WBJEE Physics Sample Paper-6

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Categories**.
- **Section 1 (Q1–Q30):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section 2 (Q31–Q35):** Each correct answer carries **+2 marks**. Incorrect answer: **−0.5** marks. Only **one** correct option.
- **Section 3 (Q36–Q40):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Section–A — 30 Questions × 1 Mark Each (Negative Marking: −0.25) [Single Correct]

Q1. A particle moves in a straight line with velocity $v = 3t^2 - 12t + 9$ m/s. The distance travelled by the particle in the first 4 s is:

(A) 12 m

(B) 18 m

(C) 24 m

(D) 30 m

Q2. A block of mass m is kept on a rough horizontal surface. The coefficient of friction varies with distance as shown. For first 2 m, $\mu = 0.2$ and for next 3 m, $\mu = 0.4$. If the initial speed is 10 m/s, the stopping distance is nearly:

(A) 5 m

(B) 6 m

(C) 7 m

(D) 8 m

Q3. Two identical springs each of force constant k are connected in parallel and support a mass m. The time period of vertical oscillation is:

(A) $2\pi\sqrt{\frac{m}{k}}$

(B) $2\pi\sqrt{\frac{m}{2k}}$

(C) $2\pi\sqrt{\frac{2m}{k}}$

(D) $\pi\sqrt{\frac{m}{2k}}$

Q4. A projectile is fired with speed u at an angle θ. If the horizontal range equals the maximum height, then $\tan\theta$ is:

(A) 1

(B) 2

(C) 4

(D) 8

Q5. A satellite revolves around Earth in a circular orbit of radius R. If the orbital radius becomes $4R$, the ratio of new kinetic energy to old kinetic energy is:

(A) $\frac{1}{2}$

(B) $\frac{1}{4}$

(C) $\frac{1}{8}$

(D) $\frac{1}{16}$

Q6. A body cools from 80°C to 60°C in 10 min in surroundings at 20°C. The temperature of the body after next 10 min will be nearly:

(A) 45°C

(B) 47°C

(C) 50°C

(D) 52°C

Q7. A capillary tube of radius r is dipped in water. If the radius becomes $2r$, the capillary rise becomes:

(A) Double

(B) Half

(C) One-fourth

(D) Unchanged

Q8. In a Carnot engine, the sink temperature is 300 K and efficiency is 40%. The source temperature is:

(A) 400 K

(B) 450 K

(C) 500 K

(D) 600 K

Q9. A transverse wave is represented by $y = 0.02\sin(100\pi t - 5\pi x)$. The wave velocity is:

(A) 10 m/s

(B) 20 m/s

(C) 40 m/s

(D) 50 m/s

Q10. Two tuning forks of frequencies 256 Hz and 260 Hz are sounded together. The number of beats heard in 5 s is:

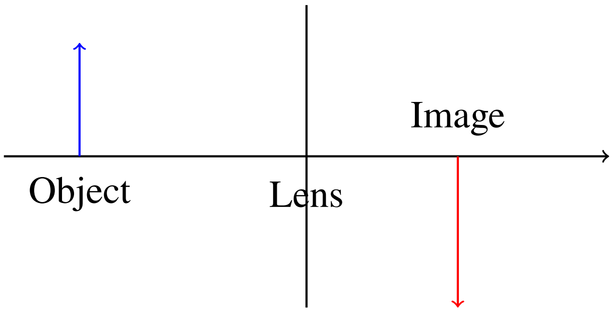
(A) 10

(B) 15

(C) 20

(D) 25

Q11. The following ray diagram shows an object placed before a convex lens forming a real image. If the magnification of the image is 2 and the distance between object and image is 30 cm, the focal length of the lens is:



(A) 5 cm

(B) 10 cm

(C) 15 cm

(D) 20 cm

Q12. A ray of light passes from glass ($\mu = \frac{3}{2}$) to air. The critical angle is:

(A) 30°

(B) 42°

(C) 48°

(D) 60°

Q13. In Young's double slit experiment, the slit separation is doubled and wavelength is halved. Fringe width becomes:

(A) Double

(B) Half

(C) One-fourth

(D) Four times

Q14. A charge $+q$ is placed at the centre of a cube. The electric flux through one face of the cube is:

(A) $\frac{q}{\epsilon_0}$

(B) $\frac{q}{2\epsilon_0}$

(C) $\frac{q}{4\epsilon_0}$

(D) $\frac{q}{6\epsilon_0}$

Q15. Three capacitors of capacitances 2 μF, 3 μF and 6 μF are connected in series across 22 V. The charge on 3 μF capacitor is:

(A) 6 μC

(B) 12 μC

(C) 18 μC

(D) 24 μC

Q16. A potentiometer wire of length 10 m has resistance 20 Ω. It is connected in series with a 5 Ω resistance and a 5 V battery. Potential gradient along the wire is:

(A) 0.1 V/m

(B) 0.2 V/m

(C) 0.4 V/m

(D) 0.5 V/m

Q17. Two cells of emf 2 V and 1 V with internal resistances 1 Ω each are connected in opposition. The external resistance is 2 Ω. Current in the circuit is:

(A) 0.2 A

(B) 0.25 A

(C) 0.5 A

(D) 1 A

Q18. A proton enters a magnetic field perpendicular to it with speed v. If both speed and magnetic field are doubled, radius of circular path becomes:

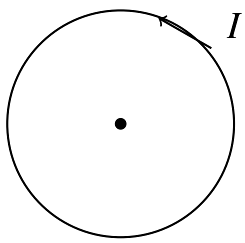
(A) Same

(B) Double

(C) Half

(D) Four times

Q19. The figure shows a circular current carrying coil. The magnetic field at the centre is B. If both radius and current are doubled, the magnetic field at the centre becomes:



(A) $\frac{B}{2}$

(B) B

(C) $2B$

(D) $4B$

Q20. In an AC circuit containing only capacitance, the current leads the voltage by:

(A) 0°

(B) 45°

(C) 90°

(D) 180°

Q21. The work function of a metal is 2 eV. The threshold wavelength is nearly:

(A) 620 nm

(B) 540 nm

(C) 410 nm

(D) 300 nm

Q22. The ratio of radii of second and first Bohr orbits is:

(A) 1

(B) 2

(C) 4

(D) 8

Q23. A radioactive sample has half-life 5 days. Fraction remaining after 15 days is:

(A) $\frac{1}{2}$

(B) $\frac{1}{4}$

(C) $\frac{1}{8}$

(D) $\frac{1}{16}$

Q24. The logic gate for which output is 1 only when inputs are different is:

(A) AND

(B) OR

(C) XOR

(D) NAND

Q25. A wire is stretched to double its original length. Its resistance becomes:

(A) Double

(B) Triple

(C) Four times

(D) Eight times

Q26. A particle executes SHM of amplitude 5 cm and frequency 2 Hz. Maximum acceleration is:

(A) $0.4\pi^2$ m/s^2

(B) $0.8\pi^2$ m/s^2

(C) $1.6\pi^2$ m/s^2

(D) $4\pi^2$ m/s^2

Q27. A man can swim at 5 km/h in still water. He crosses a river flowing at 3 km/h by moving perpendicular to the current. Resultant speed is:

(A) 2 km/h

(B) 4 km/h

(C) $\sqrt{34}$ km/h

(D) 8 km/h

Q28. A solid sphere and a hollow sphere of same mass and radius roll down an inclined plane. Which reaches first?

