JEE Main March 2021

Question Paper With Text Solution

17 March. | Shift-1

PHYSICS

MATRIX

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

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JEE MAIN MARCH 2021 | 17TH MARCH SHIFT-1

SECTION – A

1. A polyatomic ideal gas has 24 vibrational modes. What is the value of γ ?

(1) 1.37

(2) 1.03

(3) 10.3

(4) 1.30

Ans. Official Answer NTA (2)

Sol.
$$f = 3+3+24 \leftarrow (\text{vibrational})$$
$$\uparrow \quad \uparrow$$
(Translation) (Rotational)

$$f = 30 \quad = \quad y = \frac{f+2}{f} = \frac{16}{15}$$

2. A solenoid of 1000 turns per metre has a core with relative permeability 500. Insulated windings of the solenoid is : (permeability of free space = $4\pi \times 10^{-7}\,H/m$)

(1) $\frac{\pi}{5}T$

(2) $2\times10^{-3}\,\pi\,T$

(3) $\pi\,T$

(4) $10^{-4}\,\pi\,T$

Ans. Official Answer NTA (3)

Sol.
$$B = \mu_r \mu_0 ni$$
$$B = 500\times 4\pi\times10^{-7}\times1000\times5$$
$$B = \pi$$

3. A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β to come to rest. If the total time elapsed is t seconds, the total distance travelled is :

(1) $\frac{\alpha\beta}{2(\alpha+\beta)}t^2$

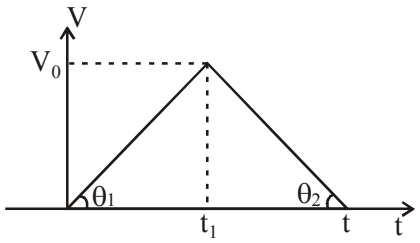
(2) $\frac{2\alpha\beta}{(\alpha+\beta)}t^2$

(3) $\frac{4\alpha\beta}{(\alpha+\beta)}t^2$

(4) $\frac{\alpha\beta}{4(\alpha+\beta)}t^2$

Ans. Official Answer NTA (1)

Sol. Graph of v–t curve (Slope of v–t curve is acceleration)



$\tan\theta_1 = \alpha$

$\tan\theta_2 = \beta$

Also $V_0 = \alpha t_1 = \beta(t - t_1)$

$t_1 = \frac{\beta t}{\alpha+\beta}$

Distance = Area under the curve

$$= \frac{1}{2}\times t \times V_0$$

$$= \frac{1}{2}\times t \times \left(\frac{\alpha\beta t}{\alpha+\beta}\right)$$

$$= \frac{\alpha\beta t^2}{2(\alpha+\beta)}$$

4. The thickness at the centre of a plano convex lens is 3 mm and the diameter is 6 cm. If the speed of light in the material of the lens is 2×10^8 ms^{-1}. The focal length of the lens is _____.

(1) 30 cm

(2) 1.5 cm

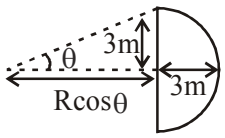
(3) 0.30 cm

(4) 15 cm

Question Type : MCQ
Question ID : 8643513343
Option 1 ID : 86435110039
Option 2 ID : 86435110041
Option 3 ID : 86435110042
Option 4 ID : 86435110040

Ans. Official Answer NTA (1)

Sol.



Given $V = 2\times10^8$

So $\mu = \frac{3}{2}$

$R\sin\theta = 3$ cm

$R - R\cos\theta = 3$ cm

$2R\sin\frac{\theta}{2}\cos\frac{\theta}{2} = 30$ .....(1)

$2R\sin^2\frac{\theta}{2} = 3$ .....(2)

From (2)/(1)

$\rightarrow \tan\frac{\theta}{2} = \frac{1}{10} = \frac{\theta}{2} = \frac{1}{10} = \theta = \frac{1}{5}$ (As angle is small)

