**Chapter – 14 Oscillations**

1. **Periodic motion**:

(i) A motion is said to be periodic when it repeats itself again and again in a given fixed interval of time called **time period**.

(ii) A periodic motion can be either rectilinear or closed or open curvilinear.

(iii) A periodic motion can be synthesized from or analysed into a number of simple harmonic components.

(iv) In a periodic motion, force is always directed towards a fixed point which may or may not be on the path of motion.

2. **Oscillatory motion**:

(i) A body is said to possess oscillatory or vibratory motion if it moves back and forth repeatedly about a mean position.

(ii) Oscillatory motion is basically a **constrained periodic motion** between two fixed limits.

(iii) Though every oscillatory motion is definitely periodic but every periodic motion is not always oscillatory.

3. **Simple harmonic motion:**

(i) SHM is the simplest kind of periodic motion. It may be defined as the periodic motion of a body such that:

(a) its acceleration at any instant is always directed towards a fixed point and

(b) the magnitude of its acceleration at that instant is directly proportional to its displacement from a fixed point in its path.

The fixed point is known as **mean position** and the force obeying above two conditions is called as **restoring force.**

**(ii) Requirements for motion to be SHM:**

(a) The motion is periodic.

(b) The motion is along a straight line about the mean or equilibrium position.

(c) The acceleration is proportional to displacement.

(d) Acceleration is directed towards mean or equilibrium position.

(iii) Simple harmonic motion may be of trro types:

(a) **Linear SHM**: in which body oscillates along a straight line path under the action of a constant restoring force given by: F = - Ky.

(b) **Angular SHM**: in which body oscillates about an axis under the action of a constant restoring torque given by: τ = - cθ.

(iv) **All SHMS are periodic but reverse may or may not be true.**

(v) In every SHM, the time period is independent of amplitude.

(vi) SHM can be easily represented as the projection on any diameter of a point moving in a circle with uniform speed

(vii) **Displacement in SHM:** It is given by either of the following two equations:

(a) y = A sin (wt + ϕ ) (**linear SHM**)

(b) θ = θo sin (wt + ϕ) (**angular SHM**) where wt + ϕ= phase angle, ϕ = epoch and w =2π/T.

- if ϕ =0 ; y = A sin (wt) & θ = θo sin (wt)

- Also, when wt = π/2 ; y = ymax.= A = amplitude or θ = θo

(viii) **Velocity in SHM**: In case of SHM, when motion is considered from the equilibrium position, velocity

at any instant r is given by:

(a)**At the mean position**, i.e., when y = 0, v= vmax =wA

(b) At the extreme positions, i.e., when y = ± A, v= vmin = 0

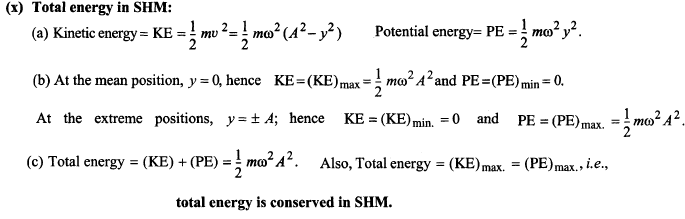
(ix) **Acceleration in SHM**: In case of SHM, when time is considered from equilibrium position, acceleration at any instant is:

a = -Aw2 sinwt = -w2 y

(a) At the mean position, i.e., when y =0, acceleration will be minimum (= 0). **Hence, in SHM acceleration is zero in equilibrium position where velocity is maximum** (= wA)

(b) At the extreme positions, i.e., when y = ± A ; acceleration will be maximum (- w2 A).**Hence, in SHM acceleration is maximum at the extreme positions where velocity is minimum**(= o).

(x) **Total energy in SHM**:



(xi) **Time period**: The time taken to complete simple harmonic motion once is called the time period. It is

given by:

(xii) **Phase:**

(a) The argument (wt + ϕ) of the sine function is called the phase of the SHM.

(b) The phase of an oscillating system at any instant represents its state regarding its position and direction of motion at that instant.

(c) If the phase is zero at a certain instant then from the equation of SHM, i.e., y= Asin (wt + ϕ),y =0 and v = (dy/dt) = Aw, i.e., particle is crossing the equilibrium position and if

- (wt + ϕ) = π/2 y = A and v =0, i.e., particle is at extreme position.

(xiii) **Phase constant or epoch**:

(a) The constant ϕ in the equation for SHM is **called epoch or phase constant or initial phase**. This enables us to find the position from where time is counted in SHM.

(b) If we consider the motion from equilibrium position, i.e., at t=0, y= , the equation y = A sin (wt+ϕ) gives ϕ = 0, i.e., if the time is counted from equilibrium position, initial phase is zero and equation becomes y = A sin wt.

4. **Simple pendulum:**

(i) A simple pendulum consists of a heavy point mass suspended by a weightless, inextensible and perfectly flexible string from a rigid support. Such an ideal pendulum is not possible in practice but a heavy bob suspended by a light inextensible thread works as simple pendulum.

(ii) The motion of simple pendulum is angular SHM. Restoring torque acting on it is: **τ = - mgLθ** and time period, T =2π√(L/g).

(iii) When the time period of a simple pendulum is 2 second, it is called a **second pendulum**.

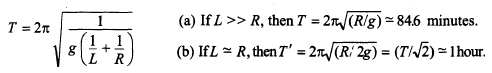
(iv) Time period of simple pendulum is independent of amplitude as long as θ is small.

(v) Time period of simple pendulum is independent of the mass of bob.

(vi) Time period of simple pendulum depends on L as Tα √L ;hence the graph between T and L will be a parabola while that between T2 and L will be a straight line.

(vii) As Tα 1/√g ; hence with increase in g, T will decrease.

(viii) If the **length of a pendulum is comparable to the radius of earth** (R), time period is given by:



5. **Spring pendulum:**

(i) A point mass suspended from a massless spring constitutes a **spring pendulum**. Such an ideal spring pendulum is not possible in practice. So, a small heavy mass suspended from a light spring is an approximate spring pendulum.

