JEE Main – Physics

Sample Paper 4

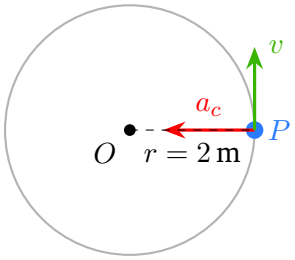
Duration: 60 Minutes | Maximum Marks: 100

Instructions

- **Section A** (Q1–Q20): Single Correct MCQ. **+4** for correct answer; **−1** for wrong answer.
- **Section B** (Q21–Q30): Numerical Value Questions. Attempt **any 5**. **+4** for correct; **0** for incorrect. No negative marking.
- Use blue/black ballpoint pen only. No calculator permitted.
- Mark only one option per MCQ. Overwriting or multiple marks will be treated as wrong.

SECTION A — Single Correct MCQ (Q1 to Q20) [+4 / −1]

Q1. A particle moves in a horizontal circle of radius $r = 2\,\text{m}$ at a constant speed $v = 4\,\text{m/s}$. The magnitude of the centripetal acceleration of the particle is:



(A) $2\,\text{m/s}^2$

(B) $4\,\text{m/s}^2$

(C) $16\,\text{m/s}^2$

(D) $8\,\text{m/s}^2$

Q2. A rocket ejects exhaust gas at a relative velocity of $v_{\text{rel}} = 500\,\text{m/s}$ with respect to the rocket. The rate of ejection of gas is $\dfrac{dm}{dt} = 50\,\text{kg/s}$. The thrust force acting on the rocket is:

(A) $25\,\text{kN}$

(B) $10\,\text{kN}$

(C) $50\,\text{kN}$

(D) $100\,\text{kN}$

Q3. Two identical balls, each of mass m, undergo a perfectly elastic head-on collision. Ball 1 moves with velocity $u_1 = 3\,\text{m/s}$ and Ball 2 is at rest ($u_2 = 0$). After the collision, the velocity of Ball 2 is:

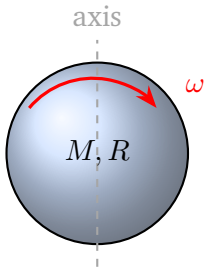
(A) $0\,\text{m/s}$

(B) $3\,\text{m/s}$

(C) $6\,\text{m/s}$

(D) $1.5\,\text{m/s}$

Q4. A solid sphere of mass $M = 2\,\text{kg}$ and radius $R = 0.1\,\text{m}$ rotates about its diameter with angular speed $\omega = 10\,\text{rad/s}$. The rotational kinetic energy of the sphere is:



(A) $0.2\,\text{J}$

(B) $0.8\,\text{J}$

(C) $0.4\,\text{J}$

(D) $1.0\,\text{J}$

Q5. Which of the following statements about a geostationary satellite is **FALSE**?

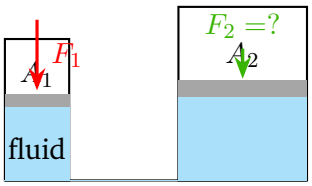
(A) It orbits in the equatorial plane of the Earth.

(B) Its angular velocity equals the angular velocity of the Earth's rotation.

(C) It appears stationary when observed from any fixed point on Earth.

(D) It orbits at an altitude equal to the radius of the Earth.

Q6. A hydraulic press has a small piston of area $A_1 = 0.02\,\text{m}^2$ and a large piston of area $A_2 = 0.4\,\text{m}^2$. A force of $F_1 = 100\,\text{N}$ is applied on the small piston. By Pascal's law, the force exerted on the large piston is:



(A) $2000\,\text{N}$

(B) $200\,\text{N}$

(C) $20000\,\text{N}$

(D) $100\,\text{N}$

Q7. A heat engine absorbs $Q_H = 1000\,\text{J}$ per cycle from the hot reservoir and rejects $Q_C = 600\,\text{J}$ to the cold reservoir. The thermal efficiency of this engine is:

(A) 60%

(B) 40%

(C) 30%

(D) 50%

Q8. Which of the following correctly describes the motion of a **critically damped** oscillator after it is displaced from equilibrium and released?

(A) The system oscillates at a reduced frequency compared to the undamped case.

(B) The system returns to equilibrium in the *minimum possible time* without oscillating.

