BiteScis

Student Handout

Curing Cancer with the Wave Properties of Light

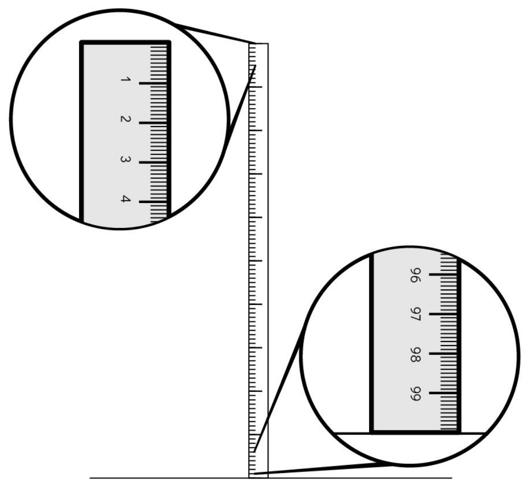
Curing Cancer with the Wave Properties of Light

Introduction

Light is a wave, but it is very different from the ocean waves that crash on the shore or sound waves that allow us to hear music. Because a light wave is composed of oscillating electric and magnetic fields it can cause electrons in metals to oscillate. In this lesson, you will model the oscillation of electrons using a mass and a spring. You will then examine how this model can be extended to understand how scientists are using light and very, very tiny pieces of gold to treat cancer.

What To Do, Part 1: An Oscillating Spring

Step 1. Orient a meter stick vertically (straight up and down), with the bottom (100-cm mark) on the ground. To do this, either tape the meter stick to the wall or have one group member hold it against the edge of a desk.

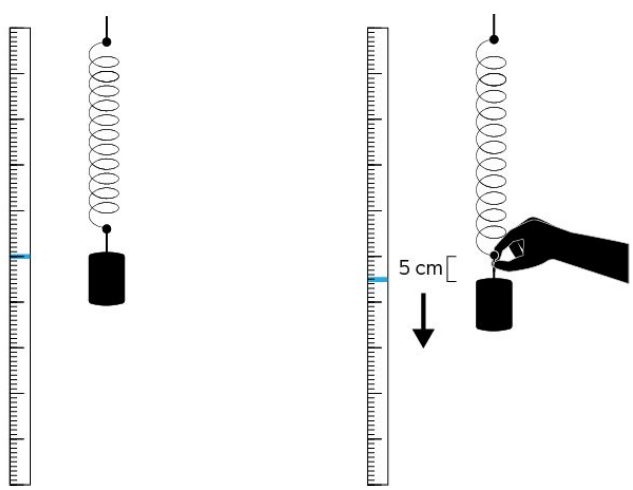


Step 2. Attach the mass to the bottom of the spring and secure it tightly enough with tape so that the mass cannot fall off the spring even if the spring is moving quickly.

Step 3. Hold the spring close to the meter stick and let the mass dangle down. You do not need to hold it at 0 cm, but you may want to try to be consistent so you can more easily compare trials.

Step 4. With a piece of tape, mark the meter stick at the spot where the top of the mass is next to the meter stick as shown in the diagram below—this is the mass's resting position.

Step 5. While holding the top of the spring still, pull the mass down 5 cm from its resting position and let it go. *Note: The mass should bounce up and down at about 5 cm from its resting position. This is the amplitude of the oscillation. One oscillation is when the mass goes from the lowest point to the highest point and back to the lowest point. The oscillation will be dampened by friction and the mass will eventually come to a stop.*



Step 6. Pull the mass down 5 cm again, but this time you will be measuring how long it takes the mass to complete five oscillations. You should have one person count the oscillations while the other person looks at the stopwatch. The stopwatch person should start the stopwatch as soon as the other person lets go of the mass. Record your data in the table below.

Step 7. Repeat Steps 5 and 6 two more times for a total of three trials.

Step 8. Repeat Steps 5–7, but pull the mass down 10 cm away from its resting position (the oscillation will have an amplitude of 10 cm now). Record your data in the table below.

Amplitude (cm)	Time for Five Oscillations (s)			
	Trial 1	Trial 2	Trial 3	Average
5 cm				
10 cm				

Step 9. Find your average time for five oscillations for both amplitudes. Show your work below and record the average in the table.

Step 10. Answer the analysis questions below, reading the Bite when instructed.

Analysis Questions, Part 1

1. Calculate the period of oscillation (the time for one cycle) for both amplitudes. Show your work and record your final answer in the table below.

Amplitude (cm)	Period (s)
5 cm	
10 cm	

2. Calculate the frequency (the number of oscillations in one second) for both amplitudes. Show your work and record your final answer in the table below.

Amplitude (cm)	Frequency (Hz)
5 cm	
10 cm	

Every vibrating object (such as a spring or a guitar string) has its own frequency at which it always oscillates after you pull it and then let it go. This is called its **natural frequency**. The natural frequency depends on the object. For example, a stiffer spring will oscillate faster and therefore have a larger natural frequency than a looser spring. For a particular spring, it doesn't matter how far you pull the spring, when you let it go, it will always oscillate at the same frequency. The same is true for other oscillating objects.

3. Does your data support there being a natural frequency for your spring? Explain your answer, referencing your data and the information above. If your data doesn't support there being a natural frequency for your spring, what errors do you think might have been present in your experiment?

Observe your teacher's light demonstration and then answer Question 4.

4. Which color of light (red or green) penetrates human tissue more easily? Explain your answer, providing evidence from the demonstration.

