End Semester Assessment (ESE) instruction & Key Concept Review P1-P13

ESE A107

- Date and time: **29th Aug, 2017 Tues (9 to 11am)**
- Inclusive of **P1-P13 → 80 marks (2 hrs)**
- 3 sections:
  - MCQ (20 marks)
  - Fill in the blanks (FIB) questions (20 marks)
  - Essay questions (40 marks)
- Access to anything in their laptop including 6th P (Open book)
- Bounded hand-written notes (A4 or smaller than A4)
- 1 piece of blank A4 size paper for workings
- No textbooks and assessment books allowed

P01 Key Concept Recap

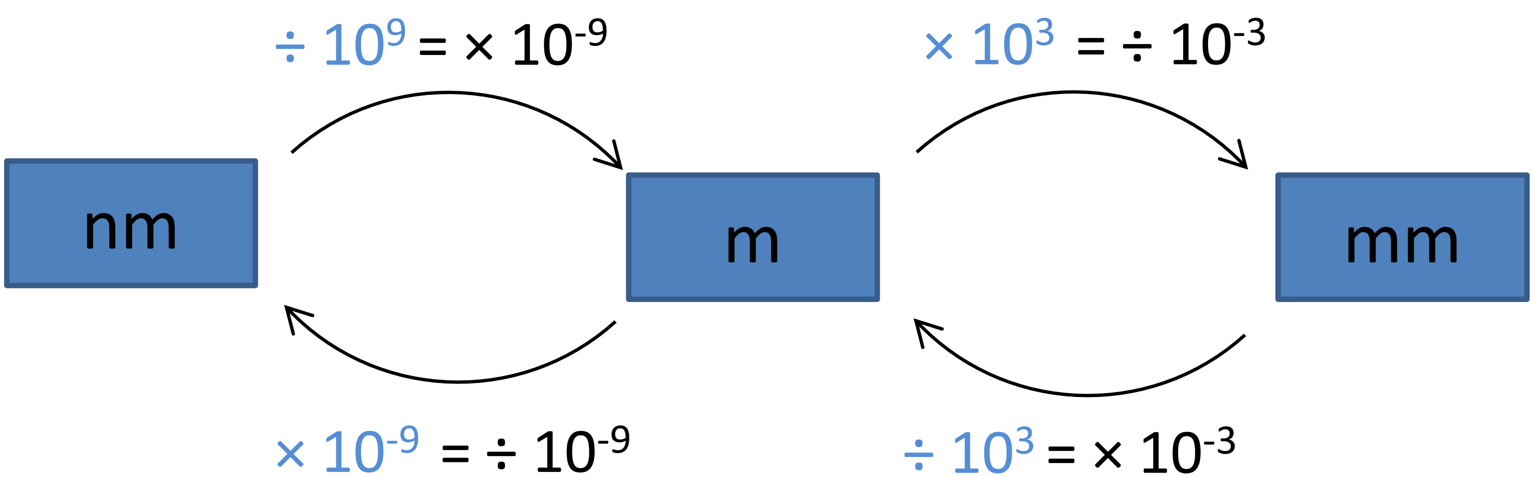
What are the SI base units?

SI base quantity	SI base unit
Length	Metre (m)
Mass	Kilogram (kg)
Velocity	Metre/second (ms^{-1})
Time	Second (s)
Electric current	Ampere (A)
Temperature	Kelvin (K)
Luminous intensity	Candela (cd)
Amount of substance	Mole (mol)

How are unit conversions done effectively?

Example

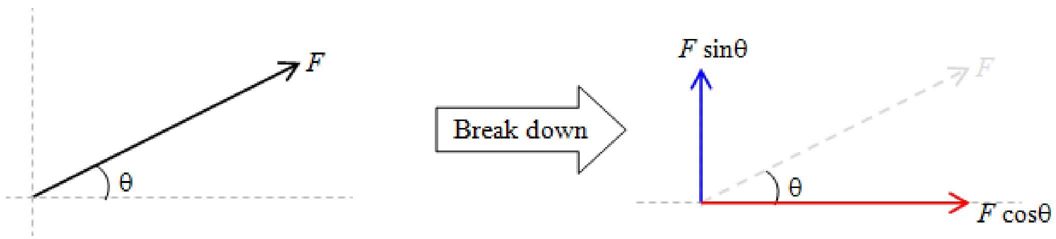
- We have 1 nm = 10^{-9} m and 1 mm = 10^{-3} m
- General rule of thumb, converting from smaller to bigger units, we divide. Converting from bigger to smaller units, we multiply.



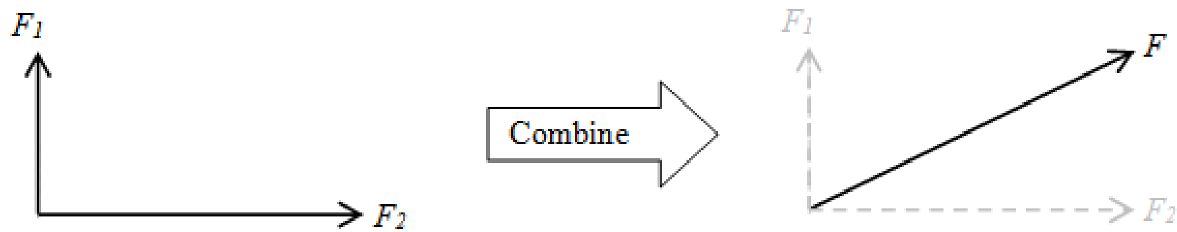
Scalar and Vectors

- A **scalar** is a physical quantity that has only magnitude but no direction.
- A **vector** is a physical quantity that has both magnitude and direction.

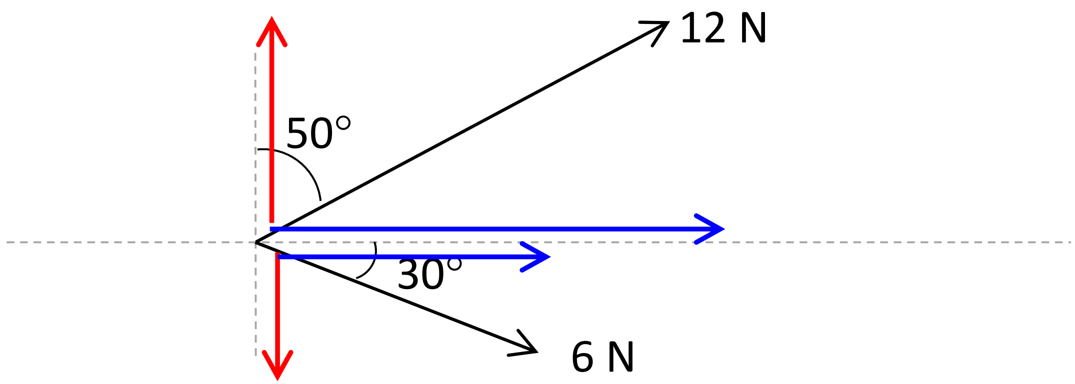
Characteristic 1:
We can resolve a vector into its perpendicular components.



Characteristic 2:
We can combine perpendicular vectors to form a single vector using Pythagoras' theorem.



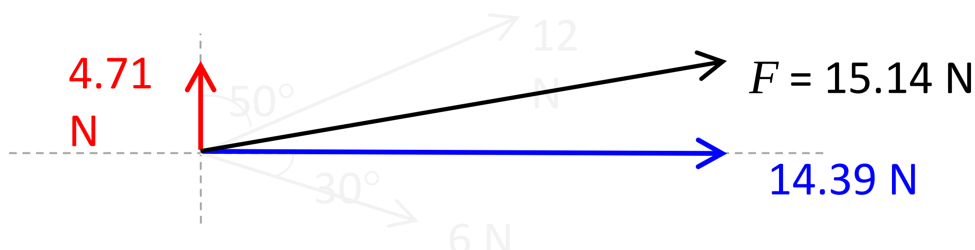
If vectors are NOT perpendicular, then how?



- We will find the vertical and horizontal components of the two forces 12 N and 6 N and add up to get the NET.

	Vertical Component	Horizontal Component
12 N	12 cos 50° = 7.71N (↑)	12 sin 50° = 9.19 N (→)
6 N	6 sin 30° = 3 N (↓)	6 cos 30° = 5.20 N (→)
Total	7.71 N – 3 N = 4.71 N (↑)	9.19 + 5.20 = 14.39 N (→)

- Then, combine perpendicular vectors to form a single vector using Pythagoras' theorem.



P02 Key Concept Recap

What are some examples of vectors and scalars?

- Some examples of vector and scalar quantities:

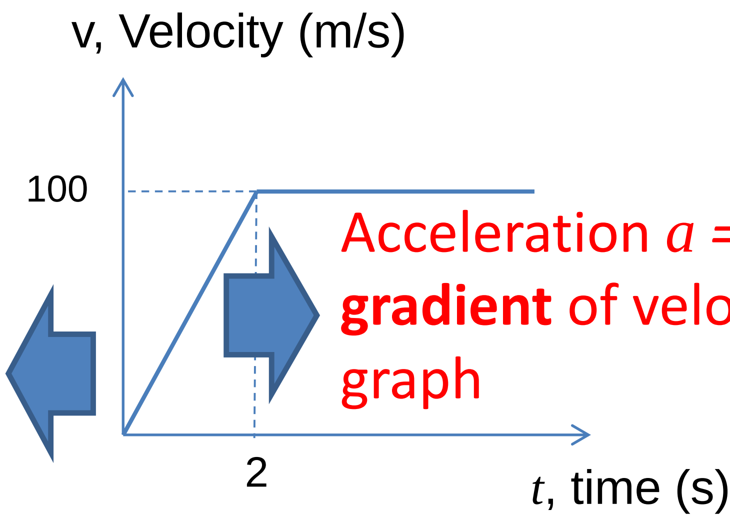
Scalar quantity	**Vector quantity**
Speed	Velocity
Distance	Displacement
Mass	Acceleration
Volume	Weight

What is the relationship between velocity and acceleration?

- Velocity is speed in a given direction.
- **Acceleration is change in velocity divided by time.**
- ***$a = (v - u)/t \rightarrow v = u + at$***
- Where a is acceleration, v is final velocity, u is initial velocity and t is time.
- Acceleration is represented by the gradient of a velocity-time graph.
- An object is accelerating if it is changing/increasing its velocity.
- Acceleration has to do with changing how fast an object is moving.
- If an object is not changing/increasing its velocity, then the object is not accelerating.

- Sketch graphs
- Understand the relationship between distance, velocity and acceleration

Distance is given by area under velocity-time graph



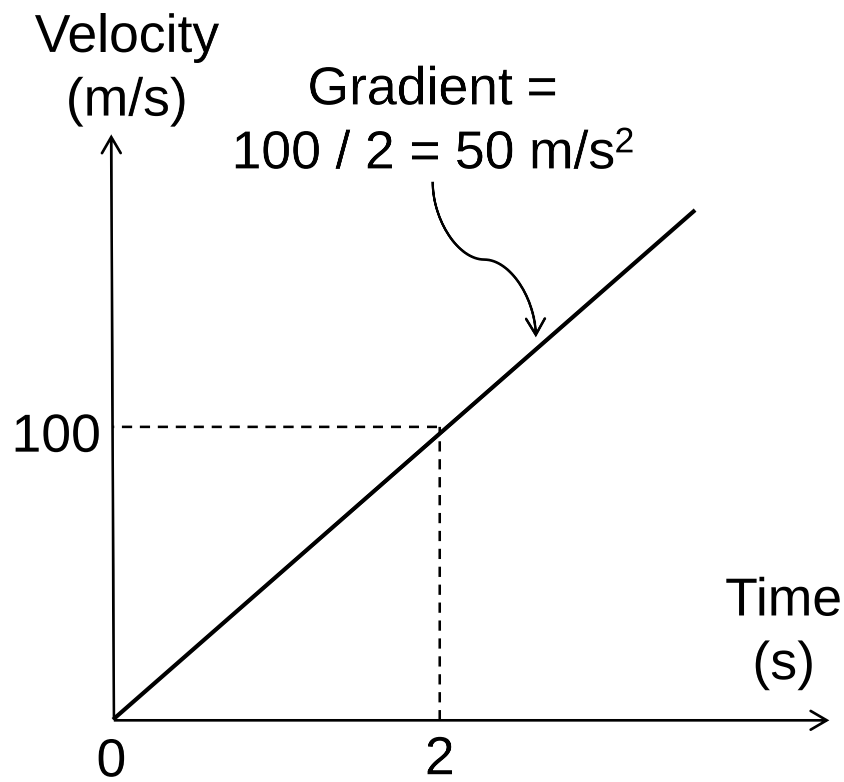
Acceleration *a = (v-u)/t*
gradient of velocity-time graph

<u>**constant velocity → no acceleration**</u>

What is the relationship between velocity and acceleration?

- If the velocity of a car is said to increase uniformly from 0 m/s to 100 m/s in 2 seconds, this means that the velocity increases linearly with time by 100 m/s over 2 seconds.
- Gradient is therefore 100 / 2

  = 50 m/s^2
- The gradient of velocity-time graph represents the acceleration undergone by the car.

