Physics 100: **Solutions** to Homework Assignment #7

Was Due on Friday, March 23rdat the Beginning of Class

Section 1. **Warm-up! Fill-in-the-Blanks (1 pt each)**

1. For a wave, the maximum displacement on either side of the equilibrium (midpoint) position is known as the ___amplitude___.
2. The distance between successive crests, troughs, or identical parts of a wave is known as the ___wavelength___
3. For a wave, the number of crests that pass a particular point per unit time is known as the ___frequency___ of the wave. For vibrations, the number of vibrations per unit time is known as the ___frequency___ of vibration.
4. The SI unit of frequency is the ___Hertz___, which equals ___one___ vibration(s) per second.
5. The time in which a vibration is completed or the time it takes for one wavelength of a wave to pass a certain point is known as the ___period___ of the vibration or wave.
6. The speed with which a wave passes a particular point is determined by multiplying its ___wavelength___ by its ___frequency___.
7. A wave in which the medium vibrates perpendicular to the direction of travel is a ___transverse___ wave, while a wave which vibrates parallel to the direction of travel is a ___longitudinal___ wave.
8. The pattern formed by superposition of different sets of waves that produces reinforcement in some areas and cancelation in others is known as the ___interference___ pattern of the waves.
9. The shift in received frequency due to motion of a vibrating source toward or away from a receiver is known as the ___Doppler___ ___Effect___.
10. The V-shaped disturbance created by an object moving across a liquid surface at a speed greater than the wave speed is known as the ___bow___ ___wave___. This is similar to the cone-shaped disturbance created by an object moving at supersonic speed through a fluid, which is known as the ___shock___ ___wave___.

Section 2. **Short Answer Questions (2 pts. each)**

11. What kind of motion should you impart to a stretched coiled spring (or Slinky[4]) to make **(A)** a transverse wave and **(B)** a longitudinal wave?

    Answer: (A) You would move the slinky up and down, to establish transverse waves as shown in in the Figure 1, top.
    (B) You would move the slinky in and out, compressing and decompressing it, to set up longitudinal waves as shown in the Figure 1, bottom.

[4]For info about Slinky's, visit Wikipedia: http://en.wikipedia.org/wiki/Slinky

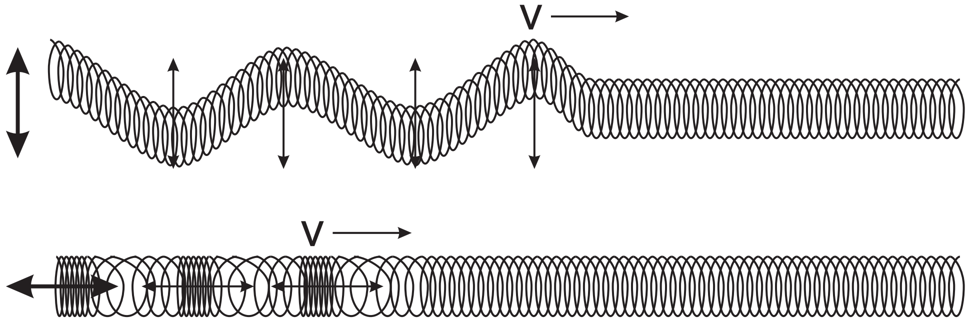

Figure 1: The moving the end of a stretched slinky up and down makes a transverse wave (TOP). Moving the slinky in and out (compressing/decompressing it) leads to longitudinal waves (BOTTOM). See Problem 11.

12. You hear an airplane flying overhead and you look up into the sky to see it. You eyes see the plane as being in front of where your ears think the plane is. Does this mean that the airplane is traveling faster than the speed of sound? Explain for full credit (i.e. just a 'yes' or 'no' answer will not earn *any* points).