(C) The amplitude of oscillation decays very slowly over many cycles.

(D) The system overshoots equilibrium and oscillates with increasing frequency.

Q9. An open organ pipe of length $L = 0.5\,\text{m}$ is set into vibration. Taking the speed of sound in air as $v = 340\,\text{m/s}$, the frequency of the **first overtone** (second harmonic) is:

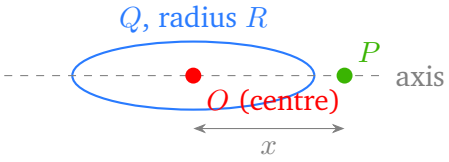
(A) $170\,\text{Hz}$

(B) $340\,\text{Hz}$

(C) $510\,\text{Hz}$

(D) $680\,\text{Hz}$

Q10. A thin ring of radius R carries a uniform total charge Q. The electric field at the **geometrical centre** of the ring is:



(A) Zero

(B) $\dfrac{kQ}{R^2}$

(C) Maximum along the axis

(D) $\dfrac{kQ}{2R^2}$

Q11. A capacitor of capacitance $C = 4\,\mu\text{F}$ is fully charged by a battery of emf $V = 100\,\text{V}$. The electrostatic energy stored in the capacitor is:

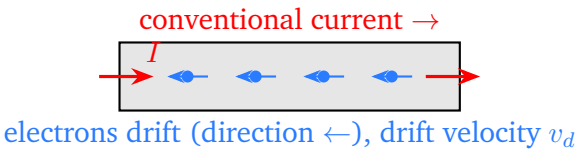
(A) $10\,\text{mJ}$

(B) $20\,\text{mJ}$

(C) $40\,\text{mJ}$

(D) $5\,\text{mJ}$

Q12. In a copper conductor of cross-sectional area $A = 10^{-6}\,\text{m}^2$ carrying a current of $I = 1\,\text{A}$, the free-electron number density is $n = 8.5 \times 10^{28}\,\text{m}^{-3}$ and the charge of each electron is $q = 1.6 \times 10^{-19}\,\text{C}$. The drift velocity v_d of the conduction electrons is of the order of:



(A) Of the order of the speed of light ($\sim 3 \times 10^8$ m/s)

(B) Of the order of metres per second

(C) Of the order of mm/s or less

(D) Exactly zero in a copper conductor

Q13. At a given location on the Earth's surface, the angle between the geographic north and the horizontal component of the Earth's magnetic field (i.e., the direction of the magnetic meridian) is called the:

(A) Angle of inclination

(B) Angle of dip

(C) Magnetic latitude

(D) Magnetic declination

Q14. An ideal LC circuit consists of an inductor $L = 0.1\,\text{H}$ and a capacitor $C = 100\,\mu\text{F}$. The frequency of electromagnetic oscillations in this circuit is approximately:

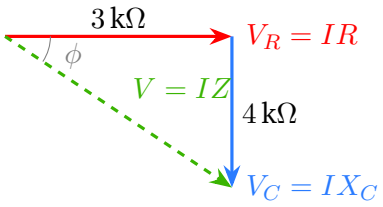
(A) $50\,\text{Hz}$

(B) $100\,\text{Hz}$

(C) $25\,\text{Hz}$

(D) $200\,\text{Hz}$

Q15. In a series RC circuit, the resistance is $R = 3\,\text{k}\Omega$ and the capacitive reactance is $X_C = 4\,\text{k}\Omega$ at the given frequency. The impedance Z of the circuit is:



(A) $7\,\text{k}\Omega$

(B) $5\,\text{k}\Omega$

(C) $3\,\text{k}\Omega$

(D) $4\,\text{k}\Omega$

Q16. An electromagnetic wave of intensity I falls normally on a surface. Compared to a **perfect absorber**, the radiation pressure on a **perfect reflector** of the same area exposed to the same beam is:

(A) The same

(B) Half as much

(C) Double

(D) Four times as much

Q17. A refracting telescope has an objective lens of focal length $f_o = 100\,\text{cm}$ and an eyepiece of focal length $f_e = 5\,\text{cm}$. The magnifying power of the telescope in normal adjustment is:

