

Exercise walk-through

1.6

Efficiency (4.1.2.2)

AQA · GCSE · Physics

Five situations the specification names

Rising and falling

Describing a change: an object projected upwards trades kinetic for gravitational potential.

A vehicle slowing down empties kinetic and fills the thermal store of the brakes.

Collisions and currents

A moving object hitting an obstacle: kinetic empties, thermal stores fill.

A kettle: electrical work fills the thermal store of the water.

A worked chain from spring to speed

- 1 **Known** $k = 50 \text{ N/m}$, $e = 0.12 \text{ m}$, $m = 0.020 \text{ kg}$; all base units.
- 2 **Store** $E_e = \frac{1}{2}ke^2 = \frac{1}{2} \times 50 \times 0.12^2 = 0.36 \text{ J}$.
- 3 **Transfer** at release all E_e becomes E_k .
- 4 **Rearrange** $v = \sqrt{2E_k/m} = \sqrt{2 \times 0.36/0.020}$.
- 5 **Answer** $v = 6.0 \text{ m/s}$, 2 s.f., unit from $\sqrt{\text{J/kg}}$.

The stairs question, start to finish

- 1 **Known** $m = 60.0 \text{ kg}$, $h = 175 \text{ cm} = 1.75 \text{ m}$, $t = 1.40 \text{ s}$, $g = 9.8 \text{ N/kg}$.
- 2 **Energy** $E_p = mgh = 60.0 \times 9.8 \times 1.75 = 1029 \text{ J}$.
- 3 **Power** $P = E_p/t = 1029/1.40$.
- 4 **Answer** $P = 735 \text{ W}$.
- 5 **Check** her total power is higher: her body also heats and pushes air.

Exercises 2.1·2.2

2.1 A motor transfers 12 000 J of the 15 000 J it takes in to a useful store. Calculate its efficiency as a decimal and as a percentage. [2]

2.2 A solar cell has an efficiency of 0.15. The total power input to it is 7.8 kW. Calculate the useful power output. [3]

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2.1

$$\text{efficiency} = \frac{12\,000}{15\,000} = \mathbf{0.80} = \mathbf{80\%}$$

(decimal 1, percentage 1.)

2.2 A solar cell has an efficiency of 0.15. The total power input to it is 7.8 kW. Calculate the useful power output. [3]

2.2 Convert: 7.8 kW = 7800 W (C1). Rearrange: useful = efficiency × total (C1).

$$P_{\text{useful}} = 0.15 \times 7800 \text{ W} = \mathbf{1200 \text{ W}} \text{ (1.2 kW, 2 s.f.)}$$

(answer A1.)

Exercise 2.3

2.3 An appliance wastes 30 % of its input energy. The input is 8.0 kJ. Calculate the useful output. [2]

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2.3 Useful share = $100 - 30 = 70\%$.

$$E_{useful} = 0.70 \times 8.0 \text{ kJ} = \mathbf{5.6 \text{ kJ}}$$

Exercise 3.1

3.1 A shop sells two heaters, both 2000 W input. Heater A delivers 1700 W to the room; heater B delivers 1500 W.

(a) Calculate the efficiency of each heater as a percentage. [4]

(b) A student says: “ heater B is 200 W worse, so it is only a little less efficient.” Comment on this with a calculation. [2]

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3.1 (a) Heater A:

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Full solution 3.1

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(set-up 1, value 1); Heater B:

$$\text{efficiency} = \frac{1500}{2000} = 0.75 = \mathbf{75\%}$$

(set-up 1, value 1). (b) The efficiencies differ by 10 percentage points ($85 - 75$), which is one-eighth of B's efficiency ($10/75 \approx 13\%$ relative); against a saving of 200 W, that is a real efficiency gap, not "only a little" – though both heaters deliver most of their input usefully.

Exercise 3.2

3.2 The National Grid takes 34.2 GJ of energy from one power station and delivers 33.9 GJ to consumers.

(a) Write down the equation which links efficiency, total energy input and useful energy output. [1]

(b) Calculate the efficiency of the National Grid transfer, as a decimal. [3]

(c) Explain why the efficiency is less than 1. [1]

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Full solution 3.2

3.2 (a) efficiency = useful output energy transfer $\div$ total input energy transfer. (b)

$$\text{efficiency} = \frac{33.9 \text{ GJ}}{34.2 \text{ GJ}} = \mathbf{0.991} \text{ (3 s.f.)}$$

(fraction 1, decimal answer 1; GJ cancels – no conversion needed when top and bottom match.) (c) Some energy is dissipated – transferred to thermal stores of the cables and transformers by heating.

Exercise 3.3

3.3 A combined heat and power (CHP) station burns fuel with a total input power of 50 MW. Of this, 17 MW becomes electrical output and 25 MW heats a district heating network; the rest is dissipated.

(a) Calculate the efficiency of the electrical output. [2]

(b) Calculate the total efficiency when the heating output is also counted as useful. [2]

(c) (HT) The station's electrical efficiency is lower than a modern power station's (about 45 %). Explain whether the CHP station is nevertheless the more efficient use of the fuel. [3]

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3.3 (a)

$$\text{efficiency}_{\text{elec}} = \frac{17}{50} = \mathbf{0.34} \text{ (34 \%)}$$

(fraction 1, value 1.) (b) Useful outputs are electrical + heating = 42 MW.

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$$\text{efficiency}_{elec} = \frac{17}{50} = \mathbf{0.34} \text{ (34 \%)}$$

(fraction 1, value 1.) (b) Useful outputs are electrical + heating = 42 MW.

$$\text{efficiency}_{total} = \frac{42}{50} = \mathbf{0.84} \text{ (84 \%)}$$

(sum 1, value 1.) (c) A modern station turns 45 % of the fuel into electricity but rejects the rest – 55 % – as waste heat at the power station. The CHP station uses 84 % of the same fuel usefully by sending its “waste” heat to buildings instead. So for combined use the CHP station is the more efficient use of fuel, even though its electrical efficiency alone is lower – the useful output must be defined before comparing efficiencies.