1. Two blocks are connected with the help of a string as shown:

If the coefficient of friction between 40 kg block and the horizontal surface is 0.02, then find the acceleration of the system.

(1) \( \frac{8}{11} \text{ m/s}^2 \)  
(2) \( \frac{11}{8} \text{ m/s}^2 \)  
(3) \( 8 \text{ m/s}^2 \)  
(4) \( 10 \text{ m/s}^2 \)

**Sol.** Answer (1)

\[
mg - T = ma \\
T - \mu Mg = Ma \\
a = \frac{m - \mu M}{m + M}g \\
a = \frac{4 - 0.02 \times 40}{4 + 40} \times 10 \\
a = \frac{32}{44} \times 8 \text{ m/s}^2 \\
\]

Correct option (1)

2. A ball can be thrown maximum of 100 meter horizontally. The maximum height the ball can be thrown is

(1) 25 m  
(2) 50 m  
(3) 100 m  
(4) 200 m

**Sol.** Answer (2)

\[
\Rightarrow \frac{u^2}{g} = 100 \\
\Rightarrow u = \sqrt{100 \times 10} = 10\sqrt{10} \text{ m/s} \\
\]

Maximum vertical height = \( \frac{u^2}{2g} \)

\[
= \frac{(10\sqrt{10})^2}{2 \times 10} \\
= 50 \text{ m} \\
\]

3. An object starts moving with constant acceleration (a). Distance travelled by it is first 't' sec is 10m. Then the distance travelled by it is next 't' sec is

(1) 10 m  
(2) 20 m  
(3) 30 m  
(4) 40 m

**Sol.** Answer (3)

\[
u = 0 \text{ m/s} \\
V = at \\
S_1 = \frac{1}{2} at^2 \\
S_2 = at + \frac{1}{2} a(t)^2 \\
S_2 = \frac{3}{2} at^2 \\
S_2 = 30 \text{ m} \\
\]
4. A particle is released from rest from a height of $y_0$ above the ground as shown. When the particle is at a height of $y$ above the ground, its kinetic energy is $K$ then

(1) $K = mg(y_0 - y)$

(2) $K = mgy$

(3) $K = -mgy$

(4) $K = mg(y - y_0)$

**Sol.** Answer (1)

Using conservation of mechanical energy

$K - E_p = K - E_f$

$O + mgy_0 = K + mgy$

$K = mg(y_0 - y)$

5. If the height of a radio station tower is $h$ and covers the area of $A$. Then the height such that it covers the area of $4A$ is

(1) $2\sqrt{2}h$

(2) $4h$

(3) $2h$

(4) $3h$

**Sol.** Answer (2)

Range of antena $(d) = \sqrt{2Rh}$

Area covered by antena $(A) = \pi d^2$

$A_1 = \pi h_1$

$A_2 = \pi h_2$

$A = \frac{h}{4A} \Rightarrow h_2 = 4h$

6. Two infinitely long conductors carry some current and are coplanar with a distance of 8 cm between them. Magnetic field strength at the mid-point is $200\mu T$. Then:

(1) Conductors carry 6A each in opposite direction

(2) Conductors carry 3A each in same direction

(3) Conductors carry 20A each in opposite direction

(4) Conductors carry 6A each in same direction

**Sol.** Answer (3)

We know, for a straight wire $B = \frac{\mu_0 l}{2\pi d}$

Both the wire should have current in opposite direction

$B = \frac{\mu_0 l}{2\pi d}$

$B = \frac{2 \times 4 \pi \times 10^{-7} \times l}{\pi \times 8 \times 10^{-2}}$

$200 \times 10^{-6} = 10^{-5} l$

$l = 20 A$

7. Speed of light for media A and B are $2 \times 10^8$ m/s and $1.5 \times 10^8$ m/s respectively. If a light ray goes from B to A, then the phenomenon of total internal reflection happens for an angle of incidence $\theta$ such that

(1) $\theta > \sin^{-1}(4/3)$

(2) $\theta < \sin^{-1}(4/3)$

(3) $\theta > \sin^{-1}(3/4)$

(4) $\theta < \sin^{-1}(3/4)$

**Sol.** Answer (3)

Refractive index $(\mu) = \frac{c}{v}$

$\mu_A = \frac{3 \times 10^8}{2 \times 10^8} = 1.5$

$\mu_B = \frac{3 \times 10^8}{1.5 \times 10^8} = 2$

Using Snell's law,

$\mu_B \sin \theta_c = \mu_A \sin 90^\circ$

$\Rightarrow 2. \sin \theta_c = 1.5 \times 1$

$\Rightarrow \sin \theta_c = \frac{3}{4}$
8. In the circuit shown:

when a voltmeter of resistance 2000Ω is connected across 500Ω, its reading is

(1) $\frac{28}{3}$ V (2) 15 V (3) 10 V (4) 8 V

Sol. Answer (4)