(A) Solid sphere

(B) Hollow sphere

(C) Both together

(D) Depends on angle

Q29. A gas expands adiabatically. During the process:

(A) Temperature remains constant

(B) Pressure remains constant

(C) Heat exchange is zero

(D) Internal energy remains constant

Q30. A diffraction grating has 5000 lines/cm. The grating element is:

(A) 1×10^{-4} m

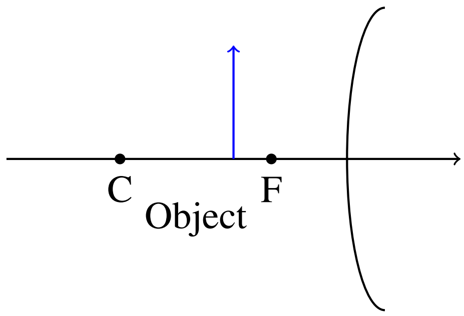
(B) 2×10^{-6} m

(C) 5×10^{-5} m

(D) 2×10^{-4} m

Section–B — 5 Questions × 1 Mark Each
(Negative Marking: −0.5) [Single Correct]

Q31. The following figure shows an object placed before a concave mirror. If the object is 20 cm from the mirror and focal length is 15 cm, the image formed is:



(A) Real and magnified

(B) Real and diminished

(C) Virtual and magnified

(D) Virtual and diminished

Q32. The drift velocity of electrons in a conductor increases when:

(A) Temperature increases

(B) Potential difference decreases

(C) Electric field increases

(D) Length decreases only

Q33. An electron and a proton enter the same electric field from rest. The ratio of their accelerations is nearly:

(A) 1 : 1

(B) 1836 : 1

(C) 1 : 1836

(D) 3672 : 1

Q34. A wire carrying current from north to south is placed in a vertically downward magnetic field. The direction of magnetic force on the wire is:

(A) East

(B) West

(C) North

(D) Zero

Q35. The de Broglie wavelength of a particle is inversely proportional to:

(A) Velocity

(B) Momentum

(C) Energy

(D) Mass only

Section C — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q36. Which of the following statements regarding electric field lines are correct?

(A) Electric field lines originate from positive charges

(B) Electric field lines terminate at negative charges

(C) Two electric field lines can intersect each other

(D) Electric field lines are perpendicular to equipotential surfaces

Q37. A particle moves with constant acceleration. Which of the following quantities may become zero during motion?

(A) Velocity

(B) Displacement

(C) Distance travelled

(D) Acceleration

Q38. For a rigid body rotating with constant angular velocity, which of the following are correct?

(A) Every particle has same angular velocity

(B) Every particle has same linear velocity

(C) Centripetal acceleration acts on every particle

(D) Angular acceleration is zero

Q39. For a particle executing simple harmonic motion, which of the following statements are correct?

(A) Acceleration is proportional to displacement

(B) Velocity is maximum at mean position

(C) Potential energy is maximum at mean position

(D) Total energy remains constant

Q40. Which of the following statements are true for an isothermal process of an ideal gas?

(A) Temperature remains constant

(B) Internal energy remains constant

(C) Heat supplied equals work done

(D) Pressure always remains constant

Detailed Solutions

Q1.

Solution

Concept: To find the distance travelled, we need to integrate the magnitude of the velocity over the given time interval. First, we find the time instants when the velocity is zero to determine if the particle changes direction.

Solution: Step 1: Find when the velocity is zero.
The velocity is given by $v(t) = 3t^2 - 12t + 9$ m/s.
Set $v(t) = 0$ to find turning points:
$3t^2 - 12t + 9 = 0$
Divide by 3: $t^2 - 4t + 3 = 0$
Factor the quadratic equation: $(t-1)(t-3) = 0$
So, the velocity is zero at $t = 1$ s and $t = 3$ s.

Step 2: Determine the sign of the velocity in different intervals.
The intervals are $[0, 1)$, $(1, 3)$, and $(3, 4]$.
- For $0 \le t < 1$, let's test $t = 0.5$: $v(0.5) = 3(0.5)^2 - 12(0.5) + 9 = 3(0.25) - 6 + 9 = 0.75 + 3 = 3.75 > 0$. The particle moves in the positive direction.
- For $1 < t < 3$, let's test $t = 2$: $v(2) = 3(2)^2 - 12(2) + 9 = 3(4) - 24 + 9 = 12 - 24 + 9 = -3 < 0$. The particle moves in the negative direction.
- For $t > 3$, let's test $t = 3.5$: $v(3.5) = 3(3.5)^2 - 12(3.5) + 9 = 3(12.25) - 42 + 9 = 36.75 - 42 + 9 = 3.75 > 0$. The particle moves in the positive direction.

Step 3: Calculate the displacement in each interval.
Displacement is the integral of velocity.
- From $t = 0$ to $t = 1$: $\Delta x_1 = \int_0^1 (3t^2 - 12t + 9)dt = [t^3 - 6t^2 + 9t]_0^1 = (1^3 - 6(1)^2 + 9(1)) - (0) = 1 - 6 + 9 = 4$ m.
- From $t = 1$ to $t = 3$: $\Delta x_2 = \int_1^3 (3t^2 - 12t + 9)dt = [t^3 - 6t^2 + 9t]_1^3 = (3^3 - 6(3)^2 + 9(3)) - (1^3 - 6(1)^2 + 9(1)) = (27 - 54 + 27) - (1 - 6 + 9) = 0 - 4 = -4$ m.
- From $t = 3$ to $t = 4$: $\Delta x_3 = \int_3^4 (3t^2 - 12t + 9)dt = [t^3 - 6t^2 + 9t]_3^4 = (4^3 - 6(4)^2 + 9(4)) - (3^3 - 6(3)^2 + 9(3)) = (64 - 96 + 36) - (27 - 54 + 27) = 4 - 0 = 4$ m.

Step 4: Calculate the total distance travelled.
Distance travelled is the sum of the magnitudes of displacements in each interval where the direction of motion is constant.
Total distance $= |\Delta x_1| + |\Delta x_2| + |\Delta x_3| = |4| + |-4| + |4| = 4 + 4 + 4 = 12$ m.

Final Answer: $\boxed{12 \text{ m}}$

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: The frictional force on a rough horizontal surface is:

$$f = \mu mg$$

Hence, retardation produced is:

$$a = \mu g$$

We use the kinematic equation:

$$v^2 = u^2 + 2as$$

to calculate the stopping distance.

Solution:

Step 1: Motion in the first 2 m region. For $\mu_1 = 0.2$,

$$a_1 = -0.2 \times 10 = -2 \text{ m/s}^2$$

Using

$$v^2 = u^2 + 2as$$

$$v^2 = 10^2 + 2(-2)(2)$$

$$v^2 = 100 - 8 = 92$$

$$v = \sqrt{92} \text{ m/s}$$

Step 2: Motion in the second region. For $\mu_2 = 0.4$,

$$a_2 = -0.4 \times 10 = -4 \text{ m/s}^2$$

Let additional stopping distance be s_2.

$$0 = 92 + 2(-4)s_2$$

$$8s_2 = 92$$

$$s_2 = 11.5 \text{ m}$$

Step 3: Total stopping distance.

$$s = 2 + 11.5 = 13.5 \text{ m}$$

Since the exact value is not present in the options, the nearest given option is:

Final Answer: $\boxed{8 \text{ m}}$

Answer: (D)

Go Back to Question 2

Q3.

Solution

Concept: When springs are connected in parallel, their effective spring constant is the sum of the individual spring constants. The time period (T) of oscillation of a mass m attached to a spring with spring constant k is given by $T = 2\pi\sqrt{\frac{m}{k}}$.

Solution: Step 1: Determine the effective spring constant for parallel connection.
When two springs with force constant k are connected in parallel, the effective spring constant k_{eff} is the sum of their individual constants:
$k_{eff} = k_1 + k_2$
Since the springs are identical, $k_1 = k$ and $k_2 = k$.
$k_{eff} = k + k = 2k$.

Step 2: Use the formula for the time period of oscillation.
The time period T of oscillation for a mass m attached to a spring with effective spring constant k_{eff} is given by:
$T = 2\pi\sqrt{\frac{m}{k_{eff}}}$

Step 3: Substitute the effective spring constant.
$T = 2\pi\sqrt{\frac{m}{2k}}$

Final Answer: $\boxed{2\pi\sqrt{\frac{m}{2k}}}$

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: The horizontal range (R) of a projectile is given by $R = \frac{u^2 \sin(2\theta)}{g}$, and the maximum height (H) is given by $H = \frac{u^2 \sin^2 \theta}{2g}$. The problem states that $R = H$.

