Exam I Solution: Chapters 13 and 14

Instructions

Put your name and section number above and the Scantron form. When you complete the exam, the test paper, Scantron, and formula sheet must be submitted. This exam paper will be returned to you, but the Scantron form will not.

You may use your calculator and the formula sheet provided. You may not use any additional reference materials.

Make sure that your cell phone is switched off. It should be put away, and nowhere visible on your desk. If your phone rings during the exam, you will be required to turn in your exam and leave the room. You will not be allowed to return and complete any unfinished portions of the exam. You may not use either your cell phone or PDA as a calculator.

Part 01

- Answer the multiple choice questions on the Scantron form provided, using a #2 pencil.
- Erase all changes completely; your Scantron form will not be hand-checked for incomplete erasures.
- There is exactly one correct answer for each question.
- Each question is worth 1.5 points.
- There is no partial credit on multiple choice questions.

Part 02

- When you have completed Part 01, you must turn it in before you are given Part 02.
- You may use your notebook as a reference. You may not use your textbook or any other ancillary materials.

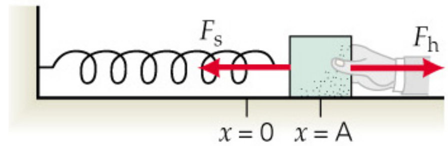
Scoring

Part 01: ________ /75

Part 02: ________ /50

1. Hooke's law is written as **F** = –k**x**. Why the negative?
   A) Because the spring force has to be negative; springs can only pull, they cannot push an object.
   B) Because the stretch of the spring has to be negative: springs can only stretch, they cannot compress.
   C) Because the force always opposes the displacement of the spring: a stretched spring wants to return to its original rest length.
   D) The negative is not necessary; it is the result of the coordinate system you choose when solving a problem. Choosing a different coordinate system can always get rid of that negative for you.

The block shown right has a mass m. It is attached to a spring with a constant k. The spring is stretched to x=+A from its equilibrium position and the system is released from rest.



2. At the instant of release, just as the hand lets go of the block, the force exerted on the block by the spring is
   A) maximum. B) zero. C) minimum.

3. As the block moves from position x=+A to position x=0, the velocity of the block
   A) remains zero.
   B) remains constant, but not zero.
   C) decreases.
   D) increases.
   E) increases from x=+A to x=+½A, then decreases back to zero from x=+½A to x=0.

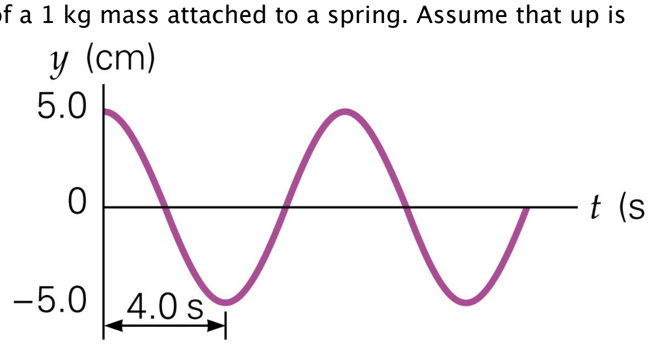
4. As the block moves from position x=0 to position x=–A, what happens to its acceleration?
   A) The acceleration remains constant everywhere: zero. The velocity of the block never changes.
   B) Constant acceleration, but not zero. The acceleration is a = (kA)/m everywhere along the block's path.
   C) At x=0, the acceleration is zero. As the block moves left toward x=–A, the magnitude of the acceleration increases while its direction remains to the right.
   D) Answer C is completely backwards! The acceleration is maximum at x=0, and decreases to zero at x=–A. The direction of the acceleration matches the direction of motion: to the left.

5. Let's talk about the energy of the system.
   A) The energy remains constant. It is all potential energy, $U = \frac{1}{2}kA^2$, when the block is at x=0.
   B) The energy is constant. It is all kinetic energy, $K = \frac{1}{2}mv^2$, when the block is at x=0.
   C) The energy is not constant. It is maximum at x=+A, zero at x=0, and minimum at x=–A.
   D) The energy varies. The total energy is zero at x=±A, and maximum at x=0.

