

McGraw-Hill Ryerson

BC Science CONNECTIONS

8

BC Science Connections 8

UNIT 3

Energy can be transferred as both a particle and a wave

TOPIC 3.2

How can models explain the properties of electromagnetic radiation?



TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Topic 3.2: How can models explain the properties of electromagnetic radiation?

- Scientists use models to represent ideas and concepts.
 - Visible light is often used as a model to study other types of electromagnetic radiation



The game plan shown here is a type of model.

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Concept 1: Visible light can be used to model all types of electromagnetic radiation.

Properties of electromagnetic radiation:

- Invisible as it travels
- Involves the transfer of energy from one place to another
- Can travel through empty space
- Travels through empty space at the speed of light (3.00×10^8 m/s)
- Has both electrical and magnetic properties

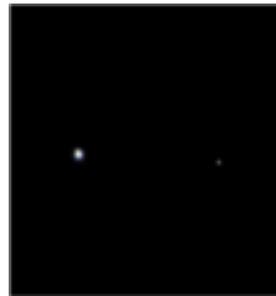


Figure 3.7: Visible light and other electromagnetic radiation from the Sun travels 150 million km to reach Earth. The brighter object is Earth; the smaller object is our Moon.

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?**Concept 1: Visible light can be used to model all types of electromagnetic radiation.**

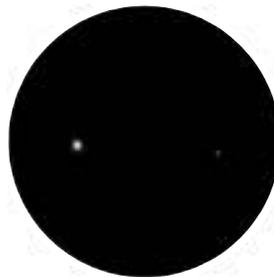
The seven types of electromagnetic radiation have a lot in common.

- Studying one type can tell you a lot about the others
- Visible light is used as a model to study electromagnetic radiation
 - Easy and safe to study
 - Becomes visible when it interacts with matter

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?**Discussion Questions**

- Why is visible light used as a model for other types of electromagnetic radiation?
- Explain one way that visible light is different from other types of electromagnetic radiation and one way it is similar to them.



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Concept 2: The ray model of light explains that light travels in straight lines.

- Euclid: Greek mathematician that suggested that light travels in straight lines
 - Led to the development of the **ray model of light**



The Sun is a source of all types of electromagnetic radiation.

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Understanding the Ray Model of Light

- The **ray model of light**:
 - The idea that light travels in straight lines
 - Ray: an arrow that is used to show the direction of the straight-line path of light



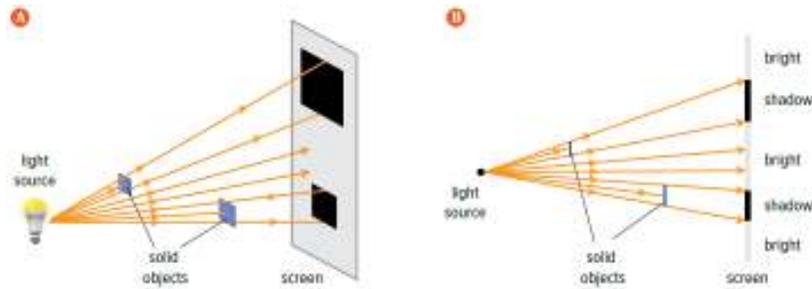
Figure 3.8: Light from the light source cannot bend around the person's hand. The hands block light and cast a shadow on the wall. Therefore, light must travel in straight lines.

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Using Ray Diagrams to Model Visible Light

- Ray diagrams:
 - Used to study and predict how light behaves
 - Rays can be used to predict the location, size, and shape of shadows

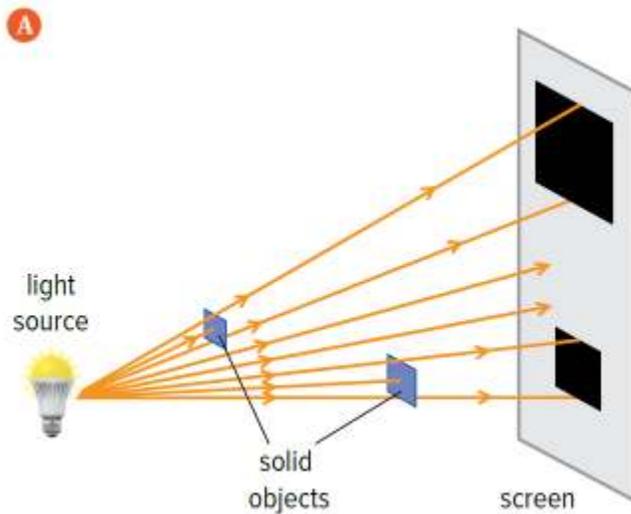


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Using Ray Diagrams to Model Visible Light

Figure 3.9A:
Notice that the distance between an object and the light source affects the size of the shadow.