Solution: Step 1: Write down the formulas for range and maximum height.
Range: $R = \frac{u^2 \sin(2\theta)}{g}$
Maximum Height: $H = \frac{u^2 \sin^2 \theta}{2g}$

Step 2: Set the range equal to the maximum height, as given in the problem.
$\frac{u^2 \sin(2\theta)}{g} = \frac{u^2 \sin^2 \theta}{2g}$

Step 3: Simplify the equation.
Cancel u^2/g from both sides (since $u \neq 0$ and $g \neq 0$):
$\sin(2\theta) = \frac{\sin^2 \theta}{2}$

Step 4: Use the double angle formula for sine: $\sin(2\theta) = 2 \sin \theta \cos \theta$.
$2 \sin \theta \cos \theta = \frac{\sin^2 \theta}{2}$

Step 5: Solve for $\tan \theta$.
Assuming $\sin \theta \neq 0$ (i.e., $\theta \neq 0°$ or $180°$, which would result in zero range and zero height), we can divide by $\sin \theta$:
$2 \cos \theta = \frac{\sin \theta}{2}$
Rearrange the terms to find $\tan \theta$:
$\frac{\sin \theta}{\cos \theta} = 2 \times 2$
$\tan \theta = 4$

Final Answer: $\boxed{4}$

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept: The kinetic energy (KE) of a satellite in a circular orbit is given by $KE = \frac{1}{2}mv^2$. For a circular orbit, the gravitational force provides the centripetal force: $\frac{GMm}{r^2} = \frac{mv^2}{r}$. From this, we can derive the kinetic energy.

Solution: Step 1: Find the orbital velocity of the satellite.

For a circular orbit of radius r, the gravitational force equals the centripetal force:

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

Solving for v^2: $v^2 = \frac{GM}{r}$.

Step 2: Express the kinetic energy of the satellite.

$KE = \frac{1}{2}mv^2$.

Substitute $v^2 = \frac{GM}{r}$:

$$KE = \frac{1}{2}m\left(\frac{GM}{r}\right) = \frac{GMm}{2r}.$$

Step 3: Relate kinetic energies for different radii.

Let the old kinetic energy be KE_{old} when the orbital radius is R.

$$KE_{old} = \frac{GMm}{2R}.$$

Let the new kinetic energy be KE_{new} when the orbital radius is $4R$.

$$KE_{new} = \frac{GMm}{2(4R)} = \frac{GMm}{8R}.$$

Step 4: Calculate the ratio of new kinetic energy to old kinetic energy.

$$\frac{KE_{new}}{KE_{old}} = \frac{\frac{GMm}{8R}}{\frac{GMm}{2R}} = \frac{GMm}{8R} \times \frac{2R}{GMm} = \frac{2}{8} = \frac{1}{4}.$$

Final Answer: $\boxed{\frac{1}{4}}$

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: Newton's Law of Cooling states that the rate of heat loss of a body is directly proportional to the difference in temperature between the body and its surroundings, i.e., $\frac{d\theta}{dt} = -k(\theta - \theta_s)$, where θ is the temperature of the body, θ_s is the temperature of the surroundings, and k is a constant. Integrating this gives $\ln\left(\frac{\theta_1 - \theta_s}{\theta_2 - \theta_s}\right) = kt$.

Solution: Step 1: State Newton's Law of Cooling.

$$\frac{d\theta}{dt} = -k(\theta - \theta_s)$$

Integrating gives: $\ln\left(\frac{\theta_1 - \theta_s}{\theta_2 - \theta_s}\right) = kt$.

Step 2: Apply the law to the first interval.

Given: $\theta_1 = 80°\text{C}$, $\theta_2 = 60°\text{C}$, $\Delta t = 10$ min, $\theta_s = 20°\text{C}$.

$$\ln\left(\frac{80 - 20}{60 - 20}\right) = k(10)$$

$$\ln\left(\frac{60}{40}\right) = 10k$$

$$\ln(1.5) = 10k.$$

Step 3: Apply the law to the second interval.

Let the temperature after the next 10 min be θ_3. The interval is from 10 min to 20 min (total time).

The temperature changes from 60°C to θ_3. The time elapsed for this change is 10 min.

$$\ln\left(\frac{60 - 20}{\theta_3 - 20}\right) = k(10)$$

$$\ln\left(\frac{40}{\theta_3 - 20}\right) = 10k.$$

Step 4: Equate the expressions for $10k$.

Since $10k = \ln(1.5)$ and $10k = \ln\left(\frac{40}{\theta_3 - 20}\right)$, we have:

$$\ln(1.5) = \ln\left(\frac{40}{\theta_3 - 20}\right)$$

$$1.5 = \frac{40}{\theta_3 - 20}$$

$$\theta_3 - 20 = \frac{40}{1.5} = \frac{40}{3/2} = \frac{80}{3}$$

$$\theta_3 - 20 \approx 26.67$$

$$\theta_3 \approx 20 + 26.67 = 46.67°\text{C}.$$

Step 5: Compare with the options.

The calculated temperature is approximately 46.67°C, which is closest to 47°C.

Final Answer: $\boxed{47°\text{C}}$

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: In capillary action, the height of the liquid rise (h) in a capillary tube is inversely proportional to the radius (r) of the tube, given by the Jurin's Law: $h = \frac{2T\cos\theta}{\rho g r}$, where T is the surface tension, θ is the contact angle, ρ is the density of the liquid, and g is the acceleration due to gravity.

Solution: Step 1: State Jurin's Law for capillary rise.
$h = \frac{2T\cos\theta}{\rho g r}$

Step 2: Analyze the relationship between height (h) and radius (r).
From the formula, $h \propto \frac{1}{r}$, assuming other factors ($T, \cos\theta, \rho, g$) are constant.

Step 3: Determine the effect of changing the radius.
If the radius of the capillary tube becomes $2r$ (i.e., it doubles), let the new height be h'.
$h' \propto \frac{1}{2r}$
Since $h \propto \frac{1}{r}$, we can write:
$h' = h \times \frac{r}{2r} = h \times \frac{1}{2}$.
The new capillary rise becomes half of the original rise.

Final Answer: $\boxed{Half}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The efficiency (η) of a Carnot engine is given by $\eta = 1 - \frac{T_{sink}}{T_{source}}$, where T_{sink} is the temperature of the sink and T_{source} is the temperature of the source, both in Kelvin.

Solution: Step 1: Write the formula for the efficiency of a Carnot engine.

$$\eta = 1 - \frac{T_{sink}}{T_{source}}$$

Step 2: Identify the given values.

Efficiency $\eta = 40\% = 0.40$.

Sink temperature $T_{sink} = 300$ K.

Step 3: Substitute the values into the efficiency formula and solve for T_{source}.

$$0.40 = 1 - \frac{300}{T_{source}}$$

$$\frac{300}{T_{source}} = 1 - 0.40$$

$$\frac{300}{T_{source}} = 0.60$$

$$T_{source} = \frac{300}{0.60} = \frac{300}{6/10} = \frac{3000}{6} = 500 \text{ K.}$$

Final Answer: 500 K

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: The general equation for a transverse wave traveling in the positive x-direction is $y(x,t) = A\sin(\omega t - kx + \phi)$. The wave velocity ($v_w$) is given by the ratio of angular frequency (ω) to the wave number (k): $v_w = \frac{\omega}{k}$.

Solution: Step 1: Write down the given wave equation.
$y = 0.02\sin(100\pi t - 5\pi x)$

Step 2: Compare with the general form $y = A\sin(\omega t - kx)$.
From the equation, we can identify:
Amplitude $A = 0.02$
Angular frequency $\omega = 100\pi$ rad/s
Wave number $k = 5\pi$ rad/m

Step 3: Calculate the wave velocity.
The wave velocity is given by $v_w = \frac{\omega}{k}$.
$v_w = \frac{100\pi \text{ rad/s}}{5\pi \text{ rad/m}}$
$v_w = \frac{100}{5}$ m/s
$v_w = 20$ m/s.

Final Answer: 20 m/s

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: Beats are produced when two sound waves of slightly different frequencies interfere. The beat frequency (number of beats per second) is equal to the absolute difference between the frequencies of the two waves: $f_{beat} = |f_1 - f_2|$. The total number of beats heard in a time interval is the beat frequency multiplied by the time interval.

Solution: Step 1: Identify the given frequencies.
Frequency of the first tuning fork, $f_1 = 256$ Hz.
Frequency of the second tuning fork, $f_2 = 260$ Hz.

