Exercise walk-through

1.4
Power (4.1.1.4)

AQA · GCSE · Physics

Energy stores and systems

- A ball thrown upwards: its kinetic store empties and the gravitational potential store fills. At the top, it stops for an instant.
- A car hitting a wall: the kinetic store empties; the thermal stores of the car and wall fill, and some energy is carried away by sound.
- A battery-powered toy car speeding up: the chemical store of the battery empties; the kinetic store of the car fills.

Power

- **Power** is the rate at which energy is transferred, or the rate at which work is done.
- A more **powerful** motor lifts the same load through the same height in less time.
- P is **power** in watts, E energy transferred in J, W the **work done** in J and t the time in s.
- A transfer of 1 J per second is a power of 1 **watt** (W).

$$P = \frac{E}{t} \qquad P = \frac{W}{t}$$

Efficiency

- **Efficiency** tells you what fraction of the input energy is transferred usefully:
- You must learn both.
- **Efficiency** can be a decimal or a percentage, and it can never be more than 1 (100%).
- It has no unit.

$$\text{efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}} \qquad \text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Exercise 2.1

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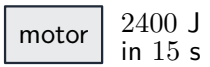
2.1 Convert: 7.2 kJ = 7200 J (C1); 4.0 min = 240 s (C1).

$$P = \frac{E}{t} = \frac{7200\ \text{J}}{240\ \text{s}} = \mathbf{30}\ \text{W}$$

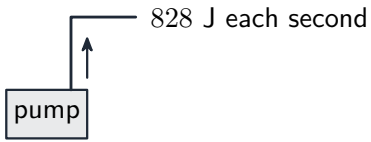
(answer A1.)

Exercise 2.2

2.2 A motor does 2400 J of work in 15 s. Calculate its power. [2]

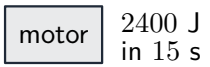


2.3 A pump lifts water, giving it 828 J of gravitational potential energy each second. State the useful output power of the pump, and explain why the electrical input power must be greater. [2]

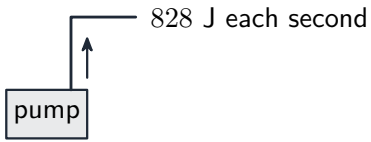


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$$P = \frac{W}{t} = \frac{2400\ \text{J}}{15\ \text{s}} = \mathbf{160}\ \text{W}$$

Full solution on next slide

Full solution 2.2

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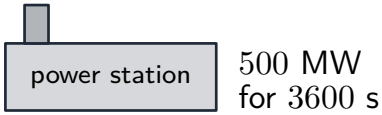
(substitution 1, answer with unit 1.)

2.3 828 J each second is a rate, so the useful power is **828** W. Some input energy is dissipated – to thermal stores of the motor and by friction in the pipes – so the input power must exceed the useful output.

Exercise 3.1

3.1 A nuclear power station has a power output of 500 MW for 3600 s.

(a) Write down the equation which links energy (E), power (P) and time (t). [1]

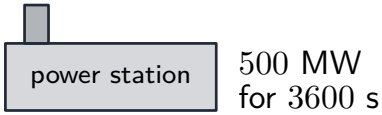


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3.1 (a) $\mathbf{E = Pt}$ (or $P = E/t$ in words: energy = power × time). (b) Convert: 500 MW = 500 000 000 W = 5×10^8 W (C1).

$$E = Pt = 5 \times 10^8 \text{ W} \times 3600 \text{ s} = \mathbf{1.8 \times 10^{12}} \text{ J}$$

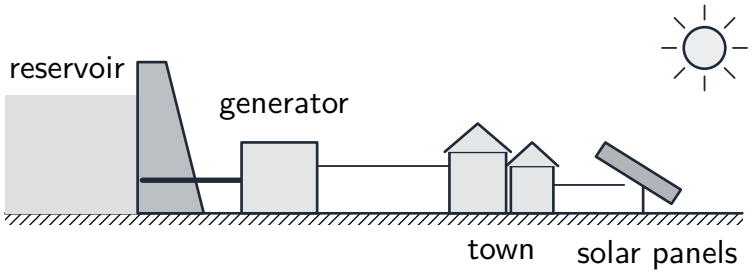
(substitution C1, answer A1 – an unconverted 500 gives 1.8×10^9 for one substitution mark only.)

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Setup for exercise 3.2

3.2 A hydroelectric generator transfers 3.0 kW of electrical power. It delivers 2.16×10^7 J to a town.

(a) Calculate the time taken, in seconds. Give your answer in standard form. [5]

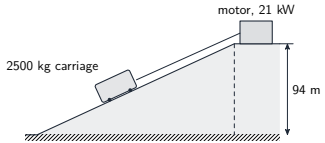


(b) The town's supply must be reliable. The generator is backed up by solar panels. Explain one reason why the solar panels make the supply more reliable, and one reason why they cannot be the only source. [2]

Exercise 3.2

3.3 A funicular railway pulls a 2500 kg carriage up a slope of vertical height 94 m in 3.0 minutes. The motors draw 21 kW of electrical power ($g = 9.8$ N/kg).

(a) Calculate the gravitational potential energy gained by the carriage. [3]



(b) Calculate the useful output power of the motors. [3]

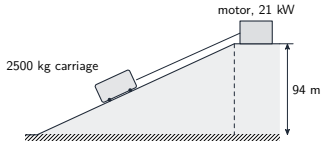
(c) Calculate the percentage of the input power that is useful. [2]

(d) Give two reasons why the useful power is less than the input power. [2]

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3.2 (a) Convert: 3.0 kW = 3000 W (C1). Rearrange first.

$$P = \frac{E}{t} \quad \Rightarrow \quad t = \frac{E}{P} = \frac{2.16 \times 10^7 \text{ J}}{3000 \text{ W}}$$

$$t = 7200 \text{ s} = \mathbf{7.2 \times 10^3} \text{ s}$$

(rearrangement C1, substitution C1, value A1, standard form A1.) (b) Hydro and solar

Full solution on next slide

Full solution 3.2 (1/2)

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(rearrangement C1, substitution C1, value A1, standard form A1.) (b) Hydro and solar fail at different times – solar stops at night and on dull days, while the river keeps flowing – so combining them covers more of the day; but solar alone is not reliable because its output changes with the weather and the season.

3.3 (a) Known: mass, height, g.

Full solution 3.2 (2/2)

$$E_p = mgh = 2500 \times 9.8 \times 94 = \mathbf{2.3 \times 10^6}\ \text{J}\ (2\ \text{s.f.})$$

(substitution C1, answer A1, unit A1.) (b) Convert: 3.0 min = 180 s (C1).

$$P = \frac{E_p}{t} = \frac{2.303 \times 10^6\ \text{J}}{180\ \text{s}} = \mathbf{12\,800}\ \text{W} \approx 13\ \text{kW}\ (2\ \text{s.f.})$$

(substitution C1, answer A1.) (c) Input power 21 kW = 21 000 W.

$$\%\ useful = \frac{12\,800}{21\,000} \times 100 = \mathbf{61}\ \%\ (2\ \text{s.f.})$$

(fraction 1, ×100 1.) (d) Any two: friction in the cable and rails dissipates energy to thermal stores; air resistance on the moving carriage; the motor and gearbox heat up; energy is transferred to the thermal store of the surroundings.