JEE Main September 2020

Question Paper With Text Solution

6 September| Shift-1

PHYSICS

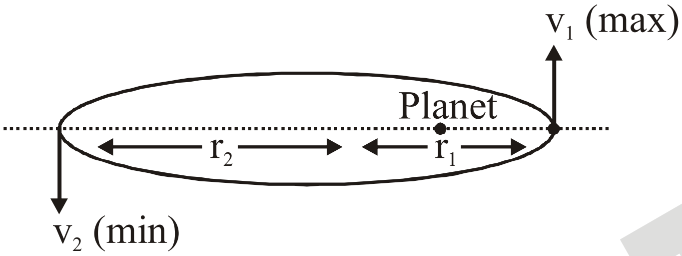
JEE MAIN SEP 2020 | 6 Sep. SHIFT-1

1. A satellite is in an elliptical orbit around a planet P. It is observed that the velocity of the satellite when it is farthest from the planet is 6 times less than that when it is closest to the planet. The ratio of distances between the satellite and the planet at closest and farthest points is :

(1) 1 : 3 (2) 1 : 2 (3) 1 : 6 (4) 3 : 4

Ans (3)

Sol.



given $\frac{v_2}{v_1} = \frac{1}{6}$

By angular momentum conservation

$m\, v_1 r_1 = m v_2\, r_2$

$\frac{r_1}{r_2} = \frac{v_2}{v_1}$

2. A point like object is placed at a distance of 1 m in front of a convex lens of focal length 0.5 m. A plane mirror is placed at a distance of 2 m behind the lens. The position and nature of the final image formed by the system is :

(1) 2.6 m from the mirror, virtual (2) 1 m from the mirror, real

(3) 1 m from the mirror, virtual (4) 2.6 m from the mirror, real

Ans (4)

Sol.

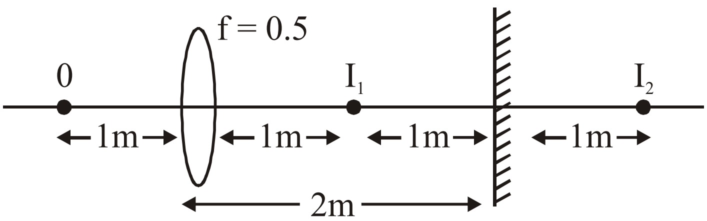


Image formed by lens

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

$$\frac{1}{v}-\frac{1}{(-1)}=\frac{1}{0.5}$$

v = 1 m
Now taking I_2 as object for lens
u = – 3m
v = 0.6
distance of final image from mirror = 2.6 m
Real image

3. An AC circuit has R = 100 Ω, C = 2 μF and L = 80 mH, connected in series. The quality factor of the circuit is :

(1) 400 (2) 0.5 (3) 2 (4) 20

Ans (3)

Sol. $Q=\frac{1}{R}\sqrt{\frac{L}{C}}$

$$Q=\frac{1}{100}\sqrt{\frac{80\times10^{-3}}{2\times10^{-6}}}$$

Q = 2

4. An object of mass m is suspended at the end of a massless wire of length L and area of cross–section, A. Young modulus of the material of the wire is Y. If the mass is pulled down slightly its frequency of oscillation along the vertical direction is :

(1) $f=\frac{1}{2\pi}\sqrt{\frac{mA}{YL}}$ (2) $f=\frac{1}{2\pi}\sqrt{\frac{mL}{YA}}$ (3) $f=\frac{1}{2\pi}\sqrt{\frac{YL}{mA}}$ (4) $f=\frac{1}{2\pi}\sqrt{\frac{YA}{mL}}$

Ans (4)

