Physicsaholics

DPP – 3 (SHM)

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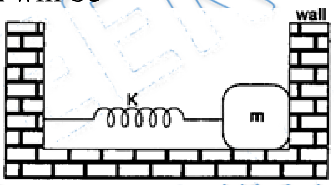
Q 1. A particle of mass 5×10^{-5} kg is placed at the lowest point of a smooth parabola having the equation $x^2 = 40y$ (x, y in cm). If it is displaced slightly and it moves such that it is constrained to move along the parabola, the angular frequency of oscillation will be, approximately:

(a) $1\ s^{-1}$ (b) $7\ s^{-1}$ (c) $5\ s^{-1}$ (d) None

Q 2. In the figure, the block of mass m, attached to the spring of stiffness k is in contact with the completely elastic wall, and the compression in the spring is e. The spring is compressed further by e by displacing the block towards left and is then released. If the collision between the block and the wall is completely elastic then the time period of oscillations of the block will be

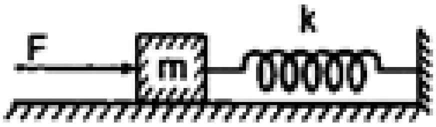


(a) $\frac{2\pi}{3}\sqrt{\frac{m}{k}}$ (b) $2\pi\sqrt{\frac{m}{k}}$ (c) $\frac{\pi}{3}\sqrt{\frac{m}{k}}$ (d) $\frac{\pi}{6}\sqrt{\frac{m}{k}}$

Q 3. Frequency of a particle executing SHM is 10 Hz. The particle is suspended from a vertical spring. At the highest point of its oscillation the spring is unstretched. Maximum speed of the particle is: (g = 10 m/s^2)

(a) 2π m/s (b) π m/s (c) $\frac{1}{2\pi}$ m/s (d) zero

Q 4. A constant force F is applied on a spring block system as shown in figure. The mass of the block is m and spring constant is k. The block is placed over a smooth surface. Initially the spring was unstretched. Choose the correct alternative(s).



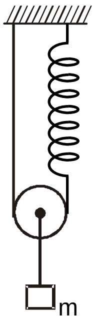
(a) The block will execute SHM

(b) Amplitude of oscillation is $\frac{F}{2k}$

(c) Time period of oscillation is $2\pi\sqrt{\frac{m}{k}}$

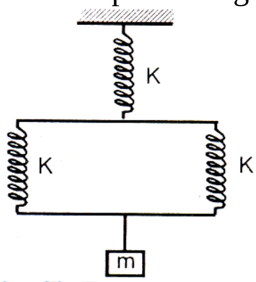
(d) speed of block at displacement x is $\sqrt{\frac{2Fx-kx^2}{m}}$

Q 5. The system is released from rest with spring initially in its natural length. If mass of the block m = 10 kg, and spring constant k = 100 N/m, then maximum extension in spring is:



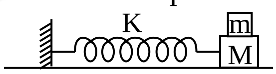
(a) 1m (b) 1/2 m (c) 2 m (d) 2.5 m

Q 6. One body of mass m is suspended from three springs as shown in figure each spring has spring constant k. If mass m is displaced slightly then time period of oscillation is



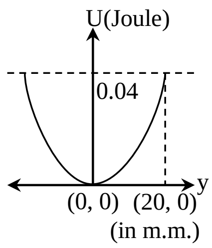
(a) $2\pi\sqrt{\frac{m}{3k}}$ (b) $2\pi\sqrt{\frac{3m}{2k}}$ (c) $2\pi\sqrt{\frac{2m}{3k}}$ (d) $2\pi\sqrt{\frac{3k}{m}}$

Q 7. A block of mass m =1 kg placed on top of another block of mass M = 5 kg is attached to a horizontal spring of force constant K = 20 N/m as shown in figure. The coefficient of friction between the blocks is μ whereas the lower block slides on a frictionless surface. The amplitude of oscillation is 0.4 m. What is the minimum value of μ such that the upper block does not slip over the lower block?



(a) 0.133 (b) 0.5 (c) 0.362 (d) 0.21

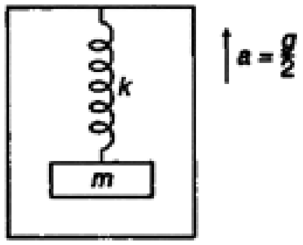
Q 8. The variation in potential energy of a harmonic oscillator is as shown in fig. The force constant is



(a) $1 \times 10^2\ Nm^{-1}$ (b) $2 \times 10^2\ Nm^{-1}$
(c) $0.667 \times 10^2\ Nm^{-1}$ (d) $3 \times 10^2\ Nm^{-1}$

Comprehension (Q9 – Q10)

There is a spring block system in a lift moving upwards with acceleration a = g/2



Q 9. In mean position (of block's oscillations) spring is:

(a) compressed by $\frac{mg}{2k}$ (b) elongated by $\frac{mg}{k}$

(c) elongated by $\frac{mg}{2k}$ (d) elongated by $\frac{3mg}{2k}$

Q 10. If maximum extension in the spring is $\frac{5mg}{2k}$, then maximum upward acceleration (a_1) and maximum downward acceleration (a_2) of the block are:

(a) $a_1 = g/2$ (b) $a_1 = 3g/2$

(c) $a_2 = g/2$ (d) $a_2 = 3g/2$

Q 11. Two masses M and m are suspended together by a massless spring of spring constant k. When masses are in equilibrium M is removed without disturbing system. The amplitude of oscillation is

(a) $\frac{Mg}{k}$ (b) $\frac{mg}{k}$ (c) $\frac{(M+m)g}{k}$ (d) $\frac{(M-m)g}{k}$

Q 12. The potential energy of a particle of mass 1 kg in motion along the x-axis is given by:U = 4(1 – cos 2x)J Here : x is in metres. The period of small oscillations (in sec) is