    Answer: No, it doesn't mean that the plane is flying faster than the speed of sound– it just means that the speed of sound is much slower than the speed of light.
    When you hear a plane, you are hearing the sound it emitted many seconds ago, because it takes many seconds for the sound to reach your ears (about 5 seconds per mile of distance between you and the plane). So your ears tell you that the plane is where it was many seconds ago.
    Light, however, travels so quickly that it only takes microseconds[5] for the light to leave the plane and reach your eyes (about 5 microseconds per mile)– so when you see a plan, you're seeing where it was microseconds ago. So your eyes tell you where the plane was several microseconds ago.
    Since the plane may be traveling at speeds around 250 m/s (well below the speed of sound), that means that your eyes will see the plane as being kilometers ahead of where your ears think they are.

13. **(A)** List one example of a longitudinal wave and **(B)** two examples of a transverse wave.

    Answer: **(A)** Answers include: Sound waves, earthquake P-waves, compressional waves in springs (like the slinky in Problem 11).
    (B) Answers include: Waves in strings (like guitars), light waves, earthquake S-waves. Even though they're a mix of both longitudinal and transverse waves, I'll accept water waves, too.

14. A grandfather pendulum clock keeps perfect time. Then it is taken to the moon to keep astronauts on time. On the moon, will it also run with perfect time? Will it run slow? fast?

    Answer: The grandfather clock will run slow. Gravity is what keeps the pendulum swinging. If gravity is weaker, the force that accelerates the pendulum is weaker, meaning that the pendulum doesn't travel as fast back and forth. This mens that the period of oscillation increases, so that instead of taking one second, the period will be longer.

15. How far, in terms of wavelength, does a wave travel in one period?

    Answer: It travels exactly one wavelength, by definition.

16. A baby duckling is floating on a lake, not swimming but enjoying the nice, sunny, and windless day. Waves from a motor boat pass under the duckling, and the duckling feels itself bob up and down *4 times in 3 seconds*. Being very observant, the duckling notices that the waves are moving exactly twice

[5] To remind you, a microsecond is *one millionth* of a second.

as fast as his mother, whom he knows swims at precisely 0.500 m/s. **(A)** How many wavelengths passed under the duckling in those three seconds? **(B)** How many wave cycles did the duckling experience in those three seconds? **(C)** What was the frequency of the water waves? **(D)** What is the wavelength of the water waves?

Answer: **(A)** One cycle up and down corresponds to one wavelength passing under the duckie, as we discussed in class[6]. Therefore, in those three seconds, four wavelengths must have passed under the duckie.

(B) One cycle corresponds to the traversal of one wavelength. Therefore, the duckie experienced four cycles.

(C) The frequency is defined as the number of cycles per second, or, equivalently, the number of wavelengths that pass per second. In this case, the duckie felt four cycles in three seconds, so the frequency is:

$$f = \frac{4\ cycles}{3\ seconds} = 1.33\ Hz$$

(D) The speed of the waves is given to us as being $v = 2 \times 0.5\ m/s = 1\ m/s$. Knowing the speed and the frequency, we can use the all-important wave equation to find the wavelength:

$$wave\ speed = wavelength \times frequency$$

$$v = \lambda \times f$$

$$\lambda = wavelength = \frac{v}{f} = \frac{1\ m/s}{1.33\ Hz} = \frac{3}{4}\ m$$

17. **(A)** For each of the waves shown in Figure 2 below, mark the **amplitude and wavelength**. **(B)** Which of the three waves has the longest wavelength? If all three waves have the same frequency, **(C)** which wave is traveling the fastest and which the slowest?

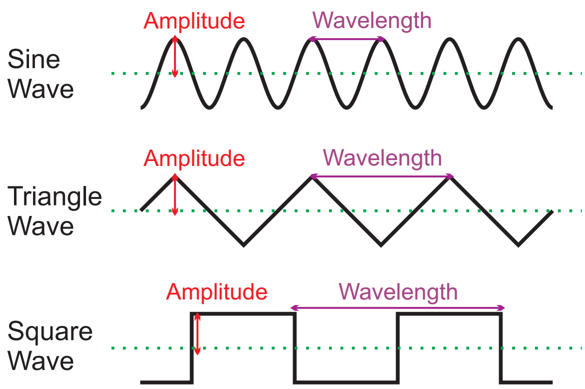

Figure 2: Mark the amplitude and wavelength for the waves in this figure. See Problem 17.

