JEE Main March 2021

Question Paper With Text Solution

16 March. | Shift-2

PHYSICS

MATRIX

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

Office : Piprali Road, Sikar (Raj.) | Ph. 01572-241911
Website : www.matrixedu.in ; Email : smd@matrixacademy.co.in

JEE MAIN MARCH 2021 | 16TH MARCH SHIFT-2

SECTION – A

1. Calculate the time interval between 33% decay and 67% decay if half-life of a substance is 20 minutes.

(1) 40 minutes

(2) 13 minutes

(3) 20 minutes

(4) 60 minutes

Ans. Official Answer by NTA (3)

Sol. $N = N_0 e^{-\lambda t}$

$$\frac{2N_0}{3} = N_0 e^{-\lambda t_1}$$

$$e^{-\lambda t_1} = \frac{3}{2}$$

$$\Rightarrow t_1 = \frac{\ell n \frac{3}{2}}{\lambda}$$

and $\frac{N_0}{3} = N_0 e^{-\lambda t_2}$

$$\Rightarrow t_2 = \frac{\ell n 3}{\lambda}$$

Now, $t_2 - t_1 = \frac{1}{\lambda}\left[\ell n 3 - \ell n \frac{3}{2}\right]$

$$\Rightarrow t_2 - t_1 = \frac{\ell n_2}{\lambda} = t_{y_2} = 20 \text{ minutes}$$

2. A resistor develops 500 J of thermal energy in 20 s when a current of 1.5A is passed through it. If the current is increased from 1.5 A to 3 A, what will be the energy developed in 20 s.

(1) 1500 J

(2) 2000 J

(3) 500 J

(4) 1000 J

Ans. Official Answer by NTA (2)

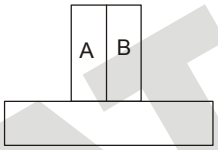
Sol. Heat = i^2Rt

$$\therefore \frac{H_1}{H_2} = \frac{i_1^2}{i_2^2}$$

$$\Rightarrow \frac{500}{H_2} = \frac{(1.5)^2}{(3)^2}$$

$$\Rightarrow H_2 = 2000 \text{ J}$$

3. A bimetallic strip consists of metals A and B. It is mounted rigidly as shown. The metal A has higher coefficient of expansion compared to the of metal B. When the bimetallic strip is placed in a cold bath, it will :



(1) Not bend but shrink

(2) Bend towards the left

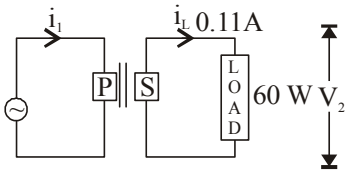
(3) Bend towards the right

(4) Neither bend nor shrink

Ans. Official Answer by NTA (2)

Sol. When it is placed in cold bath length of strip A decreases more in comparision to that of B as $\alpha_A > \alpha_B$. So it will bend towards left.

4. For the given circuit, comment on the type of transformer used.



(1) Step - up transformer

(2) Auto transformer

(3) Auxilliary transformer

(4) Step down transformer

Ans. Official Answer by NTA (1)

Sol. $P_S = V_S i_S$

$\Rightarrow V_S = \frac{60}{0.11} = 545.4 \text{ Volt}$

$\because V_S > V_P$

$\therefore$ Step-up transformer

5. Calculate the value of mean free path (λ) for oxygen molecules at temperature 27ºC and pressure 1.01×10^5 Pa. Assume the molecular diameter 0.3 nm and the gas is ideal. ($k = 1.38\times10^{-23}$ JK^{-1})

(1) 58 nm

(2) 102 nm

(3) 32 nm

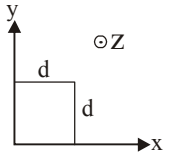
(4) 86 nm

Ans. Official Answer by NTA (2)

Sol. $\lambda = \frac{KT}{\sqrt{2}\pi d^2 P}$

$\Rightarrow \lambda = \frac{\left(1.38\times10^{-23}\right)(300)}{\sqrt{2}\pi\left(0.3\times10^{-9}\right)^2\times1.01\times10^5} \approx 102 \text{ nm}$

6. The magnetic field in a region is given by $\vec{B} = B_0\left(\frac{x}{a}\right)\hat{k}$. A square loop of side d is placed with its edges along the x and y axes. The loop is moved with a constant velocity $\hat{v} = v_0\hat{i}$. The emf induced in the loop is :



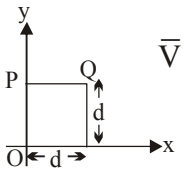
(1) $\frac{B_o v_o d^2}{2a}$

(2) $\frac{B_o v_o^2 d}{2a}$

(3) $\frac{B_o v_o d}{2a}$

(4) $\frac{B_o v_o d^2}{a}$

Ans. Official Answer by NTA (4)

Sol. 

