Chapter 1. Making measurements

1. Physical quantity (**scalar vs vector**)

   Scalar only has magnitude, **vector** has both magnitude and **direction.**

   Scalar: mass, speed, distance, density, energy, current, temperature, pressure

   Vector: weight, force, velocity, acceleration, momentum, electrical field strength, gravitational field strength

2. Measurements

a. SI unit

Mass	Kilogram	kg
Length	Metre	m
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K

b. Prefix

nano(n)	10^{-9}	kilo(k)	10^{3}
micro(μ)	10^{-6}	mega(M)	10^{6}
milli(m)	10^{-3}	giga(G)	10^{9}
centi(c)	10^{-2}		
deci(d)	10^{-1}		

c. Measuring length

Tool: **rule** (1mm), **tape measure(longer distance)**, more precise: micrometer/screw gauge(0.01mm),vernier

Measuring volume - Irregularly shaped solid:

displacement

I. Add water into measuring cylinder
II. Read the volume.
III. **Immerse** the object in the water.
IV. Read the new volume.
V. The difference between two readings is the volume of the object

d. Measuring time

Tool: analogue clock, digital clock(0.01s)

Key Measuring techniques:

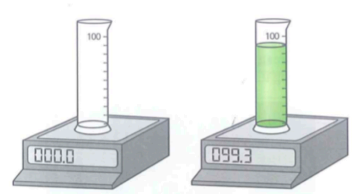
- check zero
- Measure small distance or small time intervals: measure **multiples**
- Measure multiple times and calculate the average
- Start at a recognize point in the cycle e.g. start when the pendulum is on the highest position

e. Measuring **density**

$$\rho = \frac{m}{V}$$ unit: g/cm^3 or kg/m^3

Measuring the density of liquid:

a. Find the mass of the measuring cylinder by placing it on a balance, then fill it with the liquid and measure the new mass. The difference in masses is the mass of the liquid.



b. The volume can be read from the cylinder and the density calculated using the equation.

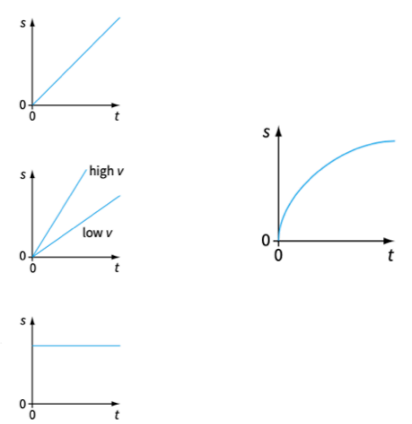
$$\rho_{oil} < \rho_{ice} < \rho_{water} = 1 g/cm^3$$

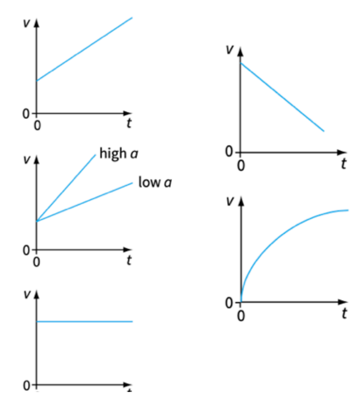
Liquid with different densities(if immiscible): form layers with small densities on the top

If the density of an object is greater than the density of liquid it will sink in the liquid- if less, it will float.

Chapter 2. Describing motion

1. average speed:
   unit: m/s or km/h;
   $$v = \frac{total\ distance}{total\ time} = \frac{s}{t} = \frac{\Delta s}{\Delta t}$$
2. velocity: speed in a given direction
3. acceleration: **the rate of change of velocity**
   $$a = \frac{\Delta v}{\Delta t} = \frac{v-u}{\Delta t} \qquad v = u + at$$
4. distance-time graph: slope = speed
5. speed-time graph: slope = acceleration





Slope: magnitude of acceleration

Larger slope: larger acceleration

Positive slope: accelerating

Negative slope: decelerating

Slope =0 (a horizontal graph): a = 0, constant speed(including stationary)

Straight line: constant acceleration

Curved line: changing acceleration

speed(v) = **gradient**

distance = **area** under speed-time graph

6. uniformly accelerated (linear) motion: constant acceleration (**a = constant**)

Average velocity:

$$v_{ave} = \frac{v+u}{2} \qquad s = v_{ave} \times t$$

7. free fall(only gravity, ignore air resistance)

$$a = g = 9.8\ m/s^2$$

Chapter 3. Forces and Motion

1. Force
   unit: N ($kg\ m/s^2$)
2. **Weight:** downward force due to gravity
   $W = mg$, unit: N

Same object on two different planets:
The **mass** is the **same**
The gravitational field strength g on the two planets will be different so the **weight is different**.

g: gravitational field strength, **g = 9.8N/kg**, equals acceleration in **free fall i**s due to gravity 9.8 m/s^2
vs mass: **mass is the quantity of matter in an object at rest to the observer.**
weights (and hence masses) can be compared using a balance.

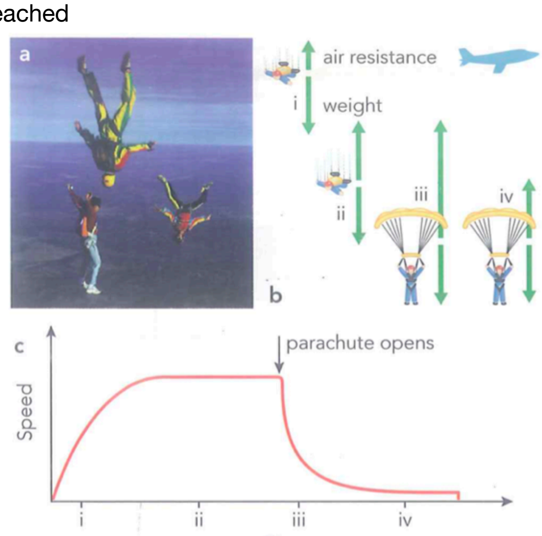
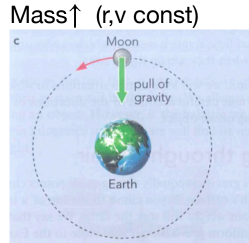
3. friction (F_f or f): a force between two surfaces which impedes motion and results in heating.

e.g. air resistance (F_f or f, $\propto v^2$, $\propto A$)

4. resultant force:
求合力：a. If forces acting along the same straight line: 同向相加， 异向相减
b. Otherwise: vector addition, apply **parallelogram law**(find the diagonal vector) or **triangle law**（head to tail）

Scale diagram：需要把力的大小成比例的画出来，比如1cm 对应1N； 可以用来求resultant force的大小及方向(量出大小和方向)。

5. Newton's second law

<table>
<tr><td rowspan="3">F_{tot}</td><td>$= 0$</td><td colspan="2">Constant velocity: stay at rest or move at steady speed along straight line</td></tr>
<tr><td rowspan="2">$\neq 0$</td><td colspan="2">F = ma (常考：已知 a 求 F, 或者反过来)
The resistance of an object to changes in motion</td></tr>
<tr><td>Accelerate or decelerate along straight line, e.g. parachutist
Initially, there is no air resistance and the only force acting on it is weight
As it falls, it accelerates which increases its speed and hence air resistance
This causes the resultant force downwards to decrease
Therefore the acceleration decreases, so it is not speeding up as quickly
Eventually they are equal and opposite and balance so there is no resultant force
So there is no acceleration and the terminal velocity is reached

</td><td>Circular motion with constant speed:
The speed is constant, but the direction is always changing
=> velocity is always changing
=> accelerating and there must be a centripetal force towards the centre of the circle. $F = \frac{mv^2}{r}$
F↑ =>
Speed↑(m,r const)
Radius↓ (m,v const)
Mass↑ (r,v const)

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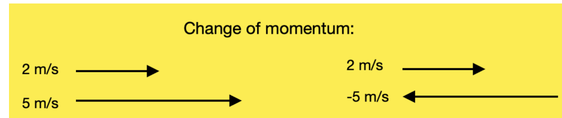


6. Momentum:

$p = mv$; Unit: $kg\ m/s$

5. Impulse:

$F\Delta t = mv - mu = \Delta p$ (冲量定理：Impulse equals the **change** of momentum.)

Unit: Ns

7. Definition of force: force is the rate of change of momentum

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

why we need airbags/safety belt during car crash: Δp same, Δt increases due to airbags/safety belt, so force F is reduced, causing less harm

8. Conservation of momentum

For an isolated system(no external forces applied), total momentum doesn't change, before and after collision, momentum are conserved: $p_i = p_f$

$$m_1 \vec{u}_1 + m_2 \vec{u}_2 = m_1 \vec{v}_1 + m_2 \vec{v}_2$$

$$|\Delta p_1| = |\Delta p_2| = F\Delta t,\ (F_{1->2} = F_{2->1} = F)$$

Collision example:

Before collision After collision

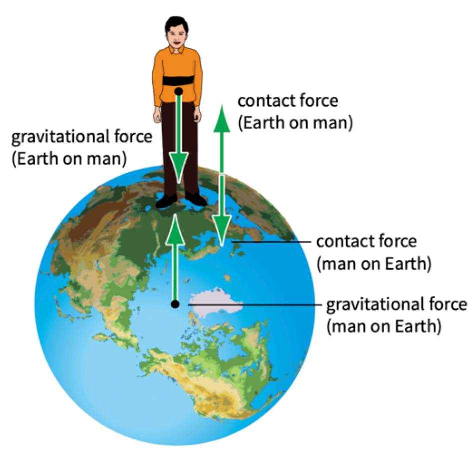
Newton's first law

An object will remain at rest or in a state of uniform motion unless it is acted on by a resultant force.

