

# Motion, forces and energy

## IGCSE Physics 0625 · Unit 1 revision notes

Measurement, motion graphs, mass and weight, density, forces and moments, momentum, energy, work, power and pressure: every definition, equation, graph and trap on one page.

49 definitions to learn word for word, 34 equations in their own column, 35 diagrams and graphs. Read it, cover it, test yourself.

1. 1.1a Measuring length, volume and time
2. 1.1b Scalars and vectors
3. 1.2a Speed, velocity and distance-time graphs
4. 1.2b Speed-time graphs and acceleration
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Definitions (mark-scheme wording) Equations Exam traps Extended = Extended tier only

### 1.1a Measuring length, volume and time

#### Definitions

**Meniscus:** the curved surface of a liquid in a tube; for water, read the volume at the bottom of the meniscus.

**Oscillation (one):** one complete swing, from one side to the other and back again.

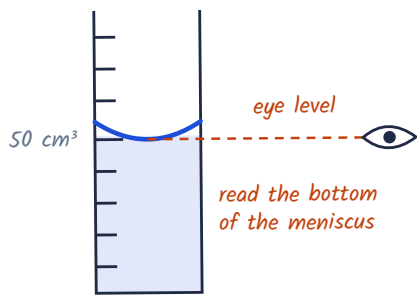
#### Equations

$$T = t / n$$

period = total time for  $n$  oscillations /  $n$

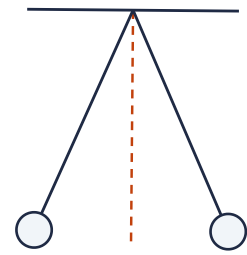
#### Key points

- ✓ **Length:** metre rule or tape, read to the nearest **mm**; look straight at the scale to avoid parallax.
- ✓ **Volume of a liquid:** measuring cylinder on a flat surface, eye level with the **bottom of the meniscus**.
- ✓ **Time:** stopwatch, clock or digital timer (light gates for very short times).
- ✓ Short interval: time **many repeats** and divide, e.g. time 20 swings, then period = total time / 20.
- ✓ Small length: measure a **stack** and divide, e.g. thickness of 100 sheets / 100.
- ✓ Timing many repeats makes the stopwatch reaction-time error a **smaller fraction** of the total.



Read a measuring cylinder with your eye level with the bottom of the meniscus.

fiducial mark at centre



$$T = t / 20$$

there and back = 1 oscillation

Pendulum: one oscillation is there and back. Time 20 of them and divide by 20.

### Watch out!

- ! Reading the **top** of a water meniscus, or reading from above or below eye level (parallax).
- ! Forgetting to **divide** by the number of swings or sheets at the end.

## 1.1b Scalars and vectors

### Definitions

**Scalar:** **Extended** a quantity that has magnitude (size) only.

**Vector:** **Extended** a quantity that has magnitude and direction.

**Resultant:** the single vector that has the same effect as two or more vectors acting together.

### Equations

$$R = \sqrt{F_1^2 + F_2^2}$$

**Extended** size of the resultant of two perpendicular vectors  
same unit as  $F$

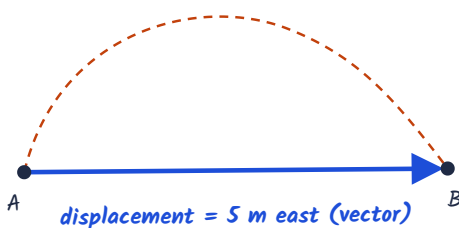
$$\tan \theta = F_2 / F_1$$

**Extended** angle of the resultant from  $F_1$ , degrees

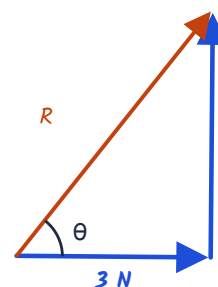
### Key points

- ✓ **Extended scalars:** distance, speed, time, mass, energy, temperature.
- ✓ **Extended vectors:** displacement, velocity, acceleration, force, weight, momentum, electric field strength, gravitational field strength.
- ✓ Vectors along the **same line:** add if in the same direction, subtract if opposite.
- ✓ **Extended** two vectors at **right angles:** resultant by Pythagoras, direction by  $\tan \theta$ .
- ✓ **Extended** or by **scale drawing:** draw head to tail to scale, measure the resultant and its angle.

distance = 8 m (scalar)



Distance follows the path walked; displacement is the straight line from A to B, with a direction.



$$R^2 = 3^2 + 4^2$$

$$R = 5 \text{ N}$$

$$\tan \theta = 4 / 3$$

$$\theta = 53^\circ$$

**Extended:** 3 N east and 4 N north, drawn head to tail, give a 5 N resultant at  $53^\circ$  north of east.

### Watch out!

- ! Extended: never add the sizes of perpendicular vectors: 3 N and 4 N at right angles give **5 N**, not 7 N.
- ! A vector answer needs a **direction** as well as a size.

