JEE Main February 2021

Question Paper With Text Solution

24 Feb.| Shift-1

PHYSICS

MATRIX

JEE Main & Advanced | XI-XII Foundation| VI-X Pre-Foundation

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JEE MAIN FEB 2021 | 24TH FEB SHIFT-1

1. A current through a wire depends on time as $i = \alpha_0 t + \beta t^2$ where $\alpha_0 = 20$ A/s and $\beta = 8\,As^{-2}$. Find the charge crossed through a section of the wire in 15s.

(1) 260 C (2) 2100 C (3) 2250 C (4) 11250 C

Ans. Official Answer by NTA (4)

Sol. $i = \frac{dq}{dt}$

$\Rightarrow dq = idt$

$\Rightarrow Q = \int_0^Q dq = \int_0^{15} (\alpha_0 t + \beta t^2)\,dt$

$= \left[\frac{\alpha_0 t^2}{2} + \frac{\beta t^3}{3}\right]_0^{15}$

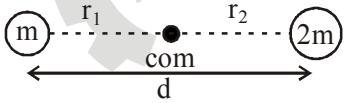
$\Rightarrow Q = \frac{20\times 15^2}{2} + \frac{8\times 15^3}{3} = 2250 + 9000 = 11250\ C$

2. Two stars of masses m and 2m at a distance d rotate about their common centre of mass in free space. The period of revolution is :

(1) $2\pi\sqrt{\frac{d^3}{3Gm}}$ (2) $2\pi\sqrt{\frac{3Gm}{d^3}}$ (3) $\frac{1}{2\pi}\sqrt{\frac{3Gm}{d^3}}$ (4) $\frac{1}{2\pi}\sqrt{\frac{d^3}{3Gm}}$

Ans. Official Answer by NTA (1)

Sol.



COM will be at rest. Time period will be same

$d = r_1 + r_2$

$r_1 = \frac{2m}{m+2m} d = \frac{2}{3} d$

$r_2 = \frac{m}{m+2m} d = \frac{d}{3}$

For m:-

$m\omega^2 r_1 = \frac{Gm(2m)}{d^2}$

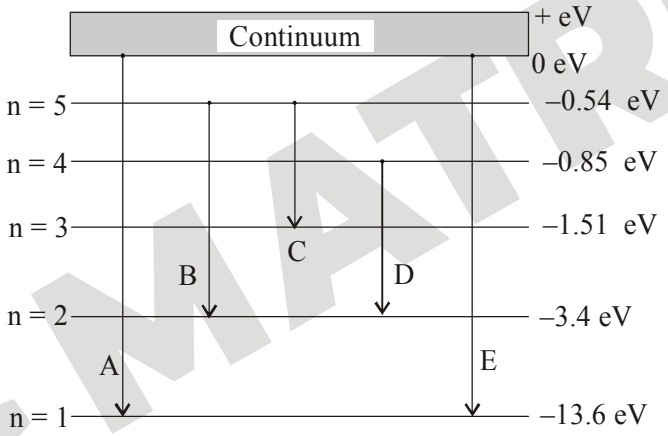
$$\Rightarrow \omega^2\left(\frac{2d}{3}\right)=\frac{2Gm}{d^2}$$

$$\Rightarrow \omega=\sqrt{\frac{3Gm}{d^3}}$$

$$\therefore T=2\pi\sqrt{\frac{d^3}{3Gm}}$$

3. In the given figure, the energy levels of hydrogen atom have been shown along with some transitions marked A, B, C, D and E.

The transitions A, B and C respectively represent :



(1) The series limit of Lyman series, third member of Balmer series and second member of Paschen series.

(2) The series limit of Lyman series, second member of Balmer series and second member of Paschen series.

(3) The ionization potential of hydrogen, second member of Balmer series and third member of Paschen series.

(4) The first member of the Lyman series, third member of Balmer series and second member of Paschen series.

Ans. Official Answer by NTA (1)

Sol. Part of Theory

4. If Y, K and η are the values of Young's modulus, bulk modulus and modulus of rigidity of any material respectively. Choose the correct relation for these parameters.

