Chapter 8
Simple Harmonic Motion and Waves
8.1 Simple Harmonic Motion-Elastic Oscillators Homework # 62

I

01. If an object is vibrating in SHM with an amplitude of 7.00 cm, what is the total distance traveled in one cycle?

02. A rubber band is 12.5 cm long when a 50.0-g mass is hanging from one end. This same rubber band is 16.3 cm when an 80.0-g mass is **ADDED** to the original mass. What is the effective "spring" constant of the rubber band?

03. The springs in a 1350-kg car compress 1.85 cm when a 92.5-kg person gets in the car.
    a.) What is the spring constant of the spring system?
    b.) What is the frequency of vibration when the car hits a bump in the road?

04. A fly with a mass of 0.650 g is caught in a spider's web that vibrates at 12.5 Hz.
    a.) What is the effective "spring" constant for the web?
    b.) What would be the frequency of the web if a 1.15-g insect (not the fly) were trapped and struggling to escape?

II

05. A fisherman's scale stretches 4.25 cm when a 3.85-kg fish is hung from it. If the fish is pulled down an additional distance and released, with what frequency will the fish vibrate?

06. A 400-g mass at the end of a spring vibrates 3.00 times per second with an amplitude of 14.00 cm.
    a.) What is velocity when it passes the equilibrium point?
    b.) What is its maximum velocity during a cycle?
    c.) What is its velocity when it is 9.00 cm from the equilibrium position?
    d.) Write an equation that describes the position of this vibrating system as a function of time assuming the displacement is a maximum when the vibration begins.

07. The position as a function of time of a 1.25-kg mass vibrating on a spring can be described as x = 0.56 cos (2.80t).
    a.) What is the amplitude of the vibration? b.) What is the frequency of the vibration?
    c.) What is the total energy of the system?

08. A 75.0-N force is required to compress the spring of a dartgun 18.0 cm to load a 125-g dart. With what speed will the dart leave the gun?

09. A 1500-g mass is hung from a vertical spring causing it to stretch 14.0 cm. The mass is struck with a hammer vertically upward giving it an initial speed of 2.25 m/s.
    a.) What is the spring constant? b.) What is the frequency of the vibration?
    c.) What is the period of the vibration? d.) What is the amplitude of the vibration?
    e.) What is the total energy of the system? f.) What equation describes the position as a function of time?

III

10. A 15.0-g bullet is fired and becomes embedded in a 0.525-kg block sitting on a surface and attached to a horizontal spring with the other end of the spring attached firmly to the wall. The spring has a spring constant of 7200 N/m. The impact of the bullet sets the system into vibration with an amplitude of 14.5 cm. What was the muzzle speed of the bullet? See Diagram on the bottom of the next page (Homework #63).

ANSWERS: **01.** 28.0 cm **02.** 20.6 N/m **03.** a.) 49,000 N/m b.) 0.928 Hz **04.** a.) 4.01 N/m b.) 9.39 Hz
05. 2.42 Hz **06.** a.) 2.64 m/s b.) 2.64 m/s c.) 2.02 m/s d.) $x = 0.14\cos(18.85t)$
07. a.) 0.56 m b.) 0.446 Hz c.) 1.54 J **08.** 10.4 m/s **09.** a.) 105 N/m b.) 1.33 Hz c.) 0.751 s
09. d.) 26.9 cm e.) 3.80 J f.) $x = 0.269\cos\left(8.37t - \frac{\pi}{2}\right)$ or $x = 0.269\sin(8.37t)$ **10.** 603 m/s

Chapter 8
Simple Harmonic Motion and Waves
8.2 Simple Harmonic Motion-Pendulums Homework # 63

I

01. A pendulum makes 20.0 vibrations in 34.6 s.
    a.) What is the frequency of the pendulum? b.) What is the period of the pendulum?