$R_V$ is in parallel with 500 Ω

Resistance of the circuit is

$R = 600 \times \frac{500 \times 2000}{500 + 2000} = 600 + 400$

$R = 1000Ω$

Current through the circuit

$I = \frac{20}{1000} = \frac{1}{50}$ A

Voltage across voltmeter is

$V = I \times 400$

$V = \frac{1}{50} \times 400 = 8V$

9. A gas is expanded from $V_1$ to $V_2$ along three different processes i.e. isothermal, adiabatic and isobaric. If $W_1$, $W_2$ and $W_3$ are the works done respectively in the mentioned processes then which of the following will be the correct order

(1) $W_3 > W_1 > W_2$
(2) $W_3 > W_2 > W_1$
(3) $W_2 > W_1 > W_3$
(4) $W_1 > W_3 > W_2$

Sol. Answer (1)

Process (1) → Isothermal process
Process (2) → Adiabatic process
Area under P-V diagram represents work done by gas. So,
$W_3 > W_1 > W_2$

10. The point charges of magnitude Q each are fixed at A and B. At what distance from O (mid-point of A and B) should a charge be placed on perpendicular bisector of AB to experience maximum force

Sol. Answer (3)

$F = \frac{KQq}{\left(\frac{d^2}{4} + x^2\right)^{3/2}}$

$F_{net} = 2F \cos \theta$

$F_{net} = \frac{2KQq}{\left(\frac{d^2}{4} + x^2\right)^{3/2}}$

To find $F_{max}$

$\frac{dF_{net}}{dx} = 0$

$2KQq \left[ \left(\frac{d^2}{4} + x^2\right)^{3/2} - x \times \frac{3}{2} \left(\frac{d^2}{4} + x^2\right)^{1/2} \right] = 0$

$x = \frac{d}{2\sqrt{2}}$
11. Calculate the value of expression given below and mark the correct option for the value of expression taking into consideration significant figures.

\[
\frac{0.002858 \times 0.112}{0.5702}
\]

(1) \(5.6137 \times 10^{-4}\)
(2) \(5.613 \times 10^{-4}\)
(3) \(5.6 \times 10^{-4}\)
(4) \(5.61 \times 10^{-4}\)

Sol. Answer (4)

\[
\frac{0.002858 \times 0.112}{0.5702} = 0.000561375
\]

Rounding off to 3 significant digit

\(0.000561375 \approx 0.000561\)

12. A simple pendulum starts oscillating as per the equation \(x = A \cos(\pi t + \phi)\). What is the length of the pendulum. \((g = 10\text{m/s}^2)\)

(1) 1 m
(2) 2 m
(3) 1.5 m
(4) 3 m

Sol. Answer (1)

Given equation of SHM for simple pendulum is

\[x = A \cos(\pi t + \phi)\]

So, \(\omega = \pi\)

\[\Rightarrow \frac{2\pi}{T} = \pi\]

\[\Rightarrow T = 2\]

Also, \(T = 2\pi \sqrt{\frac{l}{g}}\)

Hence, \(2\pi \sqrt{\frac{l}{g}} = 2\)

\[\Rightarrow \frac{l}{g} = \frac{1}{(\pi)^2}\]

\[\Rightarrow l = \frac{g}{\pi^2} = 1\text{ m}\]

13. Two identical batteries (emf \(\varepsilon\) each and internal resistant \(r\) each) are connected in two configurations as shown:

If the current in \(2\Omega\) is same in both cases, then the value of \(r\) is

(1) 4 \(\Omega\)
(2) 2 \(\Omega\)
(3) 3 \(\Omega\)
(4) 5 \(\Omega\)

Sol. Answer (2)

In case A

\[I_A = \frac{2E}{2+2r}\]

In case B

\[E_{eq} = \frac{E + E}{\frac{r}{1} + \frac{r}{1}} = E\]

\[I_B = \frac{E}{2 + \frac{r}{2}}\]