Now

$R\sin\theta = 3$

$R\times\theta = 3$

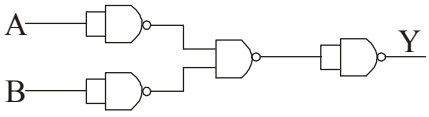
$R\times\frac{1}{5} = 3 \quad = R = 15$ cm

for focal length

$\frac{1}{f} = \left(\frac{3}{2}-1\right)\left(\frac{1}{R}\right)$

$f = 30$ cm

5. The output of the given combination gates represents :



(1) AND Gate

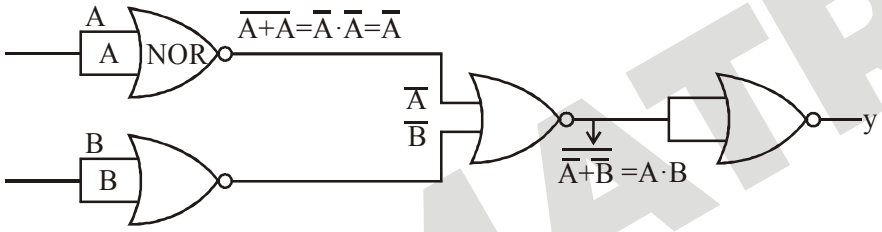
(2) NOR Gate

(3) XOR Gate

(4) NAND Gate

Ans. Official Answer NTA (4)

Sol.



$Y = \overleftarrow{\overline{A}.\overline{B}}$

$Y = \overline{A} + \overline{B}$

6. For what value of displacement the kinetic energy and potential energy of a simple harmonic oscillation become equal ?

(1) $x = \frac{A}{2}$

(2) $x = \pm\frac{A}{\sqrt{2}}$

(3) $x = \pm A$

(4) $x = 0$

Ans. Official Answer NTA (2)

Sol. In SHM

$$KE = \frac{1}{2}K(A^2 - x^2)$$

$PE = \frac{1}{2}Kx^2$

Given $KE = PE$

$x = \pm\frac{A}{\sqrt{2}}$

7. The vernier scale used for measurement has a positive zero error of 0.2 mm. If while taking a measurement it was noted that '0' on the vernier scale lies between 8.5 cm and 8.6 cm, vernier coincidence is 6, then the correct value of measurement is _____ cm.

(least count = 0.01 cm)

(1) 8.36 cm

(2) 8.54 cm

(3) 8.58 cm

(4) 8.56 cm

Ans. Official Answer NTA (2)

Sol. Reading = 8.5 + [6×0.001 – 0.02]

= 8.54 cm

8. When two soap bubbles of radii a and b (b > a) coalesce, the radius of curvature of common surface is :

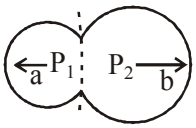
(1) $\frac{ab}{a+b}$

(2) $\frac{ab}{b-a}$

(3) $\frac{b-a}{ab}$

(4) $\frac{a+b}{ab}$

Ans. Official Answer NTA (2)

Sol. 

$P_1 = P_0 + \frac{4T}{a}$ .....(1)

$P_2 = P_0 + \frac{4T}{b}$ .....(2)

also $P_1 = P_2 + \frac{4T}{r}$

from (1) (2) & (3)

$\frac{1}{r} = \frac{1}{a} - \frac{1}{b}$

$r = \frac{ab}{b-\alpha}$

9. A Carnot's engine working between 400 K and 800 K has a work output of 1200 J per cycle. The amount of heat energy supplied to the engine from the source in each cycle is :

(1) 2400 J

(2) 3200 J

(3) 1800 J

(4) 1600 J

Ans. Official Answer NTA (1)

Sol. for carnot engine

$\frac{W}{Q} = 1 - \frac{T_2}{T_1}$

$\Rightarrow \frac{1200}{Q} = 1 - \frac{400}{800}$

$\Rightarrow Q = 2400\ J$

10. Which level of the single ionized carbon has the same energy as the ground state energy of hydrogen atom ?

(1) 6

(2) 4

(3) 1

(4) 8

Ans. Official Answer NTA (1)

