JEE Main 2023 April 11 Shift-2 Physics Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**300	**Total Questions :**90

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The Duration of test is 3 Hours.
2. This paper consists of 90 Questions.
3. There are three parts in the paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage..
4. Each part (subject) has two sections.
   (i) Section-A: This section contains 20 multiple choice questions which have only one correct answer. Each carries 4 marks for correct answer and –1 mark for wrong answer..
5. (ii) Section-B: This section contains 10 questions. In Section-B, attempt any five questions out of 10. The answer to each of the questions is a numerical value. Each carries 4 marks for correct answer and –1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer.

Physics

Section A

1: Eight equal drops of water are falling through air with a steady speed of 10 cm/s. If the drops collapse, the new velocity is :-

(1) $10cm/s$

(2) $40cm/s$

(3) $16cm/s$

(4) $5cm/s$

Correct Answer: (2): 40 cm/s

Solution:

Step 1: Volume calculation-

The volume of a sphere is Provided that by:

$$V = \frac{4}{3}\pi r^3.$$

For eight smaller spheres, the total volume is:

$$8 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3,$$

where R is the radius of the larger sphere.

Step 2: Radius calculation.

Equating the volumes:

$$R = 2r.$$

Step 3: Velocity calculation.

The terminal velocity of a sphere moving through a fluid is Provided that by:

$$V = \frac{2r^2}{9\eta}(\rho_b - \rho_{\text{air}}),$$

where:

- r is the radius of the sphere,

- η is the fluid's viscosity,

- ρ_b and ρ_{air} are the densities of the sphere and the air, respectively.

From the equation, terminal velocity is proportional to the square of the radius:

$$V \propto r^2.$$

Step 4: Ratio of velocities.

Using the proportionality:

$$\frac{V_1}{V_2} = \left(\frac{r}{R}\right)^2.$$

Substituting $R = 2r$:

$$\frac{V_1}{V_2} = \left(\frac{r}{2r}\right)^2 = \frac{1}{4}.$$

Step 5: Evaluate V_2.

Rewriting the ratio:

$$V_2 = V_1 \times 4.$$

Provided that $V_1 = 10\,\text{km/s}$:

$$V_2 = 10 \times 4 = 40\,\text{km/s}.$$

Conclusive Answer: The velocity V_2 is $40\,\text{km/s}$.

Quick Tip

Terminal velocity is reached when the gravitational force is balanced by the viscous drag and buoyant force. It is proportional to the square of the radius of the drop.

2: Provided that below are two statements : One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: A bar magnet dropped through a metallic cylindrical pipe takes more time to come down compared to a non-magnetic bar with same geometry and mass.

Reason R: For the magnetic bar, Eddy currents are produced in the metallic pipe which oppose the motion of the magnetic bar.

In the light of the above statements, choose the correct answer from the options Provided that below:

(1) A is true but R is false

(2) Both A and R are true but R is **NOT** the correct explanation of A

(3) A is false but R is true

(4) Both A and R are true and R is the correct explanation of A

Correct Answer: (4): Both A and R are true and R is the correct explanation of

Solution:

If a bar magnet falls through a metallic cylindrical pipe, its motion alters the magnetic flux, inducing eddy currents in the pipe. According to Lenz's law, these eddy currents generate a magnetic field that opposes the magnet's motion, exerting an upward force that slows its descent. As a result, the bar magnet takes longer to reach the bottom compared to a non-magnetic bar of the same shape and mass, which is unaffected by magnetic forces.

In contrast, a non-magnetic bar falling through the same pipe experiences only gravitational force and air resistance. Since there are no eddy currents or opposing magnetic forces, it falls more quickly.

Therefore, both Assertion A and Reason R are correct, and Reason R appropriately explains Assertion A.

Quick Tip

Lenz's Law states that the induced current will flow in such a direction as to create a magnetic field that opposes the change in the original magnetic flux.

3: A space ship of mass 2×10^4 kg is launched into a circular orbit close to the earth surface. The additional velocity to be imparted to the space ship in the orbit to overcome the gravitational pull will be (if $g = 10$ m/s^2 and radius of earth = 6400 km):

(1) $7.9(\sqrt{2} - 1)$ km/s

(2) $7.4(\sqrt{2} - 1)$ km/s

(3) $11.2(\sqrt{2} - 1)$ km/s

(4) $8(\sqrt{2} - 1)$ km/s

Correct Answer: (4): $8(\sqrt{2} - 1)$ km/s

Solution:

Calculating ΔV using the Provided that formula-

Step 1: Formula for ΔV.

The change in velocity is Provided that by:

$$\Delta V = \sqrt{\frac{GM}{R}}\,(\sqrt{2}-1),$$

where:

- G is the gravitational constant,

- M is the mass of the central body (e.g., Earth),

- R is the radius of the orbit.

Step 2: Evaluate the expression.

Rewrite the term $\sqrt{\frac{GM}{R}}$:

$$\Delta V = \sqrt{\frac{GM}{R}} = \sqrt{\frac{GM}{R^2}\cdot R}.$$

Thus:

$$\Delta V = \sqrt{gR}\,(\sqrt{2}-1),$$

where $g = \frac{GM}{R^2}$ is the acceleration due to gravity at the surface.

Step 3: Substitute numerical values.

Using the Provided that value for $\sqrt{gR}$:

$$\Delta V = \sqrt{gR}\,(\sqrt{2}-1) = 8000(\sqrt{2}-1)\,\text{m/s}.$$

Convert to km/s:

$$\Delta V = 8(\sqrt{2}-1)\,\text{km/s}.$$

Conclusive Answer: $\Delta V = 8(\sqrt{2}-1)\,\text{km/s}$.

Quick Tip

The escape velocity is $\sqrt{2}$ times the orbital velocity of a satellite close to the surface of a planet.

4: A projectile is projected at $30°$ from horizontal with initial velocity 40 ms^{-1}. The velocity of the projectile at $t = 2$ s from the start will be :

(Provided that $g = 10$ m/s^2)

(1) Zero

(2) $20\sqrt{3}$ ms^{-1}

(3) $40\sqrt{3}$ ms^{-1}

(4) 20 ms^{-1}

Correct Answer: (2): $20\sqrt{3}$ ms^{-1}

Solution:

Step 1: Initial velocity components.

The initial velocity of the projectile is $u = 40\,\text{ms}^{-1}$, and the angle of projection is $30°$.

1. Horizontal velocity component (U_x):

$$U_x = u\cos 30° = 40 \cdot \cos 30° = 40 \cdot \frac{\sqrt{3}}{2} = 20\sqrt{3}\,\text{ms}^{-1}.$$

2. Vertical velocity component (U_y):

$$U_y = u\sin 30° = 40 \cdot \sin 30° = 40 \cdot \frac{1}{2} = 20\,\text{ms}^{-1}.$$

Step 2: Velocity after $t = 2$ s.

1. Horizontal velocity (V_x) remains constant because there is no horizontal acceleration:

$$V_x = U_x = 20\sqrt{3}\,\text{ms}^{-1}.$$

2. Vertical velocity (V_y) is affected by gravity ($g = 10\,\text{ms}^{-2}$):

$$V_y = U_y - gt = 20 - 10 \cdot 2 = 20 - 20 = 0\,\text{ms}^{-1}.$$

Step 3: Resultant velocity (V).