Sol. $Y=\frac{F.L}{A.\Delta L}$

$$F=\left(\frac{YA}{L}\right).\Delta L$$

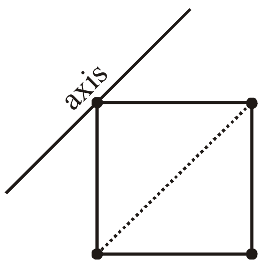
By comparing with F = –Kx

$$K=\frac{YA}{L}=m\omega^2$$

$\omega = \sqrt{\dfrac{YA}{mL}}$

$f = \dfrac{1}{2\pi}\sqrt{\dfrac{YA}{mL}}$

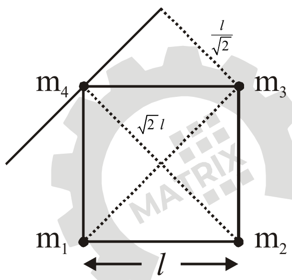
5. Four point masses, each of mass m, are fixed at the corners of a square of side l. The square is rotating with angular frequency ω, about an axis passing through one of the corners of the square and parallel to its diagonal, as shown in the figure. The angular momentum of the square about this axis is :



(1) $3\,ml^2\omega$ (2) $ml^2\omega$ (3) $2\,ml^2\omega$ (4) $4\,ml^2\omega$

Ans (1)

Sol.



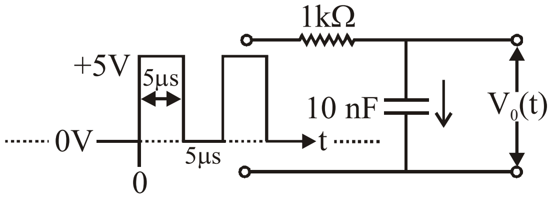
Moment of inertia about given axis

$$I = m\left(\frac{l}{\sqrt{2}}\right)^2 + m\left(\sqrt{2}l\right)^2 + m\left(\frac{l}{\sqrt{2}}\right)^2 + m(0)^2$$

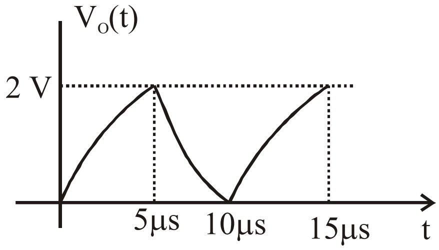
$I = 3ml^2$

Angular momentum $L = I\omega = 3ml^2\omega$

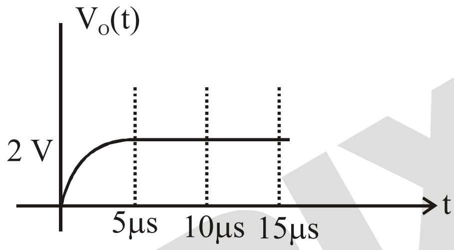
6. For the given input voltage waveform $V_{in}(t)$, the output voltage waveform $V_0(t)$, across the capacitor is correctly depicted by :



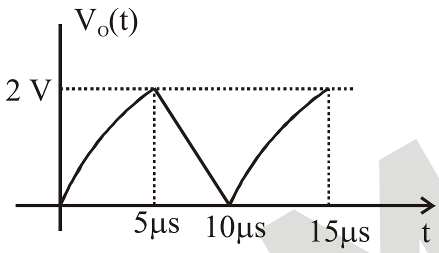
(1)



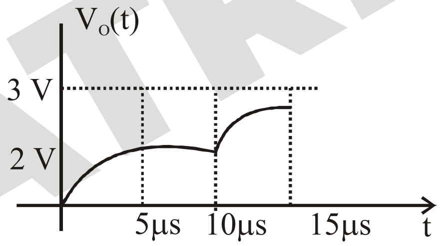
(2)



(3)



(4)



Ans (4)

Sol. From t = 0 to t = 5μs, capacitor is charging.