6. Here's a trick question about the energy. Only you can't really complain if I am telling you in advance that it's a trick, right? The trick is to look at the math carefully. There, I've said it. When the block is at exactly x=+½A, what is the distribution of the energy?
   A) The energy is ¾ kinetic, and only ¼ potential.
   B) Exactly half kinetic, half potential. So that part about being a trick wasn't exactly true, was it?
   C) The exact fraction of potential energy can't be determined unless you have an actual number to plug in for the amplitude A. But there is definitely more potential energy than kinetic.

7. This particular oscillation has a frequency of 0.05Hz. To increase the frequency, you should
   A) add mass. Replace the original mass m with a new one having exactly 2m.
   B) remove mass. Using ¼ as much mass will double the original frequency.
   C) replace the spring with one having a smaller constant k. Half the k, double the frequency.
   D) adjust the amplitude of the oscillation. Doubling the amplitude will increase the frequency by a factor of 4.

On the right is a graph illustrating the vertical oscillation of a 1 kg mass attached to a spring. Assume that up is the positive direction, and down is the negative direction.



8. The amplitude of this oscillation is
   A) 4.0 cm C) 8.0 cm
   B) 5.0 cm D) 10.0 cm

9. The period and frequency are
   A) T=0.125s, f=8.0Hz C) T=4.0s, f=0.25Hz
   B) T=0.25s, f=8.0Hz **D) T=8.0s, f=0.125Hz**

10. At t = 2.0s, the mass's position and velocity are the same as at
   A) t = 4.0s. B) t = 6.0s. C) t = 8.0s. **D) t = 10.0s.**

11. The position of the mass will be described by the equation:
   A) y = (5cm)cos[½πt] B) y = (5cm)sin[½πt] **C) y = (5cm)cos[¼πt]** D) y = (5cm)sin[¼πt]

12. The velocity and acceleration of the mass will be described by the equations:
   A) v = –(1.25π cm)sin[¼πt]
   a = –(0.3125π² cm)cos[¼πt]
   B) v = +(1.25π cm)sin[¼πt]
   a = +(0.3125π² cm)cos[¼πt]
   C) v = –(1.25π cm)sin[¼πt]
   a =+(0.3125π² cm)cos[¼πt]

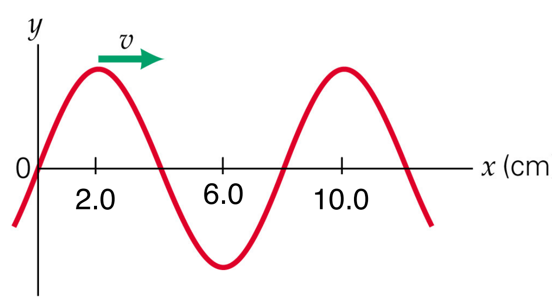
13. The periodic function x=Asin(ωt + ϕ) used to describe simple harmonic motion includes a phase angle ϕ
   A) in case the motion has an irregular frequency that does not remain constant.
   B) to satisfy the initial conditions of the oscillation (position x_o and velocity v_o).
   C) to satisfy the final conditions of the motion (final position x_f and final velocity v_f).
   D) to satisfy the equilibrium condition that the velocity must be zero at the equilibrium position.

14. Continuing to use the same graph, re-write the equation of motion using the phase angle.
   A) y = (5 cm)sin[¼πt + π/2] B) y = (5 cm)sin[¼πt + π] C) y = (5 cm)sin[¼πt + 3π/2]

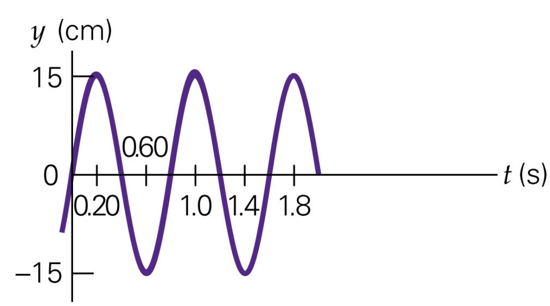
15. Compare an oscillation and a wave.
   A) Huh? Why? They are exactly the same thing: a periodic motion with respect to a fixed reference.
   B) An oscillation is a periodic motion with respect to a fixed point. A wave is not periodic, just linear.
   C) An oscillation depends on wave motion; you cannot have an oscillation without a wave.
   D) A wave combines an oscillation and propagation: an oscillation in time propagated through space.