The resultant velocity is the vector sum of V_x and V_y:

$$V = \sqrt{V_x^2 + V_y^2}.$$

Substitute the values:

$$V = \sqrt{(20\sqrt{3})^2 + (0)^2} = \sqrt{400 \cdot 3} = \sqrt{1200} = 20\sqrt{3}\,\text{ms}^{-1}.$$

Conclusive Answer: The velocity of the projectile after $t = 2$ s is $20\sqrt{3}\,\text{ms}^{-1}$.

Quick Tip

In projectile motion, the horizontal component of velocity remains constant, while the vertical component changes due to gravity.

5: A plane electromagnetic wave of frequency 20 MHz propagates in free space along x-direction. At a particular space and time, $\vec{E} = 6.6\hat{j}$ v/m. What is $\vec{B}$ at this point?

(1) $-2.2 \times 10^{-8}\hat{k}$ T

(2) $-2.2 \times 10^{-8}\hat{i}$ T

(3) $2.2 \times 10^{-8}\hat{k}$ T

(4) $2.2 \times 10^{-8}\hat{i}$ T

Correct Answer: (3): $2.2 \times 10^{-8}\hat{k}$ T

Solution:

Provided that: $\vec{E} = 6.6\hat{j}$ V/m, frequency $f = 20$ MHz, and the wave propagates along the x-direction.

Step 1: Evaluate the magnitude of $\vec{B}$.

The magnitude of the magnetic field $\vec{B}$ is related to the magnitude of the electric field $\vec{E}$ by

$$|\vec{B}| = \frac{|\vec{E}|}{c},$$

where $c = 3 \times 10^8$ m/s is the speed of light in free space.

$$|\vec{B}| = \frac{6.6}{3 \times 10^8} = 2.2 \times 10^{-8} \text{ T}.$$

Step 2: Determine the direction of $\vec{B}$.

For an electromagnetic wave propagating in the direction $\vec{C}$, the electric field $\vec{E}$, magnetic field $\vec{B}$, and propagation direction $\vec{C}$ are mutually perpendicular, and follow the right-hand rule: $\vec{E} \times \vec{B} = \vec{C}$. In this case, $\vec{C}$ is in the x-direction ($\hat{i}$), and $\vec{E}$ is in the y-direction ($\hat{j}$). Thus, $\vec{B}$ must be in the z-direction ($\hat{k}$) for the cross product to be in the x-direction. That is,

$$\hat{j} \times \vec{B} = \hat{i}.$$

Only $\vec{B}$ being in the positive z-direction satisfies this:

$$\hat{j} \times \hat{k} = \hat{i}.$$

Step 3: Combine magnitude and direction. Combining the magnitude and direction, we get

$$\vec{B} = (2.2 \times 10^{-8})\hat{k} \text{ T}.$$

Conclusive Answer: $\vec{B} = 2.2 \times 10^{-8}\hat{k}$ T.

> Quick Tip
>
> In an electromagnetic wave, the electric and magnetic fields are perpendicular to each other and to the direction of propagation.

6: A car P travelling at 20 ms^{-1} sounds its horn at a frequency of 400 Hz. Another car Q is travelling behind the first car in the same direction with a velocity 40 ms^{-1}. The frequency heard by the passenger of the car Q is approximately [Take, velocity of sound $= 360$ ms^{-1}]

(1) $471Hz$

(2) $514Hz$

(3) $421Hz$

(4) $485Hz$

Correct Answer: (3): 421 Hz

Solution:

Provided that: Velocity of car P, $V_P = 20$ ms^{-1}, velocity of car Q, $V_Q = 40$ ms^{-1}, frequency of the horn, $f = 400$ Hz, and velocity of sound, $V_s = 360$ ms^{-1}.

Step 1: Apply the Doppler effect formula. The apparent frequency f_{app} heard by the passenger in car Q when both cars are moving in the same direction is Provided that by:

$$f_{\text{app}} = \left[\frac{V_s - (-V_Q)}{V_s - (-V_P)}\right] f = \left[\frac{V_s + V_Q}{V_s + V_P}\right] f.$$

Note that we use the negative of the velocities since both cars are moving in the same direction as the sound wave. If the observer (car Q) is moving towards the source (car P) and the source is moving away from the observer, then we take V_Q positive and V_P negative. In this case, both are positive because both are moving in the same direction.

Step 2: Substitute the Provided that values. Substituting the Provided that values into the Doppler effect formula:

$$f_{\text{app}} = \left[\frac{360 + 40}{360 + 20}\right] \times 400 = \frac{400}{380} \times 400 = \frac{400}{380} \times 400 \approx 421 \text{ Hz}.$$

Conclusive Answer: The frequency heard by the passenger of car Q is approximately 421 Hz.

Quick Tip

When the source and observer are moving in the same direction, the apparent frequency is lower than the actual frequency if the source is moving faster than the observer.

7: A body of mass 500 g moves along x-axis such that its velocity varies with displacement x according to the calculation $v = 10\sqrt{x}$ m/s the force acting on the body is :-

(1) $25N$

(2) $5N$

(3) $166N$

(4) $125N$

Correct Answer: (1): 25 N

Solution:

Provided that: Mass $m = 500$ g $= 0.5$ kg and velocity $v = 10\sqrt{x}$ m/s.

Step 1: Find the acceleration.

Acceleration a is the rate of change of velocity with respect to time, which can be expressed as:

$$a = \frac{dv}{dt} = \frac{dv}{dx} \times \frac{dx}{dt} = v\frac{dv}{dx}.$$

We are Provided that $v = 10\sqrt{x}$. Differentiating v with respect to x:

$$\frac{dv}{dx} = \frac{d}{dx}(10\sqrt{x}) = 10 \times \frac{1}{2\sqrt{x}} = \frac{5}{\sqrt{x}}.$$

So, the acceleration is

$$a = v\frac{dv}{dx} = 10\sqrt{x} \times \frac{5}{\sqrt{x}} = 50 \text{ ms}^{-2}.$$

Step 2: Evaluate the force-

Force F is Provided that by Newton's second law:

$$F = ma.$$

Substituting the Provided that values:

$$F = 0.5 \times 50 = 25 \text{ N}.$$

Conclusive Answer: The force acting on the body is 25 N.

Quick Tip

When velocity is Provided that as a function of displacement, acceleration can be Evaluated using $a = v\frac{dv}{dx}$.

8: The ratio of the de-Broglie wavelengths of proton and electron having same Kinetic energy:

(Assume $m_p = m_e \times 1840$)

(1) 1 : 62

(2) 1 : 30

(3) 1 : 43

(4) 2 : 43

Correct Answer: (3): 1:43

Solution:

Provided that: Proton and electron have the same kinetic energy, K, and $m_p = 1840m_e$.

