Part 1: Background Information and Context

Activity
Pencil Lead Light Bulb
This experiment replicates the modern day incandescent light bulb by using graphite from pencils as the carbon filament . Graphite will conduct electricity, and if enough electricity is run through a mechanical pencil 'lead' it will heat up and start to glow.

Suggested NGSS Dimensions to Address (click on the titles to learn more from the K-12 Framework)

Science and Engineering Practices

- Asking Questions/Defining Problems
  - Students can observe the teacher performing this activity as a demo, record observations, and ask questions.
- Planning and Carrying Out Investigations
  - Students could then develop an experiment to test their ideas or the teacher could develop the experiment, and students could conduct it.
- Modeling
  - Students could draw an initial model how pencil becomes a light bulb. To be most effective, students should explore other examples of circuits, conductors, and resistance.
- Constructing Explanations/Designing Solutions
  - After students explore different examples the students can explain the demonstration using their model.

Disciplinary Core Ideas

- PS2.B Types of interactions
  - 3-5: Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart. (3-PS2- 3)
- PS3.B Conservation of energy and energy transfer
  - 3-5: Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form. (4-PS3-2, 4-PS3-4)

Crosscutting Concepts

Cause and Effect

- Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Energy and Matter

- Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Part 2: Lesson Facilitation for Phenomenon

Teacher Background
While graphite can conduct electricity, it is a poor conductor. As the electricity flows from one battery terminal to the other, it meets a lot of resistance within the graphite filament. This resistance causes the graphite to heat up and glow as electrical energy is converted into heat and light. The intensity of the light can be altered by changing parts of the experiment. The thinner the diameter, the more resistance, and the faster it will heat and the brighter it will light up. You can also obtain a brighter light by using more batteries, or by increasing the power source to force more electricity through the same lead. This increase of power will cause an increase in light as electrons are excited to higher energy states. The relationship between voltage and current can be expressed by Ohms Law:

Voltage = (Current) x (Resistance) or V = I x R

If we rearrange this equation, we get I = V/R

The power (Watts) passing through the pencil lead is related to the below equation:

Power =(Voltage) x (Current) or P = V x I

If we combine these two equations, we get the below equation:

P = V2/R

Knowing these equations, it can be expected that more batteries (or a higher voltage setting on the variable voltage supply) will dramatically increase the power passing through the pencil lead and, as a result, the brightness of the light will increase. As the pencil lead gets hot, it reacts with oxygen in the air and gradually burns away. This causes the pencil lead to get thinner and thinner, resulting in a lower resistance and even more power passing through the pencil lead. The brightness of the bulb will increase significantly right before the pencil lead burns out.

Materials

1. A source of electricity (DC circuit or 8 D cell batteries)
2. Alligator clamps, preferably in a stand to prevent the graphite from moving and breaking
3. A glass cover to place over the alligator clamps to prevent anyone from touching the hot filament.
4. Wire leads from the battery or power supply to the alligator clamps
5. A box of mechanical pencil 'lead'. Note: make sure that you use graphite pencil lead and not a graphite/ polymer composite (0.7mm graphite works the best). The composites do not conduct electricity and will not work in this activity.
6. Hot pads, and non-conductive gloves (depending on electrical source)

Procedures

1. Ensure that everyone understands that the graphite will get hot, and may create some smoke. It should not be touched even after the experiment is over and the lead is no longer glowing, as it may still be hot.
2. Break the graphite filament in half
3. Attach the a piece of graphite with the 2 alligator clamps such that there is a gap between them that can act as the light bulb filament.
4. Place a glass cover over the filament before you run electricity through it. Make sure nobody is touching the graphite, and connect the wires to the alligator clamps, then to the source of electricity to start the flow of electricity
5. The intensity of light will increase as the voltage and current on the power supply is increased. As the graphite becomes hot, carbon atoms from the filament will vaporize causing the filament to become thinner. As the filament thins, its resistance goes down and the current flowing through the filament increases causing a brighter light. If left connected, the filament will eventually break causing the light to go out.
6. Once the graphite glow has been sufficiently demonstrated, disconnect the electricity from the source, and remind everyone that even though it is no longer glowing, it may still be hot. Allow the apparatus to cool before replacing the broken filament with a new pencil lead.

Safety Concerns

This experiment involves electricity and high heat. A "Warning: Hot" sign next to the graphite location to remind views or to inform newcomers to the danger of being burned is advisable. Hot pads or gloves should also be present for the handling of the graphite after each use. Depending on the electrical voltage and amperage systems, non-conductive gloves should be available.

3-Dimensional Questions

1. What did you notice during the demonstration?
2. What did you wonder during the demonstration?
3. What do you think caused the lead to glow?
4. What variables do you think affect this phenomenon and how can we test your predictions?
5. How could you test the effect of voltage and current (e.g., the number of batteries) on how brightly the lead glowed?
6. What kinds of energy transfer is taking place?
7. What caused the thicker lead to be dimmer?

5E Model Alignment/Suggestions

Engage:

Consider using this activity as a demonstration and having students ask questions about what they see through a prompt such as "Make 5 observations and 3 questions about the following demonstration". Consider having the students make predictions (cause and effect chart) about the pencil's brightness when changing different variables (thickness of "lead", amount of current, or batteries).

Explore:

1. After students have made preliminary predictions and explanations, they could explore these predictions by conducting an investigation on their own changing the different variables. Students could either **develop the investigation** or simply **conduct** it using provided procedures.
2. After conducting an investigation, students could *revise* their original predictions about the causes and effects with design changes.
3. To be able to explain the phenomenon, students need to have several experiences with other examples of circuits. These can be teacher developed investigations designed to inform their knowledge of what could be happening with the pencil light bulb.
4. After conducting an investigation, students could *revise* their original thinking about the phenomenon.

Explain:

After the teacher has helped the students make meaning of their activity through direct teaching, video, or text, the students can then explain their learning back to the teacher. Through experience and instruction, students should learn the content relevant to their grade level.

The students can **construct an explanation** or write a **Claim-Evidence-Reasoning** on this phenomenon.

Elaborate:

1. Students could **apply their knowledge of circuitry and conduction** by designing a solution to a problem where electricity is a need or could design a device that transfers energy from electrical to mechanical or otherwise.