16. As a wave propagates, the molecules of the medium
   A) actually travel in the opposite direction, as the wave "pushes off" the molecules.
   B) roll forward, like water boiling in a pan: wave propagation is a convective process.
   C) are pulled forward along with the traveling wave, but do not vibrate.
   D) remain rigid, neither vibrating nor propagating as the wave passes.
   E) vibrate, but do not propagate forward with the wave.

17. Compare the direction of oscillation to the direction of propagation for the wave represented on the right.
   A) Oscillation occurs in the y-direction, propagation occurs in the x-direction.
   B) Oscillation occurs in the x-direction, propagation occurs in the y-direction.
   C) Oscillation and propagation are both in the x-direction.
   D) Oscillation and propagation are both in the y-direction.
   E) Oscillation and propagation are both in the z-direction.



18. The wave described by the graphs is a
   A) transverse wave. C) converse wave.
   B) longitudinal wave. D) latitudinal wave.



19. What is the amplitude of this wave?
   A) 0.8 cm C) 8.0 cm
   B) 2.0 cm **D) 15 cm**

20. What is the wavelength?
   A) 0.8 cm **C) 8.0 cm**
   B) 2.0 cm D) 15 cm

21. What is the wave speed?
   A) v = 6.4 cm/s **B) v = 10 cm/s** C) v = 12 cm/s D) v = 18.8 cm/s

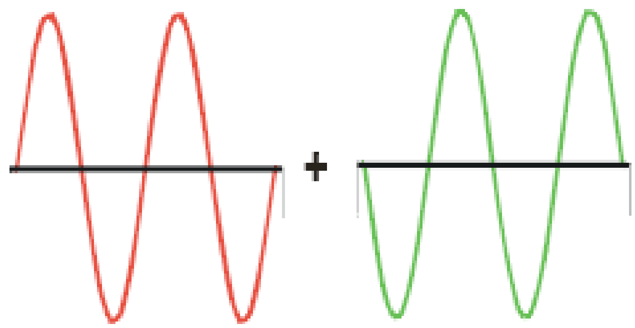
22. A longitudinal wave
   A) occurs when the direction of oscillation is perpendicular to the direction of travel.
   B) occurs when the direction of oscillation is parallel to the direction of travel.
   C) only exists in theory; there are no longitudinal waves actually found naturally.
   D) is identical to a transverse wave. If the medium is solid, the wave is called longitudinal. In a fluid medium, it's called a transverse wave.

23. The rarefactions of a longitudinal wave are analogous to the
    A) crests of a transverse wave.
    B) **troughs of a transverse wave.**
    C) amplitude of a transverse wave.
    D) wavelength of a transverse wave.

24. Compare the density of the medium in regions of compression and rarefaction.
    A) Why? Because longitudinal waves only travel through solids, the density remains constant in all regions.
    B) Rarefactions are denser regions than compressions, but both are denser than node regions.
    C) **A rarefaction is a region of reduced density, a compression has greater density.**
    D) A rarefaction is a region where the density is unchanged. Compressions may have higher or lower density, just not the same density as a rarefaction.

25. The superposition principle is based on the idea that
    A) a wave propagates by superimposing a propagation over an oscillation. The result is that the wave medium moves right along with the energy.
    B) two particles can occupy the same space at the same time: they superimpose to result in a new particle having the combined mass: $m = m_1 + m_2$.
    C) **two waves can occupy the same space at the same time: they superimpose to result in a new wave having the combined amplitude: $A = A_1 + A_2$.**
    D) two waves cannot occupy the same space at the same time. Neither can two particles. Which must mean that there really isn't any superposition of matter or energy. What a crazy universe we live in!

26. The to waves shown will interfere
    A) constructively.
    B) **destructively.**
    C) panmorphically.
    D) intragenically.



27. For the waves shown to completely reinforce, the wave on the right should be phase shifted by
    A) 0; not at all.
    B) $\pi/2$.
    C) **π.**
    D) $3\pi/2$.

A steel guitar string is 78 cm long, with diameter of 0.1 cm. The fundamental frequency of vibration is f = 320 Hz.