Newton's third law

When two bodies interact, the forces they exert on each other are equal in magnitude and opposite in direction.

- They act on **different** objects.
- They are equal in magnitude.
- They are opposite in direction.
- They are forces **of the same type**.



Chapter 4. Turning effect

1. Moment: the turning effect about a point/ **Force times perpendicular distance to the pivot**

$$M = r \times F$$

pivot: the point which the object can rotate about.

r: **perpendicular** distance to the pivot

To get larger moment:

a. Larger force
b. Act further form pivot
c. Act perpendicular to the object

If (extended) line of force ***pass through the pivot***, then moment of this force to this pivot is **0** => not rotate

2. Two conditions for **Equilibrium**:

Principle of moment

a. No resultant force
b. No net moment (**clockwise moment = anti-clockwise moment**) **(about any point)**

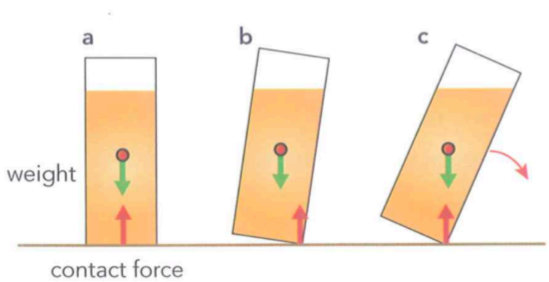
3. Center of gravity: the point at which all of its gravity can be considered to act

Finding center of gravity: a. For mass uniformly distributed object: at the geometric center

b. Otherwise: use Suspension

1. Hang up the card and suspend a plumb line from the same place.
2. Mark the position of the thread.
3. Repeat the above steps with the card suspended from different places.
4. Where these lines intersect is the centre of mass.

4. Stability



Stable: lower center of gravity, wide base

Unstable: higher center of gravity, narrow base

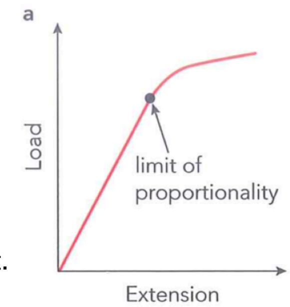
Chapter 5. Forces and Materials

1. Force acting on solids: change shape & size(storing energy)

2. <u>Limit of proportionality</u>

Up to this limit, the extension is proportional to the load.

常考点： find the limit of proportionality 首先弯折的点



3. <u>Hooke's Law</u>

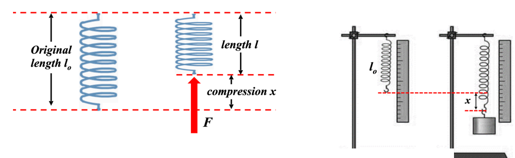
Within the limit of proportionality, the extension is proportional to the load applied to it.

$$F = kx$$

F: load
易错点：当挂的是重物时，load (F)是它的weight， 不是mass。
$F = W = mg$

k: spring constant
(A measurement of stiffness of a spring)

x: extension (measured length - original length)/ compression(original length - measured length)

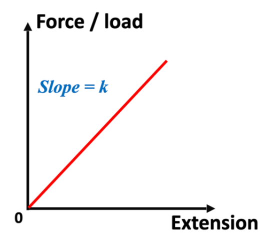


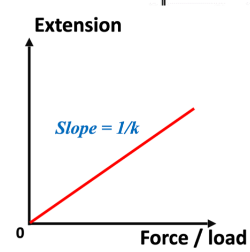
常考点：

求k (根据图像load-extension)

根据 k 和 load 求extension/length

易错点： 看清求的是**extension**还是**length**





4. pressure

$$p = \frac{F}{A}$$

Pressure is a **scalar**

Unit: Pa ($1\ Pa = 1\ N/m^2$)

Pressure depends on:	Force (F)	p directly proportional to F
	Area (A)	p inversely proportional to A

5. Pressure in liquid

Pressure caused by liquid:

$$p = \rho g h$$

Change in pressure: $\Delta p = \rho g \Delta h$

Chapter 6. Energy stores and transfers

1. Energy

Unit: Joule (J)

Energy is a **scalar**

2. Energy stores:

Gravitational potential energy(g.p.e.): energy due to height; $E_p = mgh$; $\Delta E_p = mg\Delta h$

Kinetic energy(k.e.): energy due to motion $E_k = \frac{1}{2}mv^2$; $\Delta E_k = E_{kf} - E_{ki} = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

Elastic energy; Internal energy; Chemical energy; Nuclear energy; Electrical energy

3. Energy transfers

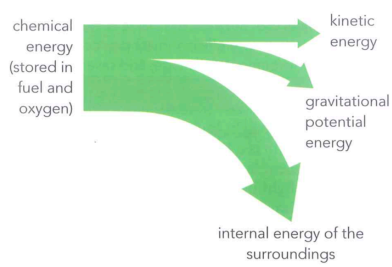
Doing work(W); Heat; Light(Electromagnetic radiation, e.g. Sun); Electrical current

4. **Energy conservation**

In any energy **transfer**, the total amount of energy before and after transfer is **constant**

Sankey diagram:

A flow of diagram representing energy conservation. Arrow width proportional to energy. Total width remains constant



Dissipated (Energy loss): energy that is spread out is not useful; usually through: heat (work of friction, conduction), light, sound.

Efficiency $= \dfrac{useful\ energy\ output}{total\ energy\ input} = \dfrac{total\ energy - wasted\ energy}{total\ energy\ input}$

常考点：

- **能量转换**：看看物体**状态**发生了什么**变化**，对应什么**能量**改变

e.g. **h** => g.p.e.; **v** =>k.e.; change size/shape => elastic energy; T => internal/thermal; nuclear reaction =>nuclear energy; chemical reaction => chemical energy

hydro-electricity(dam, tidal power station): g.p.e => k.e. => electrical energy

a.c. generator: k.e. => electrical

motor: electrical => k.e.

Nuclear power station: nuclear => heat => k.e. => electrical

- **能量守恒:**

e.g. bouncing ball (can not return to original height due to energy loss)

Falling: g.p.e => k.e. + heat(internal)

Bouncing: energy loss(heat, sound)

Bouncing back: k.e. => g.p.e. + heat(internal)

Chapter 7. Energy Resources

Energy resource	Source	From sun /not	Energy forms	Renewable /not	reliable/ not	Use steam/ not
Solar	the Sun	Y	solar	Y	**N**	N
Wind	wind	Y	k.e.	Y	N	N
Wave	water	Y	g.p.e. + k.e.	Y	N	N
Hydroelectric	water	Y	g.p.e.	Y	Y	N
Boimass	biomass	Y	chemical	Y	Y	Y
Fossil	oil gas coal	Y	chemical	N	Y	Y
Nuclear	Uranium	N	nuclear	N	Y	Y
Geothermal	the Earth	N	thermal	Y	Y	Y
Tidal	water	N	g.p.e. + k.e.	Y	Y	N

solar cell: generate electrical power
solar panel: heat water

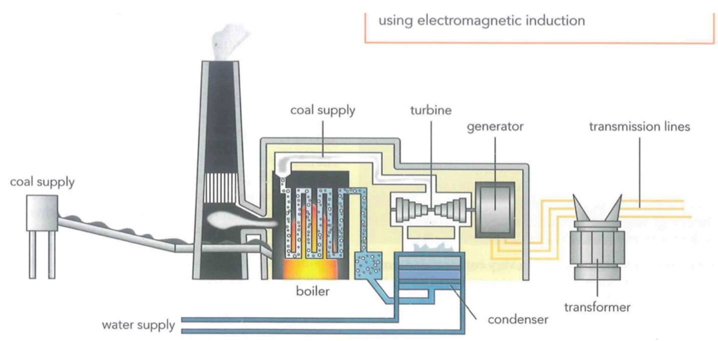
Non-renewables: fossil, nuclear

Renewable (def): An energy resource that will be replaced naturally when used

Not from the Sun: nuclear, geothermal, tidal

Sun's energy comes from **nuclear fusion** (fuse light nuclei into heavy nucleus) in the Sun's core **VS nuclear fission**(splitting heavy nucleus into 2 or 3 nuclei) used in nuclear power station.

Energy resources to **generate electricity**:



Boiler

↓

Turbine

↓

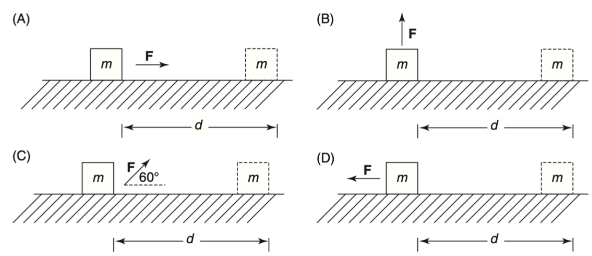
Generator

Typical advantages & disadvantages: contribute to global warming or not(CO_2); cause air pollution or not(SO_2); unreliable (e.g. solar energy): only work on daytime; not enough energy on cloudy days.

