Learner Guide

Lesson 3: Measuring Power & Energy

Name	Date	Class / Group

In this lesson, you will learn how engineers measure and describe the electrical energy used by a circuit. It is not enough to know that a circuit turns on. Engineers need to know how the circuit works, how much electrical energy is being transferred, and how changes to the circuit affect performance.

By exploring how voltage, current, power, and energy work together in a simple circuit you will begin to see how these concepts form the foundation for engineering. Engineers use electrical measurements to design, test, and improve larger energy systems, including solar-powered systems and mini-grids.

Words You Will Use

Term	What it Means
Energy	Power used over time. Measured in watt-hours (Wh). 1,000 Wh = 1 kilowatt-hour (kWh). It is calculated using the formula E = P x t.
Direct Current (DC)	Charge flows in one direction; batteries and solar panels provide DC electricity, and classroom battery circuits are examples of DC circuits.
Alternating Current (AC)	Charge changes direction periodically; wall outlets and many household electrical systems provide AC electricity, where voltage rises, falls, reverses direction, and repeats.
Multimeter	An engineering tool used to measure different electrical quantities in a circuit, such as voltage, current, and resistance; in this lesson, it is used to measure voltage and current.

Term	What it Means
Breadboard	A tool for building temporary circuits without soldering; inside the breadboard, groups of holes are connected by metal strips that organize circuit connections into rows and power rails.
LED	A light-emitting diode used in the circuit; it uses electrical energy to produce light and has polarity, so it must face the correct direction to light.
Resistor	A component that limits current and protects the LED in the circuit; changing the resistor value changes current and therefore affects power and energy use.

V: Voyage Into Your Learning

Power Detective Prediction Sort

Power Detective Prediction Sort: Rank the chargers, adapters, or device labels from lowest to highest power. At first, use only what you notice on the labels. Complete this table for the one or two groups of labels you have.

Group 1

Device or Label	Voltage (V)	Current (A)	Initial Rank	Calculated Power (W)	Revised Rank

Group 2 (Optional)

Device or Label	Voltage (V)	Current (A)	Initial Rank	Calculated Power (W)	Revised Rank

Prediction: Which device did your group first predict would use the most power? What evidence did you use?

After the Formula: Use P = V × I. Did your ranking change after calculating power? Explain.

Key Takeaway: Why is voltage alone not enough to know the whole energy story?

O: Orient Your Learning

Voltage, current, multimeters, and breadboards

Concept Check: What is one difference between direct current (DC) and alternating current (AC)?

Introducing the Multimeter: A multimeter is an engineering tool used to measure different electrical quantities in a circuit. In this lesson, you will use it to measure voltage, which tells us the electrical push across a component, and current, which tells us how much electric charge is flowing through the circuit.

Multimeter Quick Guide

Use this guide to help you determine how to connect your leads and where the probes go based on what you are measuring.

Always connect the black lead to COM.
Move the **red lead** only when you change what you are measuring.

What are you measuring?	Red Lead Terminal	Meter Setting	Where do the probes go?	Key Reminder
Voltage	VΩHz or VΩ	DC V for batteries/solar cells; AC V for outlets or AC sources	Touch probes **across** the battery, solar cell, or component.	Voltage is measured **across** a component.
Resistance	VΩHz or VΩ	Ω	Touch probes to the two ends of the resistor or component.	**Power off** the circuit first.
Continuity	VΩHz or VΩ	Continuity symbol, often a sound-wave or	Touch probes to two points you want to	**Power off** the circuit first. A beep usually

What are you measuring?	Red Lead Terminal	Meter Setting	Where do the probes go?	Key Reminder
		diode-like symbol	test for a connected path.	means the path is connected.
Small current	mA	DC mA or A, as labeled on your meter	Break the circuit and insert the meter **in series**.	Use only when the expected current is below the mA terminal's printed limit.
Larger or unknown current	10A	DC A or A, as labeled on your meter	Break the circuit and insert the meter **in series**.	Start here if instructed or if current might be too large for mA.

Remember: Voltage is measured across a component. Current is measured in series by placing the meter into the circuit path.

Quantity	Symbol	Unit	How We Use It Today
Voltage	V	Volts	Measure across a component
Current	I	Amps	Measure in series with the circuit
Power	P	Watts	Calculate using $P = V \times I$
Energy	E	Watt-hours	Calculate using $E = P \times t$

Multimeter Check: How is measuring voltage different from measuring current?