(a) 2 π (b) π (c) π/2 (d) √2 π

Q 13. The potential energy of a particle of mass 1/2 kg is, U = 10 + $(x – 2)^2$. Here, U is in joule and x in metres. On the positive x-axis particle travels upto x = + 6 m. Choose the wrong statement:

`
(a) On negative x-axis particle travels upto x = -2 m
(b) The maximum kinetic energy of the particle is 16 J
(c) The period of oscillation of the particle is π seconds
(d) None of the above

Q 14. A particle free 'to move along the x-axis has potential energy given by U(x) = k[1-exp($-x^2$)] for - ∞ ≤ x ≤ +∞, where k is a positive constant of appropriate dimensions. Then:

(a) at points away from the origin, the particle is in unstable equilibrium
(b) for any finite non-zero value of x, there is a force directed away from the origin
(c) if its total mechanical energy is k/2, it has its minimum kinetic energy at the origin
(d) for small displacements from x = 0, the motion is simple harmonic

Q 15. A particle of mass 2 kg moving along x-axis has potential energy given by $U = 16x^2 - 32x$ (in joule), where x is in meter. Its speed when passing through x = 1m is $2ms^{-1}$. Then-

(a) The motion of particle is uniformly accelerated motion

(b) The motion of particle is oscillatory from x = 0.5 m to x = 1.5 m

(c) The motion of particle is simple harmonic

(d) The period of oscillatory motion is $\pi/2$ s.

Q 16. A particle of mass m is executing oscillations about the origin on the x-axis. Its potential energy is $V(x) = k|x|^3$ where k is a positive constant. If the amplitude of oscillation is a, then its time period T is-

(a) proportional to $1/\sqrt{a}$

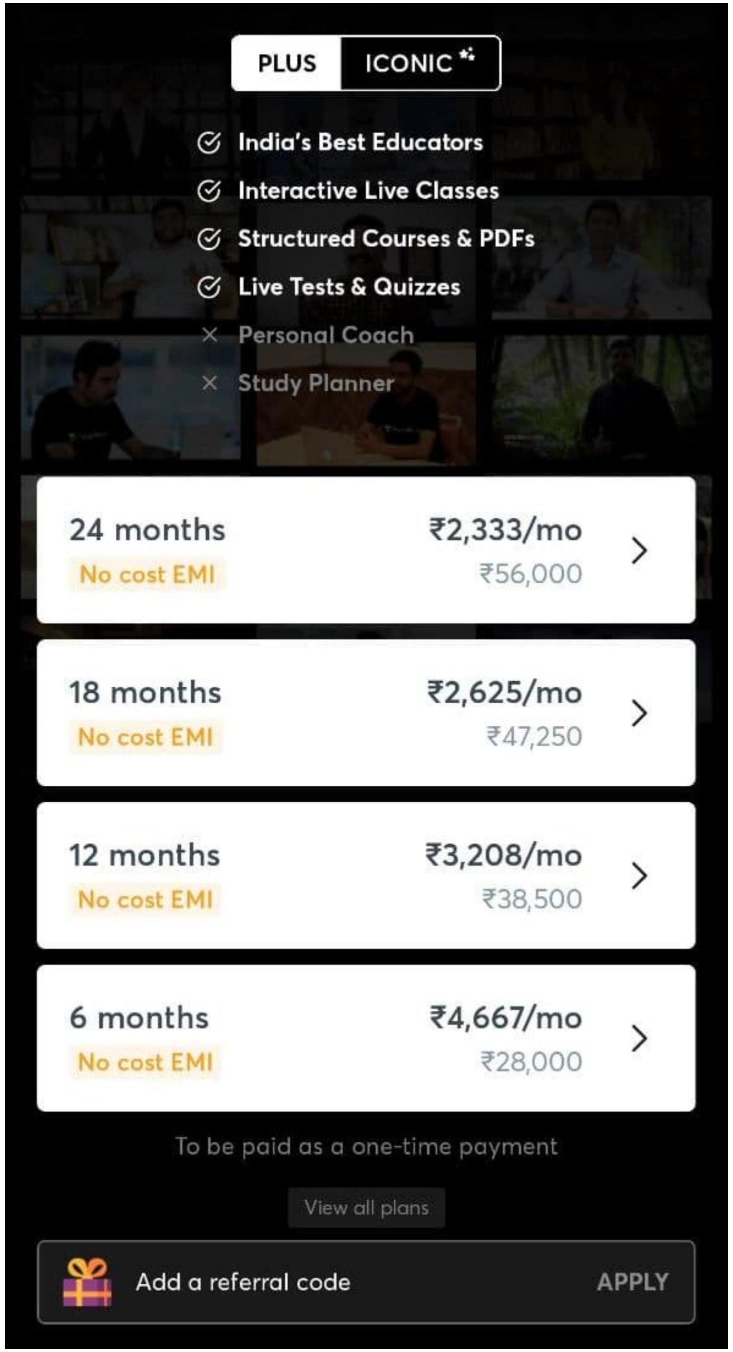
(b) independent of a

(c) proportional to $\sqrt{a}$

(d) proportional to $a^{3/2}$

Answer Key

Q.1 b	Q.2 a	Q.3 c	Q.4 a,c,d	Q.5 a
Q.6 b	Q.7 a	Q.8 b	Q.9 d	Q.10 b,c
Q.11 a	Q.12 c	Q.13 d	Q.14 d	Q.15 b,c,d
Q.16 a				



