JEE Main Physics
Sample Paper – 13

Duration: 60 Minutes | Maximum Marks: 100

Instructions

- **Section A** contains **20 Multiple Choice Questions (MCQ)**. Each question has four options, of which **only one** is correct. **Marking scheme:** **+4** for correct answer, **−1** for incorrect answer, **0** for unattempted.
- **Section B** contains **10 Numerical Value Questions (NVQ)**. The answer is a numerical value (integer or decimal). Candidates must attempt **any 5** out of 10 questions. **Marking scheme:** **+4** for correct answer, **0** for incorrect or unattempted.
- The question paper is based on the **NCERT syllabus** for Classes XI and XII (Physics).
- Personal calculators are **not permitted**. An on-screen virtual calculator will be provided during the actual examination.
- Read all questions carefully before answering. Manage your time wisely.

SECTION A — Multiple Choice Questions (Q1–Q20)

Q1. A particle moves along the x-axis with velocity $v = (3t^2 - 6t + 2)\ \mathrm{m/s}$. The displacement of the particle from $t = 1\ \mathrm{s}$ to $t = 3\ \mathrm{s}$ is:

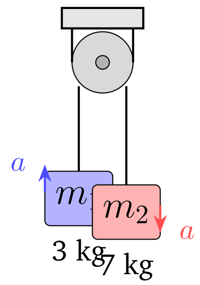
(A) 3 m

(B) 6 m

(C) 9 m

(D) 4 m

Q2. Two masses $m_1 = 3\ \mathrm{kg}$ and $m_2 = 7\ \mathrm{kg}$ are connected by a light inextensible string over a frictionless, massless pulley (Atwood machine). The system is released from rest ($g = 10\ \mathrm{m/s^2}$). The acceleration of the masses is:



(A) 2 m/s^2

(B) 3 m/s^2

(C) 5 m/s^2

(D) 4 m/s^2

Q3. A force $F = (4x + 3)$ N acts on a particle along the x-axis. The work done in displacing the particle from $x = 0$ to $x = 3$ m is:

(A) 27 J

(B) 18 J

(C) 12 J

(D) 21 J

Q4. A thin uniform ring of mass M and radius R has moment of inertia $I_{cm} = MR^2$ about its central axis. The moment of inertia about an axis passing through a point on its circumference and perpendicular to the plane of the ring is:

(A) MR^2

(B) $\frac{3}{2}MR^2$

(C) $2MR^2$

(D) $\frac{1}{2}MR^2$

Q5. The acceleration due to gravity at a height h above Earth's surface is approximately $g' = g\left(1 - \frac{2h}{R_E}\right)$ for $h \ll R_E$ (where $R_E = 6400$ km). At what altitude is g reduced to 98% of its surface value?

(A) 32 km

(B) 64 km

(C) 128 km

(D) 16 km

Q6. A particle of mass $m = 0.1$ kg executes SHM with amplitude $A = 0.1$ m and angular frequency $\omega = 10$ rad/s. The total mechanical energy of the oscillating particle is:

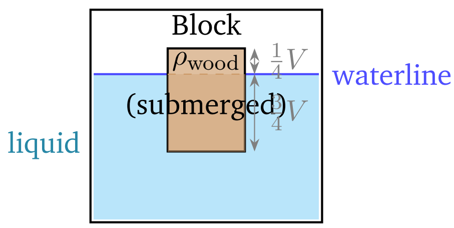
(A) 0.05 J

(B) 0.1 J

(C) 0.01 J

(D) 0.5 J

Q7. A wooden block of density $\rho_{\text{wood}} = 600\ \text{kg/m}^3$ floats with $\frac{3}{4}$ of its volume submerged in a liquid. The density of the liquid is:



(A) 600 kg/m^3

(B) 1200 kg/m^3

(C) 1000 kg/m^3

(D) 800 kg/m^3

Q8. An ideal gas undergoes an isothermal expansion and absorbs $Q = 500$ J of heat from the surroundings. The work done **by** the gas during this process is:

(A) 0 J

(B) 250 J

(C) 500 J

(D) 1000 J

Q9. For gas molecules of diameter d and number density n (molecules per unit volume), which of the following correctly gives the mean free path λ?

