PHYSICS

BOOKS - S CHAND PHYSICS (ENGLISH)

OSCILLATIONS

Solved Example

1. The restoing force acting on a body executing simple harmonic motion is 16 N when the body is 4 cm away from the

equilibrium position. Calculate the spring constant.

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2. A body executing simple harmonic motion makes 120 oscillations in one minute. Calculate (i) period (ii) frequency and (iii) angular frequency.

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3. A body is executing shm with an amplitude of 0.15 m and frequency 4. Hz. Compute (i) maximum velocity of the body (ii) acceleration when displacement is 0.09 m and time required to move from mean position to a point 0.12 m away from it.

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4. A particle executes shm with an amplitude of 10 cm and a period of 5 s. Find the velocity

and acceleration of the particle of a distance 5 cm from the equilibrium position.

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5. A bob executes shm of period 20 s. Its velocity is found to be $0.05ms^{-1}$ after 2 s when it has passed through its mean position. Find the amplitude of the bob.

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6. A body describes shm in a line 0.04 m long. Its velocity at the centre of the line is $0.12ms^{-1}$. Find the Time period.

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7. In what time after its motion began, will a particle oscillating according to the equation x = 7 sin $(0.5\pi t)$ move from the mean position to the maximum displacement ?

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8. A particle is in SHM with a mass of 0.5 kg has a velocity of $0.3ms^{-1}$ after 1s of its starting from the mean position . Calculate its K.E. and total energy , if its time period is 6 s.

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9. The period of a particle executing shm is 2π. The total energy of the particle is 0.0786 J. After a time $\pi/4s$ the displacement is 0.2m.

Calculate the amplitude and mass of the particle.

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10. A mass of 400 g is connected to a massless spring of force constant 10.0 N/m and is made to oscillate on a frictionless horizontal table. The mass is displaced 10 cm from the equilibrium position and released from rest. (i) What is the period of oscillations ? (ii) Find the maximum speed of the mass (iii) What is the

maximum acceleration of the mass ? and (iv) what is the total energy of the mass ? [See Fig]

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11. The time period of oscillation of a spring is 1.57s when a mass of 100 gm is suspended from its lower end. Calculate (i) the force constant of the spring (ii) the K.E. of the mass

when its displacement'is equal to the amplitude.

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12. If the length of a second's pendulum is decreased by 2 %, find the gain or loss in time per day.

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13. The period of oscillation of a long pendulum suspended from the ceililing of a tall building is 8 s. Calculate the height of the building ?

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14. A vertical U-tube of uniform cross-section contains water upto a height to 0.8 m. Show. that if the water on one side is depressed and

then released, its motion up and down the tube is shm. Calculate the period.

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15. A weighted glass tube is floated in a liquid with 20 cm of its length immersed. It is pushed down through a certain distance and then released. Compute the time period of its vibration.

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16. A horizontal platform moves up and down simple harmonically, the total movement being 10 cm. What is the shortest period permissible if objects resting on the platform are to remain in contact with it throughout the motion ?

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17. A solid sphere of mass 3 kg and diameter 0.2 m is suspended from a wire. The torque

required to twist the wire is 5×10^{-2} Nm/radian. Calculate the period of oscillation

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18. A disc of mass 1 kg and radius 10 cm is suspended by vertical wire at its centre. If the time period is 3.2 s. Find the modulus of torison.

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19. Two sinusoidal wave having the same frequency and travelling in the same direction are combined. What is the amplitude of the resultant motion if their amplitudes are 3cm and 4cm and they differ in phase by $\pi/2$ radian?

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20. Two shms are represented by the equations,

$y_1 = 15\sin 6t$ and $y_2 = 18\sin\left(6t + \frac{\pi}{4}\right)$. If the vibrating particles have the same mass find (i) ratio of maximum velocities (ii) ratio of time periods and (iii) ratio of total energies.

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21. A particle has a time period of 1s under the action of a certain force and 2 s under the action of another force. Find the time period when the forces are acting in the same direction simultaneously.