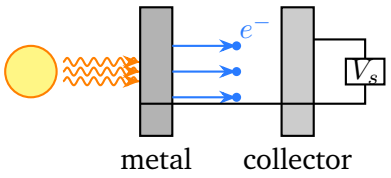
(A) 5

(B) 10

(C) 95

(D) 20

Q18. Light of frequency $f = 6 \times 10^{14}\,\text{Hz}$ falls on a metal surface whose work function is $\phi = 2\,\text{eV}$. (Use $h = 6.63 \times 10^{-34}\,\text{J s}$, $1\,\text{eV} = 1.6 \times 10^{-19}\,\text{J}$.) The stopping potential required to halt the most energetic photoelectrons is approximately:



(A) $0.5\,\text{V}$

(B) $1\,\text{V}$

(C) $2\,\text{V}$

(D) $2.5\,\text{V}$

Q19. In a **forward-biased** p-n junction diode, which of the following statements is correct?

(A) The width of the depletion region increases.

(B) Majority carriers flow across the junction, constituting the forward current.

(C) The reverse saturation current becomes very large.

(D) The p-side of the junction is connected to the negative terminal of the battery.

Q20. Each fission of a ^{235}U nucleus releases approximately $200\,\text{MeV}$ of energy ($1\,\text{MeV} = 1.6 \times 10^{-13}\,\text{J}$). In a nuclear reactor operating at a power of $P = 1\,\text{MW} = 10^{6}\,\text{W}$, the number of fissions occurring per second is of the order of:

(A) 10^{14}

(B) 10^{15}

(C) 10^{16}

(D) 10^{17}

SECTION B — Numerical Value Questions
(Q21 to Q30) Attempt ANY 5 [+4 / 0]

Q21. A particle of mass $m = 2\,\text{kg}$ moves in a circular path of radius $r = 2\,\text{m}$ at a constant speed $v = 4\,\text{m/s}$. Calculate the centripetal force (in N) acting on the particle.

(Enter the exact numerical value as your answer.)

Q22. The rms speed of oxygen molecules ($M = 32 \times 10^{-3}\,\text{kg/mol}$) at temperature $T = 205\,\text{K}$ is v_{rms}. Use $R = 8.31\,\text{J mol}^{-1}\text{K}^{-1}$. Calculate v_{rms} in m/s (rounded to the nearest integer).

(Enter the exact numerical value as your answer.)

Q23. A current of $3\,\text{A}$ flows through a resistor of resistance $3\,\Omega$. Calculate the potential difference (in V) across the resistor.

(Enter the exact numerical value as your answer.)

Q24. A battery of emf $\varepsilon = 12\,\text{V}$ and internal resistance $r = 1\,\Omega$ is connected to an external resistance $R = 1\,\Omega$. Calculate the current (in A) flowing through the circuit.

(Enter the exact numerical value as your answer.)

Q25. A straight conductor of length $L = 5\,\text{m}$ carries a current $I = 4\,\text{A}$ and is placed perpendicular to a uniform magnetic field $B = 0.5\,\text{T}$. Calculate the magnetic force (in N) acting on the conductor.

(Enter the exact numerical value as your answer.)

Q26. A refracting telescope has an objective of focal length $f_o = 200\,\text{cm}$ and an eyepiece of focal length $f_e = 10\,\text{cm}$. Calculate the magnifying power of the telescope in normal adjustment.

(Enter the exact numerical value as your answer.)

Q27. The energy released per fission of ^{235}U is approximately $200\,\text{MeV}$. Enter this value in MeV.

(Enter the exact numerical value as your answer.)

Q28. In an ideal LC circuit, $L = 0.01\,\text{H}$ and $C = 0.25\,\text{F}$. The capacitor is initially charged to a maximum charge of $Q_{\max} = 0.8\,\text{C}$ and the circuit is closed. The angular frequency of oscillation is $\omega = 1/\sqrt{LC}$. Calculate the peak (maximum) current $I_{\max}$ (in A) that flows in the circuit.

(Enter the exact numerical value as your answer.)

Q29. Two tuning forks have frequencies $f_1 = 256\,\text{Hz}$ and $f_2 = 260\,\text{Hz}$. When sounded together, beats are heard. Calculate the number of beats heard per second.

(Enter the exact numerical value as your answer.)