## 1.2a Speed, velocity and distance-time graphs

### Definitions

**Speed:** the distance travelled per unit time.

**Velocity:** the speed in a given direction.

**Average speed:** the total distance travelled divided by the total time taken.

### Equations

$$v = s / t$$

speed = distance / time

m/s

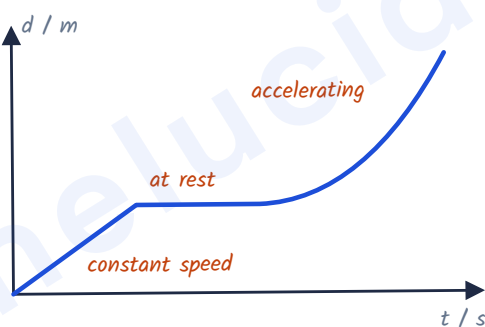
**average speed = total distance / total time**

over the whole journey, including stops

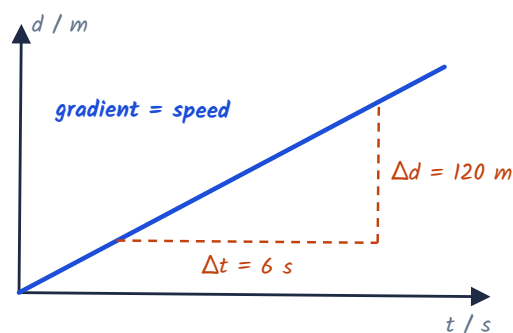
m/s

### Key points

- ✓ Distance-time graph: **gradient = speed**.
- ✓ **Horizontal** line: at rest. **Straight sloping** line: constant speed.
- ✓ **Curving upwards** (getting steeper): accelerating. **Flattening**: decelerating.
- ✓ Steeper line = **faster**.
- ✓ Speed from a straight section: draw a large triangle, gradient =  $\Delta d / \Delta t$ .
- ✓ Velocity can change even at constant speed, if the **direction** changes.



Distance-time shapes: steeper = faster, flat = at rest, curving up = accelerating.



Speed = gradient of a straight section =  $\Delta d / \Delta t = 120 / 6 = 20 \text{ m/s}$ .

### Watch out!

- ! Average speed uses the **total** time, including time spent stationary.
- ! Convert units first: km to m ( $\times 1000$ ), minutes to s ( $\times 60$ ).

## 1.2b Speed-time graphs and acceleration

### Definitions

**Acceleration:** Extended the change in velocity per unit time.

**Deceleration:** Extended a negative acceleration (the velocity decreases).

### Equations

distance = area under speed-time graph

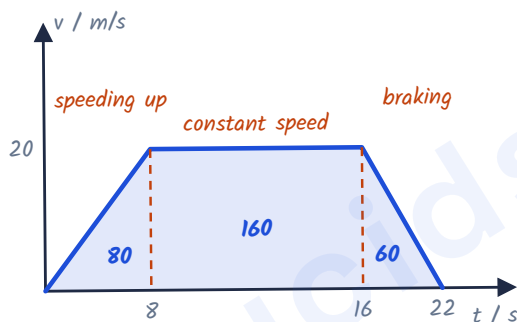
triangle =  $\frac{1}{2} \times \text{base} \times \text{height}$   
m

$$a = \Delta v / \Delta t$$

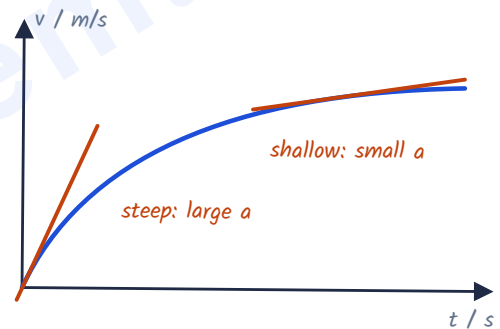
Extended acceleration = change in velocity / time taken  
 $\text{m/s}^2$

### Key points

- ✓ Speed-time graph: **horizontal** line = constant speed; **sloping up** = accelerating; **sloping down** = decelerating.
- ✓ Line along the time axis (speed = 0) = **at rest**.
- ✓ **Area under the line** = distance travelled. Split it into rectangles and triangles.
- ✓ **Extended gradient** = acceleration; a negative gradient is a deceleration.
- ✓ **Extended** a **straight** line = constant acceleration; a **curve** = changing acceleration.
- ✓ **Extended** curve getting less steep = acceleration **decreasing** (e.g. a falling object meeting air resistance).



Accelerate, cruise, brake. Total distance = shaded area =  $80 + 160 + 60 = 300$  m.



Extended: a curve that flattens means the acceleration (gradient of the tangent) is decreasing.

### Watch out!

- ! Gradient = acceleration, but **area** = distance. Do not swap them.
- ! A flat line on a **speed-time** graph means constant speed, not stopped. Check the axis label.

## 1.2c Free fall and terminal velocity

### Definitions

**Acceleration of free fall ( $g$ ):** the acceleration of an object falling with no air resistance; near the Earth it is constant, about  $9.8 \text{ m/s}^2$ .

**Terminal velocity:** *Extended* the constant velocity reached when the air resistance on a falling object equals its weight.

### Equations

$$g \approx 9.8 \text{ m/s}^2$$

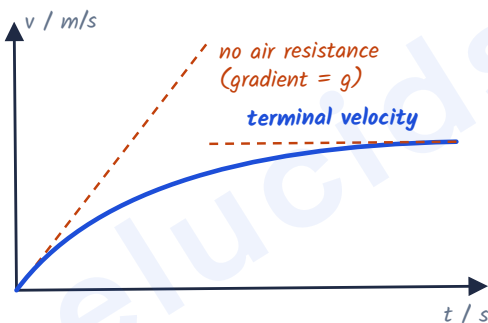
acceleration of free fall near the Earth  
 $\text{m/s}^2$

$$\text{resultant} = W - \text{drag}$$

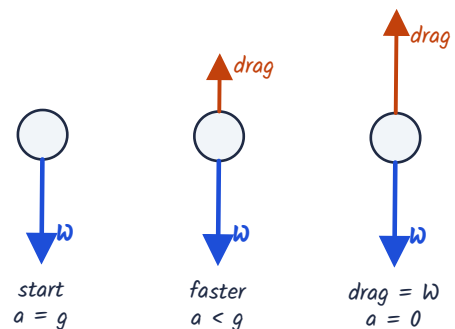
*Extended* resultant downward force on a falling object  
 $\text{N}$

