PHY2105 Spring 2025 Exercise Sheet

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Simple Harmonic Motion

This exercise is made by considering the best usage cases. Please consider the units.

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1 Mathematical Problems

1. A body of mass 12 kg is suspended by a coil spring of natural length 50 cm and force constant $2.0 \times 10^3 Nm^{-1}$. What is the stretched length of the spring? If the body is pulled down further by stretching the spring to a length of 59 cm and then released, what is the frequency of oscillation of the suspended mass

2. A body of mass 0.5 kg is suspended from a weightless spring. The length of the spring increases by 5.0 cm. When the body is slightly pulled down and let go, it oscillates in a simple harmonic way. Find the force constant and periodic time of oscillations.

3. A spring balance has a scale that reads from 0 is 50 kg. The length of the scale is 20 cm. A body suspended from this balance when displaced and released oscillates with period of 0.6 sec. What is the weight of the body?

4. A Spring is hung vertically loaded with a mass of 100 g and allowed to oscillate. Calculate the time period. When the spring is loaded with 200 grams it extends by 10 cm.

5. The period of oscillation of mass m suspended by an ideal spring is 2 sec. If an additional mass of 2 kg is suspended the time period is increased by 1 sec. Find the value of m

6. A body of mass 4.0 kg executes SHM of amplitude 0.5 m If the force constant is $100 Nm^{-1}$ calculate its kinetic energy, potential energy and total energy, when it is halfway between the equilibrium and extreme position.

7. A Particle is executing SHM, of amplitude 'a'. At what displacement from the mean position, is the energy half kinetic and half potential?

8. A 0.42 kg block is attached to the end of a horizontal ideal spring and rests on a frictionless surface. The block is pulled so that the spring stretches by 2.1cm relative to its unstrained length. When the block is released, it moves with an acceleration of 9.0 m/s^2. What is the spring constant of the spring?

9. For the simple harmonic oscillation where $k = 19.6$ N/m, $A = 0.1$ m,

$$x = -(0.1 \text{ m}) \cos(8.08t)$$

$$v = (0.808 \text{ m/s}) \sin(8.08t)$$

Determine:

(a) The total energy

(b) The kinetic and potential energy as a function of time

(c) The velocity when the mass is 0.05 m from equilibrium

(d) The kinetic and potential energies at half amplitude

10. A capacitor of capacitance $C = 10\mu F$ and an inductor of inductance $L = 5$ mH are connected to form an LC circuit. Determine the frequency of oscillations.

11. A particle executing simple harmonic motion follows the displacement equation

$$x = 0.1 \cos(10t + \phi)$$

At $t = 0$, the displacement is found to be 0.05 m. Find the initial phase ϕ.

12. A simple pendulum follows the equation of motion

$$\theta = 0.2 \sin(4t + \pi/3)$$

Find the angular displacement and velocity of the pendulum at $t = 2s$.

13. A 500g block on a spring is pulled a distance of 20 cm and released. The subsequent oscillations are measured to have a period of 0.80s. At what positions is the speed of the block 1.0 m/s?

14. A body executes SHM such that its velocity at mean position is 1m/s and acceleration at one extremity is 1.57m/s^2. Calculate time period of oscillation.

15. A block of mass $m = 680$ g is fastened to a spring of spring constant $k = 65$ N/m. The block is pulled maximum 11 cm and released from rest at $t = 0$. Find:

(a) Time period, angular frequency, and phase constant

(b) $V(4 \text{ sec})$, $V_{\max}$

(c) $a(4 \text{ sec})$, $a_{\max}$

(d) Displacement at $t = 0$ sec, $t = 7$ sec

(e) Velocity at displacements $x = 0.11$ m, $x = 0.04$ m

16. A body of mass 25g is attached to a spring of spring constant 400 dynes/cm. The body is displaced by 10 cm from its equilibrium position and released. Then the body executes simple harmonic motion. Calculate:

    (a) The time period

    (b) The frequency

    (c) The angular frequency

    (d) The maximum velocity

17. The diaphragm of a loudspeaker moves back and forth in simple harmonic motion to create sound. The frequency of the motion is $f = 1.0$ kHz and the amplitude is $A = 0.2$ mm.

