Physics

1. Kinematics

Time - seconds (s)
Length - metres (m)
Mass - kilogram (kg)

Multiplication Factor	Prefix name	Prefix symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n

- Scalars: have magnitude
- Vectors: have magnitude and a direction

When adding and subtracting vectors, make sure to remember your convention: $\rightarrow\ +ve$ (positive to the right). Then add them normally. When subtracting vectors, you subtract the **final** vector by the **initial** vector. This gives the difference or the change in vectors.

When the vectors are in 2d you can use $x\cos\theta$ to find the horizontal change and $x\sin\theta$ to find the vertical difference.

A **displacement**-time graph: *slope* = velocity.
A **velocity**-time graph: *slope* = acceleration, *area* = displacement
An **acceleration**-time graph: *area* = Δ velocity

Fundamental physics equations:

1. $\vec{v} = \vec{u} + \vec{a}t$ — $\vec{u}$ = initial velocity
2. $\vec{s} = \frac{1}{2}\vec{a}t^2 + \vec{u}t$
3. $\vec{v}^2 = \vec{u}^2 + 2\vec{a}\vec{s}$

When doing relative motion, it is A relative to B, or $x_{AB} = x_A - x_B$.

When doing direction like $N38°E$, it is always off the North-South axis.

$$\vec{v}_{AB} = -\vec{v}_{BA}$$

2. Dynamics

Newton's First Law: an object will remain at a constant velocity (which can be rest) unless acted upon by a net external force.
Force: a vector representing push/pull on an object.
Inertia: a tendency of an object to keep its velocity.
Contact force: a force transferred by physical interactions between objects.
Field force: a force exerted through the influence of a field.

- Gravity
- Magnetism
- Electricity

Free body diagram represents all forces acting on an object **(do not include F_{NET})**

Tension: $T = mg + m \times \overset{\text{opposite direction of gravity}}{\vec{a}}$

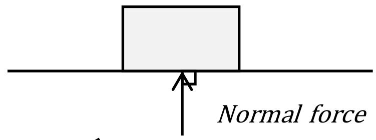
Newton's Second Law: when a net external force acts on an object, it will accelerate proportional to mass

Newton's Third Law: for every action (force) there is an equal and opposition reaction (force)

Note: not related to equilibrium

Notation:

$$\overbrace{\vec{F}_{AB}}^{\text{force applied on A by B}} = -\overbrace{\vec{F}_{BA}}^{\text{(reaction) force applied on B by A}}$$



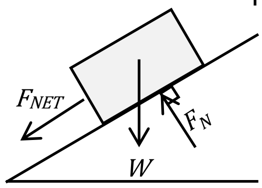
Normal force: always perpendicular to contact surface.

On a **frictionless** inclined plane:

$\vec{a} = g\sin\theta$

There is motion due to the difference between the weight force and the normal force.

$\vec{F}_{NET} = mg\sin\theta$

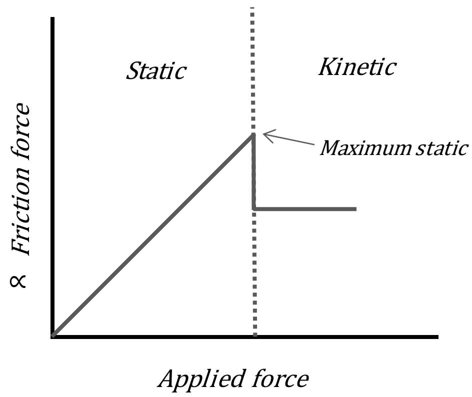


Friction:

Friction is given by $\vec{F}_{friction} = \mu \times \vec{F}_N$

Friction is independent of contact area, nor will friction vary on velocity.

Kinetic friction is commonly lower than static friction.



If a graph gives a straight line, then y-axis is proportional to the x-axis or $y \propto x$

Work and Energy:

Energy is the capacity to cause change, scalar quantity measured in Joules.

Kinetic energy associated with the motion of an object $K = \frac{1}{2}mv^2$

Potential energy is related to the position of an object in relation to another or a field (stored energy) $U = mg \times \Delta h$

Work is the change in energy, in *Joules* (J). $W = \Delta E$, $W = \vec{F}_{||}\vec{s} = \vec{F} \times \vec{s}\cos\theta$, usually is area under curve and the change must be perpendicular.

Conservation of energy: $K_0 + U_0 = K_f + U_f$. Measuring height from local reference point, accounting for barriers to movement (hills).