Step 1: Recall the de-Broglie wavelength formula-

The de-Broglie wavelength λ is Provided that by

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

where h is Planck's constant and p is the momentum. Since kinetic energy $K = \frac{p^2}{2m}$, we have $p = \sqrt{2mK}$. Therefore,

$$\lambda = \frac{h}{\sqrt{2mK}}.$$

Step 2: Evaluate the ratio of wavelengths-

Let λ_p and λ_e be the de-Broglie wavelengths of the proton and electron, respectively. Then

$$\frac{\lambda_p}{\lambda_e} = \frac{\frac{h}{\sqrt{2m_pK}}}{\frac{h}{\sqrt{2m_eK}}} = \sqrt{\frac{m_e}{m_p}}.$$

Since $m_p = 1840m_e$, we have

$$\frac{\lambda_p}{\lambda_e} = \sqrt{\frac{m_e}{1840m_e}} = \frac{1}{\sqrt{1840}} \approx \frac{1}{42.9} \approx \frac{1}{43}.$$

Conclusive Answer: The ratio of the de-Broglie wavelengths is approximately 1:43.

Quick Tip

For particles with the same kinetic energy, the de-Broglie wavelength is inversely proportional to the square root of the mass.

9: If force (F), velocity (V) and time (T) are considered as fundamental physical quantity, then dimensional formula of density will be :-

(1) $FV^{-2}T^2$

(2) FV^4T^{-6}

(3) $FV^{-4}T^{-2}$

(4) $F^2V^{-2}T^6$

Correct Answer: (3): $FV^{-4}T^{-2}$

Solution:

Provided that: Force (F), velocity (V), and time (T) are fundamental quantities.

Step 1: Write the dimensional formula for density-

Let the dimensional formula for density ρ be

$$[\rho] = F^x V^y T^z,$$

where x, y, and z are constants to be determined.

Step 2: Express the dimensions of fundamental quantities in terms of M, L, and T-

The dimensions of force, velocity, and time are:

$$[F] = [MLT^{-2}], \quad [V] = [LT^{-1}], \quad [T] = [T].$$

The dimensions of density are $[\rho] = [ML^{-3}]$.

Step 3: Substitute the dimensions and equate the powers-

Substituting the dimensions into the equation for $[\rho]$:

$$[ML^{-3}] = [MLT^{-2}]^x[LT^{-1}]^y[T]^z = M^x L^{x+y} T^{-2x-y+z}.$$

Equating the powers of M, L, and T on both sides, we get the following system of equations:

$$x = 1$$

$$x + y = -3$$

$$-2x - y + z = 0$$

Step 4: Solve the system of equations-

From the first equation, $x = 1$. Substituting into the second equation:

$$1 + y = -3 \implies y = -4.$$

Substituting $x = 1$ and $y = -4$ into the third equation:

$$-2(1) - (-4) + z = 0 \implies -2 + 4 + z = 0 \implies z = -2.$$

Step 5: Write the dimensional formula for density. Substituting $x = 1$, $y = -4$, and $z = -2$:

$$[\rho] = F^1 V^{-4} T^{-2} = F V^{-4} T^{-2}.$$

Conclusive Answer: The dimensional formula for density is $F V^{-4} T^{-2}$.

Quick Tip

Dimensional analysis is a powerful tool for checking the correctness of equations and deriving calculationships between physical quantities.

10: An electron is allowed to move with constant velocity along the axis of current carrying straight solenoid.

A. The electron will experience magnetic force along the axis of the solenoid.

B. The electron will not experience magnetic force.

C. The electron will continue to move along the axis of the solenoid.

D. The electron will be accelerated along the axis of the solenoid.

E. The electron will follow parabolic path inside the solenoid.

Choose the correct answer from the options Provided that below:

(1) A and D only

(2) B, C and D only

(3) B and E only

(4) B and C only

Correct Answer: (4): B and C only

Solution:

Provided that: An electron moves with constant velocity along the axis of a current-carrying solenoid.

Step 1: Recall the magnetic force formula. The magnetic force $\vec{F}_m$ experienced by a charged particle with charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ is Provided that by

$$\vec{F}_m = q(\vec{v} \times \vec{B}).$$

Step 2: Analyze the force on the electron. Inside a solenoid, the magnetic field is uniform and directed along the axis of the solenoid. Since the electron is moving along the axis of the solenoid, its velocity $\vec{v}$ is parallel to the magnetic field $\vec{B}$. Therefore, the cross product $\vec{v} \times \vec{B}$ is zero, and the magnetic force on the electron is also zero:

$$\vec{F}_m = 0.$$

Step 3: Determine the motion of the electron. Since the magnetic force on the electron is zero, there is no net force acting on it in the direction perpendicular to its motion. Thus, the electron will continue to move along the axis of the solenoid with constant velocity. It will not be accelerated or follow a parabolic path.

Conclusive Answer: The electron will not experience magnetic force (B), and it will continue to move along the axis of the solenoid (C).

Quick Tip

A charged particle moving parallel or antiparallel to a magnetic field experiences no magnetic force.

11: The Thermodynamic process, in which internal energy of the system remains constant is

(1) Isobaric

(2) Isochoric

(3) Adiabatic

(4) Isothermal

Correct Answer: (4): Isothermal

Solution:

Step 1: Recall the calculationship between internal energy and temperature-

The change in internal energy (ΔU) of a system is related to the change in temperature (ΔT) by

$$\Delta U = nC_v\Delta T,$$

where n is the number of moles and C_v is the molar specific heat at constant volume.

Step 2: Consider the isothermal process-

In an isothermal process, the temperature of the system remains constant. Therefore, $\Delta T = 0$.

Step 3: Evaluate the change in internal energy-

Substituting $\Delta T = 0$ into the equation for ΔU:

$$\Delta U = nC_v(0) = 0.$$

Step 4: Conclude about the internal energy-

Since $\Delta U = 0$, the internal energy of the system remains constant in an isothermal process.

Conclusive Answer: The thermodynamic process in which internal energy remains constant is isothermal.

> **Quick Tip**
>
> In an isothermal process, the temperature remains constant, leading to zero change in internal energy.

12: In satellite communication, the uplink frequency band used is:

(1) $76 - 88$ MHz

(2) $420 - 890$ MHz

(3) $3.7 - 4.2$ GHz

(4) $5.925 - 6.425$ GHz

Correct Answer: (4): 5.925 – 6.425 GHz

Solution:

In satellite communication, the uplink frequency band is used for transmitting signals from an earth station to a satellite. The downlink frequency band is used for transmitting signals from a satellite to an earth station.

Uplink frequencies are generally higher than downlink frequencies to minimize interference.

A common standard for satellite communication uses the following frequency bands:

Uplink-

5.8-6.2 GHz

Downlink -

4-4.2 GHz

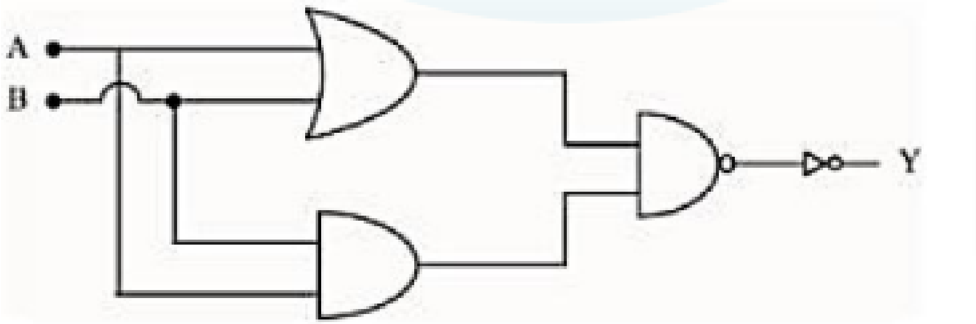
Option (4) falls within the standard uplink frequency band.