$\tau = RC = 10^{-5}$

$v = v_0(1 - e^{-\frac{t}{\tau}})$

at t = 0, v = 0 and t = 5μs, $v = 5\left(1 - e^{\frac{-5\times10^{-6}}{10^{-5}}}\right) = 1.96 \approx 2v$

from t = 5μs to 10μs, $v_{input} = 0$, means capacitor is discharging

$v = 2e^{-}\frac{t}{t}$

after time interval of 5μs at t = 10μs

$v = 2e^{-0.5} = 1.21\,\text{volt}$

from t = 10μs to 15μs, vinput = 5v, charging

$v = 5 - 3.79e^{-\frac{t}{\tau}}$

at t = 15μs, $v = 5 - 3.79e^{-0.5}$ = 2.79 ≈3 volt

So most appropriate option is 4.

7. An electron, a doubly ionized helium ion (He^{++}) and a proton are having the same kinetic energy. The relation between their respective de–Broglie wavelengths λ_e, λ_{He} + + and λ_p is :

(1) $\lambda_e > \lambda_p > \lambda_{He}++$ (2) $\lambda_e > \lambda_{He}++ > \lambda_p$

(3) $\lambda_e < \lambda_p < \lambda_{He}++$ (4) $\lambda_e < \lambda_{He}++ = \lambda_p$

Ans (1)

Sol. $\lambda = \dfrac{h}{\sqrt{2m(KE)}}$

$m_{He^{++}} > m_p > m_e$

$\lambda_e > \lambda_p > \lambda He^{++}$

8. A clock has a continuously moving second's hand of 0.1 m length. The average acceleration of the tip of the hand (in units of ms^{-2}) is of the order of :

(1) 10^{-2} (2) 10^{-1} (3) 10^{-4} (4) 10^{-3}

Ans (4)

Sol. Angular speed of second's hand $\omega = \dfrac{2\pi}{60} = \dfrac{\pi}{30}\,\text{rad}/s^2$

Acceleration = $\omega^2 r = \dfrac{\pi^2}{900} \times 0.1 \approx 10^{-3}$

9. Molecules of an ideal gas are known to have three translational degrees of freedom and two rotational degrees of freedom. The gas is maintained at a temperature of T.

The total internal energy, U of a mole of this gas, and the value of $\gamma\left(=\dfrac{C_p}{C_v}\right)$ are given, respectively, by :

(1) $U = \dfrac{5}{2}RT \text{ and } \gamma = \dfrac{7}{5}$ (2) $U = 5RT \text{ and } \gamma = \dfrac{6}{5}$

(3) $U = \dfrac{5}{2}RT \text{ and } \gamma = \dfrac{6}{5}$ (4) $U = 5RT \text{ and } \gamma = \dfrac{7}{5}$

Ans (1)

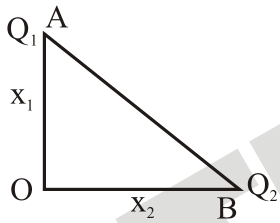
Sol. $\gamma = 1 + \frac{2}{f}$, $U = \frac{f}{2}nRT$

$n = 1$

$U = \frac{f}{2}RT$

when $\gamma = \frac{7}{5}$, $f = 5, U = \frac{5}{2}RT$

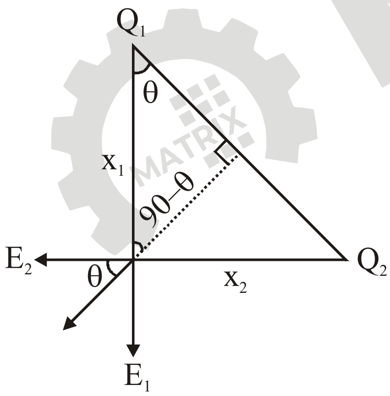
10. Charges Q_1 and Q_2 are at points A and B of a right angle triangle OAB(see figure). The resultant electric field at point O is perpendicular to the hypotenuse, then Q_1/Q_2 is proportional to :



(1) $\frac{x_1^3}{x_2^3}$ (2) $\frac{x_2}{x_1}$ (3) $\frac{x_1}{x_2}$ (4) $\frac{x_1^2}{x_2^2}$

Ans (3)

Sol.