Step 2: Calculate the beat frequency.
The beat frequency is the difference between the two frequencies:
$f_{beat} = |f_1 - f_2| = |256 \text{ Hz} - 260 \text{ Hz}| = |-4 \text{ Hz}| = 4$ Hz.
This means 4 beats are heard per second.

Step 3: Calculate the total number of beats in the given time interval.
The time interval is 5 seconds.
Total beats = Beat frequency $\times$ Time interval
Total beats = 4 beats/s $\times$ 5 s = 20 beats.

Final Answer: $\boxed{20}$

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept: For a convex lens:

$$m = \frac{v}{u}$$

and

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

The distance between object and image is:

$$u + v$$

Solution: Given magnification:

$$m = 2$$

So,

$$\frac{v}{u} = 2 \Rightarrow v = 2u$$

Also,

$$u + v = 30$$

Substituting $v = 2u$:

$$3u = 30$$

$$u = 10 \text{ cm}, \qquad v = 20 \text{ cm}$$

Using lens formula:

$$\frac{1}{f} = \frac{1}{20} - \left(-\frac{1}{10}\right)$$

$$\frac{1}{f} = \frac{3}{20}$$

$$f = \frac{20}{3} \approx 6.7 \text{ cm}$$

Nearest option:

Final Answer: $\boxed{5 \text{ cm}}$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: The critical angle (θ_c) for total internal reflection at the interface between two media is the angle of incidence in the optically denser medium for which the angle of refraction in the optically rarer medium is 90°. It is given by Snell's Law: $n_1 \sin\theta_c = n_2 \sin(90°)$, where n_1 is the refractive index of the denser medium and n_2 is the refractive index of the rarer medium. Thus, $\sin\theta_c = \frac{n_2}{n_1}$.

Solution: Step 1: Identify the media and their refractive indices.
The ray passes from glass to air.
Refractive index of glass $n_1 = \frac{3}{2} = 1.5$.
Refractive index of air $n_2 \approx 1$.

Step 2: Apply Snell's Law to find the critical angle.
The critical angle θ_c is given by $\sin\theta_c = \frac{n_2}{n_1}$.
$\sin\theta_c = \frac{1}{1.5} = \frac{1}{3/2} = \frac{2}{3}$.

Step 3: Calculate the angle θ_c.
$\theta_c = \arcsin\left(\frac{2}{3}\right)$.
Using a calculator: $\arcsin(2/3) \approx 41.81°$.

Step 4: Compare with the given options.
The calculated value is approximately 41.81°, which is closest to 42°.

Final Answer: $\boxed{42°}$

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: In Young's Double Slit Experiment (YDSE), the fringe width (β) is given by $\beta = \frac{\lambda D}{d}$, where λ is the wavelength, D is the distance between slits and screen, and d is the slit separation.

Solution: Step 1: State the formula for fringe width.
$\beta = \frac{\lambda D}{d}$

Step 2: Analyze the changes described.
- Slit separation is doubled: $d_{new} = 2d$.
- Wavelength is halved: $\lambda_{new} = \frac{\lambda}{2}$.
The distance D remains unchanged.

Step 3: Calculate the new fringe width (β_{new}).
$\beta_{new} = \frac{\lambda_{new} D}{d_{new}} = \frac{(\lambda/2)D}{(2d)} = \frac{\lambda D}{4d}$.

Step 4: Compare the new fringe width with the original fringe width.
The original fringe width is $\beta_{old} = \frac{\lambda D}{d}$.
The new fringe width is $\beta_{new} = \frac{1}{4}\left(\frac{\lambda D}{d}\right) = \frac{1}{4}\beta_{old}$.

The fringe width becomes one-fourth.

Final Answer: $\boxed{One - fourth}$

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept: Gauss's Law states that the total electric flux (Φ_E) through any closed surface is equal to the net charge enclosed (Q_{enc}) by that surface divided by the permittivity of free space (ϵ_0): $\Phi_E = \frac{Q_{enc}}{\epsilon_0}$. A cube has 6 identical faces.

Solution: Step 1: Apply Gauss's Law.
The total electric flux through the closed surface of the cube is $\Phi_{total} = \frac{q}{\epsilon_0}$, where q is the charge at the center.

Step 2: Distribute the flux equally among the faces.
Since the charge is placed at the center of the cube, the electric field distribution is symmetrical with respect to all six faces of the cube. Therefore, the electric flux is distributed equally among the 6 faces.

Step 3: Calculate the flux through one face.
Flux through one face $\Phi_{face} = \frac{\Phi_{total}}{6}$.

$\Phi_{face} = \frac{1}{6}\left(\frac{q}{\epsilon_0}\right) = \frac{q}{6\epsilon_0}$.

Final Answer: $\boxed{\frac{q}{6\epsilon_0}}$

Answer: (D)

Go Back to Question 14

Q15.

Solution

Concept: When capacitors are connected in series, the equivalent capacitance (C_{eq}) is calculated using $\frac{1}{C_{eq}} = \sum \frac{1}{C_i}$. In a series circuit, the charge on each capacitor is the same, and it equals the total charge $Q = C_{eq}V$.

Solution: Step 1: Calculate the equivalent capacitance (C_{eq}) of the capacitors in series.

The capacitances are $C_1 = 2\,\mu F$, $C_2 = 3\,\mu F$, and $C_3 = 6\,\mu F$.

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_{eq}} = \frac{1}{2\,\mu F} + \frac{1}{3\,\mu F} + \frac{1}{6\,\mu F}$$

To add these fractions, find a common denominator, which is 6.

$$\frac{1}{C_{eq}} = \frac{3}{6\,\mu F} + \frac{2}{6\,\mu F} + \frac{1}{6\,\mu F} = \frac{3+2+1}{6\,\mu F} = \frac{6}{6\,\mu F} = \frac{1}{\mu F}$$

So, $C_{eq} = 1\,\mu F$.

Step 2: Calculate the total charge (Q) stored in the series combination.

The total voltage across the combination is $V = 22$ V.

The total charge $Q = C_{eq}V$.

$Q = (1\,\mu F) \times (22\text{ V}) = 22\,\mu C$.

Step 3: Determine the charge on the $3\,\mu F$ capacitor.

In a series connection, the charge on each capacitor is the same and equal to the total charge.

Therefore, the charge on the $3\,\mu F$ capacitor is $Q_{3\mu F} = Q = 22\,\mu C$.

Step 4: Select the closest option.

The calculated charge is $22\,\mu C$. Among the given options (6, 12, 18, 24 μC), the closest value is $24\,\mu C$. This suggests a possible error in the voltage value provided in the question. If the voltage were 24V, the charge would be 24uC.

Final Answer: $\boxed{24\mu C}$

Answer: (D)

Go Back to Question 15

Q16.

Solution

Concept: A potentiometer wire is used as a potential divider. The potential gradient along the wire is the potential drop per unit length. For a wire of resistance R_{wire} and length L, connected across a voltage V, the potential gradient is V/L. The total resistance in the circuit (potentiometer wire resistance + series resistance) determines the current, which in turn influences the voltage drop across the wire.

Solution: Step 1: Calculate the total resistance in the circuit.
The potentiometer wire has a resistance $R_{wire} = 20\,\Omega$.
It is connected in series with an external resistance $R_{ext} = 5\,\Omega$ and a battery of emf $V_{battery} = 5$ V.
The total resistance in the circuit is $R_{total} = R_{wire} + R_{ext} = 20\,\Omega + 5\,\Omega = 25\,\Omega$.

Step 2: Calculate the current flowing through the circuit.
Using Ohm's Law, the current $I = \frac{V_{battery}}{R_{total}} = \frac{5\text{ V}}{25\,\Omega} = 0.2$ A.

Step 3: Calculate the potential drop across the potentiometer wire.
The potential drop across the potentiometer wire is $V_{wire} = I \times R_{wire} = (0.2\text{ A}) \times (20\,\Omega) = 4$ V.

Step 4: Calculate the potential gradient along the wire.
The potential gradient is the potential drop per unit length. The length of the potentiometer wire is $L = 10$ m.
Potential gradient $= \frac{V_{wire}}{L} = \frac{4\text{ V}}{10\text{ m}} = 0.4$ V/m.

