

Power and rates of energy transfer

Name: _____ Class: _____ Date: _____

Start here

0-5 minutes

Today: Calculate energy, power and time; compare rates with amounts and keep input/useful quantities distinct.

You need: Pen, different-coloured pen, ruler and calculator. Reading, equations, diagram and data are supplied.

Work from memory. Write directly in this booklet and show working and units.

1. Define power in terms of energy transfer or work done.

2. A winch has useful output power 300 W. State the useful energy it transfers in each second.

Useful energy each second:

3. Convert 1.5 minutes to seconds.

Time in seconds:

Stop for check 1. Wait for your teacher before moving on.

Try again A

Only if directed. Use the first 2 reading minutes, then continue on page 2.

Help: Use page 2: one watt is one joule per second; minutes $\times 60$ gives seconds. Keep a rate distinct from a total amount.

(a) A motor has useful output power 240 W: how much useful energy is transferred in one second? (b) Convert 0.25 minutes to seconds. (c) State what power compares: an energy amount, or an energy amount per unit time?

When your teacher says, turn to page 2.

Compare energy amounts and rates

5-15 minutes

$P = E/t = W/t$. P is power in watts, E is energy transferred in joules, W here means work done in joules, and t is time in seconds. The letter W for work is different from the unit symbol W for watts. A 400 W motor transfers 400 J each second. Motors doing the same work can have different powers if they take different times; power alone does not establish efficiency.

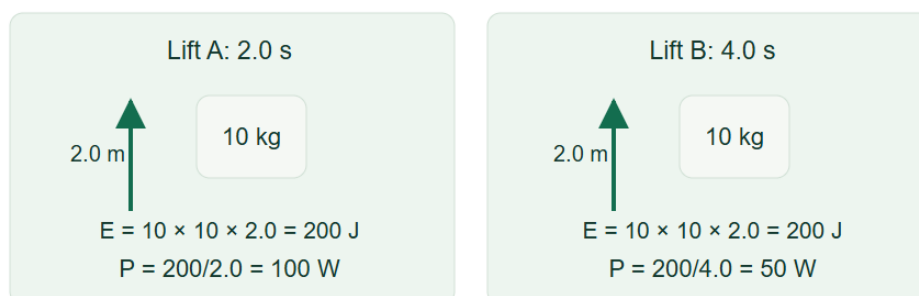
Use / unit	Rule
Power	$P=E/t=W/t$. P in watts; E and work W in joules; t in seconds.
Unknown energy / time	$E=Pt$; $t=E/P$. Use matching input or useful quantities.
Convert first	$\text{kW} \times 1000 = \text{W}$. Minutes $\times 60 = \text{s}$. $1 \text{ W} = 1 \text{ J/s}$.
Useful or input?	Useful serves the stated task. Total input is not automatically all useful output.

Worked models - power, time and input energy

A hoist transfers 12000 J in 30 s: find its mean power. In a separate test a 75 W motor transfers 9000 J: find the time. A different device receives energy at 0.20 kW for 0.50 minutes: find its input energy.

Hoist: $P=12000/30=400 \text{ W}$. Separate motor: $t=E/P=9000/75=120 \text{ s}$. Different device: $0.20 \text{ kW}=200 \text{ W}$; $0.50 \text{ minutes}=30 \text{ s}$; input $E=Pt=200 \times 30=6000 \text{ J}$. Match energy and power labels: an input calculation does not establish the useful output.

Same useful energy, different useful powers



Both lift the same mass through the same height; $g = 10 \text{ N/kg}$.

Maintained note comparison: same 200 J useful work, different times and useful powers. $g=10 \text{ N/kg}$ is supplied in the illustration.

From Energy Calculations and Power, section 3 and its comparison figure. The rearranged/conversion models are supplied for this lesson. Optional online reading.

Turn to page 3 for question 4.

Check equal work at different rates

15-20 minutes

4. Machines A and B each do 900 J of useful work. A takes 3.0 s; B takes 6.0 s. Which statement is correct? Choose a letter and justify the useful work and both powers.

- A. A does more useful work because it finishes sooner
- B. Both do 900 J; A has useful power 300 W and B 150 W
- C. Both do 900 J; A has useful power 150 W and B 300 W
- D. Both do 900 J; A has useful power 2700 W and B 5400 W

Chosen letter:

Useful work comparison:

Power calculations and reason:

Stop for check 2. Wait for your teacher before moving on.

Try again B

Only if directed. Complete B instead of questions 5-6 on page 4; then answer 7-8.

Help: Use page 2: divide useful energy by its own time for each machine. Compare useful work separately from power.

Different machines each do 600 J useful work. A takes 4.0 s and B takes 8.0 s. Find each useful power, compare useful work and explain which has greater power.

Later practice uses separate canal-maintenance winch and hoist tests. Everything needed is supplied; no lifting experiment or online device is required.

Turn to page 4. If you used B, leave questions 5-6 blank.

