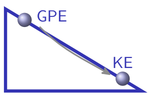
Work, Energy & Power

AS Physics ▪ Topic 5

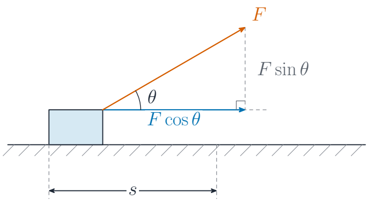
A-Level Physics



What we will cover

1 Work

Work done by a force



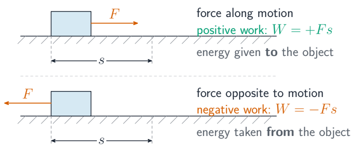
Work 功 = force × distance along the force:

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

Sledge: $20\,\text{N}$ **at** $60°$, $5.0\,\text{m}$

$W = 20 \times 5.0 \times \cos 60° = 50\,\text{J}$

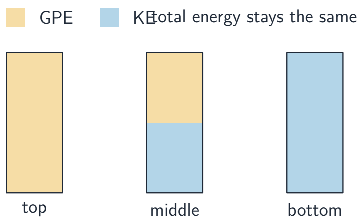
Positive, negative and zero work



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

2 Conservation of energy

Conservation of energy



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

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

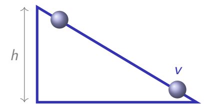
With friction, some becomes **thermal energy** 热能.

Worked example – speed down a ramp

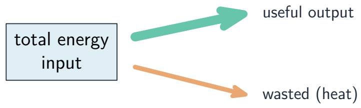
Released from rest, smooth ramp $h = 1.2\,\mathrm{m}$

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

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



Efficiency



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

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

Motor lifts $50\,\mathrm{kg}$ at $0.40\,\mathrm{m\,s^{-1}}$, draws $250\,\mathrm{W}$

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

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

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

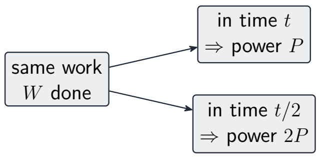
3 Power

Power – the rate of energy transfer

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

same work in less time → **more 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.

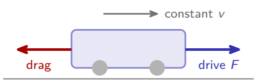
Power $=$ force $\times$ velocity

For a force F along the motion at speed v:

$$P = Fv.$$

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

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



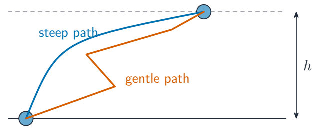
Drag grows with v^2, so doubling the speed roughly quadruples the power needed.

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:

$$\Delta E_{\mathrm{P}} = mg\,\Delta h.$$

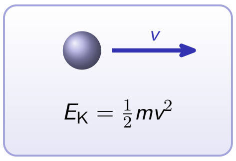
Depends only on the height risen – not on the path taken.

Kinetic energy

$$E_{\mathrm{K}} = \tfrac{1}{2}mv^2.$$

Work–energy: a resultant force F over s does $W = Fs = ma \cdot \dfrac{v^2}{2a} = \tfrac{1}{2}mv^2$. With **momentum** 动量 $p = mv$:

$$E_{\mathrm{K}} = \frac{p^2}{2m}.$$



Using energy methods

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

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

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

2 Energy

conserved; only changes form

3 Power

$P = W/t = Fv$; efficiency $< 100\%$

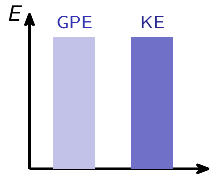
4 Stores

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

Work, Energy & Power
└Recap

Check yourself

1. Work done by a force at $90°$ to the motion?
2. Speed at the foot of a smooth $5.0\,\mathrm{m}$ drop?
3. Power to move at $20\,\mathrm{m\,s^{-1}}$ against $400\,\mathrm{N}$?
4. Why is a real machine never 100% efficient?



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