Conclusive Answer: The uplink frequency band used in satellite communication is 5.925 – 6.425 GHz.

Quick Tip

Uplink frequencies are higher than downlink frequencies in satellite communication to reduce interference.

13: The logic operations performed by the Provided that digital circuit is equivalent to:



(1) OR

(2) $NAND$

(3) NOR

(4) AND

Correct Answer: (4): AND

Solution:

Step 1: Interpret the first NAND gate-

The output of the first NAND gate (topmost) is $\overline{A \cdot B}$. Since there is a connection bridging across from the inputs A and B to the lower NAND gate this lower NAND gate's output is also $\overline{A \cdot B}$.

Step 2: Interpret the second NAND gate-

The second NAND gate (middle) takes the outputs of the first and third NAND gates as inputs. Let X_1 and X_2 be the outputs of the first and third NAND gates, respectively. Then, the output of the second NAND gate is $\overline{X_1 \cdot X_2}$. The output of the first NAND gate is $\overline{A+B}$ and the output of the second NAND gate is $\overline{AB}$. Hence the output of the second NAND gate becomes $\overline{(\overline{A+B}).(\overline{AB})}$.

Step 3: Interpret the NOT gate-

The NOT gate inverts the output of the second NAND gate. Let X_3 be the output of the second NAND gate. Then the output Y of the NOT gate is $\overline{X_3}$. The output of the NOT gate is $\overline{\overline{(\overline{A+B}).(\overline{AB})}} = (\overline{A+B}).(\overline{AB})$.

Step 4: Evaluate the expression-

Using De Morgan's theorem, we can Evaluate the expression for Y:

$$
\begin{aligned}
Y &= \overline{\overline{(A+B)} \cdot \overline{AB}} \\
&= \overline{\overline{A+B}} + \overline{\overline{AB}} \\
&= (A+B) + AB \\
&= (A+B)(1+A) + (A+B)(B) \\
&= A + AB + B + AB \\
&= A + AB + AB + B \\
&= AB + AB \\
&= AB \\
&= A \cdot B
\end{aligned}
$$

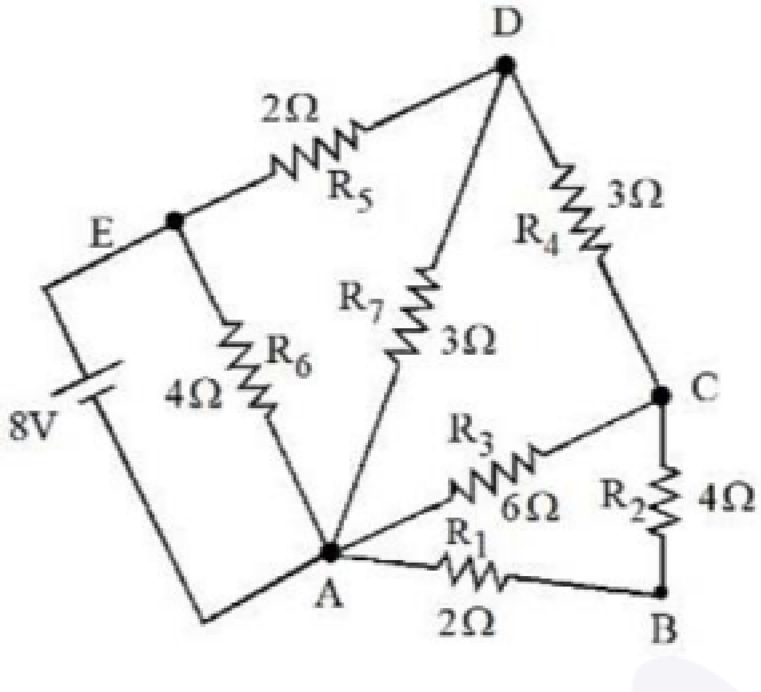
This is the logic for an AND gate.

Conclusive Answer: The Provided that digital circuit is equivalent to an AND gate.

Quick Tip

De Morgan's theorem is very useful in Evaluateing Boolean expressions. Remember to analyze each gate separately and then combine the results.

14: The current flowing through R_2 is:



(1) $\frac{1}{3}$ A

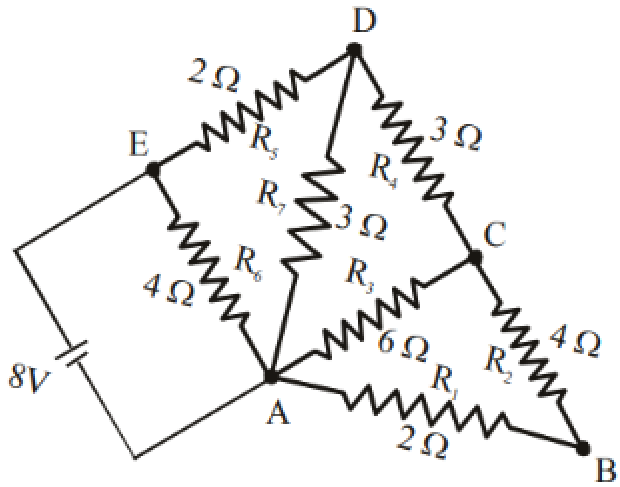
(2) $\frac{1}{4}$ A

(3) $\frac{2}{3}$ A

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

Correct Answer: (1): $\frac{1}{3}$ A

Solution:



Step 1: Determine the equivalent resistance-

The total resistance in the circuit is Provided that as:

$$R_{\text{eq}} = 4\,\Omega.$$

Step 2: Evaluate the total current (i)-

Using Ohm's law:

$$i = \frac{V}{R_{\text{eq}}}.$$

Substitute the Provided that values:

$$i = \frac{8}{4} = 2\,\text{A}.$$

Step 3: Evaluate i_1-

The current i_1 is determined using the current division rule:

$$i_1 = \frac{2 \times 3}{3 + 6}.$$

Evaluate:

$$i_1 = \frac{6}{9} = \frac{2}{3}\,\text{A}.$$

Step 4: Evaluate i_2-

The current i_2 is Provided that by:

$$i_2 = \frac{i_1}{2}.$$

Substitute $i_1 = \frac{2}{3}$:

$$i_2 = \frac{\frac{2}{3}}{2} = \frac{1}{3}\,\text{A}.$$

Conclusive Answer:

$$i = 2\,\text{A}, \quad i_1 = \frac{2}{3}\,\text{A}, \quad i_2 = \frac{1}{3}\,\text{A}.$$

Quick Tip

Symmetry in circuits can greatly Evaluate calculations. Look for identical resistances and branches to Evaluate complex networks.

15: When vector $\vec{A} = 2\hat{i} + 3\hat{j} + 2\hat{k}$ is subtracted from vector $\vec{B}$, it gives a vector equal to $2\hat{j}$. Then the magnitude of vector $\hat{B}$ will be:

(1) 3

(2) $\sqrt{5}$

(3) $\sqrt{33}$

(4) $\sqrt{6}$

Correct Answer: (3): $\sqrt{33}$

Solution:

Provided that: $\vec{A} = 2\hat{i} + 3\hat{j} + 2\hat{k}$ and $\vec{B} - \vec{A} = 2\hat{j}$.