Q30. Two plane mirrors are inclined at an angle of 90° to each other. An object is placed between them. The number of images formed is given by $n = \frac{360^\circ}{\theta} - 1$. Calculate the number of images formed.

(Enter the exact numerical value as your answer.)

Answer Key

Section A

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
Q1	D	Q2	A	Q3	B	Q4	C	Q5	D
Q6	A	Q7	B	Q8	C	Q9	D	Q10	A
Q11	B	Q12	C	Q13	D	Q14	A	Q15	B
Q16	C	Q17	D	Q18	A	Q19	B	Q20	C

Section B

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
Q21	16	Q22	400	Q23	9	Q24	6	Q25	10
Q26	20	Q27	200	Q28	16	Q29	4	Q30	3

Detailed Solutions

Section A

Q1.

Solution

For uniform circular motion, centripetal acceleration is:

$$a_c = \frac{v^2}{r} = \frac{(4)^2}{2} = \frac{16}{2} = 8\,\text{m/s}^2$$

The velocity is always tangential and a_c is directed toward the centre (radially inward).

Answer: (D)

Q2.

Solution

The thrust force on a rocket is given by Newton's third law applied to the rocket equation:

$$F_{\text{thrust}} = v_{\text{rel}} \cdot \left|\frac{dm}{dt}\right| = 500\,\text{m/s} \times 50\,\text{kg/s} = 25{,}000\,\text{N} = \mathbf{25\,kN}$$

The gas is ejected backward, and by Newton's third law, the rocket is pushed forward with this thrust force.

Answer: (A)

Q3.

Solution

For a perfectly elastic head-on collision between two *equal masses*, the velocities are exchanged:

$$v_1' = u_2 = 0\,\text{m/s}, \qquad v_2' = u_1 = 3\,\text{m/s}$$

Ball 1 comes to rest and Ball 2 moves forward with the initial velocity of Ball 1. This can be verified using both conservation of momentum and conservation of kinetic energy.

Answer: (B)

Q4.

Solution

The moment of inertia of a solid sphere about its diameter is:

$$I = \frac{2}{5}MR^2 = \frac{2}{5} \times 2 \times (0.1)^2 = \frac{2}{5} \times 2 \times 0.01 = 0.008\,\text{kg m}^2$$

Rotational kinetic energy:

$$KE = \frac{1}{2}I\omega^2 = \frac{1}{2} \times 0.008 \times (10)^2 = \frac{1}{2} \times 0.008 \times 100 = 0.4\,\text{J}$$

Answer: (C)

Q5.

Solution

A geostationary satellite orbits in the equatorial plane (A is true), has the same angular velocity as Earth's rotation (B is true), and appears stationary from a fixed point on Earth (C is true).

The orbital radius of a geostationary satellite is approximately $42{,}000\,\text{km}$, which corresponds to an altitude of about $35{,}786\,\text{km} \approx 5.6\,R_\oplus$ above Earth's surface — *not* equal to $R_\oplus \approx 6{,}371\,\text{km}$.

Hence statement **(D) is FALSE.**

Answer: (D)

Q6.

Solution

By Pascal's law, pressure is transmitted equally throughout the fluid:

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \implies F_2 = F_1 \cdot \frac{A_2}{A_1} = 100 \times \frac{0.4}{0.02} = 100 \times 20 = \mathbf{2000\,N}$$

Answer: (A)

Q7.

Solution

The thermal efficiency of a heat engine is defined as:

$$\eta = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H} = \frac{1000 - 600}{1000} = \frac{400}{1000} = 0.40 = \mathbf{40}\%$$

The net work output per cycle is $W = 400\,\text{J}$.

Answer: (B)

Q8.

Solution

In a **critically damped** system, the damping coefficient is exactly at the critical value $b_c = 2\sqrt{km}$:

- There are *no oscillations* — the displacement decreases exponentially without crossing zero.
- The system returns to equilibrium in the *minimum possible time* among all non-oscillatory cases.
- Under-damped oscillators oscillate at a reduced frequency; over-damped oscillators also don't oscillate but return *more slowly*.

Statement **(B)** is therefore correct.

Answer: (C)

Q9.