Sol. $E_n = 13.6\frac{z^2}{n^2}$

Ground level

Energy of H-atom $= 13.6$

Given $E_n = 13.6\frac{z^2}{n^2} = 13.6$

$n = z = 6$

11. Two ideal polyatomic gases at temperatures T_1 and T_2 are mixed so that there is no loss of energy. If f_1 and f_2 , m_1 and m_2 , n_1 and n_2 be the degrees of freedom, masses, number of molecules of the first and second gas respectively, the temperature of mixture of these two gases is :

(1) $\frac{n_1T_1 + n_2T_2}{n_1 + n_2}$

(2) $\frac{n_1f_1T_1 + n_2f_2T_2}{f_1 + f_2}$

(3) $\frac{n_1f_1T_1 + n_2f_2T_2}{n_1 + n_2}$

(4) $\frac{n_1f_1T_1 + n_2f_2T_2}{n_1f_1 + n_2f_2}$

Ans. Official Answer NTA (4)

Sol. $U_1 + U_2 = U_{mix}$

$f_{mix} = \frac{n_1f_1 + n_2f_2}{n_1 + n_2}$

$\Rightarrow \frac{f_1}{2}n_1RT_1 + \frac{f_2}{2}n_2RT_2 = \frac{f_{mix}}{2}(n_1 + n_2)RT_{mix}$

$\Rightarrow T_{mix} = \frac{f_1n_1T_1 + f_2n_2T_2}{n_1f_1 + n_2f_2}$

12. A boy is rolling a 0.5 kg ball on the frictionless floor with the speed of 20 ms^{-1}. The ball gets deflected by an obstacle on the way. After deflection it moves with 5% of its initial kinetic energy. What is the speed of the ball now ?

(1) 14.41 ms^{-1}

(2) 4.47 ms^{-1}

(3) 1.00 ms^{-1}

(4) 19.0 ms^{-1}

Ans. Official Answer NTA (2)

Sol. In case of pure Rolling

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}\times\frac{2}{5}mR^2\times\frac{V^2}{R^2}$$

$$= \frac{1}{2}mv^2 + \frac{1}{5}mv^2$$

$$= \frac{7}{10}mv^2$$

Given

$$KE_f = \frac{5}{100}KE_i$$

$$= \frac{7}{10}mv^2{}_f = \frac{5}{100}\frac{7}{10}m(20)^2$$

$$= V_f{}^2 = \frac{5}{100}\times 400$$

$$V_f = \sqrt{20}$$

$$= 4.47 \text{ m/sec}$$

13. An AC current is given by $I = I_1\sin\omega t + I_2\cos\omega t$ .A hot wire ammeter will give a reading:

(1) $\sqrt{\frac{I_1^2 + I_2^2}{2}}$

(2) $\frac{I_1 + I_2}{\sqrt{2}}$

(3) $\sqrt{\frac{I_1^2 - I_2^2}{2}}$

(4) $\frac{I_1 + I_2}{2\sqrt{2}}$

Ans. Official Answer NTA (1)

Sol. Ammeter reads rms value of current

$$Irm = \sqrt{\frac{\int_0^T I^2 dt}{T}}$$

$$= \sqrt{\frac{\int_0^T I_1^2 \sin^2 \omega t}{T} + \frac{\int_0^T I^2_2 \cos^2 \omega t}{T} + \frac{\int_0^T I_1 I_2 \sin(2\omega t)}{T}}$$

$$= \sqrt{\frac{I^2_1 + I^2_2}{2}}$$

14. Two identical metal wires of thermal conductivities K_1 and K_2 respectively are connected in series. The effective thermal conductivity of the combination is :

(1) $\frac{K_1 + K_2}{K_1 K_2}$

(2) $\frac{2K_1 K_2}{K_1 + K_2}$

(3) $\frac{K_1 + K_2}{2K_1 K_2}$

(4) $\frac{K_1 K_2}{K_1 + K_2}$

Ans. Official Answer NTA (2)