### Key points

- ✓ Near the Earth,  $g \approx 9.8 \text{ m/s}^2$ , the same for all masses when air resistance is negligible.
- ✓ *Extended* no air resistance: speed-time graph is a **straight line** with gradient  $g$ .
- ✓ *Extended* at the start, speed is low, so drag is small and acceleration  $\approx g$ .
- ✓ *Extended* as speed increases, **drag increases**, the resultant force falls, so acceleration **decreases**.
- ✓ *Extended* when **drag = weight**, resultant force = 0, acceleration = 0: terminal velocity.
- ✓ *Extended* opening a parachute increases drag, so the object decelerates to a new, **lower** terminal velocity.



*Extended:* without air resistance  $v$  rises steadily; with air resistance the curve levels off at terminal velocity.



*Extended:* forces on a falling object. Drag grows with speed until it balances the weight.

### Watch out!

- ! *Extended:* at terminal velocity the object is still **moving**; it is the acceleration that is zero, not the speed.
- ! *Extended:* opening a parachute does not make the skydiver move **upwards**; it slows the fall.

## 1.3 Mass and weight

### Definitions

**Mass:** a measure of the quantity of matter in an object at rest relative to the observer.

**Weight:** a gravitational force on an object that has mass.

**Gravitational field strength ( $g$ ):** the force per unit mass.

**Weight (field view):** **Extended** the effect of a gravitational field on a mass.

### Equations

$$W = m g$$

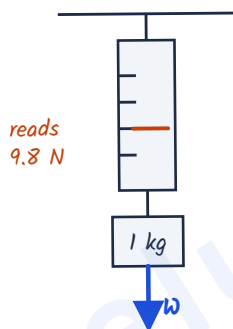
weight = mass  $\times$  gravitational field strength  
**N**

$$g = W / m$$

gravitational field strength = weight / mass  
**N/kg**

### Key points

- ✓ Mass is in **kg** and is the same everywhere; weight is a force in **N** and depends on  $g$ .
- ✓ Near the Earth's surface  $g = 9.8 \text{ N/kg}$ ; on the Moon  $g$  is about  $1.6 \text{ N/kg}$ .
- ✓ Weights (and so masses) are **compared** using a balance; a force meter (newtonmeter) measures weight.
- ✓  $g$  in  $\text{N/kg}$  is **numerically equal** to the acceleration of free fall in  $\text{m/s}^2$ .
- ✓ **Extended** weight acts **towards the centre** of the Earth (or other body).



reads  
**9.8 N**

Earth:  $g = 9.8 \text{ N/kg}$

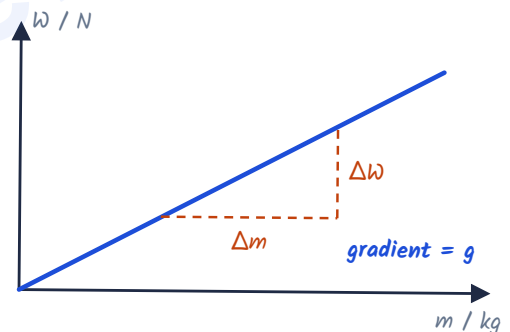
$$W = 9.8 \text{ N}$$

Moon:  $g = 1.6 \text{ N/kg}$

$$W = 1.6 \text{ N}$$

mass = 1 kg in both

A force meter reads weight. The same 1 kg mass weighs less on the Moon, but its mass does not change.



Weight is proportional to mass:  $W$  against  $m$  is a straight line through the origin with gradient  $g$ .

### Watch out!

- ! Weight is a force: give it in **newtons**, never kg. A 60 kg student weighs  $60 \times 9.8 = 588 \text{ N}$ .
- ! Going to the Moon changes **weight**, not mass.

## 1.4 Density

### Definitions

**Density:** the mass per unit volume.

### Key points

- ✓ Water:  $1.0 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$ .
- ✓ **Regular solid:** measure the sides with a rule, calculate  $V$  (e.g.  $l \times w \times h$ ), find  $m$  with a balance.
- ✓ **Liquid:** mass of empty cylinder, then with liquid; subtract. Read  $V$  from the cylinder.
- ✓ **Irregular solid:** volume by **displacement**: rise in water level in a measuring cylinder, or the overflow from a displacement (eureka) can.
- ✓ An object **floats** if its density is **less** than the liquid's, **sinks** if greater.
- ✓ **Extended** a liquid floats on another liquid that is **denser** (if they do not mix), e.g. oil on water.

### Equations

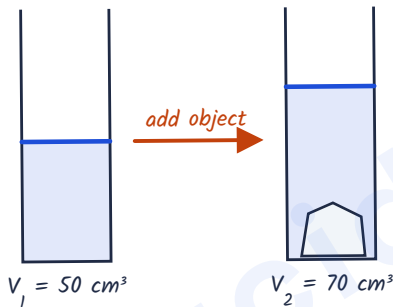
$$\rho = m / V$$

density = mass / volume  
 $\text{kg/m}^3$  or  $\text{g/cm}^3$

$$V = V_2 - V_1$$

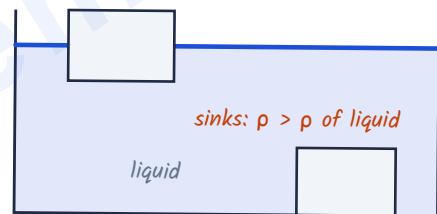
volume of irregular solid = rise in water level  
 $\text{cm}^3$

$$V = V_2 - V_1 = 20 \text{ cm}^3$$



Displacement: the rise in water level equals the volume of the object.

floats:  $\rho < \rho$  of liquid



Float or sink: compare the object's density with the liquid's density.