(1) $K = \frac{Y\eta}{9\eta - 3Y} N/m^2$ (2) $\eta = \frac{3YK}{9K + Y} N/m^2$

(3) $Y = \frac{9K\eta}{2\eta + 3K} N/m^2$ (4) $Y = \frac{9K\eta}{3K - \eta} N/m^2$

Ans. Official Answer by NTA (1)

Sol. We know that $Y = = \frac{9K\eta}{\eta + 3K}$

$\Rightarrow K = \frac{Y\eta}{9\eta - 3Y}$

5. The workdone by a gas molecule in an isolated system is given by, $W = \alpha\beta^2 e^{-\frac{x^2}{\alpha kT}}$, where x is the displacement, k is the Boltzmann constant and T is the temperature. α and β are constants. Then the dimensions of β will be :

(1) $[M^2 L T^2]$ (2) $[M L T^{-2}]$ (3) $[M^0 L T^0]$ (4) $[M L^2 T^{-2}]$

Ans. Official Answer by NTA (2)

Sol. $W = \alpha\beta^2 e^{-x^2/\alpha kT}$

$W = [\alpha][\beta^2]$

$\Rightarrow [\beta] = \frac{[W]^{1/2}}{[\alpha]^{1/2}}$

$\Rightarrow [\beta] = \frac{[M^1L^2T^{-2}]^{1/2}}{[M^1T^{-2}]^{1/2}}$

$= [M^1L^1T^{-2}]$

$[x^2] = [\alpha][K_B][T]$

$\Rightarrow [\alpha] = \frac{[L^2]}{[M^1L^2T^{-2}K^{-1}][K^1]}$

$\Rightarrow [\alpha] = [M^{-1}T^{-2}]$

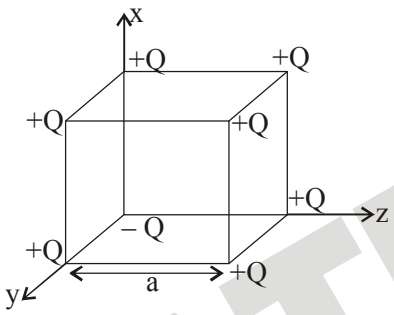
$K \cdot E = \frac{3}{2} K_B T$

$$[K_B]=\frac{[M^1L^2T^{-2}]}{[K]}$$

$$[K_B]=[M^1L^2T^{-2}K^{-1}]$$

$$[x^2]=[\alpha][K_B][T]$$

6. A cube of side 'a' has point charges +Q located at each of its vertices except at the origin where the charge is – Q. The electric field at the centre of cube is :



(1) $\frac{-Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

(2) $\frac{Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

(3) $\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

(4) $\frac{2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

Ans. Official Answer by NTA (3)

Sol. $$E=\frac{2KQ}{r^2}=2\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{Q}{\left(\frac{\sqrt{3}}{2}a\right)^2}$$

$$\Rightarrow E=\frac{2Q}{3\pi\varepsilon_0 a^2}$$

and $\overline{r_p}=a\hat{i}+a\hat{j}+a\hat{k}$

$$\hat{r}_p=\sqrt{3}(\hat{i}+\hat{j}+\hat{k})$$

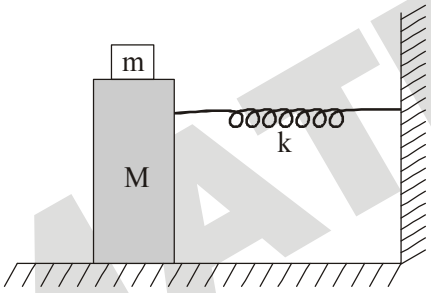
$$\overline{E}=\frac{2Q}{3\pi\varepsilon_0 a^2}\hat{E}$$

$$\Rightarrow \overline{E}=\frac{2Q}{3\pi\varepsilon_0 a^2}(-\hat{r}_P)$$

$$\overline{E}=\frac{2Q}{3\pi\varepsilon_0 a^2}\left(\frac{-\left(\hat{i}+\hat{j}+\hat{k}\right)}{\sqrt{3}}\right)$$

$$\overline{E}=\frac{-2Q\left(\hat{i}+\hat{j}+\hat{k}\right)}{3\sqrt{3}\pi\varepsilon_0 a^2}$$