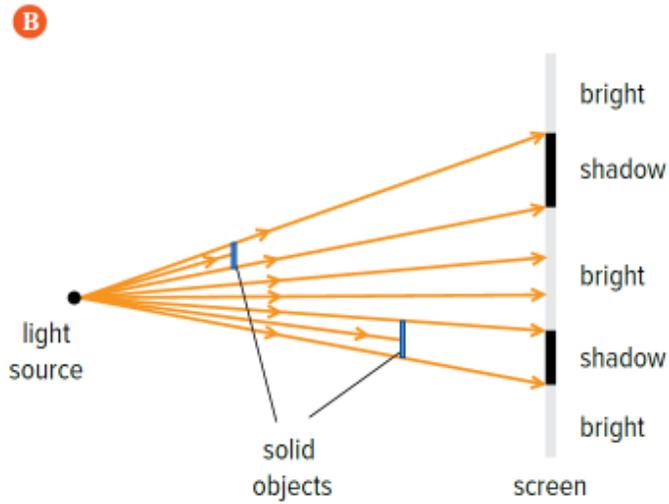


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Using Ray Diagrams to Model Visible Light

Figure 3.9B: Ray diagrams are easier to draw if you view the object from the side. The light source can be represented as a dot.



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Using Ray Diagrams to Model Visible Light

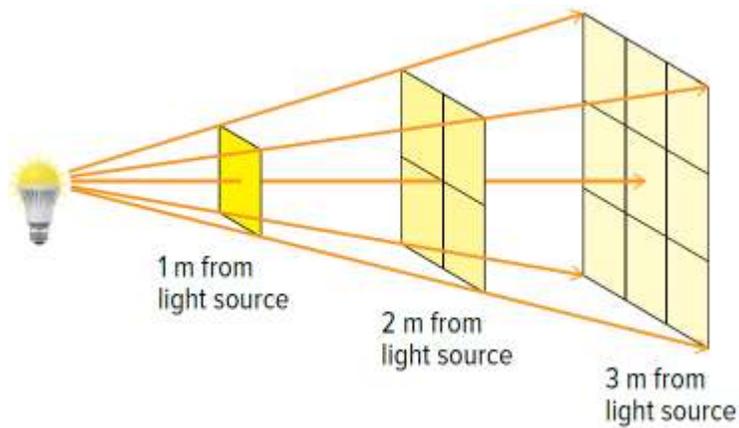


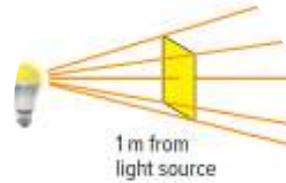
Figure 3.10: Light rays spread out as they travel from a light source and get dimmer with distance.

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Discussion Questions

- Like visible light, microwaves spread out from a source. How might this effect cell phone use?

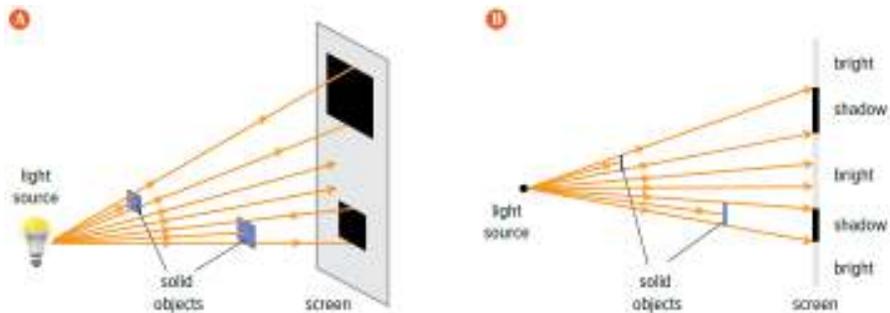


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Discussion Questions

- In Figure 3.9 (shown here), why does the smaller object cast the bigger shadow?