Answer: **(A)**They're shown above. Notice that the waves all have the same amplitude.

(B) The square wave has the longest wavelength.

(C) If they all have the same frequency, the square wave must be traveling the fastest as it has to traverse more distance to equal one cycle. The slowest wave must be the sine wave since it has the shortest wavelength and so has to traverse the least distance to equal one cycle. This relationship immediately falls out of the wave equation:

$$wave\ speed = wavelentgh \times frequency$$

[6]If you have any questions about this, come and see me immediately!

If they all have the same frequency, then their speeds are directionally proportional to their wavelengths.

18. **(A)** What is the relationship between frequency, wavelength, and wave speed? *(Write the equation down– no fancy answers needed for this part.)* **(B)** If the wavelength of a wave were doubled without changing its speed, how would its frequency change? **(C)** If the frequency of a wave were tripped while the wavelength remained constant, how would its speed change? **(D)** If the speed of a wave were quadrupled while its frequency remained constant, how would its wavelength change?

    Answer: **(A)** It's the wave equation! Memorize this!

    $$wave\ speed = wavelentgh \times frequency$$

    (B) To keep the same while doubling the wavelength requires that the frequency be halved. This makes sense: the wave travels at the same speed, but has to go twice as far to go through one cycle. Therefore the frequency drops by a factor of two.
    (C) If wavelength were kept constant while the frequency were tripped while the speed would triple. This is the same as saying that to increase the number of cycles per second while keeping the distance of travel per cycle constant, you need to increase your speed.
    (D) If the speed were quadrupled while keeping the frequency constant, the wavelength would quadruple. A way to think about this is that if you increase the distance per second the wave travels, while keeping the number of cycles passed through per second constant, then the distance between cycles has to increase.

19. A walnut falls from a tree into a shallow pond. The waves that radiate out from it form circular rings. **(A)** What does this tell you about the speed of waves moving in different directions?

    Answer: **(A)** It tells me that the speed of sound in all directions is the same.

20. Bats chirp to 'see' in the dark: they emit ultrasonic[7] pulses of sound and listen for the echoes to tell them how far away things are[8]. As a bat flies towards a wall, is the frequency of the echoed chirps it receives higher, lower, or the same as the emitted ones?

    Answer: Say that the frequency and wavelength that the bat chirps at some frequency when the bat and its target are sitting still. In this case, the bat emits some frequency, it bounces off the target and the bat hears the same frequency of sound.

    As the bat flies, the sound that it emits in front of it has its wavelength shortened, as in the most general case of the Doppler Effect of a moving source. This means that the frequency of the sound that the bat emits is increased, compared to the case when it's sitting still.

    When the chirp hits a stationary wall, it reflects back to the bat. Now the bat is flying into this sound wave (chirp), so it hears it being Doppler shifted up again– as in the case of a moving detector. So in the end, the bat hears the sound that it emits being shifted higher in frequency.

21. A train is at rest when it starts blowing its horn. Then it begins to move towards you. **(A)** Does the frequency of the whistle that you hear increase, decrease, or stay the same? **(B)** How about the wavelength reaching your ear? **(C)** How about the speed of sound in the air between you and the locomotive?

    Answer: **(A)** The frequency of the sound that you hear increases, in accordance with the Doppler effect.
    (B) The wavelength reaching your ear decreases, as in accordance with the Doppler effect of a moving source.
    (C) The speed of sound is not affected by the movement of the train.

22. What can you say about the speed of a boat that makes a bow wave?

    Answer: The boat is moving at least as fast the the speed of the water waves.

[7] The frequency of the sound waves is beyond the ability of humans to hear it.
[8] For more information on animal echolocation, I refer you to Wikipedia: http://en.wikipedia.org/wiki/Animal_echolocation .