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22. A particle executes shm with a period 8 s. Find the time in which half the total energy is potential.

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Additional Solved Problems

1. Figures below show four different spring arrangements. If the mass in each

arrangement is displaced from its equilibrium position and released, what is the resulting frequency of vibration in each case ? Neglect the mass of the each spring. (See Fig).

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2. Figure (a) shows a spring of force constant k clamped rigidly at one end and a mass attached to its free end. The spring is stretched by a force F at its free end. Figure

(b) shows the same spring with both ends free and attached to a mass m at either end. Each end of the spring in Fig.(b) is stretched by the same force F.

(i) What is the maximum extension of spring in the two cases?

If the mass in (a) and the two masses in (b) are released free, what is the period of oscillation in each case ?

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3. A spring of force constant $1200 Nm^{-1}$ is mounted on a horizontal table as shown in Fig. A mass of 3.0 kg is attached to the free end of spring, pulled sideways to a distance of 2.0 cm and released.

(a) What is the frequency of oscillation of mass ?

(b) What is its maximum acceleration ?

(c) What is its maximum speed ?

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4. A tray of mass 12 kg is supported by a two identical springs as shown in Fig. When the tray is pressed down slightly and released it executes shm with a period of 1.5 s. What is the force constant of each spring ? When a block of mass m is placed on the tray, the period of shm changes to 3.0 s What is the mass of the block ?

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5. A trolley of mass 3.0 kg is connected to two identical springs each of force constant 600 Nm as shown in Fig. If the trolley is displaced from its equilibrium position by 5.0 cm and released, what is (a) period of oscillation, (b) the maximum speed of the trolley, (c) how much is the total energy dissipated as heat by the time the trolley comes to rest due to damping force ?

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6. A trolley of mass $3.0kg$ is connected to two identical springs each of force constant $600Nm^{-1}$as shown in figure 13.32 (amplitude=5cm)

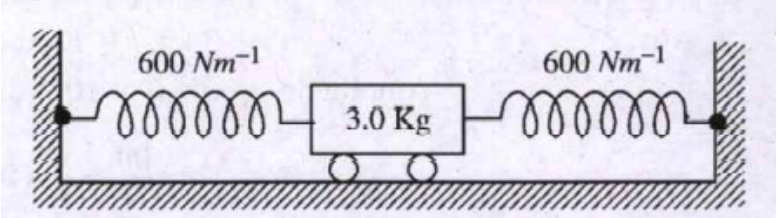

Fig. 13.32

Problem (a) period of oscillation

Problem (b) the max speed of trolley.

If the spring in the problem are replaced by rubber bands, what is the answer to the

question (a) and (b) in the problem if K of rubber band is $600 Nm^{-1}$ during extensions.

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7. Two vibrating bodies have frequencies 10 Hz and 12 Hz. They start oscillating in the sáme phase. In 3 seconds how many time they will be (i) in the same phase and (ii) in the opposite phase ?

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8. A 3 kg collar attached to a spring of force constant $1200 Nm^{-1}$ slides without friction on a horizontal rod. The collar is displaced from its equilibrium position by 6.0 cm and released. Calculate (a) the period of oscillation, (b) the maximum magnitude of acceleration and (c) the maximum speed of collar. (Fig)

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9. If the earth were a homogeneous sphere of radius R and a straight hole bored in it through its centre, show that a particle dropped into the hole will execute shm and find out its period.

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10. A particle is moving with shm in a straight line. When the distance of the particle from the equilibrium position has the value

x_1 and x_2 the corresponding values of velocities are v_1 and v_2 show that period is $T = 2\pi\left[\frac{x_2^2 - x_1^2}{v_1^2 - v_2^2}\right]^{1/2}$

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11. The acceleration due to gravity on the surface of moon is $1.7ms^{-2}$. What is the time period of a simple pendulum on the moon if its time period on the earth is 3.5 s ? (g on earth = $9.8ms^{-2}$)

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Short Answer Questions With Answer

1. Which of the following examples represents periodic motion ?

(i) A swimmer completing onė (return) trip from one bank of a river to the other bank.