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Concept 3: The wave model of light explains that light has wave-like properties.

- Some scientists thought that light was a stream of particles that had particle-like properties (**particle model of light**)
- Early 1800s: Thomas Young performed an experiment that supported the idea that light has properties of a wave
 - **Wave model of light:** the idea that light has wave-like properties

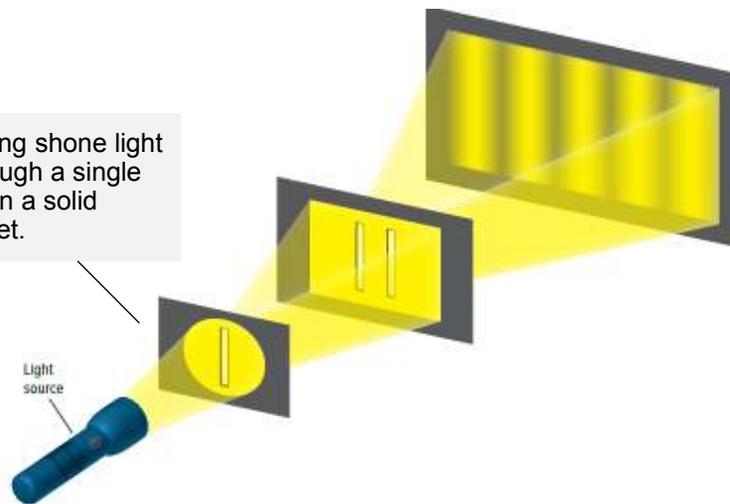


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Young's Experiment: Wave Model of Light

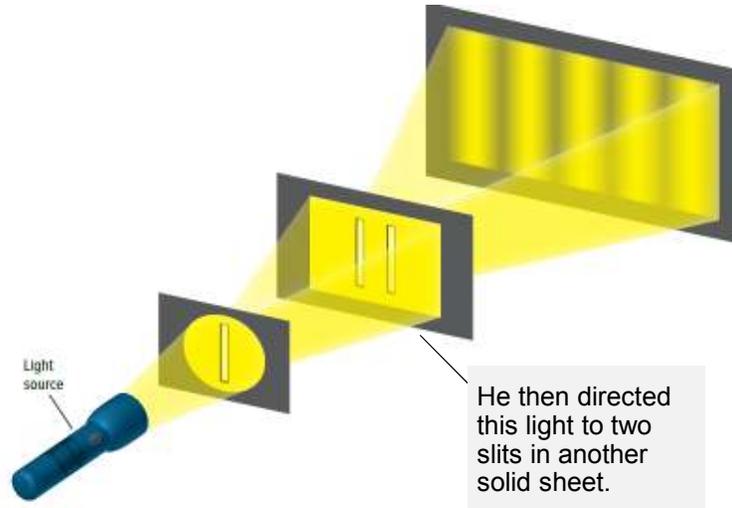
Young shone light through a single slit in a solid sheet.



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

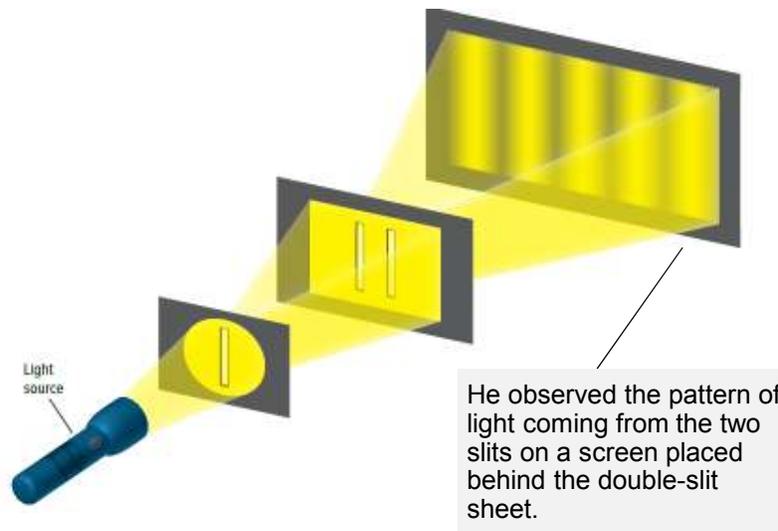
Young's Experiment: Wave Model of Light



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Young's Experiment: Wave Model of Light

