

# Power

- The power of a machine is the **rate at which it transfers energy**
- Since work done is equal to the energy transferred, power can also be defined as the rate of doing work or **the work done per unit time**
- The SI unit for power is **Watts (W)** where  $1 \text{ W} = 1 \text{ J s}^{-1}$

The diagram shows the equation  $P = \frac{E}{t} = \frac{W}{t}$  centered on the page. Four callout boxes with arrows point to the variables: 'ENERGY (J)' points to 'E', 'WORK DONE (J)' points to 'W', 'TIME (s)' points to 't', and 'POWER (W)' points to 'P'.
$$P = \frac{E}{t} = \frac{W}{t}$$

*Power is the rate of change of work*

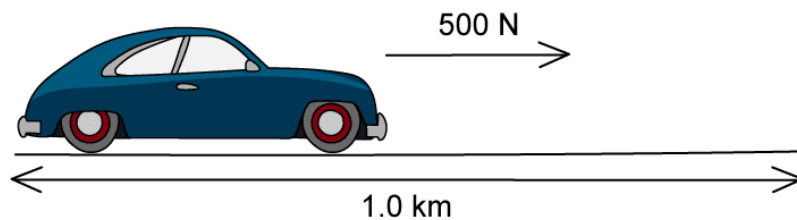
- You may be familiar with labels on lightbulbs which indicate their power such as 60 W or 100 W. These tell you about an energy transferred by an electrical current rather than by a force doing work

# Solving Problems Involving Power

## Worked example



A car engine exerts the following force for 1.0 km in 200 s.



What is the average power developed by the engine?

STEP 1

EQUATION FOR POWER

$$\text{POWER} = \frac{\text{WORK DONE}}{\text{TIME}}$$

STEP 2

CALCULATE WORK DONE

$$\begin{aligned} W &= F \times d \\ &= 500 \text{ N} \times 1.0 \times 10^3 \text{ m} \\ &= 5 \times 10^5 \text{ J} \end{aligned}$$

STEP 3

SUBSTITUTE VALUES INTO POWER EQUATION

$$\text{POWER} = \frac{5 \times 10^5 \text{ J}}{200 \text{ s}} = 2500 \text{ W} = 2.5 \text{ kW}$$

## Derivation of $P=F \cdot v$

- Moving power is defined by the equation:

The diagram shows the equation  $P = F \times v$  centered on a light blue background. Three callout boxes with arrows point to the variables: 'POWER (W)' points to 'P', 'FORCE (N)' points to 'F', and 'VELOCITY (ms<sup>-1</sup>)' points to 'v'.

- This equation is only relevant where a **constant force** moves a body at **constant velocity**. Power is required in order to produce an acceleration
- The force must be applied in the **same** direction as the velocity

### Derivation

- The derivation for this equation is shown below:



Derivation of  $P = F \times v$

POWER IS THE RATE OF CHANGE OF WORK

$$\text{POWER} = \frac{W}{t}$$

WORK DONE = FORCE × DISTANCE

$$W = F \times d$$

AT CONSTANT VELOCITY,  $d = v \times t$  THEREFORE

$$W = F \times v \times t$$

$$P = \frac{W}{t} = \frac{F \times v \times t}{t}$$

CANCELLING  $t$

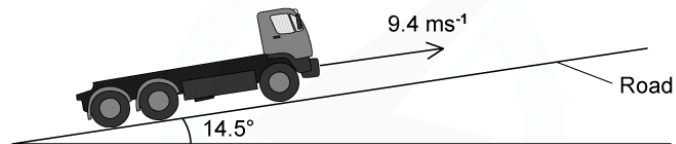
$$P = F \times v$$

*Derivation of  $P = F \times v$*

## Worked example



A lorry moves up a road that is inclined at  $14.5^\circ$  to the horizontal.



The lorry has mass 3500 kg and is travelling at a constant speed of  $9.4 \text{ ms}^{-1}$ . The force due to air resistance is negligible.

Calculate the useful power from the engine to move the lorry up the road.

STEP 1

EQUATION FOR POWER

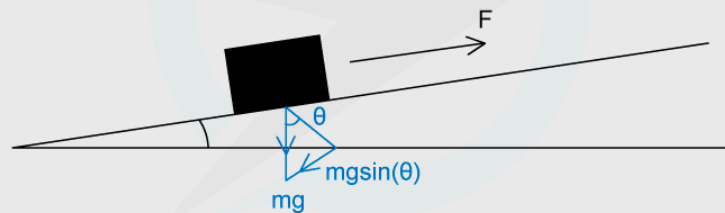
$$P = F \times v$$

STEP 2

CALCULATE THE FORCE

THE FORCE NEEDED TO MOVE THE LORRY UP THE ROAD IS THAT WHICH OVERCOMES THE COMPONENT OF ITS WEIGHT ACTING DOWN THE SLOPE

$$F = mg \sin\theta = 3500 \times 9.81 \times \sin(14.5) = 8596.8 \text{ N}$$



STEP 3

SUBSTITUTE INTO POWER EQUATION

$$P = 8596.8 \times 9.4 = 80809.9 \text{ W} = 81000 \text{ W} = 81 \text{ kW} \text{ (2.s.f.)}$$