8. Two electromagnetic waves are moving in free space whose electric field vectors are given by $\vec{E}_1 = E_0\hat{j}\cos(kx - \omega t)$ & $\vec{E}_2 = E_0\hat{k}\cos(ky - \omega t)$. A charge q is moving with velocity $\vec{v} = 0.8\, c\hat{j}$. Find the net Lorentz force on this charge at $t = 0$ and when it is at origin.

A) $qE_0(0.4\hat{i} + 0.2\hat{j} + 0.2\hat{k})$
B) $qE_0(0.8\hat{i} + \hat{j} + 0.2\hat{k})$
C) $qE_0(0.6\hat{i} + \hat{j} + 0.2\hat{k})$
D) $qE_0(0.8\hat{i} + \hat{j} + \hat{k})$

Ans. B

Sol. Magnetic field vectors associated with this electromagnetic wave are give by

$\vec{B}_1 = \frac{E_0}{c}\,\hat{k}\cos(kx - \omega t)$ & $\vec{B}_2 = \frac{E_0}{c}\,\hat{\imath}\cos(ky - \omega t)$

$\vec{F} = q\vec{E} + q(\vec{V} \times \vec{B}) = q(\vec{E}_1 + \vec{E}_2) + q\left(\vec{V} \times (\vec{B}_1 + \vec{B}_2)\right)$

By putting the value of $\vec{E}_1, \vec{E}_2, \vec{B}_1$ & $\vec{B}_2$

The net Lorentz force on the charged particle is

$\vec{F} = qE_0[0.8\cos(kx - \omega t)\,\hat{\imath} + \cos(kx - \omega t)\,\hat{\jmath} + 0.2\cos(ky - \omega t)\,\hat{k}]$

At $t = 0$ and at $x = y = 0$

$\vec{F} = qE_0[0.8\hat{\imath} + \hat{\jmath} + 0.2\hat{k}]$

9. Two ideal di-atomic gases A and B. A is rigid, B has an extra degree of freedom due to vibration. Mass of A is m and mass of B is $\frac{m}{4}$. The ratio of molar specific heat of A to B at constant volume is:

A) $\frac{7}{9}$
B) $\frac{5}{9}$
C) $\frac{5}{11}$
D) $\frac{5}{7}$

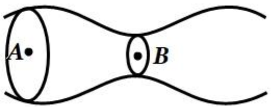
Ans. D

Sol. Molar heat capacity of A at constant volume $= \frac{5R}{2}$

Molar heat capacity of B at constant volume $= \frac{7R}{2}$

Dividing both $\frac{(C_v)_A}{(C_v)_B} = \frac{5}{7}$

10. An ideal liquid (water) flowing through a tube of non-uniform cross section area at A and B are $40\ cm^2$ and $20\ cm^2$ respectively. If pressure difference between A & B is $700\ N/m^2$ then volume flow rate is:



A) $2732\ cm^3/s$
B) $2142\ cm^3/s$
C) $1832\ cm^3/s$
D) $3218\ cm^3/s$

Ans. A

Sol. Using equation of continuity,

$40\ V_A = 20\ V_B \Rightarrow 2V_A = V_B$

Using Bernoullies equation

$P_A + \frac{1}{2}\rho V_A^2 = P_B + \frac{1}{2}\rho V_B^2$

$\Rightarrow P_A - P_B = \frac{1}{2}\rho(V_B^2 - V_A^2)$

$\Rightarrow \Delta P = \frac{1}{2}1000\left(V_B^2 - \frac{V_B^2}{4}\right)$

$\Rightarrow \Delta P = 500 \times \frac{3V_B^2}{4}$

$\Rightarrow V_B = \sqrt{\frac{(\Delta P) \times 4}{1500}} = \sqrt{\frac{(700) \times 4}{1500}}\ m/s$

Volume flow rate $= 20 \times 100 \times V_B = 2732\ cm^3/s$

11. A screw gauge advances by $3\ mm$ in 6 rotations. There are 50 divisions on circular scale. Find least count of screw gauge?

A) $0.002\ cm$
B) $0.001\ cm$
C) $0.01\ cm$
D) $0.02\ cm$

Ans. B

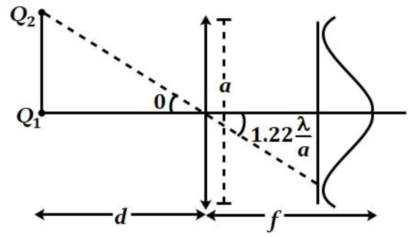
Sol. Pitch $= \frac{3}{6} = 0.5\ mm$

L.C. $= \frac{0.5\ mm}{50} = \frac{1}{100}mm = 0.01\ mm = 0.001\ cm$

12. A telescope of aperture diameter 5 m is used to observe the moon from the earth. Distance between the moon and earth is 4×10^5 km. Determine the minimum distance between two points on the moon's surface which can be resolved using this telescope. (Wave length of light is 5893 Å.

