

Ohm's Law & Watt's Law in the Field

YES Electric • Arc Workforce Academy HVAC Apprenticeship

Draft 1 (October 2026). This lesson is under review. Videos are made by other companies, not YES Electric; follow this lesson and your journeyman where they differ. Boxes marked "Shop photo coming" will get real photos from our shop in a later version.

Unit 2 • Trade Math for HVAC • RTI: Trade Math (26 hr) — math now, meters in Unit 3

Class time: ~3 hrs (1 classroom + 2 drills + demo)

1. What you'll be able to do

- Use the two laws every electrical diagnosis leans on: **Ohm's law ($V = I \times R$)** and **Watt's law ($P = V \times I$)** — pick the right one, solve for the missing piece.
- Predict what happens to current when resistance changes ("element shorted = resistance halved = amps DOUBLE") — the intuition behind half the electrical failures you'll see.
- Compute expected amp draw of resistive loads (heat strips!) and compare to a clamp reading: **the math is the spec.**
- Understand the **voltage-squared effect**: the 208 V vs 240 V strip-heat output question from Lesson 2.2, answered properly.

This is a MATH lesson — the meters, safety, and live measurement live in Unit 3. Today the numbers learn to behave; next unit your hands do.

2. Tools & materials

- Whiteboard + drill decks
- A 10 kW heat strip element (dead, on the bench) and its nameplate
- Calculator throughout

3. Watch first

Order	Video	Channel	Length	Why
1	Watt's Law Demonstrated	HVAC School (Ty)	8:21	$P = V \times I$ made physical
2	Electrical Basic Concepts — RSES NATE Prep	HVAC School	24:43	The vocabulary + both laws, exam-style
3	Resistance in Parallel Circuits	HVAC School	5:46	Why adding loads RAISES total amps
Preview	Using Your Voltmeter as a Voltage Drop Detector	HVAC School	20:30	Where this math becomes a diagnostic weapon (3.2/6.5)

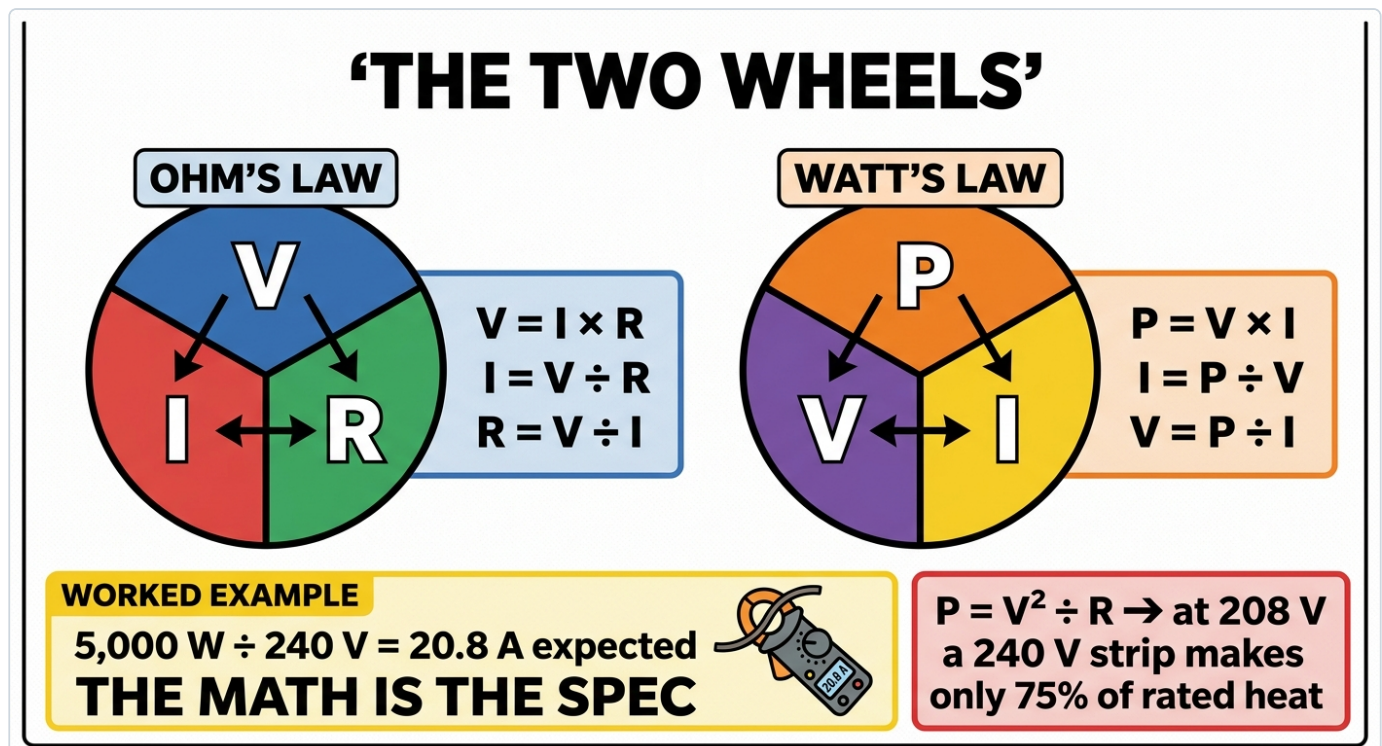
4. The idea

The two laws and the wheel

Ohm's law: $V = I \times R$ (volts = amps $\times$ ohms) — how pressure, flow, and restriction relate.

Watt's law: $P = V \times I$ (watts = volts $\times$ amps) — how much work is getting done.