Chapter 8. Work & Power

1. W = Fd Work done（做功） = force times distance in the direction of force)

2. W = Fd = ΔE work done = energy transfer



Unit: J; scalar (like energy);

a. Increase work done: increase F or increase d

b. 判断做功与否: 力的方向上是否有运动距离

c. work done = energy transfer 从转移能量多少判断做功多少

d. useful work： 增加的useful work，e.g. raise an object from ground to 5m high: useful work W = mgh = ΔE_p; e.g. push an object from 1m/s to 5m/s: useful work W = ΔE_k

e. 物体下落：g.p.e -> k.e.

f. Work against gravity/friction

物体在竖直向上拉力F下缓慢上升，g.p.e increases	物体在水平推力F下加速, 运动s米，k.e. increases
work done by gravity 重力做负功：W = -mgh (< 0)	work done by friction 摩擦力做负功：W = -fs (< 0)
Work against gravity F 抵抗重力做正功：W = mgh (>0)	Work against gravity F 抵抗摩擦力做正功：W = fs (>0)

3. power(功率) = work done per second

$$p = \frac{W}{t}$$, Unit: W

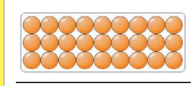
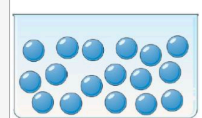
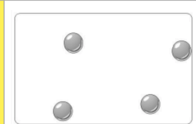
Increase power: increase work or decrease time used

4. percentage efficiency =

$$\frac{useful\ energy\ output}{total\ energy\ input} \times 100\,\% = \frac{useful\ power\ output}{total\ power\ input} \times 100\,\%$$

Chapter 9. The kinetic particle model of matter

9.1 States of matter

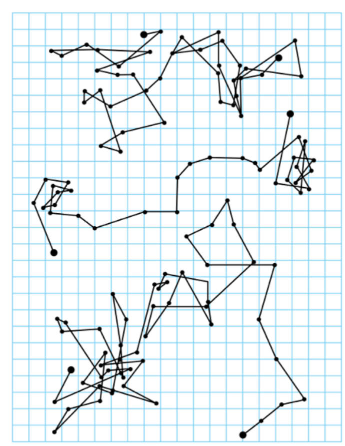
States	Volume	Shape	Arrange ment	Separation	<u>Motion</u>	<u>Attractive forces</u>	
Solid	*fixed volume;* ***Cannot be squashed*** *(No space btw molecules; will have repulsion when being compressed)*	*fixed*	*Regular Tightly bonded*	Very close in a regular pattern	<u>**Vibrate** about a fixed point</u>	<u>Very strong intermolecular force of attraction</u>	
Liquid	*fixed volume; Cannot be squashed*	*Take the shape of its container*	*Irregular Less tightly bonded than solid*	Close in a random arrangement	Vibrate and move around from place to place within the liquid	Strong, less stronger than that in solid	
Gas	*Unfixed volume; can be squashed*	*Expand to fill its container*	*Irregular Not bonded*	Far apart in random arrangement	<u>Move **freely & randomly** in all directions at high speed</u>	<u>Negligible</u>	

9.2 The kinetic particle model of matter

Matter is made up of identical, spherical, moving molecules

Temperature is <u>average kinetic energy</u> of particles in a matter

Absolute zero: the temperature at which the particles have **the minimum/least kinetic energy**



Brownian motion - Explanation:

Smaller*, lighter air molecules around pollen particles move* ***<u>randomly</u> & very fast****;*

they ***<u>collide</u>*** *repeatedly with pollen particles;*

Collision exerts ***uneven*** *forces on pollen particles and changes the motion of them.*

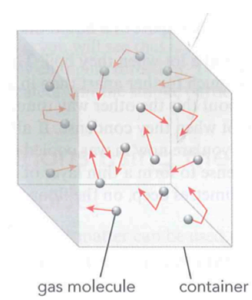
Why do gases cause pressure on the wall of its container?

Gas molecules move randomly at high speed;

collide with/hit the wall and rebound;

momentum of gas molecules change =>exert a force on the wall ($F = \dfrac{\Delta p}{\Delta t}$);

pressure is the force exerted on the unit area ($p = \dfrac{F}{A}$)



- ***Heat the gas*** *=> Molecules move faster,* ***hit the wall*** *with larger forces and more frequently. MORE change of momentum, So pressure increases.*
- ***Compress the gas*** *=>Molecules don't move far before collide with the wall, so collision is more frequent, so pressure increases.*

The gas laws: **<u>Boyle's law</u>**

At constant temperature, pressure × volume = constant, pV = constant ($p_1V_1 = p_2V_2$

9.3 Temperature and the Celsius scale

Temperature vs internal energy:

temperature: average k.e. of individual particles in the object

internal energy: total energy (k.e. + p.e.) of all particles in the object

Measuring temperature: Thermometer

The Kelvin temperature scale: absolute temperature

$T(K) = \theta(^{\circ}C) + 273$

Chapter 10. Thermal properties of matter

10.1 Thermal expansion

cause: particles gain energy, move faster/vibrate more, pushing each other further apart/take up more space (particle size unchanged as temperature rise)

States	Thermal expansion	Explanation
Solid	*Least*	*tightly bonded, so separate little*
Liquid	*More than solid*	*not so tightly bonded, a small separation*
Gas	*Even more than liquid*	*not bonded, separate most*

10.2 Specific heat capacity

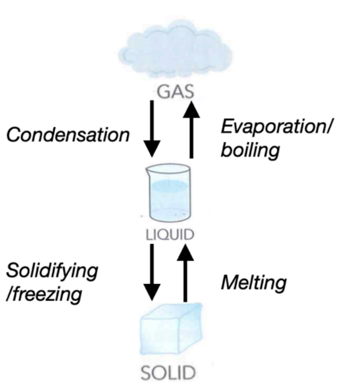
Specific heat capacity of a substance: the energy needed to raise the temperature of 1kg of the substance by 1$^{\circ}C$.

Equation: $c = \frac{\Delta E}{m\Delta\theta}$, ΔE **= increase in internal energy**

water: high specific heat capacity =>It takes a lot of energy to heat up water; Hot water takes a long time to cool down.

Experiment of Measuring the specific heat capacity of water: possible reasons for results larger than reality: *Part of energy used to increase the temperature of heater, thermometer, beaker and surrounding air;*

10.3 Changing state



Boiling point/condensing point:

Liquid <=> gas

Melting point/freezing point:

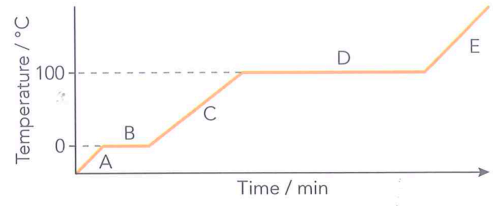
Solid <=> liquid

At standard atmospheric pressure:

Melting point of water: 0$^{\circ}C$

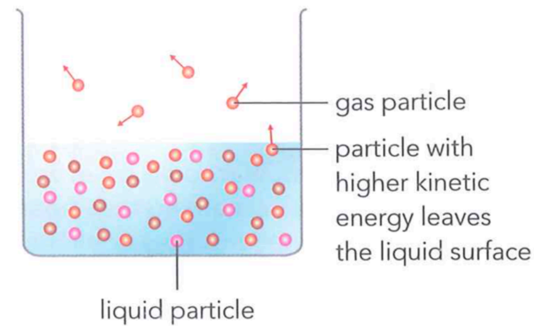
Boiling point of water: 100$^{\circ}C$

solid -> liquid, the <u>temperature stays the same.</u> **Work Done** /Energy is taken in and used to break bonds among molecules.
liquid -> gas, the <u>temperature stays the same.</u> Energy is taken in and used to overcome attraction among molecules.



Evaporation
energetic water particles overcome attraction and escape from the surface of the water. And become water vapor in the air.

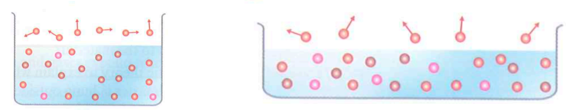
Evaporation causes **cooling of a liquid and an object in contact with the liquid**. e.g. covering a bottle of milk with a damp cloth will help to cool the milk: The water from the damp cloth will evaporate and will take energy away from milk (2'). More energetic molecules escape from damp cloth; less energetic molecules left behind, average k.e. of cloth decreases; temperature of damp cloth drops; energy transfer from milk to damp cloth(4').



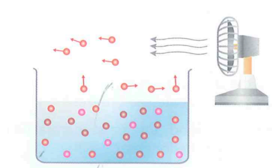
Comparing evaporation and boiling
- Boiling only happens at the boiling point of a substance. Evaporation occurs at all temperatures.
- Boiling happens throughout the liquid. Evaporation only happens at the surface
- A boiling liquid bubbles. A liquid can evaporate without bubbles
- Boiling requires heat, evaporation provides cooling.

Speeding up evaporation
Increasing the temperature
The particles on average have more kinetic energy;

Increasing the surface area
More of the particles are close to the surface,



Blowing air across the surface
When particles escape from the water, they are blown away so that they cannot fall back into water



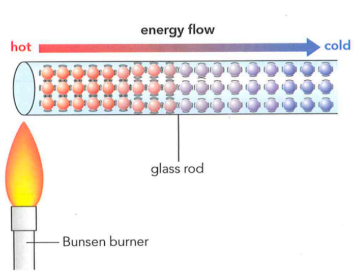
Ch11. Thermal Energy Transfer

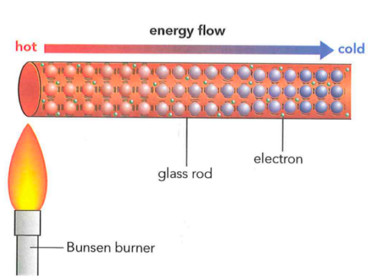
Higher temperature difference => higher energy transfer rate

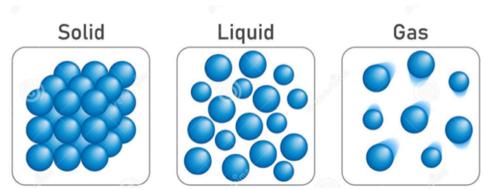
11.1 Conduction:

- conduction mainly in **solids:**

<u>non-metal:</u> atoms/molecules **vibrate**, collide with neighbors, transfer energy.
<u>metal</u><u>:</u> (main) electrons **<u>move</u>**, strike ions, carry energy through metal & (minor) atoms/molecules vibrate, collide with neighbors, transfer energy
<u>liquids:</u> are bad conductors, particles free to move vibrations not easily past, bad conductors.