Sol.

$$R_1 = \frac{L}{K_1 A} \qquad R_2 = \frac{L}{K_2 A}$$

Now

$$R_{eq} = \frac{2L}{K_{eq} A}$$

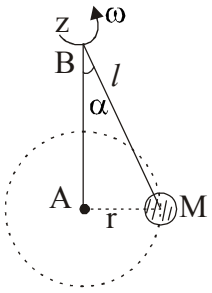
as both are connected in series

So $R_{eq} = R_1 + R_2$

$$\Rightarrow \frac{2L}{K_{eq} A} = \frac{L}{K_1 A} + \frac{L}{K_2 A}$$

$$K_{eq} = \frac{2K_1 K_2}{K_1 + K_2}$$

15. A mass M hangs on a massless rod of length l which rotates at a constant angular frequency. The mass M moves with steady speed in a circular path of constant radius. Assume that the system is in steady circular motion with constant angular velocity ω. The angular momentum of M about point A is L_A which lies in the positive z direction and the angular momentum of M about point B is L_B. The correct statement for this system is :



(1) L_B is constant, both in magnitude and direction

(2) L_A is constant, both in magnitude and direction

(3) L_A and L_B are both constant in magnitude and direction

(4) L_B is constant in direction with varying magnitude

Ans. Official Answer NTA (2)

Sol. L_A is constant in magnitude as wel as direction

L_B have constant magnitude but different direction.

16. A current of 10 A exists in a wire of crosssectional area of 5 mm^2 with a drift velocity of 2×10^{-3} ms^{-1}. The number of free electrons in each cubic meter of the wire is _____.

(1) 1×10^{23}

(2) 625×10^{25}

(3) 2×10^{25}

(4) 2×10^{6}

Ans. Official Answer NTA (2)

$I = neAV_d$

Sol. $10 = n \times (1.6 \times 10^{-19}) \times (5 \times 10^{-6}) \times 2 \times 10^{-3}$

$n = 625 \times 10^{25}$

17. If an electron is moving in the n^{th} orbit of the hydrogen atom, then its velocity (v_n) for the n^{th} orbit is given as :

(1) $v_n \propto n$

(2) $v_n \propto n^2$

(3) $v_n \propto \frac{1}{n^2}$

(4) $v_n \propto \frac{1}{n}$

Ans. Official Answer NTA (4)

Sol. Velocity in n^{th} orbit $\propto \frac{z}{n}$

$V \propto \frac{1}{n}$

18. An electron of mass m and a photon have same energy E. The ratio of wavelength of electron to that of photon is : (c being the velocity of light)

(1) $c(2mE)^{1/2}$

(2) $\left(\frac{E}{2m}\right)^{1/2}$

(3) $\frac{1}{c}\left(\frac{2m}{E}\right)^{1/2}$

(4) $\frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$

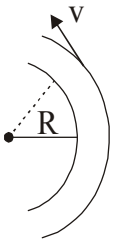
Ans. Official Answer NTA (4)

Sol. $\lambda_e = \frac{h}{P} = \frac{h}{\sqrt{2mE}}$ (Both have same energy)

$\lambda_P = \frac{hc}{E}$ (for photon)

$$\frac{\lambda_e}{\lambda_P}=\frac{\frac{h}{\sqrt{2mE}}}{\frac{hc}{E}}=\frac{1}{c}\sqrt{\frac{E}{2m}}$$

19. A modern grand - prix racing car of mass m is travelling on a flat track in a circular arc of radius R with a speed v. If the coefficient of static friction between the tyres and the track is μ_s, then the magnitude of negative lift F_L acting downwards on the car is : (Assume forces on the four tyres are identical and g = acceleration due to gravity)



(1) $m\left(\frac{v^2}{\mu_s R}-g\right)$

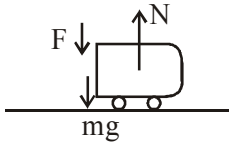
(2) $m\left(\frac{v^2}{\mu_s R}+g\right)$

