10 Oscillations and Waves

Periodic Motion and Oscillatory Motion

- A repeated motion along a fixed path, about a fixed point at a regular interval of time is called periodic motion.

  e.g. The motion of hands of a clock, the motion of the Earth around the Sun, the motion of the Earth about its own axis etc.

- If a body moves to and fro, back and forth or up and down about a fixed point, at a regular interval of time is called Oscillatory motion. e.g. the motion of the pendulum of the clock, The motion of a loaded spring etc.
- All Oscillatory motions are Periodic but all Periodic motions are not Oscillatory.

Simple Harmonic Motion (SHM)

The periodic motion of a body on a fixed linear path, under the influence of the force acting towards the fixed point and directly proportional to the distance from the fixed point is called simple harmonic motion. The body performing SHM is called simple harmonic oscillator (SHO).

The displacement of SHO at time t

$y(t) = A \sin(\omega t + \phi)$

A = Amplitude of oscillations ($y_{max} = A$)

Also,

$y(t) = A \sin(\omega t + \phi)$

$y(t) = B \cos(\omega t + \phi)$

$y(t) = a \sin(\omega t) + b \cos(\omega t)$

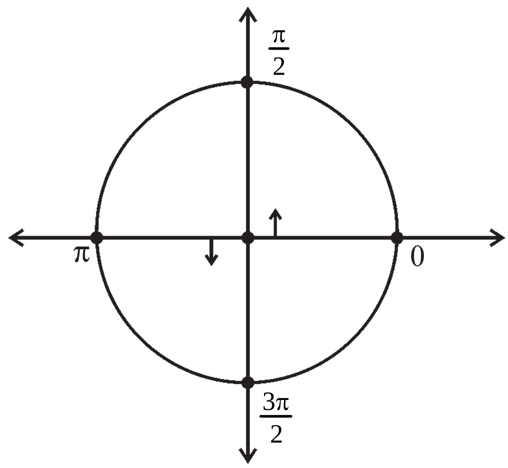
Where, $A = \sqrt{a^2 + b^2}$

initial phase $\phi = \tan^{-1}\left(\frac{b}{a}\right)$

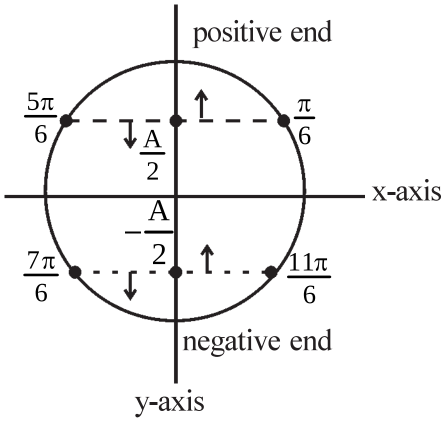
$\theta = \omega t + \phi$ is called phase of the oscillator at time t.

is called initial phase.

SHO starts its motion	Initial Phase (ϕ) (radian)
(1) From fixed point (y = 0) towards positive end	0
(2) From positive end (y = +A)	$\frac{\pi}{2}$
(3) From fixed point (y = 0) towards negative end	π
(4) From negative end (y = –A)	$\frac{3\pi}{2}$



SHO Starts its motion	Initial Phase ϕ (radian)
● From the mid point of fixed point and positive end ($y = \frac{A}{2}$) and move toward	
(1) positive end	$\frac{\pi}{6}$ rad
(2) negative end	$\frac{5\pi}{6}$
● From the mid point of fixed point and negative end ($y = -\frac{A}{2}$) moves towards	
(1) negative end	$\frac{7\pi}{6}$
(2) fixed Point	$\frac{11\pi}{6}$



- SHO starts its motion from :

(1) $y = +\frac{A}{\sqrt{2}}$ and moves towards

(a) Positive end thean $\phi = \frac{\pi}{4}$ rad

(b) Negative end then $\phi = \frac{3\pi}{4}$ rad

(2) $y = -\frac{A}{\sqrt{2}}$ and moves towards

(a) Positive end then $\phi = \frac{7\pi}{4}$ rad

(b) Negative end then $\phi = \frac{5\pi}{4}$ rad

(3) From $y = +\frac{\sqrt{3}A}{2}$ and move towards

(a) Positive end then $\phi = \frac{\pi}{3}$ rad

(b) Negative end then $\phi = \frac{2\pi}{3}$ rad

(4) from $y = -\frac{\sqrt{3}A}{2}$ and moves towards

(a) Positive end then $\phi = \frac{5\pi}{3}$ rad

(b) Negative end then $\phi = \frac{4\pi}{3}$ rad

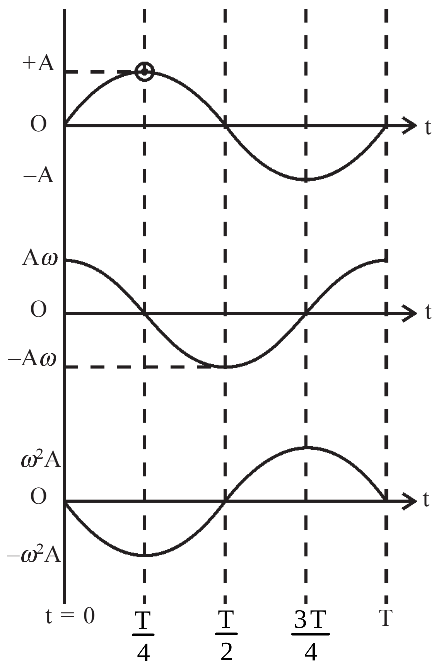
- Phase at the end of time t when periodic time is T; $\theta = \frac{2\pi}{T} t + \phi$

  When frequency is f; $\theta = 2\pi f t + \phi$

- When SHO completes n oscillations $\theta = 2\pi (n) + \phi$

Velocity (v) and Acceleration (a) of SHO

- Velocity of SHO at time t, $v(t) = A\omega \cos(\omega t + \phi)$
- When displacement is y, $v = \pm\, \omega\sqrt{A^2 - y^2}$
- Acceleration of SHO at time t, $a(t) = -A\omega^2 \sin(\omega t + \phi)$
- When displacement is y, $a = -\omega^2 y$
- The graph of $y_{(t)} \rightarrow t$, $v_{(t)} \rightarrow t$ and $a_{(t)} \rightarrow t$ $[\text{when } \phi = o]$



- At fixed point (y = 0) velocity of SHO, $v_{max} = \pm\, \omega A$
- At end points (y = ±A) acceleration of SHO is maximum, $a_{max} = \pm\, \omega^2 A$

$$\therefore \frac{a_{max}}{v_{max}} = \omega \Rightarrow T = 2\pi \frac{v_{max}}{a_{max}}$$

Also, $\frac{v^2_{max}}{a_{max}} = A$

- When displacement of SHO is y_1, its velocity is y_1 and when displacement is y_2, velocity is v_2 than

Amplitude $A = \left[\dfrac{v_1^2 y_2^2 - v_2^2 y_1^2}{v_1^2 - v_2^2}\right]^{\frac{1}{2}}$; Periodic time $T = 2\pi \left[\dfrac{y_2^2 - y_1^2}{v_1^2 - v_2^2}\right]^{\frac{1}{2}}$

y = + A Positive end — $v = 0$, $a_{max} = -\omega^2 A$, $\phi = \frac{\pi}{2}$

$\phi = \frac{2\pi}{3}$ ↓ $y = \frac{\sqrt{3}A}{2}$ — $v = \frac{v_{max}}{2}$, $a = \frac{\sqrt{3}\, a_{max}}{2}$ ↑ $\phi = \frac{\pi}{3}$

$\phi = \frac{3\pi}{4}$ ↓ $y = \frac{A}{\sqrt{2}}$ — $v = \frac{v_{max}}{\sqrt{2}}$, $a = \frac{a_{max}}{\sqrt{2}}$ ↑ $\phi = \frac{\pi}{4}$

$\phi = \frac{5\pi}{6}$ ↓ $y = \frac{A}{2}$ — $v = \frac{\sqrt{3}}{2} v_{max}$, $a = \frac{a_{max}}{2}$ ↑ $\phi = \frac{\pi}{6}$

moving from end point towards the mean position | moving from the mean position towards the positive end

v increases ↓ | ↑ *v* decrease

a decreases | *a* increases

y = 0 ...... mean — $v_{max} = A\omega$, a = 0, $\phi = 0$....

y = –A ...... negative end — $v = 0$, $a_{max} = +\omega^2 A$, $\phi = \frac{3\pi}{2}$

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(1) SHO starting from the mid point of its mean position and negative end, moves towards its negative end, completes one oscillation in 0.5 s. Its initial phase ϕ = ... rad and its phase at the end of 10 s, θ = ... rad.

(A) $\phi = \frac{3\pi}{2}$, $\theta = \frac{83\pi}{2}$ (B) $\phi = \frac{7\pi}{6}$, $\theta = \frac{247\pi}{6}$

(C) $\phi = \frac{5\pi}{6}$, $\theta = \frac{245\pi}{6}$ (D) $\phi = \frac{11\pi}{6}$, $\theta = \frac{251\pi}{6}$

(2) SHM is given by $y = \sqrt{2}\sin 10\pi t + \sqrt{7}\cos 10\pi t$. Where y is in cm and t is in sec. The amplitude, periodic time and initial phase of the oscillations are ......

(A) A = 5 cm, T = 0.2 s and ϕ = 48°52' (B) A = 3 cm, T = 0.5 s and ϕ = 48°52'

(C) A = 3 cm, T = 0.2 s and ϕ = 48°52' (D) A = 3 cm, T = 0.5 s and ϕ = 52°48'

(3) Periodic time of SHO is T, it starts its oscillation from the mean position. In what time it completes $\frac{7}{8}^{th}$ of its oscillation ?

(A) $\frac{7}{8}$ T (B) $\frac{9}{10}$ T (C) $\frac{11}{12}$ T (D) $\frac{12}{13}$ T

(4) SHO starts its oscillation from $y = \frac{A}{\sqrt{2}}$ and move towards the mean position. Its phase when it completes $10\frac{1}{2}$ oscillation, θ = ... rad.

(A) $41\frac{\pi}{4}$ (B) $\frac{43\pi}{4}$ (C) $\frac{45\pi}{4}$ (D) $87\frac{\pi}{4}$

(5) When the displacement of SHO is 1 cm, its velocity is 2 cms^{-1} and when displacement is 2 cm, its velocity is 1 cms^{-1}. Its amplitude A = ... cm and periodic time T = ... s.

(A) $\sqrt{5}$, 6.28 (B) A = 0, 0 (C) $\sqrt{5}$, 3.14 (D) A = 10, 6.28

(6) The displacement of SHO is given by $y = 10 \sin 2\pi \left(t + \frac{1}{12}\right)$; where y is in cm and t is in s. Calculate its initial displacement, initial velocity and initial acceleration.

(A) $y_0 = 10$ cm, $v_0 = 10\pi$ cms^{-1}, $a = -20\pi$ cms^{-2}

(B) $y_0 = 5$ cm, $v_0 = 17.32\ \pi$ cms^{-1}, $a = -10\pi^2$ cms^{-2}

(C) $y_0 = 10$ cm, $v_0 = 10\ \pi$ cms^{-1}, $a = -10\pi^2$ cms^{-2}

(D) $y_0 = 5$ cm, $v_0 = 17.32\ \pi$ cms^{-1}, $a = -20\pi^2$ cms^{-2}

(7) Amplitude of SHO is 0.05 m. When its displacement is 0.03 m, its acceleration is –3.0 ms^{-2}. Calculate its velocity at this time. Also calculate maximum velocity and maximum acceleration of the oscillations.

(A) $v = 0.4$ ms^{-1}, $v_{max} = 0.4$ ms^{-1}, $a_{max} = 5$ ms^{-2}

(B) $v = 0.5$ ms^{-1}, $v_{max} = 0.5$ ms^{-1}, $a_{max} = 4$ ms^{-2}

(C) $v = 0.4$ ms^{-1}, $v_{max} = 0.5$ ms^{-1}, $a_{max} = 5$ ms^{-2}

(D) $v = 0.5$ ms^{-1}, $v_{max} = 0.4$ ms^{-1}, $a_{max} = 4$ ms^{-2}

(8) Amplitude and periodic time of SHO are 20 cm and 3 s respectively. It starts its oscillation from the positive end. Calculate the time taken by it to travel first 10 cm distance towards the mean position.

(A) 0.25 s (B) 0.50 s (C) 0.75 s (D) 1 s

(9) Amplitude and periodic time of SHO are A and T respectively. Calculate the minimum time to travel $\frac{\sqrt{3}\,A}{2}$ distance from its mean position.

(A) $\frac{T}{2}$ (B) $\frac{\sqrt{3}\,T}{2}$ (C) $\frac{T}{6}$ (D) $\frac{T}{8}$

(10) A particle is moving in the X–Y plane. Where $x = A \cos(\omega t + \phi)$ and $y = A \sin(\omega t + \phi)$. The path of the motion of the particle is ....

(A) linear (B) circular (C) parabola (D) irregular

(11) Two particles are performing SHM along y-axis, with the equal amplitude A and equal angular frequency ω. The distance between their mean positions is y_0, (Where $y_0 > A$). If the maximum distance between the two particles during their motion is $(y_0 + A)$, calculate the phase difference between them, in radian.

(A) $\frac{\pi}{3}$ (B) $\frac{\pi}{4}$ (C) $\frac{\pi}{6}$ (D) π

(12) The periodic time of SHM of a particle 16 s. At time t = 2 s, it passes from its mean position, and at time t = 4 s, its velocity is $\sqrt{2}$ ms^{-1}. Then amplitude of the oscillations A = ... m.

(A) $\frac{8}{\pi}$ (B) $\frac{16}{\pi}$ (C) $\frac{32}{\pi}$ (D) $\frac{32\sqrt{2}}{\pi}$

(13) Amplitude of SHO is 1 m. When it is at a distance of 0.5 m from the mean position, it receives blow in the direction of its motion. soits, instantaneouly, velocity becomes 3 times to its initial. Find the new amplitude of its oscillations.

(A) $\sqrt{5}$ m (B) $\sqrt{7}$ m (C) $\sqrt{11}$ m (D) $\sqrt{13}$ m

(14) Velocity of SHO at its mean position is 2 ms^{-1} and its acceleration at its negative end is 1ms^{-2}. Then A = ... m, T = ... s.

(A) A = 4 m and T = π s (B) A = π m and T = 4 s

(C) A = π m and T = 4π s (D) A = 4 m and T = 4π s

(15) A particle perfoms SHM along the path of length 20 cm. When it is 6 cm away from its mean position, its velocity is 16 cms^{-1}. Calculate its acceleration when it is 3 cm away from its positive end.

(A) 7 cms^{-2} (B) 14 cms^{-2} (C) 21 cms^{-2} (D) 28 cms^{-2}

(16) An amplitude and periodic time of SHO are 10 cm and 2π s respectively. Calculate its velocity in cms^{-1}, when its acceleration is 8 cms^{-2}.

(A) 2 (B) 4 (C) 6 (D) 8

(17) The displacement of SHO performing SHM along X-axis is $x(t) = 20 \sin \frac{\pi}{3}(15t + 0.5)$ cm. And the displacement of SHO performing SHM along Y-axis is $y(t) = 8 [\sin 10\pi t + 0.75 \cos 10\pi t]$ cm. Calculate the ratio of their amplitudes and periodic times.

(A) $\frac{A_x}{A_y} = 2$; $\frac{T_x}{T_y} = 2$ (B) $\frac{A_x}{A_y} = 1$; $\frac{T_x}{T_y} = 2$

(C) $\frac{A_x}{A_y} = 2$; $\frac{T_x}{T_y} = 1$ (D) $\frac{A_x}{A_y} = 1$; $\frac{T_x}{T_y} = 1$

(18) The displacement of SHO is $y(t) = 200 \sin \left(\frac{3\pi}{5}t + \alpha\right)$ cm. It starts its oscillations from a point 100 cm away from its mean position and moves towards its positive end. Calculate its phase (in rad) at the end of 10 s.

(A) 0 (B) $\frac{\pi}{6}$ (C) $\frac{17\pi}{6}$ (D) $\frac{37\pi}{6}$

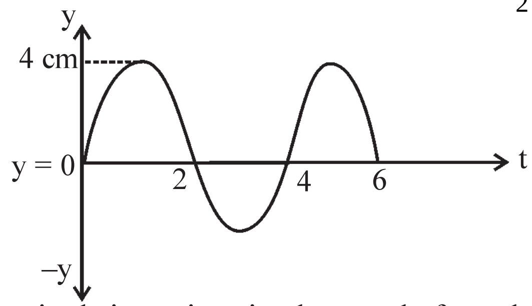
(19) The periodic time of SHO is $\frac{2\pi}{5}$ s. Its velocity at the mean Position is $10\sqrt{5}$ cms^{-1}. Calculate its displacement when its velocity is 10 cms^{-1}.

(A) 4 cm (B) $4\sqrt{5}$ cm (C) $\sqrt{5}$ cm (D) $2\sqrt{5}$ cm

(20) A simple pendulum performs SHM about $x = 0$, with an amplitude A and periodic time T. It's velocity at mean point is 0.02 ms^{-1}. Now its amplitude is made doubled by keeping its length constant. Calculate the velocity of the pendulum at its mean position.