11.2 Convection

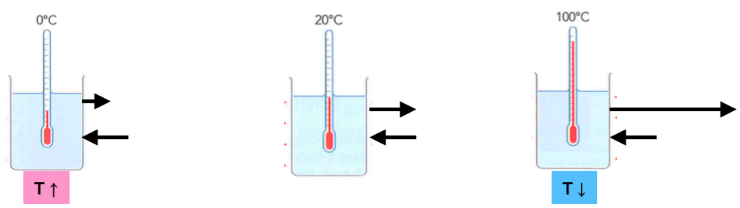
- Only in **fluids**
- Convection in fluids: temperature rises -> density decreases -> hot fluid rises (-> cold denser fluid falls)

11.3 Radiation(infrared)

- Thermal radiation doesn't require a medium, transfer mainly in empty space.
- Affected by:

1. surface color and texture, **[dull black: good absorber/emitter of infrared radiation ; shinny silver: good reflector]**
2. surface area; larger surface, higher radiation rate
3. higher temperature, higher radiation rate

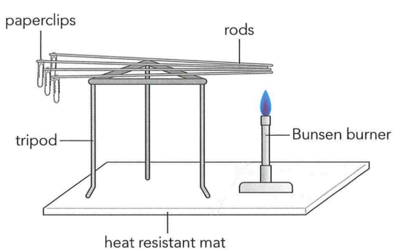
- Net radiation (received - emitted)



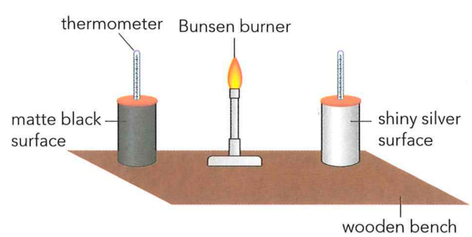
e.g. Temperature of the Earth is affected by the difference of incoming radiation and outgoing radiation; Greenhouse effect

11.4 Experiment:

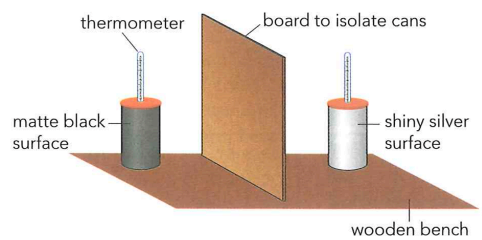
good/bad conductors



good/bad absorbers of **infrared radiation**



good/bad emitters of **infrared radiation**



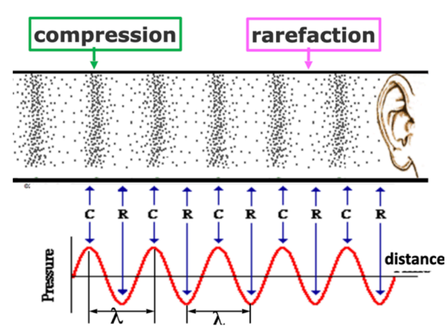
11.5 Consequence of thermal energy transfer

Kitchen pan: conduction

Heater: convection

Radiator in a car: conduction & convection & radiation

Chapter 12. Sound



1. All sounds are caused by **vibrations**
2. Sound waves are **longitudinal** waves, made by particles oscillate backwards and forwards

Compression: regions where the vibrating particles are closer together

Rarefaction: regions where the vibrating particles are further apart

3. Sound speed

Sound can travel in solid, liquid, gas; **cannot travel in vacuum**. Light can travel in vacuum.

In vacuum, speed of light = 300,000,000 m/s

In air, speed of sound = 330-350m/s; how to measure sound speed in air? e.g. echo(reflection of sound wave)

In general, speed of sound in solid (e.g. 3000m/s) > in liquid(e.g. 1500m/s) > in gas.

Explanation: Particles are closer together => vibrations can be passed on more easily

4. Properties of sound

Amplitude(A): The furthest distance the particles move from their undisturbed position => loudness

Frequency(f): The number of vibrations each second; Unit: Hertz, 1Hz = 1 wave per second => Pitch

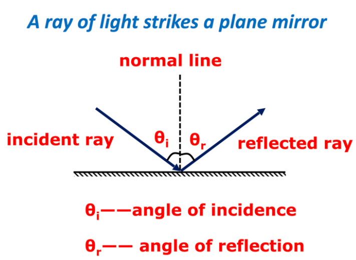
Human hearing: 20Hz - 20kHz; frequency larger than 20kHz: **Ultrasound**

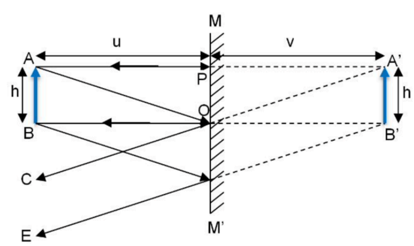
Application of ultrasound:

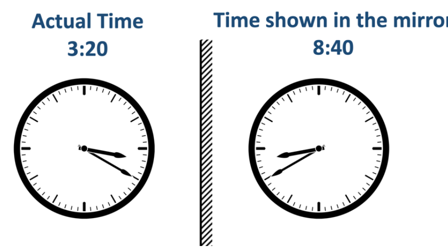
When ultrasound reaches a boundary between two media it is partially reflected back. The remainder of the waves continue to pass through => medical imaging
A transceiver can emit ultrasound and record the reflected waves to find the distance of things below the surface.

Chapter 13. Light

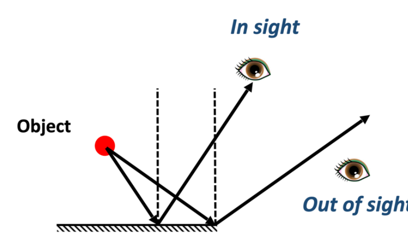
13.1 Reflection: $\theta_i = \theta_r$



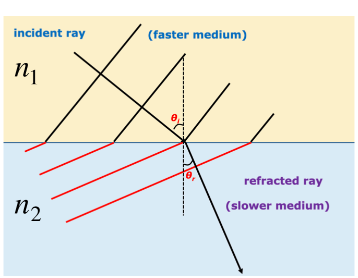




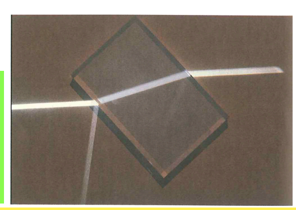
The image in a plane mirror
- same size as object
- **same distance** behind mirror as the object is in front of it
- **laterally inverted**
- **virtual** image



13.2 Refraction: the bending of the path of a light wave as it passes from one material to another material. ($\sin\theta_i$ =0 -> No bending)



$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}$$



Refractive index of a medium:

$$n = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in the medium}}$$

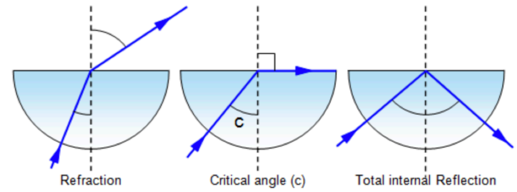
From air to medium:

$$\frac{\sin\theta_i}{\sin\theta_r} = n_{medium}$$

13.3 Total internal reflection: when light travels from a more dense(large n) material, all light is reflected, NO refracted ray.

Critical angle: the angle of incidence in the material at which angle of refraction is 90 degrees/the angle of incidence **above** which total internal reflection occurs

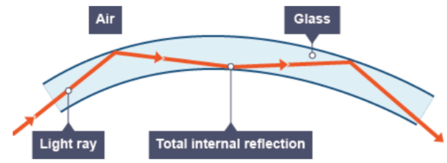
$$\sin\theta_c = \frac{1}{n}$$



TIR only takes place when

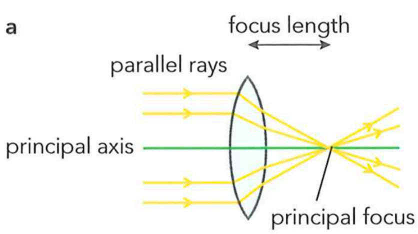
1. the light is in the more dense medium and approaching the less dense medium.
2. the angle of incidence is **greater** than the critical angle.

