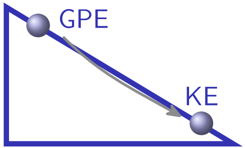
Work, Energy & Power

AS Physics ▪ Topic 5

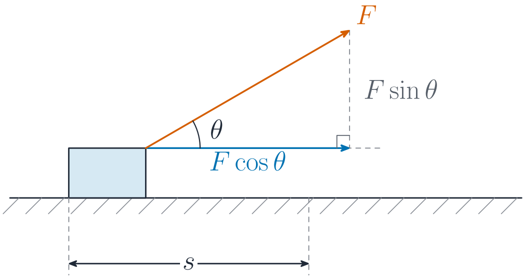
A-Level Physics



What we will cover

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

Work done by a force



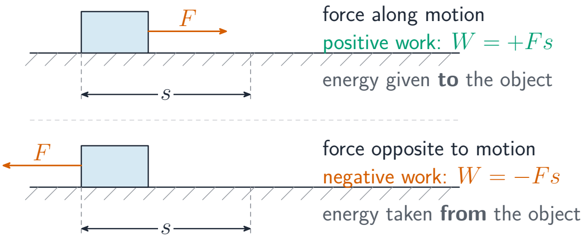
Work 功 = force × distance along the force:

$$W = F s \cos\theta, \qquad [W] = \mathrm{J}.$$

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

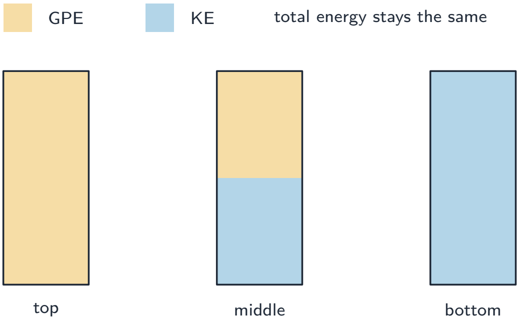
$W = 20 \times 5.0 \times \cos 60° = 50\,\mathrm{J}$

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)

Conservation of energy



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

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

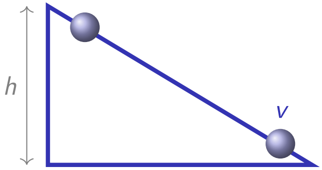
With friction, some becomes **thermal energy** 热能.

Worked example – speed down a ramp

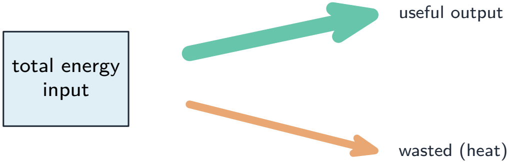
Released from rest, smooth ramp $h = 1.2\,\mathrm{m}$

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.

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

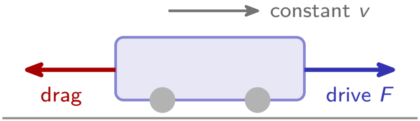
Power = force × velocity

For a force F along the motion at speed v:

$$P = Fv.$$

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

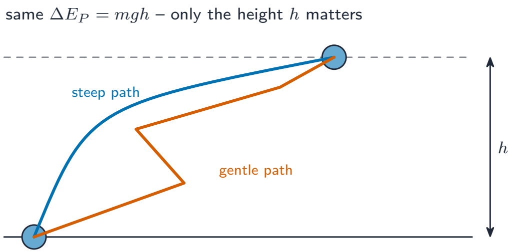
$P = Fv = 600 \times 25 = 15\,\mathrm{kW}$



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

Lifting at speed v: $P = mgv$.

Gravitational potential energy



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

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

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 $p = mv$:

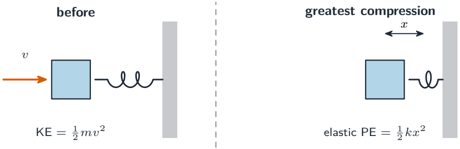
$$E_K = \frac{p^2}{2m}.$$

$$E_K = \tfrac{1}{2}mv^2$$

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.



Topic 5 – key takeaways

1 Work

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

2 Energy

conserved; only changes form

3 Power

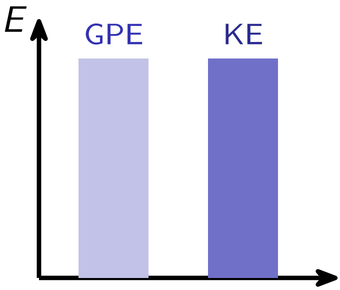
$P = W/t = Fv$; efficiency $< 100\%$

4 Stores

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

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