(ii) In the limit of small displacement, restoring force developed on a spring becomes linear and is given by:

**F =-ky**

(iii) Time period, T= 2π√(m/k) and frequency, f =1/T

(iv) Time period of a spring pendulum depends on the mass suspended, i.e., T α √m.

(v) Time period of a spring pendulum is independent of g.

(vi) As T α 1/√k hence greater the force constant lesser will be the time period or greater will be the frequency.



(vii) If M be the mass of the spring and mass m is suspended from it, then the time period is,

(viii)If a spring of force constant k is divided into N equal parts and one such part is attached to a mass m, then the time period is given by:



(ix) If two masses m1 and m2 are connected by a spring, then the time period is given by:

(x) If two springs of force constants k1 and k2 are **connected in parallel** and a mass m is attached to them, then the time period is given by:



(xi)If two springs of force constants k1 and k2 are **connected in series** and a mass m is attached to them,

then the time period is given by:



(xii) If the stretch in a vertically loaded spring is yo ,then for equilibrium of mass m



6. **Some other important points concerning SHM**:

(i) The simple harmonic oscillations may also be expressed as y = A sin wt + B cos wt, where A and B are constants related to the amplitude. We can write



(ii) If a particle executes simple harmonic oscillations, then its velocity as well as acceleration also vary simple harmonically and

velocity amplitude = (w x displacement amplitude ) and

acceleration amplitude = w x velocity amplitude = w2 x displacement amplitude

(iii) In SHM, the phase relationship between the displacement y, velocity (v) and acceleration (a) is as follows: **(a) a leads ,y by π/2; (b) a lags behind the v by π/2; (c) a differs in phase with y by π.**

(iv) (a) When y = A/2, v = 0.86 vmax

(b) When y = A/2, the KE of SHM is75% of the total energy and potential energy is 25% of the total energy.

(v) When KE of SHM is 50% of the total energy, the displacement is 71% of the amplitude. At this stage KE = PE.

(vi) Under weightlessness or in the freely falling lift T = 2π√(L/g). = ∞ [ g=0] . This means, the pendulum does not oscillate at all.

(vii) The y, v, a of SHM vary simple harmonically with the same time period and frequency.

(viii) **The KE as well as PE vary periodically but not simple harmonically in SHM. The frequency of KE or the PE is just two times that of y, v or a.**

(ix) If a wire of length L, area of cross-section A, Young's modulus Y is stretched by suspending a mass m, then the mass can oscillate with time period,

(x) If the lower surface of a cube of side L and modulus of rigidity η is fixed while fixing a particle of mass m on the upper face, a force parallel to upper face is applied to mass m and then withdrawn, the mass m can oscillate with a time period,

(xi) If a gas is enclosed in a cylinder of volume Vo fitted with a piston of cross-section A and mass M and the

piston is slightly depressed and released, the piston can oscillate with a frequency,





(xii) If a simple pendulum is suspended from the roof of a compartment of a train moving down an inclined plane of inclination θ, then the time period of oscillation is,



(xiii) If a ball of radius r oscillates in a bowl of radius R, then its time

period of oscillation is,



(xiv) If a disc of radius r oscillates about a point at its rim, then its time period is given by:

(xv) When the bob of a simple pendulum describes a horizontal circle, it is called a **conical pendulum**. If **L** be the length of simple pendulum, and the string makes angle θ w.r.t. vertical, then time period of rotatory motion is given by



(xvi) If a simple pendulum oscillates in a non-viscous liquid of density σ, then its time period is given by:

(xvii) If the mass m attached to a spring oscillates in a non-viscous liquid of density σ, then its time period

is given by:

(xviii) Physical Pendulum: An extended body, called physical pendulum, pivoted about a point O, which is at a distance d from its centre of mass. For small angular displacement θ, the time period is given by:

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**Torsional Pendulum**

**where *k* (kappa) is called the *torsion constant* of the support wire**

**Points To Ponder**

1. The period *T* is the *least time* after which motion repeats itself. Thus, motion repeats itself after *nT* where *n* is an integer.

2. Every periodic motion is not simple harmonic motion. Only that periodic motion governed by the force law *F = – k x* is simple harmonic.

3. Circular motion can arise due to an inverse-square law force (as in planetary motion) as well as due to simple harmonic force in two dimensions equal to: –*m*ω*2r*. In the latter case, the phases of motion, in two perpendicular directions (*x* and *y*) must differ by ω/2. Thus, a particle subject to a force –*m*ω*2r* with initial position (o, *A*) and velocity (ω*A*, o) will move uniformly in a circle of radius *A*.

4. For linear simple harmonic motion with a given ω two arbitrary initial conditions are necessary and sufficient to determine the motion completely. The initial condition may be (i) initial position and initial velocity or (ii) amplitude and phase or (iii) energy and phase.

5. From point 4 above, given amplitude or energy, phase of motion is determined by the initial position or initial velocity.

6. A combination of two simple harmonic motions with arbitrary amplitudes and phases is not necessarily periodic. It is periodic only if frequency of one motion is an integral multiple of the other’s frequency. However, a periodic motion can always be expressed as a sum of infinite number of harmonic motions with appropriate amplitudes.

7. The period of SHM does not depend on amplitude or energy or the phase constant. Contrast this with the periods of planetary orbits under gravitation (Kepler’s third law).

8. The motion of a simple pendulum is simple harmonic for small angular displacement.

9. For motion of a particle to be simple harmonic, its displacement *x* must be expressible in either of the following forms :

*x = A* cos ω*t* + *B* sin ω*t*

*x* = *A* cos (ω*t* + α ),

*x* = *B* sin (ω*t* + β )

The three forms are completely equivalent (any one can be expressed in terms of any other two forms).

