CHAPTER 14

14.1 Simple Harmonic Motion - The first part has basic definitions you need. Read the second part carefully and be sure you understand how the equations and the graphs relate. Try to do the examples yourself without looking at the solution.

14.1 Q1. The starting conditions of an oscillator are characterized by

1. the initial acceleration.
2. **the phase constant.**
3. the phase angle.
4. the frequency.

Feedback: review p. 415-417. The phase constant is included to describe an oscillator's initial conditions, as all oscillations do not necessarily have the same starting point.

14.1 Q2. An object undergoing simple harmonic motion has its maximum speed when
(hint: see Fig. 14.3)

1. **the object passes through x = 0.**
2. the object is at its maximum amplitude (x = A).
3. the object is at 1/2 its amplitude (x = A/2).
4. you cannot determine without knowing the initial phase constant of the object.

Comment: review p. 412-413, in Fig 14.3, the relationship between an object's position and velocity are shown. At the maximum amplitude, the object turns around, and thus must go through v = 0 m/s. The object is the fastest exactly in between the amplitudes, i.e., when passing thorough x = 0.

14.2 Simple Harmonic Motion and Circular Motion - This section uses rotational variables that we will discuss in class on Monday. Equations 14.15 hopefully make sense to you. Appreciate that you need a 'phase constant' to express initial condition at t = 0, since velocity and position are not necessarily 0. Example 14.4 is a typical exam or homework question.

14.2 Q1. Looking at the figure for the "Stop to Think 14.2", what is the phase constant, ϕ_0, of the block in part (a)?
Hint: Look at Figure 14.9 for help with determining +/-.

1. 3pi/4
2. -pi/4
3. pi/4
4. **-3pi/4**

Feedback: review p.415-416. The object is located at the 3pi/4 position in the figure, and is negative since the block is moving towards x = 0.

14.3 Energy in Simple Harmonic Motion - Read the entire section carefully. Think about the spring demo in today's class -- where is the velocity zero and where is it max -- and relate that to kinetic energy. Remember that energy is ALWAYS conserved; so what happens to the kinetic energy when the velocity is zero?
Figure 14.10 has a lot of information in it -- take your time to review all the components and try to understand how amplitude (or any x-position), and potential energy relate.

14.3 Q1. An object moves with simple harmonic motion. If the amplitude and the period are both doubled, the object's maximum speed is

1. quadrupled.
2. doubled.
3. quartered.
4. halved.
5. **unchanged**.

Feedback: review p. 418. We know that v_max = ωA. We can also write ω = 2pi/T, so v_max = (2pi/T)A. If we double A and T, v_max will not change.

14.3 Q2. Which statement is INCORRECT about energy in a simple harmonic oscillator, such as a mass oscillating on a spring like in Fig. 14.10.

1. **The potential energy of the system is half the total energy at x = A/2.**
2. The potential energy of the system is equal to the total energy minus the kinetic energy, U = E-1/2mv^2.
3. At position x=0 the total energy is equal to the kinetic energy, E = K = 1/2 mv^2.
4. At position x=A the total energy is equal to the potential energy, E = U = 1/2 kx^2.
5. The total energy, E, at position x=A and x= A/2 is the same.

Feedback: review p. 418-419. Although at some critical points the total energy might be all kinetic (at x=0) or all potential (at x = A or x = -A), the total energy, E, of the system is always written as K + U. Also, note that the graph of the potential and kinetic energies is NOT linear but rather goes by the power of ^2 (parabolic).

14.4 The Dynamics of Simple Harmonic Motion – We will be looking at Hooke's Law in class and it would be beneficial for you to review this section (if you are unfamiliar with Hooke's Law, you might want to skim through section 10.4 as well). It is important to recognize the equivalency of F = ma and F =-kx. The worked-through examples in this part are good practice; be sure to try and understand these.

14.4 Q1. An object undergoing simple harmonic motion has its maximum acceleration when
(hint: see Fig. 14.13)

1. **the object is at its maximum negative amplitude (x = -A).**
2. when the object passes through x = 0.
3. the object is at its maximum amplitude (x = A).
4. you cannot determine without knowing the initial phase constant of the object.

Feedback: review p. 420-421. The acceleration is largest when the v=0 and the object needs to accelerate towards x = 0. Think about when does the acceleration OPPOSE the movement, i.e., go in the opposite direction as the object's movement. Mathematically we also known that the acceleration is the second derivative of position, a = x''(t).