$E_1 = \frac{KQ_1}{x_1^2}, E_2 = \frac{KQ_2}{x_2^2}$

$\tan\theta = \frac{E_1}{E_2} = \frac{x_2}{x_1}$

$\frac{Q_1}{Q_2} = \frac{x_1}{x_2}$

11. A screw gauge has 50 divisions on its circular scale. The circular scale is 4 units ahead of the pitch scale marking, prior to use. Upon one complete rotation of the circular scale, a displacement of 0.5 mm is noticed on the pitch scale. The nature of zero error involved, and the least count of the screw gauge, are respectively :

(1) Negative, 2μm (2) Positive, 0.1μm

(3) Positive, 0.1mm (4) Positive, 10μm

Ans (4)

Sol. Least -Count = $\frac{\text{Pitch}}{\text{no. of divisions on circular scale}} = \frac{0.5\text{mm}}{50} = 10\mu\text{m}$

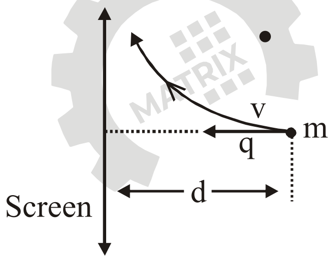
Zero error is positive in nature.

12. A particle of charge q and mass m is moving with a velocity $-v\hat{i}(v \neq 0)$ towards a large screen placed in the Y–Z plane at a distance d. If there is a magnetic field $\vec{B} = B_0\hat{k}$, the minimum value of v for which the particle will not hit the screen is :

(1) $\frac{2qdB_0}{m}$ (2) $\frac{qdB_0}{3m}$ (3) $\frac{qdB_0}{m}$ (4) $\frac{qdB_0}{2m}$

Ans (3)

Sol.

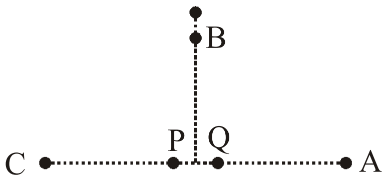


To not to hit the screen radius of circular path should be less than d.

$$r = \frac{mv}{qB_0} < d$$

$$V_{min} = \frac{qB_0 d}{mv}$$

13. In the figure below, P and Q are two equally intense coherent sources emitting radiation of wavelength 20 m. The separation between P and Q is 5 m and the phase of P is ahead of that of Q by 90º. A, B and C are three distinct points of observation, each equidistant from the midpoint of PQ. The intensities of radiation at A, B, C will be in the ratio :



(1) 0 : 1 : 4 (2) 4 : 1 : 0 (3) 2 : 1 : 0 (4) 0 : 1 : 2

Ans (3)

Sol. At point A

path difference = 5m

Phase difference due to path difference = $\frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{20}\times 5 = \frac{\pi}{2}$

Total phase difference = $\frac{\pi}{2}-\frac{\pi}{2}$ (As P is ahead of Q by $\frac{\pi}{2}$)

$\Delta\phi = 0$

$I_A = 4I_0 \cos^2\left(\frac{\Delta\phi}{2}\right) = 4I_0$

At C

Phase difference due to path difference = $\frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{20}\times 5 = \frac{\pi}{2}$

Total phase difference = $\Delta\phi = \frac{\pi}{2}+\frac{\pi}{2} = \pi$ (As P is ahead of Q by $\frac{\pi}{2}$)

$I_C = 4I_0 \cos^2\left(\frac{\Delta\phi}{2}\right) = 0$

At point B

Total phase difference $\Delta\phi = \frac{\pi}{2}$

$I_B = 2I_0$

$I_A : I_B : I_C = 2 : 1 : 0$

14. If the potential energy between two molecules is given by $U = -\frac{A}{r^6} + \frac{B}{r^{12}}$, then at equilibrium, separation between molecules, and the potential energy are :

