

ECE 215/S – Principles of Electronic Cyber Warfare

Block 1: Resistive Circuits and Power Distribution

Lesson 2: Circuit Fundamentals and Ohm's Law

Department of Electrical and Computer Engineering
United States Air Force Academy

Fall 2026

Objective 1.1

I can calculate the voltages, currents, and power associated with devices in a simple DC-powered circuit using tools such as KVL, KCL, voltage and current dividers, Ohm's Law, and the power equation.

- This objective spans **three lessons** — today the quantities and Ohm's Law, L3 Kirchhoff's Laws, L4 series/parallel and dividers
- Assessed on **Quiz 1** along with Objective 1.2

Where We Are Going

By the end of this lesson, you will be able to:

- Define **charge**, **current**, **voltage**, and **resistance**, and state the units of each
- Apply **Ohm's Law** and the **power equation** to a single-loop circuit
- Write and read answers in **engineering notation**
- Use a **DMM** to measure resistance, voltage, and current — and know where the meter goes

Charge and Current

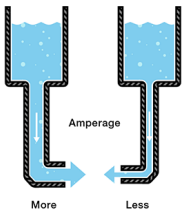
Charge is the physical property of matter that causes it to experience force.

- Charge is **quantized**: $q_p = +1.6 \times 10^{-19}$ C, $q_e = -1.6 \times 10^{-19}$ C
- Like charges repel; opposites attract

Current is the *strength* of the flow of charge.

$$I = \frac{dq}{dt} \qquad \longrightarrow \qquad 1\,\text{A} = \frac{1\,\text{C}}{\text{s}}$$

- Conventional current flows from **high to low** potential ($+$ to $-$)
- Measured **through** a point; has magnitude *and* direction



Water analogy: current is the *flow rate*.

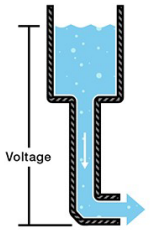
Voltage: Potential Difference

Voltage is the *potential* for charge to do work — the energy available to move it.

$$V = \frac{\Delta E}{dq} \qquad \longrightarrow \qquad 1\,\text{V} = \frac{1\,\text{J}}{\text{C}}$$

- Positive terminal (+) is the **higher** potential
- Measured **between two points** — never at one point
- Potential exists even with **no current flowing**
- Has magnitude *and* polarity

So what does a battery store? Not voltage, and not current — **charge**. A 24 A·h battery holds $24 \times 3600 = 86{,}400$ C.



Water analogy: voltage is the *pressure*.

Resistance

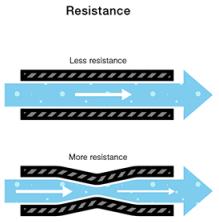
Resistance measures how much a material opposes the flow of charge. It is where power gets consumed.

$$R = \frac{\rho L}{A} \qquad \rho = \text{resistivity of the material}$$

- Measured in ohms (Ω)
- Longer wire $\rightarrow$ more resistance; fatter wire $\rightarrow$ less
- In the water analogy, resistance is the **size and shape of the pipe**

Question: copper has the lowest resistivity of the three below. Why does anyone use gold or aluminum?

Material	ρ (Ω·m)
Copper	1.72×10^{-8}
Gold	2.45×10^{-8}
Aluminum	2.80×10^{-8}

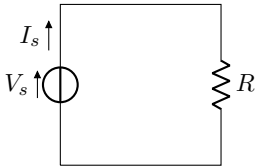


Ohm's Law

For a linear resistor, voltage, current, and resistance are locked together:

$$V = I \cdot R$$

- Know any two, you have the third
- This is the most-used equation in Block 1



A 12 V source across a 6 Ω resistor:

$$I = \frac{12\,\text{V}}{6\,\Omega} = 2\,\text{A}$$

Electrical Power

Power is work done over time:

$$P = \frac{dE}{dt} \qquad \longrightarrow \qquad \frac{\text{J}}{\text{s}} = \text{Watt}$$

Since $V = dE/dq$ and $I = dq/dt$, multiplying them gives energy per unit time:

$$P \quad = \quad I \cdot V$$

- Combined with Ohm's Law: $P = I^2R = V^2/R$ — pick whichever form matches what you know
- **Energy** is power over time: $E = P\,\Delta t$. This is what the utility bills you for, in kW·h

Engineering Notation and Standard Units

Engineering notation is scientific notation with one extra rule: the **exponent is always a multiple of 3**, so every answer maps onto a prefix.

