AP Homework 9.1
Simple Harmonic Motion

(1) If an object on a horizontal, frictionless surface is attached to a spring, displaced, and then released, it will oscillate. If it is displaced 0.120 m from its equilibrium position and released with zero initial speed, then after 0.800 s its displacement is found to be 0.120 m on the opposite side, and it has passed the equilibrium position once. Find (a) the amplitude; (b) the period; (c) the frequency. (0.120 m, 1.60 s, 0.625 Hz)

(2) The tip of a tuning fork goes through 440 complete vibrations in 0.500 s. Find the angular frequency and the period of the motion. (5.53x10^3 rad/s, 1.14x10^-3 s)

(3) The displacement of an oscillating object as a function of time is shown. What are (a) the frequency; (b) the amplitude; (c) the period; (d) the angular frequency? (0.0625 Hz, 10.0 cm, 16 s, 0.393 rad/s)

(4) When a body of unknown mass is attached to an ideal spring with force constant 120 N/m, it is found to vibrate with a frequency of 6.00 Hz. Find (a) the period of the motion; (b) the angular frequency; (c) the mass of the body. (0.167 s, 37.7 rad/s, 8.44x10^-2 kg)
A 2.00-kg, frictionless block is attached to an ideal spring with force constant 300 N/m. At \( t = 0 \) the spring is neither stretched nor compressed and the block is moving in the negative direction at 12.0 m/s. Find (a) the amplitude and (b) the phase angle. (c) Write a position equation as a function of time. (0.98 m, \( \pi/2 \text{ rad} \))

The point of the needle of a sewing machine moves in SHM along the \( x \)-axis with a frequency of 2.5 Hz. At \( t = 0 \) its position and velocity components are +1.1 cm and -15 cm/s, respectively. (a) Find the acceleration component of the needle at \( t = 0 \). (b) Write equations giving the position, velocity, and acceleration components of the point as a function of time. (-2.71 m/s\(^2\))

This procedure has actually been used to “weigh” astronauts in space. A 42.5 kg chair is attached to a spring and allowed to oscillate. When it is empty, the chair takes 1.30 s to make one complete vibration. But with an astronaut sitting in it, with her feet off the floor, the chair takes 2.54 s for one cycle. What is the mass of the astronaut? (120 kg)

On a frictionless, horizontal air track, a glider oscillates at the end of an ideal spring of force constant 2.50 N/cm. The graph shows the acceleration of the glider as a function of time. Find (a) the mass of the glider; (b) the maximum displacement of the glider from the equilibrium point; (c) the maximum force the spring exerts on the glider.
(1) A small block is attached to an ideal spring and is moving in SHM on a horizontal, frictionless surface. The amplitude of the motion is 0.120 m. The maximum speed of the block is 3.90 m/s. What is the maximum magnitude of the acceleration of the block? \(127 \text{ m/s}^2\)

(2) A tuning fork labeled 392 Hz has the tip of each of its two prongs vibrating with an amplitude of 0.600 mm. (a) What is the maximum speed of the tip of a prong? (b) A housefly \((\text{Musca domestica})\) with mass 0.0270 grams is holding onto the tip of one of the prongs. As the prong vibrates, what is the fly’s maximum kinetic energy? Assume that the fly’s mass has a negligible effect on the oscillation. \(1.48 \text{ m/s}, 2.96 \times 10^{-5} \text{ J}\)

(3) A 0.500-kg glider, attached to the end of an ideal spring with force constant \(k = 450 \text{ N/m}\), undergoes SHM with an amplitude of 0.040 m. Compute (a) the maximum speed of the glider; (b) the speed of the glider when it is at \(x = -0.015 \text{ m}\); (c) the maximum acceleration of the glider; (d) the acceleration of the glider at \(x = -0.015 \text{ m}\); (e) the total mechanical energy at any point. \(1.20 \text{ m/s}, 1.11 \text{ m/s}, 36 \text{ m/s}^2, 13.5 \text{ m/s}^2, 0.36 \text{ J}\)

(4) Inside a NASA test vehicle, a 3.50 kg ball is pulled along by a horizontal ideal spring fixed to a friction-free table. The force constant of the spring is 225 N/m. The vehicle has a steady acceleration of \(5.00 \text{ m/s}^2\), and the ball is not oscillating. Suddenly, when the vehicle’s speed has reached 45.0 m/s, its engines turn off, thus eliminating its acceleration but not its velocity. Find (a) the amplitude and (b) the frequency of the resulting oscillations. (c) What will be the ball’s maximum speed relative to the vehicle? \(0.0778 \text{ m}, 1.28 \text{ Hz}, 0.624 \text{ m/s}\)
(5) A 175 gram glider on a horizontal, frictionless air track is attached to a fixed ideal spring with force constant 155 N/m. At the instant you make measurements on the glider, it is moving at 0.815 m/s and is 3.00 cm from its equilibrium point. Use energy conservation to find (a) the amplitude of the motion and (b) the maximum speed of the glider. (c) What is the angular frequency of oscillation? (4.06 cm, 1.21 m/s, 29.8 rad/s)