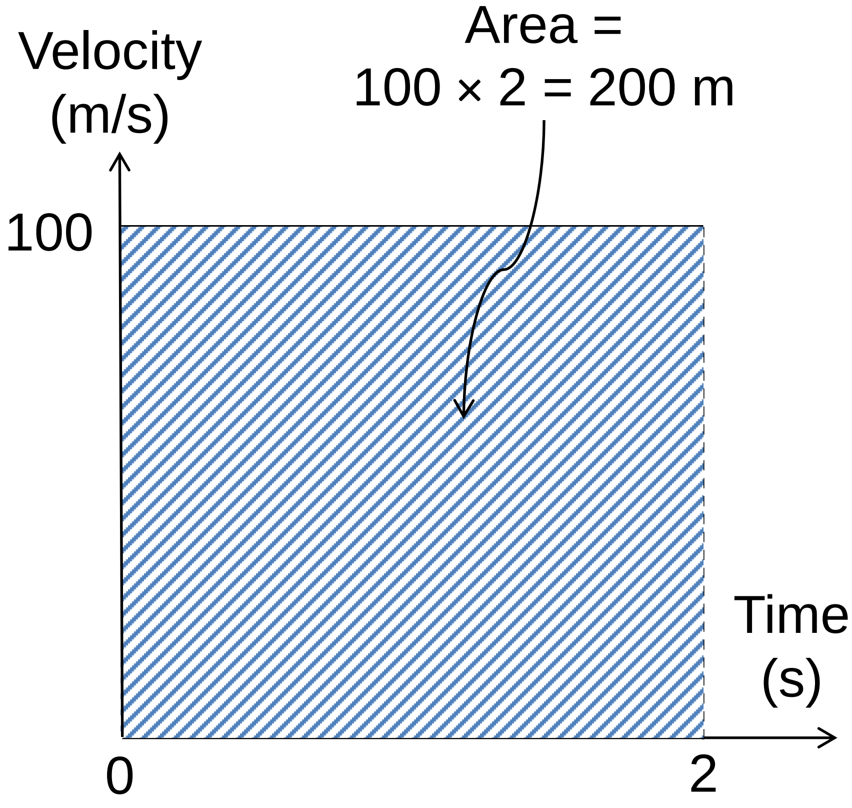


Note: Acceleration is represented by the gradient of a velocity-time graph.

What is the relationship between distance and velocity?

- Distance is given by area under velocity-time graph. In a constant speed scenario, the area is a rectangle.
- Distance = 100 × 2 = 200 m

Note: Area under velocity-time graph = Distance travelled



P03/4 Key Concept Recap

Newton Laws Summary

First Law:

An object will not change its motion, be it at rest or travelling at a constant velocity unless there is a net force acting on it.

Second Law:

$$\boldsymbol{F_{net} = m \times a}$$

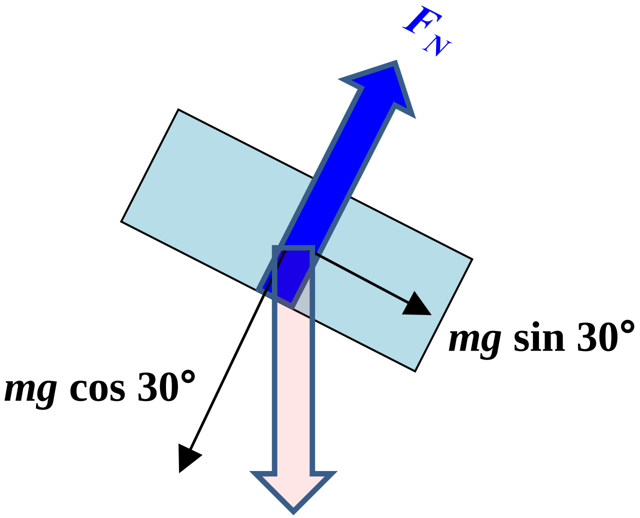
Note the $\boldsymbol{F_{net}}$ and $\boldsymbol{a}$ are in the **same** direction.

where m is the mass and a is the acceleration.

Applying the Second Law

Consider the components of all the forces acting in the direction perpendicular to the surface of the slope.

Since there is no change in velocity along this direction (i.e. acceleration in this direction = 0), we can conclude that the net force along this direction is zero. i.e. $F_{net} = 0$.



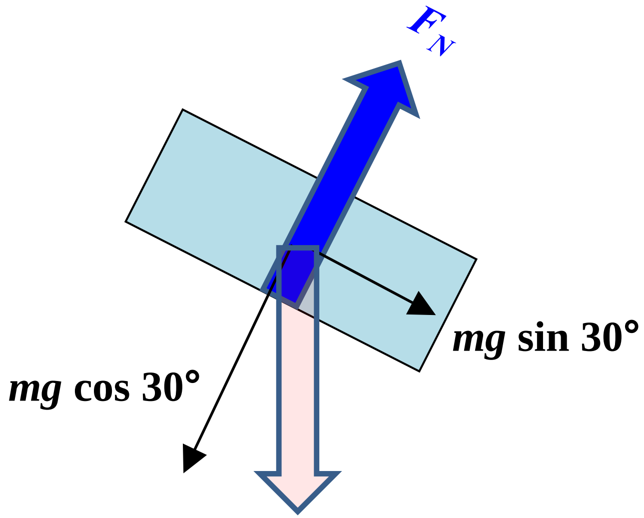
Applying the Second Law

$$F_{net} = F_N - mg\cos 30°$$

$$\Rightarrow F_N - mg\cos 30° = 0$$

$$\Rightarrow F_N = mg\cos 30°$$

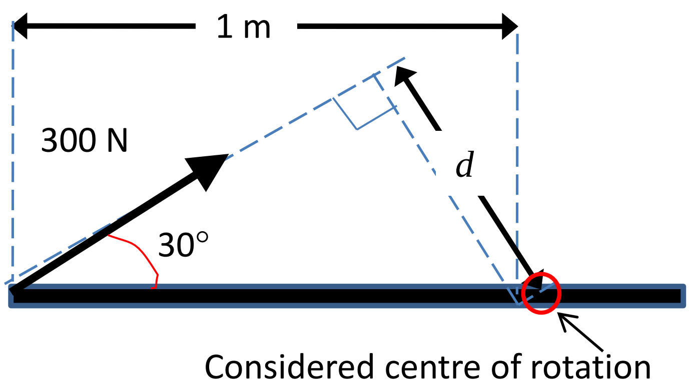
The normal reaction (F_N) of the slope on the block is equal to $mg\cos 30°$.



Moment of a force

- The moment of a force about a point is the product of **force** and **perpendicular distance** from that reference point.
- **Moment = Force X perpendicular distance**
- The reference point can be **freely chosen**.

<u>Method 1</u>

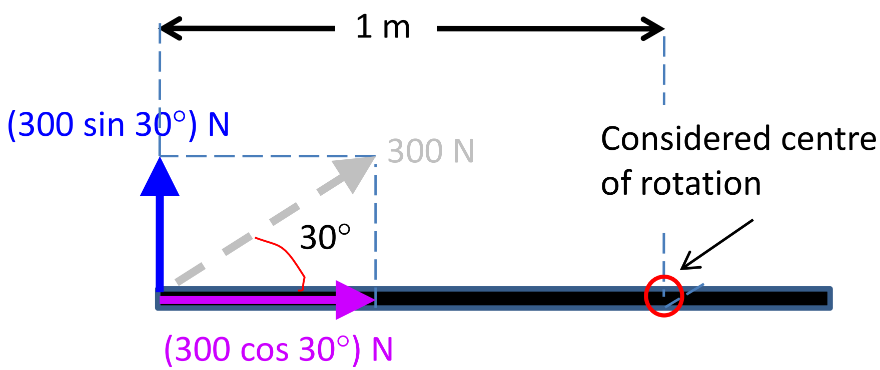


Perpendicular distance d = 1 m × sin 30°

Moment = 300 N × d

= 300 sin 30° N·m, clockwise

<u>Method 2</u>



300 N is first resolved into two perpendicular components.

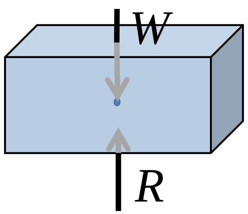
Only (300 sin 30°) N generates moment.

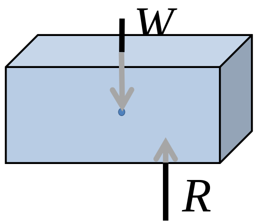
Moment = (300 N × sin 30°) × 1 m

= 300 sin 30° N·m, clockwise

Condition for static equilibrium

- If an object is in **static equilibrium**, it will fulfil both translational equilibrium (net force = 0) and rotational equilibrium (net moment = 0)



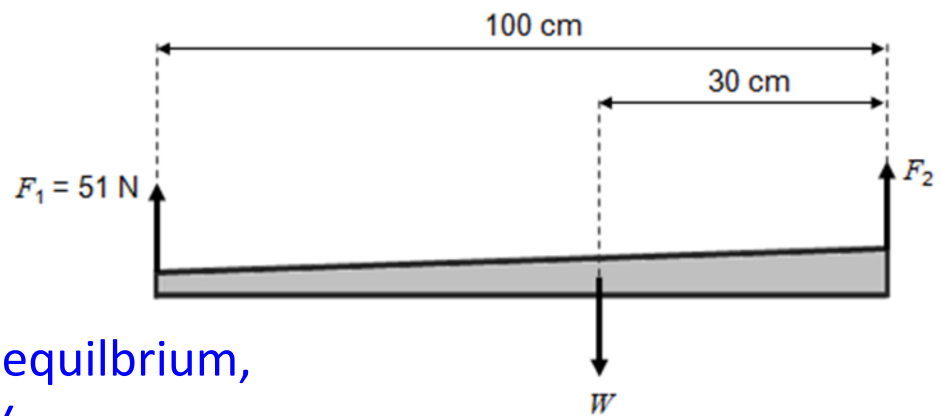


- Object is in **static equilibrium** as (net force = 0) and (net moment = 0)
- Object is NOT in **static equilibrium** as (net force = 0) but there is a turning effect due to misalignment of forces.

Static equilibrium concept in action

A non-uniform wooden plank of length 100 cm is hung using two strings attached to both ends. The figure below shows the free-body diagram of the plank, in which F_1 and F_2 is the tension in the string at each end respectively and W is the weight of the plank. The magnitude of F_1 is 51 N and W could be considered to be acting at a point which is 30 cm away from the thicker end of the plank. The plank is in **static equilibrium**.

- Determine the magnitude of F_2.
- Determine the magnitude of W.



a) Using the concept of rotational equilbrium,

Taking moments about *W*,

Sum of clockwise moments = Sum of anticlockwise moments

$F_1(0.7) = F_2(0.3) \rightarrow F_2 = 119\text{N}$

b) Using the concept of rotational equilbrium,

Taking moments about *F2*,

Sum of clockwise moments = Sum of anticlockwise moments

$51(1) = W(0.3) \rightarrow W = 170\text{N}$

P05 Key Concept Recap

Formulas relating energy, power and time

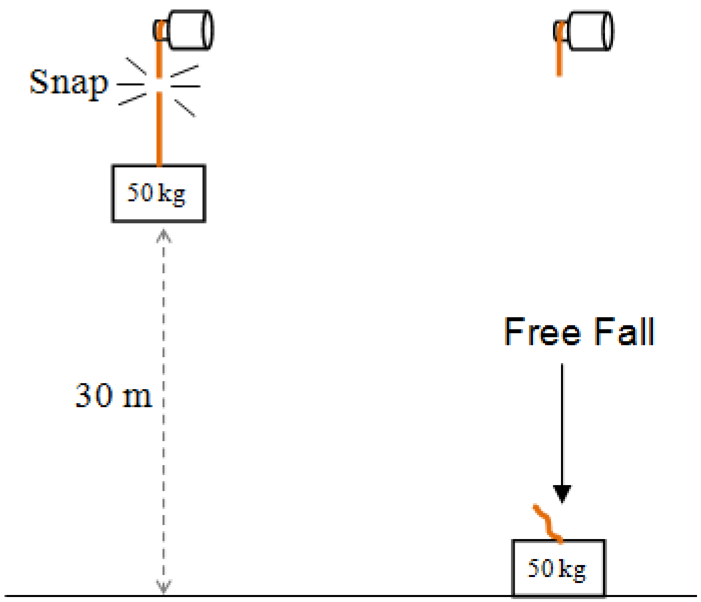
Work done = Force $\times$ distance travelled in direction of force

$$\text{Power} = \frac{\text{Work done (Energy)}}{\text{Time (s)}} = Force \times Speed$$

Energy = Power $\times$ Time

Energy Conservation

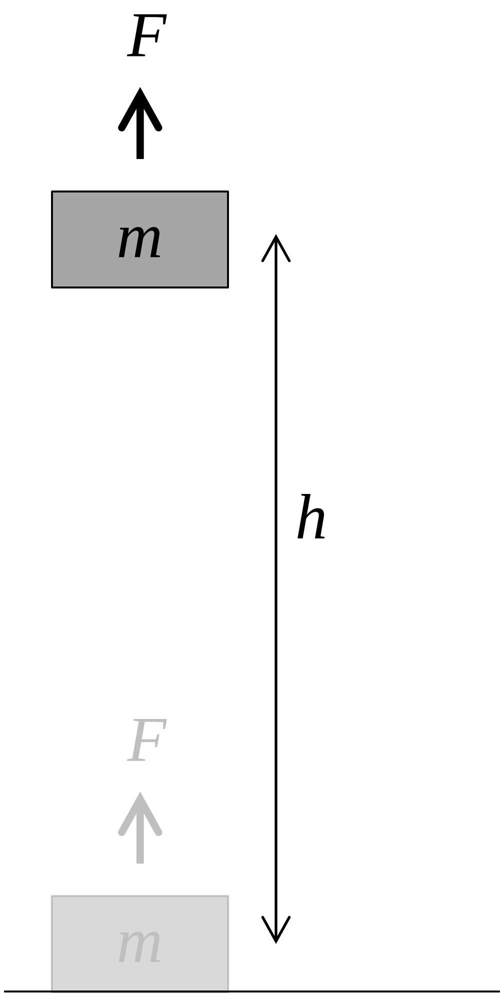
- Energy can be converted from one form to another.