(3) $m\left(g-\frac{v^2}{\mu_s R}\right)$

(4) $-m\left(g+\frac{v^2}{\mu_s R}\right)$

Ans. Official Answer NTA (1)

Sol.



$$f_{req} = \frac{mv^2}{R}$$

$$\Rightarrow f = \mu(F + mg) = \frac{mv^2}{R}$$

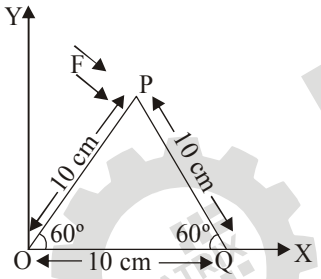
$$\mu F = \frac{mv^2}{R} - \mu mg$$

$$F = \frac{mv^2}{\mu R} - mg$$

$$\text{So } F = mg - \frac{mv^2}{\mu R}$$

$$= m\left(g - \frac{V^2}{\mu R}\right)$$

20. A triangular plate is shown. A force $\vec{F} = 4\hat{i} - 3\hat{j}$ is applied at point P. The torque at point P with respect to point 'O' and 'Q' are :



(1) $-15 - 20\sqrt{3}, 15 - 20\sqrt{3}$

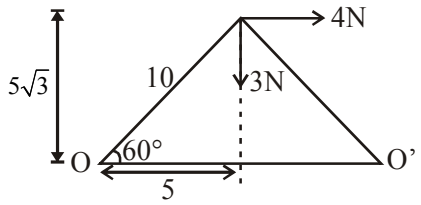
(2) $-15 + 20\sqrt{3}, 15 + 20\sqrt{3}$

(3) $15 + 20\sqrt{3}, 15 - 20\sqrt{3}$

(4) $15 - 20\sqrt{3}, 15 + 20\sqrt{3}$

Ans. Official Answer NTA (1)

Sol.



$\tau_0 = 3\times5 + 4\times5\sqrt{3}$

$= 15 + 20\sqrt{3}$

$\tau_0' = 3\times5 + 4\times5\sqrt{3}$

$= 20\sqrt{3} - 15$

or

$15 - 20\sqrt{3}$

SECTION B

1. For VHF signal broadcasting,_____km^2 of maximum service area will be covered by an antenna tower of height 30 m, if the receiving antenna is placed at ground. Let radius of the earth be 6400 km. (Round off to the Nearest Integer) (Take π as 3.14)

Ans. Official Answer NTA (1206)

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

$A = \pi d^2$

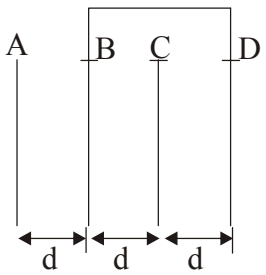
$A = \pi 2Rh$

$= 3.17\times2\times6400\times\frac{30}{1000}$

$A = 1206\ km^2$

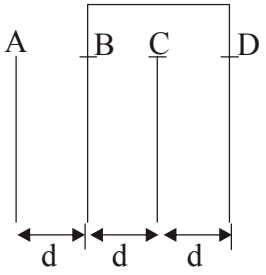
2. Four identical rectangular plates with length, $l = 2$ cm and breadth, $b = \frac{3}{2}$ cm are arranged as shown in figure. The equivalent capacitance between A and C is $\frac{x\varepsilon_0}{d}$. The vaule of x is _____.

(Round off to the Nearest Integer)



Ans. Official Answer NTA (2)

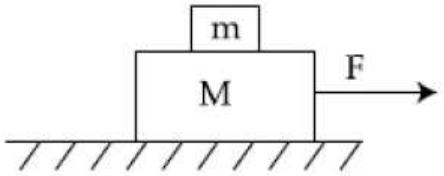
Sol.