(6) A 1.50 kg ball and a 2.00 kg ball are glued together with the lighter one below the heavier one. The upper ball is attached to a vertical ideal spring of force constant 165 N/m, and the system is vibrating vertically with amplitude 15.0 cm. The glue connecting the balls is old and weak, and it suddenly comes loose when the balls are at the lowest position in their motion. (a) Why is the glue more likely to fail at the lowest point than at any other point in the motion? (b) Find the amplitude and frequency of the vibrations after the lower ball has come loose. (23.9 cm, 1.45 Hz)

(7) A certain alarm clock ticks four times each second, with each tick representing half a period. The balance wheel consists of a rim with radius 0.55 cm, connected to the balance staff by thin spokes of negligible mass. The total mass of the wheel is 0.90 grams. (a) What is the moment of inertia of the balance wheel about its shaft? (b) What is the torsion constant of the spring? (2.7x10⁻⁸ kg•m², 4.3x10⁻⁶ N•m/rad)

(8) You want to find the moment of inertia of a complicated machine part about an axis through its center of mass. You suspend it from a wire along this axis. The wire has a torsion constant of 0.450 N•m/rad. You twist the part a small amount about this axis and let it go, timing 125 oscillations in 265 s. What is the moment of inertia you want to find?
(1) A building in San Francisco has light fixtures consisting of small 2.35 kg bulbs with shades hanging from the ceiling at the end of light, thin cords 1.50 m long. If a minor earthquake occurs, how many swings per second will these fixtures make? \(0.407 \text{ swings/s}\)

(2) After landing on an unfamiliar planet, a space explorer constructs a simple pendulum of length 50.0 cm. She finds that the pendulum makes 100 complete swings in 136 s. What is the value of \(g\) on this planet? \(10.7 \text{ m/s}^2\)

(3) A simple pendulum 2.00 m long swings through an angle of 30.0° with the vertical. Calculate its period assuming a small amplitude. What would happen to the period if the amplitude were not small? \(2.84 \text{ s}\)
(4) You pull a simple pendulum 0.240 m long to the side through an angle of $3.50^\circ$ and release it. (a) How much time does it take the pendulum bob to reach its highest speed? (b) How much time does it take if the pendulum is released at an angle of $1.75^\circ$ instead of $3.50^\circ$? (0.25 s)

(5) A 1.80 kg connecting rod from a car engine is pivoted about a horizontal knife edge as shown. The center of gravity of the rod was located by balancing and is 0.200 m from the pivot. When the rod is set into small-amplitude oscillation, it makes 100 complete swings in 120 s. Calculate the moment of inertia of the rod about the rotation axis through the pivot. (0.129 kg \(m^2\))

(6) Show that the expression for the period of a physical pendulum reduces to that of a simple pendulum if the physical pendulum consists of a particle with mass $m$ on the end of a massless string of length $L$.

(7) A holiday ornament in the shape of a hollow sphere with mass $M = 0.015$ kg and radius $R = 0.050$ m is hung from a tree limb by a small loop of wire attached to the surface of the sphere. If the ornament is displaced a small distance and released, it swings back and forth as a physical pendulum with negligible friction. Calculate its period. (Hint: Use the parallel-axis theorem to find the moment of inertia of the sphere about the pivot at the tree limb.)
(1) A 2.20 kg mass oscillates on a spring of force constant 250.0 N/m with a period of 0.615 s. (a) Is the system damped or not? How do you know? If it is damped, find the damping constant. (b) If the system undamped, underdamped, critically damped, or overdamped? How do you know?

(2) An unhappy 0.300 kg rodent, moving on the end of a spring with force constant $k = 2.50 \text{ N/m}$, is acted on by a damping force $F_x = -bv$. (a) If the constant $b$ has the value 0.900 kg/s, what is the frequency of oscillation of the rodent? (b) For what value of the constant $b$ will the motion be critically damped? (0.393 Hz, 1.73 kg/s)

(3) A 2.50 kg rock is attached at the end of a thin, very light rope 1.45 m long. You start it swinging by releasing it when the rope makes an $11^\circ$ angle with the vertical. You record the observation that it rises only to an angle of $4.5^\circ$ with the vertical after $10^{\frac{1}{2}}$ swings. (a) How much energy has this system lost during that time? (b) What happened to the “lost” energy? Explain how it could have been “lost.”

(4) An experimental package and its support structure, which are to be placed on board the International Space Station, act as an underdamped spring-mass system with a force constant of $2.1\times10^6 \text{ N/m}$ and mass 108 kg. A NASA requirement is that resonance for forced oscillations not occur for any frequency below 35 Hz. Does this package meet the requirement?