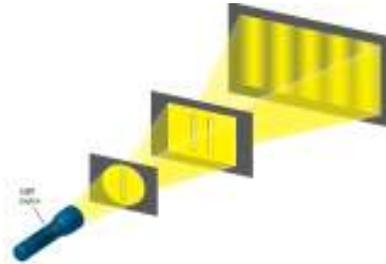


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Young's Experiment: Results and Conclusions

- If light was like a particle: pattern would be two lines.
- If light was like a wave: light would spread out into a series of lines
 - Young saw that the light spread out into a series of lines when it passed through the two narrow slits
 - Therefore, light had wave-like properties

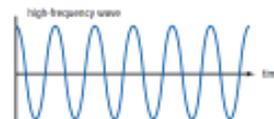
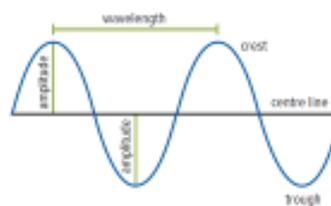


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Properties of Light Waves

- Light waves have some things in common with water waves:
 - Both move energy from one place to another
 - Both have wavelength, amplitude, and frequency



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Properties of Light Waves

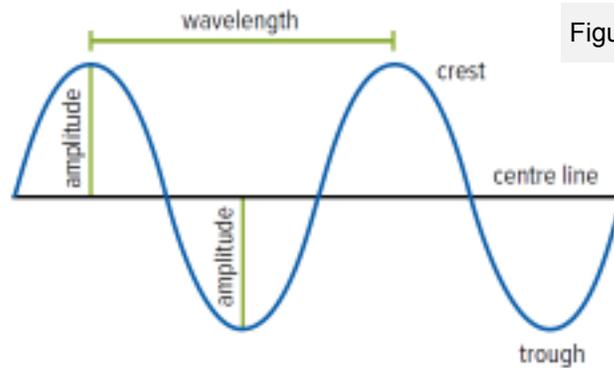


Figure 3.12

- Crest: highest point of a wave
- Trough: lowest point of a wave
- Distance from the centre line to the crest is the same as the centre line to the trough

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Properties of Light Waves

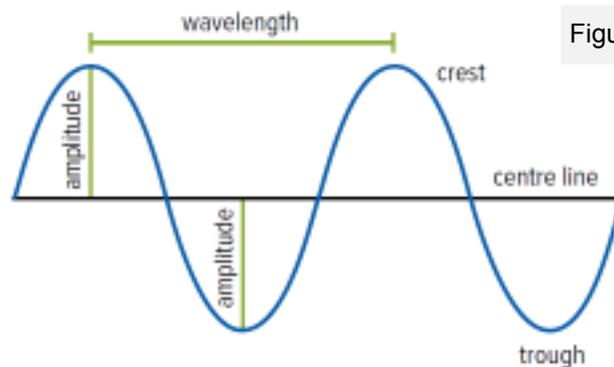


Figure 3.12

- **Wavelength:** distance from one crest (or trough) of a wave to the next crest (or trough)
- **Amplitude:** distance from the centre line to the crest of trough of the wave

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Properties of Light Waves

- **Frequency:** the number of complete wavelengths that pass a point in one second as the wave goes by
- As wavelength decreases, frequency increases
- As wavelength increases, frequency decreases