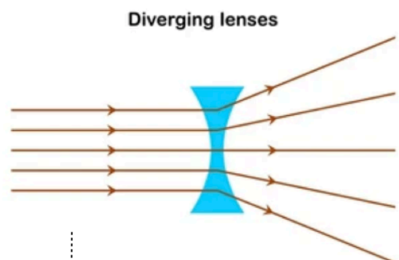
Application of TIR: optical fibre in telecommunication



13.4 Converging lens: bring light together **VS Diverging** lens: spread light apart

Principle axis: the line passing through the center of a lens perpendicular to its surface
Focal point/principle focus(F): the point at which rays of light parallel to the principle axis converge after passing through a converging lens
Focal length: the distance from the center of the lens to its principle focus



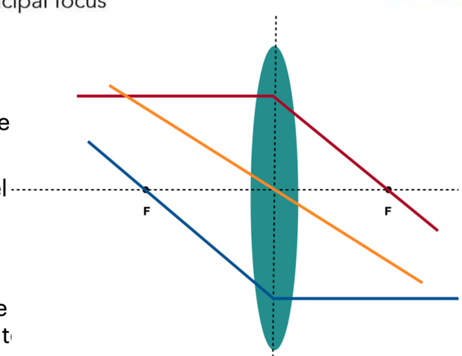


Drawing ray diagrams

1. central ray: unrefracted through the center of the lens

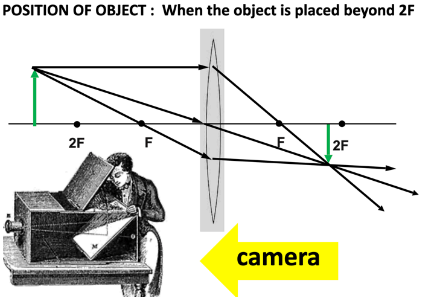
2. principle ray: parallel to the axis and then refracted through the principle focus

3. focal ray: through the focus and then parallel to the axis



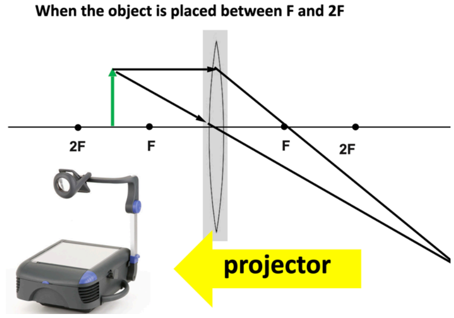
Images formed by converging lens

POSITION OF OBJECT : When the object is placed beyond 2F



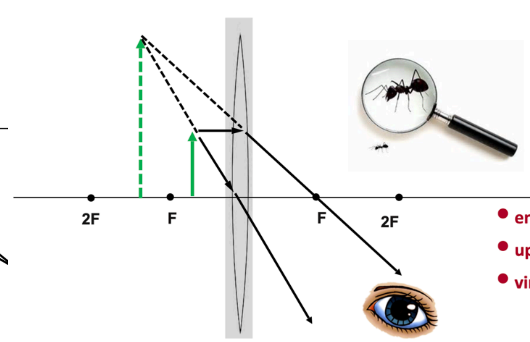
- diminished
- Inverted
- Real

When the object is placed between F and 2F



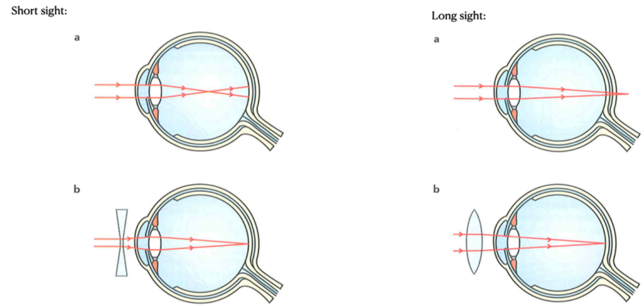
Magnifying glasses

When the object is placed within F



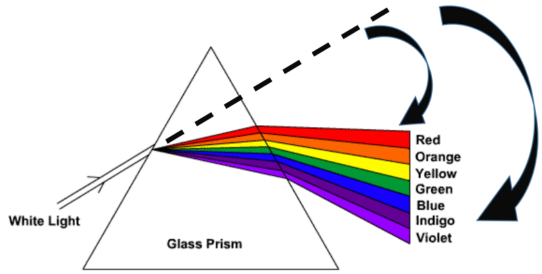
- enlarged
- upright
- virtual

Using lenses to correct eyesight



13.5. Dispersion

Monochromatic: light of a single frequency
Explanation of dispersion: In a medium (not vacuum), light with higher the frequency travels slower.



Chapter 14. Properties of waves

Wave transfers energy not matter/wave is moving not matter

Amplitude A: the distance from the equilibrium position to the maximum displacement; unit: m

Wavelength λ: the distance from one crest to the next/ btw any two points which are in step; unit: m

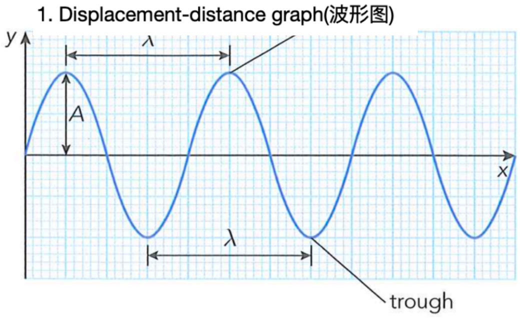
Wavefront: the set of all points having the same phase

Period T: the time taken for one complete wave to pass a point
Frequency f: the number of vibrations per second/the number of waves send out per second; unit: Hz,

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

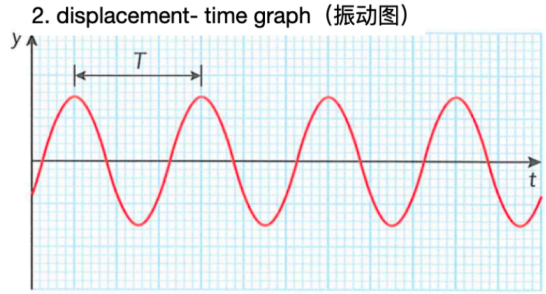
Wave speed: the distance travelled by a wave each second, $v = \lambda f$

1. Displacement-distance graph(波形图)



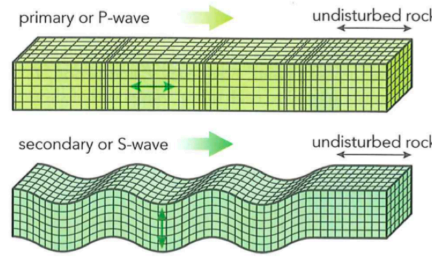
Wave at a particular time moves up and down at different positions

2. displacement- time graph（振动图）



Wave at a particular point moves up and down

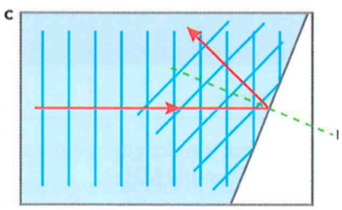
Transverse wave vs longitudinal wave:



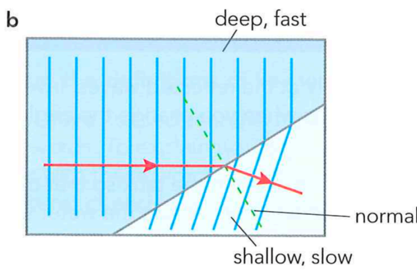
1. Transverse wave: the particles vibrate perpendicular to the direction of propagation/travel of the wave.
Longitudinal wave:the particles vibrate parallel to the direction of propagation/travel of the wave.
2. Transverse wave have crests and troughs; longitudinal wave have compressions and rarefactions

Wave phenomena:

reflection

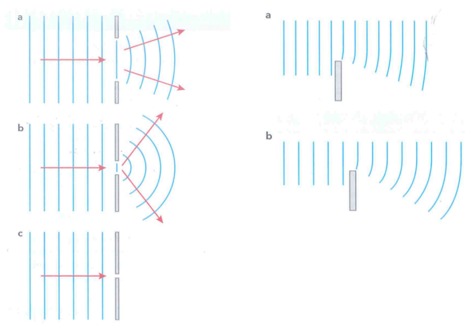


refraction



Wave travel at different speed in different medium

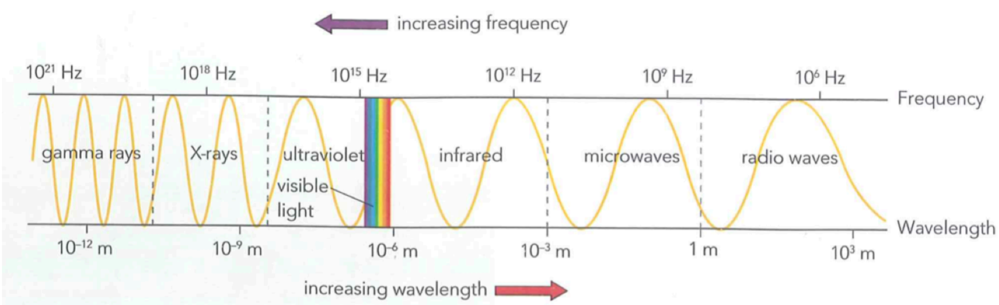
diffraction



Diffraction effect is greatest when the **size of the gap or the object** equals to the **wavelength**.

Chapter 15. The electromagnetic spectrum

Electromagnetic spectrum



Properties of electromagnetic waves:

- Transverse waves
- Do not need a medium
- All electromagnetic waves travel with the same high speed of $3.0 \times 10^{8}\ m/s$ in a vacuum and approximately the same speed in air.
- The higher the frequency of an EM wave, the greater its energy.

Uses of electromagnetic waves:

- Radio waves are used for radio and television communications, astronomy, radio frequency identification.

- Microwaves are used for satellite communication, mobile phones, and in microwave oven.
- Infrared radiation is used in electric grills, remote controllers, infrared cameras and optical fibre.
- Visible light is used in fibre optics, vision, photography, illumination.
- Ultraviolet light is used in tanning beds.
- X-rays are used in medical imaging and in security as they can penetrate material easily.
- Gamma radiation is used in medical treatment due to its high energy.

Hazards:

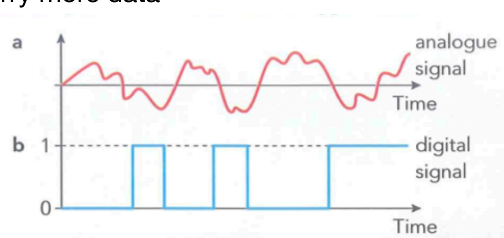
- Too much exposure to ultraviolet light increases the risk of skin cancer and eye conditions.
  - Suncream prevents over-exposure in summer.
- X-rays and gamma rays are ionising radiation that can cause mutations leading to cancer.
  - Exposure to these kinds of radiation should be minimised.
- Microwaves can cause internal heating of body tissues.
- Infrared radiation can cause skin burns.