(ii) A freely suspended bar magnet displaced form its N-S direction and released.

(iii) Halley's comet

(iv) A hydrogen molecules rotating about its

centre of mass.

(v) An arrow released from a bow.

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2. Which of the following examples represents (nearby) shm and which represents periodic but not shm.

(i) The rotation of earth about its axis.

(ii) Motion of an oscillating mercury column in a U-tube.

(iii) Motion of a ball bearing inside a smooth

curved bowl when released from a point slightly above the lowermost position.

(iv) General vibration of a polyatomic molecules about its equilibrium configuration.

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3. Which of the following x-t plots represent periodic motion ? What is its period ?

(i) Figure (a)

(ii) Figure (b)

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4. Give the characteristics of shm.

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5. Can a pendulum clock be used in an earth satellite?

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6. Suppose the bob in a simple pendulum is a hollow sphere with a small hole at the bottom. The sphere is filled with water and is made to oscillate. What happens to the period ?

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7. How will you determine the period of oscillation of a mass without the use of a clock? You are given a weightless spring, a metre scale and a known mass.

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8. The amplitude of a simple pendulum decreases with time. But there is no decrease in the amplitude of a pendulum clock. Why?

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9. The displacement of a harmonic oscillator is half of its amplitude. What fraction of the total energy is kinetic and what fraction is potential ?

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10. Time period of a particle in shm depends on the force constant k and mass m of the particle $T = 2\pi\sqrt{\frac{m}{k}}$ A simple pendulum executes shm approximately. Why then is the time period of a pendulum independent of a mass of the pendulum?

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11. A man with a wrist watch on his hand falls from the top of a tower. Does the watch give correct time during the free fall ?

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12. What is the frequency of oscillation of a simple pendulum mounted in a cabin that is freely falling under gravity ?

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13. Write down the expression for the average K.E. and average P.E. of a harmonic oscillator. How are they related ?

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14. For an oscillating simple pendulum is the tension in the string constant throughout the oscillation ? If not, when is it (a) the least (b) the greatest?

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15. A spring is cut into two halves. What happens to its period of oscillation of a mass suspended from it, before cutting and after cutting ?

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16. What is the period of oscillation of a simple pendulum if its bob is made of ice ?

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17. Distant explosion can break glass windows. How?

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18. Draw the velocity-displacement graph of a body executing shm.

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19. If x is the displacement of a simple harmonic oscillator at a certain instant and y its acceleration at that instant, draw graph of (x, y) at all instant in one complete oscillation,

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20. A pendulum clock is taken to moon. Will it gain or lose time?

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Long Answer Questions

1. (a) Define simple harmonic motion and derive, an expression for the period of simple harmonic motion by reference circle method.

(b) Derive an expression for the period of oscillations of a simple pendulum.

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2. Obtain an expression for the period of oscillations of a mass attached to end of a

spring and undergoing shm. Obtain expression for K.E. and P.E. at any position during shm.

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3. Discuss forced harmonic oscillations. Write down the expression for displacement. Explain resonance.

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Short Answer Questions

1. How would the time period of a simple pendulum be affected if (a) the length is doubled (b) the amplitude is doubled ?

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2. Sketch graph showing the variation of (i) the kinetic energy, (ii) the potential energy and (iii) the total energy of a simple harmonic oscillation with displacement.

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3. Which of the following is/are likely to affect the time period of a simple pendulum? (i) length (ii) amplitude of vibration (iii) mass of the bob

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4. What is the difference between the periodic motion and the oscillatory motion ?

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5. Give examples of shim in which elastic constants are not involved.

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6. Explain why simple harmonic motion is called so ?

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7. Give examples of (i) linear shm and (ii) angular shm.

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8. Is the motion of earth around sun oscillatory? Why?

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9. If the mass attached to a vertical spring is pulled down and left, it oscillates. why ?