(A) $\lambda = \dfrac{1}{\pi d^2 n}$

(B) $\lambda = \dfrac{1}{\sqrt{2}\,\pi d^2 n}$

(C) $\lambda = \dfrac{1}{2\pi d^2 n}$

(D) $\lambda = \dfrac{d}{n}$

Q10. A transverse wave on a string is described by $y = 0.05\sin(2\pi x - 40\pi t)$ metres (x in metres, t in seconds). The speed of the wave is:

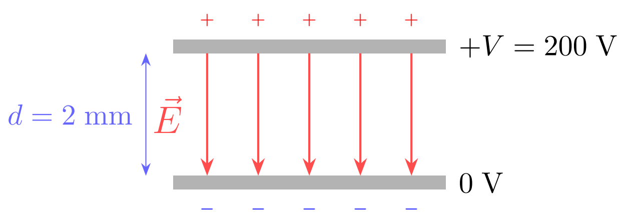
(A) 20 m/s

(B) 40 m/s

(C) 10 m/s

(D) 80 m/s

Q11. A parallel-plate capacitor has plate separation $d = 2$ mm and is connected to a battery maintaining a potential difference $V = 200$ V. The uniform electric field between the plates is:



(A) 10 kV/m

(B) 50 kV/m

(C) 200 kV/m

(D) 100 kV/m

Q12. A wire of length $L = 2$ m and cross-sectional area A has resistance $R = 8\ \Omega$. A second wire of the same material has length $L/2$ and cross-sectional area $2A$. The resistance of the second wire is:

(A) 16 Ω

(B) 8 Ω

(C) 2 Ω

(D) 4 Ω

Q13. A straight conductor of length $L = 0.5$ m carries a current $I = 4$ A and is placed perpendicular to a uniform magnetic field $B = 2$ T. The magnitude of the magnetic force on the conductor is:

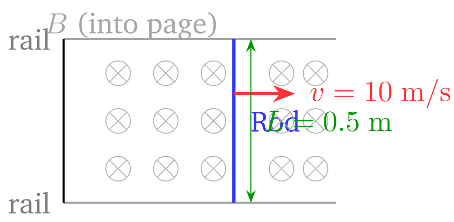
(A) 4 N

(B) 8 N

(C) 2 N

(D) 16 N

Q14. A conducting rod of length $L = 0.5$ m slides with velocity $v = 10$ m/s perpendicular to its own length in a uniform magnetic field $B = 2$ T directed into the page. The induced EMF across the ends of the rod is:



(A) 5 V

(B) 10 V

(C) 20 V

(D) 1 V

Q15. In a series LCR circuit, $R = 6\ \Omega$, $X_L = 10\ \Omega$, and $X_C = 2\ \Omega$. The impedance Z of the circuit is:

(A) 18 Ω

(B) 6 Ω

(C) 14 Ω

(D) 10 Ω

Q16. A concave mirror has focal length $f = 15$ cm. An object is placed 45 cm in front of the mirror. Using the mirror formula (sign convention: distances measured from pole, $u = -45$ cm, $f = -15$ cm), the image distance v is:

(A) -15 cm

(B) -45 cm

(C) -22.5 cm

(D) -30 cm

Q17. In Young's double-slit experiment, the slit separation is $d = 0.5$ mm and the screen is at $D = 1$ m from the slits. For light of wavelength $\lambda = 500$ nm, the fringe width β is:

(A) 1 mm

(B) 2 mm

(C) 0.5 mm

(D) 4 mm

Q18. In a photoelectric experiment, light of frequency $\nu = 6 \times 10^{14}$ Hz is incident on a metal with work function $W = 1.5$ eV. The stopping potential is approximately ($h = 6.6 \times 10^{-34}$ J · s):

(A) 2.5 V

(B) 1.0 V

(C) 0.5 V

(D) 3.0 V

Q19. In the Bohr model of the hydrogen atom, the radius of the n-th orbit is $r_n = n^2 a_0$ where $a_0 = 0.529$ is the Bohr radius. The ratio of the radii of the 3rd orbit to the 1st orbit (r_3/r_1) is:

(A) 3

(B) 6

(C) 1/3

(D) 9

Q20. When a p-n junction diode is **reverse-biased**, which statement is correct?