Thus, damped simple harmonic motion [Eq. (14.31)] is not strictly simple harmonic. It is approximately so only for time intervals much less than *2m/b* where *b* is the damping constant.

10. In forced oscillations, the steady state motion of the particle (after the force oscillations die out) is simple harmonic motion whose frequency is the frequency of the driving frequency ω*d*, not the natural frequency ω of the particle.

11. In the ideal case of zero damping, the amplitude of simple harmonic motion at resonance is infinite. This is no problem since all real systems have some damping, however, small.

12. Under forced oscillation, the phase of harmonic motion of the particle differs from the phase of the driving force.

**Home Assignment- Oscillations**

1. What is the necessary condition for SHM?
2. What type of motion is exhibited equation ***x* = *A* cos(*wt* + ϕ) ? Explain all the terms used?**
3. Define time period T of a vibratory motion and write a relation between T, *w & f ?*
4. What would the phase constant ϕ have to be in Equation ***x* = *A* cos(*wt* + ϕ)** if we were describing an oscillating object that happened to be (i) at the origin at t=0 (ii) x= A at t=0 (iii) x=A/√2 at t=0 ? ?
5. An object undergoes simple harmonic motion of amplitude *A*. Through what total distance does the object move during one complete cycle of its motion?
6. How will you find the phase constant and Amplitude of a particle executing an SHM if the particle’s initial speed and position and the angular frequency of its motion is known ?
7. Write properties of simple harmonic motion?
8. Can we use Equation v = u+at for SHM ? Explain Why?
9. Prove that motion of simple pendulum is SHM & find an expression for it’s time period T?
10. Write an expression for the time period T of a physical pendulum?
11. Write an expression for the time period T of a torsional pendulum?
12. For a particle in uniform circular motion, which point can be said to be executing an SHM?
13. What do you mean by damped oscillations?
14. Derive an expression for the displacement of a particle executing a damped oscillation? Al so find an expression for the angular frequency of damped oscillation?
15. Define and determine the condition for underdamped , critically damped & overdamped oscillatory motion?
16. What do you mean by forced oscillations?
17. Derive an expression for the displacement of a particle executing a forced oscillation? Al so find an expression for the amplitude of forced oscillation?
18. What do you mean by resonance ?
19. Why does the amplitude becomes so high at resonance?
20. Why soldiers are ordered to break there steps when passing over a bridge?
21. Define periodic motion and write difference between periodic and oscillatory motion?
22. What do you mean by epoch?
23. Derive expressions for K.E., P.E. and Total energy of simple harmonic oscillator in detail?
24. What do you mean by force law for simple harmonic motion and derive an expression for it’s time period?
25. Derive an expression for the oscillations of a liquid in a U-tube?
26. Derive an expression for the oscillations of a floating cylinder?
27. Write the expressions for time period T in detail for the following cases

(a) Vibrations in a horizontal spring (b) Vibrations in a vertical spring

(b) Vibrations of loaded spring combinations with different cases

What provides the restoring force in following cases of SHM (i) simple pendulum (ii) spring (iii) column of mercury in a U tube?

1. What will be the affect on the time period in the following cases (i) a girl is sitting on a swing and another girl sits beside her (ii) a girl sitting on the swing stands up.
2. For an oscillating simple pendulum is the tension in the string constant throughout the oscillation ?If not when it is (a) the least (b) the greatest
3. What is the frequency of seconds pendulum in an elevator moving up with an acceleration of g/2 ?
4. What is the percentage change in the time period , if the length of simple pendulum increases by 3% ?
5. It is noted some times that in earthquakes , short and tall structures remain unaffected while the medium height structures fall down.Explain why ?
6. A man with a wrist watch falls down from the top of tower. Does the watch gives correct time ?
7. The displacement of an oscillator is given by x = αsin*w*t + βcos*w*t , what is the amplitude of the oscillation?
8. A simple harmonic oscillator has amplitude A , time period T. What will be the acceleration ,when it’s displacement is half of the amplitude ?

**NCERT**

1. On an average a human heart is found to beat 75 times in a minute. Calculate its frequency and period.
2. Which of the following functions of time represent (a) periodic and (b) non-periodic motion? Give the period

for each case of periodic motion [ω is any positive constant].

(i) sin ω*t* + cos ω*t* (ii) sin ω*t* + cos 2 ω*t* + sin 4 ω*t* (iii) e–ω*t* (iv) log (ω*t*)

Which of the following functions of time represent (a) simple harmonic motion and (b) periodic but not simple harmonic? Give the period for each case. (1) sin ω*t* – cos ω*t* (2) sin2ω*t*

1. A body oscillates with SHM according to the equation (in SI units), *x =* 10 cos [3π *t* + π/4]. At *t* = 1.5 s, calculate the (a) displacement,(b) speed and (c) acceleration of the body.
2. A 5 kg collar is attached to a spring of spring constant 500 N/m. It slides without friction over a horizontal rod. The collar is displaced from its equilibrium position by 10.0 cm and released. Calculate (a) the period of oscillation,(b) the maximum speed and (c) maximum acceleration of the collar.
3. What is the length of a simple pendulum, which ticks seconds (T= 2s)?
4. Which of the following examples represent periodic motion?
   1. A swimmer completing one (return) trip from one bank of a river to the other and back.
   2. A freely suspended bar magnet displaced from its N-S direction and released.
   3. A hydrogen molecule rotating about its center of mass.
   4. An arrow released from a bow.
5. The piston in the cylinder head of a locomotive has a stroke (twice the amplitude) of 1.0 m. If the piston moves with simple harmonic motion with an angular frequency of 200 rad/min, what is its maximum speed ?

**Exemplar**

1. When will the motion of a simple pendulum be simple harmonic?
2. What is the ratio of maximum acceleration to the maximum velocity of a simple harmonic oscillator?
3. What is the ratio between the distance travelled by the oscillator in one time period and amplitude?
4. Show that for a particle executing S.H.M, velocity and displacement have a phase difference of π/2.
5. The length of a second’s pendulum on the surface of Earth is1m. What will be the length of a second’s pendulum on the moon?
6. Show that the motion of a particle represented by *y* = sinω t – cos ω t is simple harmonic with a period of 2π/ω.
7. Find the displacement of a simple harmonic oscillator at which its P.E. is half of the maximum energy of the oscillator.