(1) $\left(\frac{2B}{A}\right)^{1/6}, -\frac{A^2}{2B}$

(2) $\left(\frac{B}{A}\right)^{1/6}, 0$

(3) $\left(\frac{2B}{A}\right)^{1/6}, -\frac{A^2}{4B}$

(4) $\left(\frac{B}{2A}\right)^{1/6}, -\frac{A^2}{2B}$

Ans (3)

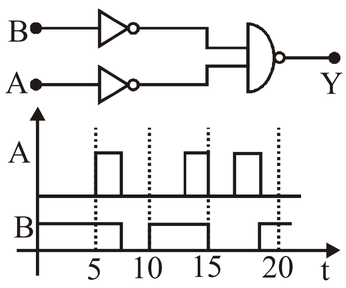
Sol. $U = \left[\frac{-A}{r^6} + \frac{B}{r^{12}}\right]$

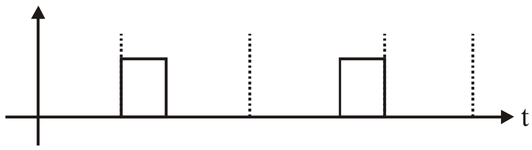
$F = \frac{-dU}{dr} = -\left[\frac{6A}{r^7} - \frac{12B}{r^{13}}\right]$

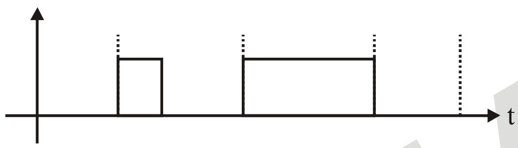
at equilibrium $F = 0 \Rightarrow r = \left(\frac{2B}{A}\right)^{\frac{1}{6}}$

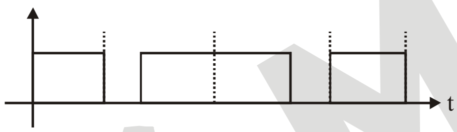
$U_{\text{at } r=\left(\frac{2B}{A}\right)^{\frac{1}{6}}} = \frac{-A}{\left(\frac{2B}{A}\right)} + \frac{B}{\left(\frac{2B}{A}\right)^2} = \frac{-A^2}{4B}$

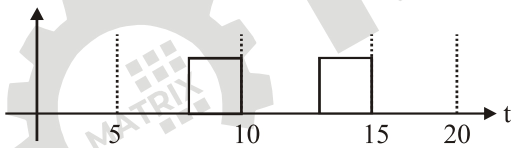
15. Identify the correct output signal Y in the given combination of gates (as shown) for the given inputs A and B.



(1) 

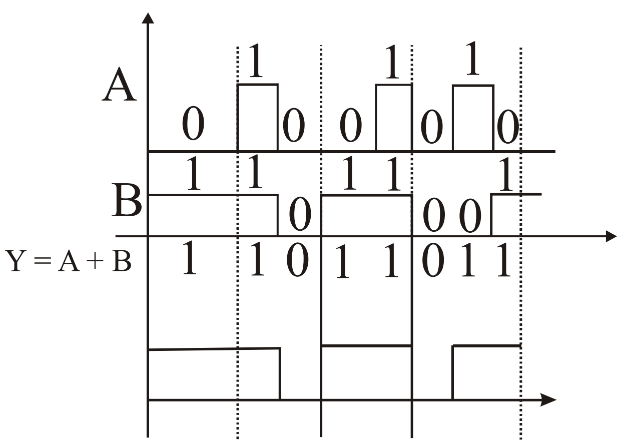
(2) 

(3) 

(4) 

Ans ()

Sol. $Y = \overline{(\overline{A}.\overline{B})} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$



16. You are given that Mass of ${}_3^7\text{Li}$ = 7.0160 u,

Mass of ${}_2^4\text{He}$ = 4.0026 u

and Mass of ${}_1^1\text{He}$ = 1.0079 u.