(A) 0.01 ms^{-1} (B) 0.02 ms^{-1} (C) 0.04 ms^{-1} (D) 0

(21) The graph of y $\rightarrow$ t for an SHO is shown in figure. Its acceleration at the end of time t = $\frac{1}{2}$ s is ...... cms^{-2}.



(A) $-\frac{\pi}{\sqrt{2}}$ (B) $-\frac{\pi^2}{\sqrt{2}}$

(C) $-\sqrt{2}\,\pi$ (D) $-\sqrt{2}\,\pi^2$

(22) Periodic times of two SHO are T and $\frac{3T}{4}$. They begin their motion simultaneously from their mean positions. What is the difference between their phases when 1 oscillation of the oscillator having periodic time T is completed ?

(A) 62° (B) 72° (C) 110° (D) 120°

(23) SHO perfoms SHM on the path of length 24 cm with the frequency of $\frac{\sqrt{3}}{2\pi}$ s^{-1}, Calculate its displacement when the magnitudes of its velocity and acceleration become equal.

(A) 3 cm (B) 6 cm (C) 7 cm (D) 9 cm

(24) Angular frequency of SHO is $2\sqrt{3}$ rad s^{-1}. If at time $\frac{T}{12}$, its displacement is 2 cm, then its velocity v = ...

(A) 6 cms^{-1} (B) 12 cms^{-1} (C) 18 cms^{-1} (D) 24 cms^{-1}

(25) What would be the amplitude of SHO whose velocity is α and acceleration is β.

(A) $\left[\frac{\alpha^2 y^2 - \beta^2 y^2}{\beta}\right]^{\frac{1}{2}}$ (B) $\left[\frac{\alpha^2 y - \beta^2 y^2}{\beta}\right]^{\frac{1}{2}}$ (C) $\left[\frac{\alpha^2 y - \beta y^2}{\beta}\right]^{\frac{1}{2}}$ (D) $\left[\frac{\alpha^2 y - \beta^2 y}{\beta}\right]^{\frac{1}{2}}$

Ans. : 1 (B), 2 (C), 3 (C), 4 (D), 5 (A), 6 (D), 7 (C), 8 (B), 9 (C), 10 (B), 11 (A), 12 (B), 13 (B), 14 (D), 15 (D), 16 (C), 17 (A), 18 (D), 19 (A), 20 (C), 21 (B), 22 (D), 23 (B), 24 (B), 25 (C)

Force Acting on SHO (Variable force depending on the displacement)

- For SHM along y-axis; $F \propto y$
  $F = -ky$
- For SHM along x-axis, $F \propto x$
  $F = -kx$

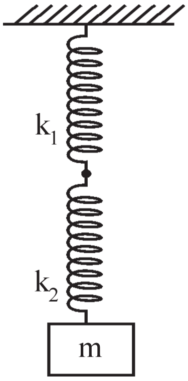
Where, k = force constant

$k = m\omega^2$

$\omega = \sqrt{\frac{k}{m}}$; $T = 2\pi\sqrt{\frac{m}{k}}$

Oscillations of the loaded Spring :

(1) Series Connection



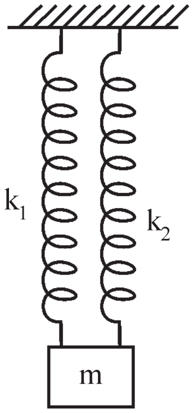
An equivalent force constant

$$k = \frac{k_1 k_2}{k_1 + k_2}$$

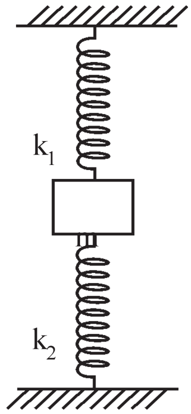
or $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2}$

Periodic time $T = 2\pi\sqrt{\frac{m(k_1+k_2)}{k_1 k_2}}$

(2) Parallel Connection



(3) Connection of two Loaded spring



In both at the case equivalent force constent

$$k = k_1 + k_2$$

Periodic time,

$$T = 2\pi\sqrt{\frac{m}{k_1+k_2}}$$

(26) N springs are having equal force constant k. When they are connected in series an equivalent force constant is k_s and when they are connected in Parallel the equivalent force constant becomes k_p. Than,

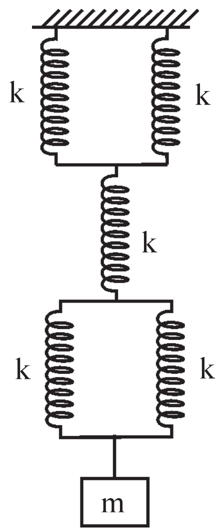
(A) $k_s = \frac{k}{N}$ and $k_p = kN$

(B) $k_s = \frac{k}{N^2}$ and $k_p = N^2k$

(C) $k_s = \frac{N}{k}$ and $k_p = kN$

(D) $k_s = \frac{N^2}{k}$ and $k_p = N^2k$

(27) 5 springs each of equal mass m and equal force constant (k) are connected as shown in the figure. Calculate the periodic time of SHM of the system.



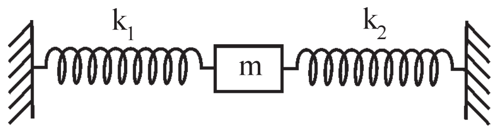
(A) $T = \sqrt{2}\,\pi\sqrt{\frac{m}{k}}$

(B) $T = 2\sqrt{2}\,\pi\sqrt{\frac{m}{k}}$

(C) $T = 2\pi\sqrt{\frac{m}{2k}}$

(D) $T = 2\pi\sqrt{\frac{3m}{2k}}$

(28) As shown in the figure a block of mass m is attached with the springs having force constant k_1 and k_2. The periodic time of SHM is T_1. When the springs having force constant $4k_1$ and $4k_2$ are used, the periodic time is T_2. Then,

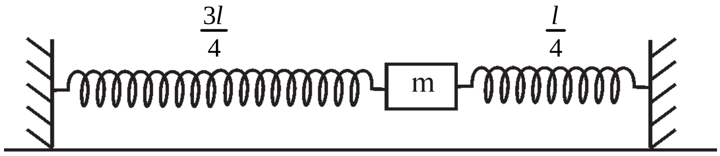


(A) $T_2 = 2T$ (B) $T_2 = 4T_1$

(C) $T_2 = \frac{T_1}{2}$ (D) $T_2 = \frac{T_1}{4}$

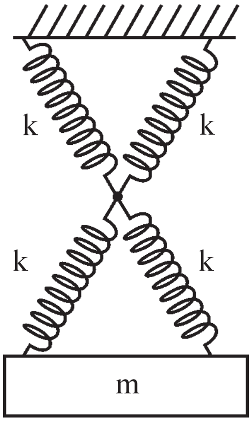
[**Note :** If we take the series connection of springs instead of parallel connection of springs then answer will remain same in this question.]

(29) The length of the spring having force constant k is l. The spring is divided in two parts of length $\frac{3l}{4}$ and $\frac{l}{4}$. A block of mass m is attaced as shown in the figure. calculate the periodic time of SHM of the System.



(A) $T = 2\pi\sqrt{\frac{3m}{k}}$ (B) $T = \frac{\pi}{2}\sqrt{\frac{3m}{k}}$ (C) $T = \frac{\pi}{2}\sqrt{\frac{m}{k}}$ (D) $T = 2\pi\sqrt{\frac{m}{3k}}$

(30) Four identical springs each of force constant k are connected as shown in the figure. calculate the frequency of the simple harmonic oscillations.



(A) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{4k}{m}}$

(C) $\frac{1}{2\pi}\sqrt{\frac{2k}{m}}$ (D) $\frac{\sqrt{2}}{\pi}\sqrt{\frac{k}{m}}$

(31) When a body of mass 1 kg is suspended at the end of the spring, its length is increased by 9.8 cm. Now if the body is given SHM, what would be the periodic time of its oscillation ?

(A) $0.2\ \pi$ s (B) $2\ \pi$ s (C) $20\ \pi$ s (D) $200\ \pi$ s

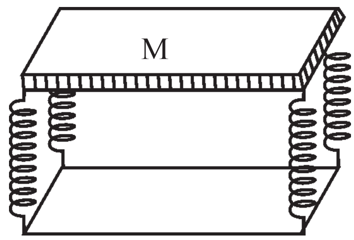
(32) A body of mass 100 g is suspended at the end of an elastic spring. Amplitude of its SHM is A_1. Now, when the body is at its mean position, another body of mass 21 g is kept on it. It both of the objects are jointly perform SHM, the amplitude becomes A_2. Than $\frac{A_1}{A_2}$ = ...

(A) $\frac{10}{11}$ (B) $\frac{20}{15}$ (C) $\frac{11}{10}$ (D) $\frac{15}{20}$

(33) When mass m is suspended by a spring of force constant k and given SHM, its period is T. Now the spring is cut in two equal parts and arranged in parallel and the same mass m is oscillated by them then the new periodic time will be ....

(A) T (B) $\frac{T}{2}$ (C) 2T (D) $\sqrt{2}$ T

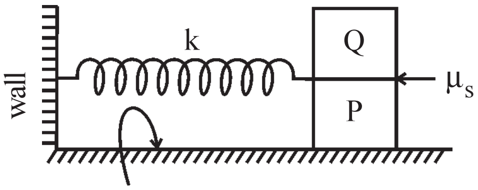
(34) Four identical springs each of force constant 1000 Nm^{-1} are connected as shown in the figure. If a body of mass 10 kg is kept at the top and the system is given SHM, the periodic time will be ....



(A) 6.28 s (B) 3.14 s

(C) 0.628 s (D) 0.314 s

(35) A block P of mass m is kept on a frictionless surface. Block Q of the same mass m is kept on block P. A spring of force constant k is connected as shown in the figure. The co-efficient of friction between P and Q is μ_s. Both the blocks are oscillating togather with equal amplitude A. The maximum static frictional force between the blocks is ....



(A) kA (B) $\frac{KA}{2}$ (C) μs kA (D) μs mg

(36) A U-tube is partially filled with a liquid of density ρ. The length of the liquid column in each arm is the same. Now the free-surface of the liquid in one arm is given a displacement 3.92 mm and allowed to oscillate. calculate the frequency of its SHM.

(A) $\frac{5}{\pi}$ (B) $\frac{10}{\pi}$ (C) $\frac{25}{\pi}$ (D) $\frac{50}{\pi}$

(37) When the compression of an elastic spring is 1 cm, the restoring force produced in it is 2 N. When an object of mass 0.5 kg is kept on the spring it is compressed by y and object performs SHM with the periodic time T, calculate y and T.

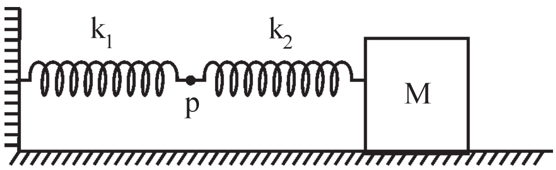
(A) y = 0.025m, T = $\frac{\pi}{10}$ s (B) y = 0.25 m, T = $\frac{\pi}{100}$ s

(C) y = 0.025 m, T = $\frac{\pi}{100}$ s (D) y = 0.25 m, T = $\frac{\pi}{10}$ s

(38) As shown in the figure, an object of mass M performs SHM with an amplitude A. The amplitude of point P is.

(A) $\frac{k_1 A}{k_1 + k_2}$ (B) $\frac{k_2 A}{k_1 + k_2}$

(C) $\frac{k_1 + k_2}{k_2 A}$ (D) $\frac{k_1 + k_2}{k_2 A}$



Ans. : 26 (A), 27 (B), 28 (C), 29 (B), 30 (A), 31 (A), 32 (C), 33 (B), 34 (D), 35 (B), 36 (C), 37 (A), 38 (B)

Energy of SHO

- Potential energy of SHO $U = \frac{1}{2}ky^2$ k = force constant = $m\omega^2$, y = displacement

- K. E. of SHO, $K = \frac{1}{2}m\omega^2(A^2 - y^2)$

- The total energy (Mechanical energy) of SHO, $E = K + U = \frac{1}{2}\, m\,\omega^2 A^2 = \frac{1}{2}\, k\, A^2$

- P. E. $U \propto y^2$

  K. E. $K \propto (A^2 - y^2)$

  M. E. $E \propto A^2$ (independent of y)

- If displacement y increases, P. E. (U) increases, K.E. (K) decreases but, E = constant.

U decreases	$y = +A$	$K = 0, U = max. = E$	U increases
K increases ↓	$y = \frac{A}{\sqrt{2}}$	$K = U = \frac{E}{2}$	K decreases ↑
E constant			E constant
— — — — —	$y = 0$	$U = 0, K = max. = E$ — — — — —	
U increases	$y = \frac{A}{\sqrt{2}}$	$K = U = \frac{E}{2}$	U decreases
K decreases ↓	$y = -A$		K increases ↑
E constant		$K = 0, U = max = E$	E constant

- If the change in the P. E. = ΔU, The change in the K. E. = ΔK then $\Delta K = -\Delta U$

  The change in the P. E. and the change in the K. E. is always equal and opposite, so that the total change is always zero.

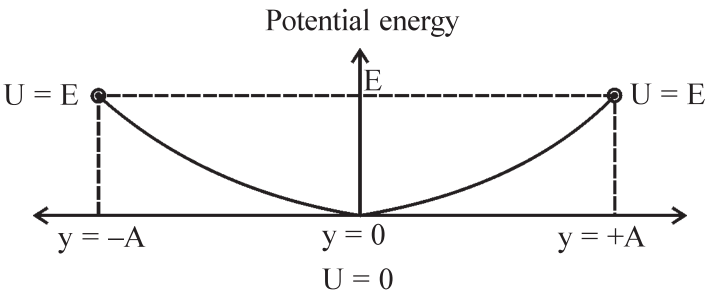
  [If U increases then K decrease and if U decreases then K increases.]

  So net change is always zero.

  $\Delta K + \Delta U = 0$ [law of conservation of M. E.]

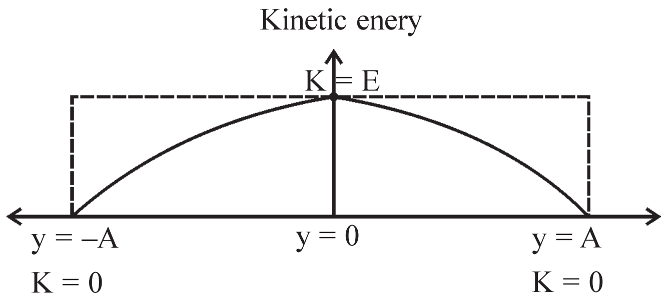
  So net mechanical energy remain constant.

- **The graph of P. E. (U) → displacement (y) :**



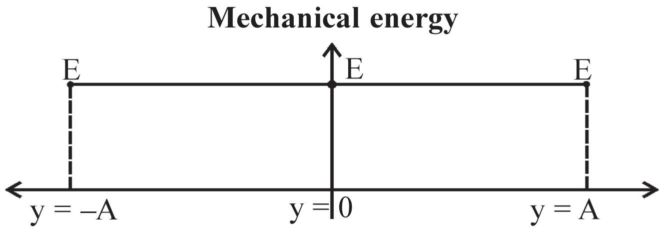
$U = \frac{1}{2}\, ky^2$

- **The graph of K.E. (K) → displacement (y) :**



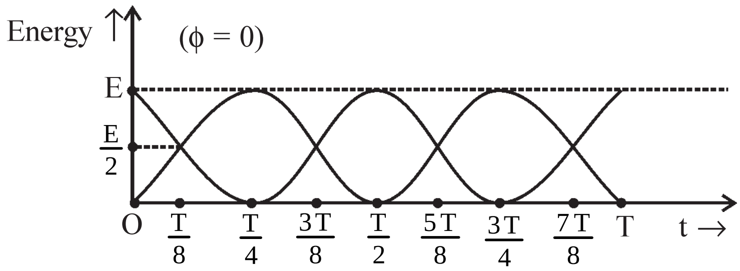
$$K = E - \frac{1}{2}ky^2$$

- **The graph of M.E. (E) → displacement (y) :**



E does not depend on displacement
E = constant

- **Energy of SHO as function of time**



- The time (T) during which SHO completes 1 oscillation, the values of K. E. and P. E. becomes twice maximum and twice minimum. Thus, if frequency of SHO is f, the frequency for K. E. or P. E. becomes $2f$.

---

(39) What would be the values of displacement, velocity and acceleration of SHO when its K. E. becomes equal to its P. E.