02. What is the length of a pendulum that completes exactly one cycle per second?

II

03. What is the period of a pendulum 1.45 m long _____?
    a.) on earth b.) on an elevator in freefall

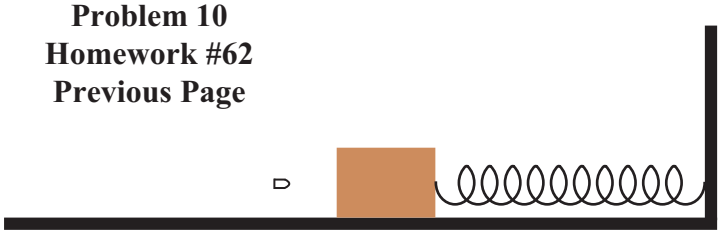
04. A pendulum is pulled back 1.45 m and released as a stopwatch is started. The pendulum oscillates with a frequency of 1.25 Hz. Ignoring any losses of energy, what will be the position of the bob at t = _____?
    a.) 0.200 s b.) 0.400 s c.) 11.7 s d.) 400 s

05. A pendulum has a bob with a mass of 2.50 kg and is 1.85 m long. The bob is pulled back 1.10 m and released.
    a.) What is the frequency of the pendulum?
    b.) What is the bob's speed as it passes through the lowest point of the swing?
    c.) What is the bob's speed when it is 35.0 cm from the lowest point of its path?
    d.) Write an equation that describes the position of this bob as a function of time.
    e.) Where is the bob after 14.0 s?
    f.) Write an equation that describes the velocity of this bob as a function of time.
    g.) What is the velocity of the bob after 14.0 s?
    h.) Write an equation that describes the acceleration of this bob as a function of time.
    i.) What is the acceleration of the bob after 14.0 s?

06. What is the effective value of the acceleration due to gravity at a location on the earth where a pendulum that is 2.50 m long has a frequency of 0.316 Hz?

07. A pendulum has a length of 0.750 m and is pulled back 0.150 m and released. By what factor will the period change if the following alterations to the pendulum are made?
    a.) Quadrupling the amplitude.
    b.) Quadrupling the mass.
    c.) Quadrupling the length.

Problem 10
Homework #62
Previous Page



ANSWERS: **01.** a.) 0.578 Hz b.) 1.73 s **02.** 0.248 m **03.** a.) 2.42 s b.) ∞
04. a.) 0 m b.) -1.45 m c.) -1.03 m d.) 1.45 m **05.** a.) 0.366 Hz b.) 2.53 m/s c.) 2.40 m/s
05. d.) $x = 1.10\cos(2.30t)$ e.) 0.761 m f.) $v = -2.53\sin(2.30t)$ g.) -1.83 m/s h.) $a = -5.83\cos(2.30t)$
05. i.) -4.03 m/s^2 **06.** 9.85 m/s^2 **07.** a.) no effect b.) no effect c.) 2 x greater

Chapter 8
Simple Harmonic Motion and Waves
Simple Harmonic Motion-Review Homework # 64

II

01. A vertical spring with a spring constant of 58.7 N/m has a 320.0-g mass hanging from it and is vibrating with an amplitude of 26.3 cm. Assume a stopwatch begins timing when the mass is at the amplitude.
    a.) Write an equation describing the position of this mass as a function of time.
    b.) At what times will the mass be at a maximum displacement?
    c.) At what times will the mass be at minimum displacement?
    d.) At which time after the start of the clock will the mass be 17.5 cm from the equilibrium point?

02. Two springs are vibrating. The two springs have identical frequencies and masses. Spring 1 has exactly 16 times the energy of Spring 2. How do the amplitudes of these two springs compare?

03. A 750-g mass is hung from a vertical spring causing it to stretch 26.25 cm. The mass is then stretched an additional 12.00 cm and released just as a stopwatch is started.
    a.) What is the spring constant?
    b.) What is the frequency of the vibration?
    c.) What is the maximum velocity of the mass?
    d.) What is the **TOTAL** energy of this system?
    e.) What is the velocity of the mass when it is 7.00 cm from the equilibrium point?
    f.) What are the elastic **AND** kinetic energies when the mass is 7.00 cm from the equilibrium point?
    g.) Write an equation that describes the position of **THIS** mass as a function of time.
    h.) What is the position of this mass after 12.0 s?
    i.) Write an equation that describes the velocity of **THIS** mass as a function of time.
    j.) What is the velocity of this mass after 12.0 s?
    k.) Write an equation that describes the acceleration of **THIS** mass as a function of time.
    l.) What is the acceleration of this mass after 12.0 s?

