Electrical Power and Energy

Matthew Williams • Physics • May 20, 2026

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Electrical Power

Power is the rate at which electrical energy is transferred. For a component with current I and potential difference V:

$$P = IV$$

Using $V = IR$ and $I = V/R$, two additional forms follow:

$$P = I^2R \qquad P = \frac{V^2}{R}$$

Unit: watt (W), where 1 W = 1 J s^{-1}.

A 60 W lamp converts 60 J of electrical energy to light and heat every second.

Electrical Energy

Energy is power multiplied by time:

$$E = Pt$$

where E is in joules (J), P is in watts (W), and t is in seconds (s).

In practice, the **kilowatt-hour (kWh)** is used for billing electricity:

$$1\text{kWh} = 1000\text{W} \times 3600\text{s} = 3.6 \times 10^6\text{J} = 3.6\text{MJ}$$

Electrical energy and cost

A 2000 W electric kettle is used for 5 minutes. The electricity costs $0.30 per kWh.

Energy used in joules:

$$E = Pt = 2000 \times (5 \times 60) = 600\,000\text{J}$$

Energy used in kWh:

$$E = \frac{2 \times 5}{60} = \frac{10}{60} \approx 0.167\text{kWh}$$

Cost:

$$\text{Cost} = 0.167 \times \backslash[Math : 0.30 \approx \backslash]0.05$$

Efficiency of Electrical Appliances

All appliances waste some energy, usually as heat. Efficiency is expressed as a percentage:

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}} \times 100\%$$

The **LED lamp** is more efficient than incandescent or fluorescent alternatives:

Lamp type	Approximate efficiency	Notes
Incandescent	5%	95% of energy wasted as heat
Compact fluorescent (CFL)	15-25%	Better than incandescent but contains mercury
LED	30-50%	Best efficiency; long lifespan; no mercury

In the Caribbean, where electricity is expensive (imported fuel), LEDs offer significant cost savings.

Using the Power Formulas

Power formulas applied

A resistor of 10 Ω carries a current of 2 A.

Power dissipated:

$$P = I^2R = 2^2 \times 10 = 4 \times 10 = 40\text{W}$$

Voltage across the resistor:

$$V = IR = 2 \times 10 = 20\text{V}$$

Check: $P = IV = 2 \times 20 = 40$ W.

Exam Tip

Three power formulas exist, choose the one that uses the quantities given:

- $P = IV$: when both current and voltage are known.
- $P = I^2R$: when current and resistance are known (saves computing V first).
- $P = V^2/R$: when voltage and resistance are known (saves computing I first).

When converting between J and kWh: 1 kWh = 3.6 × 10⁶ J. Divide joules by 3.6 × 10⁶ to get kWh; multiply kWh by 3.6 × 10⁶ to get joules.