(A) The depletion region narrows and a large current flows.

(B) Majority carriers cross the junction and generate a large current.

(C) The depletion region widens; only a tiny reverse saturation current flows due to minority carriers.

(D) The junction has zero resistance and allows unrestricted current flow.

SECTION B — Numerical Value Questions (Q21–Q30)

Attempt any 5

Q21. A ball is thrown vertically upward with initial speed $u = 30$ m/s ($g = 10$ m/s^2). The maximum height reached (in metres) is ________.

Q22. Two resistors $R_1 = 4\ \Omega$ and $R_2 = 12\ \Omega$ are connected in parallel and the combination is connected to a 6 V battery with negligible internal resistance. The total current drawn from the battery (in amperes) is ________.

Q23. An LC oscillator circuit has $L = 0.25$ H and $C = 0.01$ F. The angular frequency of oscillation ω (in rad/s) is ________.

Q24. A Carnot refrigerator operates between a cold reservoir at $T_L = 250$ K and a hot reservoir at $T_H = 300$ K. The coefficient of performance (COP) is ________.

Q25. Two point charges $+q$ and $-q$ of equal magnitude $q = 3\ \mu$C are placed at $x = -15$ cm and $x = +15$ cm respectively on the x-axis. The electric potential at the midpoint (origin) is ________ V.

Q26. A 100 W electric lamp is operated for 10 h. The energy consumed (in kWh) is ________.

Q27. The half-life of a radioactive isotope is 20 min. After 1 h $(= 60$ min$)$, the fraction of the original number of atoms remaining is ________.

Q28. A current $I = 3$ A flows through a conductor for time $t = 1$ min $= 60$ s. The total charge that passes through any cross-section of the conductor (in coulombs) is ________.

Q29. A convex lens of focal length $f = 20$ cm has an object placed 60 cm in front of it ($u = -60$ cm). The image distance v (in cm, positive for real image) is ________.

Q30. The work function of a metal is $W = 2.0$ eV. The threshold (minimum) frequency of light required to eject photoelectrons, in units of 10^{14} Hz, is approximately ________.

DETAILED SOLUTIONS

Solution

Topic: Kinematics — Displacement from Variable Velocity

The displacement is the integral of velocity over time:

$$x = \int_1^3 v\,dt = \int_1^3 (3t^2 - 6t + 2)\,dt = \left[t^3 - 3t^2 + 2t\right]_1^3$$

$$= (27 - 27 + 6) - (1 - 3 + 2) = 6 - 0 = 6\text{ m}$$

Why other options are wrong:

Q1.

- Option A (3 m): Incorrect — this would result from using only part of the integral or substituting $t = 1$ improperly.
- Option C (9 m): Incorrect — corresponds to a simple arithmetic error of not subtracting the lower limit contribution.
- Option D (4 m): Incorrect — results from a sign error in the integration.

Answer: (B)

Solution

Topic: Laws of Motion — Atwood Machine Acceleration

For an Atwood machine with masses m_1 and m_2 ($m_2 > m_1$), the acceleration is:

$$a = \frac{(m_2 - m_1)\,g}{m_1 + m_2} = \frac{(7-3)\times 10}{3+7} = \frac{4\times 10}{10} = 4\text{ m/s}^2$$

The heavier mass ($m_2 = 7$ kg) accelerates downward, and the lighter mass ($m_1 = 3$ kg) accelerates upward with the same magnitude.

Why other options are wrong:

Q2.

