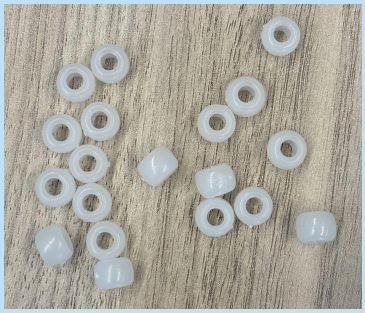
Dragonfly Sight: UV Light and Electromagnetic Waves

SPS SOCK 2024

Participants will use UV beads to learn about different types of light. The demonstration will centre a discussion on wavelengths of light humans cannot see but dragonflies can see.




PRESENTER BRIEF

Be familiar with the electromagnetic spectrum and how electromagnetic waves travel.

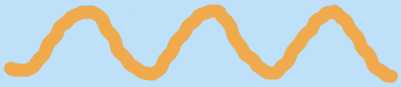
Number of Participants: 1 to 10
Audience: Elementary to High School
Duration: 10 minutes
Difficulty: Level 1

MATERIALS REQUIRED

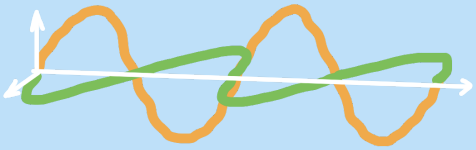
- UV beads
- Sunny day

VOCABULARY

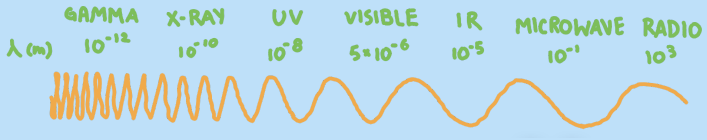
Waves: a disturbance or change in physical quantity that transports energy or information from one point to the next



Electromagnetic radiation: waves created because of vibrations between an electric field and a magnetic field



Electromagnetic spectrum: the range of all kinds of electromagnetic waves, including: radio waves, microwaves, infrared light, visible light, ultraviolet light, x-rays, and gamma rays



Wavelength: the distance between two peaks of a wave
Visible light: the part of the electromagnetic spectrum that humans can see, with

wavelengths from 380 to 750 nanometres
Ultraviolet light: electromagnetic radiation with wavelengths between 100 and 380 nanometers; shorter wavelengths than visible light

USEFUL EQUATIONS

Wavelength	$\lambda = \frac{v}{f}$	λ is wavelength, v is velocity, f is frequency

ADDITIONAL RESOURCES

This demo pairs well with *Dragonfly Colours: Thin-Film Interference* and *Dragonfly Flight: Waves and Wing Movement* from SPS SOCK 2024. If done in collaboration with biology students, discussions on opsin, rods, and cones complement this activity well. For a discussion that integrates the arts, cyanotype prints can be shown. Cyanotype pigments are sensitive to UV light and produce monochrome, blue coloured prints.

Some additional resources are:

- Video on ultraviolet light through the eyes of insects
- This Simulation of electromagnetic waves can also be used as a supplement
- This video can be used to demonstrate scale differences of different wavelengths
    - This website is an interactive scale of the universe

Current literature for presenters:

- Color vision and color formation in dragonflies (Futahashi, 2016)
- Mechanism of the wing colouration in the dragonfly *Zenithoptera lanei* (Odonata: Libellulidae) and its role in intraspecific communication (Guillermo-Ferreira et al., 2015)

Setup:

1. Give each participant at least 1 UV bead.
2. Ask participants to describe UV bead colours indoors, away from windows.
3. Ask participants to put UV beads in the sun.
    a. If there is not enough sunlight for the beads to change colour, pass out UV flashlights to groups of participants. Ask participants to run the flashlight over the beads.

Physics and Explanation:

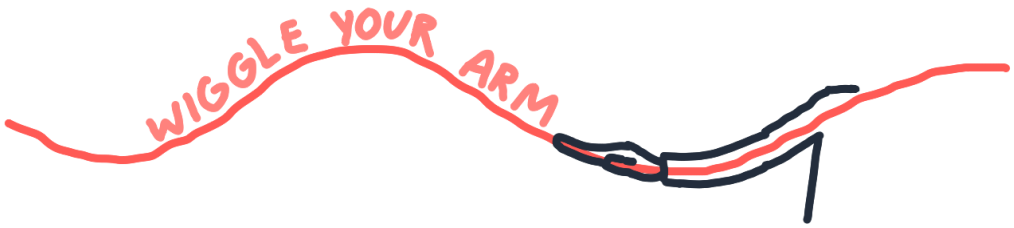
Elementary (ages 5-10):

Light is a kind of **wave** that can move through empty space. We call the different forms of light that objects in the universe give off the **electromagnetic spectrum**.