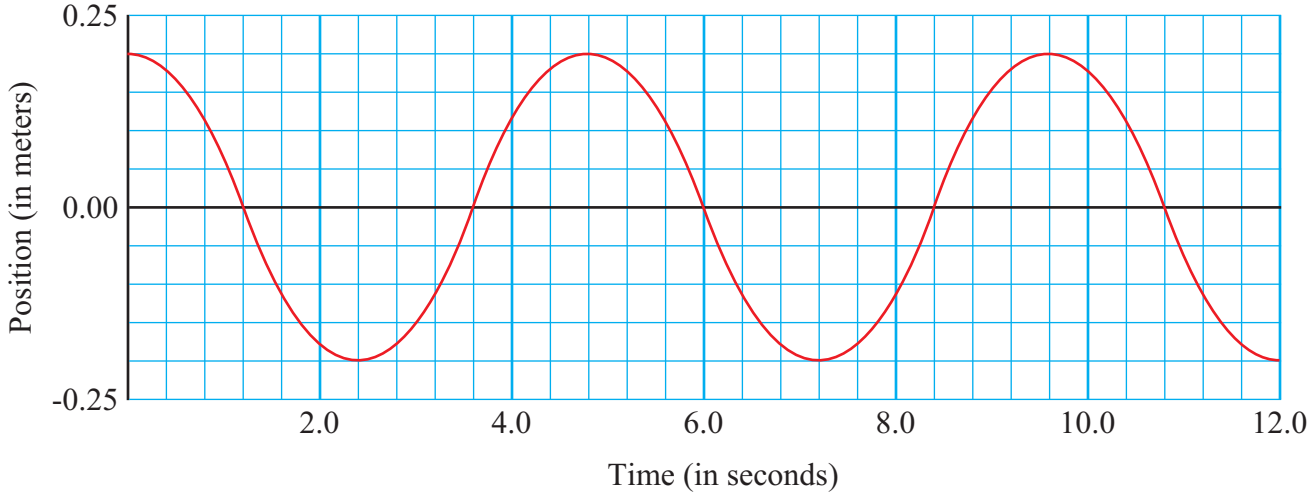
04. The displacement of a 1.65-kg mass on the end of a vibrating spring can be described by $x = 0.485\cos\left(3.92t + \frac{\pi}{2}\right)$ [which can also be written as $x = 0.485\sin(3.92t)$].
    a.) What is the amplitude of this vibration?
    b.) What is the frequency of this vibration?
    c.) What is the maximum velocity of this vibrating mass?
    d.) What is the spring constant?
    e.) What is the **TOTAL** energy of this system?

05. A 1.75-meter long pendulum whose bob has a mass of 2.30 kg is pulled back 0.450 meters and released.
    a.) Determine the period of the pendulum.
    b.) By what factor would the period of the pendulum change if the mass were quadrupled?
    c.) By what factor would the period of the pendulum change if the length were increased by a factor of 16?
    d.) By what factor would the period of the pendulum change if the amplitude were quintupled?

ANSWERS: **01.** a.) $x = 0.263\cos(13.5t)$ b.) 0.232 s, 0.464 s, 0.696 s, etc. c.) 0.116 s, 0.348 s, 0.580 s, etc. d.) 0.0624 s **02.** $A_1 = 4A_2$ **03.** a.) 28.0 N/m b.) 0.972 Hz c.) 0.733 m/s d.) 0.202 J e.) 0.596 m/s **03.** f.) $EPE = 0.0686$ J, $KE = 0.133$ J g.) $x = 0.120\cos(6.11t)$ h.) -5.82 cm i.) $v = -0.733\sin(6.11t)$ **03.** j.) 0.641 m/s k.) $a = -4.48\cos(6.11t)$ l.) 2.17 m/s^2 **04.** a.) 0.485 m b.) 0.624 Hz c.) 1.90 m/s **04.** d.) 25.4 N/m e.) 2.98 J **05.** a.) 2.66 s b.) no effect c.) 4 x d.) no effect

Chapter 8
Simple Harmonic Motion and Waves
8.3 Simple Harmonic Motion-Graphical Analysis A Homework # 65

Position of an Oscillating Mass as a Function of Time



I

Use the graph above to answer each of the following questions.

