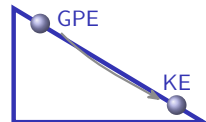


Work, Energy & Power

AS Physics ■ Topic 5

A-Level Physics



Work, Energy & Power

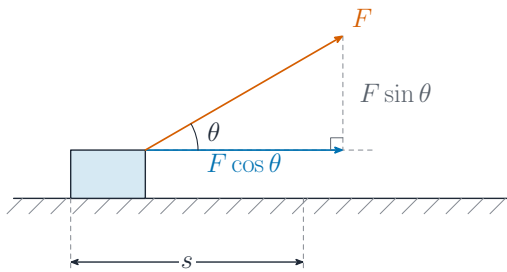
What we will cover

- 1 Work done by a force
- 2 Conservation of energy
- 3 Efficiency
- 4 Power
- 5 Potential & kinetic energy
- 6 Recap



1 Work

Work done by a force



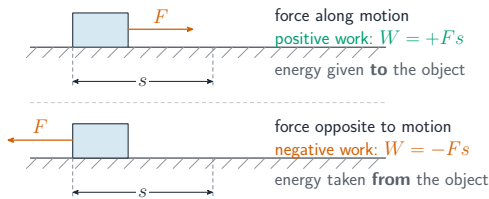
Work 功 = force $\times$ distance **along the force**:

$$W = Fs \cos \theta, \quad [W] = \text{J}.$$

Sledge: 20 N at 60° , 5.0 m

$$W = 20 \times 5.0 \times \cos 60^\circ = 50 \text{ J}$$

Positive, negative and zero work



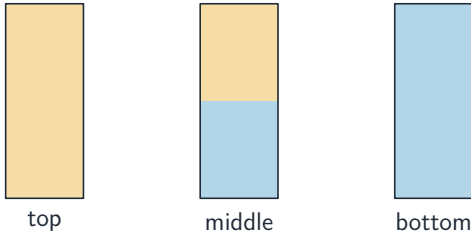
- $\theta = 0$: $W = +Fs$ – energy in
- $\theta = 90^\circ$: $W = 0$ – no work (normal force on a flat road)
- $\theta = 180^\circ$: $W = -Fs$ – energy out (friction 摩擦力)

2

Conservation of energy

Conservation of energy

■ GPE ■ KE ■ Total energy stays the same



Energy is **never made or destroyed**
– only changed in form. On a
frictionless **ramp** 斜坡:

$$mgh = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2gh}.$$

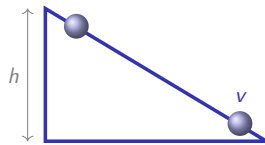
With friction, some becomes
thermal energy 热能.

Worked example – speed down a ramp

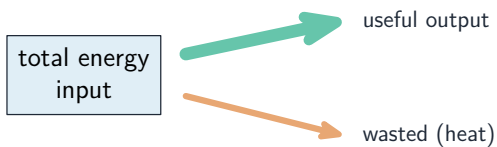
Released from rest, smooth ramp $h = 1.2 \text{ m}$

All GPE becomes KE, so $v = \sqrt{2gh}$ (mass cancels):

$$v = \sqrt{2 \times 9.81 \times 1.2} \approx 4.9 \text{ m s}^{-1}.$$



Efficiency



$$\text{efficiency} = \frac{\text{useful output}}{\text{total input}} \times 100\%$$

$$\eta = \frac{\text{useful output}}{\text{total input}} \times 100\%.$$

Motor lifts 50 kg at 0.40 m s⁻¹, draws 250 W

$$\text{useful } P = mgv = 50 \times 9.81 \times 0.40 = 196 \text{ W}$$

$$\eta = \frac{196}{250} \times 100\% \approx 78\%.$$

Always < 100% – the rest is
wasted as heat.

3 Power

Work, Energy & Power
└ Power

Power – the rate of energy transfer

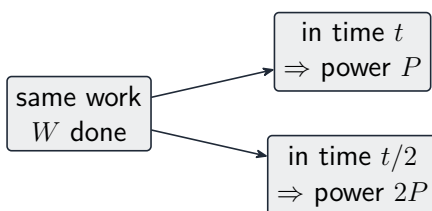
$$P = \frac{W}{t} = \frac{\Delta E}{\Delta t}, \quad [P] = W = \text{J s}^{-1}.$$

same work
in less time

more power

Work, Energy & Power
└ Power

Same work, different power



$$P = \frac{W}{t} \text{ — less time, more power}$$

Power is **work per second**. Climbing the stairs twice as fast does the same work against gravity at twice the power.

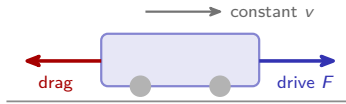
Power = force $\times$ velocity

For a force F along the motion at speed v :

$$P = Fv.$$

Car at 25 m s^{-1} , resistance 600 N

$$P = Fv = 600 \times 25 = 15 \text{ kW}$$



Drag grows with v^2 , so doubling the speed roughly quadruples the power needed.

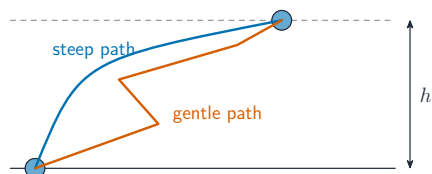
Lifting at speed v : $P = mgv$.

4

Potential and kinetic energy

Gravitational potential energy

same $\Delta E_P = mgh$ – only the height h matters



Lifting mass m through height Δh :

$$\Delta E_P = mg\Delta h.$$

Depends only on the height risen – not on the path taken.

Kinetic energy

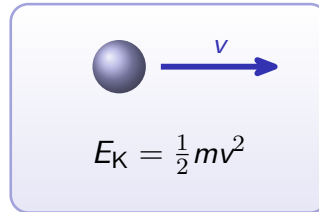
$$E_K = \frac{1}{2}mv^2.$$

Work-energy: a resultant force F over s does

$$W = Fs = ma \cdot \frac{v^2}{2a} = \frac{1}{2}mv^2. \text{ With}$$

momentum 动量 $p = mv$:

$$E_K = \frac{p^2}{2m}.$$



Using energy methods

- 1 write energies at the **start** and **end**
- 2 add work by outside forces (push in, friction out)
- 3 set $E_{\text{start}} + W_{\text{in}} = E_{\text{end}} + W_{\text{lost}}$

Into a **spring** 弹簧: $\frac{1}{2}mv^2 = \frac{1}{2}kx^2$ at **greatest compression** 压缩.



5

Recap

Topic 5 – key takeaways

1 Work

$$W = Fs \cos \theta; \text{ energy in or out}$$

2 Energy

conserved; only changes form

3 Power

$$P = W/t = Fv, \text{ efficiency} < 100\%$$

4 Stores

$$E_P = mg\Delta h, E_K = \frac{1}{2}mv^2$$

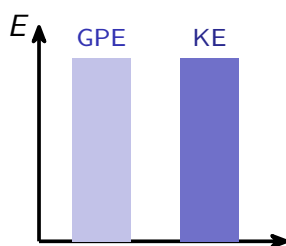
Check yourself

1 Work done by a force at 90° to the motion?

2 Speed at the foot of a smooth 5.0 m drop?

3 Power to move at 20 m s^{-1} against 400 N?

4 Why is a real machine never 100% efficient?



Answers 1. zero 2. $\sqrt{2g \cdot 5} \approx 9.9 \text{ m s}^{-1}$ 3. $Fv = 8 \text{ kW}$ 4. some energy always wasted as heat