GreatHearts®

Physics I

May 4 – May 8

Time Allotment: 40 minutes per day

Student Name: ________________________________

Teacher Name: ________________________________

Physics I
May 4 – May 8

Packet Overview

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Additional Notes:

Khan Academy is a great online resource for physics, though this packet does not require access to the Internet. The Physics videos can help with rotational motion concepts, while the algebra and geometry videos can help with the concept of radians.

Another great resource is a YouTube channel called "Doc Schuster". Dr. Schuster is a high school physics teacher in St. Louis who makes great video lectures with magic markers and paper. His playlist "AP Ch 13 – Periodic Motion and Resonance of Oscillators" will be helpful in this new unit.

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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Monday, May 4

Physics Unit: Vibrations and Waves

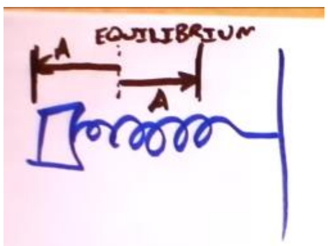
Lesson 1: Deriving the Wave Equation

Requirements: Follow the instructions on the guided worksheet below. Optional: Much of this lesson comes from Doc Schuster's YouTube video titled, "Simple Harmonic Motion Introduction" that you can watch here: https://www.youtube.com/watch?v=iNDRQnhIMK8&list=PLLUpvzaZLf3K-Tl6n_GD3ZEebgQ83QynE

Objectives: Be able to do this by the end of this lesson.

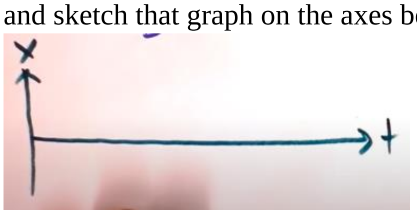
1. Graph the motion of a mass on a spring being pulled back and released.
2. Model that motion with the cosine function.
3. Derive an equation to relate the position and time of the moving mass.

Introduction to Lesson 1: Last week, we learned that swinging pendulums create what is called periodic motion. This motion can be graphed on a position versus time graph to look like the same waves we see when we graph the cosine function. In this lesson, we will use mathematics to connect the periodic motion of pendulums and springs to equations that express their motion in terms of sine and cosine waves, as well as in terms of the angular quantities we learned in the last unit.



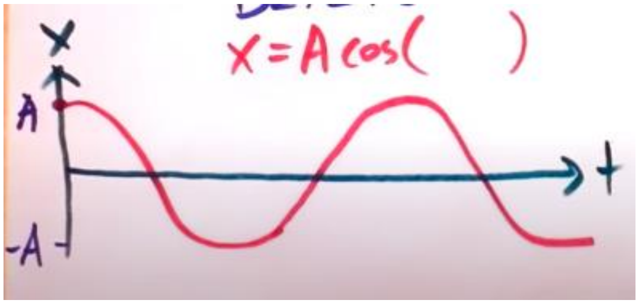
Take a look at this drawing of a spring attached to a wall on the right and mass on the left. When you leave it alone, it stays at an equilibrium position. When you pull it or push it, the distance you pull or push is giving the spring an amplitude, **A**.

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:



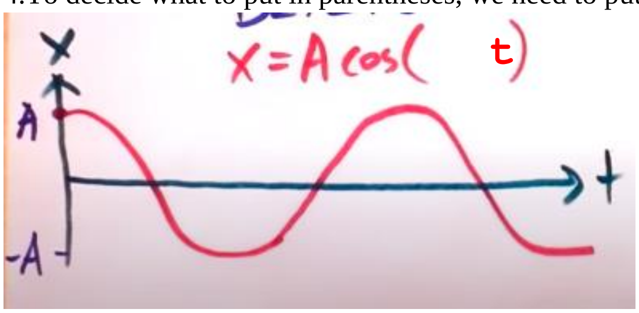
2. Now say we pull the mass on the spring back twice as far and thus double the amplitude. Sketch that graph on the axes below. Feel free to extend the x-axis to fit your graph.

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.

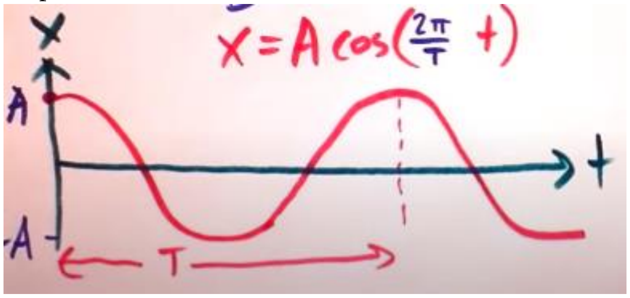


But we've got a problem because we want our final output, x, to be a measure of displacement, which does not include time. How can we cancel time? We can multiply time by a fancy version of 1, in this case, $\frac{2\pi}{T}$. Go ahead and write that to the left of the t in the parentheses in the equation 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: one of the most important equations describing the position of a wave in terms of time! If this hasn't made sense yet, that's okay. We're going to go back over it a lot this week and next week. But don't let that stop you from emailing me questions or coming to Guided Instruction on Zoom!