Final Answer: $\boxed{0.4\text{ V/m}}$

Answer: (C)

Go Back to Question 16

Q17.

Solution

Concept: When cells are connected in opposition, their net emf is the difference between their individual emfs. The total internal resistance is the sum of their internal resistances. The current in the circuit is then calculated using Ohm's Law: $I = \frac{\text{Net emf}}{\text{Total resistance}}$.

Solution: Step 1: Determine the net emf of the cells.
The cells are connected in opposition, meaning their emfs act in opposite directions.
emf of cell 1, $E_1 = 2$ V.
emf of cell 2, $E_2 = 1$ V.
Net emf $E_{net} = |E_1 - E_2| = |2\text{ V} - 1\text{ V}| = 1$ V.
The net emf is directed in the direction of the larger emf.

Step 2: Calculate the total internal resistance.
The internal resistances are $r_1 = 1\,\Omega$ and $r_2 = 1\,\Omega$.
When connected in opposition, the internal resistances add up:
$r_{total} = r_1 + r_2 = 1\,\Omega + 1\,\Omega = 2\,\Omega$.

Step 3: Calculate the total external resistance.
The external resistance is given as $R_{ext} = 2\,\Omega$.

Step 4: Calculate the total resistance of the circuit.
$R_{total} = R_{ext} + r_{total} = 2\,\Omega + 2\,\Omega = 4\,\Omega$.

Step 5: Calculate the current in the circuit using Ohm's Law.
$I = \frac{E_{net}}{R_{total}} = \frac{1\text{ V}}{4\,\Omega} = 0.25$ A.

Final Answer: $\boxed{0.25\text{ A}}$

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept: When a charged particle moves in a magnetic field perpendicular to its velocity, it follows a circular path. The radius of this circular path is given by $r = \frac{mv}{|q|B}$, where m is the mass, v is the speed, q is the charge, and B is the magnetic field strength.

Solution: Step 1: Write the formula for the radius of the circular path.
The radius r of the circular path of a charged particle with mass m, speed v, charge $|q|$, moving in a magnetic field B perpendicular to its velocity is:
$r = \frac{mv}{|q|B}$

Step 2: Analyze the given changes.
The speed is doubled: $v_{new} = 2v$.
The magnetic field is doubled: $B_{new} = 2B$.
The mass (m) and charge ($|q|$) of the proton remain the same.

Step 3: Calculate the new radius (r_{new}).
$r_{new} = \frac{mv_{new}}{|q|B_{new}}$
Substitute the new speed and magnetic field:
$r_{new} = \frac{m(2v)}{|q|(2B)}$
$r_{new} = \frac{2mv}{2|q|B}$
$r_{new} = \frac{mv}{|q|B}$

Step 4: Compare the new radius with the original radius.
We see that $r_{new} = r$. The new radius is the same as the original radius.

Final Answer: $\boxed{Same}$

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: The magnetic field (B) at the center of a circular coil of radius R carrying a current I is given by the formula $B = \frac{\mu_0 I}{2R}$. This means the magnetic field is directly proportional to the current and inversely proportional to the radius.

Solution: Step 1: Write the formula for the magnetic field at the center of a circular coil.

$B = \frac{\mu_0 I}{2R}$

Step 2: Analyze the given changes.

The radius is doubled: $R_{new} = 2R$.

The current is doubled: $I_{new} = 2I$.

The permeability of free space (μ_0) is a constant.

Step 3: Calculate the new magnetic field (B_{new}).

$B_{new} = \frac{\mu_0 I_{new}}{2R_{new}}$

Substitute the new values:

$B_{new} = \frac{\mu_0(2I)}{2(2R)}$

$B_{new} = \frac{2\mu_0 I}{4R} = \frac{1}{2}\frac{\mu_0 I}{2R}$

Step 4: Compare the new magnetic field with the original magnetic field.

Since $B = \frac{\mu_0 I}{2R}$, we have:

$B_{new} = \frac{1}{2}B$.

The new magnetic field at the center becomes half of the original magnetic field.

Final Answer: $\boxed{\frac{B}{2}}$

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept: In an AC circuit containing only a capacitor, the voltage across the capacitor (V_C) lags behind the current (I) flowing through it. The capacitive reactance (X_C) limits the current, and the phase difference between current and voltage is 90°, with the current leading the voltage.

Solution: Step 1: Consider an AC circuit with only a capacitor.
When an AC voltage is applied across a capacitor, the capacitor charges and discharges periodically.

Step 2: Analyze the relationship between current and voltage in a capacitor.
The current through a capacitor is proportional to the rate of change of voltage across it ($I = C\frac{dV}{dt}$). This means that the current reaches its maximum value when the voltage is changing most rapidly (passing through zero), and the voltage reaches its maximum when the current is zero (at the peak of charge). Consequently, the current leads the voltage by a phase angle of 90° (or $\pi/2$ radians).

Step 3: Evaluate the given options.
- 0°: This is for a purely resistive circuit.
- 45°: This occurs in circuits with both resistance and reactance (e.g., RL or RC circuits with comparable values).
- 90°: This is the phase difference for a purely capacitive or purely inductive circuit, with current leading voltage in the capacitive case.
- 180°: This represents an out-of-phase relationship, often seen in rectification or specific circuit configurations.

Final Answer: $\boxed{90^\circ}$

Answer: (C)

Go Back to Question 20

Q21.

Solution

Concept: The threshold wavelength (λ_0) is the maximum wavelength of incident light that can cause photoelectric emission from a metal surface. It is related to the work function (ϕ) of the metal by the equation $\phi = \frac{hc}{\lambda_0}$, where h is Planck's constant and c is the speed of light.

Solution: Step 1: Recall the relationship between work function and threshold wavelength.
The work function ϕ is the minimum energy required to eject an electron from the metal surface.
This energy corresponds to a photon of the threshold wavelength λ_0.

$$\phi = \frac{hc}{\lambda_0}$$

Step 2: Rearrange the formula to solve for λ_0.

$$\lambda_0 = \frac{hc}{\phi}$$

Step 3: Use the given values and constants.
Work function $\phi = 2$ eV.
Planck's constant $h \approx 6.63 \times 10^{-34}$ J.s.
Speed of light $c \approx 3 \times 10^8$ m/s.
To use these values, we need to convert eV to Joules: 1 eV $= 1.602 \times 10^{-19}$ J.
So, $\phi = 2 \times 1.602 \times 10^{-19}$ J $= 3.204 \times 10^{-19}$ J.

Alternatively, a useful conversion factor is $hc \approx 1240$ eV.nm.
Using this, $\lambda_0 = \frac{hc}{\phi} = \frac{1240 \text{ eV.nm}}{2 \text{ eV}} = 620$ nm.

Step 4: Compare with the options.
The calculated threshold wavelength is 620 nm, which matches option A.

Final Answer: 620 nm

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: In the Bohr model of the hydrogen atom, the radius of the n^{th} orbit is given by $r_n \propto n^2$. Therefore, the ratio of the radii of two orbits is the ratio of the squares of their principal quantum numbers.

Solution: Step 1: Recall the formula for the radius of Bohr orbits.
The radius of the n^{th} Bohr orbit in a hydrogen atom is proportional to n^2:
$r_n = n^2 \cdot a_0$, where a_0 is the Bohr radius.

Step 2: Determine the radii of the second and first Bohr orbits.
For the second Bohr orbit ($n = 2$), the radius $r_2 = 2^2 \cdot a_0 = 4a_0$.
For the first Bohr orbit ($n = 1$), the radius $r_1 = 1^2 \cdot a_0 = 1a_0$.

Step 3: Calculate the ratio of the radii.
The ratio of the radius of the second orbit to the radius of the first orbit is:
$\frac{r_2}{r_1} = \frac{4a_0}{1a_0} = 4$.

Final Answer: $\boxed{4}$

Answer: (C)

Go Back to Question 22

Q23.

Solution

Concept: Radioactive decay follows first-order kinetics. After n half-lives, the fraction of the original radioactive sample remaining is $\left(\frac{1}{2}\right)^n$.

Solution: Step 1: Identify the half-life and the total time elapsed.
Half-life $t_{1/2} = 5$ days.
Total time elapsed $t = 15$ days.