14.4 Q2. A block (0.2 kg) attached to a horizontal spring is pulled 20 cm and released. Which statement is NOT true about the energy in the system just BEFORE the block is released?

1. If given the spring constant k = 10 N/m, it would be possible to solve for the maximum velocity of this block.
2. **At the displacement maxima, all the energy is stored as potential energy due to gravity, so E_total = U = mgh.**
3. At the displacement maxima, all the energy is stored as potential energy of the spring, so E_total = U = 1/2kA^2.
4. E_total ALWAYS equals K + U, and at the maxima K = 0.

Feedback: review p. 418-419. The potential energy comes from the spring in this case -- NOT from gravity.

14.4 Q3. Looking at the Stop and Think 14.3, four springs have been compressed from their equilibrium position at x = 0 cm. When released, they will start to oscillate.

Rank the oscillation frequency, ω, in order from highest to lowest.
1. a > b = c > d
2. b > a > c > d
3. c > b > a = d
4. c > d = b > a
5. c > b > d > a
6. **d > c > a > b**

Feedback: review p. 418-419. Use the formula ω = sqrt(k/m) to solve for the four oscillation frequencies.

14.4 Q4. Looking at the Stop and Think 14.3, … (same as above) … Rank the period, T, in order from highest to lowest.
1. **b > a > c > d**
2. d > c > a > b
3. c > d = b > a
4. c > b > a = d
5. a > b = c > d
6. c > b > d > a

Feedback: review p. 418-419. Use the formula T = 2pi/ω to solve for the four periods. Or use equation 14.24

14.4 Q5. Looking at the Stop and Think 14.3, … (same as above) … Rank the potential energy, U, in order from Rank the potential energy, U, in order from highest to lowest
1. b > a > c > d
2. d > c > a > b
3. c > d = b > a
4. **c > b > a > d**
5. a > b = c > d

review p. 418-419. Use the formula U = 1/2 kA^2. This calculates the maximum potential energy, which can be used to determine the maximum speed because 1/2 kA^2 = 1/2m(v_max)^2.

14.5 - Vertical Oscillations: This section shows why gravity does NOT influence the oscillation frequency. Example 14.7 is very useful. Make sure you can identify the equilibrium position of a vertical spring AND a vertical spring with a mass attached. What extra features are included in a vertical harmonic oscillator that are not considered in a horizontal harmonic oscillator?

14.5 Q1. A 1.5 kg mass is attached to the end of a 10.0 cm long spring that is hanging from the ceiling. The weight of the mass stretches the spring to a length of 13.5 cm. If you pull the mass down and stretch the spring to 15.0 cm and then release it, what's the equation describing the position of the mass as a function of time?

1. $x(t) = 5\text{cm} \cos(\omega t)$
2. $x(t) = 15.0\text{cm} \cos(\omega t)$
3. **$x(t) = 1.5\text{cm} \cos(\omega t)$**
4. $x(t) = 13.5\text{cm} \cos(\omega t)$
5. $x(t) = 10\text{cm} \cos(\omega t)$

Feedback: review p. 423-424. The mass oscillates around the equilibrium position, which is at 13.5 cm. It's amplitude is the difference between 15.0 -13.5 cm.

14.6 - The Pendulum: Just read the first two pages and the 'tactics box 14.1'. Most important in this section are the expressions for period and angular frequency and examples 14.8 and 14.9.
Skip “The Physical Pendulum" section.

14.6 Q1. As a pendulum swings through its cycle, at the bottom of the swing the mass is ...

1. **moving its fastest and has its least (or zero) acceleration.**
2. moving its slowest and has its greatest acceleration.
3. moving its slowest and has its least (or zero) acceleration.
4. moving its fastest and has its greatest acceleration.

review p. 425-426. The pendulum motion is simple harmonic, so the maximum velocity is at the equilibrium position -- or in the pendulum at the bottom of the swing. When the velocity is at its max, the acceleration is at zero -- where is the acceleration at its max?

14.6 Q2. You are watching your identical twin cousins, Bob and Peter, swinging on a swing together. You use the timer in your cell phone to determine their oscillation period to be 2.0 s. Then Peter gets off. With only Bob (1 child) swinging, what is the period?