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10. Define displacement, amplitude, period and frequency.

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11. Define simple harmonic motion ?

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12. Write down the differential equation of a body executing shm. Give its solution.

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13. What is the physical significance of ω ?

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14. At what position of a body executing shm its velocity (i) maximum and (ii) zero ?

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15. At what position of a body executing shm its acceleration (i) maximum and (ii) zero.

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16. When the velocity of a body executing shm is zero its acceleration is not zero. Why?

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17. Derive an expression for the P.E. and K.E. of a body executing shm.

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18. The graph showing the variation of K.E. or P.E. with displacement of a harmonic oscillator is a parabola, but that of total energy with displacement is a straight line. Why?

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19. Give the characteristics of shm.

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20. Simple harmonic motion is the projection of uniform circular motion on

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21. Define phase and phase difference.

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22. What is epoch?

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23. Write down the expression for the period of oscillation of a mass attached to (i) a horizontal spring and (ii) a vertical spring.

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24. Define spring constant or force constant.

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25. What is simple peridulum ? Define length of the pendulum.

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26. What is a seconds pendulum?

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27. Write down the expression for the period of oscillation of a light piece of cork floating in a liquid .

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28. What is the period of oscillation of a liquid contained in a U - tube executing shm ?

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29. What is a torsional pendulum ? Name the factors on which its period of oscillation depends ?

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30. At what positions of the simple pendulum its (i) P.E. is maximum (ii) K.E. is zero ?

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31. Draw the displacement-time, velocity-time and acceleration-time graph of a body executing shm.

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32. The phase difference between two particies executing shm is $\pi / 2$. What does it mean?

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33. Name the different ways of expressing the phase of an oscillating particle.

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34. Explain (i) natural oscillation (ii) natural frequency.

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35. Draw graph showing the variation of displacement with time of a body executing (i) free oscillation (ii) damped oscillations.

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36. Give examples of damped oscillation.

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37. What are forced oscillations? Why are they called so ?

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38. What is resonance ? What is resonant frequency ?

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39. Give two examples to illustrate resonance.

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40. Draw graphs to show the variation of amplitude with driving frequency of a forced harmonic oscillator under (i) zero damping, (ii) low damping and (iii) high damping

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41. Marching soldiers are asked to break their steps while crossing a bridge. Why?

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42. When the stem of a vibrating tuning fork is gently pressed on the surface of a table louder sound is heard. Why?

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43. On what factors does the period of a simple pendulum depend ?

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44. At what displacement K.E. and P.E. are equal, for a body executing shm.

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45. Under what condition the oscillation of a simple pendulum is simple harmonic ?

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46. The length of a seconds pendulum is decreased by 1%. What is the gain or loss in time per day?

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47. Two pendulums of lengths 1.44 m and 1 m start oscillating together. After how many oscillations will Activate they again start swinging together?

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Very Short Answer Questions

1. Does the damping force remain constant on a system executing shm?

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2. What is the direction of velocity and acceleration in shm ?

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3. What is the direction of displacement and acceleration in shm?

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4. 'A point on a rotating disc is not considered to be simple harmonic". Why?

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5. A spring is made to oscillate horizontally and vertically. Will there be any change in the period ?

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6. A loaded spring is made to oscillate on the Earth surface and then in moon. Will there be any change in the time period ?

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7. The period of oscillation of a harmonic oscillator is $T = 2\pi\sqrt{\text{displacement}/\text{accelerations}}$ Does T depend on displacement ?

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8. The length of a second's pendulum on the surface of earth is 1 m. What will be the length of a second's pendulum on the moon?

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9. Two simple pendulums of equal length cross each other at mean position. What is their phase difference ?

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10. An oscillating simple pendulum is kept in a lift which is accelerating upwards. Will there be any change in the time period ?

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11. The period of oscillation of a liquid in a U. Tube is one to be T_1 The first liquid is replaced by another are of higher density. Will there be any change in the period ?