28. What are the wavelengths of the harmonics resonances 1, 3, and 4?
    A) 0.78m, 1.56 m, and 2.34m
    B) 1.56 m, 0.52m, and 0.26m
    C) 0.78m, 0.39m, and 0.195m
    D) **1.56m, 0.52m, and 0.39m**

29. How fast will a wave propagate along the string?
    A) 224 m/s
    B) 250 m/s
    C) 449 m/s
    D) **499 m/s**
    E) 896 m/s

You replace the string with a **thicker** one having a **greater** mass density.

30. When the new string is plucked, how fast will the wave propagate?
    A) As long as the supports are still 78 cm apart, the wave speed will be unaffected.
    B) As long as the tension remains constant, the wave speed will be unaffected.
    C) Because the mass density increases, the wave speed decreases with constant tension.
    D) **If the tension remains constant, the wave speed decreases.**

31. What are the wavelengths of the first three harmonic resonances of this new string?
    A) **As long as the supports are still 78 cm apart, the wavelengths will be unaffected.**
    B) As long as the tension remains constant, the wavelengths will be unaffected.
    C) Because the mass density increases, so do the wavelengths.
    D) If the tension remains constant, the wavelengths decrease.

32. If the tension has been kept constant, the fundamental frequency of the thicker string is
    A) greater than 320 Hz.
    B) equal to 320 Hz.
    C) **less than 320 Hz.**

33. For a sound to be *audible*, it must have
    A) any frequency at all, as long as the intensity is greater than $1W/m^2$.
    B) any intensity at all, as long as the frequency is greater than 20,000Hz.
    C) any frequency, any intensity. Whenever molecules vibrate, human ears hear them.
    D) frequency between 20Hz and 20,000Hz. But the intensity must be greater than $1W/m^2$.
    E) **frequency between 20Hz and 20,000Hz. It must also have an intensity greater than 10^{-12} W/m².**

34. If a tree falls in the forest and there is no one there to hear it, does it make a sound?
    A) I regret that the deeply existential nature of this question precludes a simple multiple choice response.
    B) No. If a tree falls in the forest and there is no one present, there is no sound.
    C) Maybe. *You* might not be there, but there are probably squirrels and woodchucks and ivory-billed woodpeckers present that *could* hear the sound. There has to be some living thing present, or no sound.
    D) Yes. Of course it does. The presence or absence of a pair of human ears does not affect in any way the creation of the sound wave itself.

35. Why does the speed of sound increase with air temperature?
    A) The speed of sound in air does not depend on temperature at all.
    B) Increased temperature means that the air molecules are moving less; this permits the sound energy to be transmitted unimpeded.
    C) Increased molecular motion increases the rate at which the molecules collide, which aids in the transmission of the sound energy.
    D) The speed of sound actually decreases with increasing temperature.

36. Two sound waves travel through air at **20°C**. The second wave has **half** the wavelength of the first.
    A) Both waves have the same frequency and speed. The wavelength is independent of both.
    B) Its speed is half the speed of the original wave. The frequency is the same for both waves.
    C) Its speed is twice the speed of the original wave. Its frequency is twice the original frequency.
    D) Its frequency is half the frequency of the original wave. The speed is the same for both waves.
    E) Its frequency is twice the frequency of the original wave. Its speed is the same as the original speed.

37. The 512Hz tuning fork is struck inside the lab (20°C). The wave speed is less than outdoors, where the temperature is 25°C. Striking the fork outside will result in a sound wave having the same
    A) wavelength, but decreased frequency.
    B) wavelength, but increased frequency.
    C) frequency, but decreased wavelength.
    D) frequency, but increased wavelength.

38. Why is humid air fast air?
    A) It isn't. Humid air is very dense, so sound travels much slower in humid air.
    B) Because water molecules are less massive than either N_2 or O_2 molecules; for the same amount of energy, less mass gets you a faster speed.
    C) No! Because H_2O molecules are heavier than N_2 or O_2, there are fewer of them in any given volume of air. This means there is less matter through which the wave must propagate.
    D) Water molecules weigh the same as oxygen or nitrogen molecules. It's the hydrogen bond! Water molecules are naturally sort of bell-shaped, which makes them obviously excellent sound conductors.
    E) The humidity is not material; there is a temperature dependence only.