Draw a wave. Ask participants for examples of waves. Ask them if they think those waves are a type of light. Have students stand in different parts of the room for 'yes' or 'no'.

All types of light move at the same speed, so we describe them with two words: wavelength and frequency. A **wavelength** is the distance between two closest matching points on a wave - think about the peak of one ocean wave, to the peak of the one following it. The **frequency** is how stretched or squished the wave is. Think about a slinky that you stretch–how many coils are in a certain length?

With the wave you drew, point out what a wavelength is. Draw waves of different frequencies. Have students stand up and trace waves with their arms. Do the wave dance!



There are many types of light. Radio waves have the longest wavelength, on the scale of 1000 metres between peaks. Microwaves have wavelengths of around 0.1 metres. The light we see has wavelengths even smaller.

Contextualise the wavelengths by asking students to give examples of things they think are on the scale of 1000 metres, 0.1 metres, and 400 nanometres. Some examples are a building (1000m), and a playing card (0.1m). A human hair is approximately 90,000 nanometers thick.

Ultraviolet light has waves that are just a little bit smaller, peaks that are a little more squished together, than the light we see. Lots of bugs, including dragonflies and bees, can see ultraviolet light. This lets them see colours that we cannot! Bees can see rings in flowers that tell them exactly where to find the pollen they want. Some dragonflies can see special colours on each other's bodies that tell other dragonflies that a branch belongs to them.

Ask students to name the colours of light they can see. Have students look at the UV beads indoors, asking them to discuss what colour the beads are. Move to a window or place with sunlight and how the UV beads change colour in the sun. Ask how participants' perceptions of colour would differ if they could see UV wavelengths. UV beads have different pigments that change colour in response to UV waves. Different pigments result in different colours. Discussion on things we cannot see but can detect is encouraged.

- Light is a wave.
- There are many different kinds of light.
- Some bugs can see types of light that we cannot see!

Middle School (ages 11-13) and general public:

Electromagnetic fields are created when charged particles, such as electrons and protons, move through space. These fields transport **electromagnetic radiation**, also known as **light**. Electromagnetic radiation is a type of **wave**.

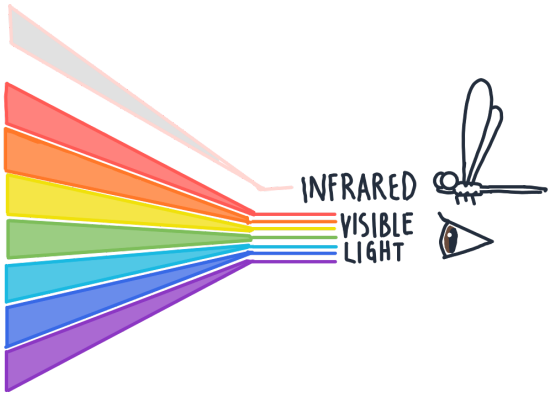
Draw a wave. Ask participants for examples of things they think are electromagnetic waves.

Types of light can be described by the different wavelengths or frequencies they have. A **wavelength** is the distance between the two closest matching points on a wave - think about the peak of one ocean wave to the peak of the one following it. The **frequency** is the number of waves that pass a point in a certain amount of time. Radio waves have the longest wavelength, on the scale of 1000 metres between peaks. Microwaves have wavelengths around 0.1 metres (about the length of a playing card) and gamma rays have wavelengths of 10^{-12} metres (1/100th the width of a hydrogen atom). The light we see, **visible light**, has wavelengths from 380 nanometres (violet) to 750 nanometres (red).

Draw out the electromagnetic spectrum. Ask participants to give an example of the size of each wavelength and a source for each type of electromagnetic wave. Have students stand up and trace waves with their arms. Do the wave dance (see image above)!