- Option A (2 m/s^2): Incorrect — this would arise from an error in computing the net force (e.g., dividing net force by only one mass).
- Option B (3 m/s^2): Incorrect — likely from using m_1 alone in the denominator.
- Option C (5 m/s^2): Incorrect — would follow from using the average mass $\frac{m_1+m_2}{2} = 5$ erroneously.

Answer: (D)

Solution

Topic: Work, Energy and Power — Work Done by Variable Force

Work done by a variable force along the x-axis:

$$W = \int_0^3 F\,dx = \int_0^3 (4x+3)\,dx = \left[2x^2 + 3x\right]_0^3$$

$$= \left(2 \times 9 + 3 \times 3\right) - 0 = 18 + 9 = 27 \text{ J}$$

Why other options are wrong:

Q3.

- Option B (18 J): Incorrect — this is only the $2x^2$ contribution; the constant term $3x$ at $x = 3$ gives an additional 9 J.
- Option C (12 J): Incorrect — results from evaluating F at $x = 3$ and multiplying by displacement, not integrating.
- Option D (21 J): Incorrect — a likely arithmetic error (e.g., $18 + 3 = 21$, forgetting to evaluate 3×3 fully).

Answer: (A)

Solution

Topic: Rotational Motion — Parallel Axis Theorem

The parallel axis theorem states: $I = I_{cm} + Md^2$, where d is the distance between the two parallel axes.

For a thin ring, the CM is at the centre and the circumference point is at distance R from the centre:

$$I = I_{cm} + MR^2 = MR^2 + MR^2 = 2MR^2$$

Why other options are wrong:

Q4.

- Option A (MR^2): This is I_{cm} itself — forgetting to add MR^2 for the shifted axis.
- Option B ($\frac{3}{2}MR^2$): Incorrect — this would be the result for a solid disc, not a ring.
- Option D ($\frac{1}{2}MR^2$): Incorrect — this is the moment of inertia of a solid disc about its diameter, not relevant here.

Answer: (C)

Solution

Topic: Gravitation — Variation of g with Altitude

Given $g' = g\left(1 - \frac{2h}{R_E}\right)$. For $g' = 0.98\,g$:

$$0.98 = 1 - \frac{2h}{R_E} \implies \frac{2h}{R_E} = 0.02 \implies h = 0.01\,R_E$$

$$h = 0.01 \times 6400 \text{ km} = 64 \text{ km}$$

Why other options are wrong:

Q5.

- Option A (32 km): Incorrect — corresponds to $h = 0.005\,R_E$, i.e., a 1% reduction, not 2%.
- Option C (128 km): Incorrect — this would give a 4% reduction in g (double the required).
- Option D (16 km): Incorrect — corresponds to only a 0.5% reduction.

Answer: (B)

Solution

Topic: Oscillations — Total Mechanical Energy in SHM

The total mechanical energy in SHM is:

$$E = \frac{1}{2}m\omega^2A^2 = \frac{1}{2} \times 0.1 \times (10)^2 \times (0.1)^2$$

$$= \frac{1}{2} \times 0.1 \times 100 \times 0.01 = \frac{1}{2} \times 0.1 = 0.05 \text{ J}$$

Why other options are wrong:

Q6.

- Option B (0.1 J): Incorrect — twice the correct answer; a factor-of-2 error in the formula.
- Option C (0.01 J): Incorrect — arises from omitting ω^2 (i.e., using $E = \frac{1}{2}mA^2$ without ω^2).
- Option D (0.5 J): Incorrect — an order-of-magnitude error.

Answer: (A)

Solution

Topic: Mechanical Properties of Fluids — Archimedes' Principle

For a floating body, the weight equals the buoyant force:

$$\rho_{\text{wood}}\, V\, g = \rho_{\text{liquid}}\, V_{\text{sub}}\, g$$

$$600 \times V = \rho_{\text{liquid}} \times \frac{3}{4}V \implies \rho_{\text{liquid}} = \frac{600 \times 4}{3} = 800 \text{ kg/m}^3$$

Why other options are wrong:

Q7.