01. What is the amplitude of this vibration?

02. What is the period of this vibration?

03. What is the frequency of this vibration?

04. What is the maximum velocity of this mass?

05. What is the velocity of this mass when it is 0.13 m from the equilibrium point?

06. Write an equation that describes the position of this vibrating mass as a function of time.

07. What will be the position of the mass at t = 18.6 s?

08. Write an equation that describes the velocity of this vibrating mass as a function of time.

09. What will be the velocity of the mass at t = 18.6 s?

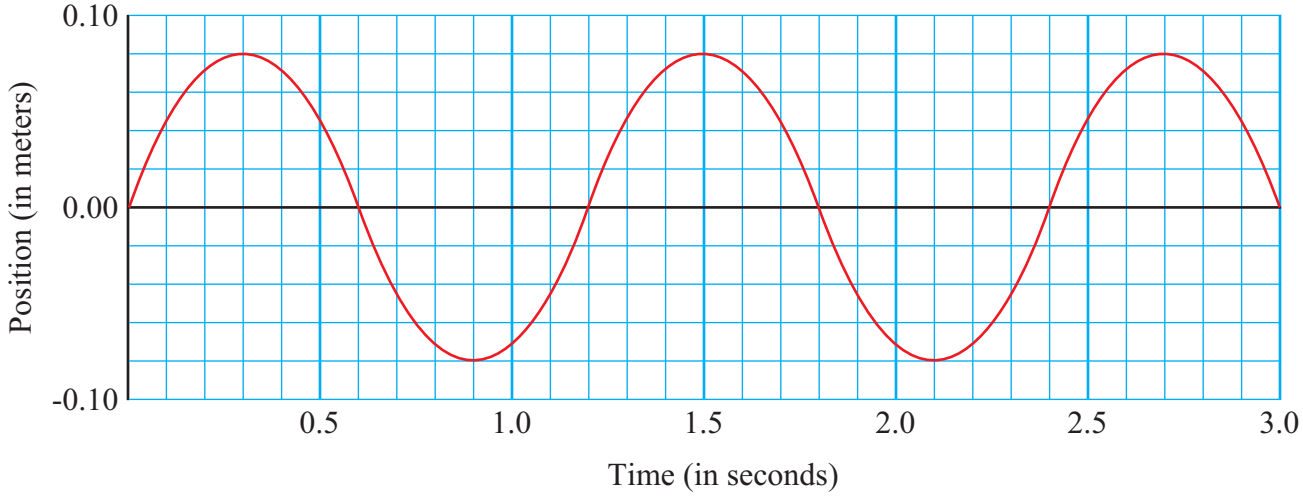
10. Write an equation that describes the acceleration of this vibrating mass as a function of time.

11. What will be the acceleration of the mass at t = 18.6 s?

ANSWERS: **01.** 0.200 m **02.** 4.80 s **03.** 0.208 Hz **04.** 0.262 m/s **05.** 0.199 m/s
06. $x = 0.200\cos(1.31t)$ **07.** 0.141 m **08.** $v = -0.262\sin(1.31t)$ **09.** 0.185 m/s
10. $a = -0.343\cos(1.31t)$ **11.** -0.242 m/s^2

Chapter 8
Simple Harmonic Motion and Waves
8.3 Simple Harmonic Motion-Graphical Analysis B Homework # 66

Position of an Oscillating Mass as a Function of Time



I

Use the graph above to answer each of the following questions.

01. What is the amplitude of this vibration?

02. What is the period of this vibration?

03. What is the frequency of this vibration?

04. What is the maximum velocity of this mass?

05. What is the velocity of this mass when it is 0.065 m from the equilibrium point?

06. Write an equation that describes the position of this vibrating mass as a function of time.

07. What will be the position of the mass at t = 18.6 s?

08. Write an equation that describes the velocity of this vibrating mass as a function of time.

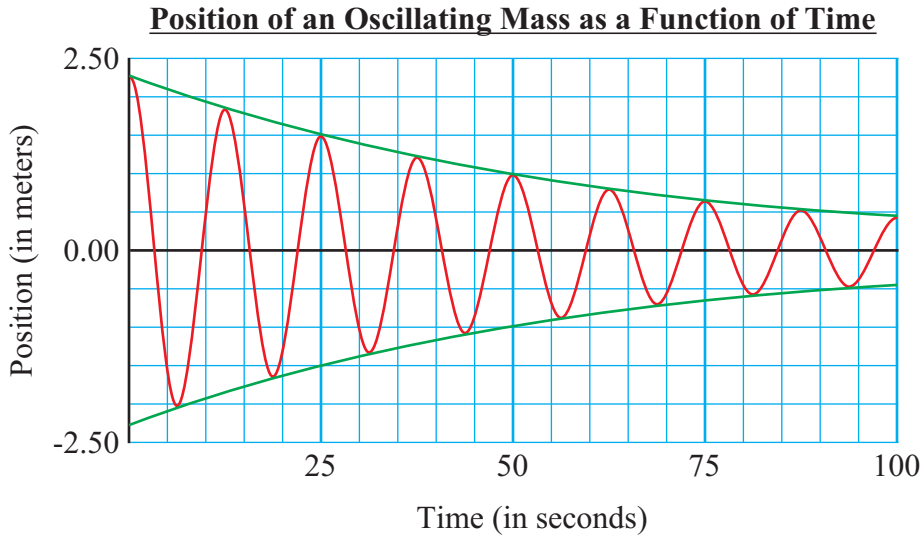
09. What will be the velocity of the mass at t = 18.6 s?

