Problem Set 13

- Leaking fishing boat

Your uncle is in the below-deck galley of his boat while you are spear fishing in the water nearby. An errant spear makes a small hole in the boat's hull, and water starts to leak into the galley.

a) If the hole is 0.900 m below the water surface and has area 1.20 cm^2, how long does it take 10.0 L of water to leak into the boat?

b) Do you need to take into consideration the fact that the boat sinks lower into the water as water leaks in?

- Artery Blockage.

A medical technician is trying to determine what percentage of a patient's artery is blocked by plaque. To do this, she measures the blood pressure just before the region of blockage and finds that it is 1.20×10^4 Pa, while in the region of blockage it is 1.15×10^4 Pa. Furthermore, she knows that blood flowing through the normal artery just before the point of blockage is traveling at 30.0 cm/s, and the specific gravity of this patient's blood is 1.06. What percentage of the cross-sectional area of the patient's artery is blocked by the plaque?

- Simple Harmonic Motion

1. 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. This procedure has 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?
3. A 175-g 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 the oscillations?

- Pendulum

1. Two pendulums have the same dimensions (length L) and total mass (m). Pendulum A is a very small ball swinging at the end of a uniform massless bar. In pendulum B, half the mass is in the ball and half is in the uniform bar. Find the period of each pendulum for small oscillations. Which one takes longer for a swing?
2. We want to hang a thin hoop on a horizontal nail and have the hoop make one complete small-angle oscillation each 2.0 s. What must the hoop's radius be?
3. A vertical, 1.20-m length of 18-gauge (diameter of 1.024 mm) copper wire has a 100.0-N ball hanging from it.
   a) What is the wavelength of the third harmonic for this wire?

b) A 500.0-N ball now replaces the original ball. What is the change in the wavelength of the third harmonic caused by replacing the light ball with the heavy one?

4. An apple weighs 1.00 N. When you hang it from the end of a long spring of force constant 1.50 N/m and negligible mass, it bounces up and down in SHM. If you stop the bouncing and let the apple swing from side to side through a small angle, the frequency of this simple pendulum is half the bounce frequency. (Because the angle is small, the back-and-forth swings do not cause any appreciable change in the length of the spring.) What is the unstretched length of the spring (with the apple removed)?

- Ultrasound Imaging

Sound having frequencies above the range of human hearing (about 20,000 Hz) is called ultrasound. Waves above this frequency can be used to penetrate the body and to produce images by reflecting from surfaces. In a typical ultrasound scan, the waves travel through body tissue with a speed of 1500 m/s. For a good, detailed image, the wavelength should be no more than 1.0 mm. What frequency sound is required for a good scan?

- Piano

1. A piano wire with mass 3.00 g and length 80.0 cm is stretched with a tension of 25.0 N. A wave with frequency 120.0 Hz and amplitude 1.6 mm travels along the wire.
    a) Calculate the average power carried by the wave.
    b) What happens to the average power if the wave amplitude is halved?
2. A piano tuner stretches a steel piano wire with a tension of 800 N. Assume the steel wire is 0.400 m long and has a mass of 3.00 g.
    a) What is the frequency of its fundamental mode of vibration?
    b) What is the number of the highest harmonic that could be heard by a person who is capable of hearing frequencies up to 10,000 Hz?

- Damped Oscillations

An unhappy 0.315-kg rodent, moving on the end of a spring with force constant k = 2.50 N/m, is acted on by a damping force $F_x = -bv_x$.

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?

- Duet

A soprano and a bass are singing a duet. While the soprano sings an A-sharp at 932 Hz, the bass sings an A-sharp but three octaves lower. In this concert hall, the density of air is 1.20 kg/m^3 and its bulk modulus is 1.42×10^5 Pa. In order for their notes to have the same sound intensity level, what must be

a) the ratio of the pressure amplitude of the bass to that of the soprano and
b) the ratio of the displacement amplitude of the bass to that of the soprano?
c) What displacement amplitude (in m and in nm) does the soprano produce to sing her A-sharp at 72.0 dB?