### Watch out!

- !  $\text{g/cm}^3$  to  $\text{kg/m}^3$ : multiply by **1000**, not 100.  $0.8 \text{ g/cm}^3 = 800 \text{ kg/m}^3$ .
- ! Displacement gives the **volume** of the object, not its mass.

## 1.5a Resultant force, friction and motion

### Definitions

**Resultant force:** the single force that has the same effect as all the forces acting on an object.

**Newton's first law:** an object stays at rest or moves at constant velocity (constant speed in a straight line) unless acted on by a resultant force.

**Solid friction:** the force between two surfaces that may impede motion and produce heating.

**Drag:** friction acting on an object moving through a liquid or a gas; air resistance is a form of drag.

**Newton's second law:** **Extended** the resultant force equals mass  $\times$  acceleration, and the acceleration is in the direction of the resultant force.

### Equations

$$F = m a$$

**Extended** resultant force = mass  $\times$  acceleration  
N

$$a = F / m$$

**Extended** bigger force or smaller mass gives bigger acceleration  
 $m/s^2$

### Key points

- ✓ A force can change an object's **size and shape**, its **speed** or its **direction**.
- ✓ Forces along a line: **add** those in the same direction, **subtract** opposite ones.
- ✓ **Zero resultant:** at rest, or constant speed in a straight line (forces balanced).
- ✓ **Non-zero resultant:** the velocity changes (speeds up, slows down or changes direction).
- ✓ Friction and drag oppose motion; drag **increases with speed**.
- ✓ **Extended** a force **perpendicular** to the velocity makes an object move in a **circle** at constant speed.
- ✓ **Extended** for circular motion a **larger force** is needed if the speed increases, the radius decreases or the mass increases.

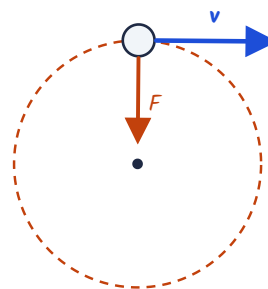


resultant = 6 N to the right



balanced: at rest or constant velocity

Top: 10 N and 4 N in opposite directions give a 6 N resultant. Bottom: balanced forces, so no change in velocity.



Bigger F if:  
speed increases  
radius decreases  
mass increases

**Extended:** circular motion. The velocity is along the tangent; the force is towards the centre, at  $90^\circ$  to the velocity.

### Watch out!

- ! Balanced forces do **not** mean the object is at rest: it may be moving at constant velocity.
- ! **Extended:** in  $F = ma$ , F is the **resultant** force, not just the driving force.

## 1.5b Springs and Hooke's law

### Definitions

**Extension:** the increase in length of a spring from its original (unstretched) length.

**Load:** the force (usually a weight) that stretches the spring.

**Hooke's law:** Beyond the syllabus (name not required): the extension of a spring is directly proportional to the load, up to the limit of proportionality.

**Spring constant (k):** Extended the force per unit extension.

**Limit of proportionality:** Extended the point beyond which the extension is no longer directly proportional to the load.

### Equations

$$x = l - l_0$$

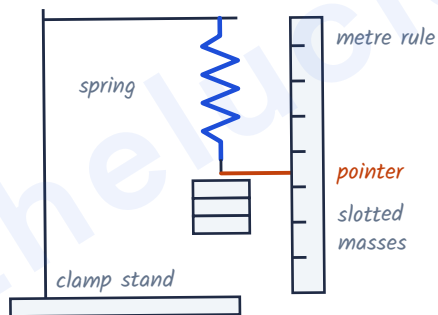
extension = stretched length - original length  
m or cm

$$k = F / x$$

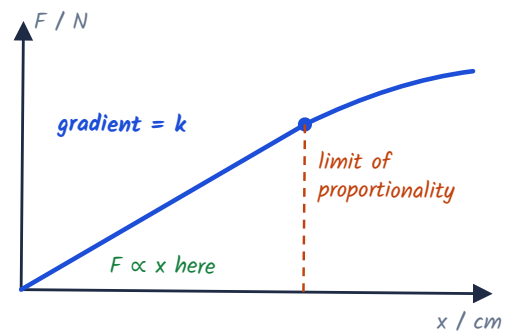
Extended spring constant = force / extension  
N/m

### Key points

- ✓ Experiment: hang the spring from a clamp, measure its **original length** against a vertical metre rule.
- ✓ Add masses one at a time; record the length each time; **extension = length - original length**.
- ✓ Load from masses:  $W = mg$  (100 g gives about 1 N).
- ✓ Read the rule at **eye level**, using a pointer fixed to the bottom of the spring.
- ✓ Load-extension graph: a **straight line through the origin** while the extension is **proportional** to the load.
- ✓ **Extended** past the limit of proportionality the line **curves** (no longer straight); identify this point on the graph.



Stretching a spring: add slotted masses and read the pointer against the metre rule each time.



Load-extension: straight through the origin up to the limit of proportionality (gradient =  $k$  when  $F$  is plotted up the side).

### Watch out!

- !  $x$  is the **extension**, not the total length of the spring.
- ! Extended: masses in g must become a **force in N** ( $W = mg$ ) before using  $k = F / x$ .

## 1.5c Turning effect of forces (moments)

### Definitions

**Moment of a force:** the product of the force and the perpendicular distance from the pivot to the line of action of the force.