- Option A (600 kg/m^3): This would mean the block is fully submerged (fraction = 1), not 3/4 submerged.
- Option B (1200 kg/m^3): Incorrect — this would apply if only half the block were submerged ($\rho_{\text{liquid}} = 2\rho_{\text{wood}}$).
- Option C (1000 kg/m^3): Incorrect — pure water density; would require submerged fraction $= 0.6$, not 0.75.

Answer: (D)

Solution

Topic: Thermodynamics — First Law for Isothermal Process

For an isothermal process of an ideal gas, the temperature is constant, hence the internal energy does not change: $\Delta U = 0$.

By the First Law of Thermodynamics:

$$\Delta U = Q - W \implies 0 = Q - W \implies W = Q = 500 \text{ J}$$

All heat absorbed is converted to work done by the gas.

Why other options are wrong:

Q8.

- Option A (0 J): Incorrect — this would apply to an isochoric (constant volume) process, where no work is done.
- Option B (250 J): Incorrect — no physical basis for splitting Q equally in an isothermal process.
- Option D (1000 J): Incorrect — the work done cannot exceed the heat absorbed when $\Delta U = 0$.

Answer: (C)

Solution

Topic: Kinetic Theory of Gases — Mean Free Path

From kinetic theory, when relative motion between molecules is accounted for, the mean free path is:

$$\lambda = \frac{1}{\sqrt{2}\,\pi d^2 n}$$

The factor $\sqrt{2}$ appears because the average relative speed of molecules is $\sqrt{2}$ times their average speed.

Why other options are wrong:

Q9.

- Option A: Missing the $\sqrt{2}$ factor — valid only if all molecules were stationary except one.
- Option C: Uses a factor of 2 instead of $\sqrt{2}$; not physically justified.
- Option D: $\lambda = d/n$ has wrong dimensions and lacks the cross-sectional area πd^2.

Answer: (B)

Solution

Topic: Waves — Wave Speed from Equation

The wave equation $y = 0.05\sin(2\pi x - 40\pi t)$ has the form $y = A\sin(kx - \omega t)$, so:

$$k = 2\pi \text{ rad/m}, \qquad \omega = 40\pi \text{ rad/s}$$

$$v = \frac{\omega}{k} = \frac{40\pi}{2\pi} = 20 \text{ m/s}$$

Why other options are wrong:

Q10.

- Option B (40 m/s): This equals $\omega/(2\pi)$ in non-SI units; a factor-of-2 error.
- Option C (10 m/s): Incorrect — this would follow from $v = k\omega$ instead of $v = \omega/k$.
- Option D (80 m/s): Incorrect — $\omega \cdot k = 40\pi \times 2\pi$ has wrong units and formula.

Answer: (A)

Solution

Topic: Electrostatic Potential and Capacitance — Electric Field in Capacitor

For a parallel-plate capacitor, the uniform electric field between the plates is:

$$E = \frac{V}{d} = \frac{200\ \text{V}}{2 \times 10^{-3}\ \text{m}} = 100{,}000\ \text{V/m} = 100\ \text{kV/m}$$

Why other options are wrong:

Q11.

- Option A (10 kV/m): Incorrect — a factor-of-10 error; d was taken as 20 mm instead of 2 mm.
- Option B (50 kV/m): Incorrect — a factor-of-2 error; d was taken as 4 mm.
- Option C (200 kV/m): Incorrect — d was not converted from mm to m (used $d = 1$ mm).

Answer: (D)

Solution

Topic: Current Electricity — Resistance and Resistivity

Resistance of a wire: $R = \rho L/A$.

For the first wire: $8 = \rho \cdot 2/A \Rightarrow \rho/A = 4\ \Omega/\text{m}$.

