AM-02.05 · SPACE ACADEMY

AM-02.05 — Work, energy, and power: how much energy, and how fast?

Why can two machines deliver the same energy but not the same power?

Course compass

Goal: understand every word, symbol, unit and operation before using the formula.

Method: concrete situation → vocabulary → step-by-step calculation → three examples → check.

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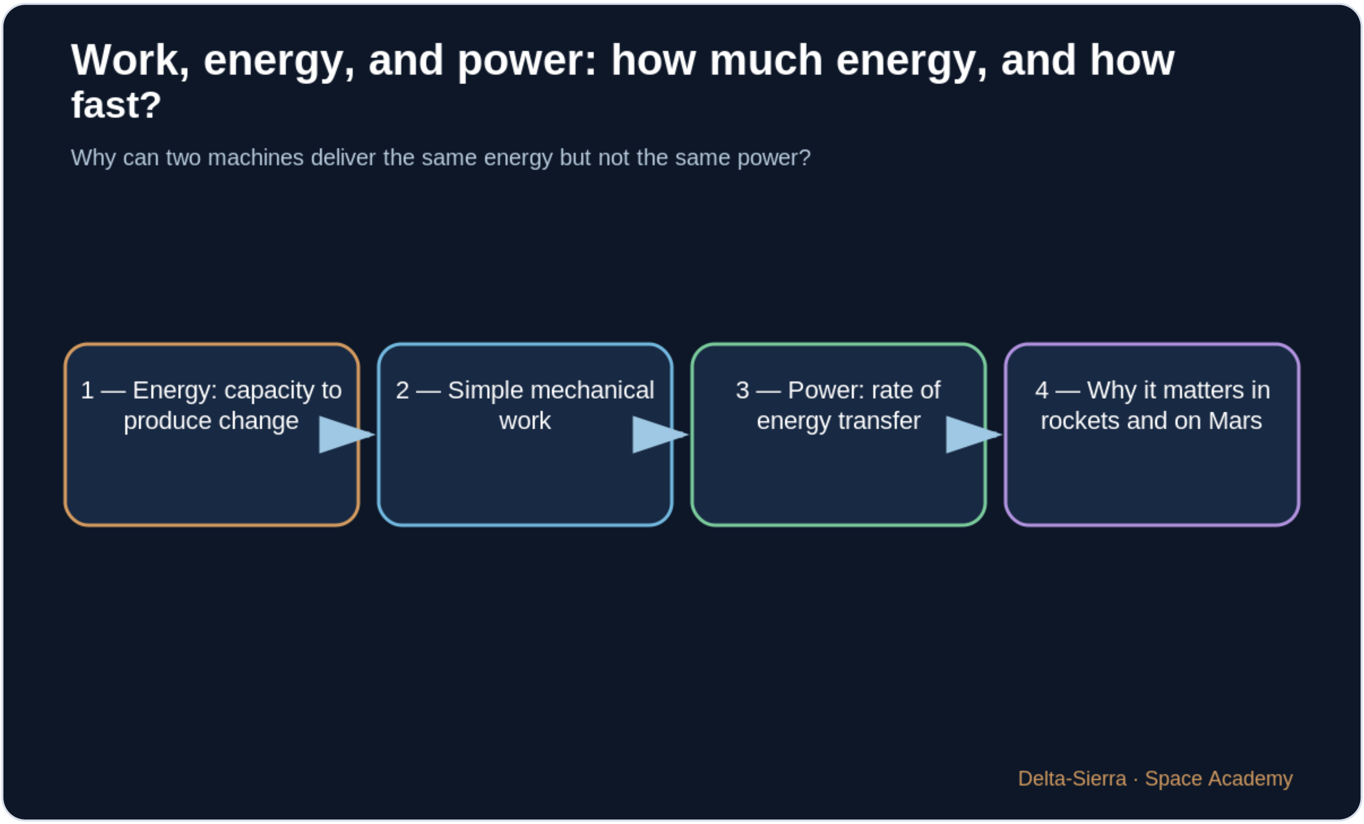
1 — Work, energy and power are related but not identical

A Mars winch lifts a crate. Mechanical **work** is done as force acts through a displacement. **Energy** is transferred or transformed. **Power** tells how quickly that energy transfer occurs.



One operation can be described by work, energy and power.

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2 — Mechanical work in the simple aligned case

$$W = F \times d$$

Read: “W equals F times d”. W is work in joules, F force in newtons, d displacement in metres.