**Principle of moments:** for an object in equilibrium, the sum of the clockwise moments about any point equals the sum of the anticlockwise moments about the same point.

**Equilibrium:** the state of an object when there is no resultant force and no resultant moment on it.

### Equations

$$\text{moment} = F \times d$$

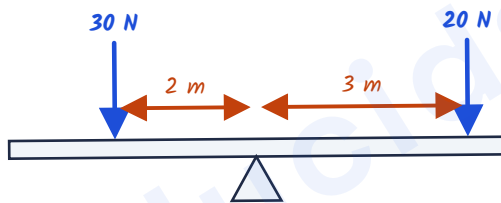
force  $\times$  perpendicular distance from the pivot  
 $\text{N m}$

$$\Sigma \text{ clockwise} = \Sigma \text{ anticlockwise}$$

principle of moments (in equilibrium)  
 $\text{N m}$

### Key points

- ✓ A moment is the **turning effect** of a force; unit  **$\text{N m}$** .
- ✓ Bigger moment from a **bigger force** or a **longer distance**: long spanners, door handles far from the hinge.
- ✓ Use the **perpendicular** distance from the pivot to the line of action.
- ✓ Balancing a see-saw: a heavier person sits **closer** to the pivot.
- ✓ **Extended** with several forces on each side, **add** all clockwise moments and all anticlockwise moments.
- ✓ **Extended** to verify, balance a metre rule on a pivot, hang masses, adjust until level, then compare the two sums.

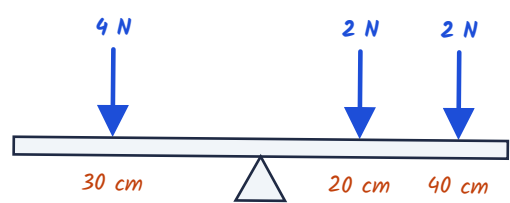


$$30 \times 2 = 20 \times 3 = 60 \text{ N m}$$

anticlockwise

clockwise

Balanced beam: anticlockwise moment  $30 \times 2 =$  clockwise moment  $20 \times 3 = 60 \text{ N m}$ .



$$4 \times 30 = 2 \times 20 + 2 \times 40$$

$$120 \text{ N cm} = 120 \text{ N cm}$$

Extended: two forces on one side. Anticlockwise  $4 \times 30 = 120 \text{ N cm}$ ; clockwise  $2 \times 20 + 2 \times 40 = 120 \text{ N cm}$ .

### Watch out!

- ! Use the **perpendicular** distance to the pivot, not the distance along a slanted line.
- ! Take all moments about the **same** pivot, and keep units consistent ( $\text{N m}$  or  $\text{N cm}$ ).

## 1.5d Centre of gravity and stability

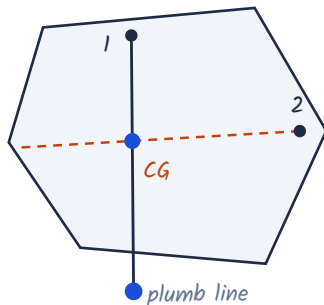
### Definitions

**Centre of gravity:** the point through which all the weight of an object appears to act.

### Key points

- ✓ Plane lamina: hang it from a pin through a hole so it **swings freely**; hang a **plumb line** from the same pin.

- ✓ Mark the plumb line on the lamina; repeat from a **second hole**. The centre of gravity is where the lines **cross**.
- ✓ An object is **stable** if, when tilted, the vertical line through its centre of gravity stays **inside its base**.
- ✓ If that line falls **outside** the base, the weight gives a moment that **topples** it.
- ✓ More stable: **low** centre of gravity and **wide** base (racing cars, bus design, Bunsen burner bases).
- ✓ A regular shape of uniform density has its centre of gravity at its **geometric centre**.



pin through  
hole 1, then  
hole 2

Plumb-line method: the lines from two holes cross at the centre of gravity (CG).



line inside: falls back

line outside: topples

Tilted objects: the low, wide block falls back; the tall, narrow one topples because its CG line is outside the base.

### Watch out!

- ! The centre of gravity can lie **outside** the material, e.g. for a ring or an L-shape.
- ! Stability depends on where the CG line falls relative to the **pivot edge** of the base, not on the mass alone.

## 1.6 Momentum Extended

### Definitions

**Momentum:** **Extended** mass  $\times$  velocity.

**Impulse:** **Extended** force  $\times$  time for which the force acts; it equals the change in momentum.

**Principle of conservation of momentum:** **Extended** when no resultant external force acts on a system, the total momentum before an interaction equals the total momentum after it.

**Resultant force (momentum form):** **Extended** the change in momentum per unit time.

### Key points

- ✓ **Extended** momentum is a **vector**, in the direction of the velocity.
- ✓ **Extended** choose a **positive direction**; anything moving the other way has negative momentum.
- ✓ **Extended** conservation applies to **collisions** and **explosions**.
- ✓ **Extended** objects that **stick together** move off with the combined mass.
- ✓ **Extended** explosion from rest: total momentum stays **zero**, so the parts have equal and opposite momenta.
- ✓ **Extended** crumple zones, airbags and seat belts **increase the time** of impact, so the force is smaller for the same  $\Delta p$ .
- ✓ **Extended** units:  $\text{kg m/s} = \text{N s}$ .