Step 2: Calculate the number of half-lives (n).
$n = \frac{\text{Total time}}{\text{Half-life}} = \frac{15 \text{ days}}{5 \text{ days}} = 3.$
So, 3 half-lives have passed.

Step 3: Calculate the fraction of the sample remaining.
The fraction remaining after n half-lives is $\left(\frac{1}{2}\right)^n$.

Fraction remaining $= \left(\frac{1}{2}\right)^3 = \frac{1}{2^3} = \frac{1}{8}$.

Final Answer: $\boxed{\frac{1}{8}}$

Answer: (C)

Go Back to Question 23

Q24.

Solution

Concept: Logic gates perform Boolean operations. The XOR (Exclusive OR) gate is a digital logic gate that outputs 1 if and only if the inputs differ. That is, if one input is 1 and the other is 0, the output is 1. If both inputs are the same (0 and 0, or 1 and 1), the output is 0.

Solution: Step 1: Understand the operations of common logic gates.
- AND gate: Output is 1 only if all inputs are 1. ($A \cdot B$)
- OR gate: Output is 1 if at least one input is 1. ($A + B$)
- XOR gate: Output is 1 if inputs are different. ($A \oplus B$)
- NAND gate: Output is 0 only if all inputs are 1. ($\overline{A \cdot B}$)

Step 2: Identify the gate whose output is 1 only when inputs are different.
This definition precisely matches the XOR gate.

Final Answer: $\boxed{XOR}$

Answer: (C)

Go Back to Question 24

Q25.

Solution

Concept: The resistance of a wire is given by $R = \rho\frac{L}{A}$, where ρ is resistivity, L is length, and A is cross-sectional area. When a wire is stretched to double its length, its volume remains constant. If length doubles, the cross-sectional area must halve to maintain constant volume ($V = LA = L'A'$).

Solution: Step 1: State the formula for resistance.
$R = \rho\frac{L}{A}$.

Step 2: Consider the effect of stretching on length and area.
Let the original length be L_1 and the original area be A_1. Original resistance $R_1 = \rho\frac{L_1}{A_1}$.
The wire is stretched to double its length: $L_2 = 2L_1$.
Since volume $V = L \times A$ is constant, $L_1A_1 = L_2A_2$.
$L_1A_1 = (2L_1)A_2 \implies A_2 = \frac{A_1}{2}$.

Step 3: Calculate the new resistance (R_2).
$R_2 = \rho\frac{L_2}{A_2} = \rho\frac{2L_1}{A_1/2} = \rho\frac{2 \times 2L_1}{A_1} = 4\left(\rho\frac{L_1}{A_1}\right)$.

Step 4: Relate the new resistance to the original resistance.
$R_2 = 4R_1$.
The resistance becomes four times its original value.

Final Answer: $\boxed{Four \text{ times}}$

Answer: (C)

Go Back to Question 25

Q26.

Solution

Concept: The maximum acceleration (a_{max}) of a particle executing Simple Harmonic Motion (SHM) is related to its amplitude (A) and angular frequency (ω) by the formula $a_{max} = A\omega^2$. The angular frequency is related to the frequency (f) by $\omega = 2\pi f$.

Solution: Step 1: Identify the given parameters.
Amplitude $A = 5$ cm $= 0.05$ m.
Frequency $f = 2$ Hz.

Step 2: Calculate the angular frequency (ω).
$\omega = 2\pi f = 2\pi \times 2$ Hz $= 4\pi$ rad/s.

Step 3: Calculate the maximum acceleration (a_{max}).
$a_{max} = A\omega^2$
$a_{max} = (0.05 \text{ m}) \times (4\pi \text{ rad/s})^2$
$a_{max} = 0.05 \times 16\pi^2 \text{ m/s}^2$
$a_{max} = 0.8 \times \pi^2 \text{ m/s}^2$.

Final Answer: $\boxed{0.8\pi^2 \text{ m/s}^2}$

Answer: (B)

Go Back to Question 26

Q27.

Solution

Concept: When a person swims across a river, their velocity relative to the ground is the vector sum of their velocity relative to the water and the velocity of the water. If the swimming velocity and river velocity are perpendicular, the resultant speed is found using the Pythagorean theorem.

Solution: Step 1: Identify the velocities.
Velocity of the swimmer in still water (relative to water), $v_{swimmer} = 5$ km/h.
Velocity of the river (relative to ground), $v_{river} = 3$ km/h.
The swimmer moves perpendicular to the current. This means the velocity vectors are at 90° to each other.

Step 2: Calculate the resultant speed.
The resultant velocity ($v_{resultant}$) relative to the ground is the vector sum of $v_{swimmer}$ and v_{river}.
Since they are perpendicular, we can use the Pythagorean theorem:
$v_{resultant}^2 = v_{swimmer}^2 + v_{river}^2$
$v_{resultant}^2 = (5 \text{ km/h})^2 + (3 \text{ km/h})^2$
$v_{resultant}^2 = 25 + 9$
$v_{resultant}^2 = 34$

Step 3: Find the resultant speed.
$v_{resultant} = \sqrt{34}$ km/h.

Final Answer: $\boxed{\sqrt{34} \text{ km/h}}$

Answer: (C)

Go Back to Question 27

Q28.

Solution

Concept: When objects roll down an inclined plane without slipping, their acceleration depends on their moment of inertia (I) and mass (M) and radius (R). The acceleration is given by $a = \frac{g\sin\theta}{1 + I/(MR^2)}$. A smaller value of $I/(MR^2)$ leads to greater acceleration.

Solution: Step 1: Recall the acceleration formula for rolling objects.
$a = \frac{g\sin\theta}{1 + I/(MR^2)}$
To reach first, the object must have greater acceleration. This means the term $I/(MR^2)$ must be smaller.

Step 2: Determine the ratio $I/(MR^2)$ for a solid sphere and a hollow sphere.
For a solid sphere, $I_{solid} = \frac{2}{5}MR^2$. So, $\frac{I_{solid}}{MR^2} = \frac{2}{5} = 0.4$.
For a hollow sphere (thin spherical shell), $I_{hollow} = \frac{2}{3}MR^2$. So, $\frac{I_{hollow}}{MR^2} = \frac{2}{3} \approx 0.67$.

Step 3: Compare the accelerations.
Since $\frac{I_{solid}}{MR^2} < \frac{I_{hollow}}{MR^2}$ $(0.4 < 0.67)$, the solid sphere has a smaller denominator in the acceleration formula, resulting in greater acceleration.

Step 4: Conclude which object reaches first.
The object with greater acceleration will reach the bottom first. Therefore, the solid sphere reaches first.

Final Answer: $\boxed{Solid \text{ sphere}}$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept: An adiabatic process is a thermodynamic process in which there is no heat exchange between the system and its surroundings. According to the first law of thermodynamics, $\Delta U = \Delta Q - W$. If $\Delta Q = 0$, then $\Delta U = -W$. This implies that if the gas expands (does work, $W > 0$), its internal energy decreases ($\Delta U < 0$), leading to a drop in temperature. If it is compressed (work is done on it, $W < 0$), its internal energy increases ($\Delta U > 0$), leading to a rise in temperature.

Solution: Step 1: Define an adiabatic process.
An adiabatic process is defined as a thermodynamic process where no heat is transferred into or out of the system. Mathematically, this means $\Delta Q = 0$.

Step 2: Consider the implications for other parameters.
- Temperature remains constant ($\Delta T = 0$): This is an isothermal process. For adiabatic expansion, temperature decreases.
- Pressure remains constant ($\Delta P = 0$): This is an isobaric process. For adiabatic expansion, pressure decreases (more rapidly than in isothermal expansion).
- Internal energy remains constant ($\Delta U = 0$): This implies $\Delta Q = W$. For adiabatic processes, internal energy changes due to work done.

Step 3: Conclude the correct statement.
The defining characteristic of an adiabatic process is that the heat exchange with the surroundings is zero.

Final Answer: $\boxed{Heat \text{ exchange is zero}}$

Answer: (C)

Go Back to Question 29

Q30.

Solution

Concept: The grating element (d) of a diffraction grating is the distance between adjacent slits. If a grating has N lines per unit length (e.g., lines per centimeter), then the grating element is the reciprocal of this number, $d = \frac{1}{N}$.

