# Work and energy

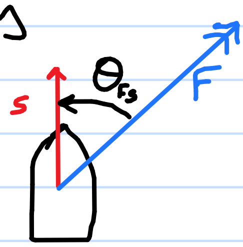
**Stores:**
- gravitational potential energy
- kinetic energy
- elastic potential energy
- thermal energy
- chemical energy
- electric potential energy
- nuclear potential energy
- pressurised gas store of energy

**Transfers:**
- mechanical (using forces)
- electric current
- waves (light, sound)
- conductive heating

- Energy is conserved in a closed system
- Work done is the transfer of energy

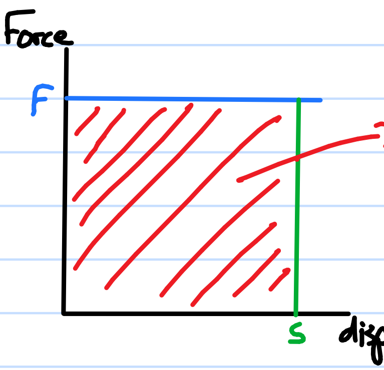
$W = \vec{F} \cdot \vec{s} = |F||s|\cos\theta_{Fs}$

scalar product



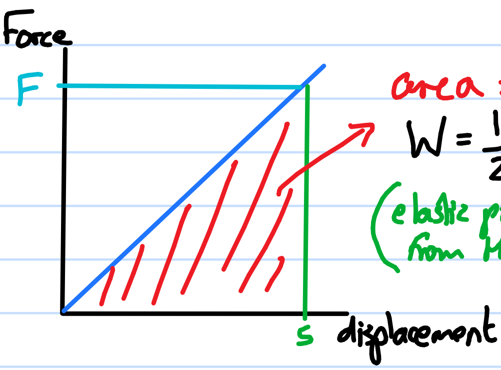

$W = Fs\cos\theta_{Fs} = \frac{1}{2}m\Delta v^2$

$W = \int \vec{F}(s) \cdot d\vec{s}$ better but generally not needed for A-level Physics




area = work done

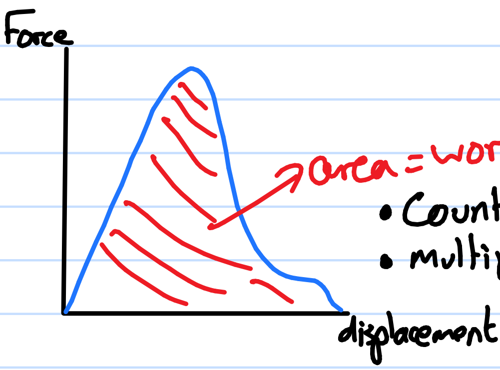
$W = Fs\cos\theta$




area = work done

$W = \frac{1}{2}Fs\cos\theta$

(elastic potential energy from Hooke's law)




area = work done
- Count squares
- multiply by work done represented by 1 sq

- Any part-square counts as $\frac{1}{2}$ sq

# Kinetic and potential energy

## Kinetic energy equation:

$$E = \frac{1}{2}mv^2$$

Derivation:

$$W = F \cdot s = ma \cdot s$$

$$a = \frac{v-u}{t} \quad \text{if } u=0 \text{ then } a = \frac{v}{t}$$

$$s = \frac{1}{2}(u+v)t \quad \text{if } u=0 \text{ then } s = \frac{1}{2}vt$$

$$W = m \times \frac{v}{\cancel{t}} \times \frac{1}{2}v\cancel{t} = \frac{1}{2}mv^2$$

Only works for constant acceleration

## Gravitational potential energy equation:

$$E = mg\Delta h$$

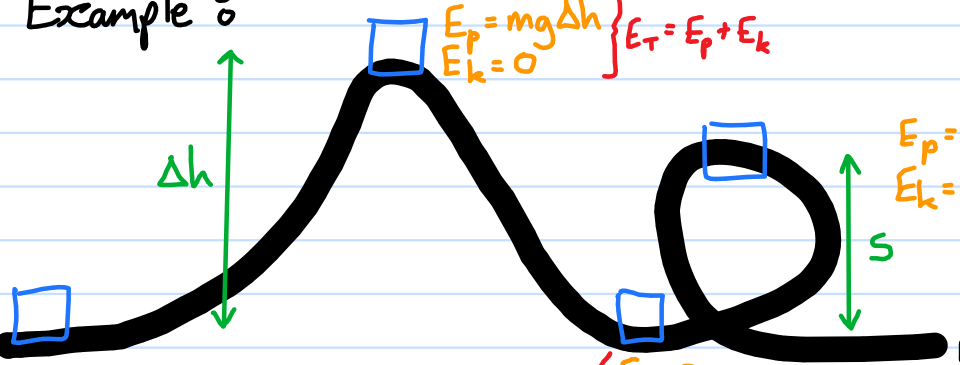
Derivation:

$$W = F \cdot s$$

$$F = mg \quad , \quad s = \Delta h$$

$$W = mg\Delta h$$

Example:




roller coaster

$$\left.\begin{matrix} E_p = mg\Delta h \\ E_k = 0 \end{matrix}\right\} E_T = E_p + E_k$$

$$\left.\begin{matrix} E_p = mgs \\ E_k = mg\Delta h - mgs \end{matrix}\right\} E_T = E_p + E_k$$

$$mg\Delta h = mgs + \frac{1}{2}mv^2$$

$$v = \sqrt{2g(\Delta h - s)}$$

$$E_T = E_p + E_k \left\{\begin{matrix} E_p = 0 \\ E_k = \frac{1}{2}mv^2 \end{matrix}\right.$$

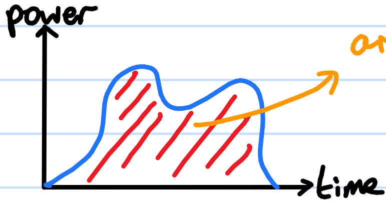
$$mg\Delta h = \frac{1}{2}mv^2$$

$$v = \sqrt{2g\Delta h}$$

# Power

$$\boxed{P = \frac{W}{t}} = \frac{dW}{dt}$$ i.e. the rate of doing work

$$W = \int P(t)\,dt$$




$W = \vec{F} \cdot \vec{s}$ assuming const force

$P = \frac{W}{t}$ assuming const power

$$P = \frac{\vec{F} \cdot \vec{s}}{t} = \vec{F} \cdot \vec{v}$$ $\boxed{P = Fv}$ Mechanical Power

$P = VI$ Electrical Power (to be covered later)

p.d. current

# Energy and efficiency

Efficiency, $\varepsilon = \dfrac{\text{energy usefully transferred}}{\text{total energy transferred}} = \dfrac{E_{out}}{E_{in}}$ ← useful, ← total

waste energy

$E_{out} = E_{in} - E_{waste}$

$E_{out} = P_{out}\, t \qquad E_{in} = P_{in}\, t$

$\varepsilon = \dfrac{P_{out}}{P_{in}}$ ← useful, ← total

$P_{out} = P_{in} - P_{waste}$

$\varepsilon = \dfrac{P_{out}}{P_{in}} = \dfrac{P_{out}}{P_{in}} \times 100\%$ $\qquad 0.50 = 50\% \qquad 25\% = \frac{1}{4} = 0.25$

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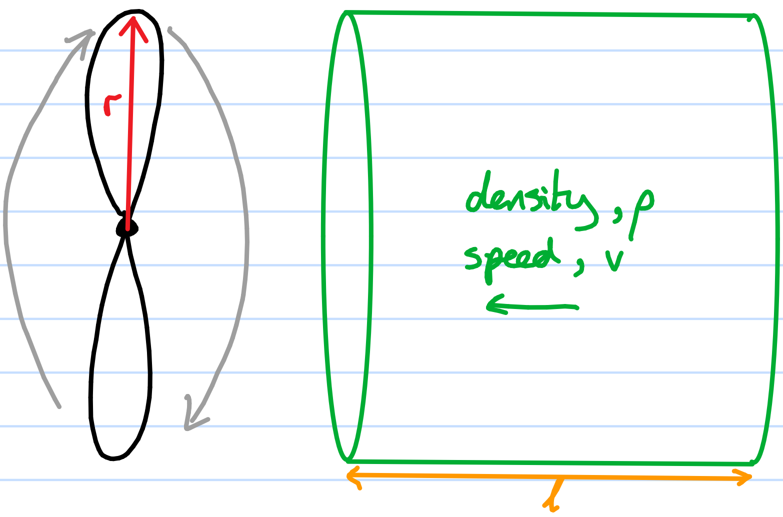
# Energy resources

Renewables :

- Photovoltaic cells } solar power
- Solar heating panels }
- Wind
- Waves
- Geothermal
- Hydroelectric
- Tidal
- Biomass

Example : wind




$E = \frac{1}{2}mv^2 \qquad m = \rho V \qquad A = \pi r^2 \qquad V = Al$

$v = \dfrac{l}{t} \qquad l = vt \qquad V = Avt$

$m = \rho A v t = \pi \rho v t r^2$

$E = \frac{1}{2} \times \pi \rho v t r^2 v^2$

$\dfrac{E}{t} = P = \frac{1}{2}\pi \rho r^2 v^3$