(Given Area $= 2\times 3/2 = 3\,cm^2$)

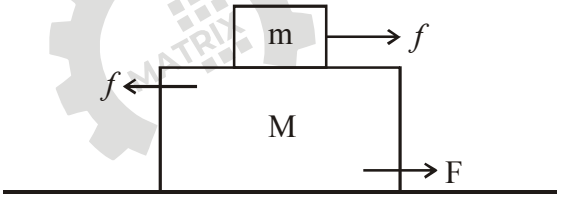
$$C_{eq} = \frac{2C\times C}{3C} = \frac{2}{3}C = \frac{2}{3}\frac{60A}{d} = \frac{2\varepsilon_0}{d}$$

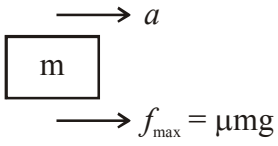
3. Two blocks (m = 0.5 kg and M = 4.5 kg) are arranged on a horizontal frictionless table as shown in figure. The coefficient of static friction between the two blocks is $\frac{3}{7}$. Then the maximum horizontal force that can be applied on the larger block so that the blocks move together is _____N. (Round off to the Nearest Integer) [Take g as 9.8 ms^{-2}]

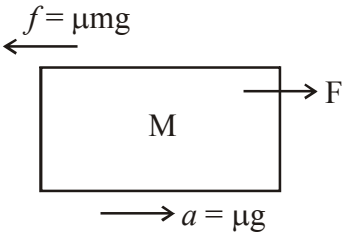


Ans. Official Answer NTA (2z1)

Sol.







$f_{max} = \mu mg$

$a = \frac{\mu mg}{m} = \mu g$

(Maximum acceleration possible for 'm')

$F - \mu mg = M(\mu g)$

$F = (M + m)\mu g$

$F = 5 \times \frac{3}{7} \times 9.8$

$F = 21\ N$

4. The equivalent resistance of series combination of two resistors is 's'. When they are connected in parallel, the equivalent resistance is 'p'. If s = np, then the minimum value for n is _____. (Round off to the Nearest Integer)

Ans. Official Answer NTA (4)

Sol. In series

$R_{eq} = R_1 + R_2 = S$

Given $(R_1 + R_2) = \frac{n(R_1 R_2)}{R_1 + R_2}$

$\leq R_1^2 + R_2^2 = nR_1R_2$

$\leq R_1^2 + R_2^2 + (2 - n)R_1R_2 = 0$

$D \geq 0$

$\leq (2 - n)^2 \geq 4$

$4 + n^2 - 4n \geq 4$

$n \geq 4$

$n_{min} = 4$

5. The following bodies,

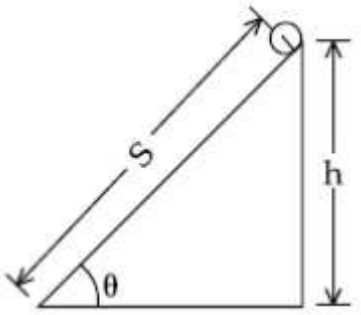
(1) a ring

(2) a disc

(3) a solid cylinder

(4) a solid sphere,

Of same mass 'm' and radius 'R' are allowed to roll down without slipping simultaneously from the top of the inclined plane. The body which will reach first at the bottom of the inclined plane is _____.
[Mark the body as per their respective numbering given in the question]



Ans. Official Answer NTA (4)

Sol. In case of rolling motion on inclined plane

$$a = \frac{g\sin\theta}{1+\left(\frac{I}{mR^2}\right)}$$

for minimum time, acceleration should be maximum.
for maximu acceleration, moment of interia should be minumum.

I is minumum for solid sphere.

6. The angular speed of truck wheel is increased from 900 rpm to 2460 rpm in 26 second. The number of revolutions by the truck engine during this time is _____.

(Assuming the acceleration to be uniform).