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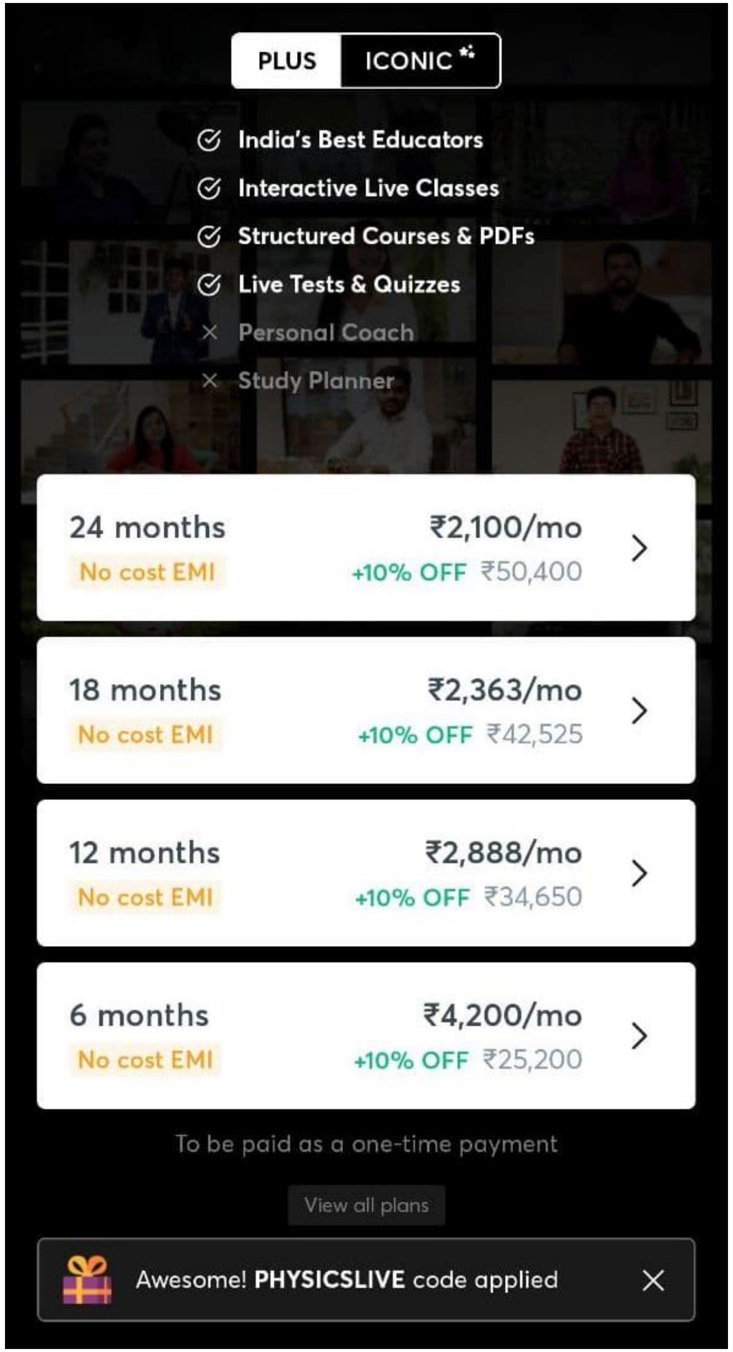

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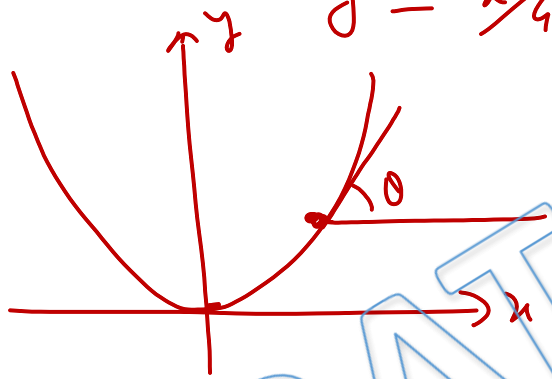
Physics DPP- Solution

DPP- 3 S.H.M. : Spring Block System,Time Period of S.H.M. of Different Systems

By Physicsaholics Team

Q1) A particle of mass 5×10^{-5} kg is placed at the lowest point of a smooth parabola having the equation $x^2 = 40y$ (x, y in cm). If it is displaced slightly and it moves such that it is constrained to move along the parabola, the angular frequency of oscillation will be, approximately:

$y = x^2/40\text{cm}$



$\tan\theta = \frac{dy}{dx} = \frac{2x}{40} = \frac{x}{20\text{cm}}$

$a = g\sin\theta \simeq g\tan\theta$ (Since θ is small)

$a = g\frac{x \times 100}{20}$

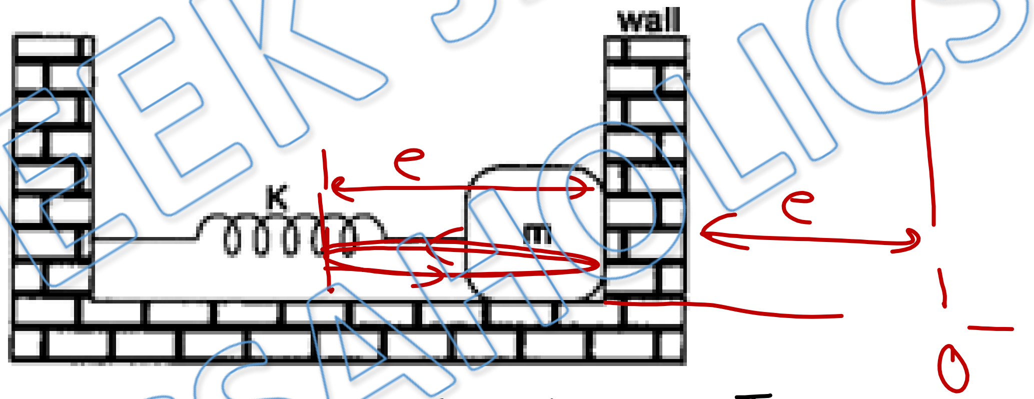
(a) $1\ s^{-1}$ (b) $7\ s^{-1}$ (c) $5\ s^{-1}$ (d) None