Step 1: Solve for vector B. We are Provided that

$$\vec{B} - \vec{A} = 2\hat{j}.$$

Adding $\vec{A}$ to both sides, we get

$$\vec{B} = 2\hat{j} + \vec{A} = 2\hat{j} + (2\hat{i} + 3\hat{j} + 2\hat{k}) = 2\hat{i} + 5\hat{j} + 2\hat{k}.$$

Step 2: Evaluate the magnitude of B. The magnitude of vector $\vec{B} = x\hat{i} + y\hat{j} + z\hat{k}$ is Provided that by $|\vec{B}| = \sqrt{x^2 + y^2 + z^2}$. Therefore,

$$|\vec{B}| = \sqrt{2^2 + 5^2 + 2^2} = \sqrt{4 + 25 + 4} = \sqrt{33}.$$

Conclusive Answer: The magnitude of vector B is $\sqrt{33}$.

Quick Tip

Vector addition and subtraction are performed component-wise. The magnitude of a vector is the square root of the sum of the squares of its components.

16: If V is the gravitational potential due to sphere of uniform density on it's surface, then it's value at the center of sphere will be:-

(1) $\frac{4}{3}V$

(2) V

(3) $\frac{3V}{2}$

(4) $\frac{V}{2}$

Correct Answer: (3): $\frac{3V}{2}$

Solution:

Step 1: Recall the gravitational potential at the surface. The gravitational potential V at the surface of a sphere of mass M and radius R is Provided that by

$$V = -\frac{GM}{R}.$$

Step 2: Recall the gravitational potential inside a uniform sphere. The gravitational potential V_{centre} at a distance r from the center of a uniform sphere of mass M and radius R, where $r \leq R$, is Provided that by

$$V(r) = -\frac{GM}{2R^3}(3R^2 - r^2).$$

At the center of the sphere, $r = 0$, so

$$V_{\text{centre}} = -\frac{GM}{2R^3}(3R^2) = -\frac{3GM}{2R}.$$

Step 3: Express the potential at the center in terms of the potential at the surface. We are Provided that that the potential at the surface is $V = -\frac{GM}{R}$. Therefore,

$$V_{\text{centre}} = -\frac{3GM}{2R} = \frac{3}{2}\left(-\frac{GM}{R}\right) = \frac{3}{2}V.$$

Conclusive Answer: The gravitational potential at the center of the sphere is $\frac{3V}{2}$.

Quick Tip

The gravitational potential inside a uniform sphere is not inversely proportional to the distance from the center, unlike the potential outside the sphere.

17: The root mean square speed of molecules of nitrogen gas at $27°$C is approximately : (Provided that mass of a nitrogen molecule $= 4.6 \times 10^{-26}$ kg and take Boltzmann constant $k_B = 1.4 \times 10^{-23}$ JK^{-1})

(1) 1260 m/s

(2) 91 m/s

(3) 523 m/s

(4) 27.4 m/s

Correct Answer: (3): 523 m/s

Solution:

Provided that: Temperature $T = 27°C = 300$ K, mass of a nitrogen molecule $m = 4.6 \times 10^{-26}$ kg, and Boltzmann constant $k_B = 1.4 \times 10^{-23}$ JK^{-1}.

Step 1: Recall the formula for root mean square speed. The root mean square (rms) speed V_{rms} of gas molecules is Provided that by

$$V_{\text{rms}} = \sqrt{\frac{3RT}{M_w}} = \sqrt{\frac{3RT}{mN_A}} = \sqrt{\frac{3k_BT}{m}},$$

where R is the universal gas constant, T is the temperature in Kelvin, M_w is the molar mass, m is the mass of one molecule, N_A is Avogadro's number, and $k_B = \frac{R}{N_A}$ is the Boltzmann constant.

Step 2: Substitute the Provided that values. Substituting the Provided that values into the formula:

$$V_{\text{rms}} = \sqrt{\frac{3 \times 1.4 \times 10^{-23} \times 300}{4.6 \times 10^{-26}}} = \sqrt{\frac{3 \times 1.4 \times 3 \times 10^{-23+2+1}}{4.6 \times 10^{-26}}} = \sqrt{\frac{12.6 \times 10^{-21+27}}{4.6}}$$

$$= \sqrt{\frac{12.6 \times 10^{6}}{4.6}} = \sqrt{2.73 \times 10^5} = \sqrt{27.39 \times 10^4} \approx 5.23 \times 10^2 = 523 \text{ m/s}.$$

Conclusive Answer: The root mean square speed of nitrogen molecules is approximately 523 m/s.

Quick Tip

The root mean square speed is directly proportional to the square root of the temperature and inversely proportional to the square root of the molecular mass.

18: The energy of He$^+$ ion in its first excited state is, (The ground state energy for the Hydrogen atom is -13.6 eV):

(1) -13.6 eV

(2) -54.4 eV

(3) -27.2 eV

(4) -3.4 eV

Correct Answer: (1): -13.6 eV

Solution:

Solution:

Step 1: Formula for energy levels.

The energy of an electron in a hydrogen-like atom is Provided that by:

$$E = -\left(\frac{13.6Z^2}{n^2}\right) \text{ eV},$$

where: - Z is the atomic number, - n is the principal quantum number (energy level), - $13.6\,\text{eV}$ is the ground state energy of the hydrogen atom.

Step 2: First excited state ($n = 2$).

For the first excited state, the principal quantum number is:

$$n = 2.$$

Substitute $n = 2$ into the energy formula:

$$E = -\frac{13.6Z^2}{2^2}.$$

Evaluate:

$$E = -\frac{13.6Z^2}{4}.$$

Step 3: For $Z = 1$ (hydrogen atom).

Substitute $Z = 1$ into the equation:

$$E = -\frac{13.6 \cdot 1^2}{4} = -13.6\,\text{eV}.$$

Conclusive Answer:

The energy of the electron in the first excited state is:

$$E = -13.6\,\text{eV}.$$

Quick Tip

The energy levels of hydrogen-like atoms are proportional to Z^2 and inversely proportional to n^2.

19: When one light ray is reflected from a plane mirror with 30° angle of reflection, the angle of deviation of the ray after reflection is:

(1) 140°

(2) 130°

(3) 120°

(4) 110°

Correct Answer: (3): 120°

Solution:

Provided that: Angle of reflection $r = 30^\circ$.

Step 1: Recall the law of reflection. According to the law of reflection, the angle of incidence (i) is equal to the angle of reflection (r). Therefore, $i = r = 30^\circ$.

Step 2: Determine the angle of deviation. The angle of deviation (δ) is the angle between the incident ray and the reflected ray. It is Provided that by:

$$\delta = 180^\circ - 2i = 180^\circ - 2r.$$

Since $r = 30^\circ$, $\delta = 180 - 2(30) = 180 - 60 = 120^\circ$.

Step 3: Evaluate the angle of deviation. Substituting $i = 30^\circ$:

$$\delta = 180^\circ - 2(30^\circ) = 180^\circ - 60^\circ = 120^\circ.$$

Conclusive Answer: The angle of deviation is 120°.