Power the rate at which work is done, in *Watts* (W). $P = \frac{\Delta E}{\Delta t} = F_{||}\vec{v} = F\vec{v}\cos\theta$

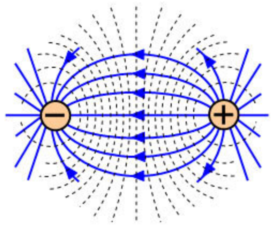
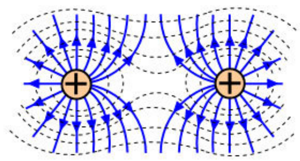
Momentum is a vector quantity of an object's mass and velocity. $\vec{p} = m\vec{v}$

Elastic collision	$\sum\vec{p}_0 = \sum\vec{p}_f$	$\sum K_0 = \sum K_f$	
Inelastic collision	$\sum\vec{p}_0 = \sum\vec{p}_f$	$\sum K_0 > \sum K_f$,	energy lost as heat, sound, etc.
└ Stick together			

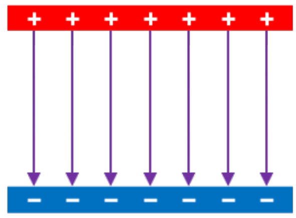
Impulse = $\vec{I} = \Delta\vec{p} = \vec{p}_f - \vec{p}_0$ **Always use only momentum (not speed) in equations**

3. Electricity and Magnetism

1 Coulomb (C) = 6.241×10^{18} protons/electrons.
(-) electrons/**(+)** protons = 1.602×10^{-19} C
Like charges repel, unlike/opposites attract

Electric field lines: show the direction of force on a positively charged particle, density is proportional to field strength.



In electrically charged plates the charge is perpendicular to the parallel plates running from positive to negative.

Electric field strength: force per unit: $\vec{E} = \frac{\vec{F}}{q}$. With $\vec{E}$ being electric field strength ($N\,C^{-1}$ or Vm^{-1}), $\vec{F}$ is the force on charge (N) and q being the amount of charge (C).

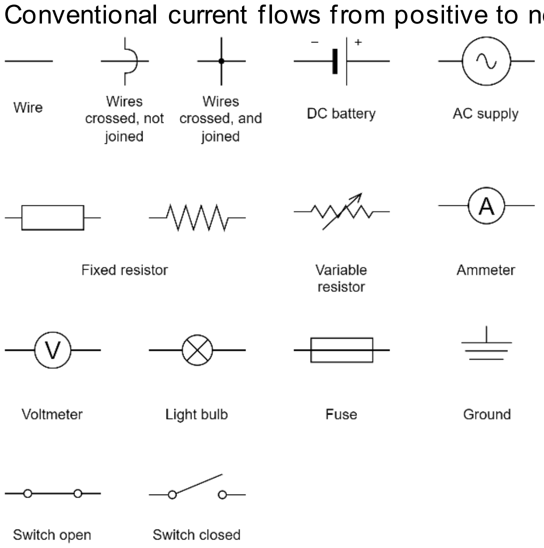
$V = \frac{\Delta U}{q}$, V is electrical potential in $J\,C^{-1}$ or Volts, V; ΔU being charge of electrical potential energy J.
When the distance between two parallel plates is known as d. $\vec{E} = \frac{V}{d}$

$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
Coulomb's law: the force between two-point charges is inversely proportional to the square of the distance between them.

Current is the flow of charged particles (<u>not</u> just electrons, protons, etc.) in a conductor. $I = \frac{q}{t}$ Needs:

- Driving force: difference in potential energy
- Conducting path
- Free charged particles: to carry the energy.

Conventional current flows from positive to negative, with electrons going from negative to positive.



Electric potential energy: when electric charges are separates leading to one area being more positive than the other.

Potential difference: the relative difference between electrical potential energy to each coulomb of charge. (Voltage)

$W = \Delta E = Vq = VIt$, which is measured in Joules (J)
$P = VI = \frac{V^2}{R}$, the rate at which energy is transferred in Watts (W) or energy dissipation

$R = \frac{V}{I}$, resistance in Ohms (Ω).

In a series circuit, current is constant.
In a parallel circuit, voltage is constant and current is $\sum I$ (based upon voltage drop)

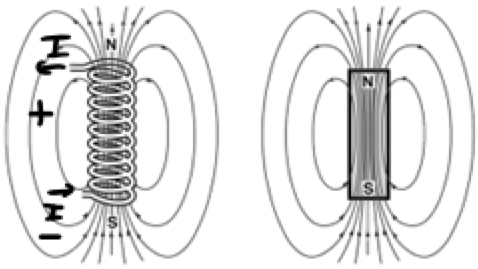
Voltage drives current to flow.
Conservation of energy (Kirchhoff's voltage law): $\Delta V_{total} = \sum V = 0$
Conservation of charge (Kirchhoff's current law): $\sum I = 0$, at a junction the charge is still $\sum I = 0$
Parallel circuit = *constant* voltage, series circuit = *constant* current

Resistors in series: $R_{total} = \sum R$
Resistors in parallel $\frac{1}{R_{total}} = \sum \frac{1}{R}$

When solving resistor problems group resistors together by series or parallel to make a simple circuit. For parallel resistors you can only calculate the potential across the combined resistor as the voltage drop is the same for every resistor in parallel.