A) 60 m B) 20 m C) 600 m D) 200 m

Ans. A



Sol. $\theta = 1.22\frac{\lambda}{a}$

Distance $= O_1O_2 = d\theta$

$= 1.22\frac{\lambda}{a}d$

Distance $= O_1O_2 = \frac{1.22 \times 5893 \times 10^{-10} \times 4 \times 10^8}{5} \approx 57.5\ m$

∴ answer from option = 60 m (minimum distance).

13. A particle of mass m is revolving around a planet in a circular orbit of radius R. At the instant the particle has velocity $\vec{v}$, another particle of mass $\frac{m}{2}$ moving at velocity $\frac{\vec{v}}{2}$ collides perfectly in-elastically with the first particle. The new path of the combined body will take is

A) Circular B) Elliptical

C) Straight line D) Fall directly below on the ground

Ans. B

Sol. Conserving momentum:

$\frac{m}{2}\frac{v}{2} + mv = \left(m + \frac{m}{2}\right)v_f$

$v_f = \frac{5mV}{4 \times \frac{3m}{2}} = \frac{5V}{6}$

$v_f < v_{orb}\ (= v)$ thus the combined mass will go on to an elliptical bath.

14. Two particle of same mass 'm' moving with velocities $\vec{v}_1 = v\hat{\imath}$ and $\vec{v}_2 = \frac{v}{2}\hat{\imath} + \frac{v}{2}\hat{\jmath}$ collide in-elastically. Find the loss in kinetic energy.

A) $\frac{mv^2}{8}$ B) $\frac{5mv^2}{8}$ C) $\frac{mv^2}{4}$ D) $\frac{3mv^2}{8}$

Ans. A

Sol. Conserving momentum

$mv\,\hat{\imath} + m\left(\frac{v}{2}\hat{\imath} + \frac{v}{2}\hat{\jmath}\right) = 2m(v_1\hat{\imath} + v_2\,\hat{\jmath})$

On solving

$v_2 = \frac{3v}{4}$ and $v_2 = \frac{v}{4}$

Change in K.E.

$\left[\frac{1}{2}mv^2 + \frac{1}{2}m\left(\frac{v}{2}\sqrt{2}\right)^2\right] - \left[\frac{1}{2}(2m)\left(\frac{9v^2}{16} + \frac{v^2}{16}\right)\right]$

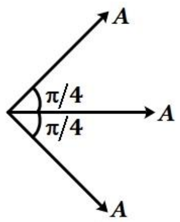
$= \frac{3mv^2}{4} - \frac{5mv^2}{8} = \frac{mv^2}{8}$

15. Three waves of same intensity (I_0) having initial phases $0, \frac{\pi}{4}, -\frac{\pi}{4}$ rad respectively interfere at a point. Find the resultant intensity.

A) I_0 B) 0 C) 5.8 I_0 D) 0.2 I_0

Ans. C

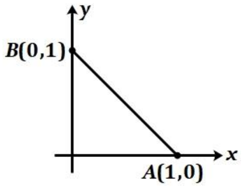
Sol. $A_{\text{res}} = (\sqrt{2} + 1)A$



$I_{\text{res}} = (\sqrt{2} + 1)^2 I_0$

$= (3 + 2\sqrt{2})I_0 = 5.8\ I_0$

16. Particle moves from point A to point B along the line shown in figure under the action of force. $\vec{F} = -x\hat{i} + y\hat{j}$. Determine the work done on the particle by $\vec{F}$ in moving the particle from point A to point B.



A) $1J$ B) $\frac{1}{2}J$ C) $2J$ D) $3J$

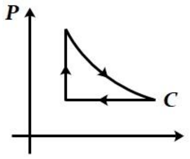
Ans. A

Sol. $W = \int \vec{F} \cdot d\vec{s}$

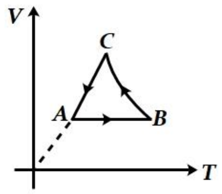
$$= (-x\hat{i} + y\hat{j}) \cdot (dx\hat{i} + dy\hat{j}) = \int_1^0 -xdx + \int_1^0 ydy$$

$$= -\frac{x^2}{2}\bigg|_1^0 + \frac{y^2}{2}\bigg|_1^0 = \left(0 + \frac{1}{2}\right) + \left(\frac{1}{2}\right) = 1J$$