$\overline{V} = V_0 \hat{i}$

εmF induced in length OP = εmFinduced in length PQ = εmF indrced in length OR = O

εmF induced in length $RQ = \int d\varepsilon = \int_0^d \left(B_0 \frac{d}{a} \right) dy \; V_0$

$\Rightarrow \varepsilon_{net} = \varepsilon_{RQ} = \frac{B_0 V_0 d^2}{a}$

7. Two identical antennas mounted on identical towers are separated from each other by a distance of 45 km. What should nearly be the minimum height of receiving antenna to receive the signals in line of sight ?

(1) 79.1 m

(2) 158.2 m

(3) 39.55 m

(4) 19.77

Ans. Official Answer by NTA (3)

Sol. $D = 2\sqrt{2Rh}$

$= h = \frac{D^2}{8R} = \frac{(45)^2}{8 \times 6400} km = 39.55 \; m$

8. Statement I : A cyclist is moving on an unbanked road with a speed of 7 kmh^{-1} and takes a sharp circular turn along a path of radius of 2m without reducing the speed. The static friction coefficient is 0.2. The cyclist will not slip and pass the curve. ($g = 9.8 \; m/s^2$)

Statement II : If the road is banked at an angle of 45°, cyclist can cross the curve of 2m radius with the speed of 18.5 kmh^{-1} without slipping.

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

(1) Both statement I and statement II are false

(2) Both statement I and statement II are true

(3) Statement I is incorrect and statement II is correct

(4) Statement I is correct and statement II is incorrect

Ans. Official Answer by NTA (2)

Sol. Statement I : $V_{max} = \sqrt{\mu Rg} = \sqrt{(0.2)\times 2\times 9.8} = 1.97 \text{ m/s}$

$$V_{cyclist} = 7\frac{km}{hr} = 1.944 \text{ m/s}$$

$\because$ Speed is lower than V_{max}, hence it can take the turn safely.

Statement II : $V_{max} = \sqrt{Rg\left(\frac{\tan\theta+\mu}{1-\mu\tan\theta}\right)} = \sqrt{2\times 9.8\left[\frac{1+0.2}{1-0.2}\right]} = 5.42 \text{ m/s}$

$$V_{cyclist} = 18.5\frac{km}{hr} = 5.14 \text{ m/s}$$

$\because$ Speed is lower than V_{max}, hence it can take the turn safely.

9. A charge Q is moving $\vec{dl}$ distance in the magnetic field $\vec{B}$. Find the value of work done by $\vec{B}$

(1) Infinite

(2) – 1

(3) 1

(4) Zero

Ans. Official Answer by NTA (4)

Sol. We know that, $\overline{F} = q\left(\overline{V}\times\overline{B}\right)$

Since force on charge by magnetic field is always perpendicular to $\overline{V}$. So work done by magnatic force on point charge is zero.

10. Red light differs from blue light as they have :

(1) Same frequencies and same wavelengths

(2) Different frequencies and different wavelengths

(3) Same frequencies and different wavelengths

(4) Different frequencies and same wavelengths

Ans. Official Answer by NTA (2)

Sol. Red light and blue light have different wavelength and different frequency.

11. A mosquito is moving with a velocity $\vec{B}=0.5t^2\hat{i}+3t\hat{j}+9\hat{k}\ m/s$ and accelerating in uniform conditions. What will be the direction of mosquito after 2 s ?

(1) $\tan^{-1}\left(\frac{5}{2}\right)$ from y-axis

(2) $\tan^{-1}\left(\frac{2}{3}\right)$ from y-axis

(3) $\tan^{-1}\left(\frac{5}{2}\right)$ from x-axis

(4) $\tan^{-1}\left(\frac{2}{3}\right)$ from x-axis

Ans. Official Answer by NTA (2)

Answer given by matrix (Bonus)

