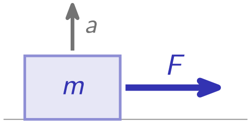
# Motion, Forces & Energy

## IGCSE Physics ▪ Topic 1

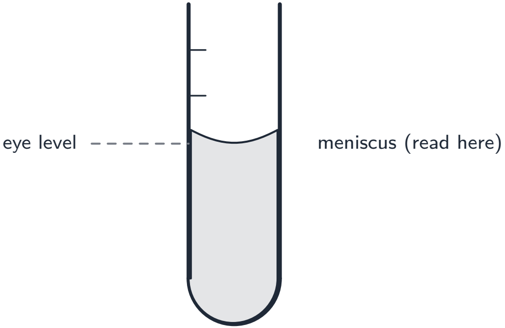
IGCSE Physics



# What we will cover

1. Measurement & motion
2. Mass, weight & density
3. Forces & moments
4. Momentum
5. Energy, work & power
6. Pressure

# Measurement

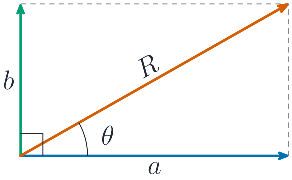



- read a **measuring cylinder** 量筒 at the **meniscus** 弯月面, eye level
- measure small amounts by measure many and divide (100 pages, 20 swings)

# Scalars and vectors

- **scalar** 标量 – size only (distance, speed, mass)
- **vector** 矢量 – size *and* direction (force, velocity)

At right angles, $R = \sqrt{a^2 + b^2}$.




$$R = \sqrt{a^2 + b^2}$$

# Speed, velocity and acceleration

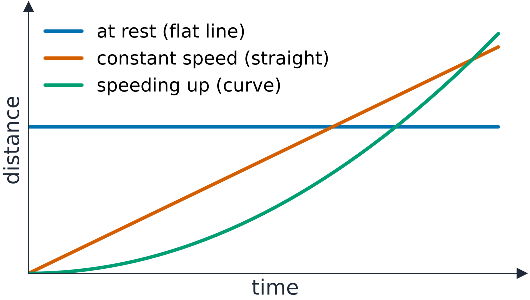
$$v = \frac{s}{t}, \qquad a = \frac{\Delta v}{\Delta t}.$$

Speed is a scalar; **velocity** 速度 is speed in a direction.

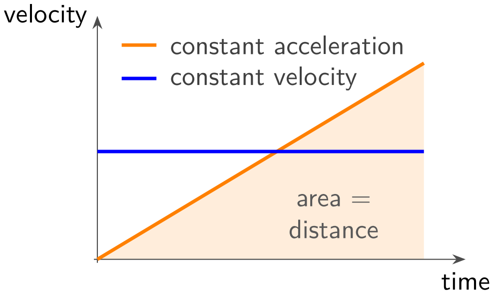
**Car:** $8 \rightarrow 20\,\mathrm{m/s}$ **in** $4.0\,\mathrm{s}$

$$a = \frac{20 - 8}{4.0} = 3.0\,\mathrm{m/s^2}$$

# Motion graphs

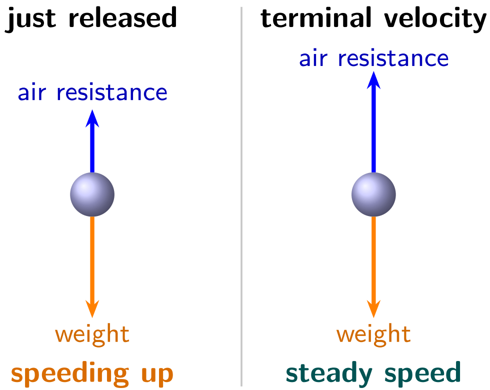



*distance–time: slope = speed*




*velocity–time: slope = a, area = distance*

# Falling and terminal velocity




Free fall: $g \approx 9.8\,\mathrm{m/s^2}$, the same for every mass. **Air resistance** 空气阻力 grows with speed. When it equals the weight → constant **terminal velocity** 终极速度.

