1.6 Efficiency

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS efficiency

Objective

Calculate efficiency from energy or from power, as a decimal or a percentage, find wasted shares, and (Higher Tier) explain how to increase efficiency. Original questions for spec statement 4.1.2.2.

1 Key knowledge and worked examples

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

Both equations are printed on the sheet. Both are on the exam.

Fact	Why it matters
decimal form: 0 to 1	an answer above 1 is impossible – check it
percentage: 0 % to 100 %	the exam may ask for either form
% wasted = 100 − % useful	quick for "find the wasted energy"
same device, either equation	power equations work per second

Worked example. An LED lamp is 0.85 efficient with a 4.0 W input. Find the useful power.

- Known: efficiency as a decimal and total input. Rearrange before substituting.

$$\text{useful power} = \text{efficiency} \times \text{total input} = 0.85 \times 4.0 \text{ W} = 3.4 \text{ W}$$

- Check: 3.4 W < 4.0 W ✓.

Worked example. A method stores 33 600 kJ in 100 kg of water and wastes 40 % of it. Find the useful energy and the efficiency.

- Percentage useful = 100 − 40 = 60 %.

$$E_{useful} = \frac{60}{100} \times 33\,600 \text{ kJ} = 20\,160 \text{ kJ}$$

$$\text{efficiency} = \frac{20\,160}{33\,600} = 0.60$$

Worked example. A pump takes 1500 W of electrical power and delivers 945 W to the water. Find the percentage efficiency.

$$\text{efficiency} = \frac{945}{1500} = 0.63 = \mathbf{63}\ \%$$

(HT) Increasing efficiency – the credited reasons:

Change	Why efficiency rises
lubricate moving parts	less energy dissipated by friction
insulate hot parts	less energy transferred away by heating
streamlined shape	less work done against air resistance
LED instead of filament lamp	more of the input becomes light, less heat

Every reason is the same sentence underneath: **less input energy is dissipated to useless stores, so a bigger share lands in the useful store.**

Comparisons ("compare two motors / two methods") want a calculation in the answer: compute both efficiencies (or useful outputs) and say which is bigger and by how much.

2 Practice

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]

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

3 Exam-style questions

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]

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]

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]

Solutions

2.1

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

(decimal 1, percentage 1.)

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

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

(answer A1.)

2.3 Useful share = 100 − 30 = 70 %.

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

3.1 (a) Heater A:

$$\text{efficiency} = \frac{1700}{2000} = 0.85 = \mathbf{85}\ \%$$

(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 ≈ 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.

3.2 (a) efficiency = useful output energy transfer ÷ total input energy transfer. (b)

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

(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.

3.3 (a)

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

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

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

(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.