Sol. At $t=2$ sec

$\overline{V}=2\hat{i}+6\hat{j}+9\hat{k}$

$|\overline{V}|=\sqrt{(2)^2+(6)^2+(9)^2}=\sqrt{121}$

Angle with x-axis $\Rightarrow \cos\alpha=\frac{2}{\sqrt{121}}=\frac{2}{11}$

$\therefore \tan\alpha=\frac{\sqrt{117}}{2}$

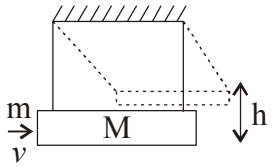
Angle with y-axis $\Rightarrow \cos\beta=\frac{6}{\sqrt{121}}=\frac{6}{11}$

$\therefore \tan\beta=\frac{\sqrt{85}}{6}$

Angle with z-axis $\Rightarrow \cos\gamma=\frac{9}{11}$

$\therefore \tan\gamma=\frac{\sqrt{40}}{9}$

12. A large block of wood of mass mass M=5.99 kg is hanging from two long massless cords. A bullet of mass m=10 g is fired into the block and gets embedded in it. The (block + bullet) then swing upwards, their centre of mass rising a vertical distance h = 9.8 cm before the (block + bullet) pendulum comes momentarily to rest at the end of its arc. The speed of the bullet just before collision is :



(1) 821.4 m/s

(2) 841.4 m/s

(3) 831.4 m/s

(4) 811.4 m/s

Ans. Official Answer by NTA (3)

Sol. from energy conservation. [after bullet gets embeded till the sysetm comes momentarity at rest]

$$\frac{1}{2}(M+m)V_1^2 = (M+m)gh$$

$$\Rightarrow V_1 = \sqrt{2gh} \rightarrow \text{Velocity after callision}$$

Now appling momentum conservation for collision

$$mV = (m+M)V_1$$

$$\Rightarrow V = \left(\frac{m+M}{m}\right)V_1 = \frac{6}{10\times10^{-3}} \times \sqrt{2\times9.8\times9.8\times10^{-2}}$$

$$\Rightarrow V \approx 831.4 m/s$$

13. The de-Broglie wavelength associated with an electron and a proton were calculated by accelerating them through same potential of 100 V. What should nearly be the ratio of their wavelengths ? (m_p = 1.00727u m_e = 0.00055u)

(1) $(1860)^2 : 1$

(2) 43 : 1

(3) 1860 : 1

(4) 41.4 : 1

Ans. Official Answer by NTA (2)

Sol. $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mk}} = \frac{h}{\sqrt{2mqv}}$

$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{m_2}{m_1}}$

$\therefore \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} = \sqrt{1831.4} \approx 42.8$

14. The refractive index of a converging lens is 1.4. What will be the focal length of this lens if it is placed in a medium of same refractive index ? Assume the radii of curvature of the faces lf lens are R_1 and R_2 respectively.

(1) 1

(2) Zero

(3) $\frac{R_1 R_2}{R_1 - R_2}$

(4) Infinite

Ans. Official Answer by NTA (4)

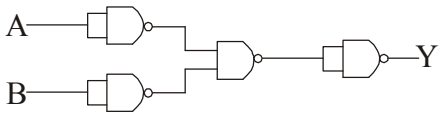
Sol. $\frac{1}{f} = \left[\frac{\mu_L}{\mu_S} - 1\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$\mu_L = \mu_S$

$\therefore \frac{1}{f} = 0$

$\Rightarrow f = \infty$

15. The following logic gate is equivalent to :



(1) OR Gate

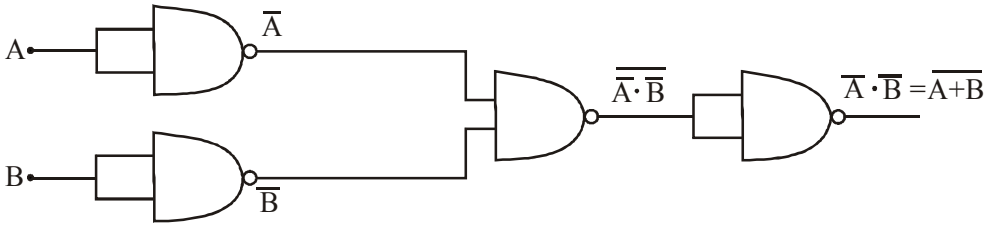
(2) NOR Gate

(3) AND Gate

(4) NAND Gate

Ans. Official Answer by NTA (2)

Sol.



So it will be NOR Gate.

16. Find out the surface charge density at the intersection of point x = 3 m plane and x-axis, in the region of uniform line charge of 8 nC/m lying along the z-axis in free space.