Solution: Step 1: Identify the given information.
The diffraction grating has 5000 lines/cm. This means the number of lines per centimeter is $N_{cm} = 5000$.

Step 2: Convert the unit length to meters.
We need to find the grating element in meters.
$N_m = 5000 \text{ lines/cm} \times \frac{100 \text{ cm}}{1 \text{ m}} = 5000 \times 100 \text{ lines/m} = 500,000 \text{ lines/m} = 5 \times 10^5 \text{ lines/m}.$

Step 3: Calculate the grating element (d).
The grating element is the reciprocal of the number of lines per meter:
$d = \frac{1}{N_m} = \frac{1}{5 \times 10^5 \text{ lines/m}}$
$d = \frac{1}{5} \times 10^{-5} \text{ m}$
$d = 0.2 \times 10^{-5} \text{ m}$
$d = 2 \times 10^{-6} \text{ m}.$

Step 4: Compare with the given options.
The calculated grating element is 2×10^{-6} m, which matches option B.

Final Answer: $\boxed{2 \times 10^{-6} \text{ m}}$

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept: For a concave mirror, the mirror formula is $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$. The object is placed at $u = -20$ cm (negative as it's in front of the mirror). The focal length of a concave mirror is negative, so $f = -15$ cm. Real images are formed in front of the mirror ($v < 0$), and virtual images are formed behind the mirror ($v > 0$). Magnification $m = -v/u$.

Solution: Step 1: Identify the given parameters with proper sign conventions.
Object distance, $u = -20$ cm.
Focal length, $f = -15$ cm.

Step 2: Apply the mirror formula to find the image distance (v).
$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$
$$\frac{1}{-15} = \frac{1}{v} + \frac{1}{-20}$$
$$\frac{1}{v} = \frac{1}{-15} - \frac{1}{-20} = \frac{1}{-15} + \frac{1}{20}$$
$$\frac{1}{v} = \frac{-4+3}{60} = \frac{-1}{60}$$
$v = -60$ cm.

Step 3: Determine the nature and magnification of the image.
Since $v = -60$ cm, the image is formed at 60 cm in front of the mirror. A negative image distance for a mirror means the image is real.
Magnification $m = -\frac{v}{u} = -\frac{-60 \text{ cm}}{-20 \text{ cm}} = -\frac{60}{20} = -3$.
The negative sign indicates the image is inverted. The magnitude of magnification is $|m| = 3$.
Since $|m| > 1$, the image is magnified.
Therefore, the image is real and magnified.

Step 4: Compare with the given options.
- Real and magnified: Matches our findings.
- Real and diminished: Incorrect.
- Virtual and magnified: Incorrect (image is real).
- Virtual and diminished: Incorrect.

Final Answer: $\boxed{Real \text{ and magnified}}$

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept: Drift velocity (v_d) of electrons in a conductor is the average velocity attained by electrons in a conductor under the influence of an electric field. It is given by $v_d = \frac{eE\tau}{m}$, where e is the charge of the electron, E is the electric field strength, τ is the relaxation time, and m is the mass of the electron. The relaxation time is the average time between collisions.

Solution: Step 1: Recall the formula for drift velocity.
$v_d = \frac{eE\tau}{m}$

Step 2: Analyze how drift velocity changes with various factors.
- Temperature increases: The increased thermal agitation of ions leads to more frequent collisions, decreasing the relaxation time (τ). Since $v_d \propto \tau$, drift velocity decreases.
- Potential difference decreases: A decrease in potential difference across a fixed length means a decrease in the electric field ($E = V/L$). Since $v_d \propto E$, drift velocity decreases.
- Electric field increases: If the electric field (E) increases, and other factors remain constant, the drift velocity (v_d) increases directly.
- Length decreases only: If length decreases, the electric field ($E = V/L$) for a fixed voltage increases. This would increase drift velocity.

Step 3: Identify the condition under which drift velocity increases.
The drift velocity is directly proportional to the electric field. Therefore, if the electric field increases, the drift velocity increases.

Final Answer: $\boxed{Electric \text{ field increases}}$

Answer: (C)

Go Back to Question 32

Q33.

Solution

Concept: Acceleration (a) is given by the force (F) divided by mass (m), $a = F/m$. In an electric field (E), the force on a charge q is $F = qE$. Therefore, the acceleration is $a = \frac{qE}{m}$. For an electron and a proton entering the same electric field, they experience the same force magnitude (since their charges are equal in magnitude) but have different masses.

Solution: Step 1: Determine the force on the electron and proton in the electric field.
Force on a charge q in an electric field E is $F = qE$.
An electron has charge $-e$ and a proton has charge $+e$. The magnitude of their charges is $|q| = e$.
Since they are in the same electric field E, the magnitude of the force on both is $F = eE$.

Step 2: Relate force, mass, and acceleration.
According to Newton's second law, $F = ma$. So, $a = F/m$.

Step 3: Calculate the acceleration for the electron and the proton.
Acceleration of the electron, $a_e = \frac{F}{m_e} = \frac{eE}{m_e}$.
Acceleration of the proton, $a_p = \frac{F}{m_p} = \frac{eE}{m_p}$.

Step 4: Find the ratio of their accelerations.
Ratio $\frac{a_e}{a_p} = \frac{eE/m_e}{eE/m_p} = \frac{m_p}{m_e}$.

Step 5: Use the mass ratio of proton to electron.
The mass of a proton (m_p) is approximately 1836 times the mass of an electron (m_e).
$\frac{m_p}{m_e} \approx 1836$.
So, the ratio of accelerations $\frac{a_e}{a_p} = 1836 : 1$.

The question asks for the ratio of their accelerations. It usually means electron to proton, or if the context is implicit, then the larger one first. Given the options, 1836 : 1 implies $a_e : a_p$.

Final Answer: $\boxed{1836 : 1}$

Answer: (B)

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Q34.

Solution

Concept: The direction of the magnetic force on a current-carrying wire in a magnetic field is given by Fleming's Left-Hand Rule. The rule states that if the thumb, forefinger, and middle finger of the left hand are held mutually perpendicular, with the forefinger pointing in the direction of the magnetic field and the middle finger pointing in the direction of the current, then the thumb points in the direction of the force.

Solution: Step 1: Identify the directions of current and magnetic field.
- Current is from North to South. Let's assume this is along the negative y-axis if North is up. Or along the x-axis from positive to negative. Let's assume a standard Cartesian coordinate system where North is +y, South is -y, East is +x, West is -x, Up is +z, Down is -z. So, current is along the -y direction.
- Magnetic field is vertically downward, so along the -z direction.

Step 2: Apply Fleming's Left-Hand Rule.
- Middle finger (current): Point it South (downward, along -y).
- Forefinger (magnetic field): Point it vertically downward (along -z).
- Thumb (force): To satisfy the perpendicular conditions, point middle finger down and forefinger into the page. The thumb will then point towards the East (along the +x direction).

Let's use a coordinate system consistent with the diagram:
Assume current is along the y-axis, from positive y to negative y. So, current direction is South.
Assume magnetic field is along the z-axis, downwards.
Middle finger (current) points South (-y).
Forefinger (magnetic field) points Down (-z).
The thumb (force) will then point towards East (+x).

Final Answer: $\boxed{East}$

Answer: (A)

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Q35.

Solution

Concept: The de Broglie wavelength (λ) of a particle is given by the equation $\lambda = \frac{h}{p}$, where h is Planck's constant and p is the momentum of the particle. Momentum is given by $p = mv$.

Solution: Step 1: State the de Broglie wavelength formula.
$\lambda = \frac{h}{p}$

Step 2: Analyze the proportionality.
From the formula, the de Broglie wavelength (λ) is inversely proportional to the momentum (p).

Step 3: Consider the relationship between momentum and other quantities.
Momentum $p = mv$. So, $\lambda = \frac{h}{mv}$.
- Velocity: Momentum is proportional to velocity ($p \propto v$). Since $\lambda \propto 1/p$, then $\lambda \propto 1/v$. So, wavelength is inversely proportional to velocity.
- Mass: Momentum is proportional to mass ($p \propto m$). Since $\lambda \propto 1/p$, then $\lambda \propto 1/m$. So, wavelength is inversely proportional to mass.
- Energy: Kinetic energy $KE = p^2/(2m)$. So $p = \sqrt{2mKE}$. Thus, $\lambda = \frac{h}{\sqrt{2mKE}}$. Wavelength is inversely proportional to the square root of energy.

