Investigating the relationship between measured brightness and length of ice cores

Objective: Students will investigate the relationship between the length of an ice core and the brightness of light transmitted through it, simulating experiments performed by scientists on photosynthetically active radiation (PAR). They will use Pringles® tubes to create frozen ice cores and measure light intensity at various lengths.

Key concepts

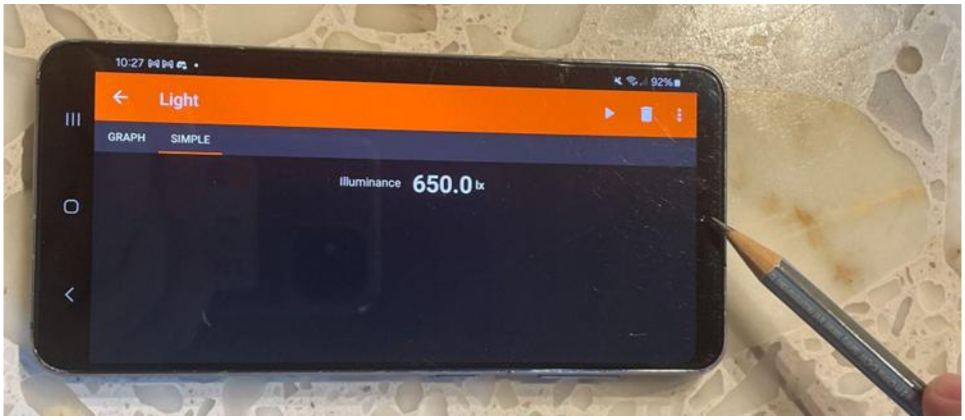
- light transmission
- absorption of light
- photosynthetically active radiation (PAR)
- diffraction of light and the visible spectrum
- experimental design and data collection
- photosynthesis provides oxygen
- photosynthesis provides energy for almost all life on Earth

Concept of absorption: Explain that, when light passes through a material (like ice), part of the light is absorbed and part is transmitted through. The longer the material, the more light may be absorbed or scattered, resulting in less brightness on the other side.

Materials needed

- Empty Pringles® tubes – note: some flavours come in shorter tubes
- Can opener
- Water (for freezing into ice)
- Freezer (for freezing the water inside Pringles® tubes)
- Torch (flashlight)

- Light meter (to measure brightness). Most phones have a built-in light meter that can be accessed using a free app such as phyphox.



The pencil is pointing at the light sensor on this phone. It is helpful to rotate the display so the reading is clear of where the sensor will be held against the Pringles® tube.

- Ruler or measuring tape
- Stopwatch (optional)
- Thermometer (optional, to monitor temperature of the ice)

Extension activity

- Diffraction grating (or a CD/DVD with reflective surface to simulate diffraction)
- Darkened room (optional)

Introduction (15 minutes):

1. **Context**: Begin by discussing the importance of ice cores in scientific research. Ice cores are used to study climate history by examining trapped air bubbles and layers of ice that have accumulated over time. Similarly, scientists study the interaction of light with various materials, such as ice, to understand the environment. One area of research that involves light transmission is photosynthetically active radiation (PAR), which refers to the portion of the light spectrum that plants and algae can use for photosynthesis. In natural environments, factors like cloud cover, ice and water can affect the transmission of light, which is why scientists study how light interacts with these materials.

2. **Hypothesis**: Ask the students to hypothesise whether they think the length of the ice core will affect the brightness of the light on the other end. Do they think a longer ice core will allow more or less light to pass through? Relate this to PAR by explaining that understanding how light transmits through materials like ice is similar to how scientists study how light reaches plants through varying atmospheric conditions. In Antarctica, the primary producers are not plants but microalgae/plankton living in the ocean. Scientists measure the amount of light that penetrates ice and study the effect on microalgae that live under the ice.

Procedure

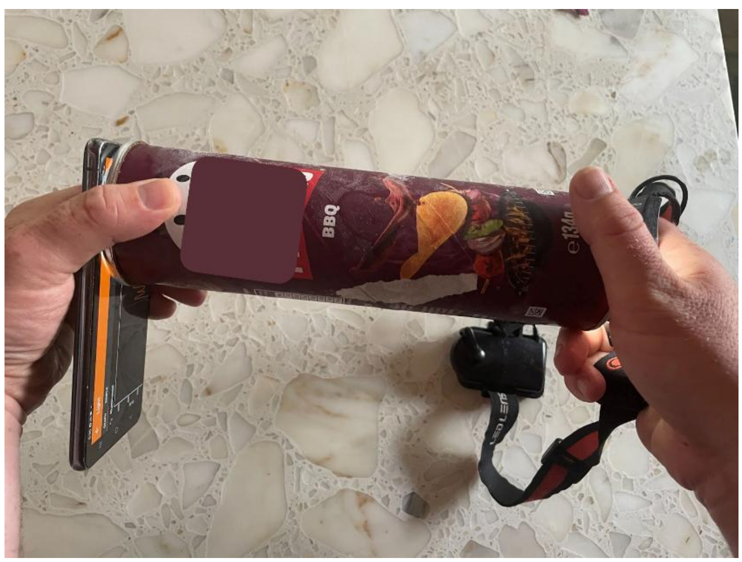
1. Prepare ice cores

Activity – [Investigating the relationship between measured brightness and length of ice cores]

- Fill Pringles® tubes with different volumes of water. Leave about 1 cm from the top to allow for expansion when freezing.
- Place the tubes in a freezer until solid ice cores are formed (may take 2–3 days).
- It can be useful to keep one Pringles® tube empty as a comparison.