Breadboard Parts and Connections

Breadboard Part	What it Looks Like	What is Connected Underneath	Main Job	Important Reminder
Terminal strips	The large center grid of holes, usually labeled A–J and numbered by rows	Each group of five holes on one side of the center gap is connected: A–E or F–J in the same numbered row.	Connect component leads and jumper wires to make circuit nodes.	Connections go **across five holes**, not up and down the board.
Five-hole group	Example: A10, B10, C10, D10, and E10	All five holes share one electrical connection.	Lets several leads meet at one point in a circuit.	Do not put both legs of a two-leg component into the same group; it bypasses the component.
Center gap (trench)	Long empty channel down the middle	No electrical connection crosses the gap.	Gives integrated circuits space to straddle the middle safely.	A–E are not connected to F–J, even when the row number matches.
Power rails (bus strips)	Long rows near the outer edges, often marked red + and blue/black –	Holes usually connect lengthwise along one rail.	Distribute positive supply and ground around the board.	The + and – rails are separate from each other.

Breadboard Part	What it Looks Like	What is Connected Underneath	Main Job	Important Reminder
Split power rail (Note: only on some breadboards)	A visible break in the red or blue marking, often near the middle	The two portions are not connected internally.	Allows separate supplies or circuit sections.	Use a jumper wire to bridge the break only if you want one continuous rail.
Hole / tie point	One plug-in hole	A metal spring clip connects it to its group or rail.	Holds a solid-core wire or component lead.	A hole is a connection point—not a direction of current flow.
Row numbers and letters	Numbers along the side; letters across the middle	Labels only	Help identify exact locations in directions and troubleshooting.	"E7" means column E, row 7.

Breadboard Thinking: Why is it important to understand the breadboard before powering the circuit?

Common Accidental Short Mistakes

What Someone Might Do	Why It Is a Problem	Safer Correction
Put a jumper directly from the + rail to the − rail.	It creates a direct battery shortcut.	Remove it; ensure every +-to-− route includes the intended load/resistor.
Put both legs of a component in the same connected row.	The component may be bypassed because both legs are at the same electrical point.	Move one leg to a different row or to the other side of the center gap, as shown in the diagram.
Connect the battery before building is complete.	A misplaced wire can energize an unintended path.	Build first; connect the battery last.
Change wires while power is connected.	A loose lead can briefly touch the wrong row or rail.	Disconnect the battery before every modification.
Run an LED without its required series resistor.	The LED may receive too much current and be damaged.	Verify the resistor is in series before power-on.
Assume colored rails are always connected exactly as expected.	Rails may be split or arranged differently across boards.	Use the board diagram; verify the specific board if uncertain.
Treat an LED like a resistor.	LEDs are polarized and must be oriented correctly.	Check the LED's long leg/anode and short leg/cathode before power-on.

L: Launch Your Learning

Build, measure, and calculate

Build the Circuit: Work with your partner to assemble a simple LED circuit. The circuit path is battery → resistor → LED → back to battery. Ensure you do a PATH check.

- **P**ower off: Do not add, remove, or move wires while the battery is connected.
- **A**nalyze the rails: Is + separate from −? Is there any wire directly connecting them?
- **T**race the path: Can you trace one intended route: + → resistor → LED/load → −?
- **H**ave a check: Ask your partner and instructor to inspect the circuit before connecting power.

Safety Check	Yes / No	Notes
The circuit has a complete path.		
The resistor is in the path.		
The LED polarity is correct.		
There are no direct short circuits.		
The instructor approved the circuit before power was applied.		

Current Measurement: Where do you place the multimeter to measure current? Why is this placement important?

Voltage Measurement: Where do you place the probes to measure voltage? Why?

Data Table: Assume the LED runs for two hours. Use your measured voltage and current to calculate power and energy.

Resistor (Ω)	Measured Voltage (V)	Measured Current (A)	Calculated Power (W)	Calculated Energy for 2 hr (Wh)

Optional

Resistor (Ω)	Measured Voltage (V)	Measured Current (A)	Calculated Power (W)	Calculated Energy for 2 hr (Wh)

Show Your Work: Write one power calculation using $P = V \times I$.

Show Your Work: Write one energy calculation using E = P × t.

Analysis: What changed when the resistor value changed? Use evidence from your table.

T: Transform Your Learning

Engineering modification challenge

Engineering Challenge: Modify the resistor size, predict and test how the change affects circuit performance. After you make predictions in the table below, gather measurements for the two different resistor sizes and complete the remaining two rows in the table in section L with this data.

Modification	Prediction: What will happen to the current?	Prediction: What will happen to the brightness of the light compared to the original circuit?
Modification 1: _____ Ohm resistor		
Modification 2: _____ Ohm resistor		

Compare and Explain: How did the modification change power? Use measurements as evidence.

Engineering Connection: How does this connect to real energy systems?

Think About It: Why do engineers measure these values instead of relying on assumptions?

Check Your Understanding

Why do engineers measure power instead of just voltage? Use evidence. What happens to power when current changes?

Looking Ahead: How can measuring voltage and current help engineers design a useful solar mini-grid?