### Equations

$$p = m v$$

**Extended** momentum = mass  $\times$  velocity  
 $\text{kg m/s}$

$$\text{impulse} = F \Delta t = \Delta(mv)$$

**Extended** impulse = change in momentum  
 $\text{N s}$

$$F = \Delta p / \Delta t$$

**Extended** resultant force = change in momentum / time taken  
 $\text{N}$

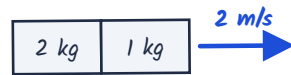
$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

**Extended** total momentum before = total momentum after  
 $\text{kg m/s}$

before



after



before:  $2 \times 3 = 6 \text{ kg m/s}$

after:  $3 \times 2 = 6 \text{ kg m/s}$

Extended: a sticking collision. The trolleys share the momentum; the total,  $6 \text{ kg m/s}$ , is unchanged.

before



after



equal and opposite momenta

Extended: an explosion from rest. Total momentum is zero before and after:  $2 \times 2 + 1 \times (-4) = 0$ .

### Watch out!

- ! Forgetting the **minus sign** for motion in the opposite direction before adding momenta.
- ! Kinetic energy is not always conserved in a collision, but **momentum** always is (no external force).

## 1.7a Energy stores, transfers and conservation

### Definitions

**Principle of conservation of energy:** energy cannot be created or destroyed; it can only be transferred from one store to another.

**Kinetic energy:** the energy an object has because of its motion.

**Gravitational potential energy:** the energy an object has because of its position (height) in a gravitational field.

### Key points

- ✓ **Stores:** kinetic, gravitational potential, chemical, elastic (strain), nuclear, electrostatic, internal (thermal).
- ✓ **Transfers:** mechanical work (forces), electrical work (currents), heating, and waves (electromagnetic, sound).
- ✓ Wasted energy is usually **dissipated** to the surroundings as internal energy, by heating.
- ✓ **Energy flow diagram:** shows the stores and transfers; total energy in = total energy out.
- ✓ **Extended Sankey diagram:** arrow widths are proportional to the energy; input width = total of the output widths.
- ✓ **Extended multi-stage** chains (e.g. power station: chemical  $\rightarrow$  internal  $\rightarrow$  kinetic  $\rightarrow$  electrical): the output of one stage is the input to the next.
- ✓ Example: battery and lamp: chemical store  $\rightarrow$  electrical work  $\rightarrow$  light (waves) + internal (heating).
- ✓ **Extended** falling with no air resistance: **loss in  $E_p$  = gain in  $E_k$** , so  $mg\Delta h = \frac{1}{2}mv^2$ .
- ✓ **Extended** doubling the speed **quadruples  $E_k$** ; doubling the mass doubles it.

### Equations

$$E_k = \frac{1}{2} m v^2$$

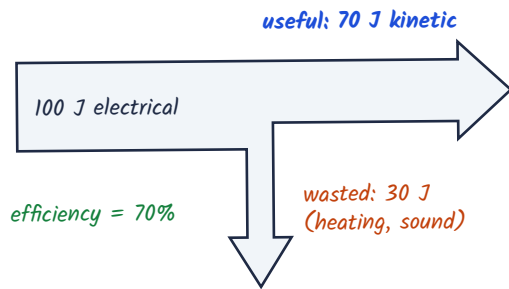
**Extended** kinetic energy  
J

$$\Delta E_p = m g \Delta h$$

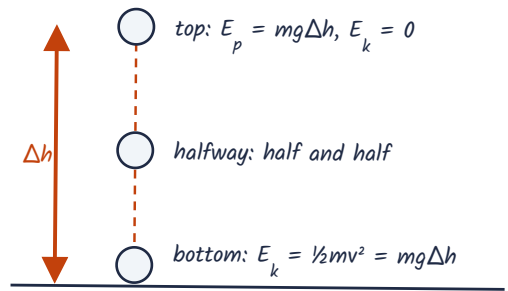
**Extended** change in gravitational potential energy  
J

**energy in = useful out + wasted out**

conservation of energy (energy flow diagram)  
J



Extended: Sankey diagram for a motor: 100 J in, 70 J useful kinetic, 30 J wasted. Widths match the energies.



Extended: a falling ball (no air resistance).  $E_p$  lost =  $E_k$  gained; the total stays  $mg\Delta h$ .

### Watch out!

- ! Energy is never "used up" or "lost": it is **transferred**, often to the surroundings.
- ! Extended: only the **speed** is squared in  $E_k = \frac{1}{2}mv^2$ ; square  $v$  before multiplying.

## 1.7b Work

### Definitions

**Work done:** the product of the force and the distance moved in the direction of the force.

**Work done (energy view):** the energy transferred by a force (mechanical work) or by an electric current (electrical work).

**Joule:** the work done when a force of 1 N moves its point of application 1 m in the direction of the force.

### Equations

$$W = Fd$$

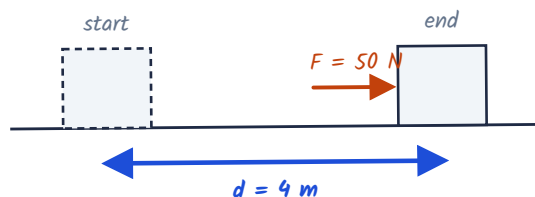
work done = force  $\times$  distance moved in the direction of the force  
J

$$W = \Delta E$$

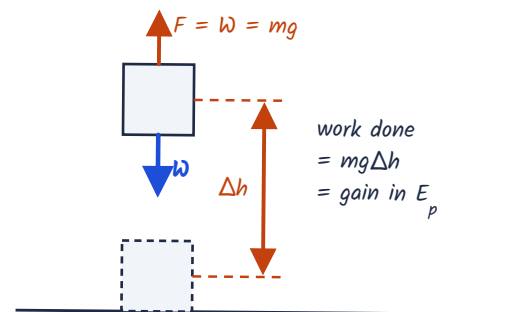
work done = energy transferred  
J

### Key points

- ✓ **Work done = energy transferred**, measured in joules ( $1 \text{ J} = 1 \text{ N m}$ ).
- ✓ No movement in the direction of the force means **no work** (e.g. holding a heavy bag still).
- ✓ Lifting at steady speed: force = weight, so work done =  $mg \times$  height = gain in  $E_p$ .
- ✓ Work done against **friction** transfers energy to the internal store (heating).
- ✓ Braking car: work done by the brakes = the kinetic energy removed.