When the object is 30 m above the ground, its GPE is $50 \times 10 \times 30 = 15000$ J with respect to the ground.

When the cable snapped and the object undergoes free fall, the entire GPE of 15000 J is converted into KE the moment the object hits the ground, assuming no loss of energy in the form of heat, sound etc.

What is Gravitational Potential Energy?

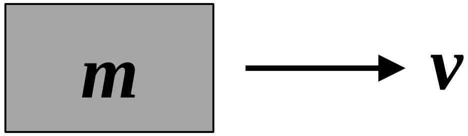


- The work done by the force in bringing the object up is stored as the gravitational potential energy (GPE) with respect to the ground.

$$\text{GPE} = mgh$$

where m is the mass, g is the gravitational acceleration and h is the vertical height.

What is Kinetic Energy?



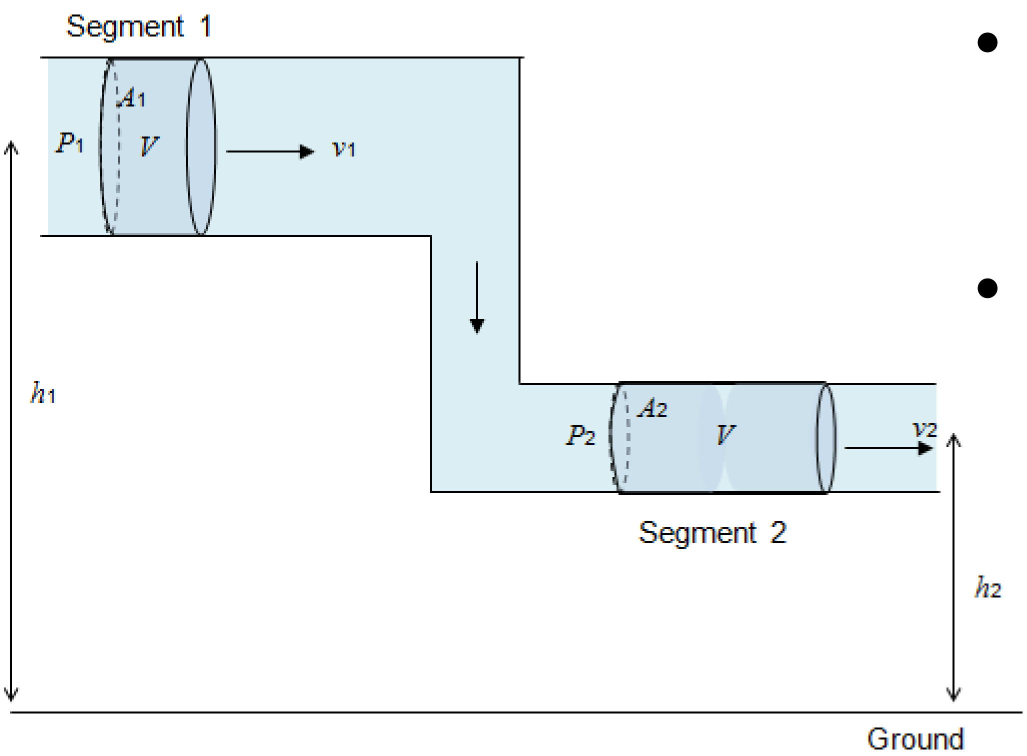
- A moving object possesses kinetic energy (KE).
- The kinetic energy (KE) of an object with mass $\boldsymbol{m}$ travelling with speed v is given as:

$$\mathrm{KE} = \tfrac{1}{2}\, m\, v^2$$

where m is the mass and v is the velocity.

P06 Key Concept Recap

Continuity equation



- Consider the flow of a liquid in two segments of the pipe as depicted.
- In theory, if a liquid flow smoothly without bubbles forming, *the volume of the liquid that passes through any cross-section along the pipe will be the same.*

- Since the volume of the two columns of liquid is the same, we have:

$$A_1 v_1 = A_2 v_2$$

where A is the cross-sectional area and v is the speed.

Bernoulli's principle (Qualitative approach)

- **When the speed of air is high, the air pressure tends to be lower. When the speed of air is low, the air pressure tends to be higher.**

Bernoulli's equation (Quantitative approach)

- $$\tfrac{1}{2}\rho v_1^2 + \rho g h_1 + p_1 = \tfrac{1}{2}\rho v_2^2 + \rho g h_2 + p_2$$

where ρ is the density, v is its speed, g is gravitational acceleration, h is the height of the liquid from the ground and p is the pressure of the liquid.

- If the height difference is negligible, equation can ignore gravitational potential energies and equation reduces to:

$$\tfrac{1}{2}\rho v_1^2 + p_1 = \tfrac{1}{2}\rho v_2^2 + p_2 = \text{constant.}$$

P07 Key Concept Recap

What is the relationship between charge, current and time?

Electric current is the movement of charges in a circuit.

Current is the amount of charge flowing per second:

$$I = \frac{Q}{t}$$

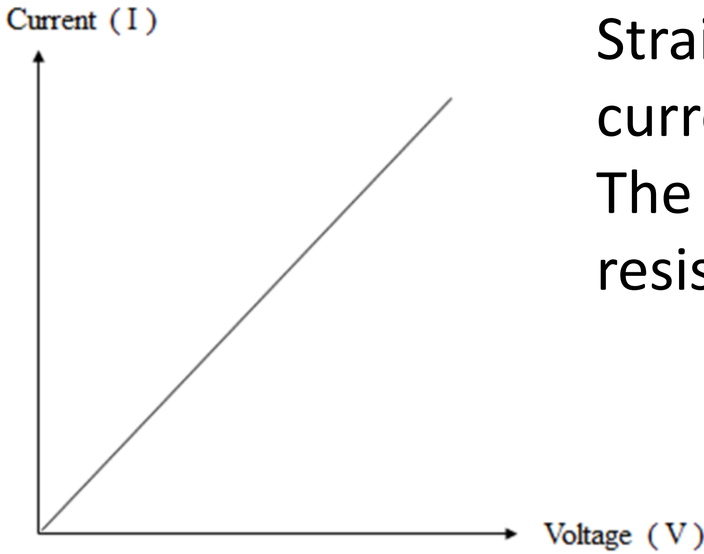
where

Q is charge transferred in Coulomb (C)

I is current in Ampere (A)

t is time in second (s)

What is the relationship between current and voltage in a resistor?



Straight line through the origin tells us that current is directly proportional to voltage. The ratio V/I is constant and is equal to resistance (R) in the circuit.

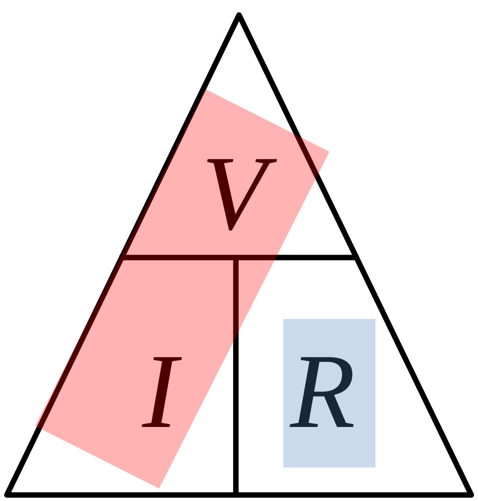
$$V = IR$$ (Ohm's law)

where V is voltage in Volt (V)
I is current in Ampere (A)
R is resistance in Ohm (Ω)

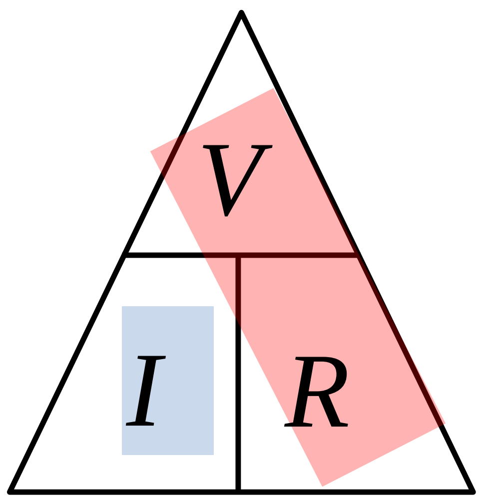
What is the relationship between current and voltage in a resistor?

$$V = IR$$

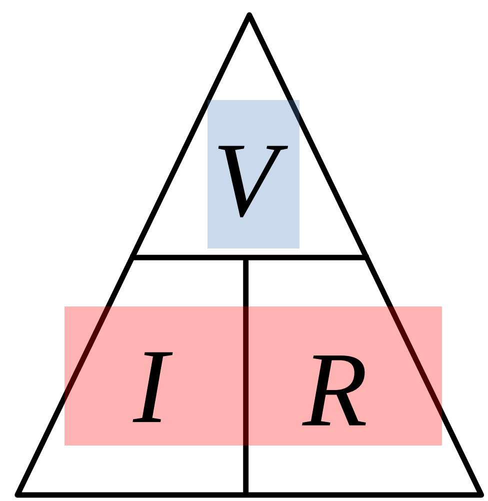
where V is voltage in Volt (V)
I is current in Ampere (A)
R is resistance in Ohm (Ω)



$$\frac{V}{I} = R$$



$$I = \frac{V}{R}$$



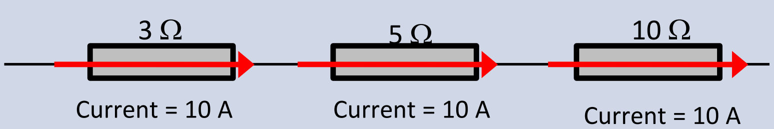
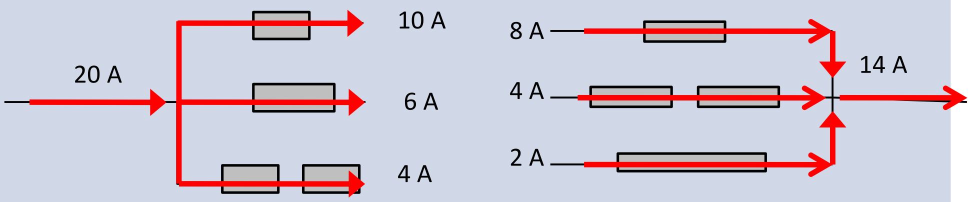
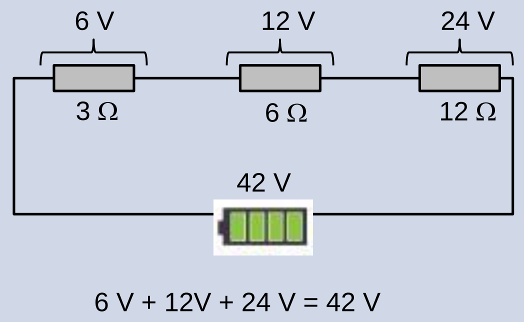
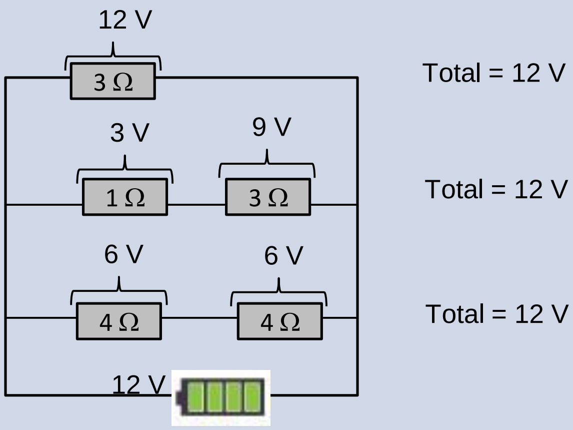
$$V = IR$$