For the second wire (length $L/2 = 1$ m, area $2A$):

$$R' = \frac{\rho \cdot (L/2)}{2A} = \frac{\rho}{A} \cdot \frac{L/2}{2} = 4 \times \frac{1}{2} = 2\ \Omega$$

Alternatively: $R' = R \times \dfrac{L'/L}{A'/A} = 8 \times \dfrac{1/2}{2} = 8 \times \dfrac{1}{4} = 2\ \Omega$

Why other options are wrong:

Q12.

- Option A (16 Ω): Incorrect — doubling R instead of applying both changes (L halved and A doubled).
- Option B (8 Ω): Incorrect — the two factors of 2 cancel, but one is in the denominator (area) and one in the numerator (length halved), giving a factor of 4 reduction overall.
- Option D (4 Ω): Incorrect — accounts for only one of the two changes (either length or area, not both).

Answer: (C)

Solution

Topic: Moving Charges and Magnetism — Force on Current-Carrying Conductor

The force on a current-carrying conductor in a magnetic field is:

$$F = BIL\sin\theta$$

Since the conductor is perpendicular to the field ($\theta = 90$, $\sin 90 = 1$):

$$F = BIL = 2 \times 4 \times 0.5 = 4\ \mathrm{N}$$

Why other options are wrong:

Q13.

- Option B (8 N): Incorrect — uses $L = 1$ m instead of 0.5 m, or doubles the answer in error.
- Option C (2 N): Incorrect — likely uses L or I halved (e.g., $2 \times 2 \times 0.5$).
- Option D (16 N): Incorrect — B or I is doubled erroneously before multiplying.

Answer: (A)

Solution

Topic: Electromagnetic Induction — Motional EMF

The EMF induced in a rod of length L moving with velocity v perpendicular to a magnetic field B is:

$$\varepsilon = BLv = 2 \times 0.5 \times 10 = 10\ \mathrm{V}$$

The rod sweeps out area at rate $A/t = Lv$, giving $\varepsilon = B(Lv)$.

Why other options are wrong:

Q14.

- Option A (5 V): Incorrect — uses $v = 5$ m/s or $B = 1$ T by mistake.
- Option C (20 V): Incorrect — uses $L = 1$ m instead of 0.5 m, giving $2 \times 1 \times 10 = 20$.
- Option D (1 V): Incorrect — likely divides instead of multiplying, or uses wrong values.

Answer: (B)

Solution

Topic: Alternating Current — Impedance of Series LCR Circuit

The impedance of a series LCR circuit is:

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{6^2 + (10-2)^2} = \sqrt{36+64} = \sqrt{100} = 10\ \Omega$$

Net reactance: $X_L - X_C = 10 - 2 = 8\ \Omega$ (inductive dominates).

Why other options are wrong:

Q15.

- Option A (18 Ω): Incorrect — adds $R + X_L + X_C$ arithmetically, not using the phasor formula.
- Option B (6 Ω): This is just R — ignoring the reactance entirely.
- Option C (14 Ω): Incorrect — adds $R + (X_L - X_C) = 6 + 8 = 14$ instead of using the quadrature sum.

Answer: (D)

Solution

Topic: Ray Optics — Mirror Formula for Concave Mirror

Using the mirror formula with sign convention ($u = -45$ cm, $f = -15$ cm):

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \implies \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-45}$$

$$= -\frac{3}{45} + \frac{1}{45} = -\frac{2}{45} \implies v = -22.5\ \text{cm}$$

The image is real, inverted, and located between the focal point and centre of curvature.

Why other options are wrong:

Q16.

- Option A (-15 cm): This is the focal point; would require object at infinity.
- Option B (-45 cm): This equals u; image at u only when object is at the centre of curvature ($u = -30$ cm here).
- Option D (-30 cm): Incorrect — this is the centre of curvature ($2f$), not the image position for object at 45 cm.

Answer: (C)

Q17.