Tuesday, May 5

Physics Unit: Vibrations and Waves
Lesson 2: Simple Harmonic Motion
Requirements: Read p. 286-289. Complete the guided worksheet below.

Objective: Be able to do this by the end of this lesson.
1. Define aspects of wave motion.
2. Describe motion of a spring in the language of periodic motion.

Introduction to Lesson 2
What is a wave? Where do waves come from? In this section, we will build vocabulary for talking about waves.

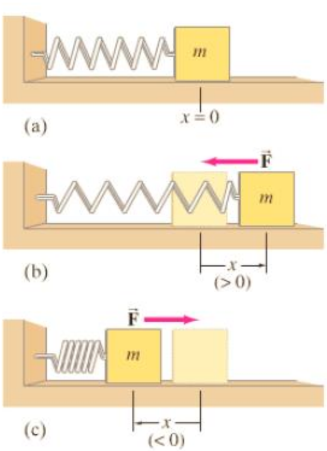
1. Read p. 286 carefully. Write at least one complete sentence explaining the difference between a vibration and a wave.

2. Define periodic motion

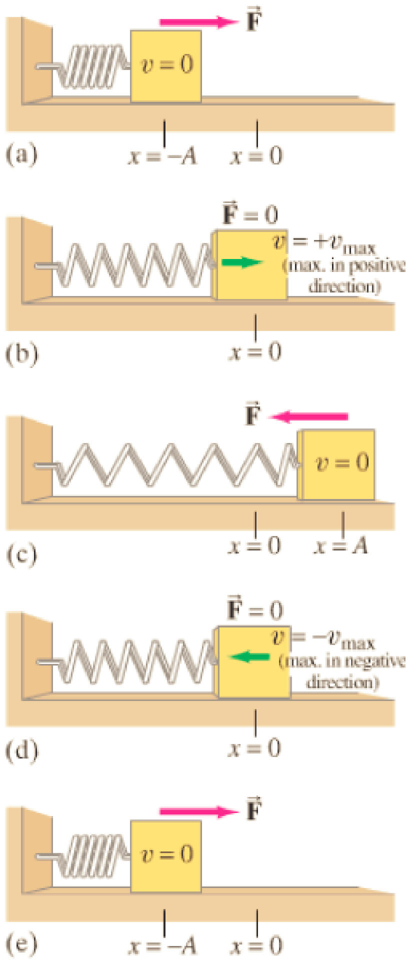
3. Define equilibrium position

4. Define restoring force for a spring.

5. Write the equation for the force exerted by a spring. What does the minus sign indicate about the direction of motion of the spring? What is the proportionality constant? Use the drawings below to illustrate your point.



6. Consider a spring compressed a distance x = -A and then released (shown below). Describe in detail its changing position relative to the equilibrium position, as well as its changing velocity. Write one sentence for each illustration (5 total).



7. Do Exercise A on p. 288. You can check your answers on p. 321.

8. Define <u>displacement</u>.

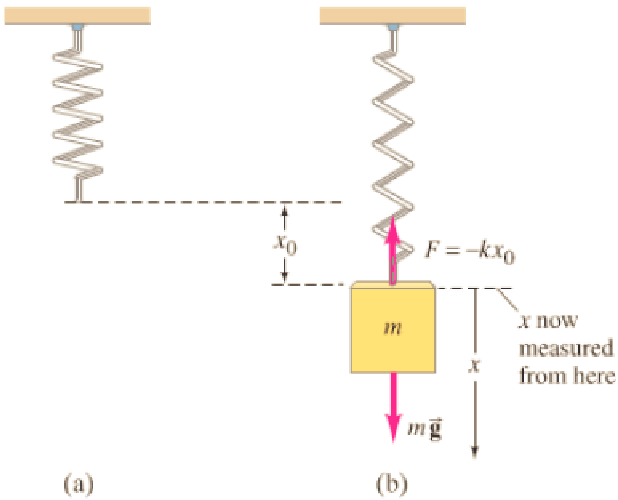
9. Define <u>amplitude</u>.

10. Define <u>cycle</u>

11. Define <u>period</u>

12. Define <u>frequency</u>

13. The diagram below shows 2 vertical springs. What is x_0? Why is x now measured lower for the spring with the mass attached to it?



Wednesday, May 6

Physics Unit: Vibrations and Waves
Lesson 3: Practice Problems and Conceptual Questions About Waves
Requirements: Follow instructions below. Work Example 11-1 on p. 289, answer Questions 1-5 on p. 316.

Objective: Be able to do this by the end of this lesson.
1. Define a simple harmonic oscillator and simple harmonic motion.
2. Apply Hooke's Law to periodic motion

Introduction to Lesson 3
Today, we're going to work through some practice examples and conceptual questions.

1. Write both parts of the question asked in Example 11-1: Car springs on p. 289. Then try to solve it without looking at the solution. Check your answer and follow the steps of the solution if you need help.

2. Define simple harmonic motion (SHM)

3. Define simple harmonic oscillator (SHO)

Answer the following Questions found on p. 316.