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12. A boy who was sitting on a swing stands up while it was swinging. Will there be any change in the period ?

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13. In a stationary lift, a simple pendulum has a period T. How does the period change when the lift (i) moves up with (a) uniform velocity and (b) uniform acceleration and (ii) move down with (a) uniform velocity and (b) uniform acceleration.

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Selected Problems From The Characteristic Of Shm

1. A particle executes shm in a line 10 cm long. When it passes through the mean position its velocity is $15cms^{-1}$. Find the period.

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2. The displacement of a particle executing shm is x = 0.5 cos (314t - 0.3) m. Find (i) amplitude (i) period.

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3. The amplitude of a body executing shm is 2 cm. Its mass is 20 g and the frequency of vibration is 20 Hz. Find its (i) maximum velocity (ii) energy ?

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4. A body executing shm completes 120 oscillations per minute. If the amplitude of oscillations is 6 cm, find the velocity and acceleration of the particle when it is at a distance of 4 cm from the mean position?

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5. A body of mass 4 kg is executing shm of amplitude 0.4 m and period 2 s. Find (i) the maximum restoring force and (ii) the restoring force at a distance of 0.1 m from extreme position.

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6. In what time after its motion began, will a particle oscillating according to the equation x = 7 sin $(0.5\pi t)$ move from the mean position to the maximum displacement ?

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7. In a shm, what is the minimum time required for a particle to move between two points 10 cm on either side of the mean position ? The

amplitude and time period of the particle are 20 cm and 2 seconds respectively.

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8. A particle is moving with shm in a-straight line. When the distance of the particle from the equilibrium position has the values 2 cm and 4 cm, the corresponding values of velocities are $5cms^{-1}$ and $3cms^{-1}$ respectively. Find the length of the path and the period.

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9. Two particles start oscillating together in shm along the same straight line. Their periods are 2 s and 4 s. What is their phase difference afterls from the start?

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10. A body has a time of 3 s under the action of one force and 4 s under the action of another force. Calculate the time period when both the

forces act in the same direction simultaneously. Assume that the body undergoes the same displacement, under the action of the two different forces.

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11. A mass of Hg is executin SHM which is given by $x = 6.0\left(100t + \frac{\pi}{4}\right)$ cm.What is the maximum kinetic energy?

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12. In a HCl molecule, we may treat Cl to be of infinite mass and H alone oscillating. If the oscillations of HCI molecule shows frequency $9 \times 10^{13} s^{-1}$, deduce the force constant. Given Avogadro's number 6×10^{26} per kg mole.

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13. The Shortest distance travelled by a particle executing SHM from mean position in

2 s is equal to $\sqrt{3}/2$ times its amplitude . Determine its time period.

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14. A particle moving with shm has a period 0.001 s and amplitude 0.5 cm. Find the acceleration, when it is 0.2 cm apart from its mean position.

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Selected Problems From Energy Of As H Oscillator

1. A body of mass 0.2 kg performing SHM has a velocity of $0.6ms^{-1}$ after one second of its starting from the mean position. If the time period is 6 seconds, find the kinetic energy, potential energy and total energy.

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2. A particle executes shm of amplitude 'a'. (i) At what distance from the mean position is its kinetic energy equal to its potential energy? (ii) At what points is its speed half the maximum speed ?

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3. A particle executes shm of period.8 s. After what time of its passing through the mean

position the energy will be half kinetic and half potential.

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4. The amplitude of a system moving inshm is doubled . Determine the change in (a) total energy (b) the maximum speed (c) the maximum acceleration and (d) the period .

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5. Calculate the ratio of displacement to amplitude when kinetic energy of a body is thrice its potential energy.

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6. A simple harmonic oscillator of period 6 second has 6 joule potential energy when its displacement is 3 cm. Calculate (i) force constant and (ii) average kinetic energy when the amplitude is 5 cm.

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7. A body of mass 2 kg is executing simple harmonic motions according to the cquation 0.06 cos (100t+ $\pi/4$) m, where t is in seconds. What is the maximum kinetic energy?