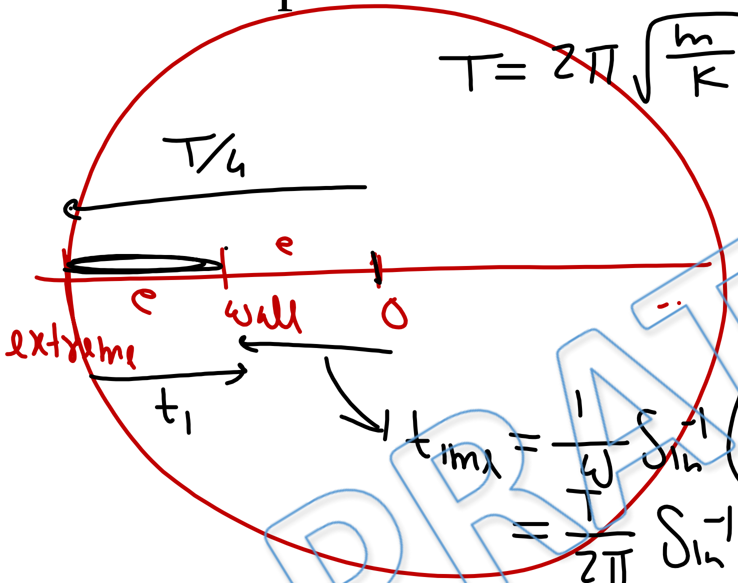
$a = 5gx = 49x$

$\omega^2 = 49$

$\omega = 7$

Q2) In the figure, the block of mass m, attached to the spring of stiffness k is in contact with the completely elastic wall, and the compression in the spring is e. The spring is compressed further by e by displacing the block towards left and is then released. If the collision between the block and the wall is completely elastic then the time period of oscillations of the block will be





$T = 2\pi\sqrt{\frac{m}{K}}$

$t_{min} = \frac{1}{\omega}\sin^{-1}\left(\frac{x}{A}\right) = \frac{T}{2\pi}\sin^{-1}\left(\frac{1}{2}\right) = \frac{T}{2\pi}\times\frac{\pi}{6} = \frac{T}{12} \Rightarrow t_1 = \frac{T}{4} - \frac{T}{12}$

(a) $\frac{2\pi}{3}\sqrt{\frac{m}{k}}$ (b) $2\pi\sqrt{\frac{m}{k}}$ (c) $\frac{\pi}{3}\sqrt{\frac{m}{k}}$ (d) $\frac{\pi}{6}\sqrt{\frac{m}{k}}$

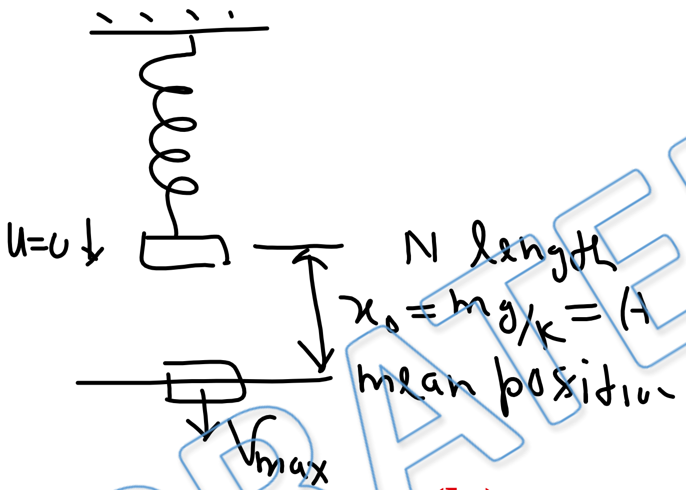
Time period of oscillation $= 2t_1 = \frac{T}{2} - \frac{T}{6} = \frac{T}{3}$

$= \frac{2\pi}{3}\sqrt{\frac{m}{k}}$

Q3) Frequency of a particle executing SHM is 10 Hz. The particle is suspended from a vertical spring. At the highest point of its oscillation the spring is unstretched. Maximum speed of the particle is: ($g = 10\ m/s^2$)

$$f = 10 \Rightarrow T = \frac{1}{10} = 2\pi\sqrt{\frac{m}{K}}$$

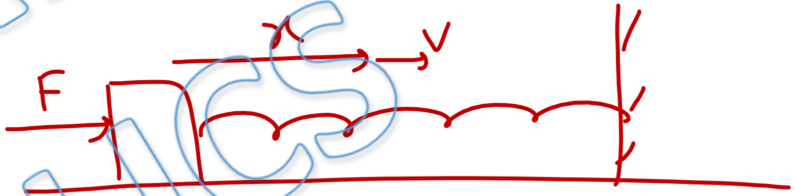
$$\Rightarrow \sqrt{\frac{m}{K}} = \frac{1}{20\pi}$$



(a) 2π m/s (b) π m/s (c) $\frac{1}{2\pi}$ m/s (d) zero

$$V_{max} = A\omega = \frac{mg}{K}\sqrt{\frac{K}{m}} = g\sqrt{\frac{m}{K}} = \frac{10}{20\pi} = \frac{1}{2\pi}$$

Q4) A constant force F is applied on a spring block system as shown in figure. The mass of the block is m and spring constant is k. The block is placed over a smooth surface. Initially the spring was unstretched. Choose the correct alternative(s).