39. So I'm listening to the radio, and they play that Sheryl Crow song, *Good Is Good*. She sings, "Every time you hear the rolling thunder, you turn around before the lightning strikes..." Why does this make my head explode every time I hear it?
    A) No clue. There's not one thing wrong with it. Whenever you see the lightning, you have already heard the thunder. Sound travels faster through air than light.
    B) The sound of thunder will always arrive after the flash of lightning. Sound travels many times more slowly through air than light.
    C) Because you will always see the lightning and hear the thunder simultaneously. Light and sound travel at exactly the same speed through air.
    D) Sometimes the sound precedes the light, sometimes the light arrives first. Because the speed of sound depends on temperature, on a warm day the sound arrives before the light. But on a cold day, the light arrives first. She never tells us in the song what the temperature is!
    E) Love Sheryl; *love* Lance—maybe we got just a little bit too invested in that whole Sheryl-Lance thing, and cannot bear that they broke up? Bigger question is why do we care who people we do not even know are dating?

40. In space, no one can hear you scream.
    A) True; sound waves cannot travel through a vacuum.
    B) True; your tiny voice will be drowned out by the ethereal music of the heavenly spheres!
    C) False: you simply are not screaming. Space is no place for sissies.
    D) False: if you *were* screaming (and I'm not saying that you *are*), there is no reason why the sound waves would not propagate normally, at about the same speed as through air.

41. Compare the speed of sound through water to the speed of sound through solid steel.
    A) The speed of sound will always be greater through a liquid medium, because the sound wave will have both longitudinal and transverse components.
    B) The speed will be greater through the water, because water is much less dense than steel. The denser the medium, the slower the sound will propagate.
    C) Steel is the faster medium for sound waves. Sound travels best through an elastic medium.
    D) The speed of sound is constant for all media: v = [331 + 0.6T]m/s. The temperature is the only significant parameter. The composition of the medium is simply not relevant.

42. Carbon is added to iron to form steel. The addition does not change the density by an appreciable amount, but it does increase the elasticity substantially. How is the speed of sound affected?
    A) It is not affected. Neither iron nor steel is capable of sound transmission.
    B) Increasing the elasticity will increase the speed of sound through the medium.
    C) Increasing the elasticity will decrease the speed of sound through the steel.

43. The intensity of a sound is exactly 16 W/m^2 at a distance of 1m. At 2m, the intensity will be
    A) 4 W/m^2 B) 8 W/m^2 C) 32 W/m^2 D) 64 W/m^2

44. You perceive that sound B is twice as loud as sound A. What is the difference in the intensity of these?
    A) B has half the intensity of A.
    B) B must have ¼ the intensity of A.
    C) Twice the loudness implies twice the intensity.
    D) Twice the loudness means the intensity is four times greater.
    E) A doubling of the loudness means an order of magnitude, or factor of 10, increase in intensity.

45. Doubling the intensity of a sound results in an intensity level increase of
    A) 2 dB **B) 3 dB** C) 5 dB D) 10 dB

46. Your cousin is visiting from Tulsa, and she brought her 3 month old baby. Cute, but colicky. You just got back from Radio Shack, where you bought a cool new sound meter. Coincidence? I don't *think* so.
    A) The screaming baby registers no more than 15dB on your most excellent digital device.
    B) Screaming baby comes in at about 30dB.
    C) Screaming baby could hit as high as 90dB.
    D) The baby will probably be screaming at 150dB or even higher.
    E) You have no idea, because when you saw your cousin's car in the driveway, you just kept driving and went back to the mall to hang out until she leaves. That baby is a monster.

47. Beats occur when
    A) two waves with the same frequency interfere constructively.
    B) two waves with slightly different frequencies interfere constructively.
    C) two waves with the same amplitude and opposite phase cancel completely.
    D) two waves with slightly different speeds reach an observer with a small time lag.

48. What is the Doppler effect?
    A) A change in the perceived frequency of a wave because the source of the wave either approaches toward or recedes away from the receiver. There is no effect if the source remains stationary and the observer is in motion.
    B) A change in the perceived frequency of a wave because the source of the wave either approaches toward or recedes away from the receiver. Or, if the source is stationary, the same effect occurs for an observer in motion.
    C) A change in the actual frequency of a wave because the source of the wave begins to vibrate at a different frequency. Any motion of either the source or the observer is not relevant.
    D) A change in the actual frequency of a wave because the medium changes, resulting in a speed change. When the speed of the wave changes, the frequency changes because the wavelength remains constant.
    E) The inexorable sequence of events set in motion when, through no fault of your own, your tornado-propelled domicile is thrust into an alternate reality and lands on a fabulous pair of shoes rather inconveniently still attached to the feet of a witch with a vindictive (and quite literally green) sister who just happens to have a terrifying army of flying monkeys. *Flying monkeys!*