Quick Tip

The angle of deviation for reflection from a plane mirror is twice the glancing angle (complement of the angle of incidence).

20: A capacitor of capacitance C is charge to a potential V. The flux of the electric field through a closed surface enclosing the positive plate of the capacitor is :

(1) Zero

(2) $\frac{CV}{\varepsilon_0}$

(3) $\frac{2CV}{\varepsilon_0}$

(4) $\frac{CV}{2\varepsilon_0}$

Correct Answer: (2): $\frac{CV}{\varepsilon_0}$

Solution:

Provided that: Capacitance C and potential difference V.

Step 1: Recall Gauss's law. Gauss's law states that the electric flux Φ through a closed surface is equal to the enclosed charge q divided by the permittivity of free space ε_0:

$$\Phi = \frac{q}{\varepsilon_0}.$$

Step 2: Relate charge, capacitance, and potential difference. The charge q on a capacitor is related to its capacitance C and the potential difference V across it by

$$q = CV.$$

Step 3: Evaluate the electric flux. Substituting $q = CV$ into Gauss's law:

$$\Phi = \frac{CV}{\varepsilon_0}.$$

Conclusive Answer: The flux of the electric field through the closed surface is $\frac{CV}{\varepsilon_0}$.

Quick Tip

Gauss's law relates the electric flux through a closed surface to the net charge enclosed by the surface. Remember the calculationship between charge, capacitance, and voltage for a capacitor: $Q = CV$.

Section B

21: A coil has an inductance of 2H and resistance of 4Ω. A 10 V is applied across the coil. The energy stored in the magnetic field after the current has built up to its equilibrium value will be ____ $\times 10^{-2}$ J.

Correct Answer: 625

Solution:

Provided that: Inductance $L = 2$ H, resistance $R = 4\Omega$, and applied voltage $V = 10$ V.

Step 1: Analyze the circuit at steady state. At steady state, the inductor acts as a short circuit, meaning it has zero resistance. The circuit effectively becomes a simple resistor connected to the voltage source.

(0,0) to[battery1, l=10V] (0,2) to[L, l=2H] (2,2) to[R, l=4Ω] (4,2) – (4,0) – (0,0) ; $\implies$ at steady state (0,0) to[battery1, l=10V] (0,2) to[R, l=4Ω] (2,2) – (2,0) – (0,0) ;

Step 2: Evaluate the current at steady state. Using Ohm's law, the current I through the resistor at steady state is

$$I = \frac{V}{R} = \frac{10}{4} = \frac{5}{2} = 2.5 \text{ A}.$$

Step 3: Evaluate the energy stored in the magnetic field. The energy E stored in the magnetic field of an inductor is Provided that by

$$E = \frac{1}{2}LI^2.$$

Substituting the Provided that values:

$$E = \frac{1}{2} \times 2 \times \left(\frac{5}{2}\right)^2 = \frac{25}{4} = 6.25 \text{ J} = 625 \times 10^{-2} \text{ J}.$$

Conclusive Answer: The energy stored in the magnetic field is 625×10^{-2} J.

Quick Tip

At steady state, an inductor in a DC circuit acts as a short circuit. The energy stored in an inductor's magnetic field is Provided that by $E = \frac{1}{2}LI^2$.

22: A metallic cube of side 15 cm moving along y-axis at a uniform velocity of 2 ms^{-1}. In a region of uniform magnetic field of magnitude 0.5T directed along z-axis. In equilibrium the potential difference between the faces of higher and lower potential developed because of the motion through the field will be _____ mV.

(0,0,0) – (2,0,0) – (2,2,0) – (0,2,0) – cycle; (0,0,2) – (2,0,2) – (2,2,2) – (0,2,2) – cycle; (0,0,0) – (0,0,2); (2,0,0) – (2,0,2); (2,2,0) – (2,2,2); (0,2,0) – (0,2,2); [-¿] (2,2,0) – (3,2,0) node[anchor=west] x; [-¿] (0,2,0) – (0,3,0) node[anchor=south] y; [-¿] (0,0,0) – (0,0,3) node[anchor=east] z; [-¿] (0.5,2.5,0) – (0.5,3,0) node[anchor=south west] $\vec{v}$; [-¿] (0,0,1.5) – (0.5,0,1.5) node[anchor=north east] $\vec{B}$;

Correct Answer: 150

Solution:

Provided that: Side of the cube $l = 15$ cm $= 0.15$ m, velocity $\vec{v} = 2\hat{j}$ ms^{-1}, and magnetic field $\vec{B} = 0.5\hat{k}$ T.

Step 1: Determine the induced EMF. The induced electromotive force (EMF) or potential difference V across the faces of the cube due to its motion in the magnetic field is Provided that by

$$V = Blv,$$

where B is the magnetic field strength, l is the length of the side perpendicular to both the velocity and magnetic field, and v is the velocity.

Step 2: Substitute the Provided that values. Substituting the Provided that values:

$$V = (0.5 \text{ T})(0.15 \text{ m})(2 \text{ ms}^{-1}) = 0.15 \text{ V} = 150 \text{ mV}.$$

Conclusive Answer: The potential difference developed between the faces is 150 mV.

Quick Tip

Motional EMF is induced when a conductor moves through a magnetic field. The induced EMF is Provided that by $V = Blv$, where l is the length of the conductor perpendicular to both the velocity and the magnetic field.

23: In the Provided that circuit, $C_1 = 2\ \mu$F, $C_2 = 0.2\ \mu$F, $C_3 = 2\ \mu$F, $C_4 = 4\ \mu$F, $C_5 = 2\ \mu$F, $C_6 = 2\ \mu$F. The charge stored on capacitor C_4 is ____ μC.

(0,0) to[battery1, l=10V] (0,2) to[C, l=C_1] (2,2) to[C, l=C_3] (4,2) to[C, l=C_4] (4,0) to[C, l=C_5] (2,0) to[C, l=C_6] (0,0) (2,0) to[C, l=C_2] (2,2) ;

Correct Answer: 4

Solution:

We are tasked with calculating the equivalent capacitance and charges in the Provided that circuit.

Step 1: Equivalent capacitance of the circuit.

The total equivalent capacitance of the circuit is Provided that as:

$$C_{\text{eq}} = 0.5\,\mu\text{F}.$$

Step 2: Total charge (Q) in the circuit.

The total charge stored in the circuit can be Evaluated using the formula:

$$Q = C_{\text{eq}} \cdot V,$$

where: - C_{eq} is the equivalent capacitance, - $V = 10\,\text{V}$ is the applied voltage.

Substitute the Provided that values:

$$Q = 0.5 \cdot 10 = 5\,\mu\text{C}.$$

Step 3: Charge redistribution (Q').

The charge on a specific branch of the circuit is Evaluated using the charge division formula. For the Provided that branch:

$$Q' = \frac{Q \cdot C_2}{C_2 + C_6}.$$

Substitute $Q = 5\,\mu\text{C}$, $C_2 = 0.8\,\mu\text{F}$, and $C_6 = 0.2\,\mu\text{F}$:

$$Q' = \frac{5 \cdot 0.8}{0.8 + 0.2}.$$

Evaluate:

$$Q' = \frac{4}{1} = 4\,\mu\text{C}.$$

Conclusive Answer:

$$C_{\text{eq}} = 0.5\,\mu\text{F}, \quad Q = 5\,\mu\text{C}, \quad Q' = 4\,\mu\text{C}.$$

Quick Tip

Capacitors in series store the same charge, while capacitors in parallel have the same voltage across them.