When 20 g of ${}_3^7\text{Li}$ is converted into ${}_2^4\text{He}$ by proton capture, the energy liberated, (in kWh), is :

[Mass of nucleon = 1 GeV/c^2]

(1) 1.33×10^6 (2) 4.5×10^5 (3) 6.82×10^5 (4) 8×10^6

Ans (1)

Sol. ${}_3^7\text{Li} + {}_1^1\text{H} \longrightarrow 2\,{}_2^4\text{He}$

$\Delta m = (7.0160 + 1.0079) - 2(4.0026)\,u$

$\Delta m = 0.0187\,u$

Energy released by 20 g Li $= \dfrac{\Delta mc^2}{m_{Li}} \times 20\text{gm}$

$$E = \left(\frac{0.187 \times 1.6 \times 10^{-19} \times 10^9}{7.016 \times 1.6 \times 10^{-24}\,\text{gm}} \times 20\text{gm}\right)\text{Joule}$$

$E = 0.05 \times 10^{14}\,J \approx 1.4 \times 10^6$ kwh $\approx 1.33 \times 10^6$ kwh

[1J = 2.778×10^{-7} kwh]

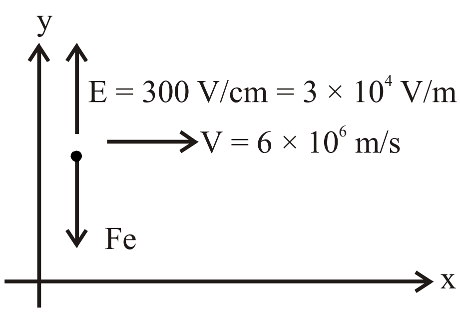
17. An electron is moving along +x direction with a velocity of 6×10^6 ms^{-1}. It enters a region of uniform electric field of 300 V/cm pointing along +y direction. The magnitude and direction of the magnetic field set up in this region such that the electron keeps moving along the x direction will be :

(1) 3×10^{-4} T, along –z direction (2) 5×10^{-3} T, along –z direction

(3) 5×10^{-3} T, along +z direction (4) 5×10^{-4} T, along +z direction

Ans (3)

Sol.



Electrostatic force will act in –ve y direction

$F_e = qE = eE = \left(3\times10^4 e\right)N$

direction of magnetic field should be in such a way that magnetic force has to be in +y direction.
So magnetic field will be in (+z) direction

$F_e = F_m$

$\left(3\times10^4\right)e = eVB$

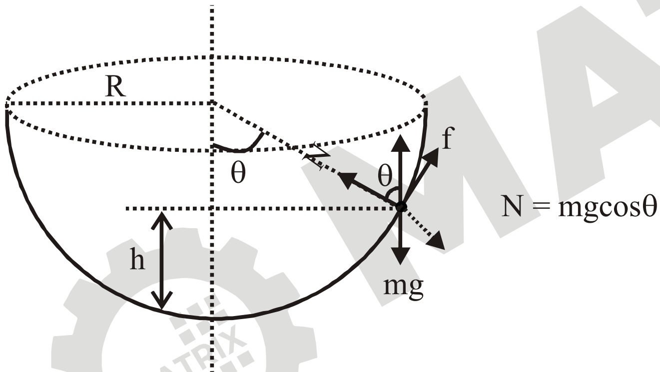
$B = \frac{3\times10^4}{6\times10^6} = 5\times10^{-3}T$ (direction in +z)

18. An insect is at the bottom of a hemispherical ditch of radius 1m. It crawls up the ditch but starts slipping after it is at height h from the bottom. If the coefficient of friction between the ground and the insect is 0.75, then h is : (g = 10 ms^{-2})

(1) 0.45 m (2) 0.80 m (3) 0.20 m (4) 0.60 m

Ans (3)

Sol.