(A) $y = \pm\frac{A}{\sqrt{2}}$; $v = \pm\frac{\omega A}{2}$; $a = \pm\frac{\omega^2 A}{\sqrt{2}}$ (B) $y = \pm\frac{A}{\sqrt{2}}$; $v = \pm\frac{\omega A}{\sqrt{2}}$; $a = \pm\frac{\omega^2 A}{2}$

(C) $y = \pm\frac{A}{\sqrt{2}}$; $v = \pm\frac{\omega A}{\sqrt{2}}$; $a = \pm\frac{\omega^2 A}{\sqrt{2}}$ (D) $y = \pm\frac{A}{2}$; $v = \pm\frac{\omega A}{2}$; $a = \pm\frac{\omega^2 A}{2}$

(40) When the K. E. of SHO is 43 J, its P. E. is 58 J. Now its K. E. increases and becomes 61 J. Calculate its displacement. [force constant k = 20 Nm^{-1}]

(A) 2m (B) $\sqrt{2}$ m (C) $\frac{1}{2}$ m (D) $\frac{1}{\sqrt{2}}$ m

(41) The mass, periodic time and amplitude of SHO are 20 g, 2π s and 10 cm respectively. Calculate its K. E., P. E. and M. E. for the displacement 6 cm.

(A) $K = 6.4 \times 10^{-5}$ J, $U = 3.6 \times 10^{-5}$ J, $E = 10^{-6}$ J

(B) $K = 4.6 \times 10^{-5}$ J, $U = 5.4 \times 10^{-5}$ J, $E = 10^{-4}$ J

(C) $K = 3.6 \times 10^{-5}$ J, $U = 6.4 \times 10^{-5}$ J, $E = 10^{-6}$ J

(D) $K = 6.4 \times 10^{-5}$ J, $U = 3.6 \times 10^{-5}$ J, $E = 10^{-4}$ J

(42) The periodic time of SHO of mass 20 kg is 6 s. It starts its oscillations from its mean position. Its velocity at the end of 1 s is 2 ms^{-1}. Calculate its K. E. and P. E. at this time.

(A) K = 40 J ; U = 120 J
(B) K = 40 J ; U = 160 J
(C) K = 80 J ; U = 160 J
(D) K = 80 J ; U = 120 J

(43) The force constant of a spring is 400 Nm^{-1}. When a massive body is suspended, the restoring force produced in the spring is 40 N. Calculate the total mechanical energy of the spring.

(A) 0.2 J
(B) 2 J
(C) 20 J
(D) 200 J

(44) When 100 J energy is given to the SHO of mass 2 kg, it perfoms SHM with the amplitude 1 cm. Calculate the force constant and angular frequency.

(A) $k = 2 \times 10^{6}$ Nm^{-1}, $\omega = 10^{6}$ $rads^{-2}$
(B) $k = 2 \times 10^{6}$ Nm^{-1}, $\omega = 10^{3}$ $rads^{-2}$
(C) $k = 2 \times 10^{-6}$ Nm^{-1}, $\omega = 10^{6}$ $rads^{-2}$
(D) $k = 2 \times 10^{-6}$ Nm^{-1}, $\omega = 10^{3}$ $rads^{-2}$

(45) Mass of SHO is 0.1 kg. The total length of the path of SHM is 20 cm. The K. E. of the SHO at its mean position is 8×10^{-3} J. Calculate angular frequency and force constant.

(A) $\omega = 4$ $rads^{-1}$, $k = 1.6$ Nm^{-1}
(B) $\omega = 4$ $rads^{-1}$, $k = 0.4$ Nm^{-1}
(C) $\omega = 2$ $rads^{-1}$, $k = 0.4$ Nm^{-1}
(D) $\omega = 2$ $rads^{-1}$, $k = 1.6$ Nm^{-1}

(46) The mechanical energy of SHO is E. Calculate its kinetic energy at the mid point of its mean position and end point.

(A) E
(B) 0
(C) $\frac{E}{4}$
(D) $\frac{3E}{4}$

(47) What would be the displacement of SHO when its potential energy becomes $\frac{1}{4}$ times its maximum value ?

(A) 0
(B) $\frac{A}{2}$
(C) $\frac{A}{\sqrt{2}}$
(D) $\frac{3A}{\sqrt{2}}$

(48) Calculate the ratio of potential energy and total energy of SHO at any instant of time.

(A) $\frac{y}{A}$
(B) $\left[\frac{y}{A}\right]^{\frac{1}{2}}$
(C) $\left[\frac{y}{A}\right]^{2}$
(D) $\frac{y^2}{A}$

(49) What would be the change in the mechanical energy of SHO on decreasing its amplitude by 25 %.

(A) decreases by 56.25 %
(B) decreases by 43.75 %
(C) increases by 56.25 %
(D) increases by 43.75 %

(50) When the displacement of SHO is y_1, its potential energy is E_1 and when displacement is y_2, the potential energy is E_2. For the displacement $(y_1 + y_2)$ where $(y_1 + y_2) < A)$ the potential energy is E. then ....

(A) $\sqrt{E} = \sqrt{E_1} + \sqrt{E_2}$ (B) $E = E_1 + E_2$

(C) $E^2 = E_1^2 + E_2^2$ (D) $E = \frac{2E_1E_2}{E_1+E_2}$

(51) One end of an elastic spring (mass less) is fixed at a rigid support. At the other end, a solid cylinder is attached in such a way that the cylinder can rotate without slipping. The force constant of a spring is 4 Nm^{-1}. Now cylinder is given 0.5 m displacement and allowed free to move. The cylinder performs SHM and rotational motion about its own axis. Calculate K. E., rotational K. E. and periodic time.

(A) $K = \frac{1}{3}J$, $K_r = \frac{1}{6}J$, $T = 2\pi\sqrt{\frac{3m}{2k}}$ (B) $K = \frac{1}{3}J$, $K_r = \frac{2}{3}J$, $T = 2\pi\sqrt{\frac{3m}{2k}}$

(C) $K = \frac{1}{3}J$, $K_r = \frac{1}{6}J$, $T = 2\pi\sqrt{\frac{2k}{3m}}$ (D) $K = \frac{2}{3}J$, $K_r = \frac{1}{3}J$, $T = 2\pi\sqrt{\frac{2k}{3m}}$

(52) The displacement of SHO is ...... % of its amplitude, when its kinetic energy is 25% of it potential energy.

(A) 69.88 % (B) 96.44 % (C) 49.88 % (D) 89.44 %

(53) SHO, starting from its mean position, completes 1 oscillation in 12 s. At what time its kinetic energy becomes 25 % of its total energy (or decreases by 75%)

(A) t = 2 s (B) t = 0.5 s (C) t = 4 s (D) t = 8 s

(54) An initial phase of SHO is $\frac{\pi}{3}$ rad. Total energy is E. Calculate its initial kinetic energy and initial potential energy.

(A) $K_0 = \frac{3E}{4}$, $U_0 = \frac{E}{4}$ (B) $K_0 = E$, $U_0 = 0$

(C) $K_0 = 0$, $U_0 = E$ (D) $K_0 = \frac{E}{4}$, $U_0 = \frac{3E}{4}$

Ans. : 39 (C), 40 (A), 41 (D), 42 (A), 43 (B), 44 (B), 45 (A), 46 (D), 47 (B), 48 (C), 49 (B), 50 (A), 51 (A), 52 (D), 53 (A), 54 (D)

Simple Pendulum

- Only for small oscillations, the motion of simple pendulum is SHM.

  If m = mass of the sphere, l = length of the pendulum, g = gravitational acceleration

  Force constant of the simple pendulum $k = \frac{mg}{l}$

  angular frequency of the simple pendulum $\omega = \sqrt{\frac{g}{l}}$

  Periodic time of the simple pendulum, $T = 2\pi\sqrt{\frac{l}{g}}$

- For constant g (place is same), $\frac{T_2}{T_1} = \sqrt{\frac{l_2}{l_1}}$ $T \propto \sqrt{l}$; ($l < R_e$)

- For constant length at different planets, $\frac{T_2}{T_1} = \sqrt{\frac{g_1}{g_2}}$ $T \propto \frac{1}{\sqrt{g}}$

- For the pendulum of thin metallic wire, $T \propto \sqrt{l}$; $l \propto$ temperature

  $\therefore$ Temperature increases periodic time increases and oscillations becomes slow.

- The value of g is less at mountains or in mines than that at surface of the earth.

  $\therefore$ Periodic time increase at mountains or inside the mines. [oscillations becomes slow]

Simple pendulum in a lift (Elevator)

(1) Elevator is moving with acceleration *a* :

moving upward $g_{eff} = g + a$; moving downward, $g_{eff} = g - a$

(2) Elevator is moving with retardation or deceleration (–a)

moving upward, $g_{eff} = g - a$; moving downward, $g_{eff} = g + a$

Periodic time $T = 2\pi\sqrt{\frac{l}{g_{eff}}}$

(3) If elevator is freely falling, a = g

$g_{eff} = g - g = 0$

$\therefore$ $T = \infty$ That is Pendulum does not oscillate.

Simple pendulum in a train

When the train is moving with an acceleration or retardation *a*,

$g_{eff} = \sqrt{g^2 + a^2}$ [a is '+ve' or '–ve' a^2 will be positive]

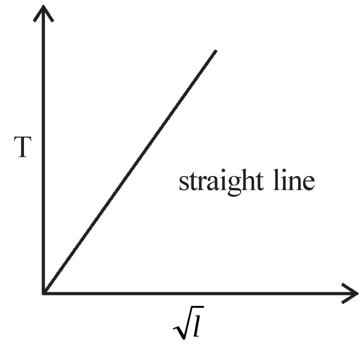
$T = 2\pi\sqrt{\frac{l}{g_{eff}}}$

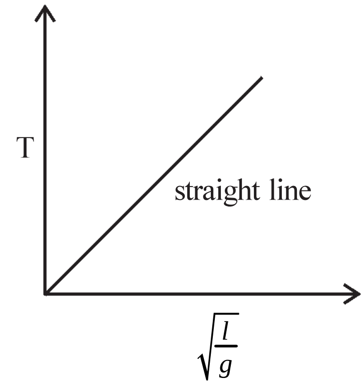
Second Pendulum

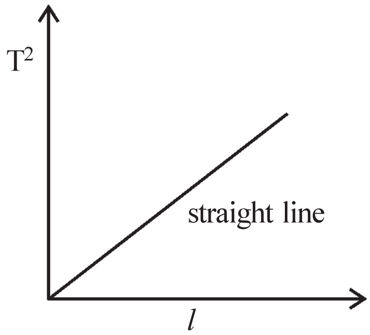
Periodic time T = 2 s

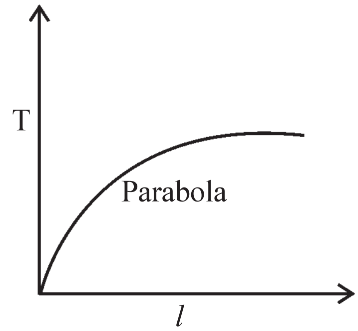
length on earth $l \approx 100$ cm ≈ 1 m

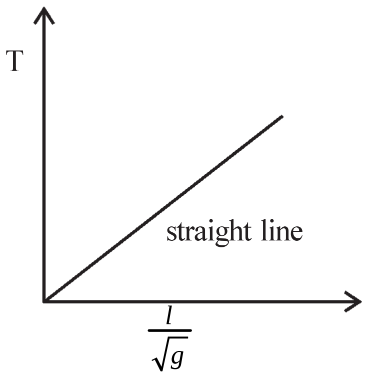
Graphs for Simple Pendulum :

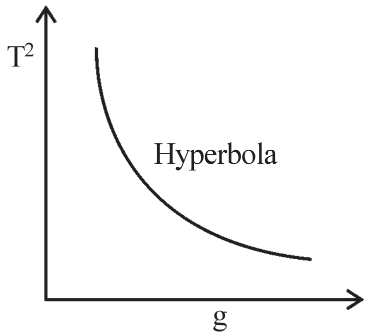












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(55) The periodic time of a simple pendulum is doubled on increasing its length by 7.5 m. The original length of the pendulum l = ... m.

(A) 1.5 m (B) 2m (C) 2.5 m (D) 3.0 m

(56) By keeping the length of a simple pendulum constant, it is taken at a place where gravitational acceleration reduces by 75%. Then the periodic time of the pendulum

(A) increases by 100 % (B) decreases by 100 % (C) increases by 200 % (D) decreaser by 200 %

(57) The mass of a planet is 4 times that of earth and the diameter of the planet is doubled than that of the earth. If the periodic time of the pendulum on the earth is T_e. What would be the periodic time of the same simple pendulum on the planet ?

(A) T_e (B) $\sqrt{2}\,T_e$ (C) $2\,T_e$ (D) $\frac{T_e}{2}$

(58) A hollow metallic sphere filled with mercury is taken as sphere of a simple pendulum. If some part of the mercury flows out of the sphere ......

(A) period and oscillations does not change (B) T decreases, Oscillations becomes slow

(C) T decreases, Oscillations becomes fast (D) T increases, Oscillations becomes slow

(59) The period of a simple pendulum in a stationary elevator is T. When an elevator moves up with an acceleration of $\frac{g}{4}$, its period is T_1. If it moves downward with the same acceleration, its period is T_2. Then $\frac{T_1}{T_2}$ = ...

(A) $\frac{T_1}{T_2} = \frac{2}{\sqrt{5}}$ (B) $\frac{T_1}{T_2} = \frac{2}{\sqrt{3}}$ (C) $\frac{T_1}{T_2} = \sqrt{\frac{3}{5}}$ (D) $\frac{T_1}{T_2} = \sqrt{\frac{5}{3}}$

(60) An electric charge –q is induced on a metallic sphere of a simple pendulum. There is positive charge on the horizontal surface below this pendulum. What would be the period of the oscillations of the simple pendulum ?

(A) $T = 2\pi\left[\frac{ml}{qE}\right]^{\frac{1}{2}}$ (B) $T = 2\pi\left[\frac{l}{g+\frac{qE}{m}}\right]^{\frac{1}{2}}$

(C) $T = 2\pi\left[\frac{l}{g-\frac{qE}{m}}\right]^{\frac{1}{2}}$ (D) $T = 2\pi\left[\frac{l}{g}\right]^{\frac{1}{2}}$

(61) Calculate the effective gravitational acceleration at a place, where periodic time of a simple pendulum of length 0.25 m is 1 s.

(A) π^2 (B) $4\pi^2$ (C) 2π (D) $0.25\ \pi^2$

(62) The ratio of frequencies of two simple pendulum kept at the same place is 5 : 4. Then the ratio of their length is ....

(A) $\frac{4}{5}$ (B) $\frac{2}{\sqrt{5}}$ (C) $\frac{16}{25}$ (D) 1

(63) The length of a simple pendulum is l. When an iron sphere is used as a bob of this pendulum, the period of its simple harmonic oscillation is T. If a steel sphere of the same volume is used instead of iron sphere the period becomes 2T. Calculate the length of the pendulum if the density of steel is n times the density of iron.

(A) $4l$ (B) $\frac{4l}{n}$ (C) $4nl$ (D) $4n^2l$

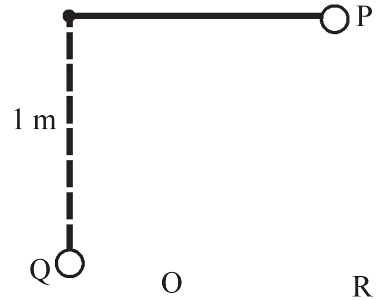
(64) A simple pendulum is suspended from the celling of an aeroplane. If the plane starts moving on the horizontal run-way with a constant acceleration of 12.49 ms^{-2}. Calculate the periodic time of simple harmonic oscillations of the pendulum. The length of the pendulum is 1m and g = 10 ms^{-2}.

(A) 2π (B) $\frac{\pi}{2}$ (C) $2\pi^2$ (D) $\frac{\pi^2}{2}$

(65) When a child swing, in sitting and standing inside the swing, the periodic time of the oscillations is T and T' respectively, then.

(A) $T' = T$ (B) $T' > T$ (C) $T' < T$ (D) $T' = T^2$

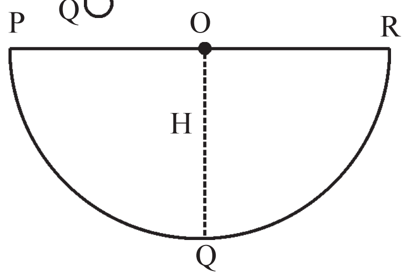
(66) A pendulum of length 1 m lift at P, when it reaches Q, it losses 20 % of its total energy due to air resistance. The velocity at Q = ... ms^{-1}. (g = 10 ms^{-2})



(A) 4 ms^{-1} (B) 6 ms^{-1}

(C) 8 ms^{-1} (D) 10 ms^{-1}

(67) A simple pendulum with a bob of mass m oscillates along PQR path. Its motion is simple periodic motion. Calculate the velocity of the bob when it passes through point Q.



(A) v = mgH (B) $v = \sqrt{2}\,gH$

(C) v = 2g H (D) $v = \sqrt{2gH}$

(68) The length of a simple pendulum is 0.9 m. When it passes through its mid point, it velocity is 5 ms^{-1}. calculate its velocity when it makes an angle of 60° with the vertical line. [g = 10 ms^{-2}]

(A) 4 ms^{-1} (B) 3 ms^{-1} (C) 2 ms^{-1} (D) 0

(69) On the surface of a planet, when the length of the simple pendulum is kept 25 m, its periodic time is T. At a height of 2000 km from the surface of this planet, when the length is kept 9 m, the periodic time remains same as T. Then the radius of the planet is ....