Calculate power, input energy and time

20-30 minutes

Complete 5-8, or 7-8 only if you completed B. Each is a separate test. Preserve the useful/input label in each answer.

5. A winch does 600 J of useful lifting work in 4.0 s. Calculate its mean useful output power.

Working and useful power:

6. In a separate test, a winch does 7200 J of useful work in 30 s. Calculate its mean useful output power.

Working and useful power:

7. A winch receives energy at constant input power 0.50 kW for 2.0 minutes. Calculate its total energy input in joules.

Input power in W and time in s:

Equation and working:

Input energy:

8. Another test needs 4500 J of useful lifting work. A winch has constant useful output power 150 W. Calculate the time required.

Rearrangement and working:

Time:

At about 30 minutes turn to page 5 for the independent check.

Pause and check both conversions

30-33 minutes

9. A motor receives energy at constant input power 0.15 kW for 2.0 minutes. Find its input energy in joules. Explain why this result is not automatically the useful lifting-energy output.

Input power in W and time in s:

Equation, working and input energy:

Why useful output is not established:

Stop for check 3. Wait for your teacher before moving on.

Try again C

Only if directed. Complete C instead of questions 10-11 on page 6. Then answer 12-15.

Help: Use page 2: convert kW to W and minutes to s before $E=Pt$. Carry the input label through the calculation.

Another device receives energy at constant input power 0.25 kW for 3.0 minutes. Find input energy and explain whether the useful output energy can be deduced from that number alone.

Continue on page 6. If you used C, leave questions 10-11 blank.

Use matching hoist quantities

33-45 minutes - continue practice

For questions 10-13, hoists A and B each raise the same 40 kg case vertically by 3.0 m. Each starts and ends at rest. The useful work is 1200 J for each lift (given); no GPE calculation is required. Table 1 gives each whole lift's time and TOTAL INPUT energy.

Table 1: hoist	Time / s	Total input energy / J
A	8.0	2000
B	12	1500

10. Use the supplied Table 1 and given useful energy 1200 J to calculate hoist A's mean useful output power.

Working and useful output power A:

11. Calculate hoist B's mean useful output power for the same 1200 J useful lift. Use Table 1.

Working and useful output power B:

12. A trainee says hoist A must do more useful work because it has greater useful power. Explain why the claim is wrong.

Useful work comparison:

Why A has greater useful power:

13. Use Table 1 to calculate the mean input power of each hoist. Label both results as input power.

Input power A - working and unit:

Input power B - working and unit:

Match the labels

Questions 10-11 use useful work. Question 13 uses total input energy. Do not mix them or infer useful output from an input value alone.

Finish practice with the display-lift questions on page 7.

Compare useful work when time halves

Finish practice by 45 minutes

For questions 14-15: a display lift raises a 3.0 kg model through 2.4 m in 1.5 minutes, starting and ending at rest. $g=10 \text{ N/kg}$. Its useful lifting work is 72 J (given). Do not calculate GPE here; compare useful work and rates.

14. A display lift's useful work is 72 J (given) over 1.5 minutes. Calculate its mean useful power.

Time in seconds:

Working and mean useful power:

15. A second lift raises the same model through the same height, doing the same 72 J useful work in half of 1.5 minutes. Compare its useful energy transfer and useful power with the first lift.

Useful energy of second lift:

Second lifting time:

Useful power working and unit:

Comparison and reason:

Check the meaning

An amount of energy is measured in J. A rate is measured in W (J each second). The same useful work can be done at different useful powers. These data alone do not establish input efficiency.

At 45 minutes turn to page 8 for review and the independent exit.

Review, then apply power independently

45-55 minutes review; 55-60 minutes independent exit

16. Correct practice in a different colour and explain one error using units, the equation or input/useful labels. If all answers were correct, explain why a larger useful power does not show that more useful work was done.

Independent exit - only when your teacher says

Cover earlier pages and answers. Complete question 17 independently.

17. Separate tests: (a) A device receives energy at constant input power 0.24 kW for 1.5 minutes. Find its input energy. (b) A lift does 840 J useful work in 7.0 s. Find mean useful power. (c) A second lift does the same useful work in 3.5 s. Compare useful energy and useful power, with a calculation.

(a) Input power in W and time in s:

(a) Input energy - working and unit:

(b) Mean useful power - working and unit:

(c) Useful energy comparison:

(c) Useful power calculation and comparison:

Stop for check 4. Wait for your teacher before moving on.

Write your name on page 1. Hand in the complete booklet with working and corrections.

Try again D - next lesson

Leave this today. Your usual teacher may direct it next lesson.

Help: Next lesson revisit page 2's units, matching labels and power models. Cover the reading before making this new independent attempt.

Next lesson, separate tests: (a) A device receives energy at 0.18 kW input for 2.5 minutes. Find input energy. (b) A lift does 600 J useful work in 5.0 s. Find useful power. (c) Another lift does the same useful work in 2.5 s. Compare useful energy and useful power with the first lift.

Hand your complete booklet to your teacher.