(a) The block will execute SHM

(b) Amplitude of oscillation is $\frac{F}{2k}$ → Amplitude = Distance b/w mean & extreme $= F/k$

(c) Time period of oscillation is $2\pi\sqrt{\frac{m}{k}}$

(d) speed of block at displacement x is $\sqrt{\frac{2Fx-kx^2}{m}}$

$W_F + W_{sF} = K_f - K_i$

$\Rightarrow Fx - \frac{1}{2}kx^2 = \frac{1}{2}mv^2 - 0$

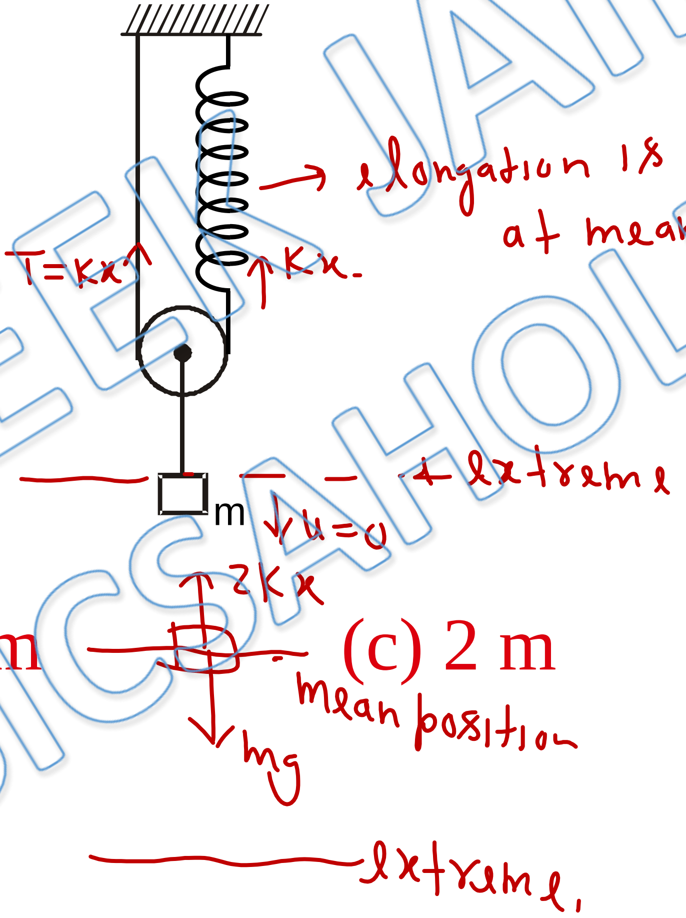
Q5) The system is released from rest with spring initially in its natural length. If mass of the block m = 10 kg, and spring constant k = 100 N/m, then maximum extension in spring is:

$2Kx = mg$

$x = \frac{mg}{2K}$

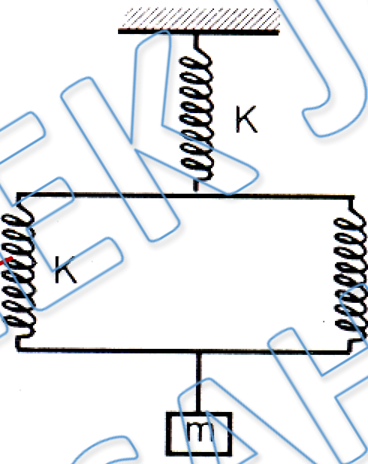
maximum elongation in spring

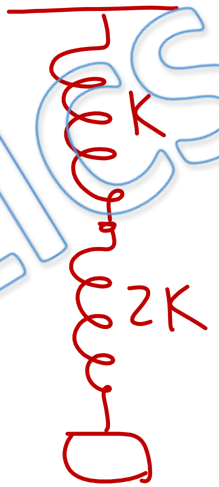
$= 2x = \frac{mg}{K} = \frac{10 \times 10}{100}$



(a) 1m ✓ (b) 1/2 m (c) 2 m (d) 2.5 m

Q6) One body of mass m is suspended from three springs as shown in figure each spring has spring constant k. If mass m is displaced slightly then time period of oscillation is





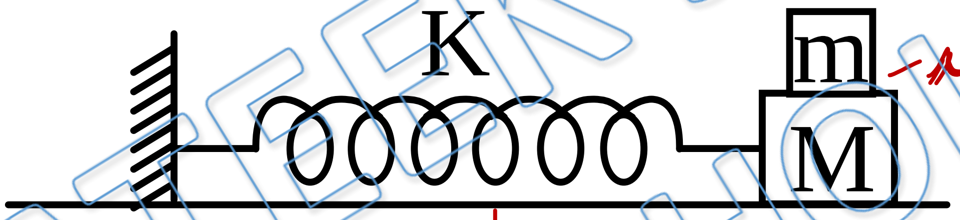
$K_{eff} = \frac{K \times 2K}{3K} = \frac{2K}{3}$

(a) $2\pi\sqrt{\frac{m}{3k}}$ (b) $2\pi\sqrt{\frac{3m}{2k}}$ (c) $2\pi\sqrt{\frac{2m}{3k}}$ (d) $2\pi\sqrt{\frac{3k}{m}}$

$T = 2\pi\sqrt{\frac{m}{K_{eff}}} = 2\pi\sqrt{\frac{3m}{2k}}$

Q7) A block of mass m =1 kg placed on top of another block of mass M = 5 kg is attached to a horizontal spring of force constant K = 20 N/m as shown in figure. The coefficient of friction between the blocks is μ whereas the lower block slides on a frictionless surface. The amplitude of oscillation is 0.4 m. What is the minimum value of μ such that the upper block does not slip over the lower block?