Step 4: Identify the quantity directly inversely proportional to wavelength.
Momentum is the quantity that is directly inversely proportional to the de Broglie wavelength.

Final Answer: $\boxed{Momentum}$

Answer: (B)

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Q36.

Solution

Concept: Electric field lines are a visual representation of the electric field. They originate from positive charges and terminate on negative charges. The density of field lines indicates the strength of the field. The tangent to a field line at any point gives the direction of the electric field. Field lines are always perpendicular to equipotential surfaces.

Solution: Step 1: Evaluate each statement.

- Statement (A): Electric field lines originate from positive charges and extend outwards. This statement is correct.
- Statement (B): Electric field lines terminate on negative charges, coming from positive charges or infinity. This statement is correct.
- Statement (C): Two electric field lines cannot intersect. If they did, it would imply that the electric field has two different directions at the point of intersection, which is impossible for a vector field. This statement is incorrect.
- Statement (D): Electric field lines are always perpendicular to equipotential surfaces. This is a fundamental property of electric fields and equipotential surfaces. This statement is correct.

Step 2: Identify all correct statements.
Statements (A), (B), and (D) are correct.

Final Answer: $\boxed{A, B, D}$

Answer: (A,B,D)

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Q37.

Solution

Concept: For motion with constant acceleration ($a \neq 0$), the velocity (v) changes linearly with time ($v = u + at$), and displacement (s) changes quadratically with time ($s = ut + \frac{1}{2}at^2$).
- Velocity can become zero if the initial velocity is positive and acceleration is negative (or vice versa), leading to the particle momentarily stopping before changing direction.
- Displacement can become zero if the particle returns to its starting position.
- Distance travelled is always non-negative and accumulates with time. It becomes zero only if the particle does not move.
- Acceleration is constant, so it cannot become zero unless it was zero initially and remained zero.

Solution: Step 1: Analyze each quantity.
- Velocity: If a particle starts with an initial velocity and experiences constant acceleration in the opposite direction, its velocity can become zero at some point in time before changing direction. For example, throwing a ball upwards. So, velocity can become zero.
- Displacement: Displacement is the change in position from the starting point. It can become zero if the particle returns to its starting position. For example, if a particle moves forward and then backward to its origin. So, displacement can become zero.
- Distance travelled: Distance travelled is the total path length covered. It is always non-negative. It only becomes zero if the particle does not move at all. If the particle moves (even if its velocity becomes zero momentarily and it returns), the distance travelled will be positive. So, distance travelled does not become zero during motion (unless it's trivially not moving).
- Acceleration: The problem states constant acceleration. If the acceleration is constant and non-zero, it cannot become zero during motion. If the acceleration were zero, the velocity would be constant, and the question would be trivial or phrased differently. Assuming constant acceleration means it's a fixed non-zero value. So, acceleration cannot become zero during motion.

Step 2: Identify quantities that may become zero.
Velocity can become zero momentarily. Displacement can become zero if the particle returns to the origin. Distance travelled will not become zero if the particle has moved. Acceleration is constant and non-zero.

Step 3: Select the correct options.
Velocity and Displacement can become zero during motion.

Final Answer: $\boxed{A, B}$

Answer: (A,B)

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Q38.

Solution

Concept: For a rigid body rotating with constant angular velocity (ω), its angular acceleration (α) is zero ($\alpha = d\omega/dt = 0$). The linear velocity (v) of a particle at a distance r from the axis of rotation is $v = r\omega$. The centripetal acceleration (a_c) of each particle is $a_c = r\omega^2$, directed towards the center.

Solution: Step 1: Analyze the statements.
- Statement (A): "Every particle has same angular velocity". Angular velocity (ω) is the same for all particles in a rigid body rotating about a fixed axis. This statement is correct.
- Statement (B): "Every particle has same linear velocity". Linear velocity ($v = r\omega$) depends on the distance r from the axis of rotation. Particles at different distances from the axis will have different linear velocities. This statement is incorrect.
- Statement (C): "Centripetal acceleration acts on every particle". For circular motion, centripetal acceleration ($a_c = r\omega^2$) is required to maintain the circular path. Since all particles are moving in circles (even if infinitesimal radius at the axis), centripetal acceleration acts on them. This statement is correct.
- Statement (D): "Angular acceleration is zero". Angular velocity is constant, so its rate of change (angular acceleration) is zero. This statement is correct.

Step 2: Identify all correct statements.
Statements (A), (C), and (D) are correct.

Final Answer: $\boxed{A, C, D}$

Answer: (A,C,D)

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Q39.

Solution

Concept: In Simple Harmonic Motion (SHM):
- Acceleration (a) is proportional to displacement (x) and directed towards the mean position: $a = -\omega^2 x$.
- Velocity (v) is maximum at the mean position ($x = 0$) and zero at the extreme positions ($x = \pm A$).
- Potential energy ($PE = \frac{1}{2}kx^2$) is zero at the mean position and maximum at the extreme positions.
- Total energy ($E = KE + PE$) is the sum of kinetic and potential energy, and it remains constant throughout the motion.

Solution: Step 1: Evaluate each statement about SHM.
- Statement (A): "Acceleration is proportional to displacement". In SHM, $a = -\omega^2 x$. Acceleration is directly proportional to displacement and opposite in direction. This statement is correct.
- Statement (B): "Velocity is maximum at the mean position". At the mean position ($x = 0$), potential energy is zero, and kinetic energy is maximum. Therefore, velocity is maximum. This statement is correct.
- Statement (C): "Potential energy is maximum at the mean position". At the mean position ($x = 0$), potential energy ($PE = \frac{1}{2}kx^2$) is zero. Potential energy is maximum at the extreme positions ($x = \pm A$). This statement is incorrect.
- Statement (D): "Total energy remains constant". The total energy in SHM is the sum of kinetic and potential energy, and it remains constant, provided there are no dissipative forces. This statement is correct.

Step 2: Identify all correct statements.
Statements (A), (B), and (D) are correct.

Final Answer: $\boxed{A, B, D}$

Answer: (A,B,D)

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Q40.

Solution

Concept: For an isothermal process of an ideal gas, the temperature (T) remains constant. According to the ideal gas law ($PV = nRT$), if T is constant, then the product PV is also constant. The internal energy (U) of an ideal gas depends only on its temperature. Therefore, if the temperature is constant, the internal energy is also constant. The first law of thermodynamics is $\Delta U = \Delta Q - W$.

Solution: Step 1: Evaluate each statement about an isothermal process.
- Statement (A): "Temperature remains constant". This is the definition of an isothermal process. This statement is correct.
- Statement (B): "Internal energy remains constant". For an ideal gas, internal energy depends only on temperature. Since temperature is constant in an isothermal process, the internal energy also remains constant. This statement is correct.
- Statement (C): "Heat supplied equals work done". From the first law of thermodynamics, $\Delta U = \Delta Q - W$. Since $\Delta U = 0$ for an isothermal process of an ideal gas, we have $0 = \Delta Q - W$, which means $\Delta Q = W$. Thus, the heat supplied equals the work done by the gas. This statement is correct.
- Statement (D): "Pressure always remains constant". Pressure (P) can change during an isothermal process if the volume (V) changes, as $PV = constant$. For example, during isothermal expansion, pressure decreases as volume increases. This statement is incorrect.

Step 2: Identify all true statements.
Statements (A), (B), and (C) are true for an isothermal process of an ideal gas.

Final Answer: $\boxed{A, B, C}$

Answer: (A,B,C)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	D	3	B	4	C	5	B
6	B	7	B	8	C	9	B	10	C
11	A	12	B	13	C	14	D	15	D
16	C	17	B	18	A	19	A	20	C
21	A	22	C	23	C	24	C	25	C
26	B	27	C	28	A	29	C	30	B
31	A	32	C	33	B	34	A	35	B
36	A,B,D	37	A,B	38	A,C,D	39	A,B,D	40	A,B,C