1)

2)

3)

4)

5)

Thursday, May 7

Physics Unit: Rotational Motion
Lesson 4: Energy in the Simple Harmonic Oscillator
Requirements: Read p. 289-290. Follow the instructions on the guided worksheet below.

Introduction to Lesson 4: Today we're going to apply energy to spring motion. We did this a few chapters ago, so much will be review, but 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 ______________________________.

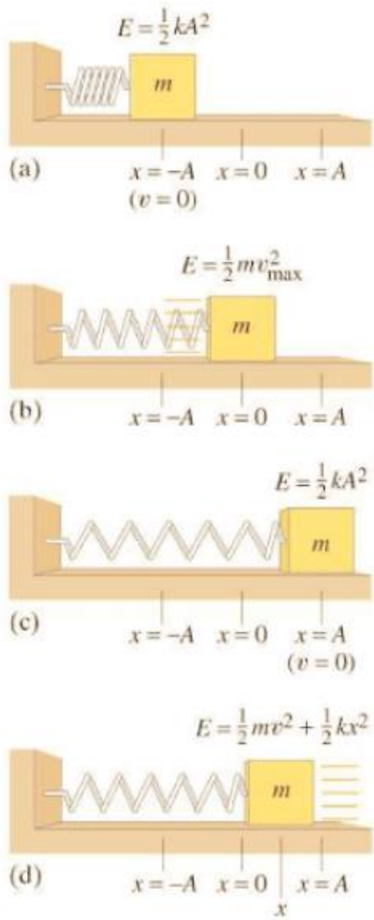
5. Write the equation that describes the energy E at these two extreme points. Remember, v = 0 at both points.

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.

9. Draw "energy buckets" for the following springs and masses in SHM (see p. 290). Which have purely potential energy? Which have purely kinetic? Which have a mixture. Write 1 sentence for each answer you give explaining why you chose what you chose.



10. Write out each part of the question asked in Conceptual Example 11-3 on p. 290. Try to answer it without looking at the response.

11. Do Exercise B on p. 290. Check your answers on p. 321

Friday, May 8

Physics Unit: Rotational Motion
Lesson 5: Quiz
Requirements: Take the quiz that follows on the next page.

Introduction to Lesson 5: Take 10-15 minutes to study for a quiz on this week's packet work. When you're ready, flip over to start the quiz. Remember to check your answers with the solutions at the end of this packet with a red pen.

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. What is amplitude?

4. What is period?

5. What is frequency?

6. Explain why the motion of a piston in an automobile engine is approximately simple harmonic motion.

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Answer Key

Lesson 3 Answers

1.

Some examples of everyday objects that exhibit S.H.M are:

(1) The balance wheel of a watch

(2) A plastic ruler held over the edge of a table

(3) The strings of a piano or guitar when gently struck.

(4) The pendulum of a grand father clock

(5) Leaves on the surface of a disturbed pond

(6) The free end of a diving board after a diver jump

(7) Cars oscillate up and down when they encounter a bumper

(8) A tuning fork when struck with a hammer.

In all the above cases the object oscillates about the mean position such that the restoring force is directly proportional to the displacement from the mean position.

2.

The maximum acceleration of simple harmonic oscillator is given by the equation $a_{\max} = -\omega^2 A$

Here, ω is angular frequency and A is displacement

Yes, at mean position the acceleration of oscillator becomes zero because the displacement at mean position is also zero. So, the acceleration of the oscillator is zero at the mean position.

3. The piston moves in a circular manner with a constant speed and constant time (assuming constant motion). During this motion, the force on the moving piston is a maximum at its extreme position and the speed of the piston at this extreme position is zero.

4.

The real spring has mass, which is greater than the mass oscillating at the end of an ideal spring results in a smaller frequency, as the frequency is inversely proportional to the given mass from the relation,

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

Here, k is the spring constant and m is the mass.

Thus, the frequency will be smaller than that for an ideal spring, and since $f = 1/T$,

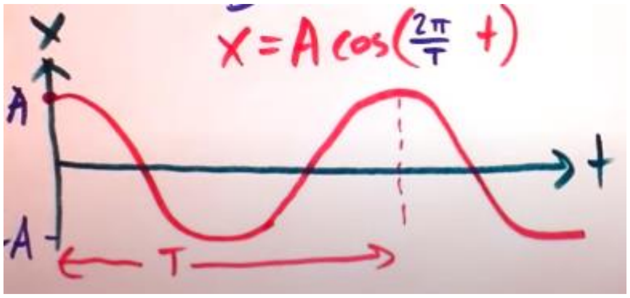
the true period will be larger than the ideal period.

It's okay if you didn't get this one exactly right. We'll look at this concept more carefully next week!

5. Double the amplitude or reduce the mass by ¼.

Quiz Answers

1.



The cosine function resets every 2π radians.

2. F = -kx. The minus sign indicates that the restoring force is always in the direction opposite to the displacement, x. k is the spring constant that describes the stiffness of a spring.

3. The maximum displacement of a pendulum, mass on spring, or object in simple harmonic motion.

4. Period is the time required for one complete cycle of an oscillatory motion.

5. Frequency is the number of cycles per second of an oscillating object.

6. See #3 on solutions for Lesson 3.