Department of
ELECTRICAL & COMPUTER ENGINEERING
THE UNIVERSITY OF UTAH

Exponentials and LEDs

Teacher Notes

Math II & III (10th & 11th grade)

Standard A.CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

Standard F.BF.1 Write a function that describes a relationship between two quantities. **b.** Combine standard function types using arithmetic operations.

Standard F.LE.5 Interpret the parameters in a linear, quadratic, or exponential function in terms of a context.

Supplies needed:

3 AA batteries	Battery holders	Resistors
LEDs	Current meter	Alligator clip wires

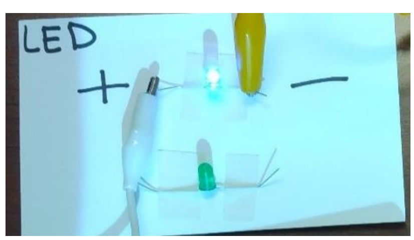
Overview:

Electrical devices work through the flow of electrons, which are charged particles. For an electrical circuit to work, it must have something that provides power (like a battery), something that consumes power (like a resistor or LED), and wires must connect everything in a circle, so the electrons can flow. The battery has a given *voltage*, which provides the "umph" needed to get the electrons flowing. We call the flow of electrons *current*.

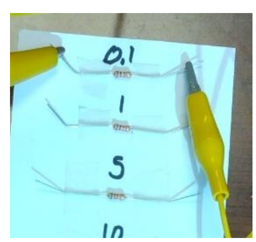
Some electrical components obey linear laws and others, like the LED, have more complicated relationships between voltage and current. Electrical engineers often represent the behavior of different circuit components by plotting their i-V curves, which is a graph relating current and voltage for that particular electrical component. Today we are going to create i-V curves for various color LEDs. By comparing these various graphs, we will better understand how different parameters of the exponential equation affect the curve.

1) Build the following circuit, which has a battery, resistor, green LED, and current meter in a loop. (Whenever we work with LEDs, we must also include a current-limiting resistor.) The + side of the LED must connect to the red side of the battery. Then connect the voltage meter across the LED to measure the voltage of the LED. This will give you a single data point of voltage and current. We will collect 3 different data points by changing the resistor (which lets you change the current and voltage). Then record a final data point with the batteries removed from the circuit. Record your 4 data points below.

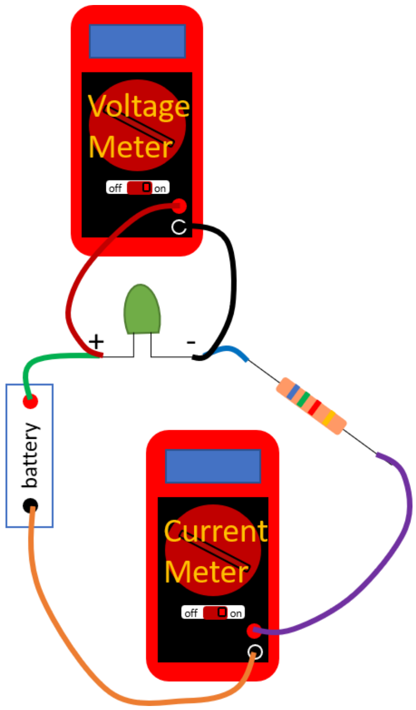
LED card

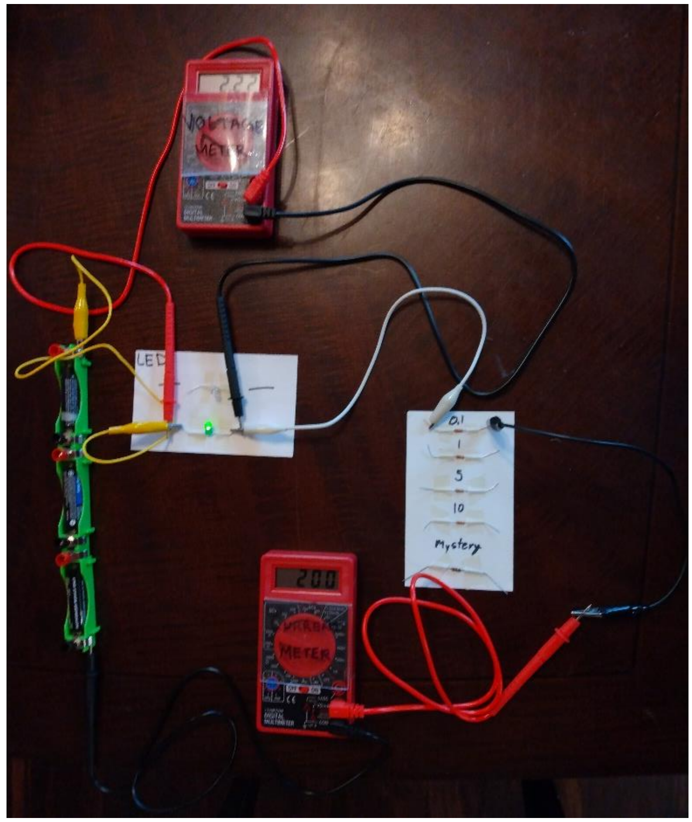


Resistor card



Connect batteries with red side in the same direction





Example experimental values:

Resistor 0.1:	Resistor 1:	Resistor 5:	No batteries:
Voltage = 2.23	Voltage = 1.93	Voltage = 1.84	Voltage = 0
Current = 20.2	Current = 2.5	Current = 0.5	Current = 0

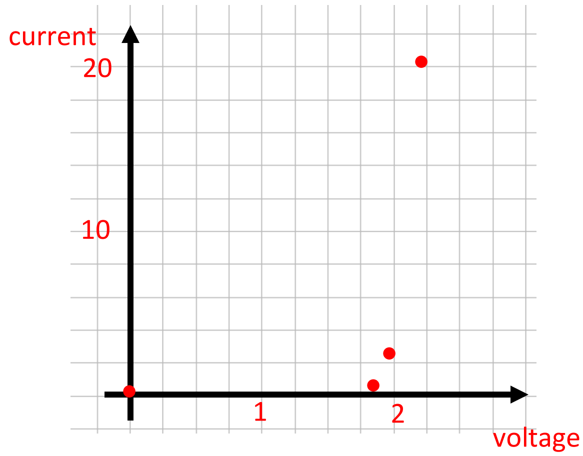
Note about units: For those who are familiar with basic circuits, you may find the current values and resistance labels strange. This is because the digital multimeter used to measure current is measuring in milliamperes (mA), not amperes. [1000 mA = 1 Ampere]. Thus, resistances are being labeled in kilo ohms (kΩ) to make the math work out. [1000 Ohms = 1 kΩ]

Common issues to look for when troubleshooting:

- Mixed up current and voltage meter
- Did not turn on current or voltage meter
- LED backwards (+ side of LED must connect to + side of batteries)
- Missing connections (forgot to connect everything in a circle)
- Loose connections (check alligator clips and check red and black cables firmly pushed into holes on meters)
- Batteries not all in same direction
- Batteries dead

2) **As current increases, the LED gets** brighter or dimmer or no change**.** (circle one)

3) Graph your points with voltage on the x-axis and current on the y-axis. Don't forget to label your axes. Draw a curve through them that best represents the trend (it should be an exponential).



4) i) Which equation best represents the situation? (a and c are constant coefficients)

a) $\text{current} = a \cdot 2.7^{\text{c}\cdot\text{voltage}}$

b) $\text{current} = a \cdot 2.7^{\text{c}\cdot\text{voltage}} + 1$

c) $\text{current} = a \cdot 2.7^{c\cdot\text{voltage}} + a$

d) $\text{current} = a \cdot 2.7^{c\cdot\text{voltage}} - a$

ii) Why?

The actual equation is something like

$$y = 1 \cdot 10^{-15}(e^{20x} - 1)$$

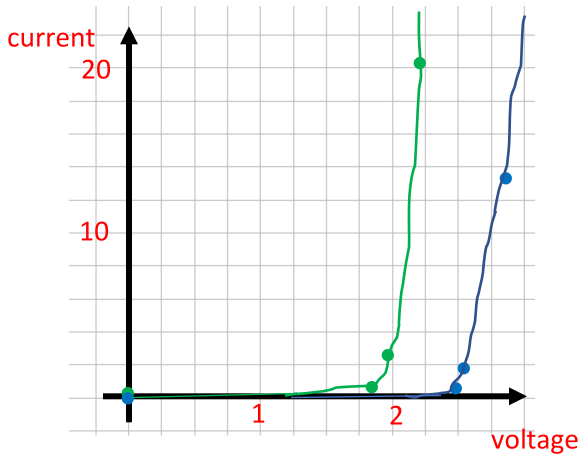
where the first coefficient and the coefficient in the exponent are dependent on material factors of the semiconductor on the atomic level.

The graph goes through the origin (0,0), so the only equation above that does that is d.

5) Now repeat the experiment with the blue LED (it is the LED with a clear cover). Record the data you collect below.

Resistor 0.1:	Resistor 1:	Resistor 5:	No Batteries:
Voltage = 2.83	Voltage = 2.57	Voltage = 2.5	Voltage = 0
Current = 13.3	Current = 1.8	Current = 0.4	Current = 0

6) Plot the data for the blue LED just like you did for the green LED. Don't forget to label your axes. Again, draw a curve connecting these points that best represents the trend. Redraw the curve for the green LED on this same graph using a different color or a dotted line.



7) Describe the difference between the graph for the blue LED and the green LED.

The exponential for the blue LED is stretched more to the right.

8) LEDs can generally be represented by an exponential equation of the form $y = a(2.7^{cx} - 1)$. How does the coefficient a compare for the blue and green LEDs (assuming c stays the same)?

The a coefficient is BIGGER or SMALLER or THE SAME for the blue LED. (circle one)