(1) 4.0 nC m^{-2}

(2) 47.88 C/m

(3) 0.424 nC m^{-2}

(4) 0.07 nC m^{-2}

Ans. Official Answer by NTA (3)

Sol. $\dfrac{2k\lambda}{r}=\dfrac{\sigma}{\varepsilon_0}$

$\Rightarrow \sigma = 2\left(\dfrac{1}{4\pi\varepsilon_0}\right)\dfrac{\varepsilon_0\lambda}{r}$

$\Rightarrow \sigma = \dfrac{1}{2\pi}\times\dfrac{8\times10^{-9}}{3}$

$= 0.424\ \dfrac{nc}{m^2}$

17. Amplitude of a mass-spring system, which is executing simple harmonic motion decreases with time. If mass=500g, Decay constant = 20 g/s then how much time is required for the amplitude of the system to drop to half of its initial value ?

(1) 17.32 s

(2) 15.01 s

(3) 0.034 s

(4) 34.65

Ans. Official Answer by NTA (4)

Sol. $A = A_0 e^{-bt/2m}$

$\Rightarrow \frac{A_0}{2} = A_0 e^{-bt/2m}$

$e^{\frac{bt}{2m}} = 2$

$\Rightarrow \frac{bt}{2m} = \ln 2$

$\Rightarrow t = \frac{(\ln 2)(2m)}{b} = \frac{0.693 \times 2 \times 500}{20} \approx 34.65$ sec.

18. The half-life of Au^{198} is 2.7 days. The activity of 1.50 mg of Au^{198} if its atomic weight is 198 g mol^{-1} is, ($N_A = 6 \times 10^{23}$/mol).

(1) 357 Ci

(2) 535 Ci

(3) 240 Ci

(4) 252 Ci

Ans. Official Answer by NTA (1)

Sol. Activity $A = \lambda N$ and $\lambda = \frac{l \ln 2}{t_{1/2}}$

and $N = nN_A$

$\Rightarrow N = \left(\frac{1.5 \times 10^{-3}}{198}\right) N_A$

$\therefore A = \left(\frac{\ln 2}{t_{1/2}}\right)\left[\frac{1.5 \times 10^{-3}}{198} N_A\right] = 1350 \times 10^{10}$ Bq

$\therefore A = \frac{1350 \times 10^{10}}{3.7 \times 10^{10}}$ curie $\approx$ 365 curie (ci)

19. In order to determine the Young's Modulus of a wire of radius 0.2 cm (measured using a scale of least count = 0.001 cm) and length 1m (measured using a scale of least count = 1 mm), a weight of mass 1 kg (measured using a scale of least count = 1 g) was hanged to get the elongation of 0.5 cm (measured using a scale of least count 0.001 cm). What will be the fractional error in the value of Young's Modulus determined by this experiment ?

(1) 0.14 %

(2) 9 %

(3) 0.9 %

(4) 1.4 %

Ans. Official Answer by NTA (4)

Sol. From hook's Law:-

Stress = Y(strain)

$$\Rightarrow \frac{F}{A}=\gamma\left(\frac{l}{L}\right)$$

$$\Rightarrow Y=\frac{FL}{Al}=\frac{mgL}{(\pi R^2)l}=$$

$$\therefore \frac{\Delta Y}{Y}=\frac{\Delta m}{m}+\frac{\Delta L}{L}+\frac{2\Delta R}{R}+\frac{\Delta l}{l}$$

$$\frac{\Delta Y}{Y}\times 100\%=100\left[\frac{1}{1000}+\frac{1}{1000}+2\left(\frac{0.001}{0.2}\right)+\frac{0.001}{0.5}\right]$$

$$=\left(\frac{1}{10}+\frac{1}{10}+1+\frac{1}{5}\right)\%$$

$$=\frac{14}{10}\%$$

= 1.4 %

20. What will be the nature of flow of water from a circular tap, when its flow rate increased from 0.18 L/ min to 0.48 L/min ? The radius of the tap and viscosity of water are 0.5 cm and 10^{-3} Pa s, respectively. (Density of water : 10^3 kg/m^3)

(1) Remains turbulent flow

(2) Remains steady flow

(3) Unsteady to steady flow

(4) Steady flow to unsteady flow

Ans. Official Answer by NTA (4)

Sol. flow Rate = AV

$$\Rightarrow V = \frac{\text{flow Rate}}{A}$$

and $R = \frac{\rho VD}{\eta}$

We know that [from NCERT]
If $R < 1000 \Rightarrow$ Flow is steady
& $1000 < R < 2000 \Rightarrow$ flow becomes unsteady
& $R > 2000 \Rightarrow$ Flow is turbulent

$$R_{initial} = 10^3 \times \frac{0.18\times10^{-3}}{\pi\left(0.5\times10^{-2}\right)^2\times60}\times\frac{10^{-2}}{10^{-3}} = 382.16$$