Artificial Satellite: low orbit vs geostationary**,** using microwave

!!EM wave used in communication systems:

- Mobile phone/wireless internet: microwave
- Bluetooth: radiowave
- Optical fibre: optical/infrared => **glass transparent to visible and IR** /carry more data

Analogue and digital signals:



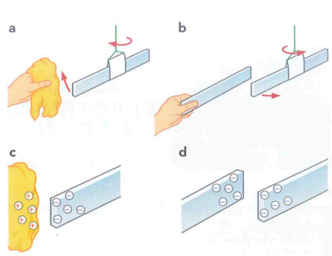
Benefits of digital signaling

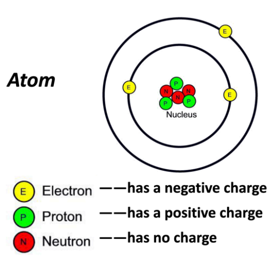
- fast data transmission rate
- Signals can be regenerated=> increased range
- Can communicate directly with computers

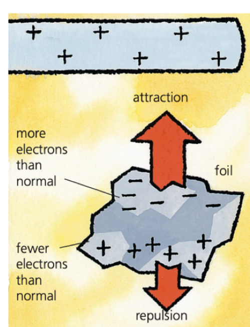
Chapter 17. Static electricity

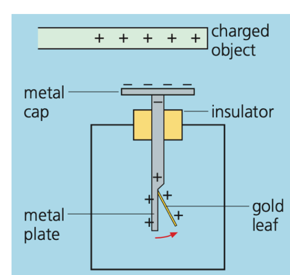
1. Charging and explanation

Two types of charge: Positive & negative
Charge: Q unit: coulomb
Like charge repels; Unlike charge attracts
Charge by friction: electrons are rubbed off one object(will be positively charged) and **move** to the other object(will be negatively charged)
Conductor vs insulators
Conductors: a substance that allows flow of electrons<= contains **free electrons**
Insulators: a substance that inhibits flow of electrons <= electrons are tightly bonded

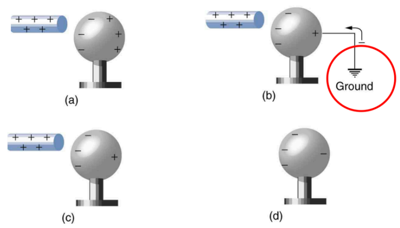








Grounding/earthing: being connected to the ground by a conducting material so that the unwanted charge flows away (because grounding will balance charge).



How to make a conductor sphere uniformly charged using a charged rod?

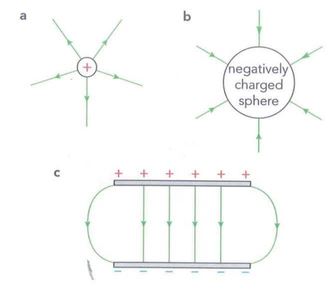
1. Put rod close to the sphere but not touching it
2. Earth the sphere with a metal wire/touch sphere with hand
3. Remove wire/hand and then remove rod

3. Electrical field

Electrical field: A region of a space in which an electric charge will experience a force

Direction of electrical field: the direction of the force on a positive charge at that point

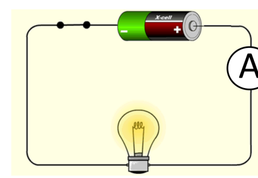
Draw electrical field line:



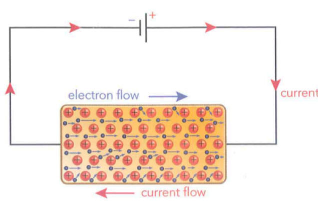
Chapter 18. Electrical Quantities

18.1 Electrical Current: $I = \frac{Q}{t}$**;** the rate at which charge flows

Unit: A (amps)
Measuring tool: **ammeter** in series



Conventional current: from positive to negative terminal; while in reality, electron moves from negative to positive terminal



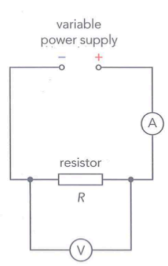
18.2 Electrical Voltage/p.d.: $V = \frac{W}{Q}$; work done per unit charge

Unit: V (volts)
Measuring tool: **voltmeter** in parallel

e.m.f(p.d. across battery)**: work done per unit charge by battery in driving the charge around a complete circuit.**

18.3 Electrical resistance: $R = \frac{V}{I}$

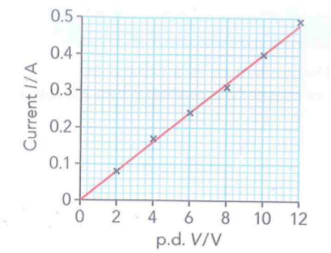
Unit: Ω (ohms)
Measuring method:

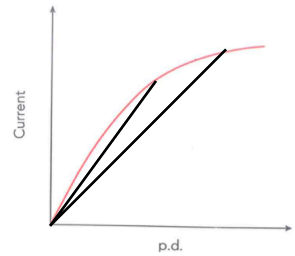


Resistance and thickness & length

$$\boxed{\begin{array}{l} R \propto L \\ R \propto \frac{1}{A} \end{array}}$$

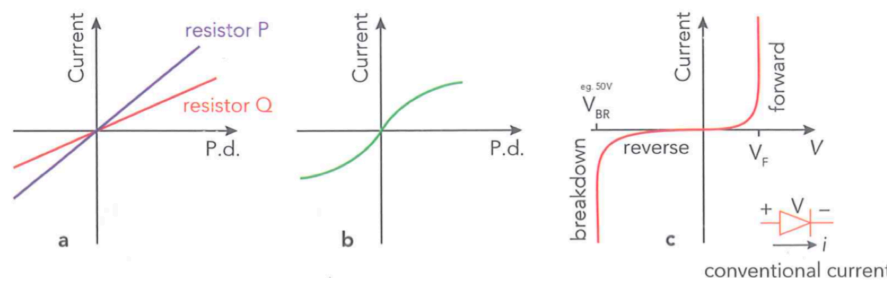
current-voltage characteristics:
Ohmic resistor: constant resistance; otherwise: non-ohmic





slope = 1/R

Typical current-voltage characteristics: For filament lamp: T increase => R increase



a: For two ohmic resistors. **b:** For a filament lamp. **c:** For a diode.

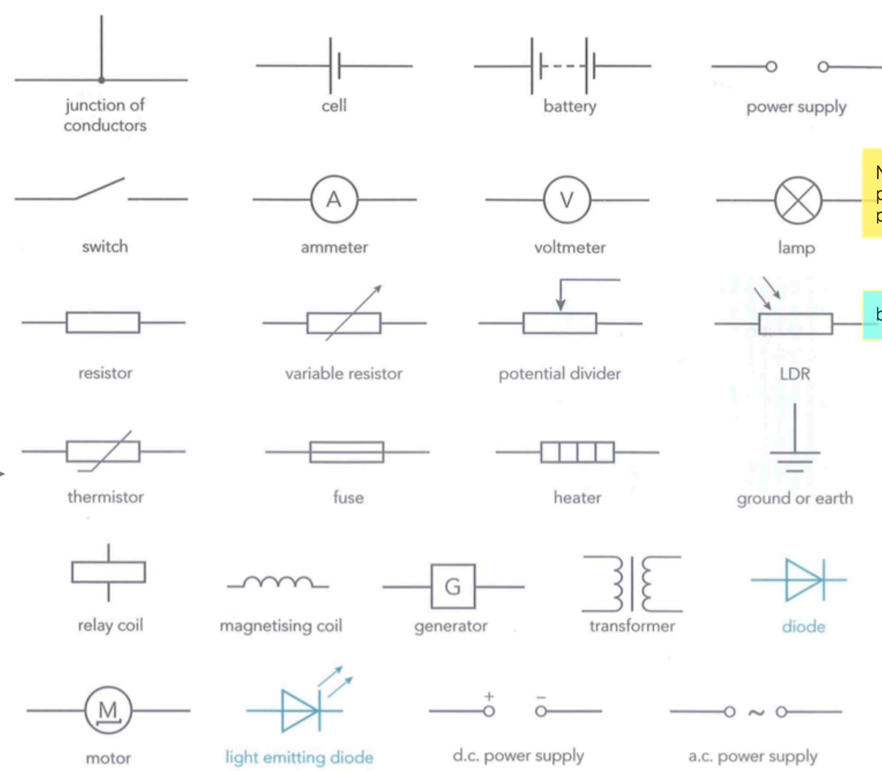
Electrical power: $P = VI = I^2R = \dfrac{V^2}{R}$

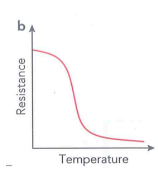
Electrical energy: $E = Pt = VIt = QV$

Unit of electrical energy: $1\,kWh = 3.6 \times 10^6 J$

Chapter 19. Electric Circuit

Circuit components



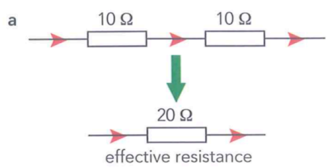


Normal brightness;
p.d. increase => brightness increase
p.d. too large => lamp will blow

brightness increase => R decrease

Combinations of resistors

1. Resistors **<u>in series</u>**

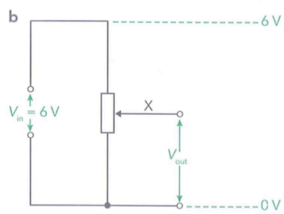


$$I = I_1 = I_2$$
$$V = V_1 + V_2$$
$$R = R_1 + R_2$$
$$V_1 = \frac{R_1}{R_1 + R_2} V$$
$$P = P_1 + P_2$$

Characteristics

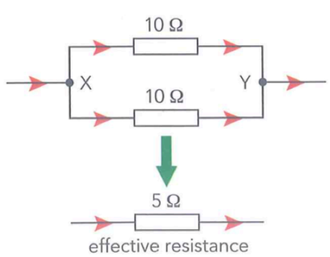
- Always switched on/off at the same time;
- One breaks, others won't work;
- Share voltage