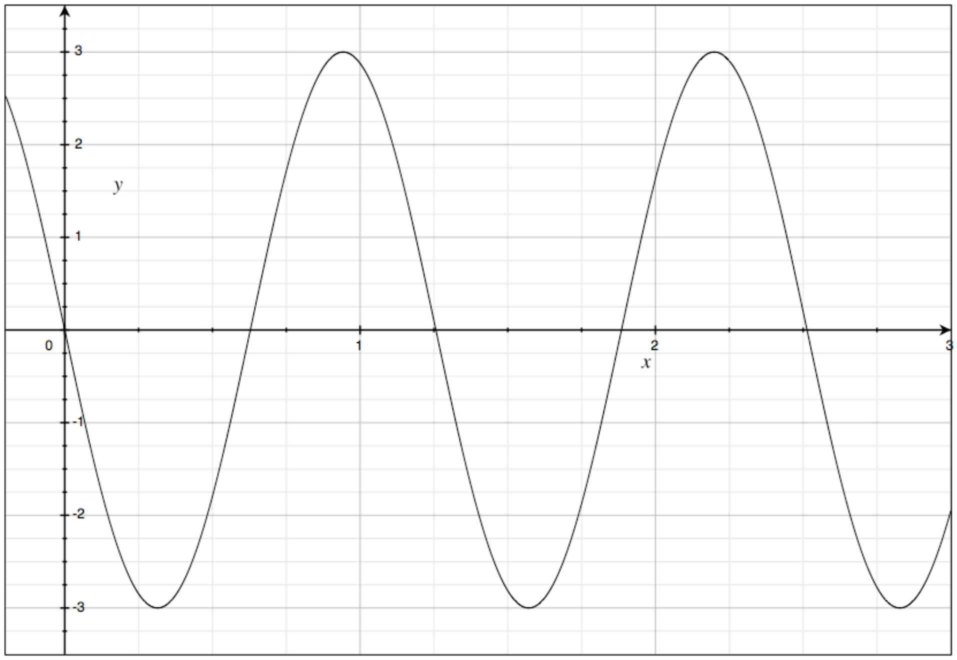
49. As you are standing stationary on the sidewalk, a black '76 Firebird zooms past (doing like, 45, in a school zone) with windows open, blasting *Have a Cigar* from the in-dash 8-track (did I mention that you have traveled back in time and it actually *is* 1976? That's a brand-new Bird).
    A) The actual frequency does not change, and neither does your perception of it. The song remains the same.
    B) The actual frequency does not change, but your perception of it does. It seems to decrease in frequency as the car approaches you.
    C) The actual frequency does not change, but your perception of it does. It seems to increase in frequency as the car approaches you.
    D) The actual frequency of the song changes as it changes its vibration. If the car moves forward, the frequency increases (regardless of what you are doing).
    E) You have no idea what happened to the frequency, because you were so astonished when Tony slammed on the brakes and offered you a ride. Must've been those fabulous freaky shoes that caught his eye. That, and not every girl has a monkey on a leash flying rings around her head.

50. You are driving down the street with Tony (you're still trapped in 1976-good luck finding a radio station that isn't playing something off *Frampton Comes Alive!,* and good luck finding a Radio Shack that has replacement parts for your time machine). He's letting you drive the Firebird, so you are proceeding at a sensible 30 mph, moving away from the factory, when the whistle blows to mark the shift change. Tony always carries that portable guitar tuner you brought him from the future, which reads a frequency of 440 Hz.
    A) As you get farther from the factory, the frequency reading will decrease.
    B) As you continue to move away from the sound, the frequency reading will increase.
    C) The frequency reading will not change, because the source of the sound is stationary.
    D) The reading on the meter does not change, even though you and Tony will hear the pitch of the sound increase.

51. By the way, which one's Pink?
    A) Roger **B) Syd** C) David D) Nick E) Richard

52. What is the difference between a llama and an alpaca?
    A) There is no difference. In Ecuador, they are alpacas, and in Peru they are called llamas.
    B) Duh. A llama is much larger than an alpaca. But the cute little alpaca has a softer coat, so you probably want to knit an alpaca sweater, not a llama sweater.
    C) A llama has two humps (use the double ll as the mnemonic device for remembering), an alpaca only has one.