**Objective Questions**

1. Which of the following expressions does not represent SHM?

(a) Acoswt (b) Asin2wt (c) Asinwt + Bcoswt (d) Asin2wt

2. How long after the beginning of motion is the displacement of a harmonically oscillating point equals one half of its amplitude , if the period is 24 sec and initial phase is zero

(a) 12 s (b) 2 s (c) 4 s (d) 6 s

3. A simple harmonic motion has an amplitude A and time period T. The time required by it to travel from x= A to x = A/2 is : (a) T/6 (b) T/4 (c) T/3 (d) T/2

4. The KE and PE of a particle executing SHM with amplitude A ,will be equal when its displacement is

(a) A√2 (b) A/2 (c) A/√2 (d) A√(2/3)

5. Two pendulums begin to swing simultaneously. The first pendulum makes 9 full oscillations whereas the other makes 7.The ratio of lengths of the two pendulums is:

(a) 9/7 (b) 7/9 (c) 49/81 (d) 81/49

6. A simple pendulum is made of a body which is a hollow sphere containing mercury suspended by means of a wire. If a little mercury is drained off ,the period of pendulum will:

(a) remain unchanged (b) increase (c) decrease (d) become erratic

7. A simple pendulum consisting of a ball of mass m tied to a string of length L is made to swing on a circular arc of angle θ in a vertical plane. At the end of this arc, another ball of mass m is placed at rest. The momentum translated to this ball at rest by the swinging ball is :

(a) zero (b) mθ√L/g (c) mθ/√(Lg) (d) m/2 √(L/g)

8. Two particles P & Q describe SHM of same amplitude ‘a’ and frequency f along the same straight line.The maximum distance between two particles is a√2.The initial phase difference between the particles is :

(a) zero (b) π/2 (c) π/6 (d) π/3

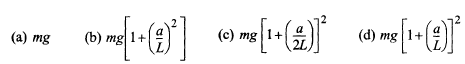
9. A cylindrical piston of mass M slides smoothly inside a long cylinder closed at one end, enclosing a certain mass of gas. The cylinder is kept with its axis horizontal. If the piston is disturbed from its equilibrium position, it oscillates simple harmonically. The period of oscillation will be:



10. For a particle executing simple harmonic motion, the kinetic energy K is given by: K=Kocos2wt. The maximum value of potential energy is: (a) Ko (b) zero (c) Ko/2 (d) not obtainable

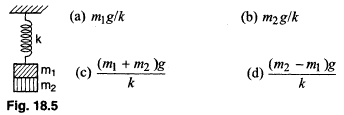
11. When a particle oscillates simple harmonically, its kinetic energy varies periodically. If frequency of the particle is *f*, the frequency of the kinetic energy is: (a) *f* /2 (b) *f* (c) 2 *f* (d) 4 *f*

12. A smooth inclined plane having angle of inclination of 300 with the horizontal has a 2.5 kg mass held by a spring which is fixed at the upper end. If the mass is taken 2.5 cm up along the surface of the inclined plane, the tension in the spring reduces to zero. If the mass is now released the angular frequency of oscillation is: (a) 7 (b) 14 (c)0.7 (d)1.4

13. A simple pendulum with length L and mass m of the bob is vibrating with an amplitude a. Then, the maximum tension in the string is:

14. The differential equation of a particle executing simple harmonic motion along y –axis is given by:

(a) d2y/dt2 +*w*2y = 0 (b) d2y/dt2 +*w*2y2 = 0 (c) d2y/dt2 - *w*2y = 0 (d) dy/dt +*w*y = 0

15. Two masses m1 and m2 are suspended together by a massless spring of constant k fig (18.5). When the masses are in equilibrium, m1 is removed without disturbing the system; the amplitude of the vibration is

16. Two pendulums of lengths l2l cm and 100 cm start vibrating. At some instant the two are in the mean position in the same phase. After how many vibrations of the shorter pendulum the two will be in phase in the mean position?

(a) l0 (b) 11 (c) 20 (d) 21

17. A uniform spring has an unstretched length *l* and a force constant k. The spring is cut into two parts of unstretched length *l*1 and *l*2 such that *l*1= η *l*2 , where η is an integer. The corresponding force constants k1 and k2 are

18. A girl is swinging in a swing in a sitting position. If she stands and swings, how will the period be affected?(a) The period will not change (b) The period will now be longer

(c) The period will now be shorter (d) The period will first increase and then decrease

19. The potential energy of a simple harmonic oscillator when the particle is half way to its end point is: (where E is the total energy) (a) E/8 (b) E/4 (c) E/2 (d) 2E/3

20. The motion which is not simple harmonic is:

(a) vertical oscillations of a spring (b) motion of simple pendulum

(c) motion of a planet around the sun (d) oscillation of liquid column in a U-tube

(e) vertical oscillation of a wooden plank floating in a liquid

21. A simple pendulum has time period T. The bob is given negative charge and surface below it is given positive charge. The new time period will be:

(a) less than T (b) greater than T (c) equal to T (d) infinite

22. A particle vibrates in SHM along a straight line. Its greatest acceleration is 5π2 cms-2 and when its distance from the equilibrium position is 4 cm, the velocity of the particle is 3π cm/s. The amplitude and the period of oscillation of the vibrating particle is:

(a) l0 cm , 4 sec (b) 5 cm , 2 sec (c) 5 cm , 4 sec (d) l0 cm, 2 sec

23. A body of mass m is released from a height h to a scale pan hung from a spring. The spring constant of the spring is k, the mass of the scale pan is negligible and the body does not bounce relative to the pan; then the amplitude of the vibration is :



24. The displacement x of a particle in motion is given in terms of time by x(x - 4) = 1 - 5 coswt.

(a) The particle executes SHM (b) The particle executes oscillatory motion which is not SHM

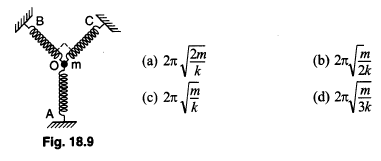
(c) The motion of the particle is neither oscillatory nor simple harmonic

(d) The particle is not acted upon by a force when it is at x=4

25. The bob of a simple pendulum executes simple harmonic motion in water with a period t, while the period of oscillation of the bob is to in air. Neglect frictional force of water and given that the density of the bob is (4/3) x 1000 kg/m3 . What relationship is true between t and to ?