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100 N × 5 m = 500 J
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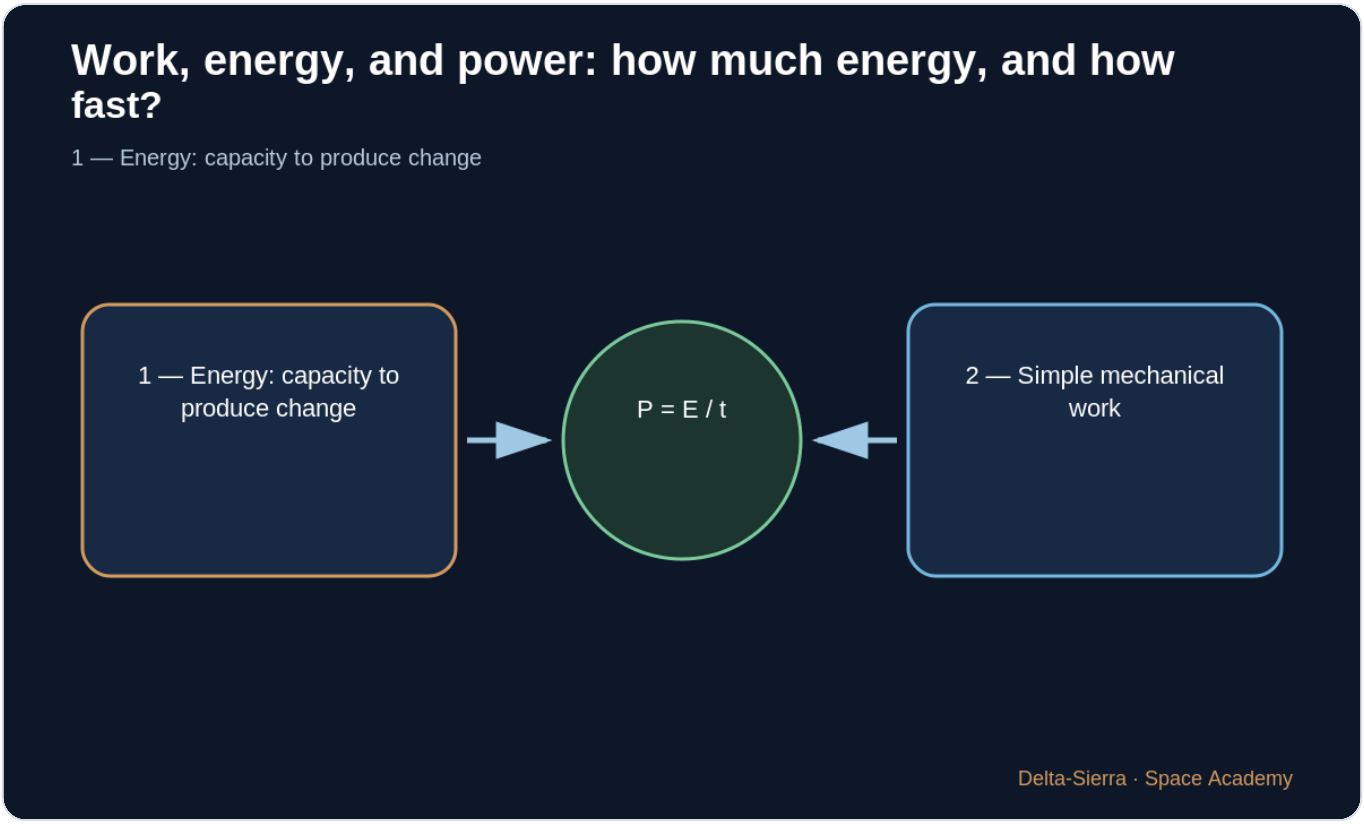
J is read “joule”.

Why multiply? The force acts throughout each metre of displacement.



Force × displacement = work in the aligned case.

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3 — Energy can be stored, transferred and transformed

A battery stores chemical energy converted to electrical energy. A motor transforms part of it into motion and heat. A lifted mass gains gravitational potential energy.

> **Symbol warning:** W is often the letter for work, while W is also the unit symbol for watt. Context matters.

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4 — Power: joules transferred each second

$$P = E \div t$$

P is power in watts, E energy in joules, t time in seconds.

