GreatHearts®

Physics I

May 11 – May 15

Time Allotment: 40 minutes per day

Student Name: ________________________________

Teacher Name: ________________________________

Packet Overview

Date	Objective(s)	Page Number
Monday, May 11	Discovering Energy in the Simple Harmonic Oscillator	2-3
Tuesday, May 12	Derive the Period and Frequency Equations for Masses in Simple Harmonic Motion	4-5
Wednesday, May 13	Practice Problems Using Period and Frequency Equations	6-7
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Academic Honesty

I certify that I completed this assignment independently in accordance with the GHNO Academy Honor Code.

Student signature:

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I certify that my student completed this assignment independently in accordance with the GHNO Academy Honor Code.

Parent signature:

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Physics I
May 11 – May 15

GreatHearts®

Monday, May 11

Physics Unit: Vibrations and Waves
Lesson 1: Energy in the Simple Harmonic Oscillator
Requirements: Complete the guided worksheet below.

Objectives: Be able to do this by the end of this lesson.
1. Use conservation of energy to describe the motion of a mass on a spring in simple harmonic motion.
2. Find the velocity of the mass in motion given any point, x.

Introduction to Lesson 1: Today we're going to review applying energy to spring motion. Again, what is new today is determining which values of a spring's amplitude (how far a spring gets stretched or compressed) correspond to the system's quantity of potential and kinetic energy.

1. To stretch or compress a spring, _______________ has to be done. This means that _________________ can be stored in a spring. The equation to describe this is ______________________.

2. Write the equation of the total mechanical energy of a mass attached to a spring.

3. As the mass oscillates back and forth, the energy continuously changes from ______________________ to ___________________________, and back again.

4. In terms of amplitude, at the extreme points, x = ____ and x = _____, the energy is stored in the spring as ______________________________.

5. Write the equation that describes the energy E at these two extreme points. Remember, v = 0 at both points.

6. The total mechanical energy of a SHO is proportional to ________________________________.

7. At the equilibrium point of an oscilating mass on a spring, all of the energy is _________________.

8. Try taking Equation 11-4c and solving for v. You'll get Equation 11-5 so you know what you're aiming for, but show more steps than your book does for full credit. What's amazing about this equation is that you can get the velocity for any position you plug in!

9. A spring stretches 0.15m when a 0.3kg mass is gently owered on it as seen below on the left. The spring is then set up horizontally with the 0.3kg mass resting on a frictionless table as seen below on the right. The mass is pulled so that the spring is stretched 0.1m from the equilibrium point, and resleased from rest. Determine the following (if you need help, let Example 11-4 on p. 291 be your guide, as well as emailing me and coming to guided instruction):

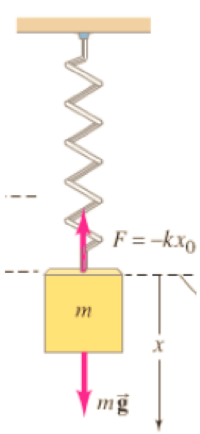
a) the spring stiffness constant *k*

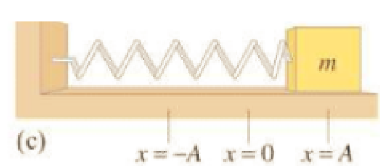
b) the amplitude of the horizontal oscillation *A*

c) the magnitude of the maximum velocity

d) the magnitude of the velocity v when the mass is 0.05m from equilibrium

e) the magnitude of the maximum acceleration of the mass.





Tuesday, May 12

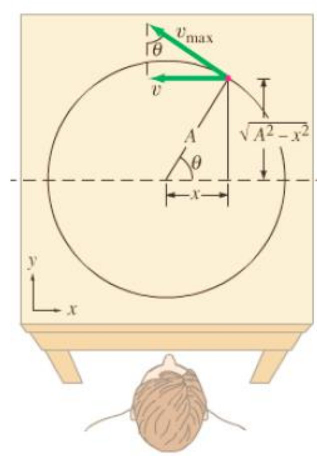
Physics Unit: Vibrations and Waves
Lesson 2: The Period and Sinusoidal Nature of Simple Harmonic Motion
Requirements: Complete the guided worksheet below.

Objective: Be able to do this by the end of this lesson.
1. Write an equation to describe the period of simple harmonic motion in terms of an object's mass and the spring constant.
2. Write an equation to describe an object's frequency in terms of its mass and spring constant.

Introduction to Lesson 2: We are going to derive a very important equation that relates the period of an oscillating spring (or any system in simple harmonic motion) to its mass and spring constant.