(a) t =to (b) t =to /2 (c) t =2 to (d) t = 4to

26. A particle at the end of a spring executes simple harmonic motion with a period t1 ,while the corresponding period for another spring is t2.If the period of oscillation with the two springs in series is T, then



27 A particle of mass m is attached to three identical springs A,B & C each of force constant k as shown in fig (18.9).If the particle of mass m is pushed slightly against the spring A and released, then the time period of the oscillation is :



28. A uniform circular disc of mass 12 kg is held by two identical springs as shown in fig (18.10). When the disc is pressed down slightly and released, it executes SHM with a time period of 2 sec. The force constant of each spring is:

(a) 236 N/m (b) 118.3 N/m (c) 59.15 N/m (d) none of the above

29. A vertical mass-spring system executes simple harmonic oscillations with a period of 2 s. A quantity of this system which exhibits simple harmonic with a period of 1 s is:

(a) velocity (b) potential energy

(c) phase difference between acceleration and displacement

(d) difference between kinetic energy and potential energy

30. Two springs of constants k1 and k2 have equal highest velocities, when executing SHM. Then, the ratio of their amplitudes (given their masses are equal) will be

(a) (k1/k2) (b) √(k1/k2) (c) (k2/k1) (d) √(k2/k1)

31. A clock which keeps correct time at 200C is subjected to 400C.If coefficient of linear expansion of pendulum is l2 x l0-6 per 0C, how much will it gain or lose in time?

(a) 10.3 seconds/day (b) 20.6 seconds/day (c) 5 seconds/day (d) 20 minutes/day

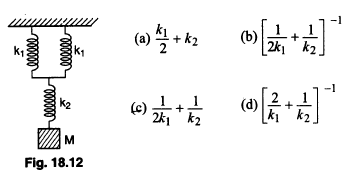
32. Two simple harmonic motions with same frequency act on a particle at right angles, i.e., along x and y axis. If the two amplitudes are equal and the phase difference is π/2 the resultant motion will be :

(a) a straight line inclined at 450 to the x –axis

(b) an ellipse with the major axis along the x - axis.

(c) an ellipse with the major axis along the y - axis. (d) a circle

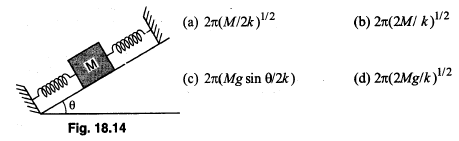
33. The total energy of simple harmonic motion is E What will be the kinetic energy of the particle when displacement is half of the amplitude? (a) 3E/4 (b) E/2 (c) E/4 (d) E/3



34. What will be the force constant of the spring system shown in fig (18.12)

35. The total energy of a particle executing simple harmonic motion is (a) α x (b) α x2 (c) Independent of x (d) α √x

36. The bob of a pendulum of length *l* is pulled aside from its equilibrium position through an angle θ and then released. The bob will then pass through its equilibrium position with a speed u, where u equals



37. On a smooth inclined plane ,a body of mass M is attached between two springs (fig 18.14). The other ends of the springs are fixed to firm supports. If each spring has force constant k, the period of oscillation of the body is: (assuming the springs as massless)

38. Which of the following characteristics does not change due to the damping of simple harmonic motion?

(a) Angular frequency (b) Time period (c) Initial phase (d) Amplitude

39. Two particles execute SHM of the same amplitude and frequency along the same straight line. If they pass one another when going in opposite directions, each time their displacement is half their amplitude; the phase difference between them is: (a) π/3 (b) π/4 (c) π/6 (d) 2π/3

40. If a pendulum, which gives correct time beats seconds on ground at a certain place, is moved to the top of a tower 320 m high, the loss of time of the pendulum clock in one day is :

(a) 2.16 sec (b) l.08sec (c) 0.54 sec (d) 4.32 sec

41. The Length of the seconds pendulum is decreased by 0.3 cm when it is shifted to Chennai from London. If the acceleration due to gravity at London is 981 cm/sec2 , the acceleration due to gravity at Chennai is: (assume π2 =10): (a) 981 cm/sec2 (b) 978 cm/sec2 (c) 984 cm/sec2 (d) 975 cm/sec2

42. A pendulum has period T for small oscillations. An obstacle is placed directly beneath the pivot, so that only the lowest one quarter of the string can follow the pendulum bob when it swings in the left of its resting position as shown in the fig (18.16). The pendulum is released from rest at a certain point A. The time taken by it to return to that point is: (a) T (b) T/2 (c) 3T/4 (d) T/4

43. Two identical balls A and B each of mass 0.1 kg are attached to two identical massless springs. The spring mass system is constrained to move inside a rigid smooth pipe bent in the form of a circle as shown in the figure(18.17). The pipe is fixed in a horizontal plane. The centres of the balls can move in a circle of radius 0.06 m. Each spring has a natural length of 0.06π m and force constant 0.lN/m . Initially, both the balls are displaced by an angle θ = π/6 radian with respect to the diameter PQ of the circle and released from rest. The frequency of oscillation of the ball B is: (a) π Hz (b) 1/π Hz (c) 2π Hz (d) 1/2π Hz