Slipping of insect will start when $mg\sin\theta > f_{max}$

$f_{max} = \mu N$

$mg\sin\theta \geq \mu mg\cos\theta$

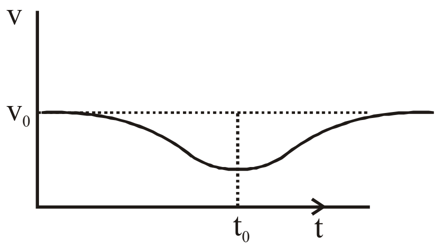
$\tan\theta = \frac{3}{4}$

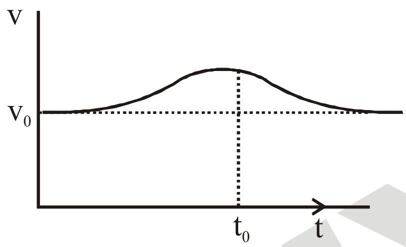
$h = R - R\cos\theta$

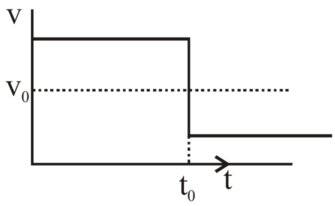
$h = 1 - 1\frac{4}{5} = 0.20m$

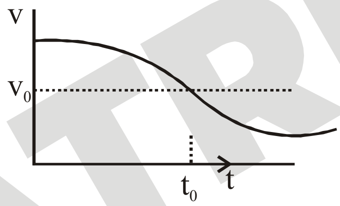
19. A sound source S is moving along a straight track with speed v, and is emitting sound of requency v_0 (see figure). An observer is standing at a finite distance, at the point O, from the track. The time variation of frequency heard by the observer is best represented by :

(t_0 represents the instant when the distance between the source and observer is minimum)

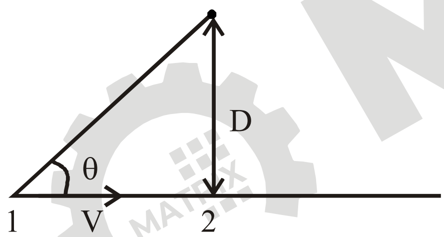
(1)


(2)


(3)


(4)


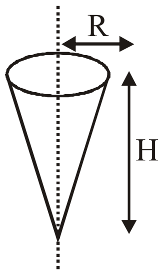
Ans (4)

Sol.


$$\upsilon_{observed} = \left(\frac{V_{sound}}{V_{sound} - V\cos\theta}\right)\upsilon_0$$

When source moves from (1) to (2) , θ increases, so $\cos\theta$ decreases, so $\upsilon_{observed}$ will decreased. After point (2) again $\upsilon_{observed}$ will decrease as source is moving away from observer.
So correct answer is option (4).

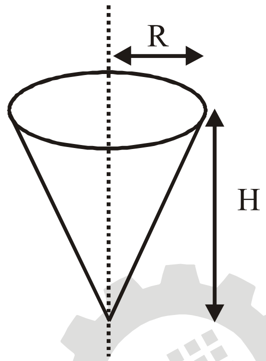
20. Shown in the figure is a hollow icecream cone(it is open at the rop). If its mass is M, radius of its top, R and height, H, then its moment of inertia about its axis is :



(1) $\frac{M\left(R^2+H^2\right)}{4}$ (2) $\frac{MR^2}{3}$ (3) $\frac{MH^2}{3}$ (4) $\frac{MR^2}{2}$

Ans (4)

Sol.



Moment of inertia of hollow cone about axis = $\frac{MR^2}{2}$

21. The density of a solid metal sphere is determined by measuring its mass and its diameter. The maximum error in the density of the sphere is $\left(\frac{x}{100}\right)$%. If the relative errors in measuring the mass and the diameter are 6.0% and 1.5% respectively, the value of x is ________.

