) Applying the loop rule to the single loop (both cells aiding):

$$E_1 + E_2 = I(r_1 + r_2 + R).$$

$$8 + 2 = I(0.5 + 0.5 + 3).$$

$$10 = I(4) \Rightarrow I = 2.5 \text{ A}.$$

Final Answer (OR): Current $I = 2.5$ A. **Go Back to Q31**

Q32.

Solution

Concept — Biot–Savart law: A current element $I\,d\vec{l}$ produces a field $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{l} \times \hat{r}}{r^2}$.

(a) Field at the centre of a loop: For a circular loop of radius R, every element is at distance R from the centre and $d\vec{l} \perp \hat{r}$, so $|d\vec{l} \times \hat{r}| = dl$:

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

All elements give fields in the same direction (along the axis at the centre), so integrate $\oint dl = 2\pi R$:

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

For N turns, $B = \frac{\mu_0 N I}{2R}$.

(b) Numerical: $N = 10$, $I = 2$ A, $R = 5$ cm $= 0.05$ m:

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

$$= \frac{(4\pi \times 10^{-7})(20)}{0.1}.$$

$$= \frac{2.513 \times 10^{-5}}{0.1} = 2.51 \times 10^{-4} \text{ T}.$$

Final Answer: $B = \frac{\mu_0 N I}{2R} = 2.51 \times 10^{-4}$ T.

OR — LC oscillations:

(a) In an LC circuit the charge oscillates between the capacitor and the inductor: energy shifts back and forth between the electric field of C and the magnetic field of L, just as energy in SHM shifts between potential and kinetic forms. The charge q plays the role of displacement, $\frac{1}{C}$ the role of the spring constant k, and L the role of mass m; the equation $L\frac{d^2q}{dt^2} + \frac{q}{C} = 0$ mirrors $m\ddot{x} + kx = 0$.

(b) The frequency is

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(2)(8\times10^{-6})}} = \frac{1}{2\pi\sqrt{1.6\times10^{-5}}}.$$

$$= \frac{1}{2\pi(4\times10^{-3})} = \frac{1}{2.513\times10^{-2}} \approx 39.8 \text{ Hz}.$$

Final Answer (OR): $f = \frac{1}{2\pi\sqrt{LC}} \approx 39.8$ Hz. **Go Back to Q32**

Q33.

Solution

Concept — Single-slit diffraction: A slit of width a gives a bright central maximum flanked by weaker maxima; minima occur at $a\sin\theta = n\lambda$.

(a) Central maximum width: The first minima on either side of the centre satisfy $a\sin\theta = \pm\lambda$. For small angles $\sin\theta \approx \theta$, so the half-angular width is $\theta = \frac{\lambda}{a}$. The linear half-width on a screen at distance D is $y = D\theta = \frac{\lambda D}{a}$, so the full width of the central maximum is

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

(b) Numerical: $a = 0.2$ mm $= 2\times10^{-4}$ m, $\lambda = 600$ nm $= 6\times10^{-7}$ m, $D = 1$ m:

$$W = \frac{2(6\times10^{-7})(1)}{2\times10^{-4}}.$$

$$= \frac{1.2\times10^{-6}}{2\times10^{-4}} = 6\times10^{-3} \text{ m} = 6 \text{ mm}.$$

Final Answer: $W = \frac{2\lambda D}{a} = 6$ mm.

OR — Convex lens:

(a) For an object beyond $2F$, a convex lens forms a real, inverted, diminished image between F and $2F$ on the far side. Two rays fix the image: one parallel to the axis that refracts through the far focus, and one through the optical centre that goes straight. The thin-lens formula is $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$.

(b) With $f = +20$ cm and $u = -30$ cm:

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{-30} = \frac{3-2}{60} = \frac{1}{60}.$$

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

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

Final Answer (OR): $v = +60$ cm; $m = -2$ (real, inverted, magnified). **Go Back to Q33**

Answer Key – Section A (Q1–Q16)

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

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