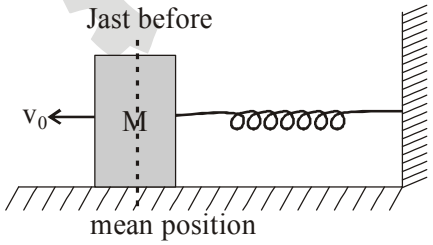
7. In the given figure, a mass M is attached to a horizontal spring which is fixed on one side to a rigid support. The spring constant of the sprign is k. The mass oscillates on a frictionless surface with time period T and amplitude A. When the mass is in equilibrium position, as shown in the figure, another mass m is gently fixed upon it. The new amplitude of oscillation will be:

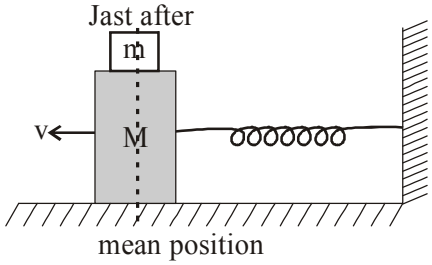


(1) $A\sqrt{\frac{M}{M-m}}$ (2) $A\sqrt{\frac{M}{M+m}}$ (3) $A\sqrt{\frac{M+m}{M}}$ (4) $A\sqrt{\frac{M-m}{M}}$

Ans. Official Answer by NTA (2)

Sol.





$$\omega=\sqrt{\frac{k}{m}} \qquad \omega'=\sqrt{\frac{k}{m+M}}$$

$$v_0=A\omega=A\sqrt{\frac{k}{M}} \qquad v=A'\omega'$$

From momentum consrvation in Horizontal

$P_i = P_f$

$\Rightarrow Mv_0 = (m+M)v$

$\Rightarrow MA\sqrt{\frac{k}{M}} = (m+M)A'\sqrt{\frac{k}{m+M}}$

$\Rightarrow A' = \sqrt{\frac{M}{m+M}}A$

8. If an emitter current is changed by 4 mA, the collector current changes by 3.5mA. The value of β will be :

(1) 0.875 (2) 7 (3) 3.5 (4) 0.5

Ans. Official Answer by NTA (2)

Sol. $I_e = I_C + I_B$

$\Rightarrow \Delta I_e = \Delta I_C + \Delta I_B$

$\Rightarrow \Delta I_B = \Delta I_e - \Delta I_C = 4 - 3.5 = 0.5$ mA

$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{3.5}{0.5} = \frac{7}{1}$

9. Given below are two statements:

Statement I : Two photons having equal linear momenta have equal wavelengths.

Statement II : If the wavelength of photon is decreased, then the momentum and energy of a photon will also decrease.

In the light of the above statements, choose the correct answer from the options given below.

(1) Statement I is false but Statement II is true

(2) Both Statement I and Statement II are false

(3) Both Statement I and Statement II are true

(4) Statement I is true but Statement II is false

Ans. Official Answer by NTA (4)

Sol. $\lambda = \frac{h}{P}$ and $E = \frac{hC}{\lambda}$

As $\lambda \downarrow \Rightarrow P \uparrow$ & $E \uparrow$

10. In a Young's double slit experiment, the width of the one of the slit is three times the other slit. The amplitude of the light coming from a slit is proportional to the slit-width. Find the ratio of the maximum to the minimum intensity in the interference pattern.

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

Ans. Offical Answer by NTA (4)

Sol. $A_1 = A \quad , \; A_2 = 3A$
$I_1 = I \quad , \; I_2 = 9I$

$$\frac{I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2}{I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2} = \frac{16}{4} = \frac{4}{1}$$

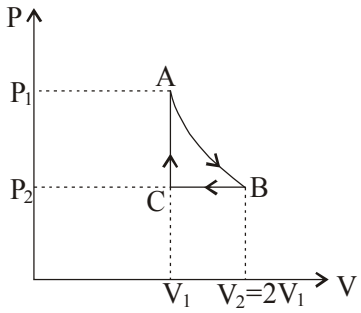
11. n mole of a perfect gas undergoes a cyclic process ABCA (see figure) consisting of the following processes.