1. Take a look at the following diagram. Notice the triangle with two green vectors and a black triangle. Fill in the following table:

	Side Opposite θ	Hypotenuse
Green Triangle		
Black Triangle		



2. Since the triangles are similar, you can use the table above to fill in the following proportion:

$$\frac{v}{\_} = \frac{\_}{A}$$

3. Solve for *v* below.

4. You should have gotten this equation: $v = v_{max}\sqrt{1 - \frac{x^2}{A^2}}$.

Look familiar? It should, and this is very important, because it shows that a mass revolving in a circle has the same relationship between its velocity, position, and amplitude that a spring in motion does. Thus, we can say that both of these systems are in *simple harmonic motion*.

5. Now write the equation for the maximum velocity. It will equal the circumference of the circle on the previous page divided by the period. When you write it down, check your equation with Equation (11-6) on p. 292 in your textbook.

6. Solve for T.

7. Finally, let's see if we can take the equation you wrote above and relate T to mass and the spring constant.

Take these two equations and set them equal to each other:

$$E = \tfrac{1}{2}m(0)^2 + \tfrac{1}{2}kA^2 = \tfrac{1}{2}kA^2.$$

and

$$E = \tfrac{1}{2}mv_{max}^2 + \tfrac{1}{2}k(0)^2 = \tfrac{1}{2}mv_{max}^2$$

8. Solve for A/v_{max}.

9. Lastly, substitute that value into the equation you wrote for #6. This result should look like Equation (11-7a). So the larger the mass, the longer the period.

10. And write the equation in terms of f (flip everything upside down to look like Eq. 11-7b on p. 293). This equation will be useful for Problems 3-5 that you'll do tomorrow.

Wednesday, May 13

Physics Unit: Vibrations and Waves
Lesson 3: Practice Problems
Requirements: Follow instructions below. Work Example 11-6 on p. 293, work Problems 1-5 on p. 317.

Objective: Be able to do this by the end of this lesson.
1. Apply period and frequency equations you derived yesterday to solving problems involving the mass and spring constants of different systems.

Introduction to Lesson 3
Today we'll do some practice problems applying the equations you derived yesterday.

Work Example 11-6: Spider Web on p. 293

Do Problems 1-5 on p. 317.

1)

2)

3)

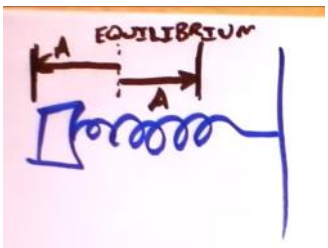
4)

5)

Thursday, May 14

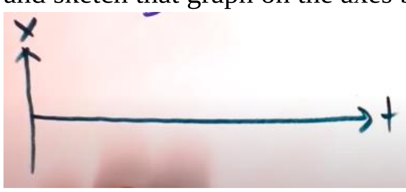
Physics Unit: Rotational Motion
Lesson 4: Wave Equation Review and Practice Problems
Requirements: Complete the guided worksheet below.

First let's do a review of how we derived the wave equation for a mass oscillating on a spring from last week. Once again, this video can be very helpful: https://www.youtube.com/watch?v=iNDRQnhIMK8

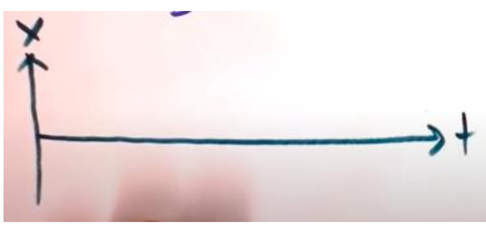


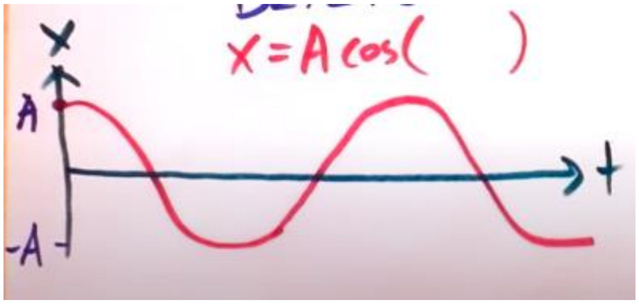
Take a look at this drawing of a spring attached to a wall on the right and mass on the left. When you leave it alone, it stays at an equilibrium position. When you pull it or push it, the distance you pull or push is giving the spring an amplitude, **A**.