10. Write an equation that describes the acceleration of this vibrating mass as a function of time.

11. What will be the acceleration of the mass at t = 18.6 s?

ANSWERS: **01.** 0.080 m **02.** 1.20 s **03.** 0.833 Hz **04.** 0.419 m/s **05.** 0.244 m/s
06. $x = 0.080\sin(5.24t)$ or $x = 0.080\cos\left(5.24t - \frac{\pi}{2}\right)$ **07.** 0 m **08.** $v = 0.419\cos(5.24t)$ or $v = -0.419\sin\left(5.24t - \frac{\pi}{2}\right)$
09. -0.419 m/s **10.** $a = -2.19\sin(5.24t)$ or $a = -2.19\cos\left(5.24t - \frac{\pi}{2}\right)$ **11.** 0 m/s^2

Chapter 8
Simple Harmonic Motion and Waves
8.4 Damped Harmonic Motion — Homework # 67



II

01. A 4545-kg (10,000-lb) wrecking ball on the end of a long cable attached to a crane is swinging back and forth. The graph above shows the position (from the natural rest position) of this swinging wrecking ball as a function of time (red line) and its amplitude as a function of time (green line).
    a.) What is the period of the wrecking ball's vibration?
    b.) What is the length of the cable?
    c.) What is the initial amplitude of the wrecking ball's vibration?
    d.) Estimate the time constant.
    e.) Write an equation that will predict the amplitude of the wrecking ball as a function of time.
    f.) What will be the amplitude of the wrecking ball after 120 s?
    g.) How long will take the amplitude of the wrecking ball to be reduced to 1.00 cm?
    h.) How long will take the amplitude of the wrecking ball to be reduced to 1.00% of its initial value?
    i.) What is the frequency of the wrecking ball's vibration?
    j.) What is the wrecking ball's approximate maximum velocity during its first vibration?
    k.) What is the approximate energy of the wrecking ball during its first vibration?
    l.) Write an equation that will predict the energy of **THIS** vibrating system as a function of time.
    m.) What is the energy of the system after 50.0 s?
    n.) When will the energy be 1.00% of its initial value?

02. A damped harmonic system has an initial amplitude of 50.0 cm and a time constant of 10.00 s.
    a.) What will be its amplitude after 35.00 s?
    b.) How long will take the amplitude to drop to 0.100% of its original value?
    c.) How long will it take the energy of the system to be 0.100% of its original value?

ANSWERS: **01.** a.) 12.5 s b.) 38.787 m c.) 2.25 m d.) 30.0 s e.) $A = (2.25\text{ m})e^{-(t/60.0\text{ s})}$ f.) 30.5 cm
01. g.) 325 s h.) 276 s i.) 0.0800 Hz j.) 1.13 m/s k.) 2907 J l.) $E = (2907\text{ J})e^{-(t/30.0\text{ s})}$ m.) 549 J
01. n.) 138 s **02.** a.) 8.68 cm b.) 138.2 s c.) 69.1 s

Chapter 8
Simple Harmonic Motion and Waves
8.5 Wave Motion and Types of Waves — Homework # 68

Selected Physical Properties of Various Materials

Material	Elastic Modulus E (N/m^2)	Bulk Modulus B (N/m^2)	Density ρ (kg/m^3)
Aluminum	70×10^9	70×10^9	2700
Brass	100×10^9	80×10^9	8560
Iron	100×10^9	40×10^9	7800
Steel	200×10^9	80×10^9	7800
Water		2.0×10^9	1000
Helium		1.01×10^5	0.179

I

01. A curious sailor with a stopwatch and a meter stick is looking at waves from the side of his anchored ship. He notices that the waves pass the bow every 4.35 s and the distance between the crests is 14.5 m. How fast are the waves moving?