24: A nucleus disintegrates into two nuclear parts, in such a way that ratio of their nuclear sizes is $1 : 2^{1/3}$. Their respective speed have a ratio of n : 1. The value of n is ____.

Correct Answer: 2

Solution:

Provided that: Ratio of nuclear sizes is $r_1 : r_2 = 1 : 2^{1/3}$ and ratio of speeds is $V_1 : V_2 = n : 1$.

Step 1: Apply conservation of linear momentum. Since the nucleus disintegrates into two parts, the total momentum before disintegration must be equal to the total momentum after disintegration. Assuming the initial nucleus is at rest, the total initial momentum is zero. Thus, the momenta of the two parts after disintegration must be equal and opposite. Let m_1 and m_2 be the masses of the two parts, and V_1 and V_2 be their respective speeds. Then by the law of conservation of linear momentum (LCM),

$$m_1 V_1 = m_2 V_2.$$

Thus,

$$\frac{V_1}{V_2} = \frac{m_2}{m_1}.$$

Step 2: Relate mass and radius. Assuming the two nuclear parts have the same density, their masses are proportional to the cubes of their radii:

$$\frac{m_2}{m_1} = \frac{r_2^3}{r_1^3} = \left(\frac{r_2}{r_1}\right)^3.$$

We are Provided that $\frac{r_2}{r_1} = 2^{1/3}$, so

$$\frac{m_2}{m_1} = (2^{1/3})^3 = 2.$$

Step 3: Find the ratio of velocities.

Therefore,

$$\frac{V_1}{V_2} = \frac{m_2}{m_1} = \left(\frac{r_2}{r_1}\right)^3 = \left(\frac{2^{\frac{1}{3}}}{1}\right)^3 = 2.$$

Since $\frac{V_1}{V_2} = \frac{n}{1}$, we have $n = 2$.

Conclusive Answer: The value of n is 2.

Quick Tip

In nuclear disintegration problems, apply conservation of linear momentum and the calcula-tionship between mass and radius (or volume) assuming uniform density.

25: The surface tension of soap solution is 3.5×10^{-2} Nm^{-1}. The amount of work done required to increase the radius of soap bubble from 10 cm to 20 cm is ____ $\times 10^{-4}$ J. (take $\pi = 22/7$)

Correct Answer: 264

Solution:

Provided that: Surface tension $S = 3.5 \times 10^{-2}$ N/m, initial radius $r_i = 10$ cm $= 0.1$ m, and final radius $r_f = 20$ cm $= 0.2$ m.

Step 1: Recall the formula for work done. The work done (W) in increasing the surface area of a soap bubble is Provided that by

$$W = \Delta U = S \times \Delta A,$$

where S is the surface tension and ΔA is the change in surface area.

Step 2: Evaluate the change in surface area. A soap bubble has two surfaces (inner and outer). The initial surface area A_i and final surface area A_f are Provided that by:

$$A_i = 2 \times 4\pi r_i^2 \quad \text{and} \quad A_f = 2 \times 4\pi r_f^2.$$

The change in surface area is

$$\Delta A = A_f - A_i = 2 \times 4\pi(r_f^2 - r_i^2) = 8\pi(r_f^2 - r_i^2).$$

Step 3: Evaluate the work done. Substituting the values into the formula for work done:

$$\begin{aligned} W &= S \times \Delta A = S \times 8\pi(r_f^2 - r_i^2) \\ &= 3.5 \times 10^{-2} \times 8 \times \frac{22}{7} \times (0.2^2 - 0.1^2) \\ &= 3.5 \times 10^{-2} \times 8 \times \frac{22}{7} \times (0.04 - 0.01) \\ &= 3.5 \times 10^{-2} \times 8 \times \frac{22}{7} \times 0.03 \\ &= \frac{3.5 \times 8 \times 22 \times 3 \times 10^{-2} \times 10^{-2}}{7} \\ &= 264 \times 10^{-4}\ \text{J}. \end{aligned}$$

Conclusive Answer: The work done is 264×10^{-4} J.

Quick Tip

The work done in changing the surface area of a liquid is Provided that by the product of surface tension and the change in surface area. Remember a soap bubble has two surfaces.

26: A circular plate is rotating horizontal plane, about an axis passing through its center perpendicular to the plate, with an angular velocity ω. A person sits at the center having two

dumbbells in his hands. When he stretches out his hands, the moment of inertia of the system becomes triple. If E be the initial Kinetic energy of the system, then final Kinetic energy will be $\frac{E}{x}$. The value of x is _____.

Correct Answer: 3

Solution:

Provided that: Initial angular velocity $\omega_1 = \omega$, initial moment of inertia $I_1 = I_0$, final moment of inertia $I_2 = 3I_0$, and initial kinetic energy E.

Step 1: Apply conservation of angular momentum. Since there is no external torque acting on the system, the angular momentum is conserved. Thus,

$$I_1\omega_1 = I_2\omega_2,$$

where ω_2 is the final angular velocity. We have $I_0\omega = 3I_0\omega_2$, so

$$\omega_2 = \frac{\omega}{3}.$$

Step 2: Evaluate the initial kinetic energy. The initial kinetic energy E is Provided that by

$$E = \frac{1}{2}I_1\omega_1^2 = \frac{1}{2}I_0\omega^2.$$

Step 3: Evaluate the final kinetic energy. The final kinetic energy E_f is Provided that by

$$E_f = \frac{1}{2}I_2\omega_2^2 = \frac{1}{2}(3I_0)\left(\frac{\omega}{3}\right)^2 = \frac{1}{2} \times 3I_0 \times \frac{\omega^2}{9} = \frac{1}{6}I_0\omega^2 = \frac{1}{3}\left(\frac{1}{2}I_0\omega^2\right) = \frac{E}{3}.$$

Step 4: Find the value of x. We are Provided that that the final kinetic energy is $\frac{E}{x}$. Comparing this with our result $E_f = \frac{E}{3}$, we find $x = 3$.

Conclusive Answer: The value of x is 3.

Quick Tip

When no external torque acts on a rotating system, angular momentum is conserved. Stretching out the arms increases the moment of inertia and decreases the angular velocity.

27: A block of mass 5 kg starting from rest pulled up on a smooth incline plane making an angle of 30° with horizontal with an affective acceleration of 1 ms^{-2}. The power delivered by the pulling force at $t = 10$ s from the starts is ____ W. [use $g = 10$ ms^{-2}] (Evaluate the nearest integer value)

Correct Answer: 300

Solution:

Provided that: Mass $m = 5$ kg, angle of incline $\theta = 30^\circ$, acceleration $a = 1$ m/s^2, time $t = 10$ s, and $g = 10$ m/s^2. Initial velocity $u = 0$ since the block starts from rest.