44. A particle is executing simple harmonic motion with an amplitude of 4 cm. At the mean position the velocity of the particle is l0 cm/sec. The distance of the particle from the mean position when its speed becomes 5 cm/s is: (a) √3 cm (b) √5 cm (c) 2√3 cm (d) 2√5 cm

45. A body of mass 20 g connected to spring of constant K executes simple harmonic motion with a frequency of (5/π)Hz. The value of spring constant is:

(a) 4 N/m (b) 3 N/m (c) 2 N/m (d) 5 N/m (e) 2.5 N/m

46. Two springs, of force constants k1 and k2 are connected to a mass m as shown in fig 18.34. The frequency of oscillation of the mass is *f*. If both k1 and k2 are made four times their original values, the frequency of oscillation becomes (a) 2 *f* (b) *f* /2 (c) *f*/4 (d) 4 *f*

47. A particle of mass m executes SHM with amplitude a and, frequency v. The average kinetic energy during motion from the position of equilibrium to the end is:

(a) 2π2ma2v2(b)π2ma2v2  (c)¼ ma2v2 (d) 4π2ma2v2

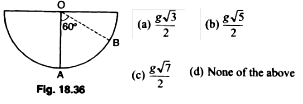
48. The displacement of an object attached to a spring and executing simple harmonic motion is given by:

*x* = 2 x 10-2 cosπt .The time at which the maximum speed first occurs is :

(a) 0.25 s(b)0.5 s (c)0.75 s (d) 0.125 s

49. A point mass oscillates along the x-axis according to the law *x* = *xo* cos(wt -π/4). If the acceleration of the particle is written as a = A cos (wt + δ), then :

(a) A = *xo*w2 , δ = 3π/4(b)A = *xo* , δ = -π/4(c)A = *xo*w2 , δ = π/4(d) A = *xo*w2 , δ = -π/4

50. when the maximum KE of a simple pendulum is K, then what is its displacement (in terms of amplitude a),when its KE is K/2 : (a) a/√2 (b) a/2 (c) a/√3 (d) a/3

51. A simple pendulum is vibrating with an angular amplitude of 900 as shown in the figure18.36. what is the magnitude of acceleration when it makes an angle 600 with the vertical?

52. A body of mass 12 kg is suspended by a coil spring of natural length 50 cm and spring constant 2 x 103 N/m. The length of the spring after extension will be

(a) 0.00588 m (b) 0.0588 m (c) 0.5588 m (d) none of these

53. A spring, which is initially in its unstretched condition, is first stretched by a length *x* and then again by a further length *x*. The work done in the first case is W1 and in the second case is W2. Then

(a) W2 = W1 (b) W2 = 2W1 (c) W2 = 3W1 (d) W2 = 4W1

54 .Two simple harmonic motions of angular frequency 100 and 1000 rad/s have the same displacement amplitude. The ratio of their maximum acceleration is :

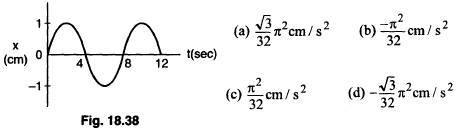
(a) 1:103 (b) 1:104 (c) 1:10 (d) 1:102



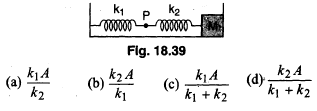
55. A point performs simple harmonic oscillation of period T and the equation of motion is given by; *x* = a sin (wt + π/6). After the elapse of what fraction of the time period the velocity of the point will be equal to half of its maximum velocity? (a) T/3 (b) T/12 (c) T/8 (d) T/6

56. A block (B ) is attached to two unstretched springs S1 and S2 with spring constants k and 4 k respectively fig 18.37 .The other ends are attached to identical supports M1 & M2 not attached to the walls. The springs and supports have negligible mass. There is no friction anywhere. The block B is displaced towards wall I by a small distance x (Fig. ii) and released. The block returns and moves a maximum distance y towards wall 2.Displacements x and y are measures with respect to the equilibrium position of the block B. The ratio y/x is:

(a) 4 (b) 2 (c) 1/2 (d) ¼ (IIT 2008)



57. The x-t, graph of a particle undergoing simple harmonic motion is shown in fig 18.38. The acceleration of the particle at t =4/3 s is : [IIT 2009]



58. The mass M shown in the figure 18.39 oscillates in simple harmonic motion with amplitude A. The amplitude of point P is : [IIT 2009]

59. If x, v and a denote the displacement, the velocity and the acceleration of a particle executing simple harmonic motion of time period T, then, which of the following does not change with time? [AIEEE 2009]

(a) a2T2 + 4π2v2 (b) aT/x (c) aT +2πv (d) aT/v

60. A particle is subjected simultaneously to two SHM's, one along the x-axis and the other along the y-axis. The two vibrations are in phase and have unequal amplitudes. The particle will execute: [UPSEE 2009]

(a) straight line motion (b) circular motion (c) elliptic motion (d) parabolic motion

61. Two identical pendulums are oscillating with amplitudes 4 cm and 8 cm. The ratio of their energies of oscillation will be: (a) 1/3 (b) 1/4 (c) 1/9 (d) 1/2

62. The displacement of a particle executing SHM is given by: y = 5 sin (4t +π/3 ). If T is the time period and the mass of the particle is 2 g, the kinetic energy of the particle when t =T/4 is given by:

(a) 0.4 J (b) 0.5 J (c) 3 J (d) 0.3 J

63. An electric motor of mass 40 kg is mounted on four vertical springs each having spring constant of 4000 Nm-l. The period with which the motor vibrates vertically is:

(a) 0.314 s (b) 3.l4 s (c) 0.628 s (d) 0.157 s (e) 0.078 s

64. A particle is executing linear simple harmonic motion. The fraction of the total energy that is potential, when its displacement is 1/2 of its amplitude is : (a) 1/16 (b) 1/8 (c) 1/2 (d) 1/4