Problem 01



A) (3 points) Write the equation for position y as a function of time t for the oscillation above.

B) (3 points) What are the amplitude, period, and frequency?

C) (4 points) If this graph represents the vertical oscillation of a 200g mass attached to a spring, what is the spring constant k?

D) Bonus (4 extra points): write the equation for velocity as a function of time, and determine the speed of the mass when t = 2 seconds.

A)
$$y = A\sin(\omega t + \varphi)$$
$$y = A\sin\left[\left(\frac{2\pi}{T}\right)t + \varphi\right]$$
$$y = (3\text{cm})\sin\left(\left(\frac{2\pi}{1.25\text{s}}\right)t + \varphi\right)$$
$$y = (3\text{cm})\sin[5t + \varphi]$$

At t = 0, y = 0 but the object is headed in the negative direction:
$$y = (3\text{cm})\sin[5t + \pi]$$ or
$$y = -(3\text{cm})\sin[5t]$$

B) Amplitude A = 3cm
Period T = 1.25s
$$f = \frac{1}{T} = \frac{1}{1.25s} = 0.8\text{Hz}$$

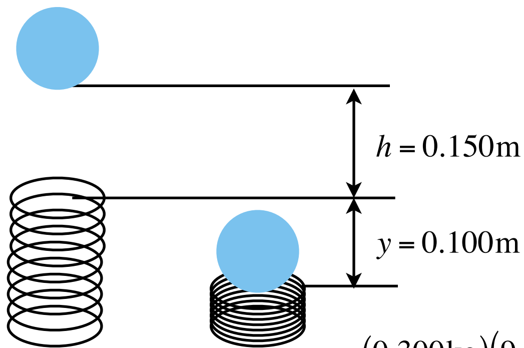
C)
$$T = 2\pi\sqrt{\frac{m}{k}}$$
$$1.25\text{s} = 2\pi\sqrt{\frac{(.200\text{kg})}{k}}$$
$$k = 5.05\,\tfrac{\text{N}}{\text{m}}$$

D) At t = 2 sec:
$$v = A\omega\cos[\omega t + \varphi]$$
$$v = (3\text{cm})(5\text{s}^{-1})\cos[(5\text{s}^{-1})(2s) + \pi]$$
$$v = 12.6\,\tfrac{\text{cm}}{\text{s}}$$

Problem 02

The 300g ball is released from rest 15.0 cm above the spring as shown. As a result, the spring is compressed by 10.0 cm.

A) (5 points) Determine the spring constant k.



$$E_i = U_g = mg(h+y)$$

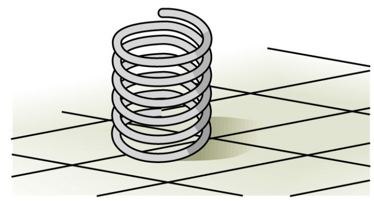
$$E_f = U_s = \tfrac{1}{2}ky^2$$

$$E_i = E_f$$

$$mg(h+y) = \tfrac{1}{2}ky^2$$

$$(0.300\text{kg})\left(9.8\,\tfrac{\text{m}}{\text{s}^2}\right)(0.250\text{m}) = \tfrac{1}{2}k(0.100\text{m})^2$$

$$k = 147\,\tfrac{\text{N}}{\text{m}}$$



B) (5 points) Next, the person shown is going to vertically launch the ball using the spring. He compresses the spring by 15.0 cm with the ball resting on it, then releases. How high (above the initial position) will the ball ultimately rise?

$$E_i = U_s = \frac{1}{2}ky^2$$

$$E_f = U_g = mgh$$

$$E_i = E_f$$

$$\tfrac{1}{2}ky^2 = mgh$$

$$\tfrac{1}{2}\left(147\,\tfrac{\text{N}}{\text{m}}\right)(0.150\text{m})^2 = (0.300\text{kg})\left(9.8\,\tfrac{\text{m}}{\text{s}^2}\right)h$$

$$h = 0.563\text{m}$$

Problem 03

It's fall, and we're all ready for the playoffs, especially the ALCS, which we anticipate will go seven games (and we also anticipate extreme disappointment and even a little bitterness when Detroit goes down to the Yankees). While we're waiting for post-season play, let's solve a sound problem: it's cool outside, only 16.0°C. You hear the crack of the bat 0.25s after you see the batter make contact.