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1,000 J ÷ 5 s = 200 W
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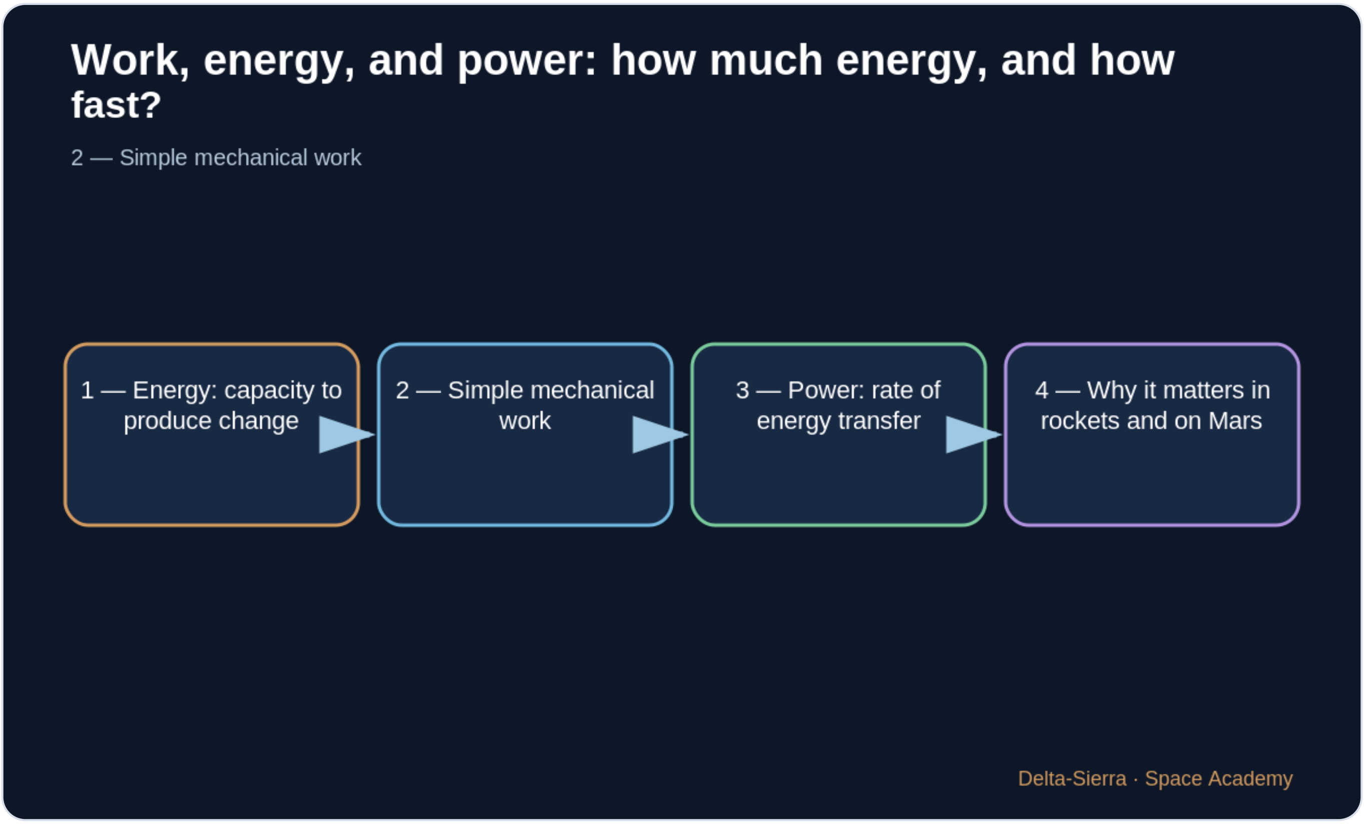
1 W = 1 J/s.

Why divide by time? We want the energy transfer corresponding to one second.



Same energy, different time: power changes.

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5 — Kinetic energy: energy of motion

$$E_k = \frac{1}{2} \times m \times v^2$$

A 100 kg rover moving at 4 m/s:

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v² = 16
E k = 0.5 × 100 × 16 = 800 J
```

Double speed gives four times the kinetic energy.

6 — Lifting a load: gravitational potential energy

$$E_p = m \times g \times h$$

Near the Martian surface, use g ≈ 3.71 N/kg for this exercise.

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50 kg × 3.71 × 2 m = 371 J
```
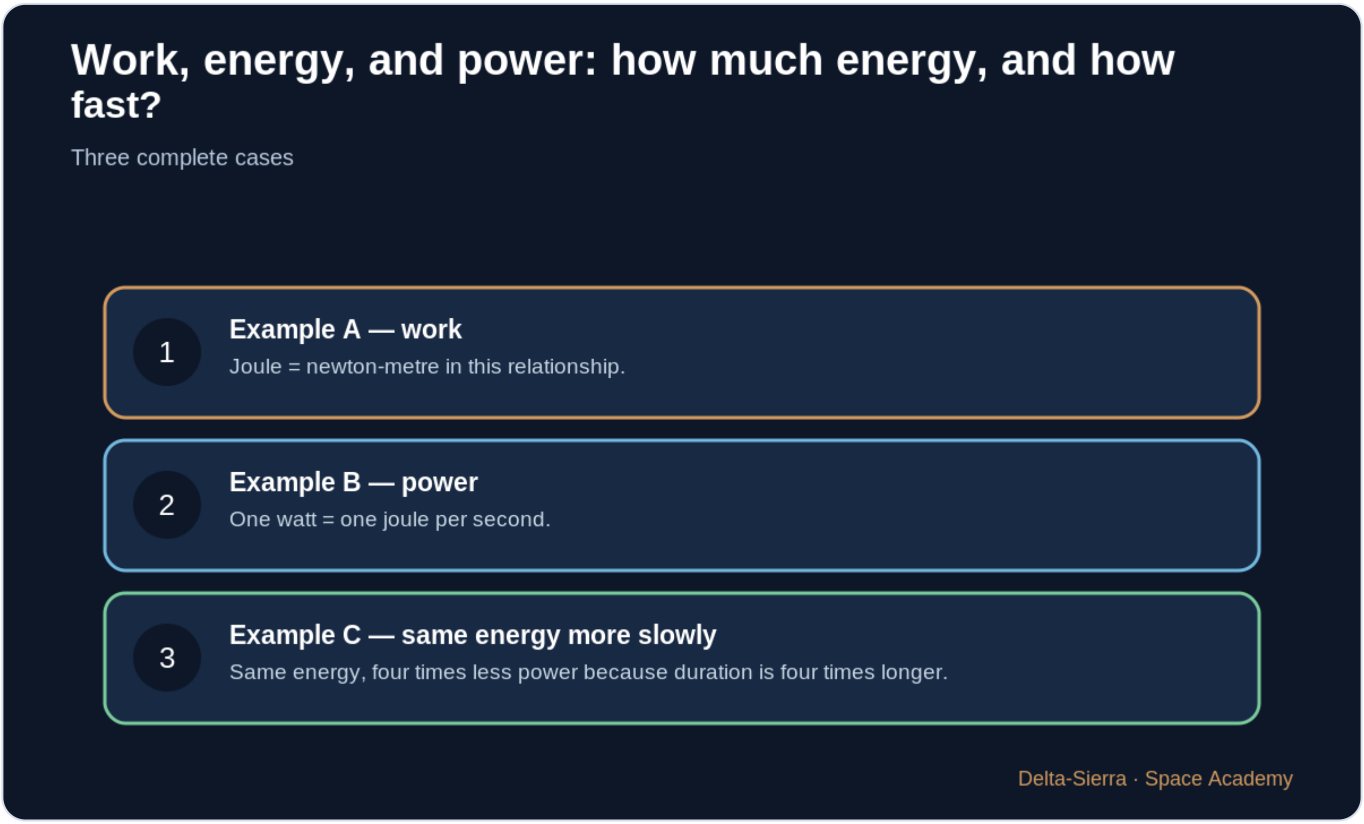

A real system draws more electrical energy because of losses.

7 — Three concrete examples



Winch, rover and pump examples.

Example A — Winch

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250 N × 4 m = 1,000 J
if done in 10 s: P = 100 W
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Example B — Same energy, different power

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2,000 J in 20 s = 100 W
2,000 J in 5 s = 400 W
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Example C — Pump efficiency