Work done =  $F \times d = 50 \text{ N} \times 4 \text{ m} = 200 \text{ J}$  transferred.



work done  
=  $mg\Delta h$   
= gain in  $E_p$

Lifting at steady speed: the force equals the weight, so  $W = mg\Delta h$ .

### Watch out!

- ! Use the distance moved **in the direction of the force**, not any distance in the question.
- ! Work and energy are both in **joules**; power is in watts.

## 1.7c Energy resources and efficiency

### Definitions

**Renewable energy resource:** a resource that is replaced naturally and will not run out.

**Non-renewable energy resource:** a resource that is finite and cannot be replaced once it is used up.

**Efficiency:** **Extended** the useful energy (or power) output divided by the total energy (or power) input, often  $\times 100\%$ .

### Equations

$$\text{efficiency} = (\text{useful energy output} / \text{total energy input}) \times 100\%$$

**Extended** energy form  
no unit (%)

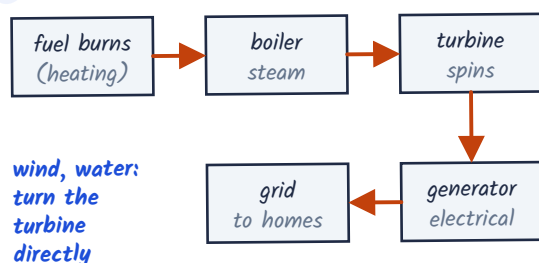
$$\text{efficiency} = (\text{useful power output} / \text{total power input}) \times 100\%$$

**Extended** power form  
no unit (%)

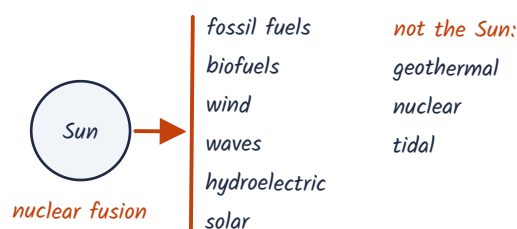
### Key points

- ✓ **Fossil fuels** (coal, oil, gas) and **biofuels**: burned to boil water in a **boiler**; steam turns a **turbine** that drives a **generator**.
- ✓ **Nuclear fission** and **geothermal** (hot rocks) also heat water to make steam for turbines.
- ✓ **Hydroelectric** dams, **tides**, **waves** and **wind** turn turbines directly.
- ✓ **Solar cells** convert light directly to electricity; **solar panels** heat water.
- ✓ Compare resources on **renewability**, **availability**, **reliability**, **scale** and **environmental impact**.
- ✓ **Efficiency** (qualitative): the larger the fraction of the input energy transferred usefully, the **more efficient** the device.
- ✓ **Extended** radiation from the **Sun** is the main source of energy for all these except **geothermal**, **nuclear** and **tidal**.
- ✓ **Extended** the Sun releases energy by **nuclear fusion**; research aims to use fusion to generate electricity on a large scale.

also nuclear and geothermal (heat water)



Thermal power station: fuel heats water, steam turns the turbine, the generator produces electricity.



**Extended:** most resources trace back to the Sun. Geothermal, nuclear and tidal do not.

### Watch out!

- ! Solar **cells** make electricity; solar **panels** heat water. Do not swap them.
- ! Efficiency can never exceed 100%, and it has **no unit**.
- ! Renewable does not mean reliable: wind and solar depend on the **weather**.

## 1.7d Power

### Definitions

**Power:** the work done per unit time, or the energy transferred per unit time.

**Watt:** a power of one joule per second.

### Key points

- ✓  $1 \text{ W} = 1 \text{ J/s}$ ;  $1 \text{ kW} = 1000 \text{ W}$ .
- ✓ More powerful = does the same work in **less time** (or more work in the same time).
- ✓ Stair-climb power: measure mass, vertical height of the stairs and time;  $P = mgh / t$ .
- ✓ On an energy-time graph, **gradient = power**.

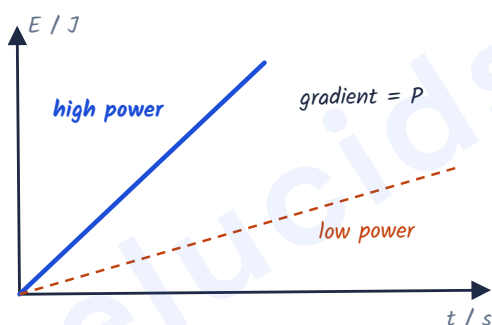
### Equations

$$P = W / t$$

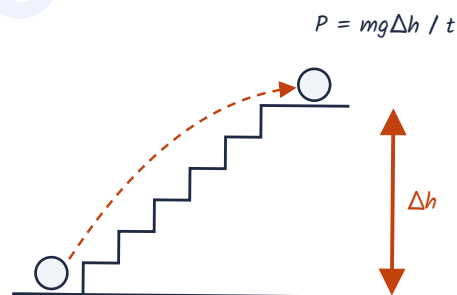
power = work done / time taken  
 $W$

$$P = \Delta E / t$$

power = energy transferred / time taken  
 $W$



Energy transferred against time: the steeper line is the more powerful machine (gradient = power).