65. If a particle takes 0.5 sec to reach position of minimum velocity from previous such position, then:

(a) T =6 s, *f* =l/6 Hz (b) T =2 s, *f* =l Hz (c) T =3 s, *f* =3 Hz (d) T =1 s, *f* =l Hz

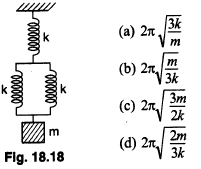
66. The maximum velocity of a particle executing SHM is u. If the amplitude is doubled and the time period of oscillation decreased to 1/3 of its original value, the maximum velocity becomes:

(a) 18u (b) 12u (c) 6u (d) 3u

67. In forced oscillation of a particle, the amplitude is maximum for a frequency *w1* of the force, while the energy is maximum for a frequency *w2* of the force, then: (AIEEE 2004)

(a) *w1* = *w2*  (b) *w1* > *w2*

(c) *w1* < *w2*  when damping is small and *w1* > *w2*  when damping is large (d) *w1* < *w2*

68. A body executes simple harmonic motion under the action of a force F1 with a time period (4/5) sec. If the force is changed to F2 it executes SHM with time period (3/5) sec. If both the forces F1 and F2 act simultaneously in the same direction on the body, its time period (in seconds) is:

(a) 12/25 (b) 24/25 (c) 35/24 (d) 25/12

69. If the displacement (*x*) and velocity *v* of a particle executing simple harmonic motion are related through the expression 4*v*2 = 25 - *x*2, then its time period is: (a) π (b) 2 π (c) 4 π (d) 6 π

70. What will be time period of the displaced body of mass m(fig 18.18)?

71. When a mass M is attached to the spring of force constant k, then the spring stretches by *l*. If the mass oscillates with amplitude *l*. What will be the maximum potential energy stored in the spring?

(a) k*l*/2 (b) 2k*l* (c) Mg*l*/2 (d) Mg*l*

72. The angular velocities of three bodies in simple harmonic motion are *w*1,*w*2 & *w*3 with their respective amplitudes as A1, A2 & A3.If all the three bodies have the same mass and velocity, then:

(a) A1w1 = A2w2 = A3w3  (b) A1w12 = A2w22 = A3w32

(c) A12w1 = A22w2 = A32w3  (d) A12w12 = A22w22 = A32w32

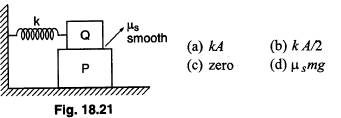
73. A simple pendulum oscillates in a vertical plane. When it passes through the mean position, the tension in the string is 3 times the weight of the pendulum bob. What is the maximum displacement of the string of the pendulum with respect to the vertical?(a) 300 (b) 450 (c) 600 (d) 900

74. A simple pendulum is executing simple harmonic motion with a time period T. If the length of the pendulum is increased by 21%, the increase in the time period of the pendulum of increased length is:

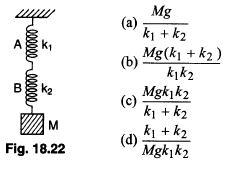
(a) 10% (b) 21% (c) 30% (d) 50% (AIEEE 2003)

75. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.17 sec. The frequency of the wave is:

(a) 0.36 Hz (b) 0.73Hz (c) 1.47Hz (d) 2.94Hz



76. A block P of mass m is placed on a frictionless horizontal surface. Another block Q of same mass is kept on P and connected to the wall with the help of a spring of spring constant k as shown in the figure(18.21). μS, is the coefficient of friction between P and Q. The blocks move together performing SHM of amplitude A. The maximum value of the friction force between P and Q is: **(IIT 2004)**



77. A mass M is suspended by two springs of force constants k1 and k2 respectively as shown in the fig 18.22. The total elongation (stretch) of the two springs is:

78. The displacement-time equation of a particle executing SHM is: *x* =A sin (wt + ϕ), At time t = 0, position of the particle is *x* = A/2 and it is moving along negative X-direction. Then, the angle ϕ can be:

(a) π/6 (b) π/3 (c) 2π/3 (d) 5π/6

79. Frequency of a particle executing SHM is l0 Hz. The particle is suspended from a vertical spring. At the highest point of its oscillation the spring is unstretched. Maximum speed of the particle in m/s is (g = l0m/s2): (a) 2π (b) π (c) 1/π (d) 1/2π

80. Time period of a simple pendulum of length L is Tl and time period of a uniform rod of the same length L pivoted about one end and oscillating in a vertical plane is T2.Amplitude of oscillations in both the cases is small. Then, T1/T2 is:(a) √(4/3) (b) 1 (c) √(3/2) (d) √(1/3)

81. The potential energy of a particle of mass 1kg in motion along the x-axis is given by:

U = 4(l- cos 2x) J, where x is in metres. The period of small oscillations (in sec) is:

(a) 2π (b) π (c) π/2 (d) √2π

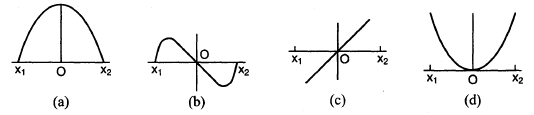
82. A particle executing SHM while moving from one extremity is found at distances x1 , x2 and x3 from the centre at the end of three successive seconds. The time period of oscillation is:

(a) 2π/θ (b) π/θ (c) θ (d) π/2θ where θ = cos-1[ (x1+x3)/2x2 ]

83. In case of a forced vibration, the resonance wave becomes very sharp when the:

(a) quality factor is small (b) dampening force is small

(c) restoring force is small (d) applied periodic force is small



84. A particle of mass m oscillates with simple harmonic motion between points X1 and X2,the equilibrium position being O. Its potential energy will be as shown in the following graph:

85. The potential energy of a simple harmonic oscillator when the particle is half way to its end point is: (where E is the total energy): (a) E/8 (b) E/4 (c) E/2 (d) 2E/3