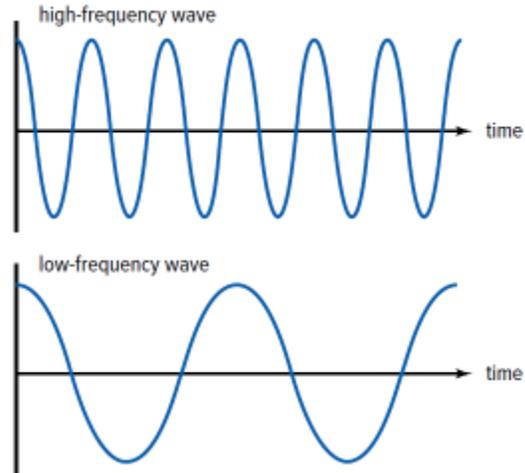


Figure 3.13

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Light, Wavelength, and Colour

- 1600s: Isaac Newton used a prism to separate visible light into colours
 - Discovered that light is a mixture of colours
 - When the colours passed through another prism, the colours recombined to form white light

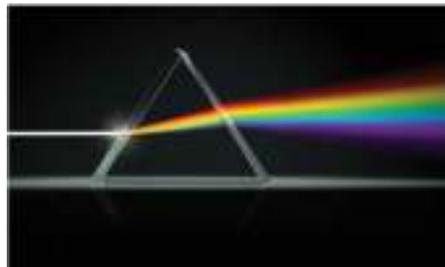


Figure 3.14: Newton separated visible light into colours.

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Light, Wavelength, and Colour

Colours of light are different wavelengths of visible light (visible light spectrum)

- Colours of the spectrum are in a certain order (**ROY G BIV**)
 - Red (longest wavelength)
 - Orange
 - Yellow
 - Green
 - Blue
 - Indigo
 - Violet (shortest wavelength)



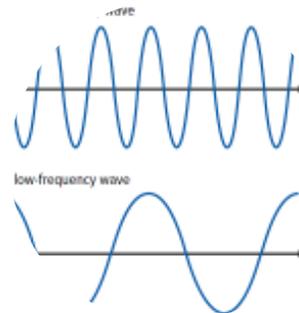
Figure 3.14: Newton separated visible light into colours.

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Discussion Questions

- Describe one way that a light wave is like a water wave. Describe one way that it is different.
- One wave has a higher frequency than another wave. Which wave would have the longer wavelength. Explain your reasoning.



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Concept 4: The particle model of light explains that light has particle-like properties.

- One property of light could not be explained with the wave model of light: **the photoelectric effect.**
- The photoelectric effect:
 - When light shines on a metal surface, the surface **can** (but not always) give off electrons

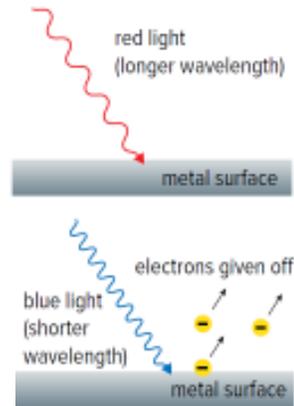


Figure 3.15: The photoelectric effect

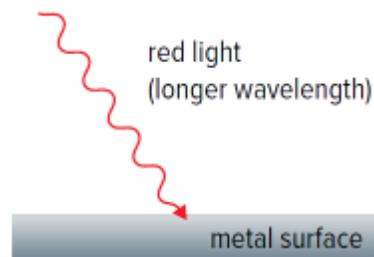
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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Lenard's Experiments: The Photoelectric Effect

1902: Phillip Lenard performed an experiment that further studied the photoelectric effect.

- **Red light (longer wavelength) shone on metal surface:**
 - Electrons are **never** given off, no matter how bright or how long the red light shines on the metal

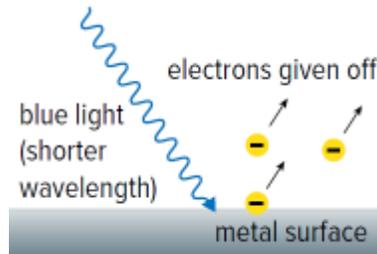


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Lenard's Experiments: The Photoelectric Effect

- **Blue light (shorter wavelength) shone on metal surface:**
 - Electrons are **always** given off, no matter how dim or how briefly the blue light shines on the metal