Resistance for Series/Parallel Circuits

Series: $R = R_1 + R_2 + \ldots R_n$

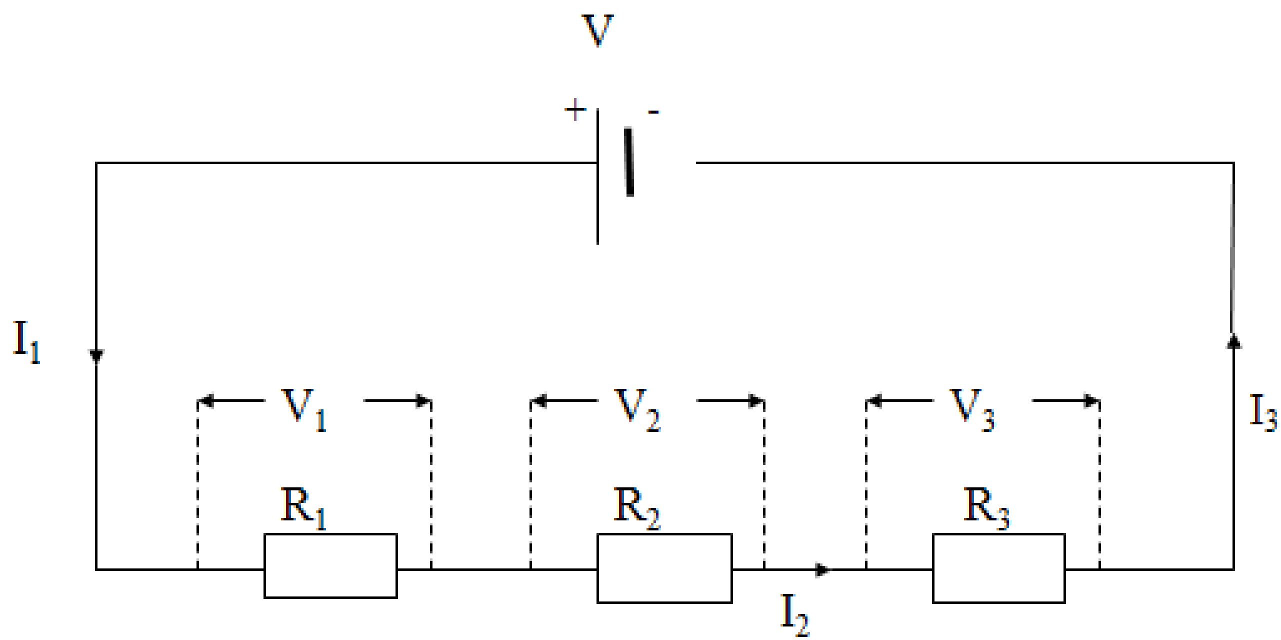
Parallel: $$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}}$$

Summary for Series/Parallel Circuits

For series circuits, the current flowing in the circuit is always constant.	For parallel circuits, currents will split up or add up.
	
The sum of potential difference across the resistors in series circuit equals to the voltage of the battery.	**The sum of potential difference across the parallel circuit is always the same.**
	

What is the relationship of Voltage, Current and Resistance in series circuits?

One electrical path from negative to positive, therefore is a series circuit.



$$V = V_1 + V_2 + V_3$$

$$I_1 = I_2 = I_3$$

$$R_{total} = R_1 + R_2 + R_3$$

where V is voltage in Volt (V)

I is current in Ampere (A)

R is resistance in Ohm (Ω)

What is the relationship of Voltage, Current and Resistance in series circuits?

- The current is the same at all points.
- The voltage is divided between the bulbs.
- When one component fails, the whole circuit fails.
- The more bulbs added, the higher the total resistance. The total current drawn decreases. Each bulb in series will be dimmer in comparison with a single bulb.

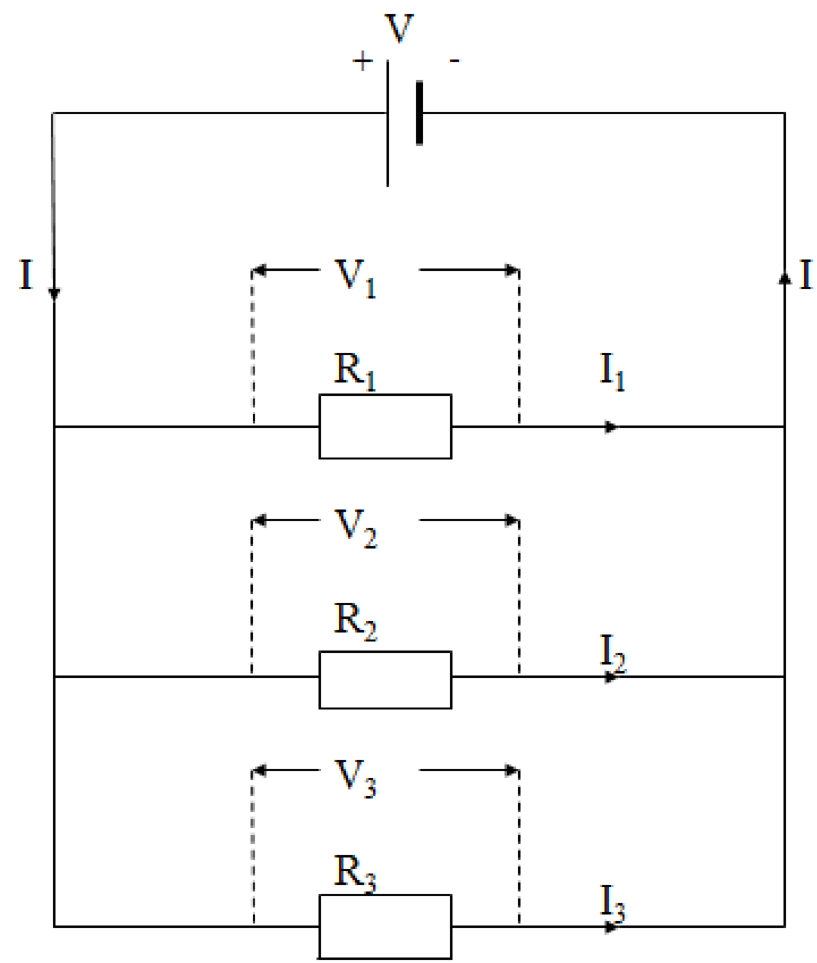
What is the relationship of Voltage, Current and Resistance in parallel circuits?

More than one electrical path – components connected on different branches therefore parallel.

$$V = V_1 = V_2 = V_3$$

$$I = I_1 + I_2 + I_3$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



P08 Key Concept Recap

Electric field and electric force

- A positive charge placed in an electric field will experience electric force in the direction of the electric field. (Figure 1)
- A negative charge placed in an electric field will experience electric force opposite to the direction of the electric field. (Figure 2)

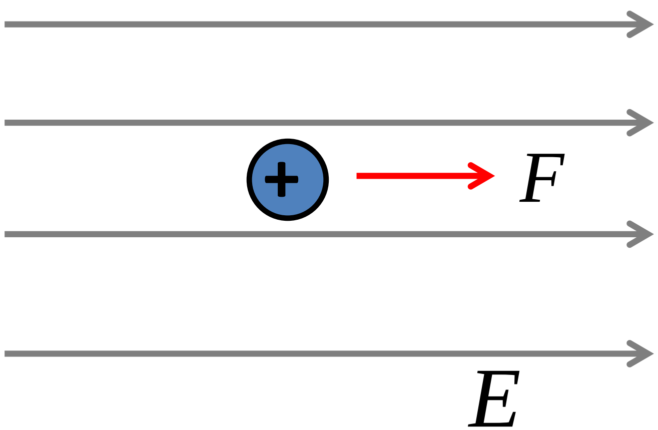


Figure 1

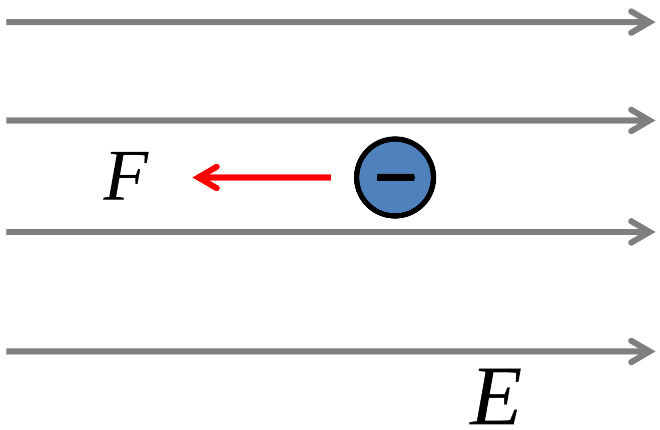
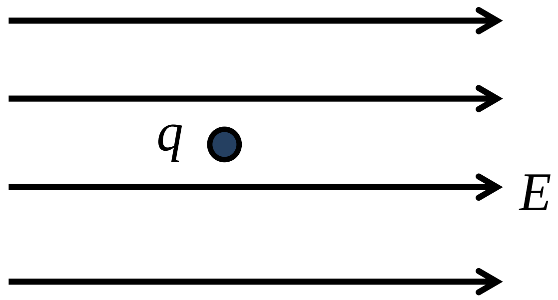


Figure 2

Electric field and electric force

- If a charge, q is brought in to a location with electric field, E, the charge experiences a force, F due to the electric field.



- The magnitude of the force is given by the following equation:

$$F = qE$$

where F *is electric force (in N)*, q is the charge (in C) and E is the electric field (in N/C).

The magnitude of the *electric field, in free space, due to a point charge q at a distance r*

$$E = \frac{q}{4\pi\varepsilon_0 r^2}$$

where the permittivity in free space, $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 / N.m^2$ and E is the electric field, q is the point charge, r is the distance

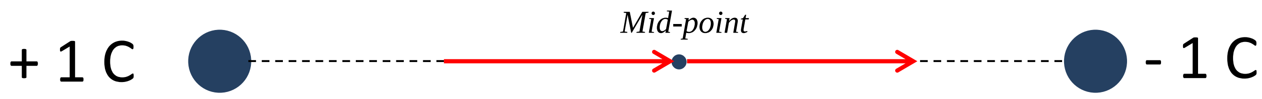
The magnitude of the *electric field, E, in a uniform electric field is constant.*

Net electric field strength direction at any point

Step 1:
Find out whether the electric field lines radiates inwards (for negative charges) or radiate outwards (for positive charges) for each of the charge in the question

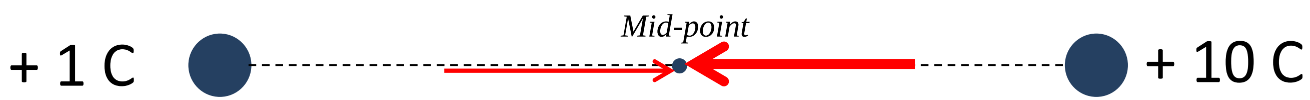
Step 2:
At the point of consideration eg. mid point, find out the net electric field direction

Net electric field strength direction at any point



<u>Opposite charges eg. +1C and -1C</u>

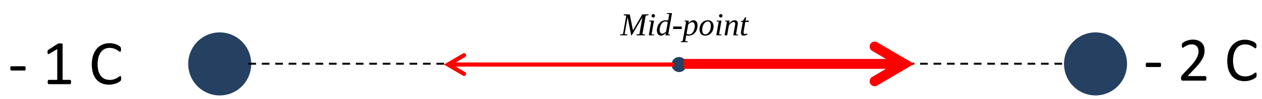
- We should expect field lines pointing away from the +1C charge and field lines pointing towards the -1C charge. In this case, at the mid-point location, they will both be facing the same direction.



<u>Both are positive charges</u>

- Positive charges have an electric field that points outward in all directions from the charge and the net electric field would point to the left away from the larger positive charge.

Net electric field strength direction at the mid-point of 2 point charges



Both are negative charges eg. -1C and -2C

- Negative charges have electric fields that point inward towards the charge from all directions.

- Because both charges are negative, we should expect one electric field line to point left towards the -1C charge, and the other to point right towards the -2C charge. The electric field inwards to 2C is larger as the strength is stronger. Net direction is towards the bigger charge, in this case to the right.