$\omega^2 = \frac{K}{M+m} = \frac{20}{6} = 10/3$



for upper block

$ma = f_r$

$f_{r_{max}} = m a_{max}$

$f_{r_{max}} = m\omega^2 A$

for no sliding $\mu m g \geq m\omega^2 A$

(a) 0.133 (b) 0.5 (c) 0.362 (d) 0.21

$\mu \geq \frac{\omega^2 A}{g}$

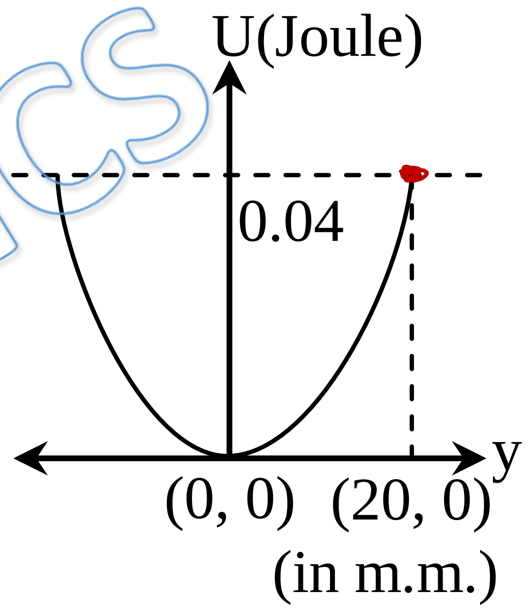
$\geq \frac{10 \times .4}{3 \times 10}$

Q8) The variation in potential energy of a harmonic oscillator is as shown in fig. The force constant is

$F = m\omega^2 x$ (with $m\omega^2 = K$)

$U = \frac{1}{2} m\omega^2 x^2$

$U = \frac{1}{2} K x^2$



(a) $1 \times 10^2\ Nm^{-1}$

(b) $2 \times 10^2\ Nm^{-1}$

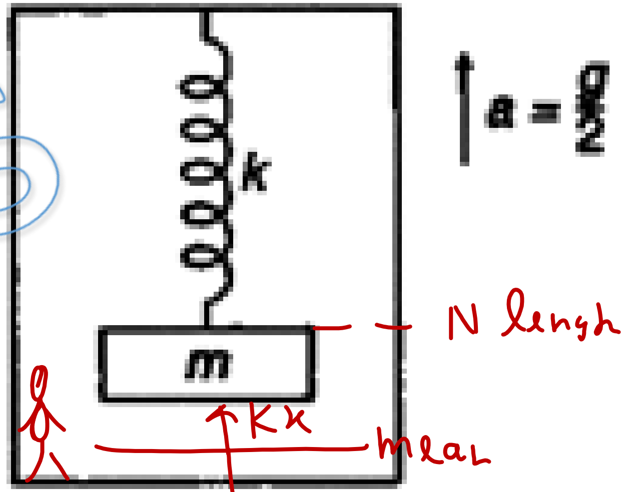
(c) $0.667 \times 10^2\ Nm^{-1}$

(d) $3 \times 10^2\ Nm^{-1}$

$K = \frac{2U}{x^2} = \frac{2 \times .04}{20 \times 20 \times 10^{-6}} = \frac{2 \times 4 \times 10^2}{2 \times 2} =$

Comprehension (Q9-Q10)

There is a spring block system in a lift moving upwards with acceleration a = g/2



Q9. In mean position (of block's oscillations) spring is:

(a) compressed by $\frac{mg}{2k}$

(b) elongated by $\frac{mg}{k}$

(c) elongated by $\frac{mg}{2k}$

(d) elongated by $\frac{3mg}{2k}$

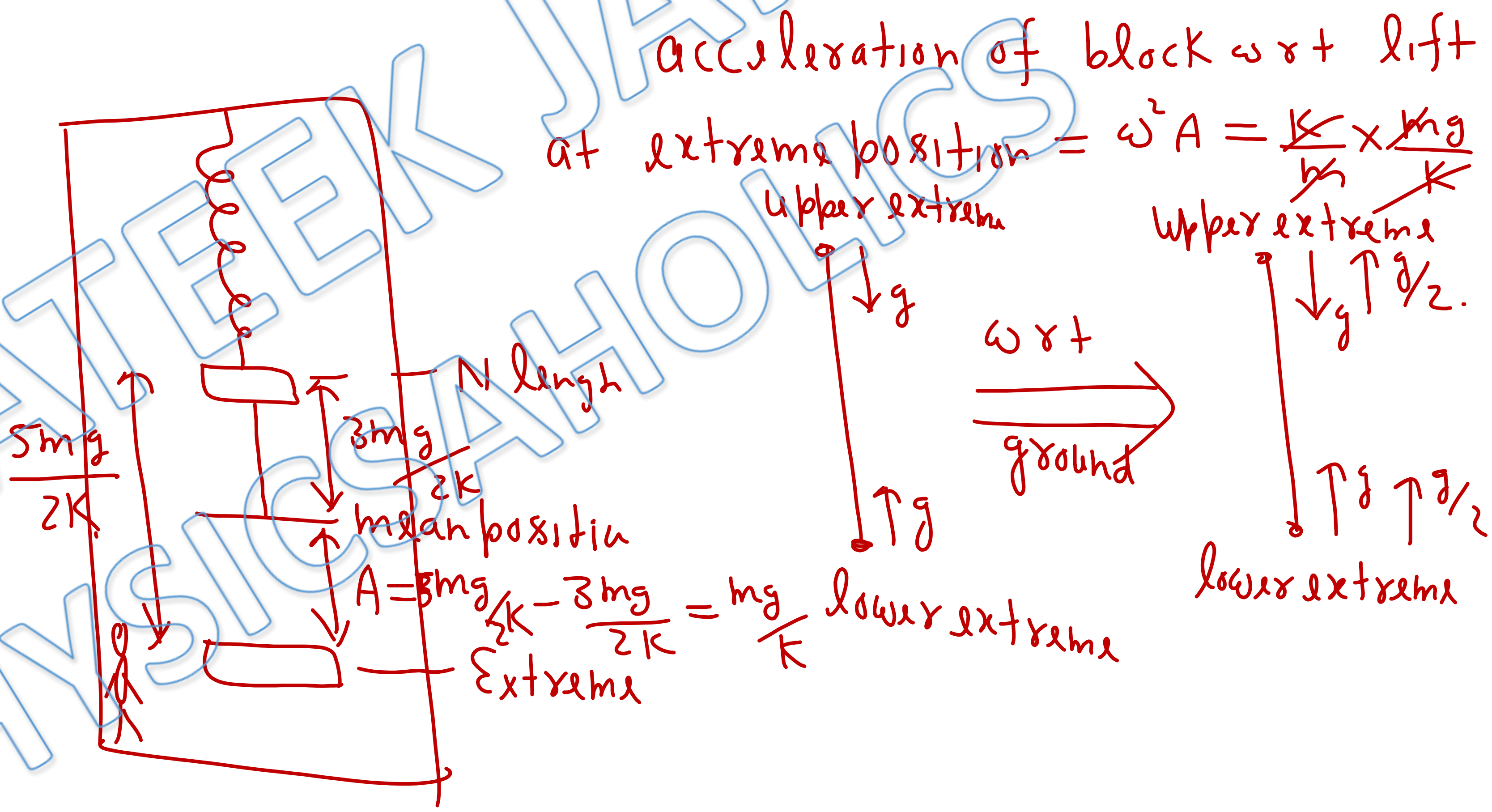
Q10) If maximum extension in the spring is $\frac{5mg}{2k}$, then maximum upward acceleration (a_1) and maximum downward acceleration (a_2) of the block are:

(a) $a_1 = g/2$

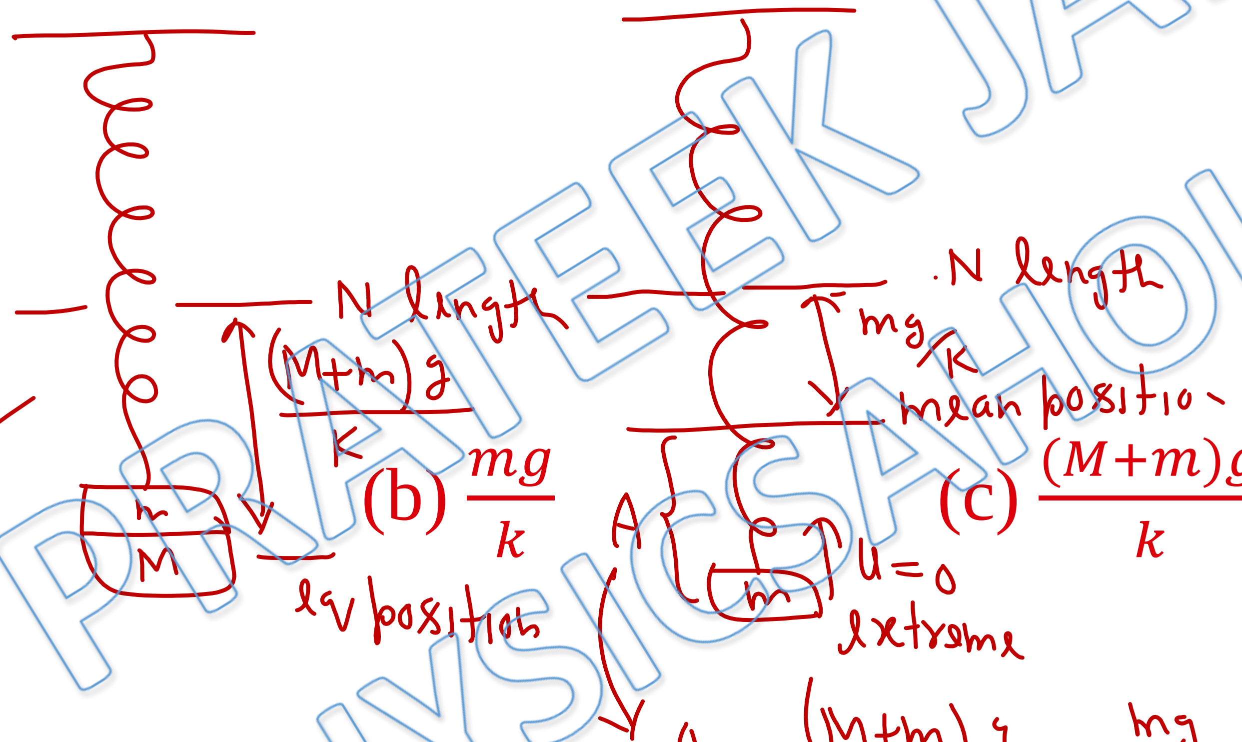
(b) $a_1 = 3g/2$

(c) $a_2 = g/2$

(d) $a_2 = 3g/2$



Q11) Two masses M and m are suspended together by a massless spring of spring constant k. When masses are in equilibrium M is removed without disturbing system. The amplitude of oscillation is



(a) $\frac{Mg}{k}$ ✓ (b) $\frac{mg}{k}$ (c) $\frac{(M+m)g}{k}$ (d) $\frac{(M-m)g}{k}$

$$A = \frac{(M+m)g}{K} - \frac{mg}{K} = \frac{Mg}{K}$$

Q12) The potential energy of a particle of mass 1 kg in motion along the x-axis is given by: $U = 4(1 - \cos 2x)$ J Here : x is in metres. The period of small oscillations (in sec) is