Magnetism

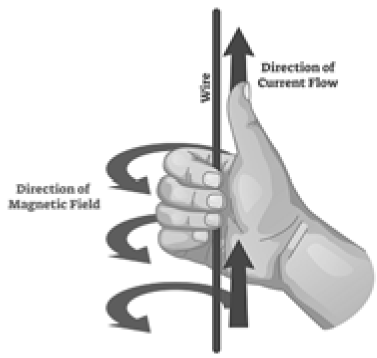
Magnetised material: material is currently generating a magnetic field.
Ferromagnetic material: material that <u>can</u> be magnetised, but not ***currently*** magnetic will induce an **attractive** force. e.g., iron, cobalt
Diamagnetic material: material that <u>can</u> be magnetised, but not ***currently*** magnetic will induce a **repulsive** force. e.g., copper



Within a ferromagnetic material, there are domains of differing orientating fields when a magnetic is brought close they align causing the material to **<u>magnetise</u>**.

Magnetic field lines are continuous, $N \to S$ external to magnet and $S \to N$ internal to magnet, never cross, the closer = the stronger the magnetic field

Magnetic field strength ($\vec{B}$) in Teslas (T) is expressed for a wire with:
$B = \frac{\mu_0 \times I}{2\pi r}$,
with μ_0 being the permeability of free space = $4\pi \times 10^{-7}$, r distance from wire (m) and I being current



A solenoid (coiled wire with current passing through it) acts just like a bar magnet.

A magnetic field within a solenoid is uniform and independent of length. It is instead dependent on the number of turns of coil per unit length.

For a solenoid: $B = \frac{\mu_0 N I}{L}$, with N being the number of turns of wire and L the length of the solenoid.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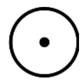
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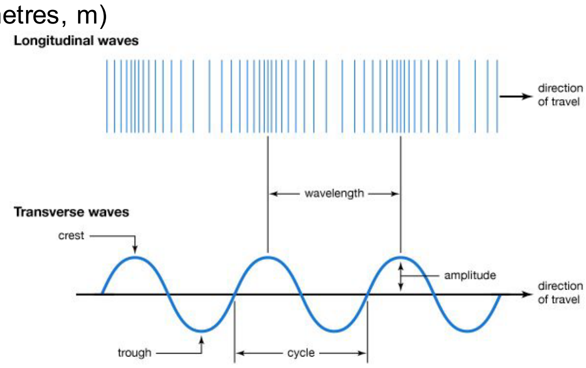
Transverse waves: points oscillate perpendicular to direction of travel.
Longitudinal (compression) waves: points oscillate parallel to direction of travel.

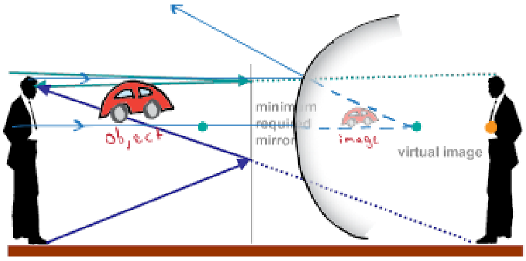
Displacement-distance graph: shows all points of the wave in snapshot.
Wavelength (λ): distance between two equal points on the wave (metres, m)



Displacement-time graph: shows the displacement of one point over time.
Period (T): time taken for any point a wave to complete a full cycle (seconds)

Wave equations: $f = \frac{1}{T}$, $v = f\lambda = \frac{\lambda}{T}$

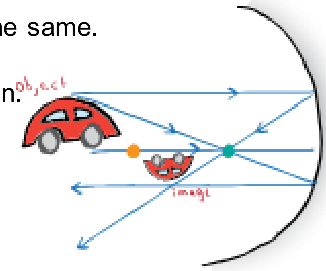
Electromagnetic waves: electric and magnetic fields oscillating perpendicular to one another.
Mechanical waves are the vibration of a series of particles.



When the medium changes or ends a wave will either be reflected, absorbed or transmitted.

Law of reflection (angles from normal to the surface) angle of incidence = angle of reflection $\theta_i = \theta_r$

When encountering a rigid surface a wave will flip (invert) otherwise the wave remain the same.