- 0.00003056 W $= 30.56 \times 10^{-6}$ W $= 30.56\,\mu$W
- 0.707 A $= 707 \times 10^{-3}$ A $= 707$ mA
- 3.014×10^{7} V $= 30.14 \times 10^{6}$ V $= 30.14$ MV

Report answers this way, and mind your **significant figures**.

10^{12}	T (tera)	10^{-3}	m (milli)
10^{9}	G (giga)	10^{-6}	μ (micro)
10^{6}	M (mega)	10^{-9}	n (nano)
10^{3}	k (kilo)	10^{-12}	p (pico)

Quantity	**Unit**
Charge	Coulomb (C)
Current	Ampere (A)
Voltage	Volt (V)
Power	Watt (W)
Resistance	Ohm (Ω)

Lab Equipment: The Digital Multimeter

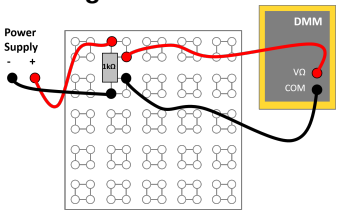


We do hands-on lab work all semester. Before you touch anything:

- Power supply **off** while changing the circuit
- Check every connection **before** energizing
- **Analyze first** — know what to expect, so you notice when it is wrong
- No food or drink near equipment

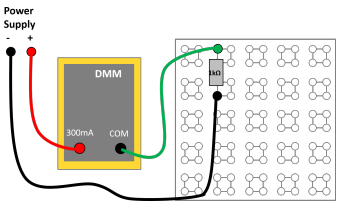
Measuring R, V, and I

Voltage and Resistance



Connect the meter **across** the device.

Current



Break the circuit; put the meter **in line**.

Think it through: should the DMM's internal resistance be *large* or *small* when measuring voltage? What about current?

Hands-On: Your First Measurements

Kit: DMM, two resistors, a jumper wire, a bench supply. In **pairs**, about **10 minutes**.

1. Read each resistor's **color code**, then measure it with the DMM on Ω. Record both values — how far off is the code?
2. Set the bench supply to 5 V and measure it on **DC V**. Does the meter agree with the front panel?
3. **Continuity-check** a jumper wire (beep mode).

Lab rules from two slides back still apply: **supply off** while you change anything.

Worked Example

A fresh 9 V battery supplies 540 mW to a load and has a capacity of 0.6 A·h. Assume the battery voltage stays constant.

What current flows?

$$P = V I \implies I = \frac{P}{V}$$

$$I = \frac{540\,\text{mW}}{9\,\text{V}} = 60\,\text{mA}$$

How long does the battery last?

$$q = I\,\Delta t \implies \Delta t = \frac{q}{I}$$

$$\Delta t = \frac{600\,\text{mA}\cdot\text{h}}{60\,\text{mA}} = 10\,\text{h}$$

Note both answers came out in engineering notation without extra work — that is the point of the convention.

Your Turn

A 120 W light bulb is connected to 120 V and left on for 365 days. Energy costs 10¢ per kW·h.

1. What current flows through the bulb?
2. What is the bulb's resistance?
3. How much energy does it consume in a year, in kW·h?
4. What does that cost?

Wrap-Up

Key ideas:

- **Charge** is the stuff; **current** is its flow rate; **voltage** is the pressure driving it; **resistance** opposes it
- **Ohm's Law** $V = IR$ and the **power equation** $P = IV$ carry most of Block 1
- Voltage is measured **across**; current is measured **through**. The meter goes in a different place for each
- Answers go in **engineering notation** with correct significant figures

Next lesson:

- **Lesson 3 — Kirchhoff's Laws:** how to handle a circuit with more than one loop
- **Quiz 0** (skills review) is due tonight