Magnetic Poles

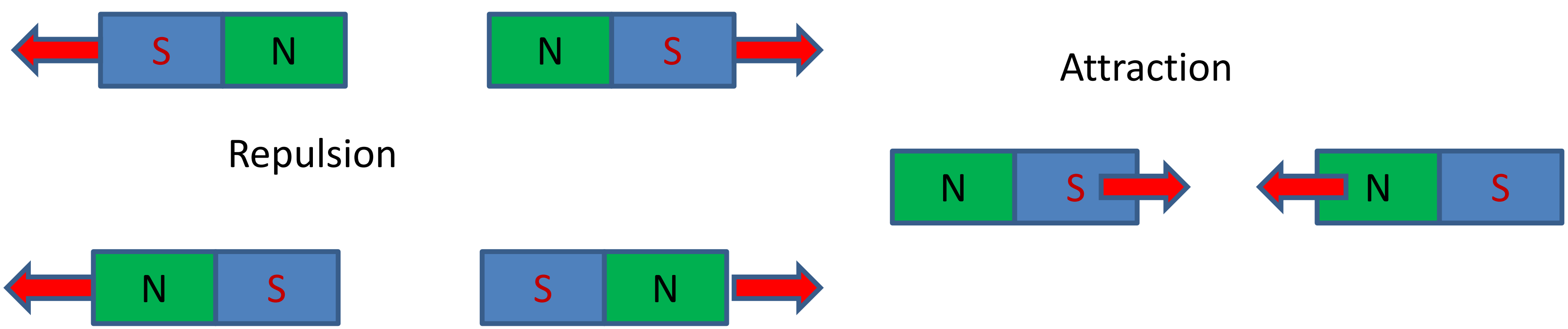
- There are two magnetic poles:

  (1) North pole (usually denoted as "N")

  (2) South pole (usually denoted as "S")

- Behaviour of magnetic poles:

  Like poles repel; and unlike poles attract



Electromagnetic Force

- In general, the magnetic force experienced by a moving charge in a magnetic field is given by:

$$F = Bqv$$

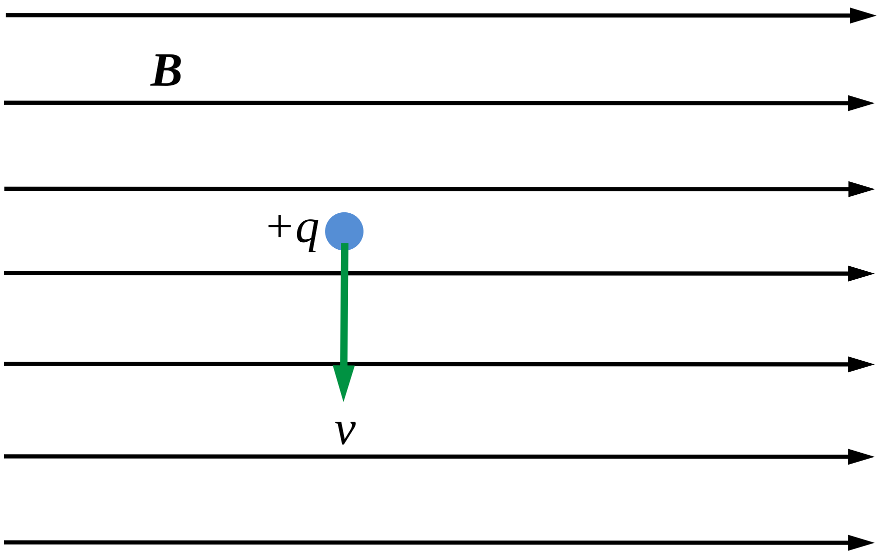
The force on the charge is directed towards the observer by the Fleming's left hand rule.

F = magnitude of the magnetic force

B = the magnitude of the magnetic field strength

q = magnitude of the charge

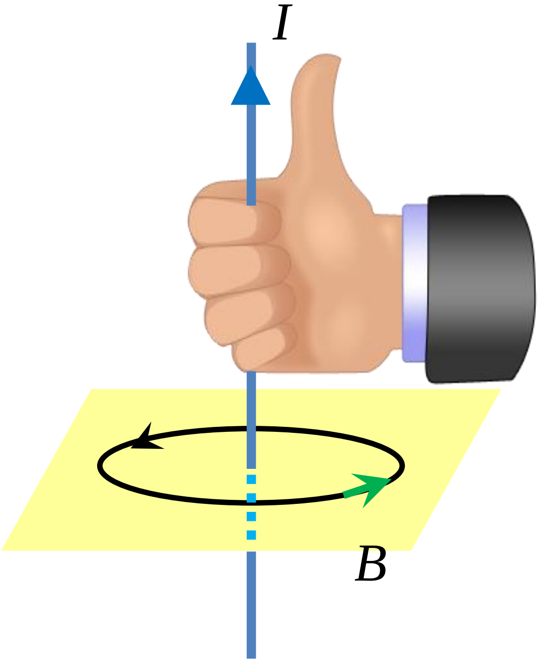
v = speed of the charge



P09 Key Concept Recap

Magnetic Effect of Current

- The direction of the magnetic field follows the "right-hand grip" rule.
- The right thumb is in the *same direction* as the flow of current, and the direction in which the other four fingers curl is the direction of the magnetic field.
- Take note that the direction of current is taken to be from the positive to the negative end of the battery (i.e. it is opposite to the direction of electron flow).



Magnetic Effect of Current

- For an **infinitely long straight** conductor (such as a very long wire) in free space, the magnetic field strength contributed by a current I in the wire at a distance r __perpendicular__ to the conductor is given by the magnetic flux density

$$B = \frac{\mu_o I}{2\pi r}$$

B = the magnitude of the magnetic field strength

I = current

r = distance

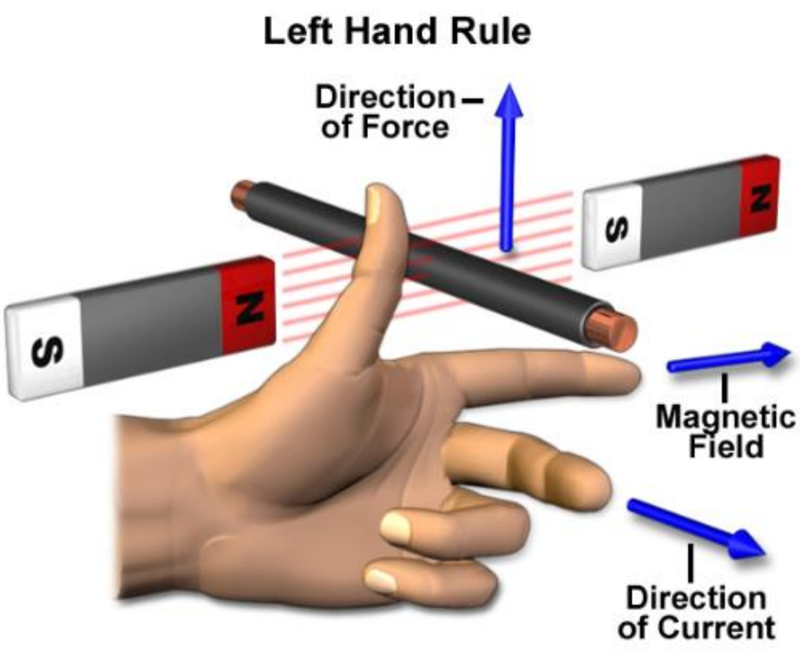
μ_o is permeability of free space

$= 4\pi \times 10^{-7}$ T.m/A

- The SI unit of magnetic flux density, B, is __Tesla (T)__.

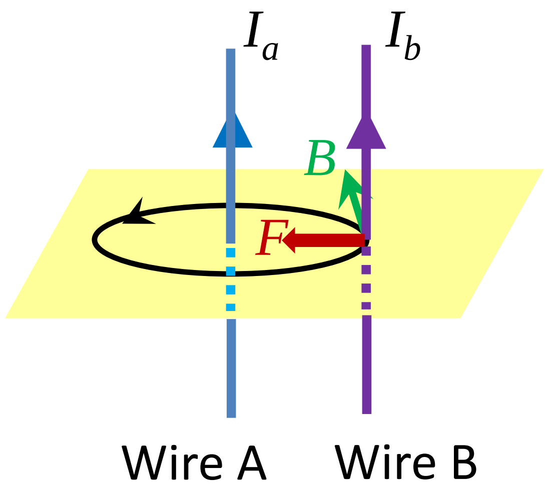
Current-carrying wire in a magnetic field

The direction of the force experienced by a current-carrying conductor in a magnetic field can also be determined by Fleming's "left-hand" rule just like the case of moving charges in magnetic field.



Forces between two parallel wires

To find out magnitude of magnetic force F,



At Wire B, $F_b = B_a I_b L_b$ where $B_a = \dfrac{\mu_o I_a}{2\pi r}$

At Wire A, $F_a = B_b I_a L_a$ where $B_b = \dfrac{\mu_o I_b}{2\pi r}$

where B = the magnitude of magnetic field strength, *I* = current

r = distance, *L* = length of wire and μ_o is permeability of free space = 4π × 10^{-7} T.m/A

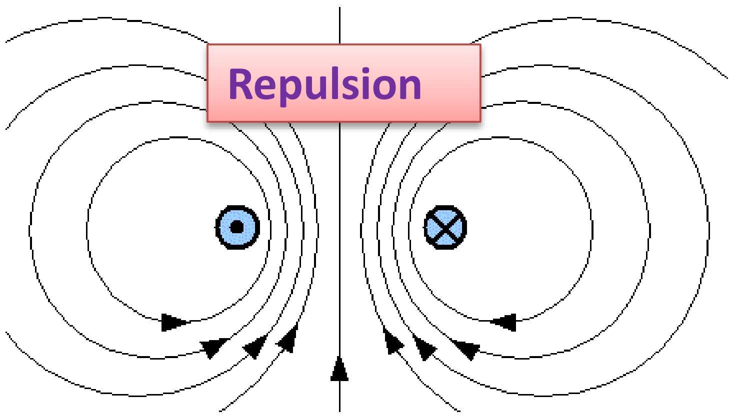
To find out direction of magnetic force,

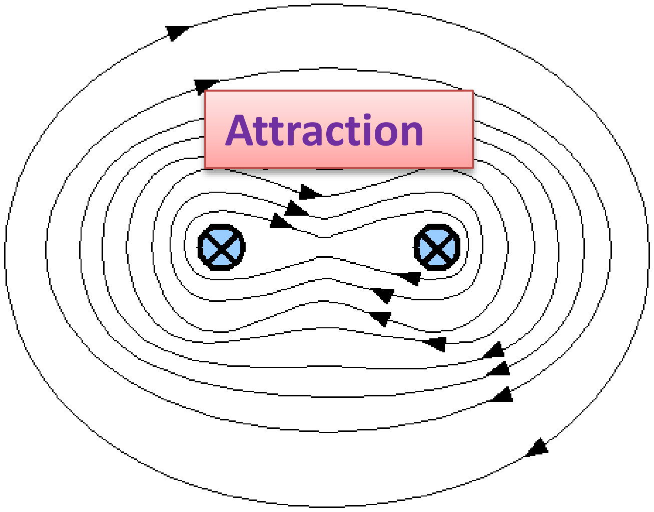
At Wire A, direction of magnetic flux density *B* generated by wire B at Wire A is out of the page using *right hand grip rule*. → Using *left hand rule*, the magnetic force is hence to the right towards wire B.

At Wire B, direction of magnetic flux density *B* generated by wire A at Wire B is into the page using *right hand grip rule*. → Using *left hand rule*, the magnetic force is hence to the left towards wire A.

Forces between two parallel wires

- When two parallel current-carrying wires are placed closed together, their magnetic fields interacts, resulting to the different effects depending on the directions of the currents in them.
- The resultant magnetic flux density at any point around the wires is the vector sum of the magnetic flux density due to each wire there.

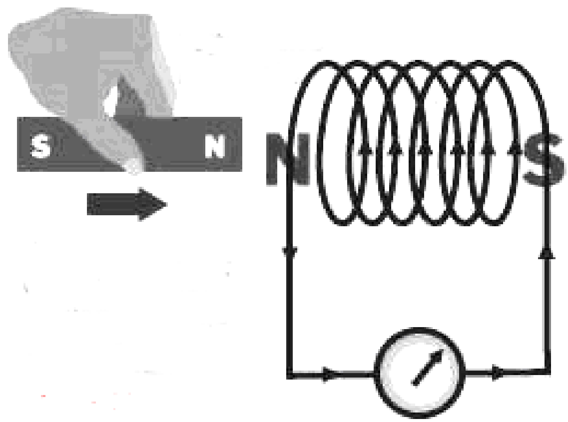




⊙ represents a wire carrying current out of the plane of the paper

⊗ represents a wire carrying current into the plane of the paper

Lenz's Law

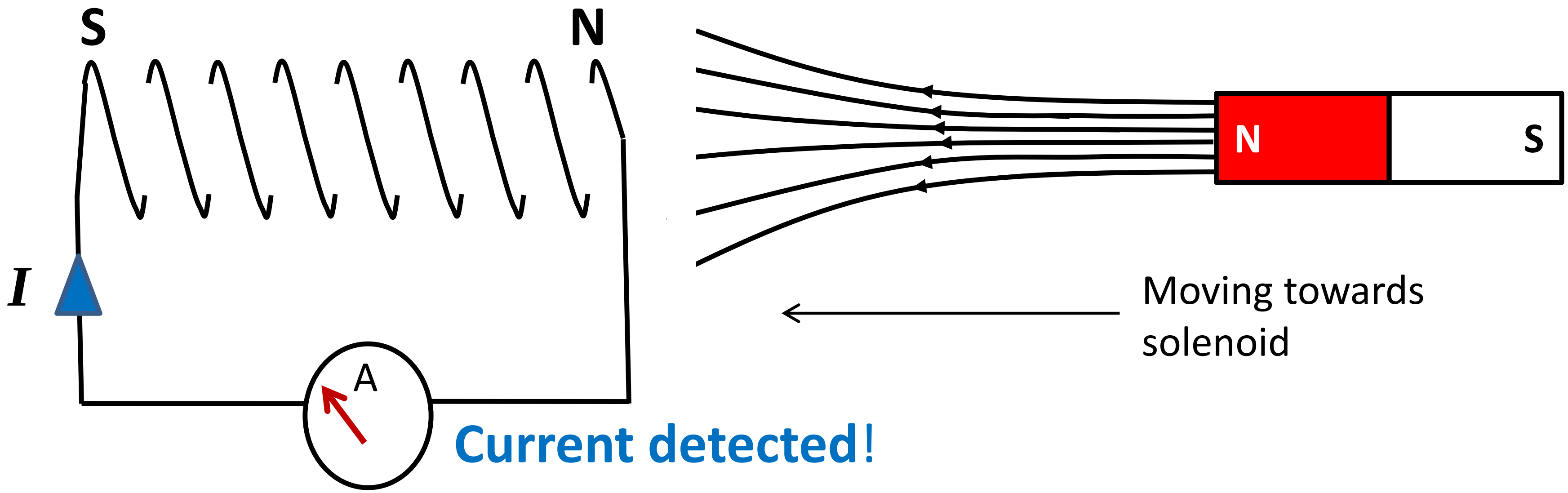


- When a magnet is being brought near to a material, the material will experience a change in magnetic field. According to Lenz's law, _electric currents_ will be generated within the material that will _oppose change_ in magnetic field.