STOP & read Science Bite:
Curing Cancer with Light and Gold

5. What properties of nanoparticles make them useful for treating cancer?

Nanoparticles come in different shapes, including elongated particles called nanorods. The electrons in gold nanorods behave much like a mass on a spring (see **Figure 1.**): after the electrons are pushed toward one end, the electrons swing back toward the other end and keep going back and forth at a particular frequency, like a natural frequency in mass-spring systems.

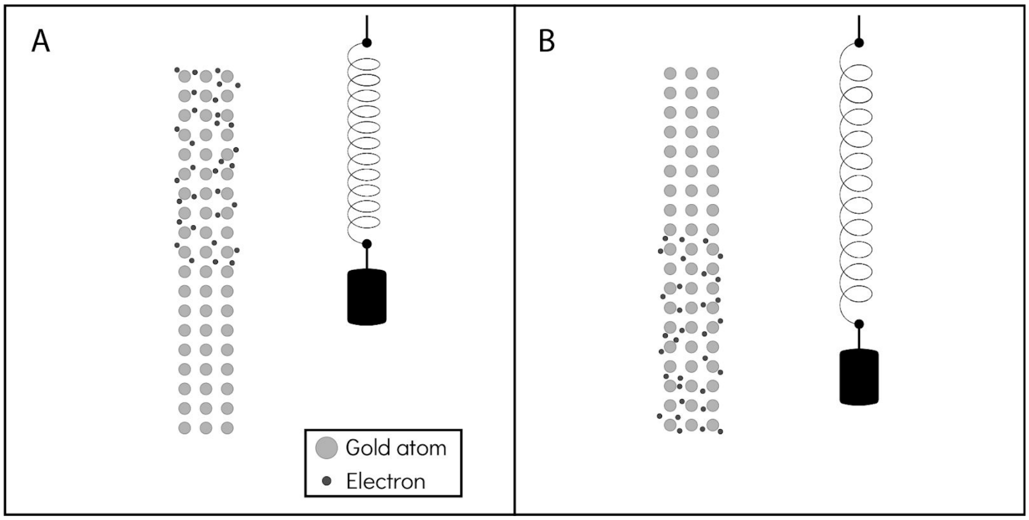


Figure 1. Gold Nanorods are Like Springs. A. Shows the electrons near the top end, like a mass on a spring that has gone up. **B.** shows the electrons near the bottom end, like a mass on a spring that has gone down.

6. Compare and contrast the electrons in a gold nanorod being hit with light and a mass on a spring—how are they similar and how are they different?

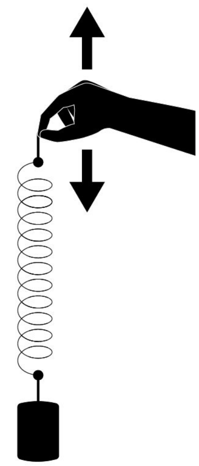
What To Do, Part 2: Modeling Nanoparticle Movement

Now you will use the spring to understand in detail what happens to electrons in a gold nanoparticle when they are exposed to light. This time, you won't pull the mass down and let it go. Instead, you will repeatedly move the top of the spring up and down. When you move up, the spring pulls the mass upward. When you move down, the spring pushes the mass downward. This is similar to how the light wave's electric field pushes the electrons up and down in the gold nanoparticle.

Step 11. Warning! **The spring can move a lot, so put on safety goggles and hold the spring far from your face so it does not hit you.**

Step 12. Hold the spring high above the floor so it does not hit the ground.

Step 13. Repeatedly move the top of the spring up and down as close as you can to the mass and spring's natural frequency, which is the frequency you wrote down in Question 2. When moving the top of the spring, move it up approximately 2 cm above its starting position and then down approximately 2 cm below its starting position and repeat this about 10 times in a row—in other words, do this for 10 oscillations. For example, if the mass and spring had a natural frequency of 4 seconds, it should take you 4 seconds to go from pulling the spring up to pushing it down to pulling it back up again. You can use the stopwatch to make sure you are approximately moving the spring at the right frequency.



Try this a few times to get the hang of it. You should notice your hand is moving in sync with the mass. Observe carefully and answer Question 5.

7. What happens to the amplitude of the mass over the course of the 10 oscillations?

The frequency at which you are moving the top of the spring up and down is called the **driving frequency** because you are driving (exerting a force on) the spring.

Step 14. Now you are going to repeat the Steps 11–13, using a different driving frequency. Try to use a frequency that is about half the natural frequency (you will push down on the spring half as often). Observe carefully and answer question 5.

Step 15. Answer the analysis questions below.

Analysis Questions, Part 2

8. What is different about the movement of the spring when you are driving the spring at half the natural frequency as compared to when you are driving the spring at its natural frequency?

As you saw, a particular driving frequency caused the spring to have a large amplitude and a steady motion. We call it **resonance** when an oscillating object has a large amplitude as a result of being pushed by a particular frequency. The electrons in gold nanoparticles also experience resonance. Use your understanding of springs, gold nanoparticles and light to answer the following questions.

9. Why do the electrons in a gold nanorod oscillate with the largest amplitude and largest speed when they are exposed to light with a frequency that is the same as the natural frequency of the electrons' oscillation?

10. Why is it important to make the electrons move as fast as possible when treating cancer?

11. To transfer energy to the spring by moving it up and down, you needed to be touching the spring. Does the source of light the scientists use need to be in direct contact with the gold nanoparticles in order to transfer energy to the nanoparticles? Explain your answer.

12. Connect to the Big Question. Electrons are very small and impossible to see with the naked eye or a standard microscope. However, scientists are able to tell when the electrons are resonating in the gold nanoparticles. What macroscopic observation could scientists make that would provide evidence that the electrons are resonating? How is this type of observation different from how you determined that your mass on a spring was resonating?