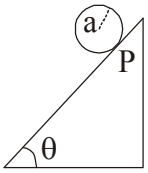
$\therefore$ intially flow is steady flow.

$$R_{final} = 10^3 \times \frac{0.48\times10^{-3}}{\pi\left(0.5\times10^{-2}\right)\times60}\times\frac{10^{-2}}{10^{-3}} = 1019.09$$

$\therefore$ Finally flow is unsteady.

SECTION B

1. A solid disc of radius 'a' and mass 'm' rolls down without slipping on an inclined plane making an angle θ with the horizontal. The acceleration of the disc will be $\frac{2}{b}g\sin\theta$ where b is _____. (Round off to the Nearest Integer)
(g = acceleration due to gravity, θ = angle as shown in figure)



Ans. Official Answer by NTA (3)

Sol. We know that $a = \frac{g\sin\theta}{1+\frac{I}{mR^2}}$

$$\Rightarrow a = \frac{g\sin\theta}{1+\frac{1}{2}} = \frac{2}{3}g\sin\theta$$

$$\therefore b = 3$$

2. A force $\vec{F} = 4\hat{i}+3\hat{j}+4\hat{k}$ is applied on an intersection point of x = 2 plane and x=axis. The magnitude of torque of this force about a point (2, 3, 4) is _____ (Round off to the Nearest Integer)

Ans. Official Answer by NTA (20)

Sol. $\bar{r} = 2\hat{i}-(2\hat{i}+3\hat{j}+4\hat{k}) = -3\hat{j}-4\hat{k}$

& $\bar{F} = 4\hat{i}+3\hat{j}+4\hat{k}$

$$\therefore \bar{\tau} = \bar{r}\times\bar{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & -3 & -4 \\ 4 & 3 & 4 \end{vmatrix}$$

$$= \hat{i}(-12+12)-\hat{j}(0+16)+\hat{k}(0+12)$$

$$= -16\hat{j}+12\hat{k}$$

$$\therefore |\bar{\tau}| = \sqrt{(16)^2+(12)^2} = 20$$

3. For an ideal heat engine, the temperature of the source is 127ºC. In order to have 60% efficiency the temperature of the sink should be _____ºC. (Round off to the Nearest Integer)

Ans. Official Answer by NTA (113)

Sol. Wee know that, $\eta = 1 - \frac{T_L}{T_H} = 0.6$

$$\Rightarrow \frac{T_L}{T_H} = 0.4$$

$$\Rightarrow T_L = 0.4\,T_H = 0.4(400) = 160\,K = -113^{o}\,C$$

4. A deviation of 2º is produced in the yellow ray when prism of crown and flint glass are achromatically combined. Taking dispersive powers of crown and flint glass as 0.02 and 0.03 respectively and refractive index for yellow light for these glasses are 1.5 and 1.6 respectively. The refracting angles for crown glass prism will be _____º(in degree).

(Round off to the Nearest Integer)

Ans. Official Answer by NTA (12)

Sol. $\omega_1 = 0.02,\ \mu_1 = 1.5$ and $\omega_2 = 0.03, \mu_2 = 1.6$

for Achromatic combination

$\theta_{net} = 0$

$\Rightarrow \theta_1 = \theta_2$

$\Rightarrow \omega_1\delta_1 = \omega_2\delta_2$

and $\delta_{net} = \delta_1 - \delta_2 = 2^{o}$

$$\delta_1 - \frac{\omega_1\delta_1}{\omega_2} = 2^{o}$$

$$\Rightarrow \delta_1\left(1 - \frac{\omega_1}{\omega_2}\right) = 2^{o}$$

$$\Rightarrow \delta_1\left(1 - \frac{2}{3}\right) = 2^{o}$$

and $\delta_1 = (\mu_1 - 1)A_1$

$\Rightarrow 6^{o} = (1.5 - 1)A_1$

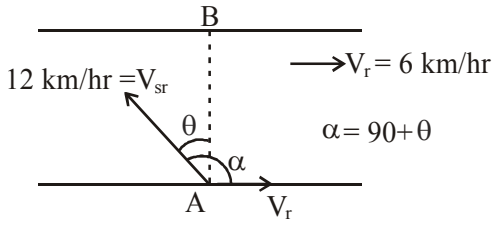
$\Rightarrow A_1 = 12^{o}$

5. A swimmer can swim with velocity of 12 km/h in still water. Water flowing in a river has velocity 6 km/h. The direction with respect to the direction of flow of river water he should swim in order to reach the point on the other bank just opposite to his starting point is _____°. (Round off to the Nearest Integer)

(Find the angle in degrees)

Ans. Official Answer by NTA (120)

Sol.