02. Sound waves travel in air at 343 m/s on a particular day. How far apart are the compressions for a 383 Hz sound?

03. Electromagnetic waves (light) travel at 3.00×10^8 m/s. An AM radio station is granted a license to produce a carrier wave with an assigned frequency. These assigned frequencies range from 550 kHz to 1600 kHz. The FM frequencies range from 88 MHz to 108 MHz. [1 Megahertz (MHz) = 1×10^6 Hz = 1,000,000 Hz)]
    a.) What is the wavelength of the AM radio carrier wave with the lowest frequency?
    b.) What is the wavelength of the AM radio carrier wave with the highest frequency?
    c.) What is the wavelength of the FM radio carrier wave with the lowest frequency?
    d.) What is the wavelength of the FM radio carrier wave with the highest frequency?

04. What is the speed of a longitudinal wave in _____?
    a.) water b.) aluminum

II

05. A rope with a mass of 675 g is stretched and tied tautly between two rigid poles that are 37.5 m apart. If the tension in the rope is 225 N, how long will it take a wave to travel from one end of the rope to the other?

06. What is the wavelength of a 12,000 Hz sound traveling along steel rod?

07. A deep-sea fisherman is pulling up his anchor (using a winch) out of the water. At the top, the anchor bangs against the side of the ship. Part of the sound wave produced travels to the ocean floor below and reflects (echos) back up to the ship 2.75 s later. How deep is the ocean at this location?

ANSWERS: **01.** 3.33 m/s **02.** 0.896 m **03.** a.) 545 m b.) 187.5 m c.) 3.41 m d.) 2.78 m
04. a.) 1414 m/s b.) 5092 m/s **05.** 0.335 s **06.** 0.422 m **07.** 1945 m

Chapter 8
Simple Harmonic Motion and Waves
8.6 Energy of Waves and Refraction — Homework # 69

I

01. Wave 1 on the ocean surface has twice the energy of Wave 2. What is the ratio of their amplitudes?

02. An earthquake wave traveling 8.25 km/s strikes a boundary where the earth changes to a different material. The direction of the wave in the first material makes a 26.0° angle with the boundary. If the direction of the wave in the second material changes to 36.5° with the boundary, what is the speed of the wave in the second medium?

03. The Atlantic Ocean's floor drops dramatically as you go from the coast of the Eastern United States eastward. This is known as the Continental Shelf. If water waves coming from the east toward the coastline approaches the shelf at 40.0° angle and is traveling at 2.80 m/s, what will be the angle of refraction if the wave travels 2.15 m/s in the shallow water?

II

04. Leaves on the surface of a pond move a total vertical distance of 24.00 cm between lowest and highest points as a wave passes through the pond.
    a.) What is the amplitude of the wave?
    b.) By what factor would the energy of the wave change if the amplitude were reduced to 9.00 cm?

05. An earthquake passes through two towns. Town X is 20.0 km from the epicenter while town *Y* is 100.0 km from the epicenter.
    a.) Compare the intensities, I_X to I_Y, as the earthquake passes through the respective towns.
    b.) If the intensity of the wave at town X was 2.5 x 10^7 W/m^2, at what rate does energy pass through a person's property with an area of 1200.0 m^2 in town Y.
    c.) Compare the amplitudes, A_X to A_Y, as the earthquake passes through the respective towns.

06. Waves on the surface of water controlled by a dam have swells that are 0.640 m high and have an intensity of 64.5 W/m^2. If the dam is 400 m wide, how much energy does it absorb each hour from the waves battering its face? Note: The height of a swell is the distance between the lowest and highest points of the wave (from trough to crest).

07. A longitudinal earthquake wave strikes a boundary between two types of rock at 38.5° angle. As it crosses the interface, the density of the rock changes from 3800 kg/m^3 to 2700 kg/m^3, while the elastic modulus of the two rocks are similar. Calculate the angle of refraction.