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8. A particle is executing shm. What fraction of its energy is kinetic when the displacement is half the amplitude ?

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9. The kinetic energy of a particle executing shm is 32 J when it passes through the mean position. If the mass of the particle is.4 kg and the amplitude is one metre, find its time period.

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Selected Problems From Time Period Of Oscillation Of A S H Oscillator

1. A 0.02 kg weight produces an extension of 0.02 m in a vertical spring. A mass of 0.1kg is suspended at its bottam and is left after putting down. What is the period of oscillation ?

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2. A spring balance is found to have a period of oscillation of 3.14 s, when a 12 kg weight is suspended from it. How much does the spring

elongate when a 2 kg weight is suspended from it ?

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3. A body of mass 4 kg is made to oscillate on a spring of force constant 10 N/m. Calculate (i) angular frequency (2) frequency of vibration and (3) time period of vibration.

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4. A mass m attached to a spring oscillates with a period of 3 second. If the mass is increased by 2 kg, the period increases by one second. Calculate the initial mass m. (Assume that elastic limit is not crossed)

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5. A spring balance has a scale that reads from 0 to 50 kg. The length of the scale is 20 cm. A body suspended from this spring, when

displaced and released, oscillates with a period of 0.6s. What is the weight of the body? When 50 kg is put, the extension of spring is 20 cm.

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6. A mass m is suspended from a spring of force constant k. The period of oscillation is T_0 The spring is cut into 4 equal parts: The same mass m is suspended from one of the parts. What is the new period?

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7. An impulsive force gives an initial velocity of $-1.0ms^{-1}$ to the mass in the unstretched spring position. What is the amplitude of motion ? Give x as a function of time for the oscillating mass. Given m=3 kg, $k = 1200Nm^{-1}$

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8. A small trolley of mass 2.0 kg resting on a horizontal turntable is connected by a light spring to the centre of the table. When the turntable is set into rotation at a speed of 300 rev/min the length of the stretched spring is 40 cm. If the original length of the spring is 35 cm, determine the force constant of the spring.

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9. If two springs of force constants $7\mathrm{Nm}^{-1}$ and $9\mathrm{Nm}^{-1}$ are connected in series and is fixed to a body of mass 100 g. Find the period of oscillation.

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10. A block of mass 0.01 kg is attached to a spring of force constant $10^{-1}Nm^{-1}$. If the energy of oscillation is 10^{-5} J, find the angular frequency and amplitude of oscillation.

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11. A horizontal coiled spring is found to stretch 3 cm by a force of 6×10^{-5} N. A bob of 2×10^{-3} kg is attached to the end of the spring and the spring is pulled by 4 cm along a horizontal frictionless table and then released. Find the force constant, period, potential energy and kinetic energy when the displacement is 2 cm.

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12. A body weighing 0.02 kg has a velocity of $0.06ms^{-1}$ after one second of start from the mean position. If the time period is 6 s find the K.E., P.E. and the total energy.

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13. In Fig. AB is a horizontal plank of length 1 and mass m. It is pivoted at one end and the other end is attached to a spring of force constant k. The moment of inertia of the plank about the pivot is $\frac{1}{3}ml^2$ ml. If the plank is

displaced by a small angle θ from the horizontal and released show that its motion is shm. What is the period of oscillation ?