Given \(I_A = I_B\)

\[\frac{E}{1+r} = \frac{2E}{4+r}\]

\[\frac{1}{1+r} = \frac{2}{4+r}\]

\[4 + r = 2 + 2r\]

\[2 = r\]
14. In the shown RC discharging circuit switch S is closed at \( t = 0 \). The circuit takes \( t_1 \) time for charge on capacitor to reduce to 1/8th of original value and takes \( t_2 \) time for charge to reduce to ½ of the original value. Then \( \frac{t_1}{t_2} \) is equal to

\[
\begin{align*}
(1) & \quad 2 \\
(2) & \quad 3 \\
(3) & \quad \sqrt{3} \\
(4) & \quad 2\sqrt{2}
\end{align*}
\]

Sol. Answer (2)

\[
Q = Q_0 e^{-\frac{t}{RC}}
\]

At \( t = t_1 \quad Q = \frac{Q_0}{8}
\]

\[
\frac{Q_0}{8} = Q_0 e^{-\frac{t_1}{RC}}
\]

\[
\frac{t_1}{RC} = \ln 8
\]

At \( t = t_2 \quad Q = \frac{Q_0}{2}
\]

\[
\frac{Q_0}{2} = Q_0 e^{-\frac{t_2}{RC}}
\]

\[
\frac{t_2}{RC} = \ln 2
\]

\[
\frac{t_1}{t_2} = \frac{\ln 8}{\ln 2} = 3
\]

15. Half-life of a radioactive element is 5 years. How much time it would take for number of radioactive nuclei to become 6.25% of original value?

(1) 20 years
(2) 30 years
(3) 40 years
(4) 15 years

Sol. Answer (1)

\[
N_0 = 5 \quad 5 \quad 5 \quad 5 = 20 \text{ years}
\]

16. A block of mass \( m \) is kept inside a box. The box is falling down with acceleration of \( g/4 \). Find the force exerted by block (\( m \)) on the surface of the box.

(1) \( \frac{3mg}{2} \)
(2) \( \frac{3mg}{4} \)
(3) \( \frac{4mg}{5} \)
(4) \( \frac{3mg}{5} \)

Sol. Answer (2)

\[
mg - N = ma
\]

\[
mg - N = \frac{mg}{4}
\]

\[
N = \frac{3mg}{4}
\]

17. Three point charges of charge \( q \) each are kept at the vertices of an equilateral triangle of side \( a \) as shown in the diagram:

The electric field at the centroid of the triangle is \( kq \frac{x}{a^2} \). Find \( x \).

Sol. Answer (0.00)

\[
|E_1| = |E_2| = |E_3|
\]
Angle between \( E_2 + E_3 \) and \( E_1 \) is \( 180^\circ \) and they are equal in magnitude, hence resultant is zero

\[
E_2 + E_3 = -E_1
\]

\[
E_1 + E_2 + E_3 = 0
\]

So, Net field at centroid is zero.

18. Moment of inertia of a uniform rod about an axis perpendicular to it and passing from COM is \( I_1 \). The rod is bent in the shape of ring, then the moment of inertia of ring about axis is \( I_2 \) then

\[
\frac{I_1}{I_2} = \frac{mR^2}{\frac{mL^2}{12}}
\]

The value of \( n \) is:

Sol. Answer (01.00)

For rod (about an axis passing through COM)

\[
I_1 = \frac{mL^2}{12}
\]

\[L = 2\pi R \text{ (rod is bent to form thin ring)}\]

For ring (about an axis passing through COM and perpendicular to plane of ring)

\[
I_2 = mR^2
\]

\[
\frac{I_1}{I_2} = \frac{L^2}{12R^2} = \left(\frac{1}{12}\right)\left(\frac{\pi^2}{3}\right) = \frac{mR^2}{3}
\]

\[n = 1\]

19. A satellite revolving around earth has a time period of 7 hours. If the speed of the satellite becomes 3 times, the new time period (in hours) is \( x \). Find \( x \).

Sol. Answer (07.00)

Orbital velocity of satellite \( v_0 = \sqrt{\frac{GM}{r}} \)

\[
\frac{v_1}{v_2} = \sqrt{\frac{r_2}{r_1}}
\]

\[
\Rightarrow \frac{v_1}{3v_1} = \sqrt{\frac{r_2}{r_1}}
\]

\[\Rightarrow \frac{r_1}{r_2} = \frac{9}{1}\]

Time period of revolution \((T) \propto r^3\)

So, \( T_1 = \left(\frac{r_1}{r_2}\right)^3 \)

\[\Rightarrow \frac{T_1}{T_2} = \left(\frac{9}{1}\right)^3 = 7^3 = 343 \]

\[\Rightarrow T_2 = \frac{7}{343} \text{ hour}\]

20. If the units of length and force increased 4 times, the unit of energy will become \( n \) times. The value of \( n \) is ____.