ANSWERS: **01.** $A_1 = \sqrt{2}A_2$ **02.** 7.38 km/s **03.** 54.0° with the shelf edge (36.0° with normal to shelf edge)
04. a.) 12.0 cm b.) $E_2 = 0.563E_1$ **05.** a.) $I_x = 25I_y$ b.) 1.2 x 10^9 W c.) $A_x = 5A_y$ **06.** 5.94 x 10^7 J
07. 21.8° with the interface (68.2° with the normal to the interface)

Chapter 8
Simple Harmonic Motion and Waves
8.7 Standing Waves and Two Point Sources of Waves Homework # 70

I

01. If a violin string has a fundamental frequency of 294 Hz, what are its first four harmonics?

02. A violin string vibrates at 440 Hz when unfingered. At what frequency will it vibrate when fingered one-fourth of the way down the neck?

03. A standing wave is produced on a string tied between two supports with four loops by vibrating at 180 Hz. List the fundamental frequency and the next four harmonics.

II

04. A standing wave on a string tied between two supports is created by vibrating the string at 380 Hz. If the speed of the waves is 240 m/s, how far apart are the _____? a.) nodes b.) antinodes

05. If two successive overtones of a vibrating string are 660 Hz and 715 Hz, what is the frequency of the fundamental?

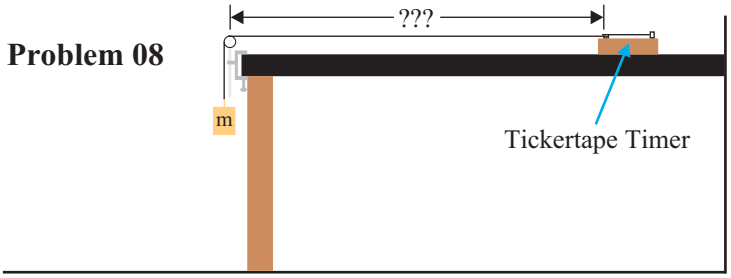
06. A guitar string is 90.0 cm long and has a mass of 3.60 g. The string is "strung" on a guitar with a distance from the bridge to the support post of 60.0 cm. If the tension in the string is 520 N, what are the frequencies of the fundamental and first two overtones?

07. A particular violin string vibrates at 440 Hz. If the tension in the string is increased by 12.5%, at what frequency will it now resonate?

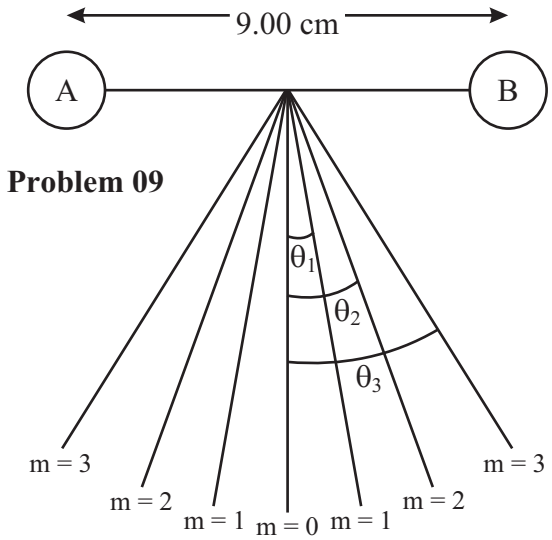
08. The electric company produces AC electricity with a frequency of 60.0 Hz which causes a tickertape timer plugged into an outlet to vibrate at this frequency. A 2.00-m long string with a mass of 3.15 g has one end attached to the vibrating mechanism of the timer with the rest of the string draped across a lab table, over a pulley on the far edge of the table and supporting a mass of m = 200 g. The position of the timer can be adjusted. How far from the pulley must the timer be located to produce three antinodes on the string? See diagram below and to the left.

09. Two point sources are generating waves simultaneously as shown in the diagram (not drawn to scale) to the right. The wavelength of the waves produced is 1.60 cm and the distance between the two sources is 9.00 cm as shown.
a.) At what angle will the third order antinode appear?
b.) What will be the maximum order of the antinodes that these two sources can generate?

Problem 08



Problem 09



ANSWERS: **01.** f_1 = 294 Hz, f_2 = 588 Hz, f_3 = 882 Hz, f_4 = 1176 Hz **02.** 587 Hz
03. f_1 = 45.0 Hz, f_2 = 90.0 Hz, f_3 = 135 Hz, f_4 = 180 Hz **04.** a.) 0.316 m b.) 0.316 m
05. 55.0 Hz **06.** f_1 = 300 Hz, f_2 = 600 Hz, f_3 = 900 Hz **07.** 467 Hz **08.** 0.882 m **09.** a.) 32.2° b.) 5