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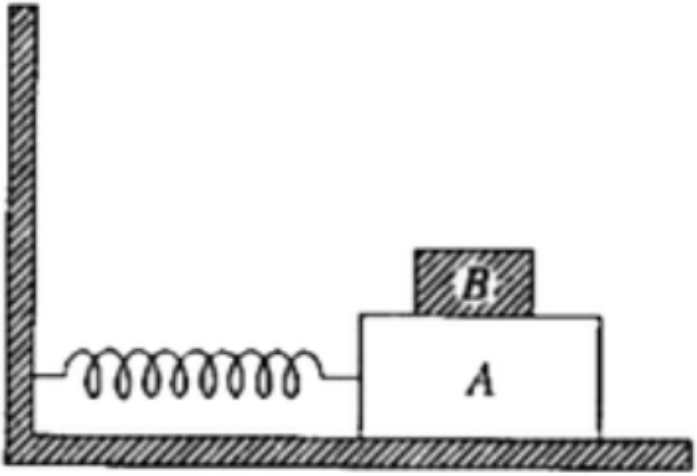
14. In Fig. A is a large block which executes shm by sliding across a frictionless surface with a frequency n. The block B is at rest on the surface of the block μ_s The coefficient of static friction between the two is H. Find the

maximum amplitude of oscillation of the system so that the block B does not slip.



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15. Two springs of force constants $7Nm^{-1}$ and $9Nm^{-1}$ are connected in

parallel and is fixed to body of mass 100 g. Find the period of oscillation.

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16. What is the period of a simple pendulum whose length is 50 cm?

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17. What is the length of a simple pendulum whose time period of oscillation is 2 second ?

If this pendulum is mounted in a lift which accelerates downwards at $4ms^{-2}$, by what factor docs its period of oscillations change from the original value?

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18. The period of a simple pendulum on the surface of the earth is 2s. Find its period on the surface of this moon, if the acceleration due to gravity on the moon is one-sixth that on the earth ?

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19. If the length of a seconds pendulum is decreased by 2% find the gain or loss per day.

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Selected Problems Period Of Oscillation Of I A Liquid In A U Tube Ii Test Tube Float Iii Iii A Piston In An Engine Etc

1. A U-tube contains a liquid to a height of 9.8 cm in one of the limbs. The tube is vertical. If the liquid on one side is depressed a little and released its motion in the tube is simple harmonic motion. Find its period.

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2. The radius of the earth is 6.37×10^6 m and its mean density is $5.5 \times 10^3 \mathrm{kg\,m^{-3}}$ and $G = 6.67 \times 10^{-11} \mathrm{N\text{-}m^2} kg^{-2}$ Find the

gravitational potential on the surface of the earth.

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3. The period of a piston in an engine, moving simple harmonically is 2 s. A body of mass 10 kg is placed on the piston. Calculate the maximum amplitude of the piston such that the mass is not thrown out from the platform.

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4. A cubical wood piece of mass 13.5 gm and volume $0.0027m^3$ float in water. It is depressed and released, then it executes simple harmonic motion. Calculate the period of oscillation ?

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5. A cylindrical piece of cork of height 4.9 cm floats in water with its axis vertical and is made to execute slın. Calculate its time period of oscillation if its density is 0.2 gm/cc ?

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6. A horizontal board is oscillating with an amplitude of 3 m. If the frequency of oscillation is 15 per minute, find the minimum value of coefficient of friction in order that a body placed on the board will A not slide when the board oscillates ?

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7. A small lead sphere is made to execute shm inside a concave dish of radius of curvature 1 m. What is its period ?

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8. A uniform circular disc of moment of inertia $7.35 \times 10^{-3} kgm^2$ is suspended by a wire of length 1 m and executes torsional oscillations. The couple per unit twist of the wire is

2×10^{-2} N/m. Calculate the period of oscillation ?

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9. A solid sphere is suspended from a wire and is made to execute torsional oscillations with a period of 2 second. The torque required to twist the wire through unit radian is 6×10^{-2} N/m. Calculate the moment of inertia of the sphere about the axis of rotation.

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Selected Problems Oscillation In A Tunnel Bored Through The Earth

1. If the earth was a homogeneous sphere and a straight hole was bored through its centre, show that a body dropped into this hole will execute shm. Calculate the time period if the radius of the earth is 6400 km and g = $9.8ms^{-2}$

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2. A particle is dropped down in a deep hole which extends to the centre of the earth. Calculate the velocity at a depth of one km from the surface of this carth ? Assume that $g = 10m/s^2$ and radius of the earth = 6400 km.

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