Water analogy, one last time: voltage = pressure, amps = flow, ohms = pipe restriction, watts = water actually delivered. Squeeze the pipe (more R) $\rightarrow$ less flow (fewer A) at the same pressure (V).



Rearrangements you'll actually use:

You know	You want	Use
V and R	expected amps	$I = V \div R$
V and I	watts	$P = V \times I$
P (nameplate) and V	expected amps	$I = P \div V$
V and I	resistance check	$R = V \div I$

The worked example that pays your bills — heat strips

A "5 kW / 240 V" strip element:

- Expected amps: $I = P \div V = 5,000 \div 240 = 20.8 \text{ A}$ ← what your clamp should read (Unit 8 checkout uses exactly this)
- Element resistance: $R = V \div I = 240 \div 20.8 = 11.5 \Omega$ ← what your ohmmeter should read, dead
- BTU output: $5 \text{ kW} \times 3,412 = 17,060 \text{ BTU/hr}$ (Lesson 2.2, still true)

Now the diagnosis intuitions, all from the same two formulas:

- **Element reads 23 Ω instead of 11.5** (two elements' worth)? You're across two in series, or the wrong terminals — re-look before condemning.
- **Clamp reads 10 A instead of 20.8?** Half the power. Maybe half the voltage path (one leg lost) — heat strips that "kinda warm" usually do this.
- **Reads 0 Ω (dead short)?** $I = V \div R$ goes toward infinity → breaker SLAMS. Resistance protects the circuit; losing it is the bang.
- **Reads OL/infinite?** Open element. No flow at all. The "no heat" half of the same coin.

The voltage-squared effect (the 2.2 homework, solved)

Resistance is fixed by the metal. Drop the voltage and BOTH V and I fall:

$P = V^2 \div R$. At 240 V: $240^2 \div 11.5 = 5,009 \text{ W}$ ✓. At 208 V: $208^2 \div 11.5 = 3,762 \text{ W} — 75\%$ of rated.

A "10 kW" kit on a 208 V commercial panel makes 7.5 kW of heat. Strip kits are rated at 240; buildings aren't always. This one formula explains a thousand "the aux heat seems weak" calls (and the strip table in Unit 8 lists both columns — now you know why).

Series vs parallel — the 30-second version

- **Series** (one path): resistances ADD, current is the same everywhere. Controls live here: switches and safeties in series so ANY one can stop the show (3.3).

- **Parallel** (side-by-side paths): each load sees full voltage; total amps ADD. Heat strip banks are parallel — every added element adds ~20 A. That's why big kits get multiple breakers (8.3).

5. Drills & bench

1. **The wheel gauntlet (20 Qs):** mixed solve-for-the-blank: nameplate watts+volts → amps; volts+ohms → amps; volts+amps → watts and ohms. 90% to pass.
2. **Strip-kit teardown math:** the dead 10 kW kit on the bench: read nameplate, predict per-element ohms and amps, then ohm the actual elements (dead bench reading — safe, instructor-checked). Predicted vs measured side by side.
3. **Voltage-squared drill:** compute three kits (5/7.5/10 kW) at 240 V and 208 V. Fill the table; circle the % loss (it's always ~25%).
4. **Failure-intuition round:** instructor calls a symptom; students answer with a formula. ("Breaker trips instantly when strips engage" → R collapsed → $I=V \div R$ spiked. "One element reads OL" → open → that 20 A is missing → 'kinda warm'.)
5. **Series/parallel sort:** ten circuit sketches; mark each "controls (series)" or "loads (parallel)" and say what total amps do when one more load joins.

Checkout: unaided — compute expected amps & ohms from a strip nameplate; compute its 208 V output; explain one symptom in formula language.

6. Field gotchas

- **The math IS the spec.** Clamp reads 14 A on a element whose math says 20.8 — that's a finding, not a shrug.
- **Resistive loads only, for now:** motors and compressors draw amps by a different rulebook (inductance, power factor, LRA vs RLA — Unit 3/6). Don't apply today's strict math to a compressor and panic.
- **Cold vs hot resistance:** elements read slightly lower ohms cold; igniters (Unit 7) dramatically so. Expect drift, not exactness.
- **Never ohm a live circuit** — the ohmmeter pushes its own tiny voltage and reads garbage (or dies) against a live one. De-energize, verify dead, THEN ohm (the full ritual is Unit 3's heart).
- **0.5 Ω vs 0 Ω matters at high amps:** a "nearly zero" bad connection at 20 A makes $P = I^2 \times R = 200 \text{ W}$ of heat in a wire nut. That's the melted-lug photo in every fire investigation. (I^2R heating — same wheel, third arrangement.)

7. Competency link

- RTI Trade Math; the computational spine of **Comp 6** (multimeter, Unit 3), **Comp 19-20** (components/troubleshooting, Unit 6), strip heat (Comp 24, Unit 8).

8. Check yourself

1. State both laws. Which one answers "how much work"?
2. 7.5 kW kit at 240 V — expected amps? Expected total ohms?
3. That kit at 208 V — output watts? (Use $V^2 \div R$.)
4. Clamp shows 10.4 A on a single 5 kW/240 V element. Healthy?
5. An element ohms at 0. What happens at power-on and why?
6. An element ohms OL. Symptom the customer reports?
7. Why do safeties wire in series but heat elements in parallel?
8. Each added parallel element changes total amps how?
9. A loose lug adds 0.5 Ω in a 20 A path. Watts of heat at the lug? Why is that a fire?
10. Why can't you ohm a live circuit?

Arc Workforce Academy · YES Electric LLC Apprenticeship 2026-AL-141731 · Lesson 2.4 v1.0
(2026-06-10)