3.2 Grade 8

CONCEPT 4

The particle model of light explains that light has particle-like properties.

Activity

Thought Experiment

A thought experiment is an experiment that is carried out in your head.

1. Complete the thought experiment below before you read Concept 4.

   Your friend challenges you to try to make a bowling ball start rolling by rolling other balls toward it. What would happen in the following situations?

   a) You roll table-tennis balls toward the bowling ball. You can use as many table-tennis balls as you want. Can you make the bowling ball roll?

   b) Repeat the thought experiment with tennis balls. What will happen?

   c) You can choose any other type of ball you want. What type of ball would you choose to roll at the bowling ball to make it start rolling? Explain why you made the choice that you made.

2. Read Concept 4. Compare the results of your thought experiment with **Figure 3.16**. What part of your thought experiment is similar to the red light? What part of your thought experiment is similar to the blue light?

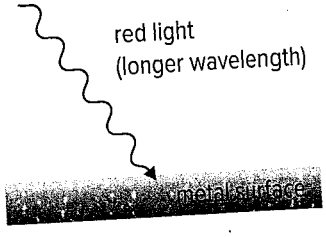
You might think Young's experiment convinced scientists that light (and every type of electromagnetic radiation) has the properties of a wave. But there was a property of light that the wave model could not explain: the photoelectric effect. **Figure 3.15** describes this effect. **Figure 3.16** on the next page gives Albert Einstein's explanation of why the effect occurs and why light has both wave-like and particle-like properties.

Figure 3.15 The Photoelectric Effect

This effect was first discovered by a scientist named Philipp Lenard. He shone different colours of light onto the surface of a certain metal and observed the following results:

Red Light: Electrons are *never* given off when energy from red light hits the metal.

- Electrons are not given off no matter how bright the red light is.
- Electrons are not given off no matter how long the red light shines on the metal.



Blue Light: Electrons are *always* given off when energy from blue light hits the metal.

- Electrons are always given off no matter how dim the blue light is.
- Electrons are always given off no matter how briefly the blue light shines on the metal.

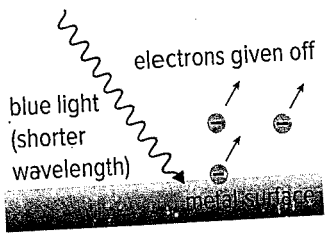


Figure 3.16 Einstein's Thought Experiment

Einstein realized that the wave model of light could not explain the photoelectric effect. If light interacts with the metal like a wave, waves of red light should eventually "pile up" enough energy to give off electrons. But this doesn't happen. So some other difference between red and blue light must cause the effect. Here is how Einstein reasoned.

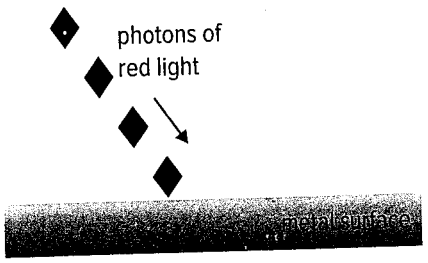
1. The photoelectric effect can only be explained if light acts like a particle when it interacts with matter.

Light does not interact with matter as a flowing stream, like water from a faucet.

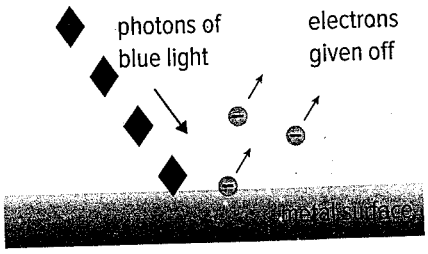
Light interacts with matter as packets or distinct particles, like water in ice cubes.

2. Einstein called the packets or particles of energy *photons*. Each photon must carry an exact amount of energy that is enough to make the metal give off electrons. Otherwise, nothing will happen when the photons strike the metal.

Red Light: Photons of red light *do not* carry enough energy to make the metal give off electrons.



Blue Light: Photons of blue light *do* carry enough energy to make the metal give off electrons.



3. Photons must carry more energy as the frequency of electromagnetic radiation increases and wavelength decreases.

Red Light: Red light has a lower frequency and a longer wavelength. Photons of red light carry less energy.

Blue Light: Blue light has a higher frequency and a shorter wavelength. Photons of blue light carry more energy.

In summary: Einstein realized that the best explanation for the photoelectric effect was that light acts like a particle when its energy is absorbed by an object. This particle, called a photon, acts a lot like a particle of matter.

Before you leave this page . . .

1. Does light have the properties of a wave, a particle, or both? Explain your reasoning.
2. Scientists build on the work of other scientists. Explain how this is true of Einstein's explanation of the photoelectric effect.