86. The time period of a particle in simple harmonic motion is 8 seconds. At t = 0, it is at the mean position. The ratio of the distances travelled by it in the first and second seconds is:

(a) ½ (b) 1/√2 (c) 1/(√2 -1) (d) 1/√3

87. If a spring balance having frequency *f* is taken on the moon (having g' = g/6) it will have a frequency of:

(a) 6*f* (b) *f* /√6 (c)  *f* √6 (d) *f*

88. When a body of mass 1.0 kg is suspended from a certain light spring hanging vertically, its length increases by 5 cm. By suspending 2.0 kg block to the spring and if the block is pulled through l0 cm and released, the maximum velocity of it (in m/s) is: (a) ½ (b) 1 (c) 2 (d) 4

89. An object is attached to the bottom of a light vertical spring and set vibrating. The maximum speed of the object is 15 cm/sec and the time period is 628 milliseconds. The amplitude of the motion (in centimetres) is:

(a) 3 (b) 2 (c) 3/2 (d) 1

90. The displacement of a particle varies according to the relation: *x* = 4(cos πt + sin πt). The amplitude of the particle is: (a) 8 (b) - 4 (c) 4 (d) 4√2 (AIEEE 2003)

91. A mass M is suspended from a spring of negligible mass. The spring is pulled a little and then released, so that the mass executes SHM of time period T. lf the mass is increased by m, the time period becomes 5T/3. The ratio of m/M is : (a) 5/3 (b) 3/5 (c) 16/9 (d) 25/9 (AIEEE 2003)

92. A body executes simple harmonic motion. The potential energy (PE), kinetic energy (KE) and total energy (TE) are measured as a function of displacement *x*. Which of the following statements is true? (AIEEE 2003)

(a) TE is zero when x = 0 (b) PE is maximum when x = 0

(c) KE is maximum when r = 0 (d) KE is maximum when x is maximum

93. Two particles A and B of equal masses are suspended from two massless springs of spring constants k1 and k2, respectively. If maximum velocities during oscillation are equal the ratio of amplitudes of A and B is:

(a) k1/k2 (b) k2/k1 (c) √ ( k1/k2) (d) √ ( k2/k1) (AIEEE 2003)

94. The equation of motion of a particle executing simple harmonic motion is **a + l6π2 *x* = 0**.In this equation, a is the linear acceleration in m/s 2 of the particle at a displacement *x* in metre. The time period in simple harmonic motion is(in sec): (a) ¼ (b) ½ (c) 1 (d) 2

95. A spring is loaded with two blocks m1 and m2, where m1 is rigidly fixed with the spring and m2 is just kept on the block m1.The maximum energy of oscillation is possible for the system having the block m2 in contact with m1 is: (a) m12g2/2k (b) m22g2/2k (c) (m1+m2)2g2/2k (d) none of these

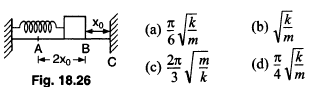
96. An object of mass 0.2kg executes simple harmonic motion along x-axis with frequency of 25/π Hz. At the position x = 0.04 m, the object has a kinetic energy of 0.5 J and potential energy of 0.4 J. The amplitude of oscillation is equal to: (a) 0.05 m (b) 0.06 m (c) 0.01 m (d) none of these

97. A particle of mass m is executing oscillations about the ', origin on the *x*-axis. Its potential energy is U(x) =k*x*3,where k is a positive constant. If the amplitude of oscillation is a, then its time period T is:

(a) proportional to l/√a (b) independent of a

(c) proportional to √a (d) proportional to a3/2

98. The period of oscillation of a simple pendulum of length *l* suspended from the roof of the vehicle which moves down without friction on an inclined plane of inclination α, is

99. One end of a spring of force constant k is fixed to a vertical wall Fig. 18.26 and the other to a body of mass m resting on a smooth horizontal surface. There is another wall at a distance xo from the body. The spring is then compressed by 2xo and released. The time taken to strike the wall is:

100. In a simple pendulum at mean position:

(a) KE is maximum and PE is minimum (b) KE is minimum and PE is maximum

(c) both PE and KE are maximum (d) both PE and KE are minimum (AIEEE 2002)

101. The bob of a pendulum clock is made of iron. If a magnet is placed below the central position of the bob, it will: (a) start losing time (b) start gaining time (c) still give correct time (d) stop working

102. Which of the following characteristics does not change due to the damping of simple harmonic motion?

(a) Angular frequency (b) Time period (c) Initial phase (d) Amplitude

**Answers Objective ( Oscillations )**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1. D | 1. B | 1. A | 1. C | 1. C | 1. B |
| 1. A | 1. B | 1. A | 1. A | 1. C | 1. B |
| 1. B | 1. A | 1. A | 1. B | 1. D | 1. C |
| 1. B | 1. B | 1. A | 1. B | 1. C | 1. A |
| 1. C | 1. B | 1. B | 1. C | 1. B | 1. D |
| 1. A | 1. D | 1. A | 1. B | 1. C | 1. E |
| 1. A | 1. C | 1. D | 1. D | 1. B | 1. C |
| 1. B | 1. C | 1. C | 1. A | 1. B | 1. B |
| 1. A | 1. A | 1. C | 1. C | 1. C | 1. D |
| 1. B | 1. C | 1. D | 1. D | 1. B | 1. A |
| 1. B | 1. D | 1. A | 1. D | 1. D | 1. C |
| 1. A | 1. A | 1. C | 1. C | 1. D | 1. A |
| 1. D | 1. A | 1. C | 1. B | 1. B | 1. D |
| 1. D | 1. C | 1. C | 1. A | 1. B | 1. D |
| 1. B | 1. C | 1. D | 1. B | 1. C | 1. D |
| 1. C | 1. C | 1. D | 1. B | 1. C | 1. B |
| 1. A | 1. A | 1. C | 1. A | 1. B | 1. C |

**Explanations Objective –Oscillations**