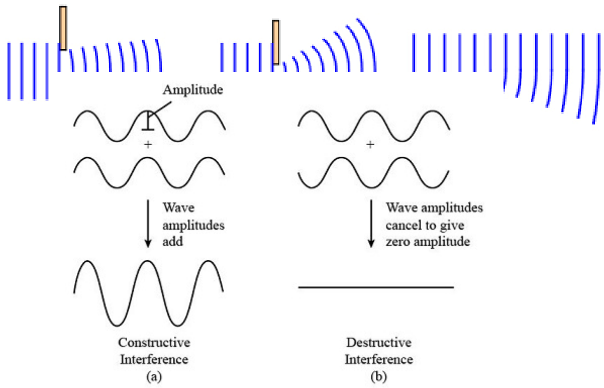


Waves refract when encountering a medium of different density to the one it was just in.
If the waves enter a <u>more</u> dense medium, they refract towards the normal.
If the waves enter a <u>less</u> dense medium, they refract **away** the normal.
This happens with all waves i.e., sound, light and ocean waves.

Refraction is when light changes mediums.
n, refractive index with x being medium: $n_x = \frac{c}{v_x}$
Snell's law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$
For reflection: f generally stays the same, so v & λ change

Total internal reflection: when waves are reflected back into the medium. When $n_1 > n_2$
Critical angle: $n_1 \sin\theta_1 = n_2 \sin 90° \rightarrow \sin\theta_c = \frac{n_2}{n_1}$

Diffraction is the spreading out of waves into a space beyond a gap or an obstacle.
v, λ & f don't change. The diffraction will be at the max when the wavelength equals (or is close to equalling) the width of the gap.



Superposition: when waves of the same nature occupy the same space and pass through each other.
Constructive interference: waves are superimposed, and the amplitudes add.
Destructive interference: waves are superimposed, and the amplitudes negate.

Standing waves: two superimposed waves create a larger wave that doesn't appear to be travelling (stationary nodes)

An object has a natural (free) vibrational frequency which will happen when disturbed from equilibrium (i.e., striking a wine glass)
Resonance: when the frequency of the incoming (forced) vibration matches the natural vibration leading to a standing wave with maximum efficiency.

Standing wave experiment given harmonics, time (t), number of waves ($\#w$) and distance (d)
Harmonics adjustment factor $h = \frac{2}{\text{harmonic value}}$
Period: $T = \frac{t}{\#w} \times h$, $f = \frac{1}{T}$, $\lambda = dh$, $v = f\lambda$

Sound is a longitudinal wave, speed of sound at sea level: $v = 340ms^{-1}$
The denser the object, the faster sound waves can travel.
Higher frequency = higher pitch, higher amplitude = louder

Sound intensity is a measure of the amount of sound energy in a unit area per second.
Units: $I = Jm^{-2}s^{-1} = Wm^{-2}$ $\quad I \propto \frac{1}{r^2}$, $\quad \frac{I_2}{I_1} = \frac{r_1^2}{r_2^2}$, $\quad I = 10^{\left(\frac{\text{dB}}{10} - 12\right)}$

Reverberation is the prolonging of a sound after it bounces off surfaces not far away, usually when the source is less than 17m away from a wall.

Vibration in strings where each end is a node (which is fixed)
1st harmonic = fundamental mode of vibration, ½ wavelength – lowest frequency a string will resonate at.
$f_n = nf_1$, $\lambda_n = \frac{2l}{n}$, where $n = 1,2,3,\cdots$
$v = \sqrt{\frac{T}{m/l}}$ with T being tension (N), m/l mass per unit length $(\mathrm{kg/m})$

Overtone: notes/tones of higher frequency than the fundamental frequency.

For stationary waves in open pipes: both ends are anti-nodes.
With $\lambda_n = \frac{2l}{n}$, $f = n\frac{v}{2l} = nf_1$ where $n = 1,2,3,\cdots$

In a pipe with one end closed, the open end is an anti-node with the closed end being a node.
With $\lambda_n = \frac{4l}{n}$, $f = n\frac{v}{4l} = nf_1$ where $n = 1,3,5,\cdots$

Regular reflection off a smooth surface (i.e., a mirror, shiny object)
Diffuse reflection off an irregular surface (i.e., matte object)

Inverse square law for light, units $Js^{-1}m^{-2} = Wm^{-2} = cd$ (Candela)

$$I_1r_1^2 = I_2r_2^2$$

Chromatic dispersion: when white light passes from one material to another incurring refraction. As each colour has different speeds (due to wavelength), they refracted by different amounts.