600 W useful at 75% efficiency.

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input power = 600 ÷ 0.75 = 800 W
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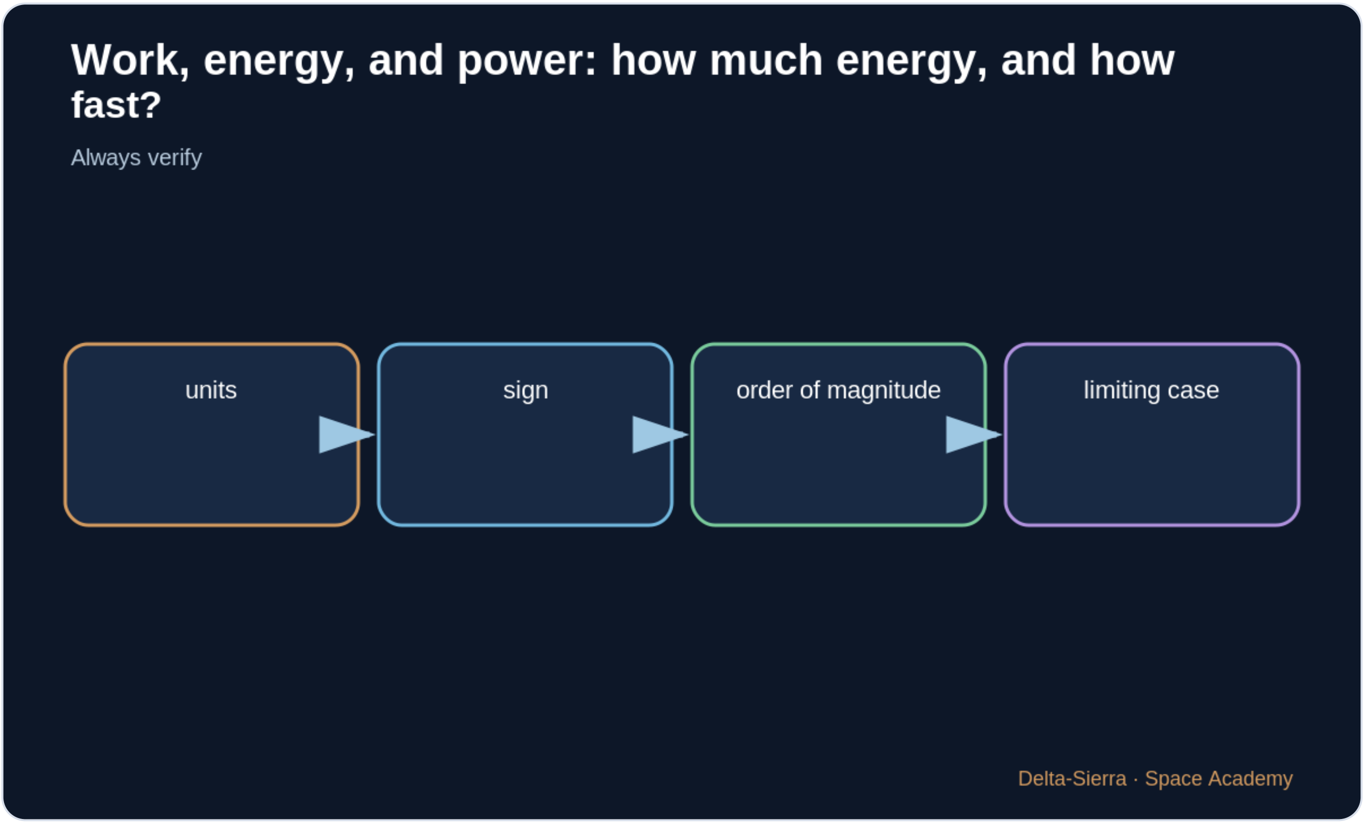
8 — Building an energy budget on Mars

Power rating alone is not enough. A base must track operating duration, total energy, efficiency, startup peaks and reserve margins.

A 1,000 W device used for 2 h ideally uses 2 kWh. 1 kWh = 3.6 MJ.



Final check: distinguish joules of energy from watts of power.

Beginner checkpoint — joules answer “how much?”, watts answer “how fast?”

Energy and power are often confused because both appear on equipment specifications. Joules measure an amount of energy. Watts measure the rate at which energy is transferred: one watt is one joule per second. A small machine can therefore use a large total amount of energy if it runs for a long time, while a powerful machine may use less total energy if it operates only briefly.

For Mars systems this distinction is essential. Battery sizing depends on energy over time, while cables, converters, motors and generators must also handle power peaks. A base can possess enough stored energy for the day and still fail if it cannot deliver the required instantaneous power to start a pump, compressor or machine tool.

9 — Corrected exercises

Exercise 1

80 N over 3 m?

240 J.

Exercise 2

3,600 J in 30 s?

120 W.

Primary and educational sources

- [NIST - International System of Units (SI)]
- [NASA Glenn - Guide to Rockets]