# Mass, weight and density

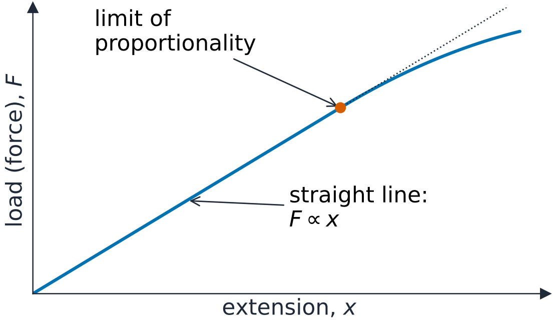
- mass (kg) – amount of **matter** 物质, same everywhere
- weight (N) – gravity's pull, $W = mg$
- **density** 密度 $\rho = \dfrac{m}{V}$

Floats if its density $<$ the liquid's.

**Stone** $54\,\mathrm{g}$, **water** $20 \to 40\,\mathrm{cm}^3$

$$V = 20\,\mathrm{cm}^3,\ \rho = \frac{54}{20} = 2.7\,\mathrm{g}/\mathrm{cm}^3$$

# Hooke's law

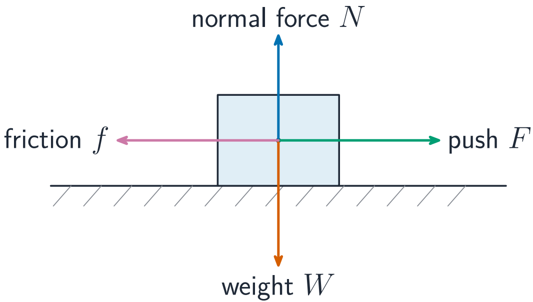



**Extension** 伸长量 is proportional to load up to the **limit of proportionality** 比例极限.

$$k = \frac{F}{x}.$$

A large **spring constant** 弹簧常数 $k$ means a stiff spring.

# Resultant force and $F = ma$




**Resultant force** 合力 zero $\Rightarrow$ rest or constant velocity. Otherwise

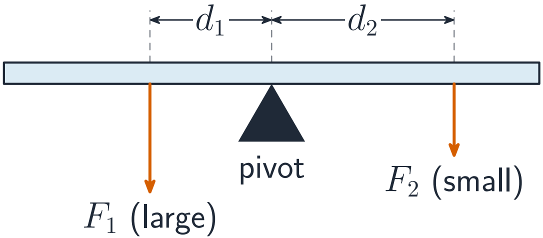
$$F = ma.$$

**Car** $1200\,\mathrm{kg}$**:** $3000 - 600\,\mathrm{N}$

$$a = \frac{2400}{1200} = 2.0\,\mathrm{m/s^2}$$

# Moments – the turning effect

**balanced:** $F_1 d_1 = F_2 d_2$




**Moment** 力矩 = force × perpendicular distance.

> Balanced: total clockwise = total anticlockwise moment.

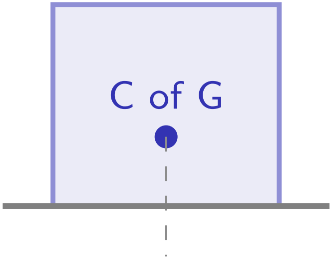
**$30\,\mathrm{N}$ at $0.20\,\mathrm{m}$ vs $20\,\mathrm{N}$**

$$d = \frac{30 \times 0.20}{20} = 0.30\,\mathrm{m}$$

# Centre of gravity and stability

The **centre of gravity** 重心 is where all the weight seems to act.

> More stable with a low centre of gravity and a wide base. It tips when the C of G passes outside the base.



# Momentum

**Momentum** 动量 $p = mv$ (a vector). Force is the change per unit time:

$$F = \frac{\Delta p}{\Delta t}.$$

> **Conservation** 动量守恒: total momentum before = after (no outside force).