With wavelengths just a little bit shorter than that, **ultraviolet light** covers the range of 100 to 380 nanometres. Lots of bugs, including dragonflies and bees, can see ultraviolet light. Some parts of their DNA tell their bodies to make proteins that can sense different wavelengths of light. Like visible light, UV radiation comes from the sun and bounces off objects and into our eyes. Some UV light can damage our skin cells, causing us to burn and develop skin cancer. Lots of flowers reflect UV light, showing bees exactly where to find the pollen they want. Some dragonflies have special structures that reflect UV light, which they use to tell other dragonflies that they have claimed territory. This is a type of structural colouration; colour from microscopic structures that reflect specific wavelengths. In contrast, the UV beads have pigment colour, which absorbs all the wavelengths of light except the one you see. UV beads have a chemical pigment that changes colour when exposed to UV light. The beads are white in visible light but in UV light, turn different colours depending on what pigment is added to each bead.

Have students look at the UV beads indoors, asking them to discuss what colour the beads are. Move to a window or place with sunlight and how the UV beads change colour in the sun. Ask how participants' perceptions of colour would differ if they could see UV wavelengths. Discussion on things we cannot see but can detect is encouraged.



- Light is an electromagnetic wave.
- Other types of electromagnetic waves include ultraviolet light and radio waves.

High School (ages 14+):

Electromagnetic fields are created when charged particles, such as electrons and protons, move through space. These fields transport **electromagnetic radiation**, also known as **light**. Electromagnetic radiation is a type of **wave** that travels through both the electric field and magnetic field. This relationship between electric and magnetic fields was discovered by James Clerk Maxwell, who developed equations–Maxwell's equations–to describe them.

Draw an electromagnetic wave. Ask participants for examples of things they think are electromagnetic waves.

These **electromagnetic waves** can be described by their different wavelengths or frequencies. A **wavelength** is the distance between two closest matching points on a wave - think about the peak of one ocean wave to the peak of the one following it. The **frequency** is the number of waves that pass a point in a certain amount of time. They are related by an equation that involves the velocity the waves travel at: $\lambda = \frac{v}{f}$. All electromagnetic waves travel at the speed of light, so $v = c = 3 \times 10^8$ metres per second. Radio waves have the longest wavelength, on the scale of 1000 metres between peaks. Microwaves have wavelengths around 0.1 metres and gamma rays have wavelengths that are 10^{-12} metres. The light we see, **visible light**, has wavelengths from 380 nanometres (violet) to 750 nanometres (red).

Draw out the electromagnetic spectrum. Ask participants to give an example of the size of each wavelength and a source for each type of electromagnetic wave. Participants can also be asked to calculate the frequency of each type of EM wave. Have students stand up and trace waves with their arms. Do the wave dance (see image above)!

With wavelengths just a little bit shorter than that, **ultraviolet light** covers the range of 100 to 380 nanometres. Lots of bugs, including dragonflies and bees, can see ultraviolet light. SSome

parts of their DNA tell their bodies to make light sensor proteins called opsin that are sensitive to different wavelengths of light. Like visible light, UV radiation comes from the sun and bounces off objects and into our eyes. Some UV light can damage our skin cells, causing us to burn and develop skin cancer. Many flowers reflect UV light, showing bees where to find the pollen they want. Some dragonflies have special structures that reflect UV light, which they use to tell other dragonflies that they have claimed territory. This is a type of structural colouration; colour from microscopic structures that reflect specific wavelengths. In contrast the UV beads have pigment colour, which absorbs all the wavelengths of light except the one you see. UV beads have a chemical pigment that changes colour when exposed to UV light. The beads are white in visible light. In UV light, the beads turn different colours depending on what pigment they have.

> *Have students look at the UV beads indoors, asking them to discuss what colour the beads are. Move to a window or place with sunlight and how the UV beads change colour in the sun. Ask how participants' perceptions of colour would differ if they could see UV wavelengths. Discussion on things we cannot see but can detect is encouraged.*

Another word for light, electromagnetic radiation, and radiation is **electromagnetic energy**. This is often described with the units of **electron volts**, the kinetic energy needed to move one electron through a potential of one volt. Energy increases as wavelengths get shorter. Let us consider pulling the end of a rope up and down. It takes more energy to create more waves closer together.

- Light is an electromagnetic wave.
- Waves can be described by the equation $\lambda = \frac{v}{f}$.
- Electromagnetic radiation is energy.