2. Set up equipment

- Use the can opener to remove the metallic end from the Pringles® tube.
- Set up the ice core (Pringles® tube) horizontally on a flat surface.
- Place a torch at one end of the ice core to shine light into the tube.
- Position the light meter at the other end of the ice core to measure the brightness (intensity of light).



Remove as much ambient light as possible.

3. Varying the length of the ice core

- Create several ice cores of different lengths. For example, use tubes with 5 cm, 10 cm, 20 cm and 30 cm of ice. Alternatively, if using one tube, you can slice the frozen core at different lengths.

4. Measure light intensity

- For each ice core, turn on the torch and measure the brightness (in lux) using the light meter at the far end of the ice core. Take a brightness measurement for an empty Pringles® tube for comparison.

- Record the brightness readings for each ice core length.

5. **Repeat the experiment**
   - For more accurate data, repeat the experiment several times for each length and calculate the average brightness. This could be a great opportunity to teach students about outliers.

Data analysis and discussion

1. **Graphing results**
   - Have students plot the data on a graph with the length of the ice core on the y-axis and the measured brightness (lux) on the x-axis. (If you are graphing by hand, allow more time.) Alternatively, the data could be collated and graphed digitally – possibly demonstrated by the teacher.

2. **Analysis**
   - Discuss the trend observed in the graph. Do they see a decrease in brightness as the length of the ice core increases? Why do they think this happens? (The light gets absorbed and scattered as it passes through more ice.)
   - Ask students how they might quantify the relationship between length and brightness. What kind of pattern is forming (linear, exponential, etc.)?

3. **Relating to photosynthetically active radiation (PAR)**
   - Explain that this experiment simulates how photosynthetically active radiation (PAR) is measured in natural environments. Just like the ice cores absorb and scatter light, various materials like clouds and particles in the air, and ice sheets, can affect the amount of light that reaches plants and microalgae. The goal of PAR studies is to understand how much usable light these organisms can receive for photosynthesis. This experiment allows students to explore the concept of light transmission in a simplified system.

4. **Discuss variables**
   - Ask students to consider other variables that could affect the results. For instance:
     - ambient light
     - the length of the Pringles® tube (some flavours come in shorter tubes)
     - the distance between the light sensor and torch
     - the angle of the light sensor
     - the type of light used (different light wavelengths might be absorbed differently by ice).

Conclusion

1. **Review findings**
   - Summarise the key findings with the class. Was the hypothesis correct? How did the length of the ice core affect the brightness? What trends did students notice in the data?

2. **Application to real-world scenarios**
   - Discuss how this experiment simulates the way light interacts with sea ice and how this is relevant to scientific studies of photosynthetically active radiation (PAR). Scientists rely on measurements of

light transmission in ice to study how much light penetrates into ice-covered environments, which has implications for understanding climate change and ecosystems in polar regions.

3. **Extension questions**
    - How would you change the experimental setup if you were to use a different material instead of ice (e.g., plastic, glass)?
    - What other factors might influence the amount of light that gets transmitted through the ice?
    - How could those factors relate to the study of PAR in the natural world?
    - Would more light always be useful to microalgae or plants? (Hint: Consider some of the harmful effects of too much sunlight on humans.)

Extension activity: Exploring light spectrum with diffraction grating (optional: 20–30 minutes)

Objective: Students will explore the different wavelengths (colours) of visible light and compare light sources, helping to understand how light can be absorbed and transmitted in various contexts, including PAR.

By adding this extension activity, students will gain a deeper understanding of light and its different properties, especially as it relates to the transmission of PAR and its effect on plant life. The diffraction experiment offers a hands-on way to explore light's properties and how it is used by both plants and scientists in environmental studies.

1. **Diffraction grating**
    - If the teacher can source a diffraction grating or if a CD/DVD with a reflective surface is available, explain that these can be used to split light into its component colors. This process is known as **diffraction**. The grating separates different wavelengths of light, allowing students to see the full spectrum of colors.

2. **Setting up the activity**
    - In a darkened room, use different light sources (e.g., sunlight, LED torch, fluorescent light).
    - Shine each light through the diffraction grating and observe the pattern that emerges. The light will be split into different colors, and students should be able to see the full spectrum with white light (sunlight) but not with monochromatic lights (such as LEDs).

3. **Discussion**
    - Ask students what they notice about the light from different sources. Sunlight should show a continuous spectrum (all visible wavelengths), while other light sources like LED torches will show limited colors (because they emit light at specific wavelengths).
    - Discuss how this is related to PAR, as plants can only use certain wavelengths of light for photosynthesis. Different light sources might provide different amounts of usable light, which could affect plant growth in real environments.

4. **Reflection**
    - Have students consider how the diffraction experiment and the ice core experiment both illustrate concepts of light absorption, transmission and the interaction of light with different materials.

- How might different light sources affect the transmission of PAR through ice or snow in natural environments?

Assessment

- Review students' work to ensure they recorded data accurately and explained their reasoning.
- Evaluate students' ability to analyse the data and draw conclusions based on the observed trends, especially in the context of PAR.
- Assess students' engagement and understanding of the light spectrum through the extension activity.

Additional notes

- This activity requires careful preparation ahead of time.
- Groups can take turns with ice cores to reduce the number that need to be prepared.
- As always, for optimum learning, it is helpful for the teacher to run this activity prior to teaching it to students.
- If students are working in groups, make sure each student takes turns measuring the light intensity and recording the data.
- The diffraction grating activity will require a dark environment to clearly see the light spectrum. Ensure that enough diffraction gratings (or CDs) are available for all groups if possible.

Acknowledgement

This activity was written by Douglas Walker, Head of Science at St Patrick's College, Wellington. Doug conducted field work in McMurdo Sound as part of the K892 expeditions, with an additional focus on educational outreach.