Stair climb: power = gain in  $E_p$  / time =  $mg\Delta h / t$ .

### Watch out!

- ! Time must be in **seconds**: 2 minutes = 120 s.
- ! Use the **vertical** height of the stairs, not the length along the slope.

## 1.8a Pressure on surfaces

### Definitions

**Pressure:** the force per unit area.

**Pascal (Pa):** a pressure of one newton per square metre.

### Equations

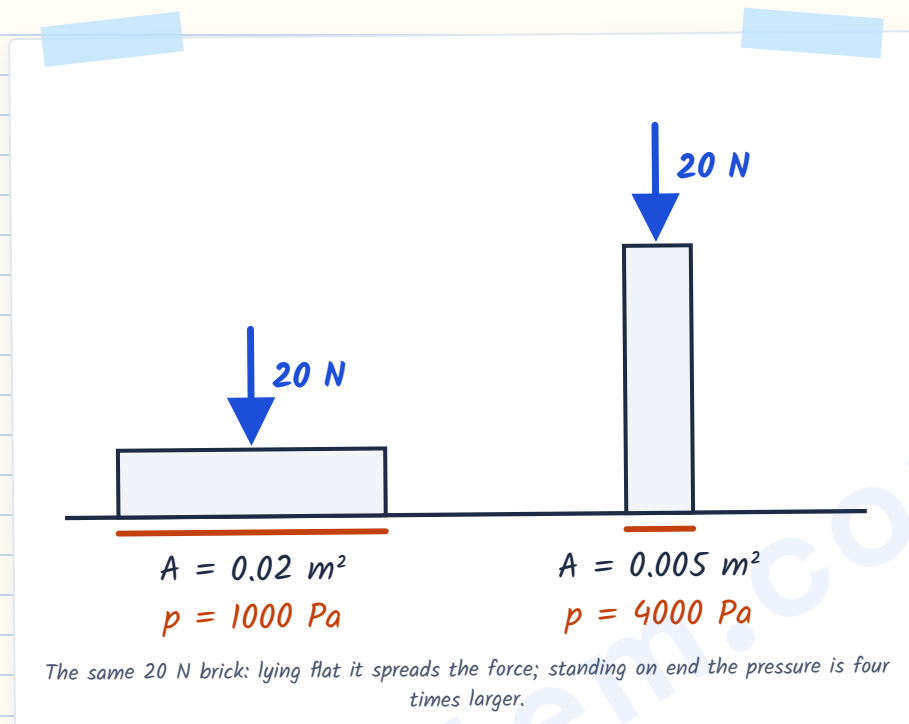
$$p = F / A$$

pressure = force / area  
 $\text{Pa (N/m}^2\text{)}$

### Key points

- ✓ Same force on a **smaller area** gives a **larger pressure**.

- ✓ High pressure (small area): knife blades, drawing pins, nails, stiletto heels.
- ✓ Low pressure (large area): snowshoes, wide tractor tyres, building foundations, camel feet.
- ✓ Pressure increases with **force** and decreases with **area**.
- ✓ Area conversions:  $1 \text{ m}^2 = 10\,000 \text{ cm}^2$ .



### Watch out!

- ! Area in  $\text{cm}^2$  must be converted to  $\text{m}^2$  (divide by 10 000) to get pascals.
- ! Mass in kg is not force: find the weight ( $W = mg$ ) first.

## 1.8b Pressure in liquids

### Definitions

**Pressure in a liquid:** the pressure caused by the weight of liquid above a point; it acts equally in all directions.

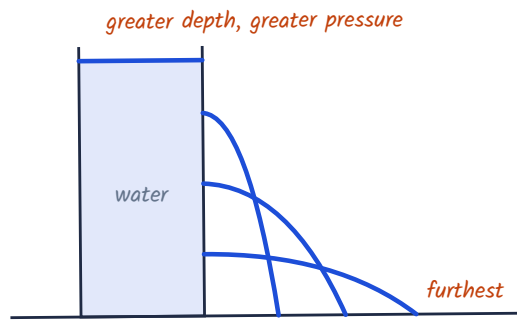
### Key points

- ✓ Pressure beneath a liquid surface **increases with depth**.
- ✓ At the same depth, pressure is greater in a **denser** liquid.
- ✓ At a given depth pressure acts **equally in all directions** and does not depend on the container's shape.
- ✓ Dams are **thicker at the bottom**; water spurts furthest from the lowest hole in a can.
- ✓ **Extended** the **change** in pressure between two depths is  $\Delta p = \rho g \Delta h$ .

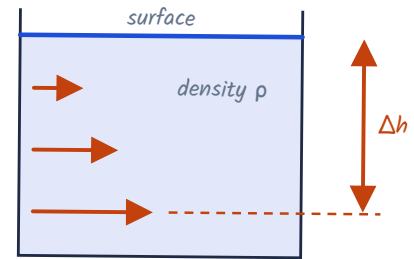
### Equations

$$\Delta p = \rho g \Delta h$$

**Extended** pressure change = density  $\times$  g  $\times$  change in depth  
Pa



Water spurts furthest from the lowest hole, where the pressure is greatest.



$$\Delta p = \rho g \Delta h$$

Extended: pressure arrows grow with depth. The extra pressure over a depth  $\Delta h$  is  $\rho g \Delta h$ .

### Watch out!

- ! Extended:  $\rho g \Delta h$  is only the pressure **due to the liquid**; the total also includes atmospheric pressure on the surface.
- ! Extended:  $\Delta h$  is the **vertical** depth, not the distance along a sloping pipe.