(A) 2400 km (B) 3000 km (C) 6000 km (D) 8000 km

(70) The periodic time of a simple pendulum is T_1. When the point of suspension from the rigid support is moved by $y = kt^2$, its periodic time becomes T_2. Then $\frac{T_1^2}{T_2^2}$ = ... [g = 10 ms^{-2}, k = 1]

(A) $\frac{6}{7}$ (B) $\frac{6}{5}$ (C) $\frac{5}{7}$ (D) $\frac{5}{6}$

Ans. : 55 (C), 56 (A), 57 (A), 58 (D), 59 (C), 60 (B), 61 (A), 62 (C), 63 (A), 64 (B), 65 (C), 66 (A), 67 (D), 68 (A), 69 (B), 70 (B)

Natural Oscillations Damped Oscillations, Forced Oscillations and Resonance :

- **Natural Oscillations :** The oscillations performed in absense of any type of resistive forces are known as Natural oscillations (free oscillations)

  frequency of the natural oscillations = f_0.

  natural angular frequency $\omega_0 = 2\pi f_0$.

- **Damped Oscillations :** The oscillations performed in the presence of resistive force, which are of decreasing amplitude are called damped oscillations.

- **Forced Oscillations :** The oscillations performed in the Presanse of external periodic force with constant amplitude are called forced oscillations.

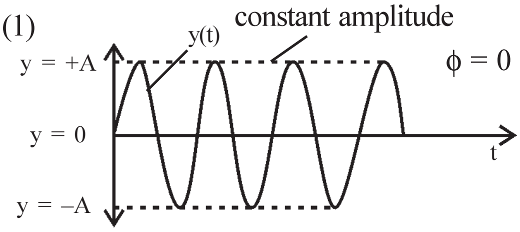
Natural Oscillations	Damped Oscillations	Forced Oscillations
● Amplitude (A) remains constant with time	● A exponentially decrease with time	● A remains constant with time
● The resultant Force F = –ky	● F = –ky –bv	● F = –ky – bv + F_0 sin ωt

● differential equation $\frac{d^2y}{dt^2} + \omega_0^2 y = 0$	$\frac{d^2y}{dt^2} + \left(\frac{b}{m}\right)\frac{dy}{dt} + \omega_0^2 y = 0$	$\frac{d^2y}{dt^2} + \left(\frac{b}{m}\right)\frac{dy}{dt} + \omega_0^2 y = \frac{F_0}{m}\sin\omega t$
● Solution; $y(t) = A\sin(\omega_0 t + \phi)$	● $y(t) = A'(t)\sin(\omega' t + \phi)$	● $y(t) = A\sin(\omega t + \phi)$
● A doesnot depend on time t	● $A'(t) = Ae^{-bt/2m}$	● $A = \frac{F_0}{[m^2(\omega_0^2 - \omega^2)^2 + b^2\omega^2]^{\frac{1}{2}}}$
● Natural angular frequency $\omega_0^2 = \frac{k}{m}$, $\omega_0 = \sqrt{\frac{k}{m}}$	$\omega' = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$ b = damping co-efficient of the medium	$\phi = \tan^{-1}\left(\frac{\omega y_0}{v_0}\right)$
● Natural frequency $f_0 = \frac{1}{2\pi}\ 2\pi\sqrt{\frac{k}{m}}$	$b = \frac{F}{v}$ (for small velocity) If velocity is large $b = \frac{F}{v^n}$ (n depends on velocity) unit of b $\frac{N-s}{m} = Nsm^{-1}$ $[b] = M^1L^0T^{-1}$	

For Forced oscillations (y)

Displacement (y) → time (t)

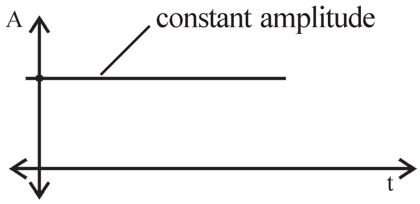
(1)



$\phi = 0$

Amplitude (A) → time (t)

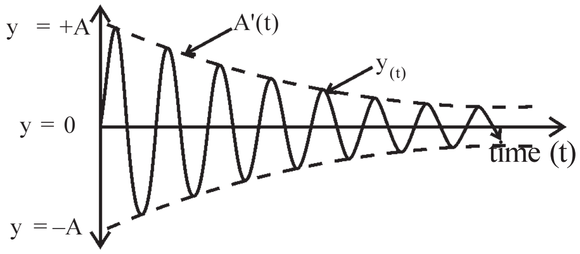
(2)



For Damped Oscillations

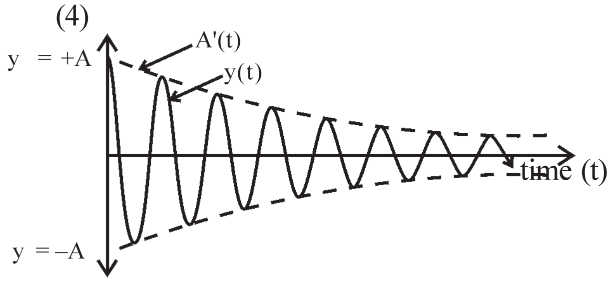
Displacement (y) → time (t) ($\phi = 0$)

(3)



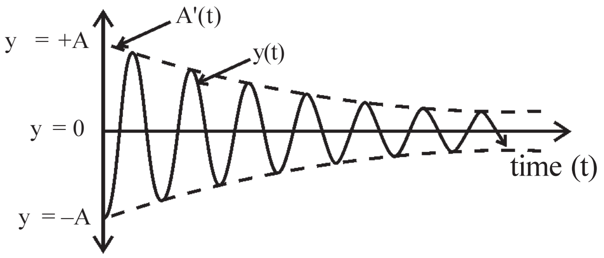
Displacement (y) → (t) ($\phi = \frac{\pi}{2}$)

(4)



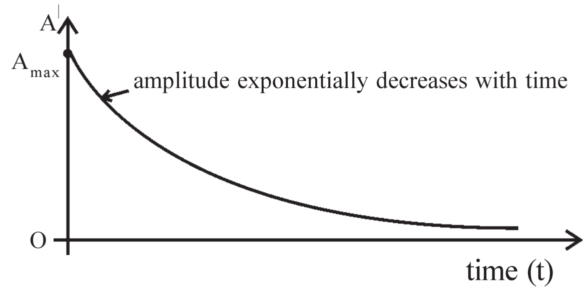
Displacement (y) $\rightarrow$ time (t) ($\phi = \frac{3\pi}{2}$)

(5)



Damping Ossicillation

(6) **Amplitude (A') $\rightarrow$ time (t)**



Resonance

Amplitude of forced oscillation $A \propto \frac{1}{\left(\omega_0^2 - \omega^2\right)}$

As ω move toward ω_0, A increases

- When $\omega = \omega_0$, A = maximum. This phenomenon is called Resonance.

  For Resonance $f = f_0$

  When the frequency of external periodic force becomes equal to the natural frequency of the oscillations, the amplitude of the oscillations becomes maximum. This phenomenon is called resonance.

  ω_0 is called resonant angular frequency

  f_0 is called resonant frequency

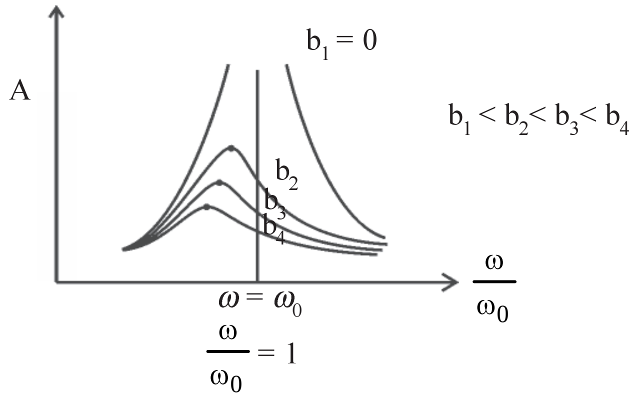
- At the time of resonance $A = \frac{F_0}{b\omega}$
- $b \rightarrow 0; A \rightarrow \infty$

Resonance Curves

- $b = 0 \Rightarrow A = \infty$

  With the increase of b, maximum amplitude decreases.

- When the external periodic force is acting on the system and frequency of the external periodic force becomes equal to the natural frequency (or nearly equal), the system oscillates with a very large amplitude and the system may break or collapse. e.g.



(1) When soldiers are marching on a suspended bridge, the frequency of the external periodic force becomes equal to the natural frequency of the bridge, the bridge might be collapse.

(2) The gusts of wind exerts external periodic force to the trees and structures. If this frequency becomes equal to the natural frequency, tree oscillate with very large amplitude and collapses.

(3) When a bridge is designed, care is taken so that the external force due to gusts of wind and natural frequency of the bridge do not becomes equal.

Frequency of the Seismic waves (f) :

The frequency (f) of the seismic waves is very less than the natural frequency (f_0) of low rise structures. ($f < f_0$)

The frequency (f) of the seismic waves is greater than the natural frequency (f_0) of high rise structures. ($f > f_0$)

Therefore, in an earthquake, low and high-rise structures remain less affected while medium high structure fall down. ($f = f_0$)

Significant Amplitude :

$\frac{1}{e}$ times the amplitude of the damped oscillator is called its significant amplitude.

---

(71) In what time the amplitude of damped oscillator becomes $\frac{1}{e}$ times of its maximum value ?

(A) $\frac{b}{2\text{m}}$ (B) $\frac{\text{m}}{2b}$ (C) $\frac{2\text{m}}{b}$ (D) $\frac{2b}{\text{m}}$

(72) The mass of an oscillator is 100 g. It is oscillating in a medium having damping co-efficient 0.805 dyne s cm^{-1}. Calculate the time during which its amplitude decreases by 80 % of its initial value.

(A) 200 s (B) 400 s (C) 600 s (D) 800 s

(73) The mass of a damped oscillator is m. Its initial amplitude is A_0. If at time t, its amplitude becomes A_t, then the damping co-efficent of the medium is ....

(A) $b = \left[\frac{2\text{m}}{t\ln\left(\frac{A_t}{A_0}\right)}\right]$ (B) $b = \left[\frac{2\text{m}}{t\ln\left(\frac{A_0}{A_t}\right)}\right]$ (C) $b = \left[\frac{t\ln\left(\frac{A_t}{A_0}\right)}{2\text{m}}\right]$ (D) $b = \left[\frac{t\ln\left(\frac{A_0}{A_t}\right)}{2\text{m}}\right]$

(74) The mass and periodic time of a damped oscillater is 500 g and 2 s respectively. Its amplitude reduces by 50 % of its initial value, When it completes 50 oscillations. Calculate the damping co-efficient of the medium.

(A) 0.6930 dyne s cm^{-1} (B) 6.930 dyne s cm^{-1} (C) 0.06930 dyne s cm^{-1} (D) 69.30 dyne s cm^{-1}

(75) The amplitude of damped oscillator becomes 0.8 times of its initial value in 5 s. Then it becomes N times of its initial value in next 10 s. What would be the value of N ?

(A) 0.813 (B) 0.729 (C) 0.512 (D) 0.343

(76) The periodic time of a simple pendulum in air is T_0. If the pendulum oscillate in the medium of a liquid, the period becomes T. If the density of the liquid is 4 times the density of the material of the sphere, calculate T.

(A) $T = \frac{T_0}{2}$ (B) $T = 2T_0$ (C) $b = \frac{\sqrt{3}}{2}T_0$ (D) $\frac{2}{\sqrt{3}}T_0$

(77) When the damped oscillator completes 100 oscillations its amplitude becomes 20 % of its initial value. What will be the amplitude when it completes 200 oscillations ?

(A) 10 % of A_0 (B) 4 % of A_0

(C) 6 % of A_0 (D) 8 % of A_0

(78) The mass of a damped oscillator is m. The damping co-efficent of the medium is b. How many oscillations are performed in 1 s ?

(A) $\frac{1}{2\pi}\sqrt{\frac{k}{m}-\frac{b}{2m}}$ (B) $\frac{1}{2\pi}\sqrt{\left(\frac{k}{m}\right)^2-\left(\frac{b}{2m}\right)^2}$

(C) $\frac{1}{2\pi}\sqrt{\left(\frac{k}{m}\right)^2-\frac{b}{2m}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{k}{m}-\left(\frac{b}{2m}\right)^2}$

(79) What would be the time taken by a damped oscillator to acheive its significant amplitude (average life time) ?

(A) $\frac{2m}{b}$ (B) $\frac{b}{2m}$ (C) $\frac{0.6930\,m}{b}$ (D) $\frac{0.6930}{2mb}$

(80) What would be the amplitude of the forced oscillations at the time of resonance ?

(A) $\frac{b\omega}{a_0}$ (B) $\frac{b\omega}{m\,a_0}$ (C) $\frac{m\,a_0}{b\omega}$ (D) $\frac{a_0}{b\omega}$

(81) During earthquake, which one of the following structure have maximum posibility of fall down ?

(A) High rise structure (B) low rise structure

(C) medium high structure (D) All of them having equal probability

(82) In the case of forced oscillations, the resonant wave becomes more sharp when.

(A) the magnitude of resistive force is less (B) the magnitude of external periodic force is less.

(C) the frequency of external periodic force is less. (D) the damping coeffcient of the medium is less.

(83) If ω_0 is the natural angular frequency and ω is the angular frequency of the external periodic force, then at the time of resonance $\frac{\omega_0}{\omega}$.

(A) $\frac{\omega_0}{\omega} \geq 1$ (B) $\frac{\omega_0}{\omega} = 0$ (C) $\frac{\omega_0}{\omega} = 1$ (D) $\frac{\omega_0}{\omega} = \infty$

(84) A damped oscillator of mass m performs damped oscillation in the medium of damping co-efficient b. At time t_1 and t_2, its amplitude is A_1 and A_2 respectively. Which one of the following is true ?

(A) $A_2 = A_1 e^{\frac{b(t_1-t_2)}{2m}}$ (B) $A_2 = A_1 e^{\frac{b(t_2-t_1)}{2m}}$

(C) $A_2 = A_1 e^{\frac{-b(t_1+t_2)}{2m}}$ (D) $A_2 = A_1 e^{\frac{-b\left(\frac{t_1+t_2}{2}\right)}{2m}}$

(85) At a certain time the amplitude of a damped oscillator is 10 % of its initial value. Now the oscillator is allowed to oscillate in the medium having damping co-efficient twice that of the previous one. Calculate the percentage decrecse in its amplitude during the same time.

(A) 20 % (B) 5 % (C) 2 % (D) 1 %

Ans. : 71 (C), 72 (B), 73 (B), 74 (B), 75 (C), 76 (D), 77 (B), 78 (D), 79 (A), 80 (C), 81 (C), 82 (D), 83 (C), 84 (A), 85 (D)

Waves

- The motion of the disturbance propagating in the medium (or in free space) is called a wave.
- The wave is neither a 'Physical body' travelling in the medium nor medium Particles are moving as a single unit.

Mechanical waves : The waves which require elastic medium for their transmission are called mechanical waves.

Non-mechanical waves : The waves which do not require any elastic medium [even propagate in the medium] and also propagate in the free space are called non mechanical waves [They are also known as electro magnetic waves]

Transverse waves : The waves in which the oscillations of the particles are in a direction perpendicular to the direction of propagation are called transverse waves.

Longitudinal waves : The waves in which the oscillations of the particles are in the direction of propagation of the wave are called longitudinal waves.

- Sound waves are mechanical and longitudinal.
- waves produce on the string are mechanical and transverse.
- Light waves are non mechanical and transverse.

Intensity of the wave (I) : Energy passing through a unit area, taken in the direction normal to the propagation, in one second is called intensity of the wave.

$$(I) = \frac{\text{Energy (E)/Time (t)}}{\text{Area (A)}}$$

Its unit is : $\frac{Js^{-1}}{m^2} = \frac{\text{watt}}{m^2} = Wm^{-2}$

$[I] = M^1L^0T^{-3}$

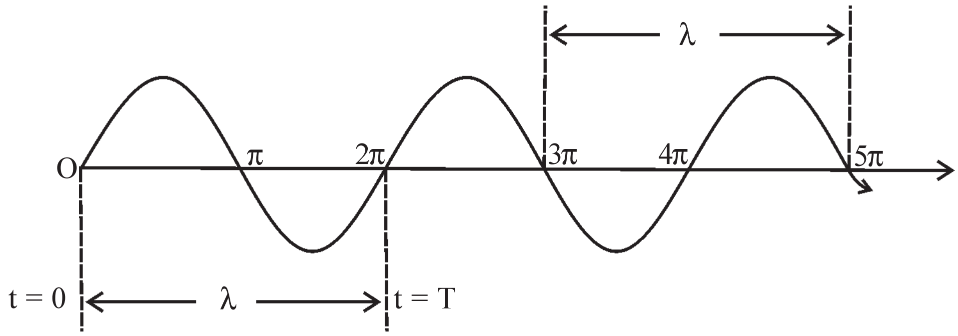
Note :

Dimensional Formula	**Quantity**
MT^{-1} :	damping coefficient to the medium
MT^{-2} :	Force constant of the spring, surface tension.
MT^{-3} :	Wave intensity, emissive power ot the surface

Intensity $I \propto E \left(= \frac{1}{2} kA^2\right)$

$\therefore I \propto A^2$, Intensity $\propto$ (Amplitude)^2

Wave length (λ) and Velocity (v) of the wave



Wave length (λ) : The distance between two particles having phase difference 2π rad is called wave length (λ).