$A \rightarrow B$: Isothermal expansion at temperature T so that the volume is doubled from V_1 to $V_2 = 2V_1$ and pressure changes from P_1 to P_2.

$B \rightarrow C$: Isobaric compression at pressure P_2 to initial volume V_1.

$C \rightarrow A$: Isochoric change leading to change of pressure from P_2 to P_1.

Total workdone in the complete cycle ABCA is :



(1) nRTln 2 (2) 0 (3) $nRT\left(\ln 2 + \frac{1}{2}\right)$ (4) $nRT\left(\ln 2 - \frac{1}{2}\right)$

Ans. Official Answer by NTA (4)

Sol. From ideal gas eq^n at state A $\Rightarrow P_1V_1 = nRT$

$$W_{net} = W_{AB} + W_{BC} + W_{CA}$$

$$= nRT\ln\left(\frac{2V_1}{V_1}\right) + P_2\left(V_1 - 2V_1\right) + 0$$

$$= nRT\ln -\frac{P_1V_1}{2}$$

$$= P_1V_1\left(\ln 2 - \frac{1}{2}\right)$$

12. Match List I with List II.

List I	List II
(a) Isothermal	(i) Pressure constant
(b) Isochoric	(ii) Temperature constant
(c) Adiabatic	(iii) Volume constant
(d) Isobaric	(iv) Heat content is constant

Choose the correct answer from the options given below :

(1) (a) $\rightarrow$ (ii), (b) $\rightarrow$ (iii), (c) $\rightarrow$ (iv), (d) $\rightarrow$ (i)

(2) (a) $\rightarrow$ (iii), (b) $\rightarrow$ (ii), (c) $\rightarrow$ (i), (d) $\rightarrow$ (iv)

(3) (a) $\rightarrow$ (i), (b) $\rightarrow$ (iii), (c) $\rightarrow$ (ii), (d) $\rightarrow$ (iv)

(4) (a) $\rightarrow$ (ii), (b) $\rightarrow$ (iv), (c) $\rightarrow$ (iii), (d) $\rightarrow$ (i)

Ans. Offical Answer by NTA (1)

Sol. Part of theory.

13. Consider two satellites S_1 and S_2 with periods of revolution 1 hr. and 8 hr. respectively revolving around a planet in circular orbits. The ratio of angular velocity of satellite S_1 to the angular velocity of satellite S_2 is :

(1) 1 : 4 (2) 1 : 8 (3) 8 : 1 (4) 2 : 1

Ans. Official Answer by NTA (4)

Official Answer by Matrix (3)

Sol. $\frac{T_1}{T_2}=\left(\frac{r_1}{r_2}\right)^{3/2}$

$=\frac{r_1}{r_2}=\left(\frac{T_1}{T_2}\right)^{2/3}=\left(\frac{T_1}{T_2}\right)^{2/3}=\frac{1}{4}$

$\frac{GMm}{r^2}=m\omega^2 r$

$\Rightarrow \omega^2=\frac{GM}{r^3}$

$\therefore \quad \frac{\omega_1}{\omega_2}=\left(\frac{r_2}{r_1}\right)^{3/2}=\frac{8}{1}$

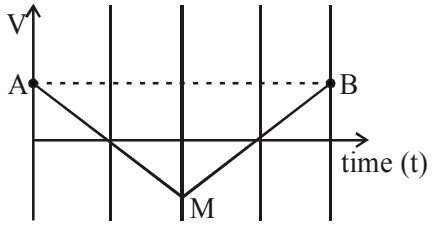
14. The focal length f is related to the radius of curvature r of the spherical convex mirror by :

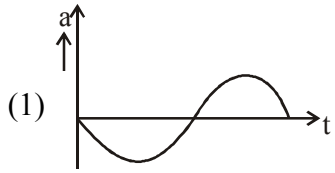
(1) $f=+\frac{1}{2}r$ (2) $f=r$ (3) $f=-r$ (4) $f=-\frac{1}{2}r$