1. Say we pull the mass on the spring to the right and plot its back and forth motion on a graph. Go ahead and sketch that graph on the axes below:



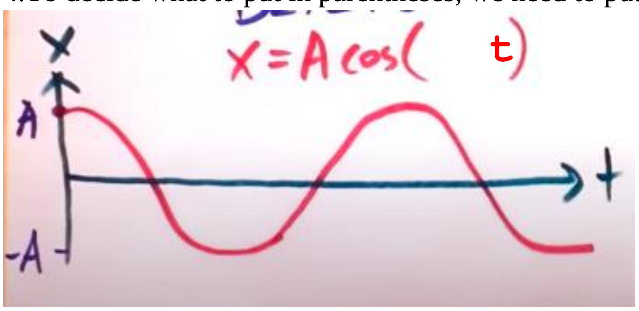
2. Now say we pull the mass on the spring back twice as far and thus double the amplitude. Sketch that graph on the axes below. Feel free to extend the x-axis to fit your graph.





3. Hopefully the shape of your graph looks something like this, and you can see that we're using the cosine function. We can make the function "taller" by multiplying by a number greater than 1. We can also make it "shorter" by multiplying by a number less than one. This is what the amplitude A does. Now what needs to go inside the parentheses? Take a guess and write something inside of them. Hint, think about what the function takes as its input (time), and how to express that input in radians.

4.To decide what to put in parentheses, we need to put in *t*, because the output, *x*, depends on time.

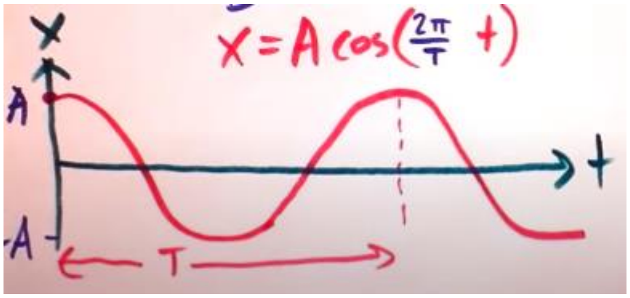


But we've got a problem because we want our final output, x, to be a measure of displacement, which does not include time. How can we cancel time? We can multiply time by a fancy version of 1, in this case, $\frac{2\pi}{T}$. Go ahead and write that to the left of the t in the parentheses in the equation above.

5. Let's make sure this works. In the space below, write what happens to $x = A\ cos(\frac{2\pi}{T}t)$ when t = T. What is cos (2π) ?

6. Do the same thing, except write what happens to $x = A\ cos(\frac{2\pi}{T}t)$ when t = 2T.

7. So this equation works. Whenever we plug in any integer number times T for t, we get a multiple of 2π, which "resets" the cosine wave and gives us the local maximum point, which is the magnitude of the amplitude.



$x = A\,cos(n2\pi)$, where n is any integer. Then, x = cos (n2π) will equal 1, and x = A.

Try it out! Plug in 2, 3, 4, and 10 for n in x = cos (n2π) in the space below and write the number you get. Did you get the same answer for all of them?

8. Let's go back to $x = A\,cos(\frac{2\pi}{T}t)$. What is the $\frac{2\pi}{T}$ part? Look familiar? Take a guess, and then read below.

We haven't seen exactly this form before, but what we're looking at is a measure of radians over time, or angular velocity. Because we're looking at bit T, or period, and not little t, or time, we're going to call $\frac{2\pi}{T}$ **angular frequency**. We'll use the same symbol ω (omega) for angular frequency. For the last item of the day, in the space below, substitute ω in for $\frac{2\pi}{T}$ and rewrite the wave equation $x = A\,cos(\frac{2\pi}{T}t)$ above.

Congratulations, you've just derived the wave equation again.

Now let's put this equation to work!
9. Work all steps for Example 11-7 on p. 294.

10. Do Problem 16 (a) and (b).

11. Do Problem 19 (a) and (b).

Friday, May 15

Physics Unit: Waves and Vibrations
Lesson 5: Minor Assessment
Requirements: Take the minor assessment that follows on the next page.

Introduction to Lesson 5: Take 10-15 minutes to study for the minor assessment on this week's packet work. When you're ready, flip over to start.

Physics I – Minor Assessment on Simple Harmonic Motion Name: ___________________________

1. Draw the graph of a mass on a spring pulled back and then released. How many radians does the graph "restart"?

2. Write the equation for the force exerted by a spring. What does the minus sign indicate? What is the proportionality constant?

3. An elastic cord is 2m long when a weight of 120N hangs from it but is 2.6m long when a weight of 180N hangs from it. What is the spring constant *k* of this elastic cord?