$U = 4 - 4\cos 2x$

$F = -\frac{dU}{dx} = -[0 + 4\times 2 \sin 2x]$

$F = -8 \sin 2x$

(a) 2π (b) π (c) $\pi/2$ (d) $\sqrt{2}\,\pi$

$a = -8 \times 2x$ if x is small

$a = -16x$

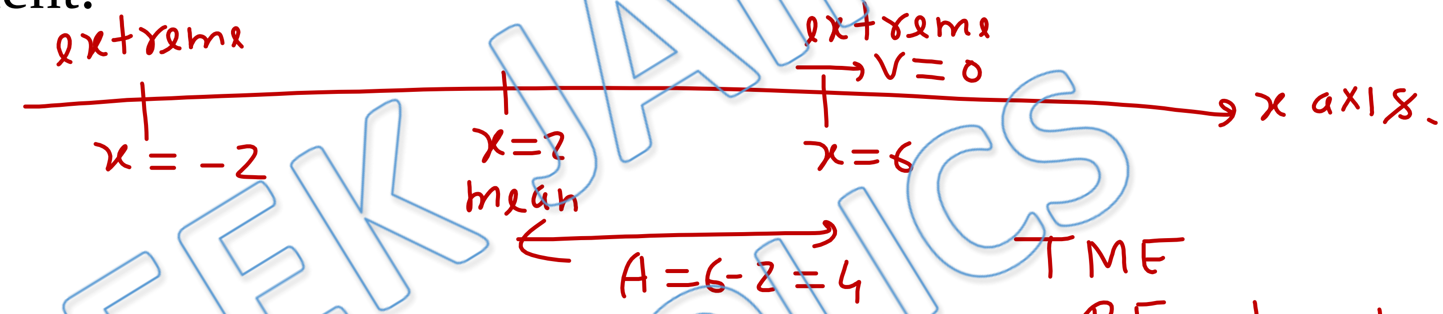
$\omega^2 = 16$, $\omega = 4$

$T = 2\pi/4 = \pi/2$

$U = U_0 + \frac{1}{2} m\omega^2 x^2$ (x: displacement from mean)

Q13) The potential energy of a particle of mass 1/2 kg is, U = 10 + (x – 2)^2. Here, U is in joule and x in metres. On the positive x-axis particle travels upto x = + 6 m. Choose the wrong statement:

U is minimum at $x = 2 \Rightarrow x = 2$ is mean position



TME = PE at extreme $= 10 + (6-2)^2 = 26\,J$

(a) On negative x-axis particle travels upto x = -2 m

(b) The maximum kinetic energy of the particle is 16 J

(c) The period of oscillation of the particle is π seconds

(d) None of the above

$\frac{1}{2} m\omega^2 = 1$

$\omega^2 = 4$

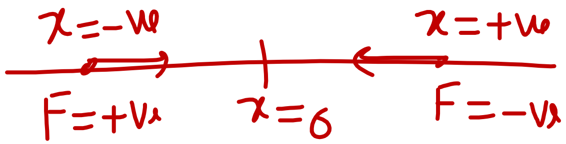
$\omega = 2 \Rightarrow T = \frac{2\pi}{2} = \pi$

At mean position

$U_0 = 10$

$KE_{max} = 26 - 10 = 16\,J$

Q14) A particle free 'to move along the x-axis has potential energy given by $U(x) = k[1-\exp(-x^2)]$ for $-\infty \le x \le +\infty$, where k is a positive constant of appropriate dimensions. Then:



$$U = K(1-e^{-x^2}) = K - Ke^{-x^2}$$

$$F = -\frac{dU}{dx} = -\left[0 - K(-2x)e^{-x^2}\right]$$

$$F = -2Kxe^{-x^2}$$ ⇒ equilibrium is at $x=0$ only.

(a) at points away from the origin, the particle is in unstable equilibrium

(b) for any finite non-zero value of x, there is a force directed away from the origin ⇒ force is towards origin

(c) if its total mechanical energy is k/2, it has its minimum kinetic energy at the origin ⇒ KE is maximum at origine

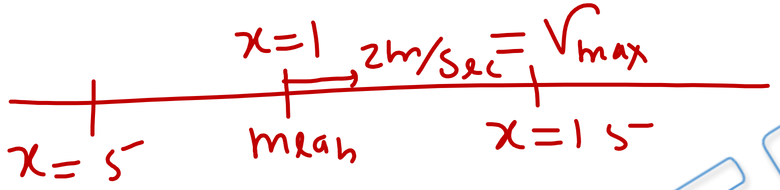
(d) for small displacements from x = 0, the motion is simple harmonic

for small displacement $e^{-x^2} \to 1$

$F = -2kx$

⇒ motion is SHM

Q15) A particle of mass 2 kg moving along x-axis has potential energy given by $U = 16x^2 - 32x$ (in joule), where x is in meter. Its speed when passing through x = 1m is $2ms^{-1}$. Then-



$U = 16x^2 - 32x$

$F = -\frac{dU}{dx} = -32x + 32$

$F = -32(x-1)$

(a) The motion of particle is uniformly accelerated motion

(b) The motion of particle is oscillatory from x = 0.5 m to x = 1.5 m

(c) The motion of particle is simple harmonic

(d) The period of oscillatory motion is $\pi/2$ s.

At mean position $F = 0 \Rightarrow x = 1$

$V_{max} = A \times 4 = 2$

$A = 1/2$

$F = -32X$ where $X = x - 1$

motion is SHM

$m\omega^2 = 32$

$\omega^2 = 16$

$\omega = 4$

$T = 2\pi/4 = \pi/2$

Q16) A particle of mass m is executing oscillations about the origin on the x-axis. Its potential energy is $V(x) = k|x|^3$ where k is a positive constant. If the amplitude of oscillation is a, then its time period T is-

$V = k|x|^3 \Rightarrow [k] = \frac{[V]}{[x^3]} = \frac{ML^2T^{-2}}{L^3}$

$[k] = ML^{-1}T^{-2}$

$T \propto a^{-1/2}$

$\propto \frac{1}{\sqrt{a}}$

Let $T = c\, m^x a^y k^z$

$[T] = [m]^x [a]^y [k]^z$

$M^0 L^0 T^1 = M^x L^y (ML^{-1}T^{-2})^z$

$x + z = 0$

$y - z = 0$

$-2z = 1 \Rightarrow z = -1/2 \Rightarrow y = z = -1/2$

(a) proportional to $1/\sqrt{a}$ ✓

(b) independent of a

(c) proportional to $\sqrt{a}$

(d) proportional to $a^{3/2}$

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