Solution

For an **open pipe**, harmonics are at frequencies $f_n = n\,\dfrac{v}{2L}$ $(n = 1, 2, 3, \ldots)$:

$$f_1 = \frac{v}{2L} = \frac{340}{2 \times 0.5} = \frac{340}{1} = 340\,\text{Hz} \quad \text{(fundamental)}$$

$$f_2 = 2f_1 = 2 \times 340 = \mathbf{680}\,\text{Hz} \quad \text{(first overtone / second harmonic)}$$

Answer: (D)

Q10.

Solution

The electric field on the axis of a uniformly charged ring at distance x from its centre is:

$$E_{\text{axis}} = \frac{kQx}{(R^2 + x^2)^{3/2}}$$

At the **centre** of the ring, $x = 0$:

$$E = \frac{kQ \cdot 0}{(R^2 + 0)^{3/2}} = \mathbf{0}$$

By symmetry, every charge element on the ring has a diametrically opposite element whose field contribution cancels exactly at the centre.

Answer: (A)

Q11.

Solution

Energy stored in a capacitor:

$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 4 \times 10^{-6} \times (100)^2 = \frac{1}{2} \times 4 \times 10^{-6} \times 10^4 = 2 \times 10^{-2}\,\text{J} = \mathbf{20}\,\text{mJ}$$

Answer: (B)

Q12.

Solution

Drift velocity is related to current by:

$$v_d = \frac{I}{nAq} = \frac{1}{8.5 \times 10^{28} \times 10^{-6} \times 1.6 \times 10^{-19}} = \frac{1}{8.5 \times 1.6 \times 10^{28-6-19}} = \frac{1}{13.6 \times 10^3} \approx 7.4 \times 10^{-5}\,\text{m/s}$$

This is approximately 0.07 mm/s, confirming that drift velocity in metals is extremely small — of the order of **mm/s or less**.

Answer: (C)

Q13.

Solution

- **Angle of dip (inclination):** The angle the Earth's magnetic field vector makes with the horizontal.
- **Magnetic declination:** The angle between the *geographic* north (true north) and the *magnetic* north (direction of horizontal component of Earth's field) at a given location.

The question describes the magnetic declination. **Answer: (D)**.

Answer: (D)

Q14.

Solution

Angular frequency of LC oscillations:

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.1 \times 100 \times 10^{-6}}} = \frac{1}{\sqrt{10^{-5}}} = \frac{1}{10^{-2.5}} = 10^{2.5} \approx 316\,\text{rad/s}$$

Frequency:

$$f = \frac{\omega}{2\pi} = \frac{316}{2\pi} \approx \frac{316}{6.28} \approx \mathbf{50}\,\text{Hz}$$

Answer: (A)

Q15.

Solution

In a series RC circuit, impedance is:

$$Z = \sqrt{R^2 + X_C^2} = \sqrt{(3\,\text{k}\Omega)^2 + (4\,\text{k}\Omega)^2} = \sqrt{9+16}\,\text{k}\Omega = \sqrt{25}\,\text{k}\Omega = \mathbf{5\,k\Omega}$$

This is a classic 3-4-5 Pythagorean triple applied to impedance triangles.

Answer: (B)

Q16.

Solution

Radiation pressure depends on whether the surface absorbs or reflects the EM wave:

$$P_{\text{absorber}} = \frac{I}{c}, \qquad P_{\text{reflector}} = \frac{2I}{c}$$

The factor of 2 arises because the incident momentum p is absorbed in one case, but the reflected wave carries momentum p in the opposite direction, giving a total momentum change of $2p$ per photon in the reflecting case.

Hence radiation pressure on a perfect reflector is **double** that on a perfect absorber.

Answer: (C)

Q17.

Solution

For a refracting telescope in normal adjustment (final image at infinity):

$$M = \frac{f_o}{f_e} = \frac{100\,\text{cm}}{5\,\text{cm}} = \mathbf{20}$$

The length of the telescope in this adjustment is $f_o + f_e = 105\,\text{cm}$.

Answer: (D)

Q18.

Solution

Photon energy:

$$E = hf = 6.63 \times 10^{-34} \times 6 \times 10^{14} = 39.78 \times 10^{-20}\,\text{J} = 3.978 \times 10^{-19}\,\text{J}$$

Converting to eV:

$$E = \frac{3.978 \times 10^{-19}}{1.6 \times 10^{-19}} \approx 2.49\,\text{eV}$$

Stopping potential from Einstein's photoelectric equation:

$$eV_s = E - \phi = 2.49 - 2.00 = 0.49\,\text{eV} \implies V_s \approx \mathbf{0.5\,V}$$

Answer: (A)

Q19.