1. 4.0 s.
2. >2.0 s but not necessarily 4.0 s.
3. **2.0 s**
4. <2.0 s but not necessarily 1.0 s.
5. 1.0 s
6. Cannot determine without knowing the length of the swing.

Feedback: review p426 -- see equation 14.49. Is there a mass term in the equation for a pendulum?

14.6 Q3. In the past, the swinging weight in a pendulum of a grandfather clock was made entirely of brass. Brass expands when the temperature rises. On a hot day the clock would be ...
**SOME COMPLAINTS ABOUT WORDING !!!

1. too fast.
2. too slow.
3. close enough to the same that one must not compensate for it.

*Feedback: review p.426, particularly eq.14.49. If the length increases then so, too, will the period, thus each swing will take longer and the time will run slower. You can read about the compensation for thermal expansion on wikipedia here:
http://en.wikipedia.org/wiki/Pendulum_clock#Thermal_compensation*

14.7 Damped Oscillations: Read this section carefully. Think about how the loss of energy is responsible for a DECREASE in the AMPLITUDE (and energy), but it has NO EFFECT on the FREQUENCY. Compare this idea to Figure 14.23; try to explain what the envelope of the amplitude is in your own words. Look carefully at equations 14.56 and 14.58 showing the equations underlying Fig. 14.23 and Fig. 14.24. Carefully look at "Energy in Damped Systems". Make sure you understand the definition of the time constant, i.e., how the time constant relates to the amount of energy in a system AND the maximum displacement (amplitude). Look at Fig. 14.25 and work through the Example 14.11 "A damped pendulum".

14.7 Q1. READ THIS QUESTION CAREFULLY:
For non-ideal oscillators (such as a real pendulum) energy is lost and the amplitude (which is the maximum displacement) is no longer constant but also decreases with time.
The energy loss is described by a TIME CONSTANT, τ. This time constant measures the 'characteristic time' during which the energy in an oscillation is dissipated; see Fig. 14.25.
Typically after ONE time constant has elapsed, the system has ...
1. LOST half of its initial energy.
2. LOST 63% of its initial energy.
3. LOST 37% of its initial energy.
4. LOST 13% of its initial energy.
5. lost NO energy.
Feedback: review p. 430. After one complete time constant, the energy in the system is 37% of the initial energy, or in other words, the system has LOST 63% of its initial energy.

14.7 Q2. Which of the following statements, if any, is FALSE about a damped oscillator?
1. The equation for a damped oscillator is the same as for an (undamped) harmonic oscillator BUT with an added exponential decay function e^(-bt/2m) to account for the damping.
2. Energy is always conserved when there is no damping.
3. A larger damping constant, b, causes the oscillations to damp more quickly.
4. decreasing the damping constant, b, will make the oscillations last longer.
5. Light damping, ($b/2m \ll \omega_0$), does not greatly affect the system's oscillation frequency, ω.
6. ALL of the statements are TRUE.

Feedback: review p. 428-429. All the statements are there. Also look at the frequency in Fig. 14.23 -- does it change over time.

14.8 Driven Oscillations and Resonance – There is no math but the concept is important. Try to explain the collapse of the Tacoma Narrows Bridge in the video using the concepts of this section.

14.8 Q1. Chose ALL ANSWERS that CORRECTLY describe a driven oscillator?
(consider the oscillator to be perfect, i.e., no damping).

1. The driving frequency is completely dependent of the oscillator's natural frequency.
2. The driving frequency is completely independent of the oscillator's natural frequency.
3. The amplitude does not increase (much) if the driving frequency is very different from the natural frequency of the oscillator.
4. The amplitude does not increase (much) if the driving frequency matches the natural frequency of the oscillator.
5. The amplitude increases substantially if the driving frequency is very different from the natural frequency of the oscillator.
6. The amplitude increases substantially if the driving frequency matches the natural frequency of the oscillator.

Feedback: review p. 432. Only the frequency-matching system builds up amplitude. If we think of a child on a swing, every time we push the child, the amplitude of their swing increases -- as long as we push them when the child is at the top of their swing. These pushes add up to a large (and fun) swing ride for the child. Note, this push is EXTERNAL from the oscillating system (the child). I could push them at any time I want, but only at one particular time (or position) will I be able to increase the swing amplitude.