Sol. Answer (16.00)

Units of energy = units of force \( x \) units of length

If units of force and length are increased four times, units of energy would be increased by 16 times.

21. Electric potential in the function of \( x \) is given as \( V = 3x^2 \), then electric field at \((1, 0, 4)\) is:

(1) 6 unit in positive \( x \) direction
(2) 300 unit in negative \( x \) direction
(3) 6 unit in negative \( x \) direction
(4) 30 unit in positive \( x \) direction

Sol. Answer (3)

\[
E_x = \frac{-dv}{dx} = -6x
\]

At \((1, 0, 4)\)

\[E_x = -6\]

\[E_y = E_z = 0\]

22. In Young's double slit experiment the separation between the slits is 1 mm. If the screen is shifted by \( 5 \times 10^{-2} \) m, fringe width changes by \( 3 \times 10^{-3} \) cm. The wavelength of light used is \( 10^x \) nm. Find \( x \).

Sol. Answer (60.00)

\[
\beta = \frac{\lambda D}{d}
\]

\[\beta_2 - \beta_1 = \frac{\lambda}{d}(D_2 - D_1)\]

\[3 \times 10^{-5} = \frac{\lambda}{10^{-3}}(6 \times 10^{-2})\]

\[
\lambda = 3 \times 10^{-8} \quad \text{and} \quad 5 \times 10^{-2} = 0.6 \times 10^{-6}
\]

\[\lambda = 600 \text{ nm}\]
23. Electric field is given by

\[ E = 200 \left[ \sin(6 \times 10^{15} t) + \sin(9 \times 10^{15} t) \right] \]

It is incident on a metal surface of work function 2.5 eV. Find the maximum kinetic energy of emitted electrons:

1. 3.4 eV
2. 2.5 eV
3. 3.8 eV
4. 4 eV

Sol. Answer (1)

\[ K.E_{max} = E - \phi \]

\[ = \frac{h\omega}{2\pi} - \phi \]

\[ = 4.14 \times 10^{-15} \times 9 \times 10^{15} \times 2 \times 3.14 - 2.5 = 5.9 - 2.5 = 3.4 \text{ eV} \]

24. In the decay process

\[ ^{182}_{74}D_{\alpha} \rightarrow ^{178}_{72}D_{1 \beta} \rightarrow ^{178}_{72}D_{2 \alpha} \rightarrow ^{174}_{71}D_{3 \gamma} \rightarrow ^{174}_{71}D_{4} \]

Find the atomic number and mass number of element D:

1. 174, 71
2. 176, 72
3. 174, 70
4. 176, 71

Sol. Answer (1)

25. Time taken by a capacitor to reduce its energy by half is \( t_1 \) and time taken by the same capacitor to reduce its charge by \( 1/8^n \) is \( t_2 \). The value of \( \frac{t_1}{t_2} \) will be

1. 1/3
2. 1/6
3. 1/2
4. 1/4

Sol. Answer (2)

\[ q = Qe^{-\frac{t}{t}} \]

\[ U = \frac{q^2}{2C} \]

26. Verneir constant of verneir scale is 0.1 mm. On measuring the diameter of a shaft, main scale reading is 1.7 cm. If the fifth division of Vernier scale coincides with main scale & zero error is −0.05 cm. Then the diameter of shaft is:

1. 1.80 cm
2. 2.80 cm
3. 4.80 cm
4. 6.80 cm

Sol. Answer (1)

Reading = MSR + L.C × V

Correction = − zero error = 0.05 cm

Reading = 1.7 + 0.1 × 10−1 (5) + 0.05

= 1.7 + 0.05 + 0.05 \Rightarrow 1.80 cm

27. In resonance tube first resonance is obtained at 20 cm, then third resonance length will be: (frequency of source = 400 Hz, Speed of sound in air = 336 m/s)

1. 60 cm
2. 104 cm
3. 60 cm
4. 100 cm

Sol. Answer (2)

Wavelength of wave \[ \lambda = \frac{V}{f} = \frac{336}{400} = 84 \text{ cm} \]

At first resonance

\[ \frac{\lambda}{4} = \ell + e \Rightarrow \frac{84}{4} = 20 + e \]

\[ \Rightarrow e = 1 \]

So third resonance length

\[ \frac{\lambda}{4} = \ell_2 + 1 \]

\[ 5(\ell_2 + 1) = \ell_2 + 1 \]

\[ \ell_2 = 104 \text{ cm} \]