    (a) What is the maximum speed of the diaphragm?

    (b) In the motion, where does this maximum speed occur?

18. What is the oscillation period of an FM radio station that broadcasts at 100 MHz?

19. A 2.00 kg block is attached to a spring as shown. The force constant of the spring is 196 N/m. The block is held a distance of 5.00 cm from equilibrium and released at $t = 0$.

    (a) Find the angular frequency

    (b) Linear frequency

    (c) Time period

    (d) Write the equation of motion for this system.

20. An oscillating block–spring system has a mechanical energy of 1.00 J, an amplitude of 10.0 cm, and a maximum speed of 1.20 m/s. Find:

    (a) The spring constant

    (b) The mass of the block

    (c) The frequency of oscillation

21. A mass oscillates with an amplitude of 4.00 m, a frequency of 0.5 Hz, and an initial phase angle of $\pi/4$.

    (a) What is the period T?

(b) Write an equation for the displacement of the particle.

(c) Calculate the velocity and acceleration of the object at time $t = 5$ s.

22. Draw the following displacement vs time graphs:

    (a) $y = A\sin(\omega t - \pi/3)$

    (b) $y = A\sin(\omega t + \pi/3)$

    (c) $y = A\sin(\omega t - \pi/2)$

    (d) $y = A\sin(\omega t + \pi)$

    (e) $y = A\sin(\omega t - 3\pi/4)$

23. Draw the phase difference diagram for the waves:

    (a) $y_1 = A\sin(\omega t - \pi/3)$, $y_2 = A\sin(\omega t)$

    (b) $y_1 = A\sin(\omega t + \pi/3)$, $y_2 = A\sin(\omega t)$

    (c) $y_1 = A\sin(\omega t + 2\pi/3)$, $y_2 = A\sin(\omega t - \pi/3)$

    (d) $y_1 = A\sin(\omega t - 3\pi/4)$, $y_2 = A\sin(\omega t + \pi/2)$

24. Determine the frequency angular frequency of a pendulum with a length of 2 m. Also determine its frequency on the moon

25. 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 sec?

26. Two pendulums begin to swing simultaneously. The first pendulum makes 9 oscillations when the other makes 7. Calculate the ratio of the length of the two pendulum

27. Simple pendulum oscillates with an amplitude of 50 mm and time period 2s. Calculate the maximum velocity of its bob.

28. A pendulum is taken in a carriage. Find the time period of oscillation if the carriage moves with an acceleration of $5ms^{-2}$ vertically upwards. Length of the pendulum is 1 m

29. A body of mass 4.0 kg executes SHM of amplitude 0.5 m If the force constant be $100Nm^{-1}$ calculate its kinetic energy, potential energy and total energy, when it is halfway between the equilibrium and extreme position.

30. A Particle is executing SHM, of amplitude 'a'. At what displacement from the mean position, is the energy half kinetic and half potential?

31. The displacement of a particle of mass 3g executing SHM is given by $y = 3sin(0.2\omega t)$. Calculate the K.E of the particle at a point which is at a distance equal to one-third of its amplitude from its mean position.

32. A spring is extended by 2 cm energy stored is 100 J. When extended by a further 2 cm calculate the energy increased, stored in spring.

2 Derivation

(a) Derive the Equation of motion of an oscillating mass by a spring or an oscillation by considering its energy.

(b) Deduce the solution of the differential equation.

(c) Derive the Equation of Motion for the following system along with its frequency

(a) Horizontal Spring

(b) Vertical Spring

(c) Pendulum

(d) LC Oscillation

(e) Compound Pendulum

Best of Luck!!!