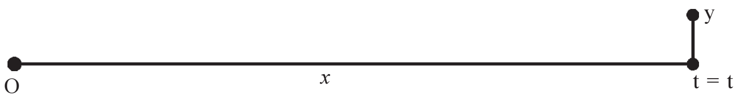
Velocity of the wave (v) : The effect of disturbance travels distance λ in time T.

$\therefore$ Velocity of the wave $v = \frac{\lambda}{T} = \lambda f = \frac{\omega}{k}$; $k = \frac{2\pi}{\lambda}$ = wave vector

Note : distance $\equiv$ Phase difference $\equiv$ time

$\lambda \equiv 2\pi \equiv T$

Wave equation



The displacement of a particle at a distance x from the origin at time t is,

$y = A \sin(\omega t - kx)$ [for positive X-direction]

$$y = A \sin 2\pi \left(ft - \frac{x}{\lambda}\right)$$

$$y = A \sin 2\pi f \left(t - \frac{x}{v}\right)$$

For the wave propagating in the – X direction take $x = -x$.

- The phase difference between the two particles having seperation x is, $\delta = \frac{2\pi \quad x}{\lambda}$

Note : The time derivative of wave equation represent velocity of the particle at a distance x from the origin, at time t.

[It does not represent velocity of the wave]

$$v = \frac{dy}{dt} \Rightarrow v = A\omega \cos(\omega t - kx)$$

- The slope of the wave form at a distance x from the origin at time t

$$\frac{dy}{dx} = -Ak \cos(\omega t - kx)$$

(86) The minimum distance between the two particles having phase difference $17\,\frac{\pi}{2}$ is ...... A°. [$k = 6.28 \times 10^8$ rad cm^{-1}]

(A) 4.25 (B) 8.5 (C) 17 (D) 3.4

(87) The value of a wave vector is $10\,\pi$ rad cm^{-1}. Calculate the phase difference between two particles having 3.6 cm distance.

(A) 1.8π (B) 3.6π (C) 18π (D) 36π

(88) Wave equation is $y = 10 \sin (4\pi t - \pi x)$ cm, t is in second. Calculate the ratio of velocity of a particle at 38 cm away from the origin at the end of 10 s and velocity of the wave.

(A) $40\,\pi$ (B) $10\,\pi$ (C) $0.1\,\pi$ (D) $4\,\pi$

(89) An amplitude of a progressive harmonic wave is 5 cm. The displacement of a particle at a distance 4 cm away from the origin, at the end of 2 s is $\frac{5}{\sqrt{2}}$ cm and the displacement of a particle 16 cm away from the origin, at the end of 4 s is 2.5 cm. Calculate the values of ω and k.

(A) $\omega = \frac{7\pi}{24}$, $k = \frac{\pi}{24}$ (B) $\omega = \frac{5\pi}{24}$, $k = \frac{\pi}{24}$ (C) $\omega = \frac{\pi}{24}$, $k = \frac{3\pi}{24}$ (D) $\omega = \frac{\pi}{24}$, $k = \frac{\pi}{12}$

(90) The frequency of a wave is $\frac{10}{\pi}$ Hz. If the maximum displacement of particles of the medium is 0.4 cm, the maximum velocity of the particle is ...... cms^{-1}.

(A) 2 (B) 4 (C) 8 (D) 10

(91) The wave equation is $y = 10 \sin (\pi t - \pi x)$ cm. Time t is in second. Calculate the displacement and acceleration of a particle which is 2 cm away from the origin, at the end of $\frac{13}{6}$ s.

(A) $y = 5$ cm, $a = -5\pi^2\ cms^{-2}$ (B) $y = 10$ cm, $a = -10\,\pi^2\ cms^{-2}$

(C) $y = 5$ cm, $a = -10\,\pi^2\ cms^{-2}$ (D) $y = 10$ cm, $a = -5\pi^2\ cms^{-2}$

(92) The frequency of an electromagnetic wave is 150 MHz. Calculate the value of wave-vector in rad m^{-1}.

(A) π (B) $\frac{\pi}{2}$ (C) $\frac{3\pi}{2}$ (D) $\frac{3\pi}{4}$

(93) The wave equation for a progressive harmonic wave is $y = 0.5 \sin (0.05t + 0.02\pi x - \frac{\pi}{6})$ cm. Where time t is in second. Calculate the minimum distance between the two particles having phase difference $\frac{\pi}{4}$ rad.

(A) 3.125 cm (B) 6.25 cm (C) 12.5 cm (D) 25 cm

(94) The frequency and velocity of a wave are 1 kHz and 330 ms^{-1} respectively. Calculate the minimum distance (in metre) between the two particles having phase difference 60°.

(A) 11×10^{-2} (B) 5.5×10^{-2} (C) 6.6×10^{-2} (D) 3.3×10^{-2}

(95) For particle-1, wave equation is $y_1 = 10 \sin (50\pi t + \frac{\pi}{3})$. For particle-2, wave equation is $y_2 = 10 \cos \pi t$. Calculate the phase difference of the displacement [or velocity or acceleration] of the particle-2 with respect to particle-1.

(A) $\frac{\pi}{6}$ (B) $\frac{\pi}{3}$ (C) $-\frac{\pi}{6}$ (D) $-\frac{\pi}{3}$

(96) The wave equation for a wave propagetting in X-direction is $y = 0.008 \cos(\alpha x - \beta t)$ m. The wavelength and periodic time are 0.08 m and 0.5 s respectively. Calculate values of α and β.

(A) $\alpha = 25\pi, \beta = 4\pi$ (B) $\alpha = 4\pi, \beta = 25\pi$ (C) $\alpha = 50\pi, \beta = 2\pi$ (D) $\alpha = 2\pi, \beta = 50\pi$

(97) The wave equation is $y = y_0 \sin 2\pi (f t - \frac{x}{\lambda})$. The maximum velocity of a particle is 4 times the velocity of the wave. Calculate the wave length of the wave.

(A) $\frac{\pi y_0}{4}$ (B) $\frac{\pi y_0}{8}$ (C) $\frac{\pi y_0}{2}$ (D) $4\pi y_0$

(98) The wave equation is $y = 0.01 \sin 2\pi \left(\frac{t}{0.05} - \frac{x}{0.02}\right)$ m [Where y and x are in metre, t is in second] Calculate the values of maximum velocity and maximum acceleration.

(A) $v_{max} = 0.4\pi$, $a_{max} = 4\pi^2$ ms^{-2} (B) $v_{max} = 16\pi$, $a_{max} = 4\pi^2$ ms^{-2}

(C) $v_{max} = 16\pi$ ms^{-1}, $a_{max} = 16\pi^2$ ms^{-2} (D) $v_{max} = 0.4\pi$ ms^{-1}, $a_{max} = 16\pi^2$ ms^{-2}

(99) The displacement of some particle of the medium is given by $y = 10^{-6} \sin(100\,t + 20x + \frac{\pi}{4})$m. (where x is in metre, t is in second). Calculate the wave-speed.

(A) 5 ms^{-1} (B) 0.5 ms^{-1} (C) 5π ms^{-1} (D) $5\pi^2$ ms^{-1}

(100) The wave equation for one dimensional progressive harmonic wave is $y = 10 \sin 20\pi (t - \frac{x}{160})$ m. (where x is in metre, t is in second). Calculate the slope of the wave at a distanace of 320 m, at the end of 2 s.

(A) $-10\frac{\pi}{5}$ (B) $-\frac{5\pi}{4}$ (C) $-\frac{5\pi}{8}$ (D) $-\frac{3\pi}{8}$

Ans. : 86 (A), 87 (D), 88 (B), 89 (B), 90 (C), 91 (A), 92 (A), 93 (C), 94 (B), 95 (C), 96 (A), 97 (C), 98 (D), 99 (A), 100 (B)

Speed of waves in a medium :

- Speed of transverse wave on stretched string

$v = \sqrt{\frac{T}{\mu}}$ Where T = Tension force

μ = linear mass density of the string

- **Speed of longitudinal wave (sound wave) in a medium :**

$v = \sqrt{\frac{E}{\rho}}$ E = Elastic constant of the medium

B = Bulck's modulus

$v = \sqrt{\frac{B}{\rho}}$ Y = Young's modulus

P = Pressure

$v = \sqrt{\frac{Y}{\rho}}$ ρ = density of the medium

$v = \sqrt{\frac{\gamma P}{\rho}}$ $\gamma = \frac{C_p}{C_v}$

$$v = \sqrt{\frac{\gamma RT}{\rho V}}$$ ρV = mass

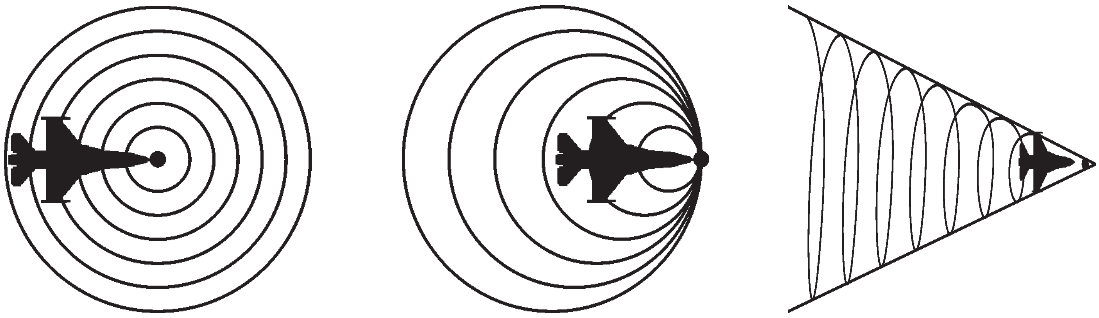
V = volume of gas

$$v = \sqrt{\frac{\gamma RT}{M}}$$ m = Molar mass of gas.

Note :

- The phenomenon of the propagation of sound in the gas is adiabatic
- At a constant temperature, velocity of sound in the gas is independent of the Pressure.
- Velocity (speed) of sound increases with increasing humidity
- The speed of sound is comparatively much greater in solid than that in the liquid and in the gas. [except Vulcanized rubber]
- At STP, the speed of sound in air $v = 332\ ms^{-1}$.
- In practice, the range of wave length of audible sound is from $\lambda = 1.7$ cm to $\lambda = 17$ m.
- Waves having $\lambda < 1.7$ cm are not audible. They are known as Ultrasonic waves.
- Waves having $\lambda > 17$ m are also not audible. They are know Infrasonic waves.
- An object moving with a velocity greater than the velocity of sound is called supersonic.

  When such supersonic body (e.g. an aeroplane) travels in air, it produces energetic disturbance. Such disturbance moves in backward direction and diverge in the form of a cone. Such waves [disturbances] are called Shock waves. When Shock waves collides with structure, a very huge sound is produced.



The speed of supersonic is measured in Mach Number

$$\text{Mach Number} = \frac{\text{Velocity of source}}{\text{Velocity of sound}}$$

- Speed of the sound is directly proportional to its absolute temperature.

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$

- For two different gases having equal pressure (P) and equal value of γ, the ratio of velocity of sound.

$$\frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}}$$, ρ_1 and ρ_2 are the density of the gas.

- For sound, the temperature coefficient of expansion (α) is given by

$\alpha = \frac{v_T - v_0}{T}$, where, v_T = velocity of sound at T °C, v_0 = velocity of sound at 0 °C. The unit of α is $°C^{-1}$.

- For sound waves, the time interval between two successive condensation and rarefaction is equal to $\frac{T}{2}$.
- When a person hear echo sound from the reflector at a distance d, then velocity of sound.

$v = \frac{2d}{t}$

$\therefore$ Time interval of Echo. $t = \frac{2d}{v}$

- Sound intensity level is given by $L = 10 \log\left(\frac{I}{I_0}\right)$ Where I_0 = minimum intensity (refrence intensity), I = intensity of the sound

Sound intensity level is meausured in decibels (dB).

---

(101) A sound wave of frequency 400 Hz is propagating with the speed of 332 ms^{-1}. What would be the minimum time to form rarefaction at a place where maximum condensatin occurs.

(A) $\frac{1}{800}$ s (B) $\frac{1}{200}$ s (C) $\frac{1}{332}$ s (D) $\frac{1}{664}$ s

(102) The speed of sound in H_2 is 1225 ms^{-1}. By taking volume ratio 1:2 of H_2 and O_2, a mixture H_2O_2 is prepared. What would be the speed of sound (in ms^{-1}) in the mixture ? [density of O_2 is 16 times that of H_2]

(A) 2450 (B) 1000 (C) 500 (D) 250

(103) At what temperature the speed of sound would be double than its value at NTP ?

(A) 600 K (B) 1200 K (C) 150 K (D) 75 K

(104) A person standing at the mid point of the two parallel walls claps his hand, hears its echo after 1 s. Calculate the distance between the two walls (in metre) if the speed of the sound in air is 332 ms^{-1}.

(A) 332 (B) 116 (C) 664 (D) 58

(105) A stone is dropped in a well from the height of 20 m from the water surface. The sound of collision of the stone with water is heard after 2.06 s (after dropping). Then the velocity of sound in ms^{-1} is .... [take g = 10 ms^{-2}]

(A) 333 (B) 300 (C) 350 (D) 260

(106) The minimum intensity of an audible sound is 10^2 Wm^{-2}. Calculate the sound intensity level (in decibel) when the intensity of the sound becomes 10^7 Wm^{-2}.

(A) 5 (B) 3 (C) 30 (D) 50

(107) A sound of intensity level 50 dB is how many times powerful than the sound of intensity level 20 dB ?

(A) 30 (B) 300 (C) 900 (D) 1000

(108) What would be the minimum distance (in metre) of reflector from the person (source) for listening the echo of sound ? Velocity of sound is 330 ms^{-1}.

(A) 16.5 (B) 33 (C) 66 (D) 99

(109) An intensity of a sound wave decreases by 10 % while passing through a slab. Such two slabs are kept together and sound wave is allowed to pass through it. Calculate the percentange decrease in the intensity of the sound wave.

(A) 20 % (B) 19 % (C) 21 % (D) 10 %

(110) Young's modulus of a matter is 13.2×10^{10} Nm^{-2}. The density of this matter is 3.3×10^{2} kg m^{-3}. Calculate the velocity (in ms^{-1}) of longitudinal wave in this matter.

(A) 500 (B) 1000 (C) 2000 (D) 2500

(111) Velocity of sound in a gas at STP is 273 ms^{-1}. Calculate the temperature coefficient of velocity in ms^{-1} K^{-1}.

(A) 0.5 (B) 0.25 (C) 0.8 (D) 0.75

(112) A wire PQR is prepared by connecting two wires PQ and QR of equal radius. The length and mass of wire PQ are 2 m and 0.025 kg respectively. Those for wire QR are 1 m and 0.05 kg respectively. The tension produced in wire PQR is 80 N. Calculate the time taken by the sound (in second) to travel from P to R.

(A) 0.025 (B) 0.05 (C) 0.25 (D) 0.5

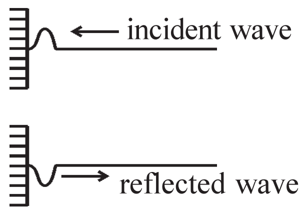
Ans. :	**101 (A), 102 (C), 103 (B), 104 (A), 105 (A), 106 (D), 107 (D), 108 (B), 109 (B), 110 (C), 111 (A), 112 (B)**

Principle of Superposition

'When two or more waves superpose at same particle of the medium, the resultant displacement of a particle at the superposition is equal to the vector sum of the individual displacement produced by each wave.

Reflection of Waves

- **Reflection from the rigid support :**
- When a wave is reflected from the rigid support, its phase is increased by π.



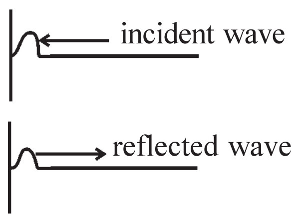
$\therefore$ "crest" becomes "trough"
and "trough" becomes "crest"

If $y_i = A \sin(\omega t - kx)$ its reflected wave,

$y_r = -A \sin(\omega t + kx)$

[**Note :** The negative sign indicates that the phase increases by π. The sign inside the bracket changes indicates that direction of propogation is reversed]

- **From the free end**
- The reflection at free end (open boundary) takes place without any change in the phase.



"crest" remains "crest"
"trough" remains "trough"

If $y_i = A \sin(\omega t - kx)$

$y_r = A \sin(\omega t + kx)$

Stationary Waves

The resultant wave obtained due to the superposition of two waves having equal amplitude (A), equal wave length (λ) [or equal frequency f] and travelling in mutually opposite directions, is called Stationary wave.