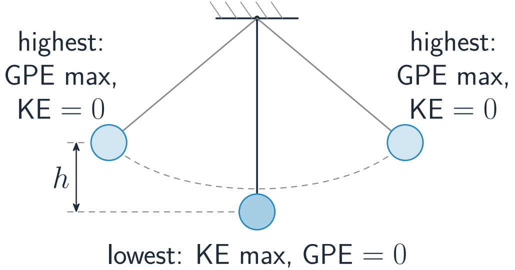
**$2.0\,\mathrm{kg}$ at $3.0\,\mathrm{m/s}$ hits a still $1.0\,\mathrm{kg}$; they stick**

$$v = \frac{2.0 \times 3.0}{3.0} = 2.0\,\mathrm{m/s}$$

# Energy stores and transfers

Energy is stored (kinetic, gravitational, chemical, elastic, nuclear, internal) and transferred by forces, currents, heating and waves.

# Kinetic and potential energy




$$E_k = \frac{1}{2}mv^2, \qquad \Delta E_p = mg\Delta h.$$

**Conservation of energy** 能量守恒定律: a falling object turns $E_p$ into $E_k$.

**Drop from $1.8\,\mathrm{m}$ ($g = 10$)**

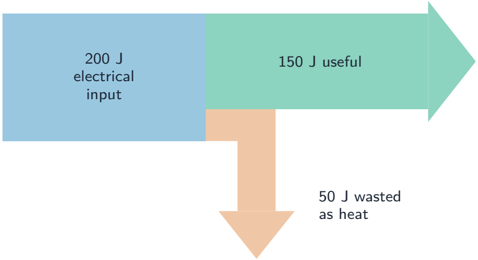
$v = \sqrt{2g\Delta h} = 6.0\,\mathrm{m/s}$

# Work, power and efficiency

$$W = Fd, \quad P = \frac{W}{t}, \quad \eta = \frac{\text{useful}}{\text{total}} \times 100\%.$$

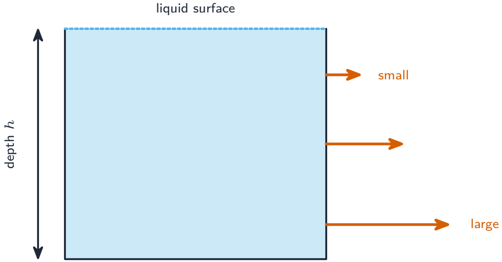
**Motor: $200\,\mathrm{J}$ in, $150\,\mathrm{J}$ useful**

$$\eta = \frac{150}{200} \times 100\% = 75\%$$




***Sankey diagram*** 桑基图*: useful vs wasted*

# Pressure




**Pressure** 压强 $p = \dfrac{F}{A}$ (Pa). A small area gives a large pressure. In a liquid it grows with depth: $\Delta p = \rho g \Delta h$.

**$2.0\,\mathrm{m}$ deep in water**

$$\Delta p = 1000 \times 10 \times 2.0 = 2.0 \times 10^4\ \mathrm{Pa}$$

# Topic 1 – key takeaways

## 1 Motion

$v = s/t$, $a = \Delta v/\Delta t$; graphs

## 2 Forces

$F = ma$; moments balance; $W = mg$

## 3 Momentum

$p = mv$, conserved in collisions

## 4 Energy

$E_k = \frac{1}{2}mv^2$, $E_p = mgh$; conserved

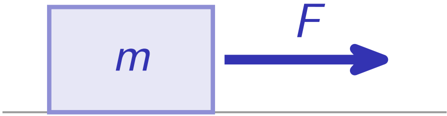
# Check yourself

1. What does the area under a velocity–time graph give?

2. A $2\,\mathrm{kg}$ mass on the Moon – does its mass change?

3. Resultant force at terminal velocity?

4. Why is a knife sharp (small area)?




**Answers** **1.** the distance **2.** no (weight does) **3.** zero **4.** large pressure from a small area