Solution

Topic: Wave Optics — Young's Double-Slit Fringe Width

The fringe width in YDSE is:

$$\beta = \frac{\lambda D}{d} = \frac{500 \times 10^{-9}\ \text{m} \times 1\ \text{m}}{0.5 \times 10^{-3}\ \text{m}} = \frac{5 \times 10^{-7}}{5 \times 10^{-4}} = 10^{-3}\ \text{m} = 1\ \text{mm}$$

Why other options are wrong:

- Option B (2 mm): Incorrect — would require $d = 0.25$ mm or $\lambda = 1000$ nm.
- Option C (0.5 mm): Incorrect — would require $d = 1$ mm, doubling the slit separation.
- Option D (4 mm): Incorrect — would require $D = 4$ m or $d = 0.125$ mm.

Answer: (A)

Q18.

Solution

Topic: Dual Nature of Radiation and Matter — Photoelectric Stopping Potential

Energy of incident photon:

$$E = h\nu = 6.6 \times 10^{-34} \times 6 \times 10^{14} = 3.96 \times 10^{-19}\ \text{J}$$

Converting to eV: $E = \frac{3.96 \times 10^{-19}}{1.6 \times 10^{-19}} \approx 2.475\ \text{eV}$

Maximum kinetic energy of emitted electrons:

$$KE_{\max} = E - W = 2.475 - 1.5 = 0.975\ \text{eV} \approx 1.0\ \text{eV}$$

Stopping potential: $eV_0 = KE_{\max} \Rightarrow V_0 \approx 1.0\ \text{V}$

Why other options are wrong:

- Option A (2.5 V): Incorrect — this is approximately the photon energy in eV, not the stopping potential (work function not subtracted).
- Option C (0.5 V): Incorrect — results from using $W = 2.0$ eV (confusing with Q30 work function value).
- Option D (3.0 V): Incorrect — exceeds photon energy; physically impossible.

Answer: (B)

Solution

Topic: Atoms — Bohr Model Orbital Radii

In the Bohr model, $r_n = n^2 a_0$. Therefore:

$$r_1 = 1^2\, a_0 = a_0, \qquad r_3 = 3^2\, a_0 = 9\, a_0$$

$$\frac{r_3}{r_1} = \frac{9\, a_0}{a_0} = 9$$

Why other options are wrong:

Q19.

- Option A (3): Incorrect — this would apply if $r_n \propto n$ (linear), not n^2 (quadratic).
- Option B (6): Incorrect — no physical basis; possibly from $r_3/r_1 = 2n+1 = 5$ type confusion.
- Option C (1/3): Incorrect — this is the inverse ratio r_1/r_3, indicating the orbit indices were swapped.

Answer: (D)

Solution

Topic: Semiconductor Electronics — p-n Junction Under Reverse Bias

When a p-n junction is reverse-biased, the external voltage pushes majority carriers away from the junction. This causes the depletion region to widen, increasing the potential barrier. As a result:

Q20.

- Majority carriers cannot cross the junction.
- Only minority carriers (thermally generated) can cross, producing a tiny **reverse saturation current** ($\sim \mu$A).
- The junction acts as a very high-resistance element.

Why other options are wrong:

- Option A: Completely opposite — the depletion region widens (not narrows) under reverse bias.
- Option B: Describes forward bias behaviour; majority carriers cross in forward bias, not reverse.
- Option D: Opposite of reality — zero resistance corresponds to the ideal forward-biased diode, not reverse bias.

Answer: (C)

SECTION B — Numerical Value Solutions (Q21–Q30)

Q21.

Solution

Topic: Kinematics — Maximum Height of Vertical Projectile

At maximum height, the final velocity $v = 0$. Using the equation $v^2 = u^2 - 2gH$:

$$0 = u^2 - 2gH \implies H = \frac{u^2}{2g} = \frac{(30)^2}{2 \times 10} = \frac{900}{20} = 45 \text{ m}$$

Answer: (45)

Q22.

Solution

Topic: Current Electricity — Parallel Resistors and Total Current

For resistors in parallel, the equivalent resistance is:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4} + \frac{1}{12} = \frac{3}{12} + \frac{1}{12} = \frac{4}{12} = \frac{1}{3}\ \Omega^{-1}$$

$$R_{eq} = 3\ \Omega$$

Total current: $I = \dfrac{V}{R_{eq}} = \dfrac{6}{3} = 2$ A

Alternatively: $I = V\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right) = 6 \times \dfrac{1}{3} = 2$ A

Answer: (2)

Q23.