$\Rightarrow V_{sr} \sin\theta = V_r$

$\Rightarrow 12\sin\theta = 6$

$\Rightarrow \sin\theta = y_2$

$\Rightarrow \theta = 30^o$

$\therefore \alpha = 120^o$

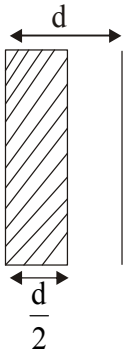
6. The energy dissipated by a resistor is 10 mJ in 1 s when an electric current of 2 mA flows through it. The resistance is _____ Ω. (Round off to the Nearest Integer)

Ans. Official Answer by NTA (2500)

Sol. Heat $= i^2Rt$

$$\Rightarrow R = \frac{\text{Heat}}{i^2t} = \frac{10\times10^{-3}}{(2\times10^{-3})^2\times1} = 2500\,\Omega$$

7. In a parallel plate capacitor set up, the plate area of capacitor is 2 m^2 and the plates are separated by 1 m. If the space between the plates are filled with a dielectric material of thickness 0.5 m and area 2 m^2 (see fig) the capacitance of the set-up will be _____ ε_o.
(Dielectric constant of the material = 3.2) (Round off to the Nearest Integer)



Ans. Official Answer by NTA (3)

Sol. $$C=\frac{\varepsilon_0 A}{\frac{d}{2k}+\frac{d}{2}}=\frac{2\varepsilon_0 A}{d+\frac{d}{k}}$$

$$C=\frac{2\times 2\varepsilon_0}{\frac{1}{3.2}+1}=\frac{4\times 3.2}{4.2}\varepsilon_0$$

$$\Rightarrow C=3.04\,\varepsilon_0$$

8. If one wants to remove all the mass of the earth to infinity in order to break it up completely.

The amount of energy that needs to be supplied will be $\frac{x}{5}\frac{GM_2}{R}$ where x is _____

(Round off to the Nearest Integer)

(M is the mass of earth, R is the radius of earth, G is the gravitational constant)

Ans. Official Answer by NTA (3)

Sol. Energy given $= U_f - U_i$

$$=0-\left(-\frac{3}{5}\frac{Gm^2}{R}\right)$$

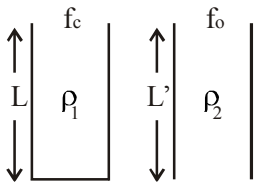
$$=\frac{3}{5}\frac{Gm^2}{R}$$

$$\therefore x=3$$

9. A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The comressibelity of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open pipe is $\frac{x}{3}L\sqrt{\frac{\rho_1}{\rho_2}}$

where x is _____. (Round off to the Nearest Integer)

Ans. Official Answer by NTA (4)

Sol. 

$f_c = f_0$

$\frac{3V_c}{4L} = \frac{2V_0}{2L}$

$\Rightarrow L' = \frac{4L}{3}\frac{V_0}{V_c}$

$\Rightarrow L' = \frac{4L}{3}\sqrt{\frac{\beta.\rho_1}{\rho_2.\beta}} = \frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$

$\therefore x = 4$

10. A body of mass 2 kg moves under a force of $(2\hat{i}+3\hat{j}+5\hat{k})$ N. It starts from rest and was at the origin initially. After 4 s, its new coordinates are (8, b, 20). The value of b is _____.

(Round off to the Nearest Integer)

Ans. Official Answer by NTA (12)

Sol. $\bar{a} = \frac{\bar{F}}{m} = \frac{2\hat{i}+3\hat{j}+5\hat{k}}{2} = \hat{i}+(1.5)\hat{j}+(2.5)\hat{k}$

$\bar{S} = \bar{u}t + \frac{1}{2}\bar{a}t^2$

$= 0 + \frac{1}{2}\left[\hat{i}+(1.5)\hat{j}+(2.5)\hat{k}\right](4)^2$

$= 8\hat{i}+12\hat{j}+20\hat{k}$

and it is given that $\bar{S} = 8\hat{i}+b\hat{j}+20\hat{k}$

$\therefore b = 12$