- equation for the stationary wave $y = -2A \sin kx \cos \omega t$
- energy does not propagate in this type of wave.

Nodes

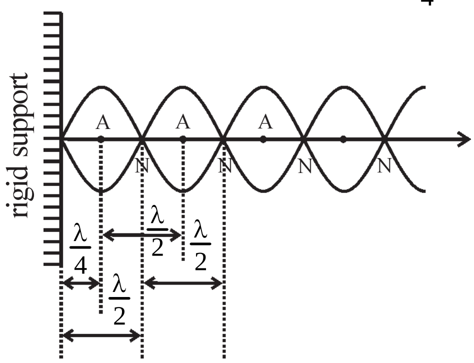
The positions in a stationary wave where the amplitude always remains zero are called the "Nodes".

- The nodes are located at a distance $x = \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}, 2\lambda, ..., \frac{n\lambda}{2}$ from the end $x = 0$
- The distance between two successive node is $\frac{\lambda}{2}$
- The first nodel point is at a distance of $\frac{\lambda}{2}$ (from $x = 0$ end).

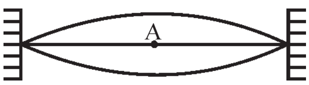
Antinodes

The positions in a stationary wave where the amplitude always remains maximum are called "Antinodes".

- Antinodes are located at a distance $x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$ ......, $(2n-1)\frac{\lambda}{4}$ from the end $x = 0$.
- The distance between two successive antinode or two successive node is $\frac{\lambda}{2}$
- The distance between successive node and antinode is $\frac{\lambda}{4}$
- The first antinodel point is at a distance of $\frac{\lambda}{4}$ (from $x = 0$ end).



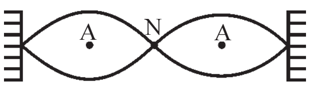
Normal Modes of Vibration

n = 1 

Fundamental frequency (First harmonic)

$f_1 = \frac{v}{2L}$ $\qquad \lambda_1 = 2L$

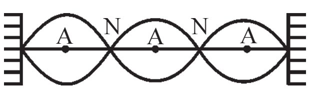
Second harmonic (First overtone)

n = 2 

$f_2 = \frac{2v}{2L}$ $\qquad \lambda_2 = L$

$f_2 = 2f_1$

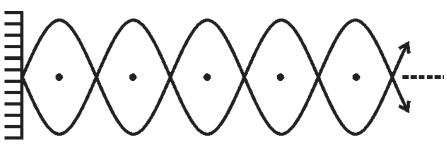
Third harmonic (Second overtone)

n = 3 

$f_3 = \frac{3v}{2L}$ $\qquad \lambda_3 = \frac{2}{3}L$

$f_3 = 3f_1$

n^{th} harmonic ($n-1^{th}$ overtone)

n = n 

$f_n = \frac{nv}{2L}$ $\qquad \lambda_n = \frac{2L}{n}$

$f_n = nf_1$

Note :

- For oscillations having n^{th} harmonic;

  number of closed loops = n

  number of Antinodes = n

  number of Nodes = (n–1)

- The difference between two successive harmonic is equal to fundamental frequency.

  $f_n - f_{n-1} = f_1$ or $f_{n+1} - f_n = f_1$

Stationary Waves in Pipes

- For closed pipe

frequency	wave length	
$f_n = \frac{v(2n-1)}{4L}$	$\lambda_n = \frac{4L}{(2n-1)}$	n = 1 fundamental frequency (first harmonic) n = 2 third harmonic (first overtone) n = 3 fifth harmonic (second overtone) n = n $(2n-1)^{th}$ harmonic ((n –1) overtone)

Note : For closed piple all harmonics are not possible only f_1, $3f_1$, $5f_1$, $7f_1$ ...... possible.

- Open pipe

frequency	wave length	
$f_n = \frac{nv}{2L}$	$\lambda_n = \frac{2L}{n}$	n = 1 fundamental (first harmonic) n = 2 Second harmonic (first overtone) n = 3 third harmonic (second overtone) n = n, n^{th} harmonic $((n-1)^{th}$ overtone)

$f_{open\ pipe} = 2 f_{closed\ pipe}$

(113) The possible maximum wave length of the stationary wave produced on the string of length 100 cm is ...... cm.

(A) 25 (B) 50 (C) 100 (D) 200

(114) In a case of stationary wave, the distance between successive node and antinode is 0.01 m. If the speed of the components of the wave is 320 ms^{-1}, calculate the frequency of the stationary wave.

(A) 4 kHz (B) 8 kHz (C) 800 kHz (D) 0

(115) The fundamental frequency for an open-pipe is 512 Hz. If it is closed at one end the fundamental frequency becomes ...... Hz.

(A) 256 (B) 512 (C) 1024 (D) 0

(116) The air column in a closed pipe experiences first resonance with a tuning fork of frequency 160 Hz. The length of the air column in the closed pipe is ...... cm. (v = 320 ms^{-1})

(A) 25 (B) 50 (C) 2.5 (D) 5

(117) A closed organ pipe and an open organ pipe are tuned to the same fundamental frequency. What is the raito of lengths.

(A) 2 : 3 (B) 3 : 4 (C) 1 : 2 (D) 3 : 2

(118) What would be the minimum length (in cm) of an open-pipe to have resonance with the tuning fork of 160 Hz ? (v = 320 ms^{-1})

(A) 10 (B) 25 (C) 50 (D) 100

(119) The frequencies of two consecutive overtone are 285 Hz and 325 Hz respectively. What would be the fundamental frequency ?

(A) 20 Hz (B) 40 Hz (C) 80 Hz (D) 305 Hz

(120) The length of a closed pipe is 130 cm. The frequency of stationary waves form is equal to the frequency of third overtone. Calculate wavelenth (in cm) of the wave.

(A) 40 (B) 80 (C) 130 (D) 260

(121) A closed pipe and an open pipe have their first overtones identical in frequency. Their lengths are in the ratio ....

(A) 1 : 2 (B) 3 : 4 (C) 4 : 5 (D) 5 : 6

(122) A string of length 100 cm is oscillating with 10^{th} harmonic. The number of nodes and antinodes form on the string are ...... and ...... respectively.

(A) 9 and 10 (B) 10 and 9 (C) 10 and 11 (D) 11 and 10

(123) The length of a closed pipe is 125 cm. The sound wave is produced with a tuning fork of frequency 320 Hz. Now water is filled gradually in this tube. For which height of water column will resonance occur ? v = 320 ms^{-1}.

(A) 25 (B) 75 (C) 100 (D) 125

(124) A string is attached with rigid supports separated by 100 cm distance. It is observed to have resonant frequencies of 295 Hz and 415 Hz. There is no other resonant frequency between these two. Then, the lowest resonant frequency for this string is ....

(A) 120 Hz (B) 60 Hz (C) 220 Hz (D) 250 Hz

(125) The wave equation for a stationary wave produced on a stretched string is $y = 10 \sin \frac{2\pi}{7} x \cos 70\pi t$

Distance between two successive node is ...... cm. [Where x and y are in cm, t is in sec.]

(A) 1.75 cm (B) 3.5 cm (C) 6.5 cm (D) 7.5 cm

(126) The length of the wire of guitar is 100 cm. Its fundamental frequency is 250 Hz. Calculate the length of the wire required to have 500 Hz frequency.

(A) 50 cm (B) 100 cm (C) 200 cm (D) 250 cm

(127) The stationary wave produced on a string is given by $y = 10 \sin \frac{\pi}{4} x \cos 40\pi t$ [Where x and y are in cm, t is in s] The positions of antinodes from the rigid support are ....

(A) 2 cm, 6 cm, 10 cm, 14 cm... (B) 4 cm, 8 cm, 16 cm, 20 cm...

(C) 2 cm, 4 cm, 6 cm, 8 cm.... (D) 4 cm, 6 cm, 8 cm, 10 cm...

(128) A block is attached at the free end of the sonometer wire. The fundament frequency for the vibrations of the wire is 500 Hz. When the block is immersed in the water the fundamental frequency becomes 300 Hz. Now, instead of water the block is immersed in the liquid. the fundamental frequency becomes 100 Hz. Calculate the specific density of the liquid.

(A) 1 (B) 1.5 (C) 2 (D) 2.5

(129) A string of length 35 cm is vibrating with the frequency of 3 kHz. The velocity of the wave is 350 ms^{-1}. Find the fundamental frequency and number of closed loops formed on the string.

(A) f_1 = 1000 Hz, n = 6 (B) f_1 = 500 Hz, n = 5

(C) f_1 = 500 Hz, n = 6 (D) f_1 = 300 Hz, n = 10

(130) The wave equation for a progresive harmonic wave propagating in the negative X-direction is $y = 20 \sin (4\pi t + 3\pi x)$. The wave reflects from the rigid support. The equation for the reflected wave is ....

(A) $y = 20 \sin (4\pi t - 3\pi x)$ (B) $y = -20 \sin (4\pi t + 3\pi x)$

(C) $y = 20 \sin (4\pi t - 3\pi x + \frac{\pi}{2})$ (D) $y = 20 \sin (4\pi t + 3\pi x + \frac{\pi}{2})$

(131) The wave equation for a progressive harmonic wave is $y = 10 \sin (4\pi t - \frac{2\pi}{5}x)$. It reflects from the rigid support. If the intensity of the reflected wave is 0.81 times the intensity of the incident wave, what would be the wave equation for the reflected wave ?

(A) $y_r = -8.1 \sin (4\pi t + \frac{2\pi}{5}x)$ (B) $y_r = -0.81 \sin (2\pi t + \frac{2\pi}{5}x)$

(C) $y_r = -9 \sin (4\pi t - \frac{2\pi}{5}x)$ (D) $y_r = -9 \sin (4\pi t + \frac{2\pi}{5}x)$

Ans. :	**113 (D), 114 (B), 115 (A), 116 (B), 117 (C), 118 (D), 119 (B), 120 (A), 121 (B), 122 (A), 123 (C), 124 (A), 125 (B), 126 (A), 127 (A), 128 (B), 129 (C), 130 (C), 131 (D)**

Beats

The Phenomenon of the loudness of sound becoming maximum and minimum periodically due to super-position of two sound waves of equal amplitude (A) and slightly different frequencies ($f_1 - f_2 < 7$) is called 'beats'.

The number of beats in unit time $= f_1 - f_2$

The periodic time of sound intensity becomes maximum or minimum $T = \frac{1}{f_1 + f_2}$

- By filing one of the prongs of a tuning fork, its frequency will increase a little.
- By putting some wax on one of the prongs of a tuning fork, its frequency will decrease a little.

Doppler Effect

Whenever there is a relative motion between a source of a sound and a listener, with respect to medium in which the waves are propagatting, the frequency of the sound experienced by the listener is different from the frequency emitted by the source. This phenomenon is called Doppler effect.

If, f_s = Original frequency of the sound emitted by the source, f_L = frequency of the sound experienced by the listener, v_s = velocity of the source of sound, v_L = velocity of the listener v = velocity of the sound.

The general formula for the frequency experienced by the listener is, $f_L = \left(\frac{v + v_L}{v + v_s}\right) f_s$

Spaceial cases :

(1) The listener is moving towards the stationary source

$v_s = 0,\ v_L = \text{positive};\ f_L = \left(\frac{v+v_L}{v}\right) f_s$

(2) The listener is moving away from the stationary source.

$v_s = 0,\ v_L = \text{negative};\ f_L = \left(\frac{v-v_L}{v}\right) f_s$

(3) The source is moving towards the stationary listener.

$v_L = 0,\ v_s = \text{negative};\ f_L = \left(\frac{v}{v-v_S}\right) f_s$

(4) The source is moving away from the stationary listener.

$v_L = 0,\ v_s = \text{positive};\ f_L = \left(\frac{v}{v+v_S}\right) f_s$

(5) Both (source and listener) are moving towards each other (approaching each other)

$v_s = \text{negative},\ v_L = \text{positive};\ f_L = \left(\frac{v+v_L}{v-v_S}\right) f_s$

(6) Both are moving away from each other

$v_s = \text{positive},\ v_L = \text{negative};\ f_L = \left(\frac{v-v_L}{v+v_S}\right) f_s$

(7) The listener is moving away from the source and the source is moving towards the listener, with relative velocity.

$v_s = \text{negative},\ v_L = \text{negative};\ f_L = \left(\frac{v-v_L}{v-v_S}\right) f_s$

(8) The listener is moving towards the source and the source is moving away from the listener with relative velocity.

$v_s = \text{positive},\ v_L = \text{positive},\ f_L = \left(\frac{v+v_L}{v+v_S}\right) f_s$

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(132) Frequencies of two tuning forks are 320 Hz and 480 Hz respectively. They produced sound waves in air having difference in the wave length $\frac{17}{48}$ m. Calculate velocity of sound in air (in ms^{-1})

(A) 280 (B) 300 (C) 340 (D) 360

(133) Two waves having wavelengths 50 cm and 50.5 cm produced 6 beats in 1s. Calculate the velocity of the waves.

(A) 303 ms^{-1} (B) 404 ms^{-1} (C) 505 ms^{-1} (D) 606 ms^{-1}

(134) The wave lengths of two pitches of the sound are $\frac{90}{175}$ m and $\frac{90}{173}$ m respectively. Both of them produces 4 beats in 1s with the third pitch. Calculate the fixed frequency of this third pitch.

(A) 174 Hz (B) 348 Hz (C) 522 Hz (D) 696 Hz

(135) Frequencies of three sound sources having equal intensity are 312 Hz, 316 Hz and 320 Hz respectively. Calculate the number of beats produced by any two successive source in 1 s.

(A) 2 (B) 4 (C) 6 (D) 0

(136) A tunimg fork P, produces 4 beats in 1s with a tuning fork Q of frequency 384 Hz. filing one of the prongs of tuning fork P, it produces 3 beats in 1s. Calculate the original frequency of the tuning fork P. (in Hz).

(A) 380 (B) 388 (C) 381 (D) 387

(137) A tuning fork M, produces 5 beats in 1s with a tuning fork N of frequency 588 Hz. After loading one of the prongs of tuning fork M, it produces 3 beats in 1s. Calculate the original frequency of the fork M. (in Hz).

(A) 583 (B) 593 (C) 585 (D) 591

(138) 51 tuning forks are arranged in the ascending order of their frequencies. Any two consecutive forks produce 3 beats in 1s. If the frequency of the last fork is 3 times that of the first fork, calculate the frequency of 26^{th} tuning fork.

(A) 120 Hz (B) 150 Hz (C) 170 Hz (D) 190 Hz

(139) 21 tuning forks are arranged in the ascending order of their frequecies. Any two consecutive forks produces x beats in 1s. The frequency of 21^{st} fork is 1.4 times that of the first fork. Calculate x if the frequency of 11^{th} fork is 120 Hz.

(A) 2 (B) 4 (C) 6 (D) 8

(140) Two tuning forks are of frequency 350 Hz and 355 Hz produces beats. After what time (least) the minimum occurs at a place where maximum is occured ?

(A) $\frac{1}{5}$ s (B) $\frac{1}{10}$ s (C) $\frac{1}{15}$ s (D) $\frac{1}{20}$ s

(141) A tuning fork produces 2 beats in 1s with the stretched wire of sonometer of length 80 cm and 60 cm. What would be the frequency of the tuning fork ?

(A) 12 Hz (B) 14 Hz (C) 16 Hz (D) 18 Hz

(142) A tuning fork produces 5 beats in 1s with the sonometer wire of length 50 cm. If the length of the wire is reduced by 2 cm then also the number of beats remains 5. Calculate the frequency of the tuning fork. (in Hz).

(A) 490 (B) 245 (C) 390 (D) 295

(143) A tuning fork having unknown frequency produces 4 beats in 1s with the fork having 350 Hz frequency and produces 6 beats in 1s. with the fork having frequency 360 Hz. Find the unknown frequency.

(A) 354 Hz (B) 346 Hz (C) 366 Hz (D) 358 Hz

(144) The frequencies of three sound waves of equal amplitude are (f_1-2), f_1 and (f_1+2) respectively. If they superpose to produce beats, calculate number of beats produced in 1s.

(A) 1 (B) 2 (C) 3 (D) 4

(145) f_1, $1.5f_1$, $2.25f_1$, $3.375f_1$ ...... are the frequencies of the tuning forks in the ascending order. Any two consecutive forks produces N beats in 1 s. Calculate frequency f_1.

(A) N (B) 2N (C) 3N (D) 4N

(146) When two tuning forks are made vibrate they produces 4 beats in 1s. Now a strip is attached with one of the prongs of fork-2, they produces 6 beats in 1s. Calculate the frequency of fork-2 if the frequency of tuning fork-1 is 200 Hz.

(A) 196 Hz (B) 194 Hz (C) 204 Hz (D) 206 Hz

(147) What would be the difference of angular frequencies in order to hear the beats clearly, in the case of sound waves ?

(A) $> 6\pi$ (B) $\le 6\pi$ (C) $> 12\pi$ (D) $\le 12\pi$

(148) Using the superposition, for which of the following waves phenomenon of beats can be possible ?