A) (4 points) Find the speed of sound through the air.

$$v = \left[331 + 0.6T\right]\frac{\text{m}}{\text{s}}$$
$$v = \left[331 + 0.6\left(16.0°\text{C}\right)\right]\frac{\text{m}}{\text{s}}$$
$$v = 340.6\,\frac{\text{m}}{\text{s}}$$

B) (6 points) Determine how far you are sitting from home plate.

$$x = vt$$
$$x = \left(340.6\,\frac{\text{m}}{\text{s}}\right)\left(0.25\text{s}\right)$$
$$x = 85\text{m}$$

Problem 04

The air-raid siren is being tested, because it's Tuesday and it's noon. Or maybe it's Wednesday, but anyway, it's noon. And we're testing the siren. The siren frequency is 1000Hz, and at a distance of 3.0m from this point source, the sound level is 100dB.

A) (3 points) What is the intensity of this sound?

$$\beta = 10\log\left(\frac{I}{I_o}\right)$$

$$100\text{dB} = 10\log\left(\frac{I}{10^{-12}\ \frac{\text{W}}{\text{m}^2}}\right)$$

$$10 = \log\left(\frac{I}{10^{-12}\ \frac{\text{W}}{\text{m}^2}}\right)$$

$$10^{10} = \left(\frac{I}{10^{-12}\ \frac{\text{W}}{\text{m}^2}}\right)$$

$$I = 10^{-2}\ \frac{\text{W}}{\text{m}^2}$$

B) (3 points) What is the power?

$$I = \frac{P}{4\pi r^2}$$

$$P = 4\pi r^2 I$$

$$P = 4\pi(3.0\text{m})^2\left(10^{-2}\ \tfrac{\text{W}}{\text{m}^2}\right)$$

$$P = 1.13\text{W}$$

C) (4 points) At what distance from the speaker will the sound level be 60dB?

$$\beta = 10\log\left(\frac{I}{I_o}\right)$$

$$60dB = 10\log\left(\frac{I}{I_o}\right)$$

$$I = 10^{-6}\ \frac{\text{W}}{\text{m}^2}$$

$$I = \frac{P}{4\pi r^2}$$

$$r = \sqrt{\frac{P}{4\pi I}}$$

$$r = \sqrt{\frac{(1.13\text{W})}{4\pi\left(10^{-6}\ \frac{\text{W}}{\text{m}^2}\right)}}$$

$$r = 300\text{m}$$

Problem 05

The bat shown emits a sound with frequency **35.0kHz**. He is screaming at the insect, probably saying something like, “Hold still so I can eat you!” Predator and prey are in air at **22.5°C**, and the bat is approaching the stationary insect at **12.0m/s**.

A) (3 points) What is the speed of the sound wave emitted by the bat?

$$v = [331 + 0.6T]\frac{\text{m}}{\text{s}}$$

$$v = [331 + 0.6(22.5°\text{C})]\frac{\text{m}}{\text{s}}$$

$$v = 344.5\,\frac{\text{m}}{\text{s}}$$

B) (3 points) What is the wavelength of the sound wave?

$$v = \lambda f$$

$$344.5\,\frac{\text{m}}{\text{s}} = \lambda\left(35x10^3\,\text{Hz}\right)$$

$$\lambda = 0.10\text{m}$$

C) (4 points) What frequency does the insect perceive?

$$f_o = \left[\frac{v}{v - v_s}\right] f_s$$

$$f_o = \left[\frac{344.5}{344.5 - 12.0}\right](35\text{kHz})$$

$$f_o = 36.3\text{kHz}$$

D) Bonus (2 extra points): The sound wave bounces off the insect, and travels back to the bat. What frequency does he (the bat) perceive?
Note: with respect to the bat, the moth is the source, with f_s = 36.3 kHz.

$$f_o = \left[\frac{v + v_0}{v}\right] f_s$$

$$f_o = \left[\frac{344.5 + 12.0}{344.5}\right](36.3\text{kHz})$$

$$f_o = 37.5\text{kHz}$$