Potential divider



$$\boxed{\frac{V_1}{V_2} = \frac{R_1}{R_2}}$$

2. Resistors **<u>in parallel</u>**



$$I = I_1 + I_2$$
$$V = V_1 = V_2$$
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$P = P_1 + P_2$$

N R in parallel:

$$R_{tot} = \frac{R}{n}$$

Characteristics

- Can be switched on/off separately
- One breaks, others still work
- Can have full voltage

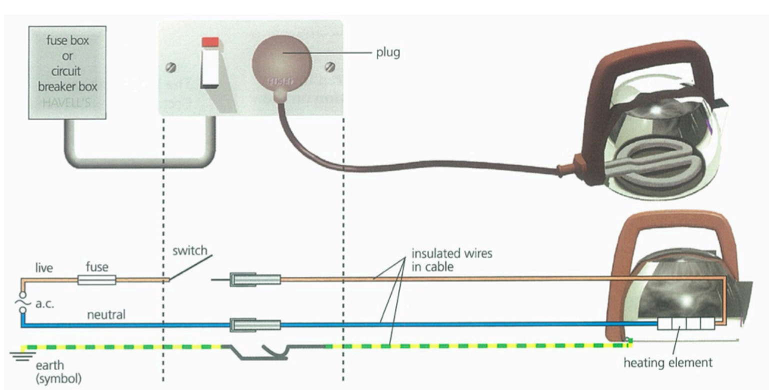
<u>Electrical safety</u>

<u>Electrical hazards:</u>

1. Damaged insulation – contact with the wire due to gaps in the insulation can cause an electric shock or pose a fire hazard by creating a short circuit.
2. Overheating of cables – high currents (e.g. overloading; to prevent: add a fuse) passing through thin wire conductors cause the wires to heat up to very high temperatures which could melt the insulation and cause a fire.
3. Damp conditions – water can conduct a current so wet electrical equipment can cause an electric shock.

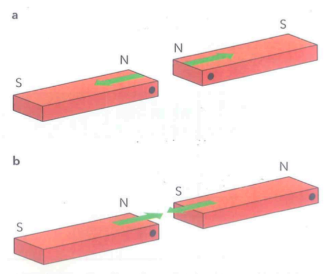
<u>Solutions:</u>

1. Earthing metal cases
2. Use fuse / trip switch (live wire)
3. Double insulation



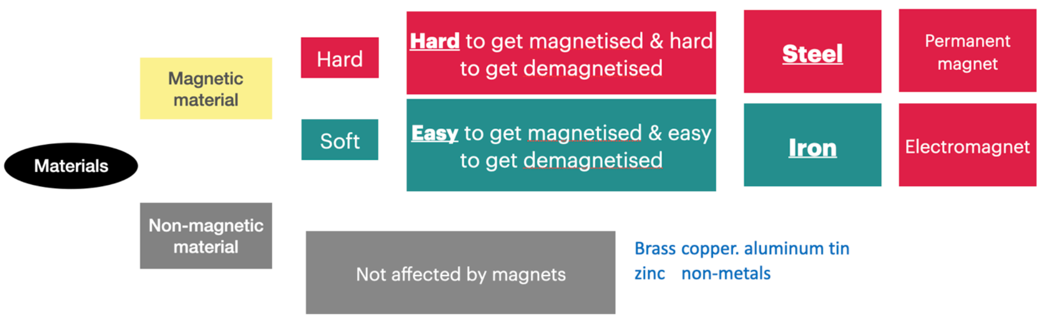
Chapter 16. Magnetism

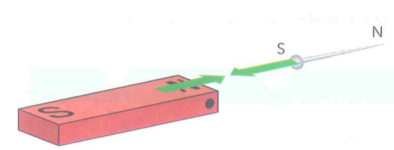
Permanent magnets



Like poles **repel**
Unlike poles **attract**

Magnetic material: Can be magnetized and be attracted to magnets; (containing **iron, nickel, cobalt)**



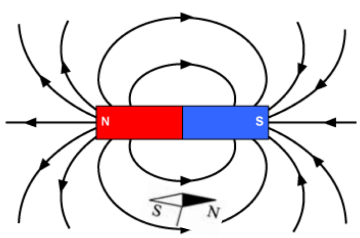


- What can be **attracted** by magnetic magnets: <u>magnets and magnetic material</u>
- What can be **repel** by magnetic magnets: <u>only magnets</u>
- Why can magnet attract magnetic material: <u>induced magnetism</u>

Magnetic field

Region around the magnet where magnetic materials experience forces

<u>Direction of magnetic field:</u> the dire ction of force on the N pole of a magnet at that point

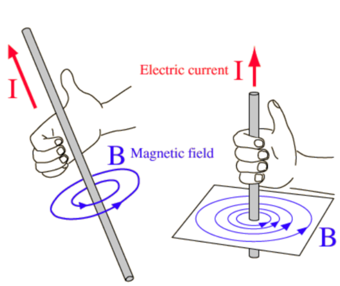


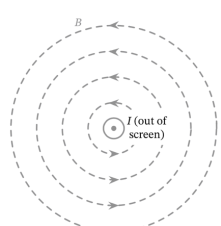
- Magnetic field lines start from N, ends at S (**N -> S**)
- Compass (N pole) points to the direction of field lines
- The closer the field lines, the stronger the field

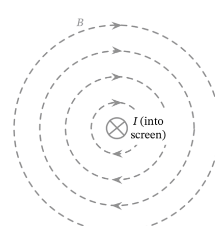
Magnetic field around a current

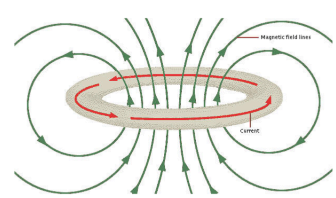
1. Magnetic field(B) direction: **right hand grip rule**
2. Outer => weaker
3. Increase **I** => increase **B**

The Right-hand Grip Rule

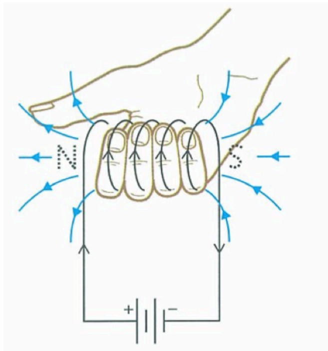








Electromagnet



Ways to increase the strength of the magnetic field in a solenoid:

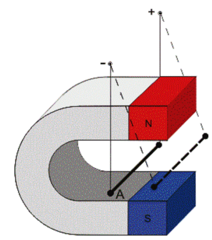
1. Increase the current
2. Increase the number of turns on the coil
3. Using a magnetic core

The magnetic field produced by the current in the coil magnetizes the core and the strength of the magnetic field is greatly increased.

Chapter 20. Electromagnetic Forces

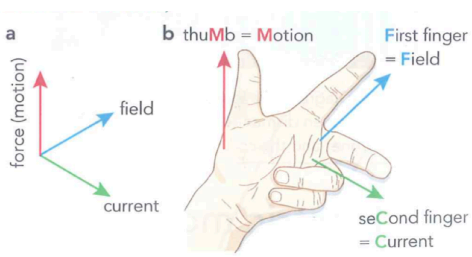
Force on a Current-Carrying conductor

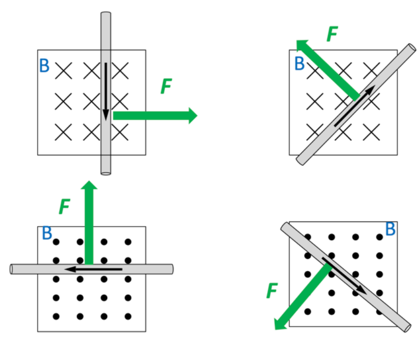
Motor effect: When **current** flows in a wire in a **magnetic field** which is not **parallel** to the current, a force is exerted on the wire



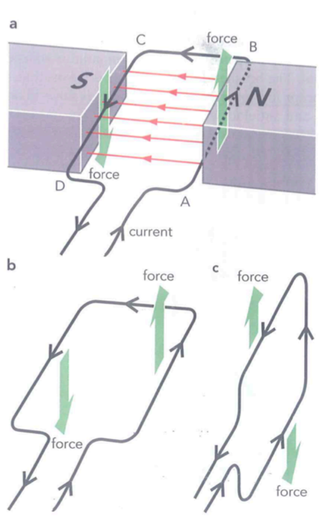
The direction of force can be **reversed** by:
Reversing the direction of current
Reversing the direction of the field of the permanent magnet(given the magnet can be changed)

How do we determine the direction of force (Ampere's force)? => **Fleming's left-hand rule**