(A) $y_1 = A_1 \sin \omega_1 t$ and $y_2 = A_2 \sin \omega_2 t$ (B) $y_1 = A_1 \sin \omega t$ and $y_2 = A_2 \sin \omega t$

(C) $y_1 = A \sin \omega t$ and $y_2 = A \sin \omega t$ (D) $y_1 = A \sin \omega_1 t$ and $y_2 = A \sin \omega_2 t$

(149) Wave equation for two waves propagating the medium and producing beats are; $y_1 = A \sin 2\pi f_1 t$ and $y_2 = A \sin 2\pi f_2 t$. What would be the resultant amplitude ?

(A) $A' = \frac{A}{2}$ (B) $A' = 2A$

(C) $A' = 2A \cos 2\pi \left(\frac{f_1 - f_2}{2}\right)t$ (D) $A' = 4A^2 \cos^2 2\pi \left[\frac{f_1 - f_2}{2}\right]t$

(150) Two harmonic waves having slightly different frequencies f_1 and f_2 superpose on each other to produce beats. The loudness of sound in unit time becomes ......

(A) $(f_1 - f_2)$ times maximum and $(f_1 + f_2)$ times minimum.

(B) $(f_1 - f_2)$ times maximum and $(f_1 - f_2)$ times minimum.

(C) $(f_1 + f_2)$ times maximum and $(f_1 - f_2)$ times minimum.

(D) $(f_1 + f_2)$ times maximum and $(f_1 + f_2)$ times minimum.

(151) The ratio of the frequencies of the sound of a car horn heard by a stationary traffic police when the car is moving towards and away from him is 1.5. If the speed of the sound is 340 ms^{-1}. Calculate the speed of the car in ms^{-1}.

(A) 68 (B) 78 (C) 48 (D) 58

(152) The frequency of the sound of a car horn experienced by a stationary listener, when car is moving towards him is 5 % more than its original frequency. If the speed of the sound is 325 ms^{-1}, find the speed of the car in ms^{-1}.

(A) 6 (B) 8 (C) 15 (D) 25

(153) Find the difference of apparent frequencies of the sound of a car horn heard by a stationary listener when the car is moving towards and away from the listener with a speed of 72 kmh^{-1}. The frequency of the sound emitted by the horn is 1000 Hz, velocity of sound $v = 320$ ms^{-1}.

(A) 124.8 Hz (B) 142.8 Hz (C) 184.2 Hz (D) 0

(154) Two trains are moving towards a stationary listener with the speed of 72 kmh^{-1} and 36 kmh^{-1}. The frequency of the sound of the whistle of both the trains is 200 Hz. Velocity of sound is 320 ms^{-1}. Calculate the number of beats heared by the listener in 1 s.

(A) 4 (B) 5 (C) 7 (D) 8

(155) The whistle of an engine, approaching a hill with the speed of 72 kmh^{-1} produces sound of frequency 600 Hz. Find the frequency heared by the driver of the same engine, of the sound of whistle reflected from the hill. The speed of sound is 320 ms^{-1}.

(A) 680 Hz (B) 700 Hz (C) 780 Hz (D) 860 Hz

(156) The driver of a stationary train at the railway plateform blows the whistle of sound frequency 700 Hz. A person is moving towards the train with the speed of 36 kmh^{-1}. Calculate the frequency experienced by the person. Velocity of sound $v = 350$ ms^{-1}.

(A) 640 Hz (B) 720 Hz (C) 780 Hz (D) 820 Hz

(157) A source of sound is moving towards the listener with the speed of 72 kmh^{-1} and the listener is moving away from the source with the speed of 36 kmh^{-1}. The source emitts the sound of frequency 990 Hz with the speed of 350 ms^{-1}. Calculate the frequency experienced by the listener.

(A) 660 Hz (B) 900 Hz (C) 1020 Hz (D) 1300 Hz

(158) A rickshaw is moving with the speed of 10 ms^{-1}. A loudspeaker on this rickshaw emits the sound with the speed of 330 ms^{-1}. A car is behind this rickshaw and moving towards the rickshaw with the speed of 108 kmh^{-1}. Calculate the ratio of the frequency experienced by the driver of the car to the original frequency of the sound emitted by the loudspeaker.

(A) $\frac{36}{32}$ (B) $\frac{36}{17}$ (C) $\frac{18}{34}$ (D) $\frac{18}{17}$

(159) A Radar transmits radio waves of frequency 10^3 MHz towards an aeroplane. The frequency of the reflected radio waves observed by Radar is 5 kHz more than the frequency send by it. Calculate the speed of the aeroplane. Speed of the radio wave is 3×10^8 ms^{-1}.

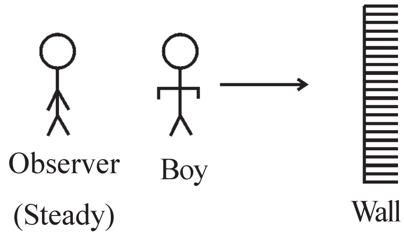
(A) 0.5 kms^{-1} (B) 1 kms^{-1} (C) 1.5 kms^{-1} (D) 3 kms^{-1}

(160) A sound of frequency 500 Hz is performing uniform circular motion on the circumference of a circle of radius 50 cm, with a constant angular speed of 20 $rads^{-1}$. A person is standing very far away on the line passing through the centre of this circle and along the plane of the circle. (The person is stationary). The velocity of the sound is 340 ms^{-1}. Calculate the maximum and minimum frequency experienced by the person.

(A) 515 Hz and 486 Hz (B) 846 Hz and 515 Hz

(C) 515 Hz and 400 Hz (D) 648 Hz and 515 Hz

(161) As shown in the figure, a boy is in between a wall and a stationary observer. The boy is walking towards the wall at a speed of 2 ms^{-1} in a direction at right angles to the walll. The boy blows a whistle. The observer hears 4 beats in 1 s. If the speed of the sound is 332 ms^{-1}. Calculate the frequency of the whistle.



(A) 150 Hz (B) 200 Hz (C) 330 Hz (D) 440 Hz

(162) A source emitting a sound of frequency *f*, which is placed at a very large distance from the listener. The source starts moving towards the listener with a constant acceleration a. Calculate the frequency experienced by the listener corresponding to the sound emitted just after the source starts. The speed of the sound is *v*.

(A) $\frac{2vf^2}{2vf-a}$ (B) $\frac{vf^2}{2vf-a}$ (C) $\frac{2vf^2}{3vf-a}$ (D) $\frac{vf^2}{2vf+a}$

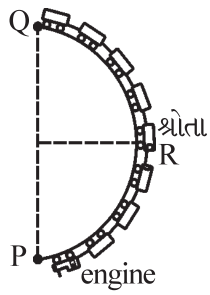
(163) A stationary listener experiences the frequency of a sound of the horn of a car moving towards him with the difference of 10% with the original frequency. Velocity of sound is 330 ms^{-1}. Compute the velocity of the car in ms^{-1}.

(A) 10 ms^{-1} (B) 20 ms^{-1} (C) 30 ms^{-1} (D) 40 ms^{-1}

(164) A train moving towards a stationary listener with a constant speed of 108 km h^{-1}. The driver of the train keeps on blowing the whistle continuously. Calculate the ratio of the frequencies heard by the listener, for the train coming towards him and moving away from him. Velocity of the sound is 330 ms^{-1}.

(A) 9 : 8 (B) 9 : 5 (C) 6 : 1 (D) 6 : 5

(165) As shown in the figure a train has just completed semicircular path on a U-shaped railway track. The engine is at one end of the semicircular path while the last coach is at the other end of the path. The driver blows a whistle of frequency 160 Hz. Compute the apparent frequency heared by a passenger in the middle of a train. The velocity of the sound is 330 ms^{-1}.



(A) 160 Hz (B) 200 Hz

(C) 80 Hz (D) 320 Hz

Ans. : 132 (C), 133 (A), 134 (D), 135 (B), 136 (A), 137 (B), 138 (B), 139 (A), 140 (B), 141 (B), 142 (B), 143 (A), 144 (B), 145 (B), 146 (A), 147 (D), 148 (D), 149 (C), 150 (B), 151 (A), 152 (C), 153 (A), 154 (C), 155 (A), 156 (B), 157 (C), 158 (D), 159 (C), 160 (A), 161 (C), 162 (A), 163 (C), 164 (D), 165 (A)

Questions based on practicals :

(166) In an experiment of determining the force constant of a spring, dead weight is 100 g. When 100 g mass is suspended, the length of the spring increases by 1 mm and equilibrium is maintained. Now if the mass is given SHM, Calculate its periodic time. [g = 10^3 cms^{-2}]

(A) π s (B) 2 π s (C) 0. π s (D) 0. 02 π s

(167) In an experiment of simple pendulum, the diameter of the sphere is 1.98 cm. The length of the pendulum is 50 cm. Calculate the total time taken for 25 oscillations. [$g = 980\ cms^{-2}$]

(A) 38.1 s (B) 35.8 s (C) 53.8 s (D) 13.8 s

(168) In an experiment to determine the force constant of a spring by the method of oscillations, when the mass 250 g is suspended the periodic time is 0.5 s. What would be the increase in the length of the spring, when the system is in the equilibrium ? ($\pi^2 = 10$ and $g = 10^3\ cms^{-2}$.)

(A) 0.625 cm (B) 6.25 cm (C) 0.625 mm (D) 0.625 m

(169) What would be the slope of $l \rightarrow T^2$ graph in an experiment of simple pendulum ?

(A) $\frac{2\pi}{g}$ (B) $\frac{4\pi^2}{g}$ (C) $\frac{g}{4\pi^2}$ (D) $\frac{g^2}{4\pi^2}$

(170) In an experiment of simple pendulum, what is the necessary angular amplitude so that the motion of the pendulum can be considerd to be SHM ?

(A) greater than 10° (B) greater than 6° (C) less than 4° (D) in between 6° and 4°

(171) A rubber cork is used as the rigid support in an experiment of simple pendulum. By mistake of experimenter, the string comes out of the cork from a thin cruck and oscillates from a point above the lowest end of cork. Then ....

(A) T will be more then its actual value. (B) T will be less than its actual value.

(C) T increase, oscillations becomes slow. (D) T increases, oscillations becomes fast.

(172) In an experiment of simple pendulum, the length of the pendulum is taken as 50 cm, 60 cm, 70 cm, 80 cm and 90 cm. The periodic time is measured by taking 20 oscillations for each length. Then with the increase of length.

(A) periodic time decreases, oscillations become slow

(B) periodic time decreases, oscillations become fast

(C) periodic time increases, oscillations become slow

(D) periodic time increases, oscillations become fast

(173) The length of second pendulum from the graph of $l \rightarrow T^2$ is 99.4 cm. The slope of this line is ...... cms^{-2}.

(A) 980.5 (B) 49.75 (C) 24.85 (D) 100

(174) In an experiment of resonance tube, which one of the following is correct regarding the frequency of the fork and balancing length ?

(A) length decreases with the increase of frequency

(B) length increases with the increase of frequency

(C) length will not change with the frequency

(D) Initially length increases with increase of frequency and than length decreases

(175) In an experiment of resonance tube, what would be the velocity of the sound wave at 0° C ?

(A) $v_0 = v_t (1 + \frac{1}{2}\alpha T)$ (B) $v_0 = \frac{v_t}{1+\frac{1}{2}\alpha T}$ (C) $v_0 = v_t + \frac{1}{2}\alpha T^2$ (D) $v_0 = \frac{v_t}{1+\frac{1}{2}\alpha T^2}$

(176) In an experiment of resonance tube, three readings are taken by using three different frequencies. An average value of measured fl is 82.55 Hz m. Calculate the velocity of the sound at the given constant temperature.

(A) 3×10^8 ms^{-1} (B) 165.1 ms^{-1} (C) 330.2 ms^{-1} (D) 825.5 ms^{-1}

(177) In an experiment of measuring speed of sound using resonance tube, a student measures length of tube at first resonance at 12 cm, on winter morning (at comparatively low temperature). When same experiment is repeated with same tuning fork in summer afternoon (comparatively high temperature), length for second resonance is found to be x cm. Then which of the followin goptions is correct ?

(A) $12 > x$ (B) $x > 36$ (C) $36 > x > 12$ (D) $36 > x > 24$

Ans. : 166 (D), 167 (B), 168 (B), 169 (C), 170 (C), 171 (A), 172 (C), 173 (C), 174 (A), 175 (B), 176 (C), 177 (B)

Assertion - Reason type Question :

Instruction : Read assertion and reason carefully, select proper option from given below.

(a) Both assertion and reason are true and reason explains the assertion.

(b) Both assertion and reason are true but reason does not explain the assertion.

(c) Assertion is true but reason is false.

(d) Assertion is false and reason is true.

(178) **Assertion** : All oscillatory motions are periodic motions but all periodic motions are not oscillatory.

Reason : For small oscillations, motion of the simple pendulum is oscillatory motion.

(A) a (B) b (C) c (D) d

(179) **Assertion** : The kinetic energy and the mechanical energy of SHO is equal at the end points.

Reason : At the end point, velocity of SHO is zero.

(A) a (B) b (C) c (D) d

(180) **Assertion** : Acceleration of SHO $a = -\omega^2 y$.

Reason : Acceleration of SHO is always negative

(A) a (B) b (C) c (D) d

(181) **Assertion** : At mean position, acceleration of SHO is zero

Reason : At mean position, velocity of SHO is zero

(A) a (B) b (C) c (D) d

(182) **Assertion** : The mechanical energy of SHO does not depend on its displacement.

Reason : The mechanical energy of SHO $E = \frac{1}{2}kA^2$.

(A) a (B) b (C) c (D) d

(183) **Assertion** : At mean position of SHO, its kinetic energy is equal to its mechanical energy.

Reason : At mean position of SHO, its velocity is zero.

(A) a (B) b (C) c (D) d

(184) **Assertion** : Oscillations performed by a hard-spring are slow.

Reason : The force constant of hard spring is high.

(A) a (B) b (C) c (D) d

(185) **Assertion** : If the kinetic energy of SHO increases, its potential energy decreases and if its P. E increases, its K. E. decreases.

Reason : The mechanical energy of SHO remains constant.

(A) a (B) b (C) c (D) d

(186) **Assertion** : The mechanical energy of SHO does not depend on its maximum displacement

Reason : The maximum displacement of SHO is equal to its amplitude.

(A) a (B) b (C) c (D) d

(187) **Assertion** : The periodic time of the simple pendulum increases with the increase of mass of the bob.

Reason : The periodic time of SHO is given by $T = 2\pi\sqrt{\frac{m}{k}}$.

(A) a (B) b (C) c (D) d

(188) **Assertion** : On doubling the amplitude of the simple pendulum its period remains the same.

Reason : The period of the simple pendulum is independent of its amplitude.

(A) a (B) b (C) c (D) d

(189) **Assertion** : The amplitude of the damped oscillations decreases with time.

Reason : There exsi resistive force of air on the oscillator.

(A) a (B) b (C) c (D) d

(190) **Assertion** : An oscillator can possess more than one natural frequency.

Reason : Natural oscillations are performed in the absanse of all external forces.

(A) a (B) b (C) c (D) d

(191) **Assertion** : An amplitude of the forced oscillations remains constant.

Reason : No external force acts on the forced oscillator.

(A) a (B) b (C) c (D) d

(192) **Assertion** : During an earthquake, high-rise structures fall down.

Reason : The frequency of the Seismic waves is very greater than the natural frequency of high-rise structures.

(A) a (B) b (C) c (D) d

(193) **Assertion** : Mechanical waves require some elastic medium for their propagation.

Reason : Mechanical waves Propogate due to an elastic property of the medium.

(A) a (B) b (C) c (D) d

(194) **Assertion** : Electromagnetic waves space require any medium and even propagate in the free-space.

Reason : Electromagnetic waves do not propagate in the medium.

(A) a (B) b (C) c (D) d

(195) **Assertion** : Longitudinal waves are also called pressure - waves.

Reason : The pressure of the different regions change with time, during the propagation of longitudinal waves.

(A) a (B) b (C) c (D) d

(196) **Assertion** : Longitudinal waves can propagate in the solid-medium.

Reason : Solid-medium can posses shearing strain.

(A) a (B) b (C) c (D) d

(197) **Assertion** : The origin of earthquake (epicentre) can be determined by using seismograph.

Reason : Both transverse and longitudinal waves are produced during an earthquake.

(A) a (B) b (C) c (D) d

(198) **Assertion** : Wave equation represents the displacement of a particle at a distance x from the origin.

Reason : The time derivative of wave equation represents velocity of the wave.

(A) a (B) b (C) c (D) d

(199) **Assertion** : When a wave changes its medium, its wave length remains constant.

Reason : The wavelength is a property of the medium.

(A) a (B) b (C) c (D) d

(200) **Assertion** : When a wave changes its medium, its frequency remains constant but its wave length does not.

Reason : Frequency is the Property of the source, and wavelength is a Property of the medium.

(A) a (B) b (C) c (D) d

(201) **Assertion** : Speed of the transverse wave Propagating on stretched string does not depend on frequency and amplitude of the wave.

Reason : Elasticity and inertia of medium are necessary for the propagation of the mechanical waves.

(A) a (B) b (C) c (D) d

(202) **Assertion** : The phenomenon of propagation of sound in air is adiabatic.