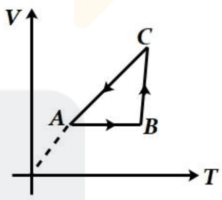
17. For the given P-V graph for an ideal gas, chose the correct V-T graph. Process BC is adiabatic



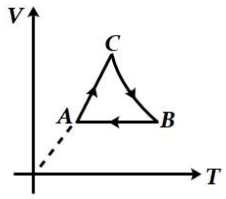
A)



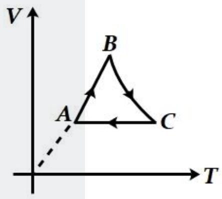
B)



C)



D)



Ans. A

Sol. For process A-B ; Volume is constant ;

$PV = nRT$; as P increases ; T increases

For process B-C ;

$PV^{\gamma} =$ Constant

$\Rightarrow TV^{\gamma-1} =$ Constant

For process C–A ; pressure is constant

$V = kT$

18. Given $\vec{p} = -\hat{\imath} - 3\hat{\jmath} + 2\hat{k}$ and $\vec{r} = \hat{\imath} + 3\hat{\jmath} + 5\hat{k}$. Find vector parallel to electric field at position $\vec{r}$ [Note that $\vec{p} \cdot \vec{r} = 0$].

A) $\hat{\imath} - 3\hat{\jmath} + 2\hat{k}$ B) $3\hat{\imath} + \hat{\jmath} + 2\hat{k}$ C) $-3\hat{\imath} - \hat{\jmath} - 2\hat{k}$ D) $-\hat{\imath} - 3\hat{\jmath} + 2\hat{k}$

Ans. A

Sol. Since $\vec{p} \cdot \vec{r} = 0$

$\vec{E}$ must be antiparallel to $\vec{p}$

So, $\vec{E} = -\lambda(\vec{p})$, where λ is a arbitrary positive constant

Now $\vec{A} = a\hat{\imath} + b\hat{\jmath} + c\hat{k}$

$\vec{A} \parallel \vec{E}$

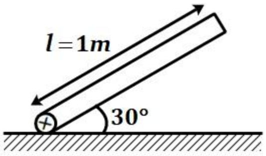
$$\frac{a}{\lambda} = \frac{b}{3\lambda} = \frac{c}{-2\lambda} = k$$

So, $\vec{A} = \lambda k(\hat{\imath} + 3\hat{\jmath} - 2\hat{\jmath})$

19. Coming Soon

20. Coming Soon

21. A rod of length $1\ m$ is released from rest as shown in the figure below.



If ω of rod is $\sqrt{n}$ at the moment it hits the ground, then find n.

Ans. 15

Sol. $mg\frac{l}{2}\sin 30° = \frac{1}{2}\frac{ml^2}{3}\omega^2$

Solving

$\omega^2 = 15$

$\omega = \sqrt{15}$

22. If reversible voltage of $200\ V$ is applied across an inductor, current in it reduces from $0.25A$ to $0A$ in$0.025\ ms$. Find inductance of inductance of inductor (in mH).

Ans. 20

Sol. $200 = \frac{L(0.25)}{0.025} \times 10^3$

$\therefore L = 200 \times 10^{-4} H$

$= 20\ mH$

23. A wire of length $l = 3m$ and area of cross section $10^{-2} cm^2$ and breaking stress $4.8 \times 10^{-7} N/m^2$ is attached with block of mass $10\ kg$. Find the maximum possible value of angular velocity with which block can be moved in circle with string fixed at one end.

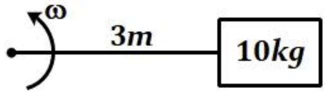
Ans. $4\ rad/s$

Sol. $\frac{T}{A} = \sigma$ (1)

$T = m\omega^2 l$ (2)

Solving

$\omega = 4\ rad/s$



24. Position of a particle as a function of time is given as $x^2 = at^2 + 2bt + c$, where a, b, c are constants. Acceleration of particle varies with x^{-n} then value of n is.

Ans. $n = 3$

Sol. $x^2 = at^2 + 2bt + c$

$2xv = 2at + 2b$

$xv = at + b$

$v^2 + ax = a$

$$ax = a\left(\frac{at+b}{x}\right)^2$$

$$a = \frac{a(at^2 + 2bt + c) - (at+b)^2}{x^3}$$

$$a = \frac{ac - b^2}{x^3}$$

$a \propto x^{-3}$

25. Coming Soon.