Solution

In **forward bias**:

- The p-side is connected to the *positive* terminal (not negative) — (D) is wrong.
- The depletion region *narrows* (not widens) — (A) is wrong.
- Majority carriers flow: holes from p-region cross to n-region and electrons from n-region cross to p-region — (B) is correct.
- It is the *minority carrier current* (reverse saturation current) that is small; forward current is large due to majority carriers — (C) is wrong.

Answer: (B).

Answer: (B)

Q20.

Solution

Number of fissions per second:

$$N = \frac{P}{E_{\text{fission}}} = \frac{10^6\,\text{W}}{200\,\text{MeV}} = \frac{10^6}{200 \times 10^6 \times 1.6 \times 10^{-19}\,\text{J}}$$

$$= \frac{10^6}{200 \times 1.6 \times 10^{-13}} = \frac{10^6}{3.2 \times 10^{-11}} = \frac{10^6}{3.2} \times 10^{11} \approx 3.1 \times 10^{16}$$

This is of the order of $\mathbf{10^{16}}$.

Answer: (C)

Section B — Numerical Solutions

Q21.

Solution

Centripetal force:

$$F_c = \frac{mv^2}{r} = \frac{2 \times (4)^2}{2} = \frac{2 \times 16}{2} = \frac{32}{2} = \mathbf{16\,N}$$

Answer: (16)

Q22.

Solution

Root mean square speed of gas molecules:

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.31 \times 205}{32 \times 10^{-3}}}$$

$$= \sqrt{\frac{3 \times 8.31 \times 205}{0.032}} = \sqrt{\frac{5110.65}{0.032}} = \sqrt{159{,}707} \approx 399.6 \approx \mathbf{400\,m/s}$$

Answer: (400)

Q23.

Solution

By Ohm's law:

$$V = IR = 3\,\text{A} \times 3\,\Omega = \mathbf{9\,V}$$

Answer: (9)

Q24.

Solution

Current in a simple circuit with internal resistance:

$$I = \frac{\varepsilon}{R + r} = \frac{12}{1 + 1} = \frac{12}{2} = \mathbf{6\,A}$$

Answer: (6)

Q25.

Solution

Force on a current-carrying conductor in a magnetic field:

$$F = BIL\sin\theta = 0.5 \times 4 \times 5 \times \sin 90^\circ = 0.5 \times 4 \times 5 \times 1 = \mathbf{10}\,\text{N}$$

The conductor is perpendicular to the field, so $\sin 90^\circ = 1$.

Answer: (10)

Q26.

Solution

Magnifying power of a refracting telescope in normal adjustment:

$$M = \frac{f_o}{f_e} = \frac{200\,\text{cm}}{10\,\text{cm}} = \mathbf{20}$$

Answer: (20)

Q27.

Solution

The energy released per fission of ^{235}U is a standard nuclear physics result:

$$E \approx \mathbf{200}\,\text{MeV}$$

This energy is distributed as kinetic energy of fission fragments, neutrons, gamma rays, and energy carried away by neutrinos in subsequent beta decays.

Answer: (200)

Q28.

Solution

Angular frequency of the LC circuit:

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

The peak current in LC oscillations:

$$I_{\max} = \omega\, Q_{\max} = 20 \times 0.8 = \mathbf{16}\,\text{A}$$

(When all energy is in the inductor: $\frac{1}{2}LI_{\max}^2 = \frac{1}{2}\frac{Q_{\max}^2}{C}$, giving the same result.)

Answer: (16)

Q29.

Solution

The beat frequency equals the absolute difference in frequencies of the two sources:

$$f_{\text{beat}} = |f_2 - f_1| = |260 - 256| = \mathbf{4}\,\text{beats per second}$$

Answer: (4)

Q30.

Solution

Number of images formed by two plane mirrors inclined at angle θ:

$$n = \frac{360^\circ}{\theta} - 1 = \frac{360^\circ}{90^\circ} - 1 = 4 - 1 = \mathbf{3}$$

(Valid when $360/\theta$ is an even integer or when the object is placed symmetrically.)

Answer: (3)