Reason : Isothermal bulk modulus is equal to the Pressure of the air.

(A) a (B) b (C) c (D) d

(203) **Assertion** : When "crest" of the wave is incident at a rigid support, it becomes "trough" due to the reflection from the rigid support.

Reason : The Phase of the wave increases by π rad when it reflects from the rigid support.

(A) a (B) b (C) c (D) d

(204) **Assertion** : Energy does not Propagate in the Stationary wave.

Reason : Stationary wave is not Prograssive.

(A) a (B) b (C) c (D) d

(205) **Assertion** : For closed-pipe f_n represents $(n-1)^{th}$ Overtone.

Reason : All the harmonics are Possible for closed-pipe.

(A) a (B) b (C) c (D) d

(206) **Assertion** : During the Phenomenon of beats, the loudness of sound becomes 2 $(f_1 - f_2)$ times maximum.

Reason : The number of beats in unit time is $(f_1 - f_2)$.

(A) a (B) b (C) c (D) d

(207) **Assertion** : In Doppler effect, the wavelength of sound waves in the front of the source decreases while behind the source, its wavelength increases.

Reason : There is relative displacement between the source of sound and wave.

(A) a (B) b (C) c (D) d

Ans. : 178 (B), 179 (D), 180 (C), 181 (C), 182 (a), 183 (C), 184 (B), 185 (A), 186 (B), 187 (D), 188 (A), 189 (A), 190 (B), 191 (C), 192 (D), 193 (A), 194 (C), 195 (A), 196 (A), 197 (B), 198 (C), 199 (D), 200 (A), 201 (B), 202 (C), 203 (A), 204 (B), 205 (C), 206 (D), 207 (A)

Comprehension Type Questions :

(208) A particle perfoms SHM along the path of length 20 cm. Initially it is at the mid point of its mean position and positive end, and start moving towards the mean position. It completes 2.5 Oscillations in 8 s.

(1) Its amplitude A = ... cm

(i) 20 (ii) 10 (iii) 5 (iv) 40

(2) Its initial phase ϕ = ... rad

(i) $\frac{\pi}{6}$ (ii) $\frac{5\pi}{6}$ (iii) $\frac{7\pi}{6}$ (iv) $\frac{11\pi}{6}$

(3) Its phase at the end of 2.5 oscillation θ = ... rad.

(i) $\frac{35\pi}{6}$ (ii) $25\frac{\pi}{6}$ (iii) $45\frac{\pi}{6}$ (iv) $15\frac{\pi}{6}$

(4) Its periodic time T = ... s.

(i) 1.6 (ii) 0.8 (iii) 3.2 (iv) 4.8

(A) 1 (i) 2 (ii) 3 (iii) 4 (iii)
(B) 1 (ii) 2 (ii) 3 (iii) 4 (iii)
(C) 1 (ii) 2 (ii) 3 (i) 4 (iii)
(D) 1 (ii) 2 (ii) 3 (iv) 4 (iv)

(209) An amplitude and periodic time of SHO are 10 cm and $\frac{2\pi}{3}$ s respectively :

(1) Its velocity at its mean position v = ... cms^{-1}

(i) 0 (ii) 10 (iii) 20 (iv) 30

(2) Its acceleration at its mean position a = ... cms^{-2}

(i) 0 (ii) 30 (iii) 60 (iv) 90

(3) Its velocity at the positive end v = ... cms^{-1}

(i) 0 (ii) 10 (iii) 20 (iv) 30

(4) Its acceleration at the negative end a = ... cms^{-2}

(i) 0 (ii) 30 (iii) 60 (iv) 90

(A) 1 (i) 2 (i) 3 (i) 4 (i)
(B) 1 (iv) 2 (i) 3 (i) 4 (iv)
(C) 1 (iv) 2 (iv) 3 (iv) 4 (iv)
(D) 1 (iv) 2 (i) 3 (iv) 4 (i)

(210) The mechanical energy of SHO is twice its kinetic energy.

(1) What would be its displacement ?

(i) $y = \pm \frac{A}{2}$ (ii) $y = \pm \frac{A}{\sqrt{2}}$ (iii) $y = \pm \frac{\sqrt{3}\,A}{2}$ (iv) $y = 0$

(2) What would be its velocity ?

(i) $v = 0$ (ii) $v = v_{max}$ (iii) $v = \frac{v_{max}}{\sqrt{2}}$ (iv) $v = \frac{v_{max}}{2}$

(3) What would be its acceleration ?

(i) $a = 0$ (ii) $a = a_{max}$ (iii) $a = \frac{a_{max}}{\sqrt{2}}$ (iv) $a = \frac{a_{max}}{2}$

(4) What would be its potential energy ?

(i) $U = 0$ (ii) $U = \frac{E}{2}$ (iii) $U = \frac{E}{\sqrt{2}}$ (iv) $U = 2E$

(A) 1 (i) 2 (iii) 3 (i) 4 (iii)
(B) 1 (ii) 2 (iii) 3 (iii) 4 (iv)
(C) 1 (ii) 2 (iv) 3 (iii) 4 (iii)
(D) 1 (ii) 2 (iii) 3 (iii) 4 (ii)

(211) The wave equation for a prograssive harmonic wave is $y = 10 \sin (4\pi t - \frac{\pi}{5}x)$ cm.

(Where x and y are in cm, t is in s)

(1) The wave length of the wave λ = ... cm ?

(i) 10 (ii) 5 (iii) 20 (iv) 30

(2) What would be the frequency of the wave ?

(i) 0.5 (ii) 2 (iii) 20 (iv) 50

(3) What would be the wave-vector in rad cm^{-1} ?

(i) $\frac{2\pi}{5}$ (ii) $\frac{3\pi}{5}$ (iii) $\frac{\pi}{5}$ (iv) $\frac{2\pi}{3}$

(4) What would be the velocity of the wave in cms^{-1} ?

(i) 10 (ii) 20 (iii) 15 (iv) 30

(A) 1 (i) 2 (ii), 3 (iii) 4 (iv)
(B) 1 (i) 2 (iii) 3 (ii) 4 (ii)
(C) 1 (ii) 2 (ii) 3 (iii) 4 (iv)
(D) 1 (i) 2 (ii) 3 (iii) 4 (ii)

(212) The wave equation for a progressive harmonic wave is $y = 10 \sin (2\pi t - \frac{\pi}{8}x)$

[Where x and y are in cm and t is in s.]

(1) What would be the velocity of the wave in cms^{-1} ?

(i) 0 (ii) 8 (iii) 16 (iv) 32

(2) What would be the displacement of a particle at a distance 4 cm away from the origin at the end of 1 s ?

(i) 10 cm (ii) –10 cm (iii) 4 cm (iv) 5 cm

(3) What would be the velocity of a particle at a distance 16 cm away from the origin at the end of 1 s. [in cms^{-1}]

(i) 0 (ii) 10π (iii) 20π (iv) 30π

(4) What would be the acceleration (in cms^{-2}) of the particle in the question 3.

(i) 0 (ii) 20π (iii) $40\pi^2$ (iv) $-40\pi^2$

(A) 1 (iii) 2 (ii) 3 (iii) 4 (i)
(B) 1 (iii) 2 (i) 3 (iii) 4 (iv)
(C) 1 (ii) 2 (iii) 3 (iv) 4 (iv)
(D) 1 (ii) 2 (ii) 3 (ii) 4 (i)

(213) The stationary waves produced in a 20 cm long string fixed at both the ends with rigid support are represented by y = 20 sin $\left(\frac{\pi}{4}x\right)$ cos $(80\pi t)$. (Where x and y are in cm at t is in s)

(1) Wavelength of the wave in cm is ......

(i) 8 cm (ii) 2 cm (iii) 20 cm (iv) 5 cm

(2) Velocity of the wave in cms^{-1} is ....

(i) 20 cms^{-1} (ii) 80 cms^{-1} (iii) 160 cms^{-1} (iv) 320 cms^{-1}

(3) The positions of nodes from x=0 (in cm) are ....

(i) 1, 5, 9, 13 (ii) 4, 8, 12, 16 (iii) 2, 6, 10, 14, 18 (iv) 3, 7, 11, 15

(4) The positions of antinodes from x = 0 (in cm) are.

(i) 1, 5, 9, 13 (ii) 4, 8, 12, 16 (iii) 2, 6, 10, 14, 18 (iv) 3, 7, 11, 15

(A) 1 (i) 2 (iv) 3 (ii) 4 (iii)
(B) 1 (i) 2 (i) 3 (iii) 4 (ii)
(C) 1 (i) 2 (iv) 3 (iii) 4 (ii)
(D) 1 (iii) 2 (iii) 3 (ii) 4 (iii)

Ans. : 208 (C), 209 (B), 210 (D), 211 (D), 212 (A), 213 (A)

Matching Column Type :

(214) Column-1 represents time in terms of periodic time T and Column-2 represents phase at that time. Correctly match the columns. (ϕ= 0).

	Column-1		Column-2
a	$t = \frac{T}{8}$	(i)	$\theta = \pi$
b	$t = \frac{T}{2}$	(ii)	$\theta = 5\frac{\pi}{4}$
c	$t = 5\frac{T}{8}$	(iii)	$\theta = \frac{\pi}{4}$
d	$t = 3\frac{T}{4}$	(iv)	$\theta = \frac{3\pi}{2}$

(A) a (iii), b (i), c (iv), d (ii)
(B) a (iii), b (i) c (ii) d (iv)
(C) a (ii), b (iii), c (i), d (iv)
(D) a (iv), b (i) c (ii) d (iii)

(215) The SHO is given 100 J energy to perform SHM. Values of kinetic energy and potential energy are given in column 1 and columns 2 respectively. Match them :

	Column-1		Column-2
a	K = 0	(i)	U = 40 J
b	K = 50 J	(ii)	U = 90 J
c	K = 10 J	(iii)	U = 50 J
d	K = 60 J	(iv)	U = 100 J

(A) a (iv), b (ii), c (i), d (iii)
(B) a (ii), b (iii) c (i) d (iv)
(C) a (iv), b (iii), c (i), d (ii)
(D) a (iv), b (iii) c (ii) d (i)

Match the columns :

(216) Match the column-1 (DF) with column-2 (physical quantity) :

Column-1		Column-2	
a	$M^1L^0T^{-1}$	(i)	Wave intensity
b	$M^1L^0T^{-2}$	(ii)	damping force
c	$M^1L^0T^{-3}$	(iii)	damping coefficients
d	$M^1L^1T^{-2}$	(iv)	force constant of spring

(A) a (iii), b (iv), c (i), d (ii)
(B) a (ii), b (iv), c (i), d (iii)
(C) a (iii), b (iv), c (ii), d (i)
(D) a (iii), b (ii), c (i), d (iv)

(217) For simple pendulum, graph of Y-axis $\rightarrow$ X-axis is given in column 1. In column 2, shape of graph is given. Match them.

Column-1		Column-2	
a	$T^2 \rightarrow l$	(i)	Straightline
b	$T^2 \rightarrow g$	(ii)	Straightline
c	$T \rightarrow l$	(iii)	Paraboba
d	$T \rightarrow \sqrt{l}$	(iv)	Hyperboly

(A) a (i), b (ii), c (iii), d (iv)
(B) a (ii), b (iv), c (iii), d (i)
(C) a (iii), b (i), c (ii), d (iv)
(D) a (iv), b (ii), c (iii), d (i)

(218) Match the velocity and acceleration of SHO in column-2 with its displacement in column-1.

Column-1		Column-2	
a	$y = \pm \frac{A}{2}$	(i)	$v = \frac{v_{max}}{2}$
b	$y = \pm \frac{2A}{\sqrt{3}}$	(ii)	$a = \frac{a_{max}}{2}$
c	$y = \pm \frac{A}{\sqrt{2}}$	(iii)	$v = \frac{v_{max}}{\sqrt{2}}$
d	$y = \pm \frac{\sqrt{3}A}{2}$	(iv)	$a = \frac{2a_{max}}{\sqrt{3}}$

(A) a (ii), b (iv), c (i), d (iii)
(B) a (iv), b (iii), c (i), d (ii)
(C) a (ii), b (iv), c (iii), d (i)
(D) a (i), b (iii), c (ii), d (iv)

(219) Correctly Match the values of kinetic energy of SHO with its displacement in column-1.

Column-1		Column-2	
a	$y = \frac{A}{\sqrt{2}}$	(i)	$K = \frac{3E}{4}$
b	$y = \frac{A}{\sqrt{3}}$	(ii)	$K = \frac{E}{4}$
c	$y = \frac{A}{2}$	(iii)	$K = \frac{2E}{3}$
d	$y = \frac{\sqrt{3}A}{2}$	(iv)	$K = \frac{E}{2}$

(A) a (iv), b (iii), c (i), d (ii)
(B) a (iv), b (iii), c (ii), d (i)
(C) a (iv), b (i), c (ii), d (iii)
(D) a (iv), b (i), c (iii), d (ii)

(220) Match the column-1 and column-2 for SHO :

Column-1		Column-2	
a	At mean position (y = 0)	(i)	K increasese, U decreases.
b	negative end (y = –A)	(ii)	K decreases, U increases.
c	moving from m. p. towards positive end	(iii)	U = E and K = 0
d	moving from negative end toward m.p.	(iv)	K = E and U = 0

(A) a (iv), b (iii), c (i), d (ii)
(B) a (iii), b (iv), c (i), d (ii)
(C) a (iv), b (iii), c (ii), d (i)
(D) a (iii), b (iv), c (ii), d (i)

(221) Correctly match the characteristic of the wave in column-2 with the given wave in column-1.

Column-1		Column-2	
a	Sound waves	(i)	Nonmechanical and transverse
b	light waves	(ii)	mechanical, transverse and longitudinal
c	seismic waves	(iii)	mechanical and transverse
d	waves on the string	(iv)	mechanical and longitudinal

(A) a (iv), b (iii), c (i), d (ii)
(B) a (i), b (iv), c (ii), d (iii)
(C) a (i), b (iv), c (iii), d (ii)
(D) a (iv), b (i), c (ii), d (iii)

(222) Correctly match the Dimensional formula in column-2 with the physical quantity given in column-1.

Column-1		Column-2	
a	Wave vector	(i)	$M^1L^0T^{-3}$
b	mass density	(ii)	$M^1L^{-1}T^{-2}$
c	Elastic constant	(iii)	$M^0L^{-1}T^0$
d	Intensity of wave	(iv)	$M^1L^{-1}T^0$

(A) a (iii), b (iv), c (i), d (ii)
(B) a (iii), b (iv), c (ii), d (i)
(C) a (iv), b (iii), c (ii), d (i)
(D) a (iii), b (i), c (iv), d (ii)

(223) Correctly match the frequency given in column-2 Corresponding to various harmonic or overtone for clarinet given in column-1 :

Column-1		Column-2	
a	Second harmonic	(i)	$f_2 = 3\, f_1$
b	Seccond overtone	(ii)	$f_3 = 5\, f_1$
c	Third harmonic	(iii)	$f_5 = 7\, f_1$
d	Third overtone	(iv)	Not possible

(A) a (iv), b (ii), c (iii), d (i)
(B) a (i), b (ii), c (iii), d (iv)
(C) a (iv), b (i), c (ii), d (iii)
(D) a (iv), b (ii), c (i), d (iii)

(224) Correctly match the amplitude given in column-1 with column-2.

Column-1		Column-2	
a	Amplitude of damped oscillation	(i)	$2A \sin 2\pi \left(\frac{f_1 + f_2}{2}\right) t$
b	Amplitude of forced oscillation	(ii)	A
c	Amplitude of Stationary waves	(iii)	$A\ e^{\frac{-bt}{2m}}$
d	resultant amplitude in phenomenon of Beast	(iv)	$2A \sin kx$

(A) a (iii), b (ii), c (i), d (iv)
(B) a (iii), b (ii), c (iv), d (i)
(C) a (ii), b (iii), c (i), d (iv)
(D) a (ii), b (iii), c (iv), d (i)

(225) The various relative motion between the source of sound and the listener is given in column-1. The frequency experienced by the listner is given in column-2. Correctly match the columns.

Column-1		Column-2	
a	The source and the listener are moving towards each other.	(i)	$f_L = \left(\frac{v+v_L}{v+v_s}\right) f_s$
b	Both are moving in the opposite direction.	(ii)	$f_L = \left(\frac{v-v_L}{v-v_s}\right) f_s$
c	Source is moving towads the listener and the listener is moving away from the source.	(iii)	$f_L = \left(\frac{v+v_L}{v-v_s}\right) f_s$
d	listener is moving towards the source and the source is moving away from the listener.	(iv)	$f_L = \left(\frac{v-v_L}{v+v_s}\right) f_s$

(A) a (iii), b (iv), c (ii), d (i)
(B) a (iii), b (iv) c (i) d (ii)
(C) a (iv), b (iii), c (ii), d (i)
(D) a (iv), b (iii) c (i) d (ii)

Ans. : 214 (B), 215 (D), 216 (A), 217 (B), 218 (C), 219 (A), 220 (C), 221 (D), 222 (B), 223 (D), 224 (B), 225 (A)

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