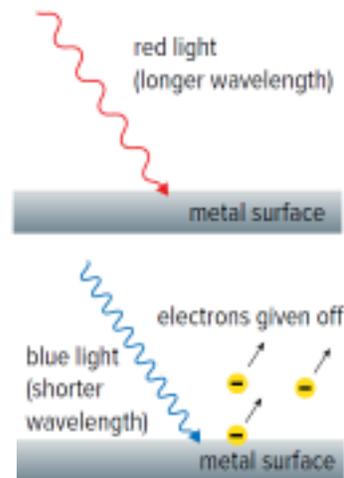


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Lenard's Experiment: Conclusions

- Why did the red light not give off electrons when it hit the metal, but the blue light did?
- If light was a wave:
 - Any wavelength of light (including red) could “pile up” enough energy when it hits the metal to cause electrons to be given off by the metal
 - The wave model of light could not explain the photoelectric effect

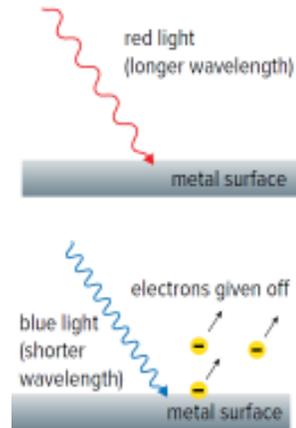


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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Einstein's Thought Experiment: Explaining the photoelectric effect

- Albert Einstein:
 - Realized that the wave model of light could not explain the photoelectric effect
 - Some difference between red and blue light must cause the effect



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Einstein's Thought Experiment: Light acts as a particle when it interacts with matter

- The photoelectric effect can be explained if light acts as 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.



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Einstein's Thought Experiment: The particles of light energy are called photons.

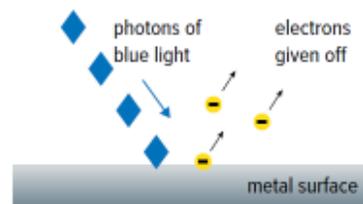
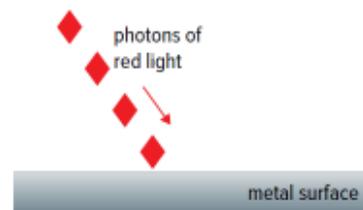
- Einstein called the particles of light energy **photons**.
 - Each photon carries an exact amount of energy that is enough to make the metal give off electrons
 - Otherwise, nothing will happen when the photon hits the metal

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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Einstein's Thought Experiment: The particles of light energy are called photons.

- **Red light:**
 - Photons of red light do not carry enough energy to make metal give off electrons
- **Blue light:**
 - Photons of blue light do carry enough energy to make the metal give off electrons



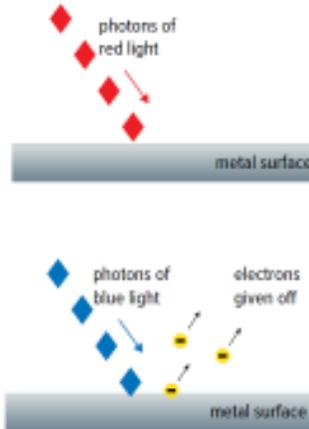
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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Einstein's Thought Experiment: Photons carry more energy as the frequency increases and wavelength decreases.

- **Red light:**
 - Has a lower frequency and longer wavelength
 - Photons carry less energy

- **Blue light:**
 - Has a higher frequency and shorter wavelength
 - Photons carry more energy



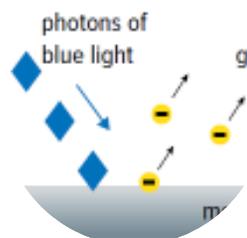
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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?

Discussion Questions

- Does light have the properties of a wave, a particle, or both? Explain your reasoning.

- Scientists build on their work of other scientists. Explain how this is true of Einstein's explanation of the photoelectric effect.



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TOPIC 3.2 How can models explain the properties of electromagnetic radiation?**Summary: How can model explain the properties of electromagnetic radiation?**

- Visible light can be used to model all types of electromagnetic radiation.
- The ray model of light explains that light travels in straight lines.
- The wave model of light explains that light has wave-like properties.
- The particle model of light explains that light has particle-like properties.