Ans. Official Answer NTA (728)

Sol.

$$\omega_i = 900\times\frac{2\pi}{60} \quad \text{rad/sec}$$

$$= 30\pi \quad \text{rad/sec}$$

$$\omega_f = 2460\times\frac{2\pi}{60} = 82\pi \text{ rad/sec}$$

$$\omega_f = \omega_i + \alpha t$$

$$82\pi = 30\pi + \alpha\times 26 \quad \Rightarrow \quad \alpha = \frac{(82-30)}{26}\pi$$

$$\alpha = 2\pi \quad \text{rad/sec}^2$$

$\Rightarrow \omega_f^2 = \omega_i^2 + 2\alpha\theta$

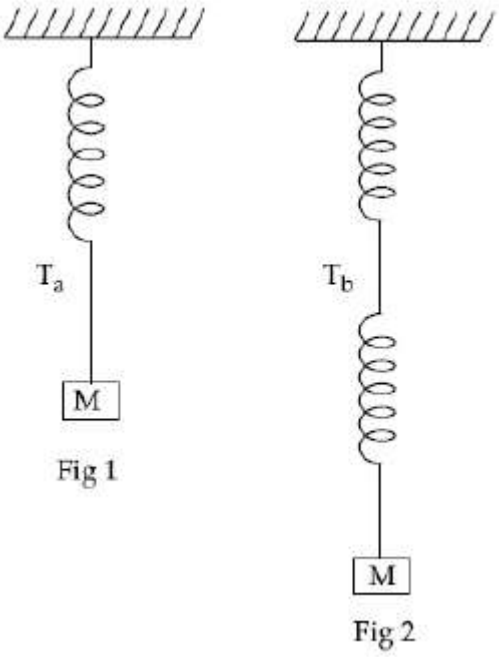
$\Rightarrow \theta = \dfrac{(82\pi)^2 - (30\pi)^2}{2 \times 2\pi}$

$\theta = 1456\pi$

no of revolution = 728

7. Consider two identical springs each of spring constant k and negligible mass compared to the mass M as shown. Fig. 1 shows one of them and Fig. 2 shows their series combination.

The ratios of time period of oscillation of the two SHM is $T_b/T_a = \sqrt{x}$, where value of x is _____. (Round off to the Nearest Integer)



Ans. Official Answer NTA (2)

Sol For fig–1

$T_a = 2\pi\sqrt{\dfrac{M}{K}}$

For fig–2

$K_{eq} = \dfrac{k}{2}$ (series combination)

$$T_b = 2\pi\sqrt{\frac{m}{\frac{k}{2}}} = 2\pi\sqrt{\frac{2m}{k}}$$

So $\frac{T_b}{T_a} = \sqrt{2} \quad \Rightarrow x = 2$

8. The radius in kilometer to which the present radius of earth (R = 6400 km) to be compressed so that the escape velocity is increased 10 times is _____.

Ans. Official Answer NTA (64)

Sol
$$V_E = \sqrt{\frac{2GM}{R}}$$
$$V_e' = 10\,Ve$$
$$\text{So } R' = \frac{R}{100}$$
$$R' = \frac{6400}{100} = 64\,km$$

9. If 2.5×10^{-6} N average force is exerted by a light wave on a non -reflecting surface of 30 cm^2 area during 40 minutes of time span, the energy flux of light just before it falls on the surface is _____ W/cm^2. (Round off to the Nearest Integer)

(Assume complete absorption and normal incidence conditions are there)

Ans. Official Answer NTA (25)

Sol
$$F = \frac{IA}{C}$$
$$I = \frac{FC}{A} = \frac{2.5\times10^{-6}\times3\times10^{8}}{30} = 25\,W/cm^2$$

10. A parallel plate capacitor whose capacitance C is 14 pF is charged by a battery to a potential difference V = 12 V between its plates. The charging battery is now disconnected and a porcelin plate with k = 7 is inserted between the plates, then the plate would oscillate back and forth between the plates with a constant mechanical energy of _____pJ.

Ans. Official Answer NTA (864)

Sol $U_i = \frac{1}{2} \times 14 \times 12 \times 12 \text{ pJ} = 1008 \text{ pJ}$

$U_f = \frac{1008}{7} \text{ pJ} = 144 \text{ pJ}$

Mechanical energy = ΔU = 1008 – 144 = 864 pJ