- The bigger the rate of change in magnetic flux, the "_"harder"_" the system will try to oppose this change.

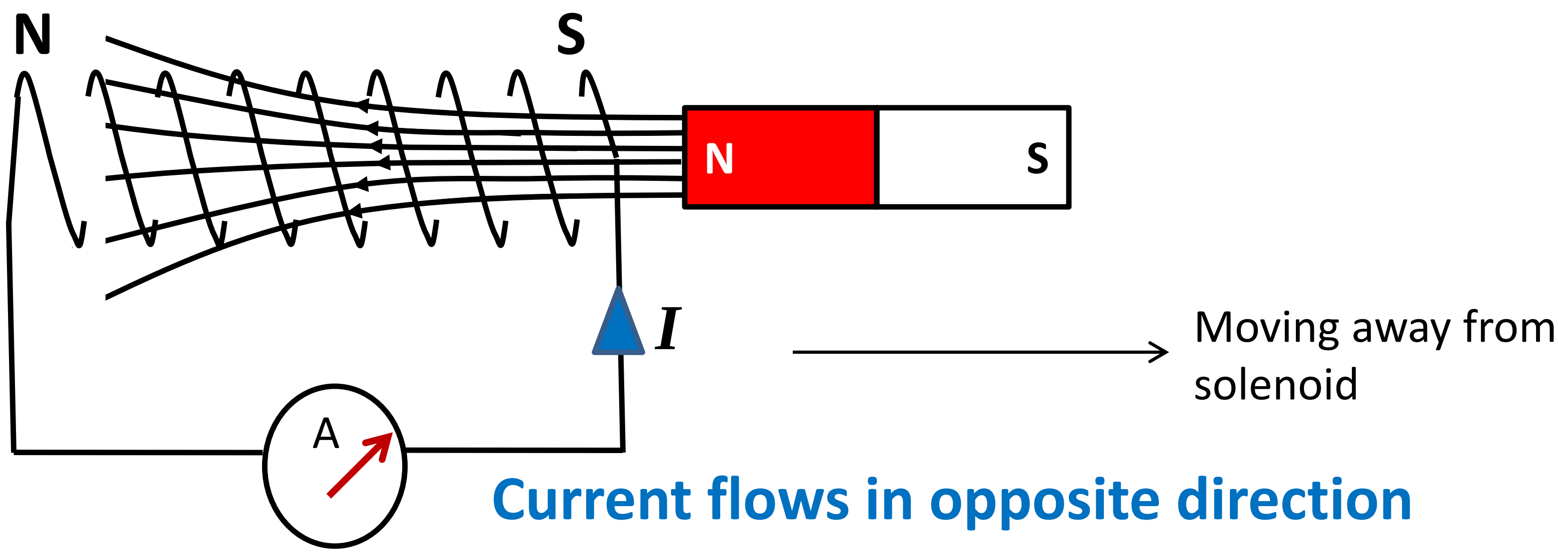
- The system can oppose this change by inducing a _voltage_ and _current_ in itself (for conductor).

Example of Lenz's Law in Action



- When the magnet is stationary, there is __no change__ in magnetic flux through the coil and no voltage and current is induced in the wire.
- When the magnet is brought towards the coil, the magnetic flux passes through the coil __increases__ and a voltage and current is induced.
- The direction of current is such that it induces a magnetic north pole (**N**) on the right side of the coil so as to __oppose__ the motion of magnet coming towards it.

Example of Lenz's Law in Action

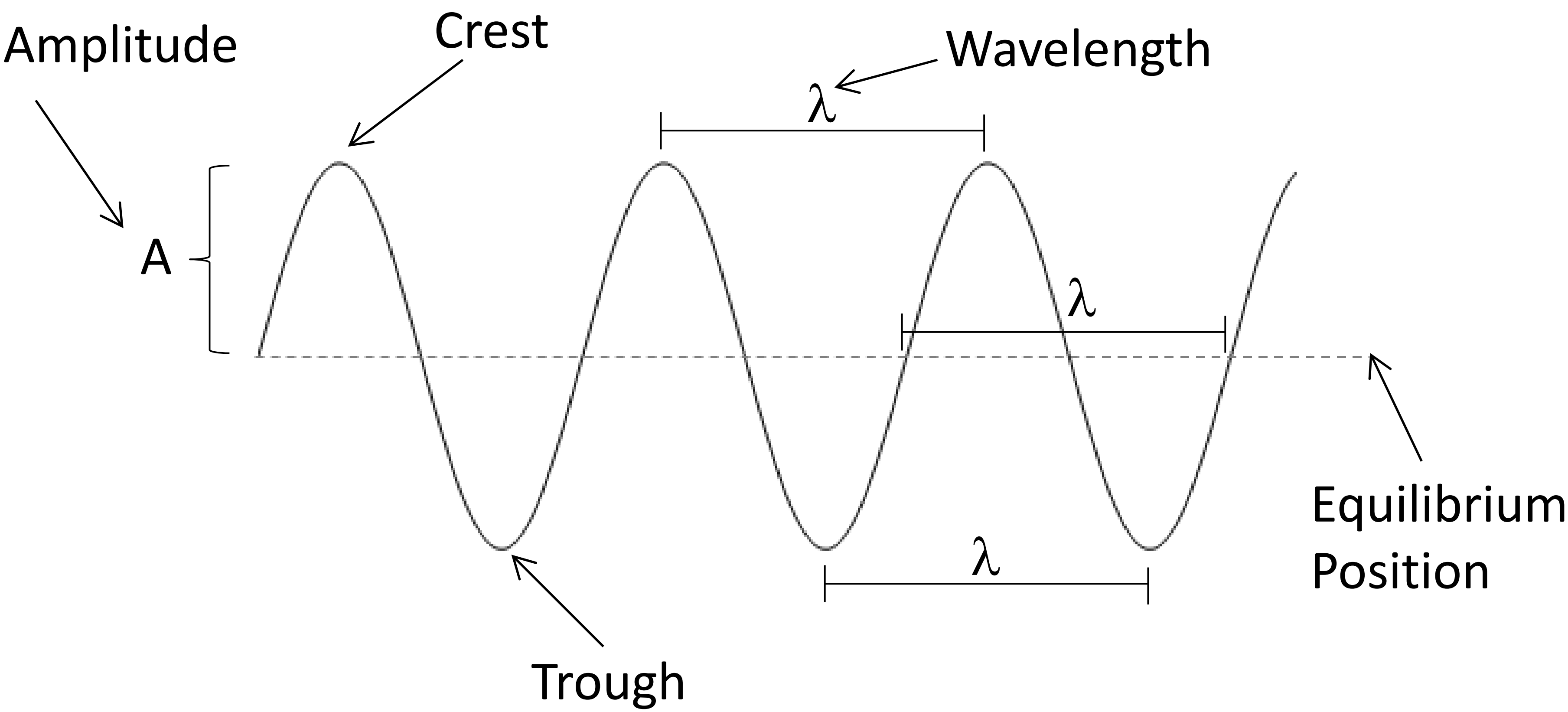


Current flows in opposite direction

- Conversely, when the magnet is __moved away__ from the coil, the magnetic flux passing through the coil is __reduced____.
- This in turn will induce a voltage and current in such a direction that the right side of the coil becomes magnetically __south (S)__ so as to try to __"attract"__ back the magnet that is moving away.

P10 Key Concept Recap

The basic properties of wave are as shown:



Formulae

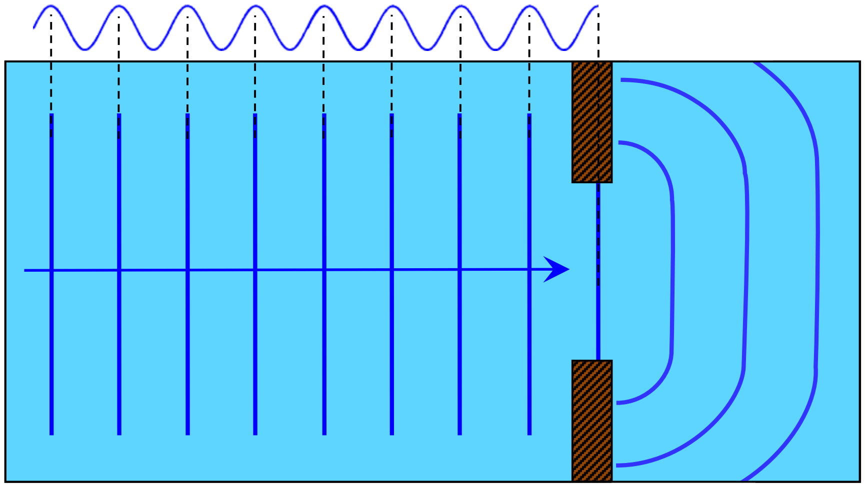
$$f = \frac{1}{T}$$

- The frequency, f, of a wave is the number of oscillation of in one second. The unit for frequency is Hertz (Hz).
- The period, T, of a wave is the time taken for one complete oscillation. The unit for period is second (s).

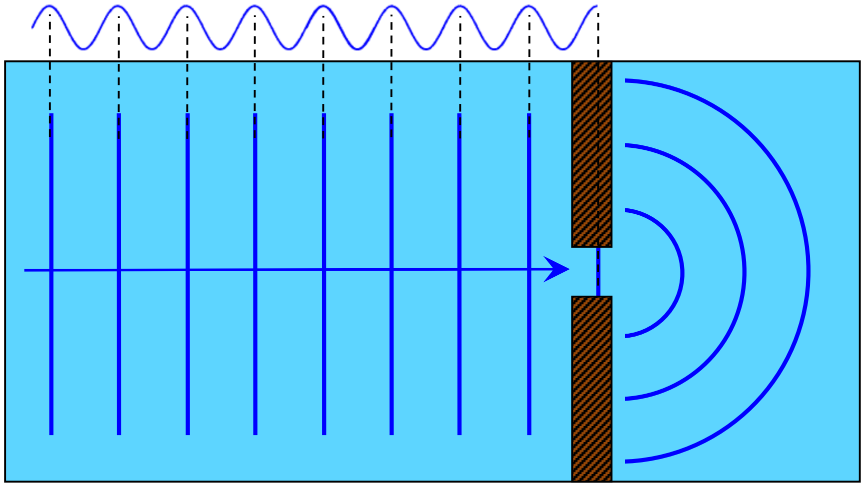
$$v = f\lambda$$

v – speed of wave (in m/s)
f – frequency of wave (in Hz)
λ - wavelength of wave (in m)

What is Diffraction?



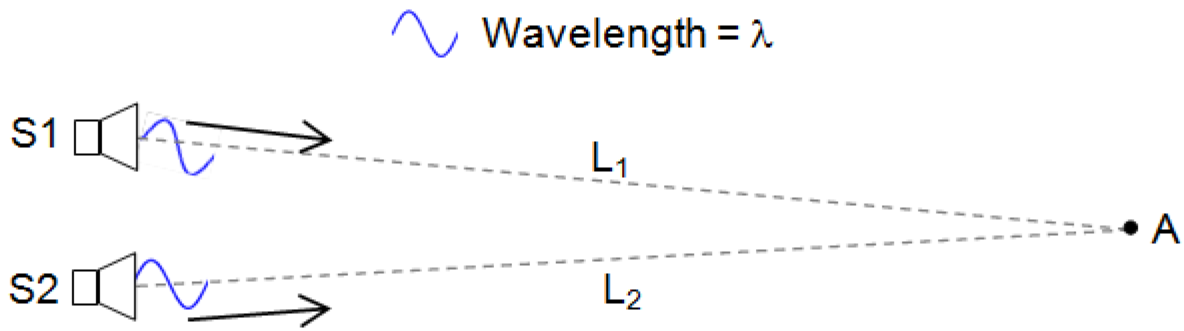
Waves passing through a small opening



Waves passing through a smaller opening

- Waves spread out when they pass through a small opening.
- The waves will spread out more when the opening becomes smaller.