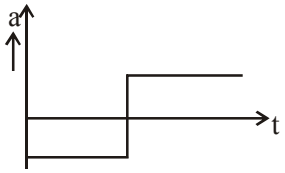
Ans. Official Answer by NTA (1)

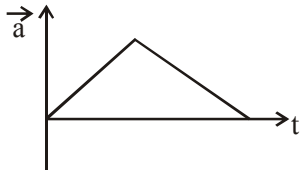
Sol. Focal length of convex mirror $=+\frac{r}{2}$

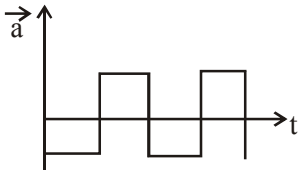
15. If the velocity-time graph has the shape AMB, what would be the shape of the corresponding acceleration-time graph ?



(1) 

(2) 

(3) 

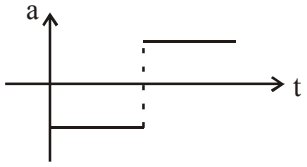
(4) 

Ans. Offical Answer by NTA (2)

Sol. Slope of velocty time graph = acceleration

for AM : $\rightarrow$ Slope = acceleration = –constant

for MB : $\rightarrow$ Slope = acceleration = + constant



16. Each side of a box made of metal sheet in cubic shape is 'a' at room temperature 'T', the coefficient of linear expansion of the metal sheet is 'α'. The metal sheet is heated uniformly, by a small temperature ΔT, so that its new temperature is $T+\Delta T$. Calculate the increase in the volume of the metal box.

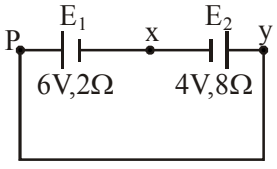
(1) $3a^3\alpha\Delta T$ (2) $\frac{4}{3}\pi a^3\alpha\Delta T$ (3) $4a^3\alpha\Delta T$ (4) $4\pi a^3\alpha\Delta T$

Ans. Offical Answer by NTA (1)

Change in valume, $\Delta v = v_0 Y\Delta T = a^3(3\alpha)\Delta T$

$\Rightarrow \Delta v = 3a^3\alpha\Delta T$

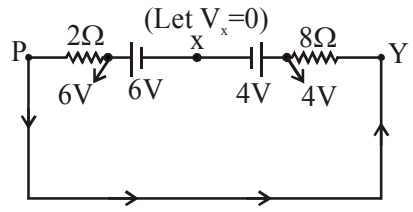
17. A cell E_1 of emf 6V and internal resistance 2Ω is connected with another cell E_2 of emf 4V and internal resistance 8Ω (as shown in the figure). The potential difference across points X and Y is :



(1) 3.6 V (2) 5.6 V (3) 2.0 V (4) 10.0 V

Ans. Offical Answer by NTA (2)

Sol.



$0+6-2i-8i-4=0$

$\Rightarrow 10\ i=2$

$\Rightarrow i=1/5$

$y-4=8i$

$\Rightarrow y=4+\frac{8}{5}=\frac{28}{5}$

$\therefore$ potential difference, $\Delta v=v_y-v_x=\frac{28}{5}=5.6$ volt

18. Moment of inertia (M.I.) of four bodies, having same mass and radius, are reported as ;

I_1 = M.I. of thin circular ring about its diameter,

I_2 = M.I. of circular disc about an axis perpendicular to disc and going through the centre,

I_3 = M.I. of solid cylinder about its axis and

I_4 = M.I. of solid sphere about its diameter.

Then :

(1) $I_1=I_2=I_3<I_4$ (2) $I_1+I_3<I_2+I_4$ (3) $I_1+I_2=I_3+\frac{5}{2}I_4$ (4) $I_1=I_2=I_3>I_4$

Ans. Offical Answer by NTA (4)

Sol. Part of Theory.

19. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be :

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

Ans. Offical Answer by NTA (2)

Sol. $C_1=\frac{C}{2}$ & $C_2=2C$

$\therefore \quad \frac{C_1}{C_2}=\frac{1}{4}$

20. Four identical particles of equal masses 1kg made to move along the circumference of a circle of radius 1m under the action of their own mutual gravitational attraction. The speed of each particle will be :

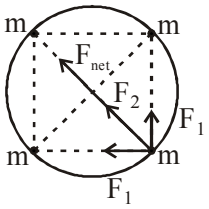
(1) $\sqrt{G(1+2\sqrt{2})}$

(2) $\sqrt{\frac{G}{2}(2\sqrt{2}-1)}$

(3) $\frac{\sqrt{(1+2\sqrt{2})G}}{2}$

(4) $\sqrt{\frac{G}{2}(1+2\sqrt{2})}$

Ans. Offical Answer by NTA (3)



$m = 1kg$

$R = 1m$

$$F_1 = \frac{Gm^2}{\left(\sqrt{2}R\right)^2} = \frac{Gm^2}{2R^2}$$

$$F_2 = \frac{Gm^2}{4R^2}$$

$$\therefore \quad F_{net} = \sqrt{2}F_1 + F_2 = \frac{Gm^2\sqrt{2}}{2R^2} + \frac{Gm^2}{4R^2}$$

$$= \frac{G}{\sqrt{2}} + \frac{G}{4} = \frac{G}{4}\left(2\sqrt{2}+1\right)$$

and $F_{net} = \frac{mV^2}{R}$

$$\Rightarrow \frac{G}{4}\left(2\sqrt{2}+1\right) = \frac{(1)V^2}{(1)}$$

$$\Rightarrow V = \frac{\sqrt{G(2\sqrt{2}+1)}}{2}$$

Section-B

1. A common transistor radio set requires 12V (D.C.) for its operation. The D.C. source is constructed by using a transformer and a rectifier circuit, which are operated at 220 V (A.C.) on standard domestic A. C. supply. The number of turns of secondary coil are 24, then the number of turns of primary are ..... .

Ans. Official Answer by NTA (440)

Sol. $\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$\Rightarrow \frac{N_P}{24} = \frac{220}{12}$

$\Rightarrow N_P = 440$

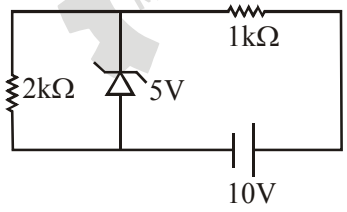
2. A resonance circuit having inductance and resistance 2×10^{-4} H and 6.28Ω respectively oscillates at 10 MHz frequency. The value of quality factor of this resonator is ____ .$[\pi = 3.14]$

Ans. Official Answer by NTA (200)

Sol. $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{(2\pi f)L}{R} = \frac{2\times3.14\times10\times10^6\times2\times10^{-4}}{6.28}$

$\Rightarrow Q = 2000$

3. In connection with the circuit drawn below, the value of current flowing through $2k\Omega$ resistor is ____ $\times 10^{-4}$ A.



Ans. Official Answer by NTA (25)

Sol. Potention differencl across zener diode inreverse bias 5V

$\therefore$ Potential difference across $2k\Omega = 5V$

$\therefore$ Current through $2k\Omega = \frac{5}{2\times10^3} = 25\times10^{-4}$

4. An unpolarized light beam is incident on the polarizer of a polarization experiment and the intensity of light beam emerging from the analyzer is measured as 100 Lumens. Now, if the analyzer is rotated around the horizontal axis (direction of light) by 30° in clockwise direction, the intensity of emerging light will be ____ Lumens.

Ans. Offical Answer by NTA (75)

Sol. Case-I Pass axis of polariser and analyzer are aligned.

$$\therefore\ I = \frac{I_0}{2}\cos^2 0 = 100$$

$$\Rightarrow\ I_0 = 200$$

Case-II angle between pass axis of polariser and analyzer is 30°

$$I' = \frac{I_0}{2}\cos^2 30° = 100 \times \frac{3}{4} = 75$$

5. A hydraulic press can lift 100 kg when a mass 'm' is placed on the smaller piston. It can lift ____ kg when the diameter of the larger piston is increased by 4 times and that of the smaller pistion is decreased by 4 times keeping the same mass 'm' on the smaller piston.