4. A 2kg weight oscillates from a vertically hanging light spring once every 0.65s. Write the equation giving the weight's position *y* as a function of time, assuming it started by being compressed 18cm from the equilibrium position (where y = 0) and released. The following equations may be helpful.

$f = \frac{1}{T}$, $\omega = 2\pi f$, $Y = A\cos \omega t$

Answer Key

Lesson 3 Answers

1.

$d = 4A$

Substitute 0.18m for *A* and find the distance travelled by the particle.

$$\begin{aligned} d &= 4A \\ &= 4(0.18\text{m}) \\ &= 0.72\text{ m} \end{aligned}$$

Therefore, the total distance travelled by the particle in a simple harmonic motion is $\boxed{0.72\text{ m}}$.

2.

Increase in weight $(\Delta w) = 180\,N - 75N$

$= 105\,N$

Increase in length $(\Delta l) = 0.85 - 0.65$

$= 0.2\,m$

Using Hooke's Law,

$F = k\Delta l$

$k = F / \Delta l$

$= \dfrac{105\text{N}}{0.2\text{m}}$

$= 5.25 \times 10^2$ N/m

Spring constant $\boxed{k = 5.3 \times 10^2\text{ N/m}}$

3.

Mass of car $(m) = 1500\ kg$

Amount of compression $(x) = -5 \times 10^{-3}\ m$

Mass of driver $(M) = 68\,kg$

The added force of 68 kg causes the spring to compress by an amount 'x'

The spring constant

$k = \dfrac{F}{x}$

$= \dfrac{68 \times 9.8}{5 \times 10^{-3}}\,N/m$

$k = 1.33 \times 10^5\ \ N/m$

The frequency of vibrations

$$f = \frac{1}{2\pi}\sqrt{k/m}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1.33\times10^5}{(1500+68)}}Hz$$

$$= 1.5\,H_z$$

Frequency of vibration $\boxed{f = 1.5\ H_z}$

4.

(A) Mass of fish $(m) = 2.7kg$

Amount of stretching $(x) = 3.6cm$

The spring constant $k = \frac{F}{x} = \frac{mg}{x}$

$$= \frac{2.7\times9.8}{3.6\times10^{-2}}N/m$$

$$\therefore \boxed{k = 735N/m}$$

(B) If the fish is pulled down by 2.5cm more, the amplitude is the distance pulled down form equilibrium

$$\therefore \boxed{A = 2.5\times10^{-2}m}$$

The frequency of oscillation is found from the total mass and the spring constant

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{735N/m}{2.7kg}}$$

f = 26 Hz

5.

Since the same cord is using in both the cases so spring constant is same regardless of what mass is hung from the spring.

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$f\sqrt{m} = \text{constant}$$

Apply this equation for mass m_1 and m_2 then we get

$$f_1^2 m_1 = f_2^2 m_2$$

$$f_2 = f_1\sqrt{\frac{m_1}{m_2}}$$

Substitute $3.0\,\text{Hz}$ for f_1, $0.6\,\text{kg}$ for m_1 and $0.38\,\text{kg}$ for m_2 in the above equation an solve for frequency of cord.

$$f_2 = (3.0\,\text{Hz})\sqrt{\frac{0.60\,\text{kg}}{0.38\,\text{kg}}}$$

$$= 3.769\ \text{Hz}$$

Therefore, the frequency of the cord is $\boxed{3.769\ \text{Hz}}$

16)

Given equation is $x = 0.45\ \cos 6.40t$

(A) Comparing this equation with the standard SHM equation $x = A\cos\ \omega t$

The amplitude $\boxed{A = 0.45\,m}$

(B) The angular frequency ω = 6.40 rad/s

$2\pi f = 6.40$

$f = 6.40 / 2\pi$

Frequency $\boxed{f = 1.02\,Hz}$

19)

Mass of pumpkin $(m) = 2.00\,kg$

Time taken for 1 oscillation $(T) = 0.65\,\text{secs}$

The frequency of oscillation $f = \dfrac{1}{T}$

$= \dfrac{1}{0.65}$ Hz

$= 1.54\ Hz$

Angular frequency $\omega = 2\pi\ f$

$= 2\pi \times 1.54$

$= 9.67 / \text{sec}$

The amplitude of oscillation is the compression $A = 0.18\,m$

(A) As the mass is released at the maximum displacement

the equation of displacement of the pumpkin as a function of time't' is given

by a cosine function

$Y = A\cos\ \omega t$

$\boxed{Y = (0.18)\cos(9.67)t}$

(B) The time taken to return to the equilibrium position,

t = one quarter of T (Period)

$t = \dfrac{0.65}{4}$ s

$\boxed{t = 0.16\,\text{secs}}$