Question Type : SA

Question ID : 40503611476

Ans 1050

Sol. $\rho = \frac{M}{V}$

M = mass
V = volume
d = diameter

$$\rho = \frac{M}{\frac{4}{3}\pi\left(\frac{d}{2}\right)^3} = \frac{6M}{\pi d^3}$$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + 3\frac{\Delta d}{d}$$

$$\frac{\Delta\rho}{\rho}\% = (6+3\times1.5)\% = 10.5\ \% = \left(\frac{x}{100}\right)\%$$

x = 1050

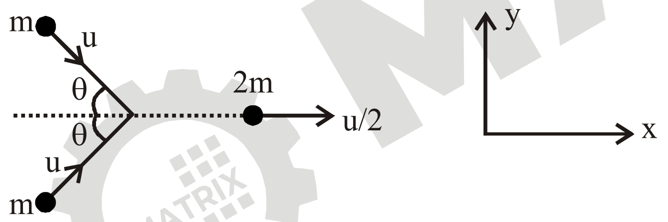
22. Two bodies of the same mass are moving with the same speed, but in different directions in a plane. They have a completely inelastic collision and move together thereafter with a final speed which is half of their initial speed. the angle between the initial velocities of the two bodies (in degree) is ______.

Question Type : SA

Question ID : 40503611477

Ans 120

Sol.



By momentum conservation along x-direction

$$2mu\cos\theta = \frac{2mu}{2}$$

$$\cos\theta = \frac{1}{2}$$

$$\theta = 60^o$$

angle between initial velocites = $2\theta = 120^o$

23. Suppose that intensity of a laser is $\left(\frac{315}{\pi}\right)$ W/m^2. The rms electric field, in units of V/m associated with this source is close to the nearest integer is ______.
($\in_0 = 8.86 \times 10^{-12}$ C_2Nm^{-2}; $c = 3 \times 10^8$ ms^{-1})
Question Type : SA

Question ID : 40503611480

Ans 194

Sol. $I = \in_0 E_{rms}^2 C$

$$E_{rms} = \sqrt{\frac{I}{\in_0 C}}$$

$E_{rms} \approx 194$

24. Initially a gas of diatomic molecules is contained in a cylinder of volume V_1 at a pressure P_1 and temperature 250 K. Assuming that 25% of the molecules get dissociated causing a change in number of moles. the pressure of the resulting gas at temperature 2000 K, when contained in a volume $2V_1$ is given by P_2. The ratio P_2/P_1 is _______.

Question Type : SA

Question ID : 40503611480

Ans 5

Sol.

P_1, V_1
$T_1 = 250K,$
Number of moles = n

(1)

$V_2 = 2V_1, T = 2000\,K$
Number of moles = n_2
P_2

(2)

In case 2

When 0.25 n moles of diatomic gas change into monoatomic gas, then number of moles of mono atomic gas = $(0.25 \times 2)n = 0.5$ n

Remaining number of moles of diatomic gas = 0.75n

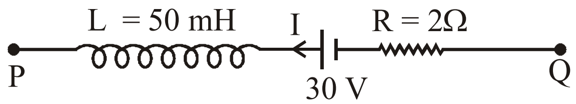
Ideal gas equation in case (1) $P_1V_1 = nR \times 250$ .....(1)

Ideal gas equation in case (2) $P_2(2V_1) = (0.5 + 0.75)\, nR \times 2000$ ....(2)

from (1) and (2)

$$\frac{P_2}{P_1} = 5$$

25. A part of a complete circuit is shown in the figure. At some instant, the value of current I is 1 A and it is decreasing at a rate of 10^2 A s^{-1}. The value of the potential difference $V_P - V_Q$, (in volts) at instant, is ______.



Question Type : SA

Question ID : 40503611479

Ans 33

Sol. $$V_P - L\frac{di}{dt} - 30 + 2\times1 = V_Q$$

$$V_P - \left(50\times10^{-3}\right)(10)^2 - 28 = V_Q$$

$$V_P - V_Q = 33 \text{ volt}$$