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Student Activity

Measuring Planck's Constant (Option 2: Conductive Dough Circuit)

Science Background

A light-emitting diode (LED) is a device that produces light when we apply a potential difference, ΔV, across it. The potential difference allows electrons to move from high-energy states to lower-energy ones, like lowering a dam and allowing water to flow downhill. Energy is released from the system as photons. The energy of each photon, hf, is equal to the change in energy of each electron, $e\Delta V$. So

$$hf = e\Delta V$$

where e is the elementary charge (1.602×10^{-19} C), h is Planck's constant (6.626×10^{-34} J·s), and f is the frequency of the light.

In this activity, you will use conductive dough to build a circuit, use the circuit to observe different LEDs, and then analyze your observations to determine the value of Planck's constant.

Useful Information

$E = hf$ $E_e = e\Delta V$ $e = 1.602 \times 10^{-19}$ J $h = 6.626 \times 10^{-34}$ J·s

SAFETY ALERT
Never stare at a brightly lit LED.
Do not connect an LED directly to a battery.

Part 1: Experiment

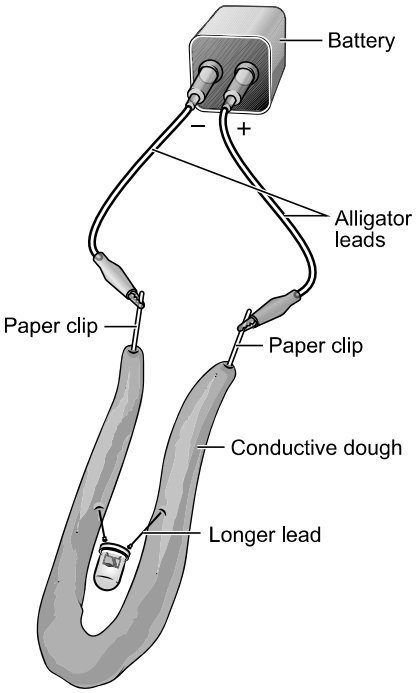
Procedure

1. Gather the materials provided by your teacher.

2. Create a circuit using the battery, alligator leads, paper clips, and conductive dough. The conductive dough "snake" should be about 20 cm long and have a diameter of about 1 cm, but these measurements do not need to be exact. Embed one paper clip in each end of the conductive dough snake. Then connect one alligator clip to each paper clip, as shown on the right.

3. Bend the leads of one of the LEDs so that they can reach across the gap between the two long parallel sides of the conductive dough.

4. Connect the leads of the LED to either side of the conductive dough about 1 cm from where the paper clips are embedded in each end of the conductive dough snake. Place the longer lead of the LED on the side closest to the battery's positive terminal. **Caution:** Do *not* stare at a brightly lit LED.



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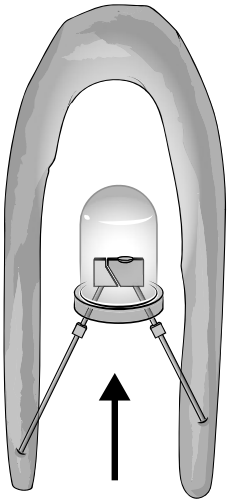
5. Looking down at the top of the LED, gradually move the LED closer to the bend in the circuit until it turns off, as shown below.



6. Fine-tune the placement of the LED by keeping one of its leads in place and moving the other lead until the LED just barely emits light. Cup your hands over the LED to block out ambient light and more clearly see when the LED first begins to emit light.

7. Use the data table below to record the potential difference at which the LED first begins to emit light. Move the LED lead backward and forward past the point at which the LED just begins to glow a few times to locate it as accurately as possible.

8. Repeat Steps 4 to 7 for the other four LEDs.

Observations

LED Colour	**Red**	**Amber**	**Yellow**	**Green**	**Blue**
Frequency, *f* ($\times 10^{14}$ Hz)	4.54	5.00	5.08	5.31	6.38
Electric Potential Difference, ΔV (V)					

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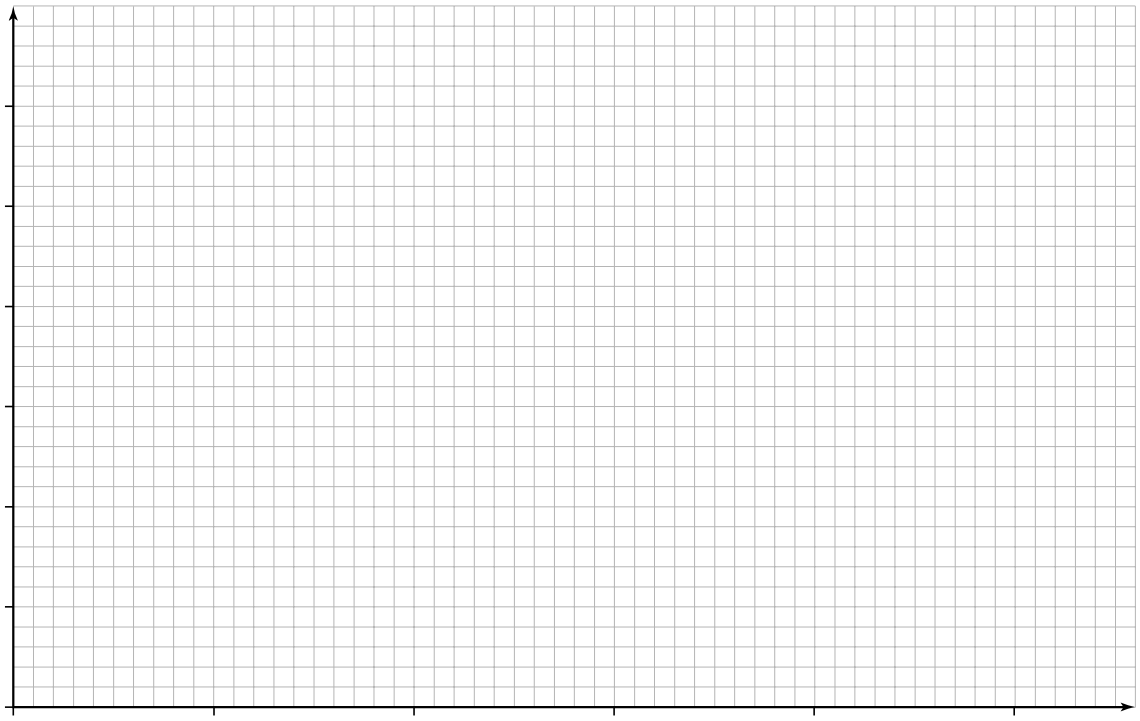
Measuring Planck's Constant

Part 2: Analysis

1. Plot a labelled graph of electric potential difference versus frequency.



2. Calculate the value of the graph's slope. Use it and $e\Delta V = hf$ to calculate the value of Planck's constant.

3. What is the percent error in your value of Planck's constant? What are the sources of error?

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Consolidate Your Learning

Answer the following questions to check your understanding of Planck's constant.

1. What are some ways that you could modify the experimental procedure to determine *h* more accurately?

2. Weather reports include a statement about ultraviolet (UV) light levels. Why is UV light a particular health concern, compared with infrared or visible light?

3. TV remote controls use infrared LEDs with wavelengths of around 900 nm. According to your graph, what is the minimum battery voltage needed to operate them?

4. In a typically lit room, the light intensity is around 1 $W \cdot m^{-2}$. Estimate the number of photons hitting your body each second when you are sitting in class. State any assumptions you make.