Solution

Topic: Alternating Current — Angular Frequency of LC Oscillator

The angular frequency of oscillation in an LC circuit:

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.25 \times 0.01}} = \frac{1}{\sqrt{0.0025}} = \frac{1}{0.05} = 20 \text{ rad/s}$$

Answer: (20)

Q24.

Solution

Topic: Thermodynamics — Coefficient of Performance of Carnot Refrigerator

The COP of a Carnot refrigerator is:

$$\text{COP} = \frac{T_L}{T_H - T_L} = \frac{250}{300 - 250} = \frac{250}{50} = 5$$

This means for every 1 J of work input, the refrigerator extracts 5 J of heat from the cold reservoir.

Answer: (5)

Q25.

Solution

Topic: Electrostatic Potential and Capacitance — Superposition of Potentials

Electric potential is a scalar quantity. At the midpoint (origin), both charges are at equal distance $r = 15 \text{ cm} = 0.15 \text{ m}$:

$$V = \frac{kq}{r} + \frac{k(-q)}{r} = \frac{kq - kq}{r} = 0 \text{ V}$$

The positive and negative potentials exactly cancel by symmetry.

Answer: (0)

Q26.

Solution

Topic: Current Electricity — Electrical Energy Consumption

Energy consumed:

$$E = P \times t = 100\ \text{W} \times 10\ \text{h} = 1000\ \text{Wh} = 1\ \text{kWh}$$

One kilowatt-hour (1 kWh) is also known as one "unit" of electricity.

Answer: (1)

Q27.

Solution

Topic: Nuclei — Radioactive Decay and Half-Life

Number of half-lives elapsed:

$$n = \frac{t}{T_{1/2}} = \frac{60\ \text{min}}{20\ \text{min}} = 3$$

Fraction remaining:

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^3 = \frac{1}{8} = 0.125$$

Answer: (0.125)

Q28.

Solution

Topic: Current Electricity — Electric Charge and Current

By definition, current is charge per unit time: $I = Q/t$. Therefore:

$$Q = I \times t = 3\ \text{A} \times 60\ \text{s} = 180\ \text{C}$$

Answer: (180)

Q29.

Solution

Topic: Ray Optics — Convex Lens and Lens Formula

Using the lens formula with $f = +20$ cm and $u = -60$ cm:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \implies \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{-60}$$

$$= \frac{3}{60} - \frac{1}{60} = \frac{2}{60} = \frac{1}{30} \implies v = 30 \text{ cm}$$

The image is real (positive v), inverted, and diminished.

Answer: (30)

Q30.

Solution

Topic: Dual Nature of Radiation and Matter — Threshold Frequency

At the threshold frequency ν_0, the photon energy exactly equals the work function:

$$h\nu_0 = W = 2.0 \text{ eV} = 2.0 \times 1.6 \times 10^{-19} \text{ J} = 3.2 \times 10^{-19} \text{ J}$$

$$\nu_0 = \frac{W}{h} = \frac{3.2 \times 10^{-19}}{6.6 \times 10^{-34}} \approx 4.85 \times 10^{14} \text{ Hz} \approx 4.8 \times 10^{14} \text{ Hz}$$

So $\nu_0 \approx 4.8$ (in units of 10^{14} Hz).

$\boxed{\textbf{Answer: (4.8)}}$

ANSWER KEY

Section A — MCQ Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	D	3	A	4	C	5	B
6	A	7	D	8	C	9	B	10	A
11	D	12	C	13	A	14	B	15	D
16	C	17	A	18	B	19	D	20	C

Section B — Numerical Answer Key

Q	Ans	Q	Ans
21	45	22	2
23	20	24	5
25	0	26	1
27	0.125	28	180
29	30	30	4.8