How to distinguish between constructive interference and destructive interference using the concept of path difference?



When two waves which are in phase emerging from two different sources heading to the same point A, the path difference is given by
$|L_1 - L_2|$.

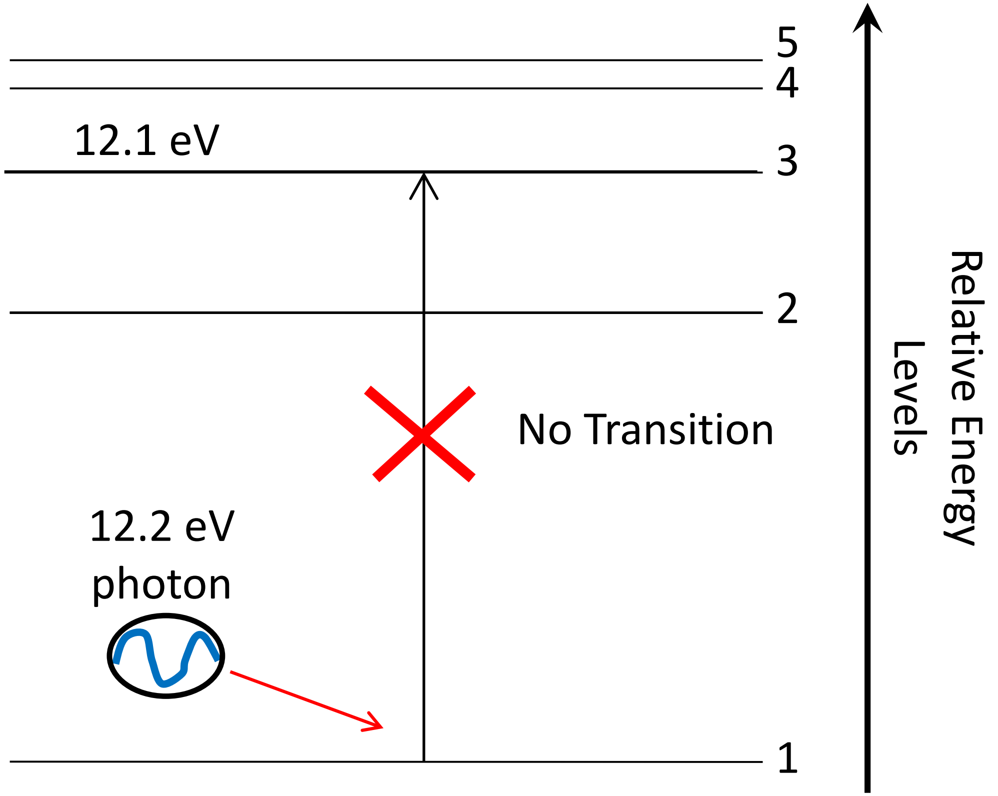
- **Total constructive interference** will take place at point A if
  path difference / $\lambda = n$ (where n is an integer)
- **Total destructive interference** will take place at point A if
  path difference / $\lambda = n + ½$ (where n is an integer)

Note: Total constructive/destructive interference will reverse if the initial two waves emerging from two different sources are 180 ° out of phase.

P11 Key Concept Recap

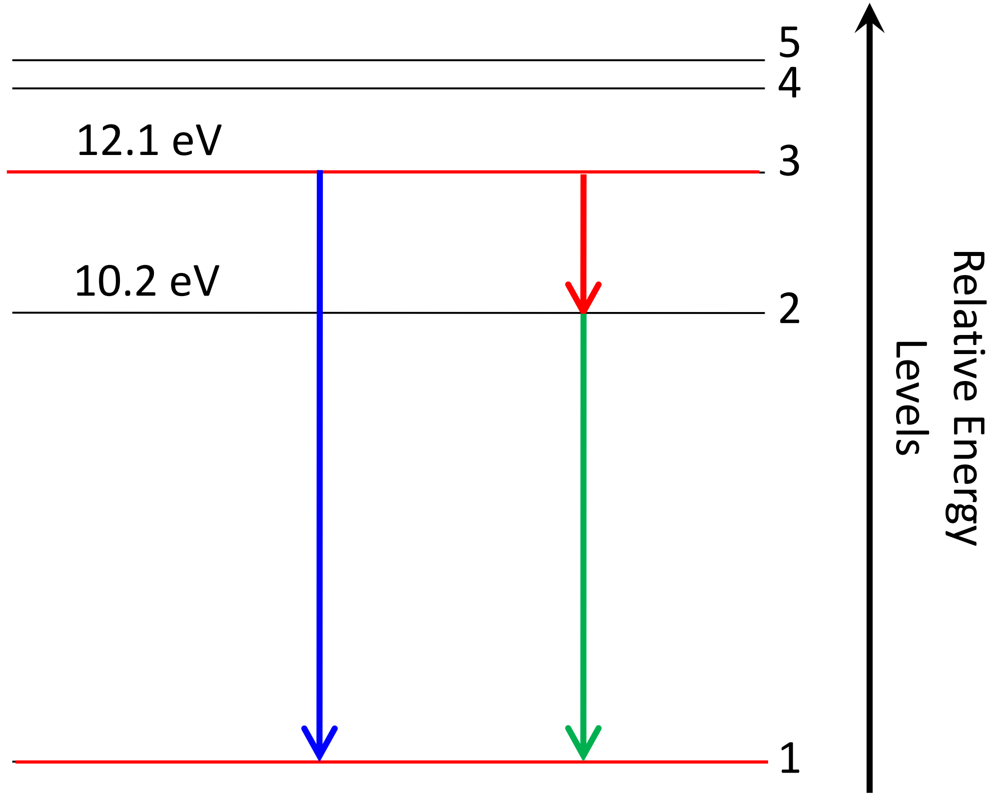
How electrons behave when photons of specific energy are absorbed/emitted?

- In order for an electron to jump from one level to another, the energy of the photon supplied must be **EXACTLY** equal to the energy gap between the two levels.
- e.g. the electron will **NOT** jump from level 1 to 3 as 12.2 eV is more than 12.1 eV



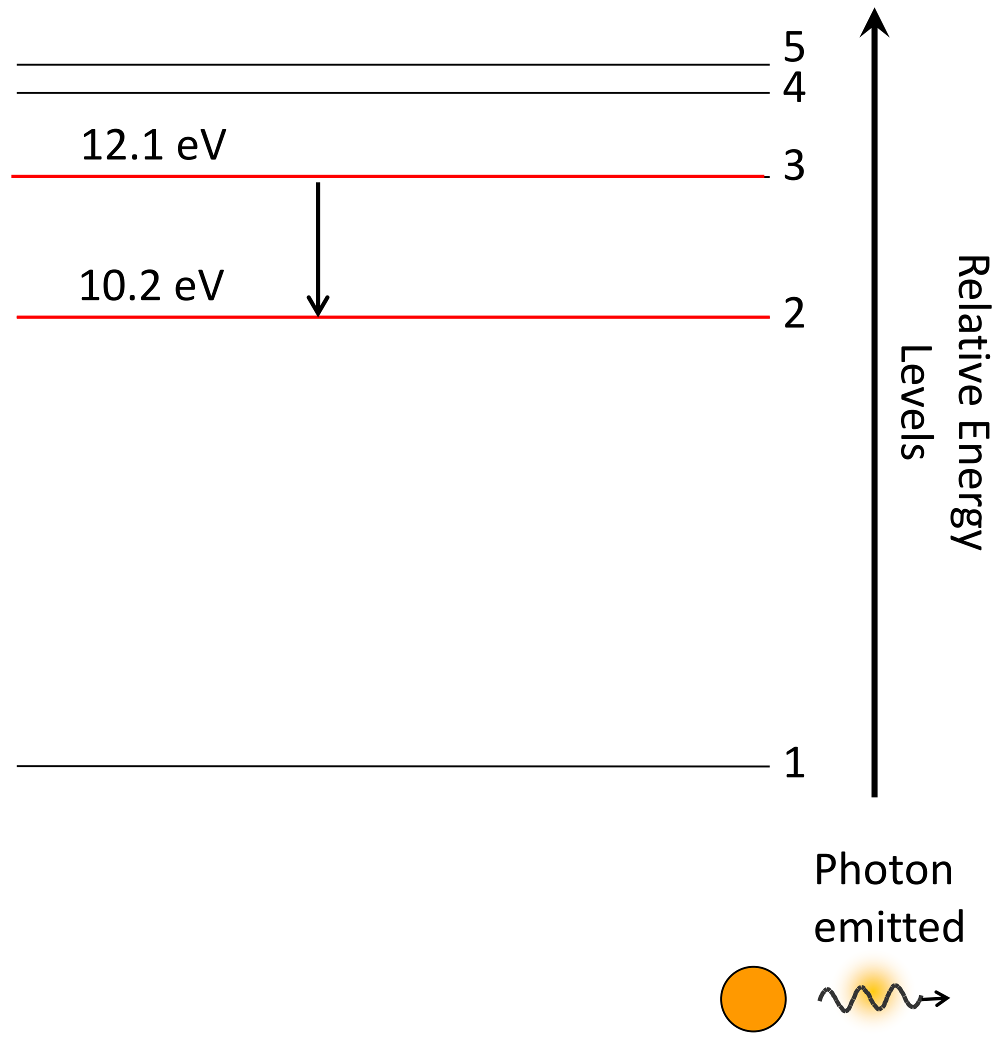
How electrons behave when photons of specific energy are absorbed/emitted?

- When returning to a lower energy level, there are different possible pathways.
- For example, when an electron returns from Energy Level 3 to Energy Level 1, the possible pathways are :
  - 3 → 1
  - 3 → 2 → 1



How electrons behave when photons of specific energy are absorbed/emitted?

- Whenever an electron jumps from a higher energy level to a lower energy level, it loses quantized energy (photon) with an amount equal to the difference in the energy levels.
- Eg. An electron which jumps from Energy Level 3 to Energy Level 2, will emit an energy packet containing (12.1 – 10.2) = 1.9 eV of energy released as light photon.



Formulae

$$E = hf$$

where
E is the energy of photon and f is the frequency of wave,

Planck's constant (*h*) = 6.63 × 10^{-34} Joule seconds (J·s)
OR
Planck's constant (*h*) = 4.14 × 10^{-15} electron Volt seconds (eV·s)

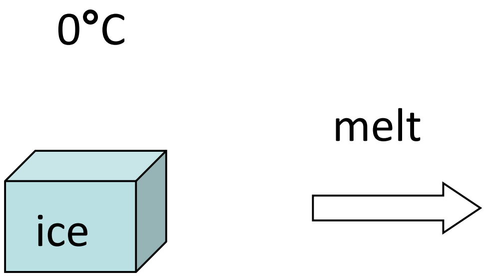
$$v = f\lambda$$

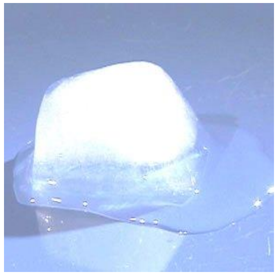
v – speed of wave (in m/s)
f – frequency of wave (in Hz)
λ - wavelength of wave (in m)

Note: Inverse relationship between frequency and wavelength

P12 Key Concept Recap

What is specific latent heat of fusion?




Ice melting at 0^oC

- The specific latent heat of fusion of a material which is denoted by ***L*** is the amount of energy per kg (unit mass) required to change from one state to another state without any change in temperature.

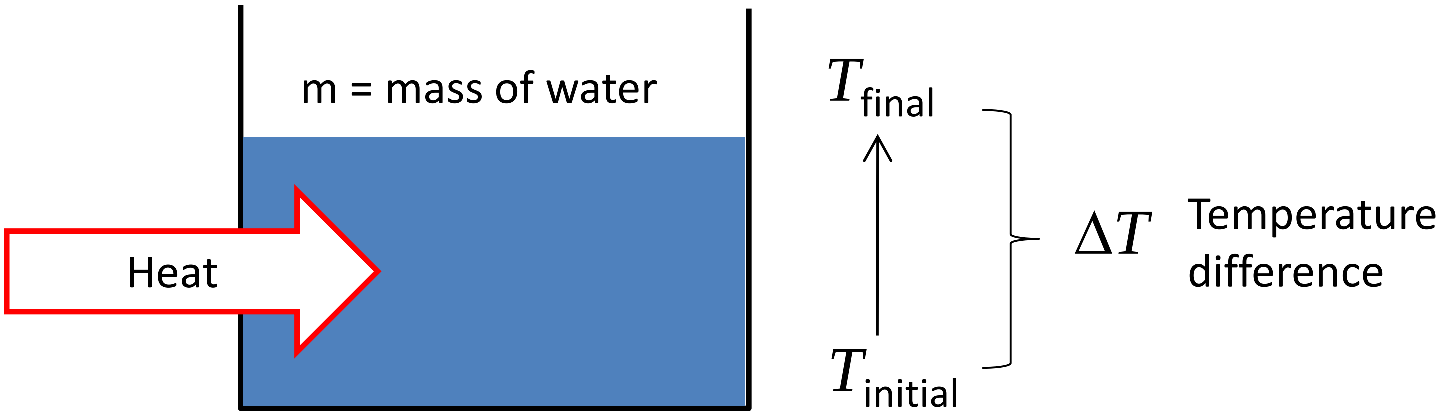
$$\Delta Q = mL$$

where Q is heat change (in Joules), mass is in kg and L is specific latent heat of fusion (J/kg)

- Different materials have different values of Specific latent heat of fusion

What is specific heat capacity?