(0,0) – (4,0); (0,0) – (30:3); (1,0) arc (0:30:1) node[midway,right] 30°; [fill=white] (30:1.5) – ++(0.3,0) – ++(-30:0.3) – ++(-0.3,0) – cycle; [-¿] (0,0) – (30:2) node[midway,above left] $mg \sin 30$;

Step 1: Resolve forces and find pulling force The forces acting on the block along the incline are the pulling force F (upwards), the component of the weight $mg \sin \theta$ (downwards), and the force causing the acceleration ma (upwards). Applying Newton's second law along the incline:

$$F - mg \sin \theta = ma.$$

Substituting the Provided that values:

$$F - 5 \times 10 \times \sin 30^\circ = 5 \times 1.$$

$$F - 5 \times 10 \times \frac{1}{2} = 5 \implies F - 25 = 5.$$

$$F = 30 \text{ N}.$$

Step 2: Evaluate the velocity. Using the first equation of motion:

$$v = u + at,$$

where v is the final velocity, u is the initial velocity, a is the acceleration, and t is the time. Substituting $u = 0$, $a = 1$ m/s^2, and $t = 10$ s:

$$v = 0 + 1 \times 10 = 10 \text{ m/s}.$$

Step 3: Evaluate the power. Power P is the rate at which work is done, which is Provided that by the product of force and velocity:

$$P = Fv.$$

Substituting $F = 30$ N and $v = 10$ m/s:

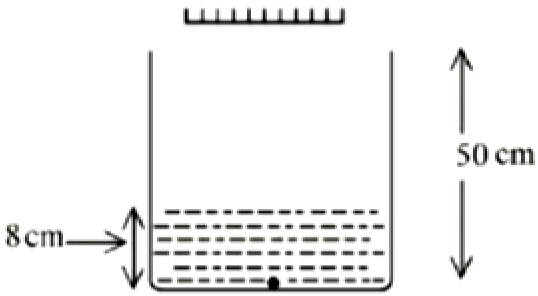
$$P = 30 \times 10 = 300 \text{ W}.$$

Conclusive Answer: The power delivered by the pulling force is 300 W.

Quick Tip

Power is the rate of doing work. For constant force and velocity along the direction of the force, it can be Evaluated as the product of force and velocity.

28: As shown in the figure, a plane mirror is fixed at a height of 50 cm from the bottom of tank containing water $\left(\mu = \frac{4}{3}\right)$. The height of water in the tank is 8 cm. A small bulb is placed at the bottom of the water tank. The distance of image of the bulb formed by mirror from the bottom of the tank is _____ cm.



Correct Answer: 98

Solution:

Step 1: Apparent depth of O.

The calculationship between the apparent depth and real depth in a medium is Provided that by:

$$\text{Apparent depth} = \frac{\text{Real depth}}{\mu},$$

where: - Real depth $= d = 8\,\text{cm}$, - $\mu = 4/3$ is the refractive index of the medium.

Substitute the values:

$$\text{Apparent depth of } O = \frac{d}{\mu} = \frac{8}{4/3} = 6\,\text{cm}.$$

Step 2: Distance between O and I_2.

1. The total real depth of the liquid column is:

$$\text{Real depth} = 42\,\text{cm}.$$

2. The refracted depth:

$$\text{Apparent shift} = \frac{8}{4} \cdot 3 = 6\,\text{cm}.$$

The distance between O and I_2 is Evaluated as:

$$\text{Distance between } O \text{ and } I_2 = 48 + 50 = 98\,\text{cm}.$$

Conclusive Answer:

$$\text{Apparent depth of } O = 6\,\text{cm}, \quad \text{Distance between } O \text{ and } I_2 = 98\,\text{cm}.$$

Quick Tip

When dealing with apparent depth, remember that the object appears closer to the surface than its actual depth. The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of the mirror.

29: Two identical cells each of emf 1.5 V are connected in series across a $10\ \Omega$ resistance. An ideal voltmeter connected across $10\ \Omega$ resistance reads 1.5 V. The internal resistance of each cell is ____ Ω.

Correct Answer: 5

Solution:

Provided that: EMF of each cell $\varepsilon = 1.5$ V, external resistance $R = 10\ \Omega$, and voltmeter reading across the external resistance $V_R = 1.5$ V.

Step 1: Evaluate the current in the circuit. Let r be the internal resistance of each cell. Since the cells are connected in series, the total EMF is $2\varepsilon = 2 \times 1.5 = 3$ V, and the total internal resistance is $2r$. The current I in the circuit is Provided that by

$$I = \frac{2\varepsilon}{R + 2r}.$$

The voltmeter reads the potential difference across the $10\ \Omega$ resistor, which is $V_R = IR = 1.5$ V. Therefore,

$$I = \frac{V_R}{R} = \frac{1.5}{10} = 0.15\ \text{A}.$$

Step 2: Solve for the internal resistance. Substituting $I = 0.15$ A and $2\varepsilon = 3$ V:

$$0.15 = \frac{3}{10 + 2r}.$$

$$10 + 2r = \frac{3}{0.15} = 20.$$

$$2r = 20 - 10 = 10.$$

$$r = \frac{10}{2} = 5\ \Omega.$$

Conclusive Answer: The internal resistance of each cell is 5 Ω.

> Quick Tip
>
> When cells are connected in series, their EMFs add up, and so do their internal resistances.

30: A wire of density 8×10^3 kg/m^3 is stretched between two clamps 0.5 m apart. The extension developed in the wire is 3.2×10^{-4} m. If $Y = 8 \times 10^{10}$ N/m^2, the fundamental frequency of vibration in the wire will be _____ Hz.

Correct Answer: 80

Solution:

Step 1: Formula for frequency.

The frequency of a vibrating string is Provided that by:

$$f = \frac{1}{2\ell}\sqrt{\frac{T}{\mu}},$$

where: - ℓ is the length of the string, - T is the tension in the string, - μ is the linear mass density of the string.

Step 2: Substitute tension in terms of Young's modulus.

The tension T can be expressed in terms of Young's modulus Y as:

$$T = Y \cdot A \cdot \frac{\Delta\ell}{\ell},$$

where: - Y is Young's modulus, - A is the cross-sectional area of the string, - $\Delta\ell$ is the extension of the string, - ℓ is the original length of the string.

Substituting for T in the frequency formula:

$$f = \frac{1}{2\ell}\sqrt{\frac{Y \cdot A \cdot \Delta\ell}{\ell \cdot \mu}}.$$

Step 3: Substitute the Provided that values.

Substitute the numerical values:

$$f = \frac{1}{2 \cdot 0.5}\sqrt{\frac{8 \times 10^{10} \cdot 3.2 \times 10^{-4}}{8 \times 10^{3} \cdot 0.5}}.$$

Evaluate the terms:

$$f = \frac{1}{1}\sqrt{\frac{8 \times 10^{10} \cdot 3.2 \times 10^{-4}}{4 \times 10^{3}}}.$$

$$f = \frac{1}{1}\sqrt{6400}.$$

Step 4: Evaluate the frequency.

Evaluate:

$$f = \sqrt{6400} = 80\,\text{Hz}.$$

Conclusive Answer:

The frequency of the vibrating string is:

$$f = 80\,\text{Hz}.$$

Quick Tip

The fundamental frequency of a stretched wire depends on its length, tension, and mass per unit length. Young's modulus relates stress and strain in the wire.
