Physics 9, Fall 2018, Homework #2.

Due at start of class on Friday, September 21, 2018

Problems marked with (*) must include your own drawing or graph representing the problem and at least one complete sentence describing your reasoning.

Problems for Giancoli 11 (Vibrations and waves) / Mazur 16

(A note about waves and oscillations: don't be confused by the fact that the same symbol k is used for the spring constant (k in newtons per meter: $F = -kx$) for an oscillator and for the wave number (k in radians per meter: $k = 2\pi/\lambda$) in the wave equation. When writing a wave function $D(x,t)$, it is often convenient (less cluttered) to use wave number $k = 2\pi/\lambda$ and angular frequency $\omega = 2\pi f$, but you can feel free to use λ and f if you find them more familiar.)

1. The position of a particle undergoing simple harmonic motion is given by $x(t) = 4.00\cos(9.0\pi t)$, where x is in meters and t is in seconds. For this motion, what are the (a) amplitude, (b) frequency f, and (c) period T? (d) What are the first three instants at which the particle is at $x = 0$ m? (e) Find the position, velocity, and acceleration of the particle at $t = 1.00$ s.

2. A 4.00 kg pumpkin oscillates from a vertically hanging light spring once every 1.00 s. (a) Write down the equation giving the pumpkin's position y (where $+y$ points upward) as a function of time t, assuming that the spring started by being compressed 0.200 m from the equilibrium position (where $y = 0$), and released. (b) How long will it take to get to the equilibrium position for the first time? (This will be some fraction of a period: you have to think about what fraction.) (c) What will be the pumpkin's maximum speed? (d) What will be the pumpkin's maximum acceleration? (e) When and where will the pumpkin's maximum acceleration first be attained?

3. A "human wave" is created by a crowd of people in a stadium when each person stands up just as her neighbor sits down and then sits down just as her neighbor stands. So that we all get the same answer, assume that a person (person n) just begins to stand up at exactly the instant when the person four seats to her left (person $n-4$) just begins to sit back down, etc., that seats are spaced 1.0 m apart (center-to-center), that a person's body is 1.0 m higher when standing than when sitting, and that a person can go from seated to standing and back to seated (round-trip) every 1.0 s. (a) Estimate values for the frequency f, wavelength λ, wave number $k = 2\pi/\lambda$, wave speed v, and amplitude A of such a wave. (b) Use

these values to construct a wave function $D(x,t)$ describing the wave. (c) What is the maximum speed of each person in the wave as she stands up and then sits down? (d) If you look at a video of a real "human wave" at a soccer game, do your numbers seem realistic? (e) Is this a transverse or a longitudinal wave?

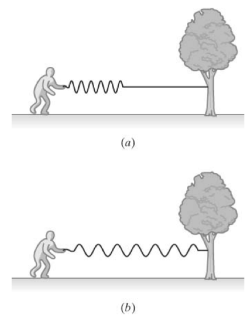
4*. A 100 m steel cable that helps support the Golden Gate Bridge is 72 mm (that's 0.072 m) in diameter and composed of 100 steel wires bound together and then twisted. Approximate this as a single uniform steel cable that has a mass density of 7.86×10^3 kg/m^3. (You can multiply this density by the cross-section to get the mass per unit length.) The wind generates in the cable a vibration that creates a wave that travels down the cable at 380 m/s. What is the tension in the cable?

5. Suppose that doubling the tension in a rubber band doubles its length. (This is much more extreme than what would happen to a steel wire under normal circumstances, but it might also happen to a slinky coil.) When the tension is doubled, by what factor does the speed of a wave traveling in the rubber band increase? (Consider how the mass per unit length changes when the length doubles.)

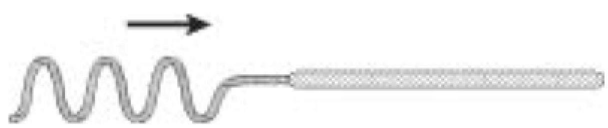
6*. A guitar string has a length of 0.650 m and a mass of 4.00×10^{-3} kg. (a) If it is kept under a tension of 126 N, what is the fundamental (smallest harmonic) frequency at which it vibrates? (b) At what other frequencies (higher harmonics) could the string vibrate at this fixed length? (c) Draw a sketch depicting the motion of the string for the lowest harmonic and the first two higher harmonics.

7*. Suppose that a guitar string has a length $L = 0.650$ m, a mass $m = 4.00 \times 10^{-3}$ kg, and a tension $T = 126$ N. (a) What is the fundamental (lowest) frequency f at which it vibrates? (You already answered this in the previous problem.) (b) Write the wave function $D(x,t)$ for this guitar string vibrating at its fundamental frequency. The string is immobile at $x = 0$ and at $x = L$. Let the amplitude in the center of the string be $A = 5.0$ mm. (c) What is the wavelength λ (on the string) for the vibration of the string at the fundamental frequency?

8*. Identical ropes (same mass, same length, but one person may be holding her rope more tightly than the other person) are tied to two trees, and two people started shaking the free ends of the ropes at the same instant a short time ago. The resulting waves are shown in the figure. Which rope has the higher tension? (Clearly explain why, using both an equation from the chapter and a short sentence of reasoning.) Which person is shaking with the higher frequency? (Again, clearly explain why, using both a sentence and an equation. You may find that the two frequencies are only a little bit different.)



9. A harmonic wave traveling along a light string approaches a splice to a heavier string, as shown below. Which changes as the wave crosses the boundary: wavelength, frequency, both, or neither? Explain your reasoning. (To think about the frequency, imagine painting a bright orange dot at precisely the point where the two strings are spliced together, and imagine the motion of that dot. Also, notice that the tension does not change from one side of the splice to the other, because if it did, then the splice would accelerate horizontally.)



Problems for Giancoli Chapter 12 (Sound)

10. Suppose that a guitar string vibrating at 110 Hz causes sound at this frequency to propagate through air from the guitar to your ear. (a) What is the wavelength in air of these sound waves? (b) What is the wavelength in air for frequency $f = 20$ Hz, near the bottom of the range of human hearing? (c) What is the wavelength in air for $f = 20$ kHz, near the upper end of the audible spectrum (for human ears)?

Remember **online response** at `positron.hep.upenn.edu/wja/jitt/?date=2018-09-21`

XC1*. Optional/extra-credit. A 350 g mass vibrates according to the equation $x = 0.45\sin(6.20t)$, where x is in meters and t is in seconds. Determine (a) the amplitude, (b) the frequency, (c) the period, (d) the total energy, and (e) the KE and PE when $x = 10.0$ cm. (f) Draw a careful graph of x vs. t showing the correct amplitude and period.

XC2*. Optional/extra-credit. A sound source-receiver combined unit is traveling at 85 km/hour. The source emits a frequency of 523 Hz. If the sound waves are reflected off a stationary flat surface and back toward the source, what frequency is detected by the receiver?

XC3*. Optional/extra-credit. You have tickets for an outdoor rock concert, fourth row from the stage. At that distance, however, the intensity level is 110 dB, too loud to be enjoyable. (Alas, you didn't bring ear plugs.) You decide to move to a row where the intensity level is a more tolerable 92 dB. Fortunately, turning around and counting the right number of rows back (assuming that the distance between rows is uniform), you see that just the seats you want are available. Which row are they in? (Assume that the sound propagates in all directions from a point source located zero rows from the stage and that the sound waves do not encounter any obstacles that would reflect or dissipate them.)

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