- The **Specific Heat Capacity** (c) is defined as the amount of heat required to raise 1 kg of a substance by 1 °C. Its unit is given as J/kg·ºC or J/kg.K.
- Different materials have different values of Specific Heat Capacity.

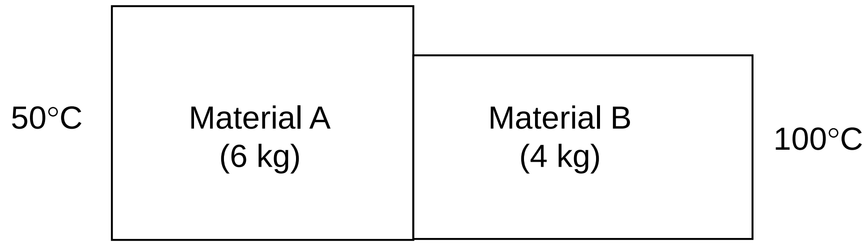


Heat absorbed = $\Delta Q = mc\Delta T$

Where ΔQ (J) is heat gained, m (kg) is mass, c (J/kg·ºC) is specific heat capacity, ΔT(ºC) is the change in temperature

(Hint: For ΔT, always take the higher temp minus lower temp)

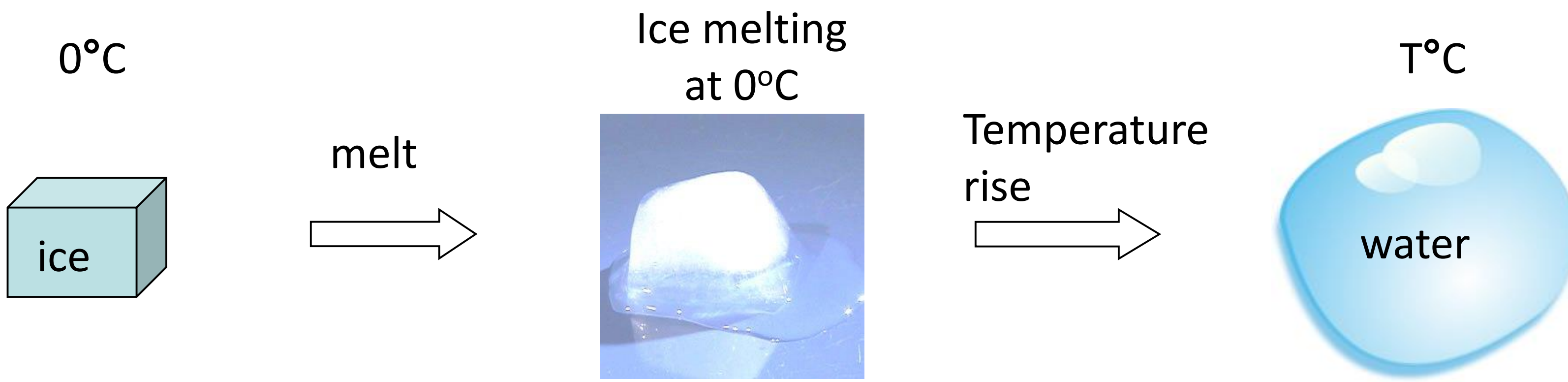
Example of heat gain and heat loss



Total heat gained = Total heat lost

Heat gained to raise temperature of Material A from 50ºC to TºC = Heat lost to decrease temperature of Material B from 100 ºC to TºC

Example of heat gain and heat loss



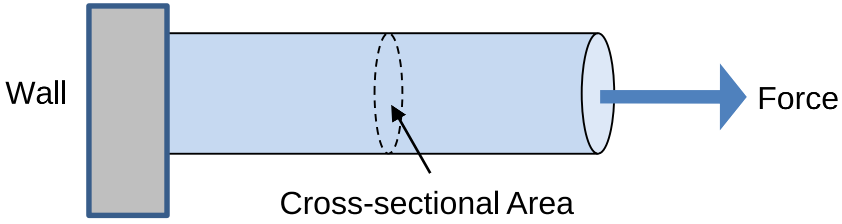
Total heat gained = Total heat lost

Heat gained to melt ice + Heat gained to raise melted ice temperature from 0ºC to TºC	=	Heat lost to decrease water temperature from 90 ºC to TºC

P13 Key Concept Recap

Measuring the action of deformation

- Any action that deforms an object is commonly defined in terms of **stress**.



$$\text{Stress} = \text{Force acting per unit cross sectional area}$$

$$\text{i.e.}\quad \text{Stress (Pa or N/m}^2) = \frac{F\,(\text{in N})}{A(\text{in m}^2)}$$

F = applied force

A = cross-sectional area normal (perpendicular) to the applied force

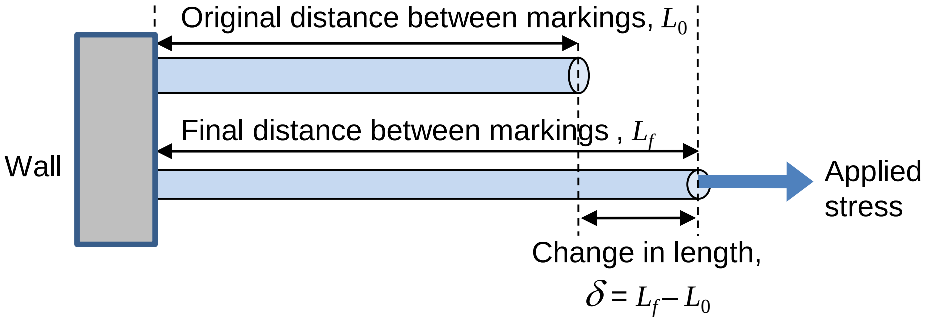
Units of stress: (Pa or N/m^2)

- Stress on a object can be *positive or negative* depending on the sign convention which one sets for *tension or compression*.

A possible way to measure deformation

- For lengthwise deformation caused by tension and compression, we can measure it in terms of **strain**.

$$\text{Strain} = \frac{\text{change in length}}{\text{original length}} = \frac{Lf - L_o}{L_o} = \frac{\delta}{L_o}$$



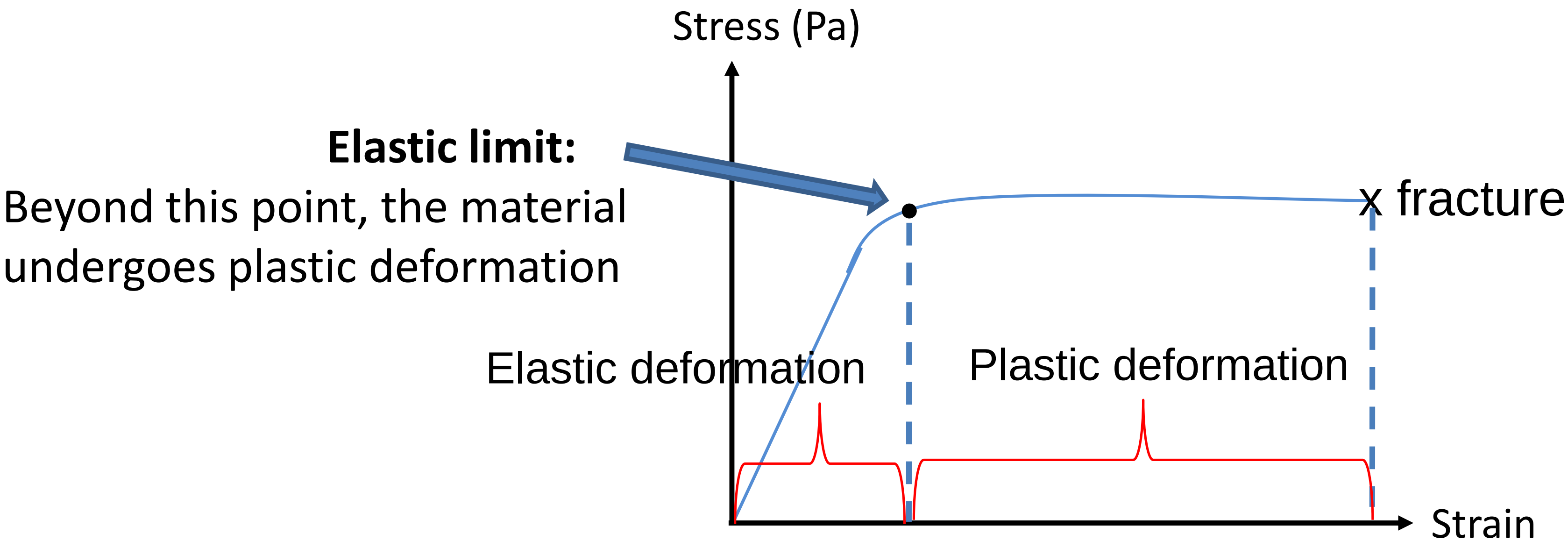
L_0 = original length
δ = change in length

Strain does not have a unit

- Strain on a object can be positive or negative depending on whether the object is under tension or compression respectively.

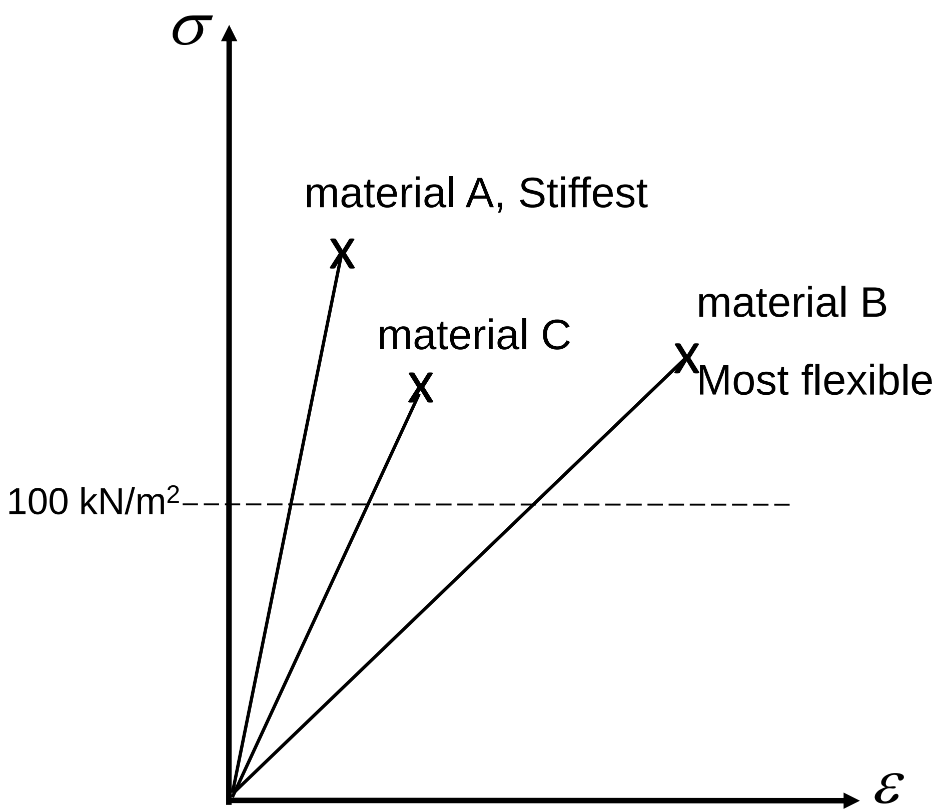
Stress-strain relationship

- The stress-strain relationship describes a material's behaviour under different types of loading.
- Elastic behaviour: The material goes back to its original shape when the stress on it is removed.
- Plastic behaviour: The material does not go back to its original shape (it deforms permanently) when the stress on it is removed.
- Young's Modulus is the gradient of the proportional part of the stress-strain curve. It is a material property.



Young's modulus = Stress/Strain

Characteristics of Materials



- Material A is the stiffest as its strain is the least for the same applied stress. This corresponds to the largest Young's modulus. It also has the highest strength as it fractures at the highest stress.

- Material B is the most flexible as its strain is the largest for the same applied stress.