1.4 Power

Name: _____ Class: _____ Date: _____ **Total: 28 marks**

KEY WORDS power • work done • watt

Objective

Use $P = E/t$ and $P = W/t$ forwards and backwards, chain them with $E_p = mgh$, and convert kW/MW/GJ with standard-form answers. Original questions for spec statement 4.1.1.4.

1 Key knowledge and worked examples

Power is the rate of energy transfer, or the rate of doing work.

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

- P power in watts, W; E energy in J; W work done in J; t time in **seconds**.
- An energy transfer of **1 J per second is 1 watt**.

Prefix	Meaning	Example use
kW	10^3 W	a kettle
MW	10^6 W	a wind farm
GW	10^9 W	a power station
kJ	10^3 J	appliance energy
MJ / GJ	10^6 / 10^9 J	grid energy

Worked example. A 60.0 kg athlete runs up a staircase of height 175 cm in 1.40 s ($g = 9.8$ N/kg). Find the useful power.

- Known: mass, height, time. Convert height: 175 cm = 1.75 m (C-mark step).
- Useful energy = the gain of gravitational potential energy.

$$E_p = mgh = 60.0 \times 9.8 \times 1.75 = 1029 \text{ J}$$

$$P = \frac{E_p}{t} = \frac{1029 \text{ J}}{1.40 \text{ s}} = 735 \text{ W}$$

Worked example. A generator supplies 3.0 kW for 2 hours. Find the energy in J.

- Convert both quantities: 3.0 kW = 3000 W; 2 h = 7200 s.

$$E = Pt = 3000 \text{ W} \times 7200 \text{ s} = 2.16 \times 10^7 \text{ J}$$

"Per second" clues. "0.343 J of energy is transferred to the water each second" already gives a *rate*: that IS the useful power in watts for that store. And "power per home" shares a total: divide.

Worked example. A wind farm has mean power output 696 MW and serves 580 000 homes.

- Convert: 696 MW $= 6.96 \times 10^8$ W.

$$P_{per\ home} = \frac{6.96 \times 10^8}{580\,000} = \mathbf{1200}\ \text{W (2 s.f.)}$$

Comparing motors: two motors lifting the same load the same height do the same work; the more powerful one does it in less time. State both halves for the explanation mark.

2 Practice

2.1 A lamp transfers 7.2 kJ in 4.0 minutes. Calculate the power of the lamp. [3]

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]

3 Exam-style questions

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

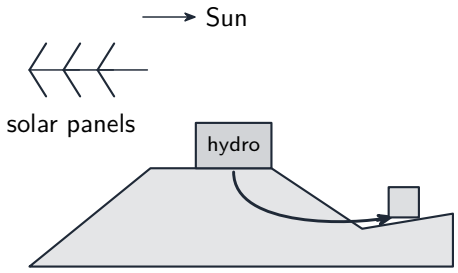
(a) Write down the equation which links energy (E), power (P) and time (t). [1]

(b) Calculate the energy output in J. [3]

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]

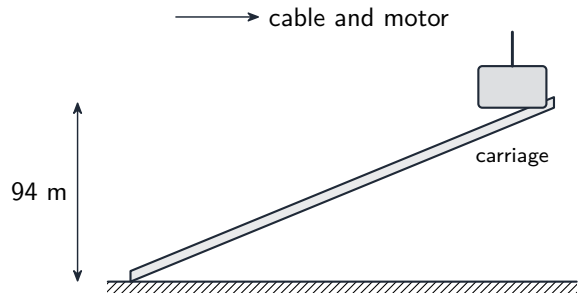
(b) The town's supply must be reliable. The generator is backed up by solar panels. Explain one reason why the solar panels make the supply more reliable, and one reason why they cannot be the only source. [2]



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]