Ans. Official Answer by NTA (25600)

Sol. $$\frac{mg}{a} = \frac{100 \times g}{A} \text{.....(1)}$$

and $$\frac{mg}{a'} = \frac{Mg}{A'}$$

$$= \frac{mg}{a/16} = \frac{Mg}{16A}$$

$$\Rightarrow \frac{mg}{a} = \frac{Mg}{16 \times 16 \times A} \text{....(2)}$$

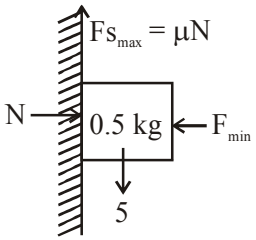
From (1) & (2) $\Rightarrow M = 25600\,kg$

6. The coefficient of static friction between a wooden block of mass 0.5 kg and a vertical rough wall is 0.2. The magnitude of horizontal force that should be applied on the block to keep it adhere to the wall will be __ N.

[$g = 10ms^{-2}$]

Ans. Official Answer by NTA (25)

Sol.



$N = F_{min}$ and $F_{S_{max}} = 5$

$\Rightarrow \mu N = 5$

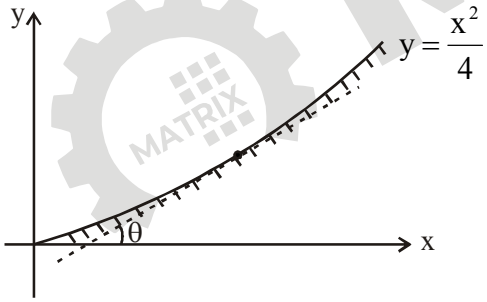
$\Rightarrow 0.5 \times F_{min} = 5$

$\Rightarrow F_{min} = 25$

7. An inclined plane is bent in such a way that the vertcal cross-section is given by $y = \frac{x^2}{4}$ where y is in vertical and x in horizontal direction. If the upper surface of this curved plane is rough with coefficient of friction $\mu = 0.5$, the maximum height in cm at which a stationary block will not slip downward is ____ cm.

Ans. Official Answer by NTA (25)

Sol.



$\theta \rightarrow$ should be equal to angle of repose

$\therefore \tan\theta = \mu$

$\Rightarrow \frac{dy}{dx} = 0.5$

$\Rightarrow \frac{2x}{4} = 0.5$

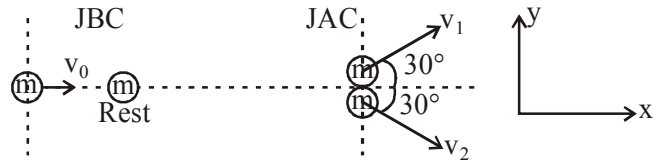
$\Rightarrow x = 1m$

$\therefore$ height $= y = \frac{1}{4}m = 25cm$

8. A ball with a speed of 9m/s collides with another identical ball at rest. After the collision, the direction of each ball makes an angle of 30° with the original direction. The ratio of velocities of the balls after collision is x : y, where x is ____

Ans. Offical Answer by NTA (1)

Sol.



From momentum conservation in y direction.

$0 + 0 = mv_1 \sin 30° - mv_2 \sin 30°$

$\Rightarrow v_1 = v_2$

9. An electromagnetic wave of frequency 5GHz, is travelling in a medium whose relative electric permittivity and relative magnetic permeability both are 2. Its velocity in this medium is ____$\times 10^7$ m/s.

Ans. Offical Answer by NTA (15)

Sol. $C = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$$v = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}}$$

$$\Rightarrow \frac{C}{v} = \sqrt{\mu_r \varepsilon_r}$$

$$\Rightarrow v = \frac{C}{\sqrt{\mu_r \varepsilon_r}} = \frac{3\times10^8}{2} = 15\times10^7 \text{ m/s}$$

10. An audio signal $v_m = 20 \sin 2\pi(1500\,t)$ amplitude modultes a carrier $v_c = 80 \sin 2\pi(10,000t)$.

The value of percent modulation is ____

Ans. Offical Answer by NTA (25)

Sol. % modulation $= \dfrac{A_m}{A_c} \times 100\% = \dfrac{20}{80} \times 100\% = 25\%$