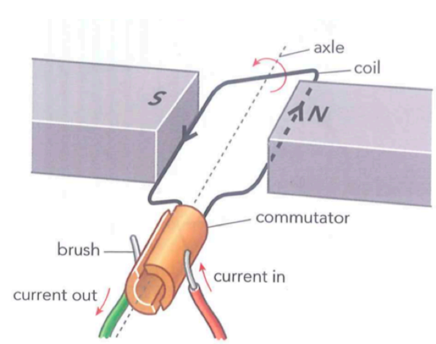




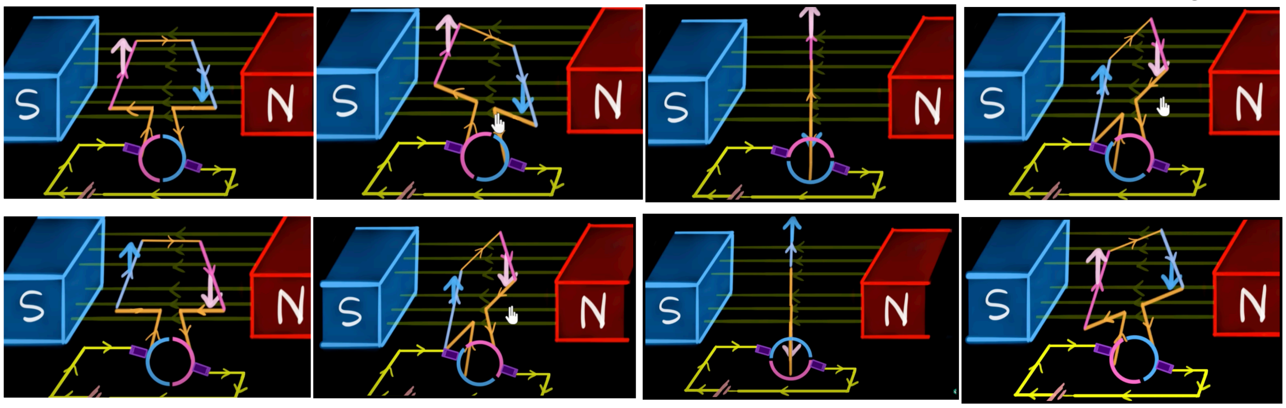
Electric Motors (d.c. motor)



keep the motor turning? => Brush + Commutator



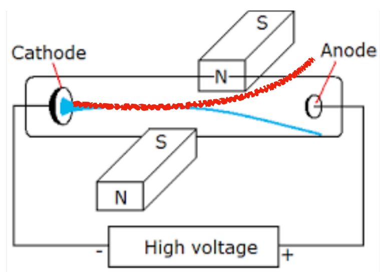
Keep the coil rotating by change the direction of current in the coil every half cycle



How to increase turning effect of d.c. motor?

1. Increase the **current**
2. Increase the **number of turns** of wire in the coil
3. Increase the strength of magnetic field/use a stronger **magnet**

Electron beam in cathode-ray tube



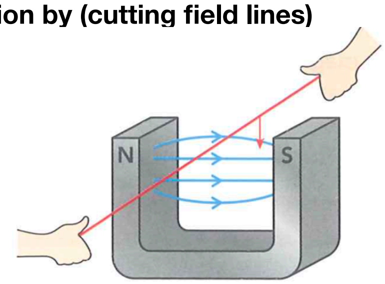
Red line is correct,
blue line is wrong

Chapter 21. Electromagnetic Induction

Electromagnetic induction: the production of an e.m.f. across an electrical conductor when the conductor **move across** a magnetic field or there is change in **magnetic flux** in the conductor

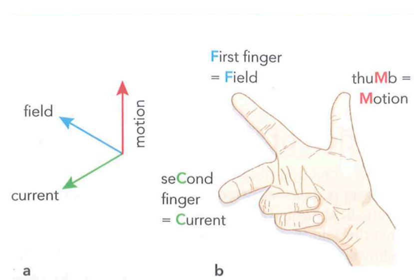
Two ways to induce e.m.f. :
1. Wire cutting field lines
2. Magnetic flux change in coil

1. Induction by (cutting field lines)

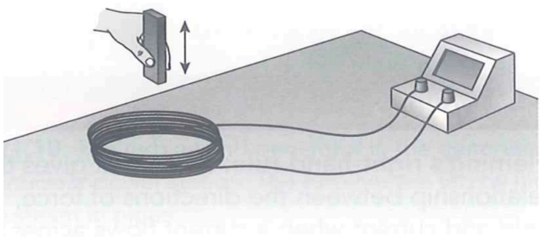


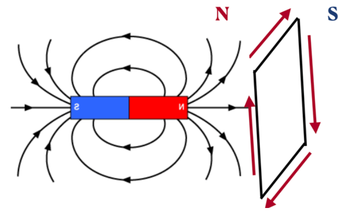
Cutting field lines → **Current/e.m.f.**

Determine direction of current => Fleming right hand rule

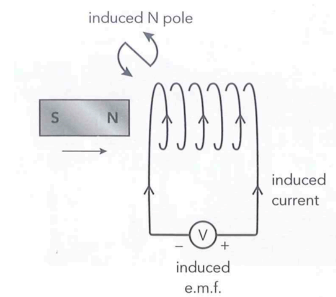


2. Induction by (moving a magnet relative to a coil)





Cutting field lines/ change flux/linkage inside coil → **Current/ e.m.f.**



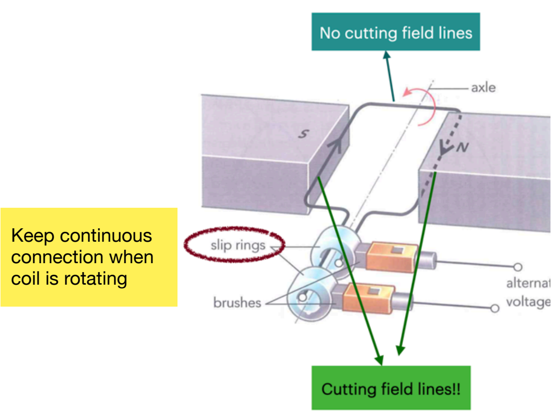
Determine direction of current => Lenz's law:
The direction of an induced current always <u>**opposes**</u> the change in the circuit or the magnetic field that produce it.

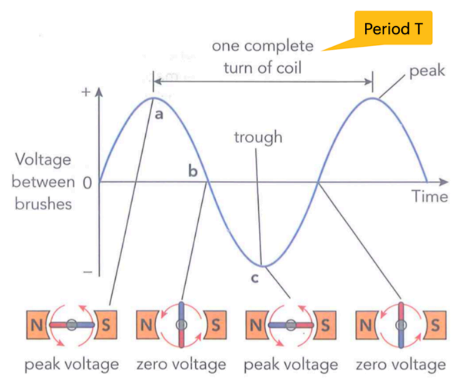
How to increase the induced current?

- Use stronger magnet
- Move wire/magnetic quickly relative to each other
- Add more turns of wire

→ <u>cutting more field lines per unit time</u>

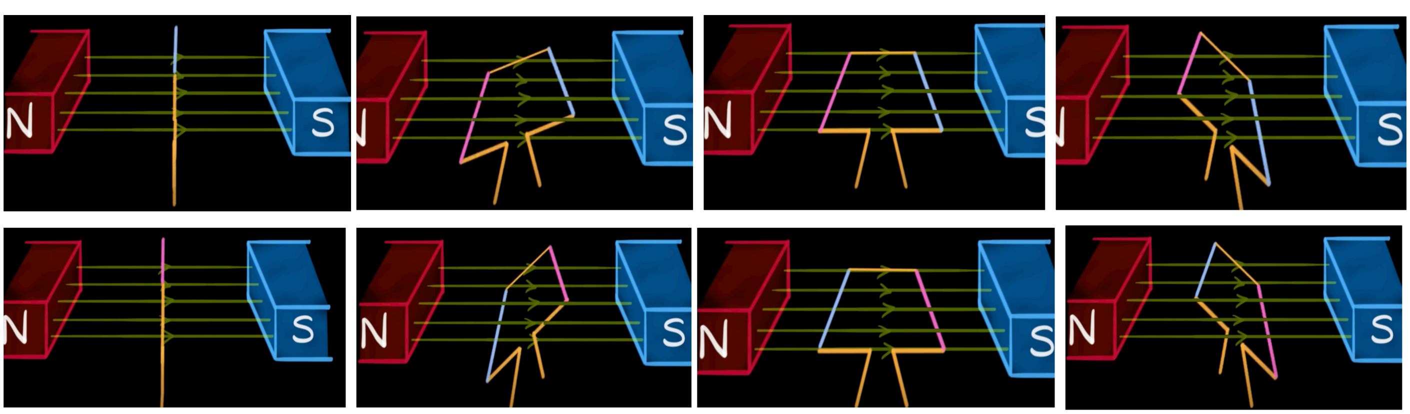
a.c. generator





Increase generated voltage?

- Turn the coil more rapidly
- Use a coil with more turns of wire
- Use a coil with a bigger area
- Use stronger magnets



Power lines and Transformers

<u>Why use high voltage?</u>

To **reduce power loss** by reducing **<u>current</u>** in transmission line;
(Reduce cost due to less metal use in cable)

Power loss:

$$P_{loss} = I^2 R$$

Current in transmission line:

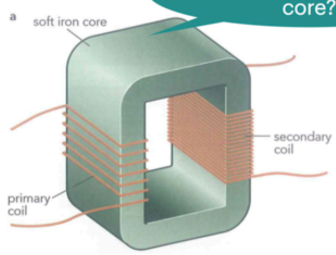
$$I = P_{tot}/V$$

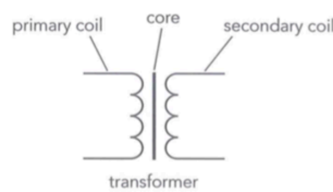
How to get high/low voltage?

→ **transformers**

Why soft iron core?

iron core is a soft magnetic material, so it can be easily magnetized; using it will make it easy to transfer magnetic field induced in primary to secondary coil.





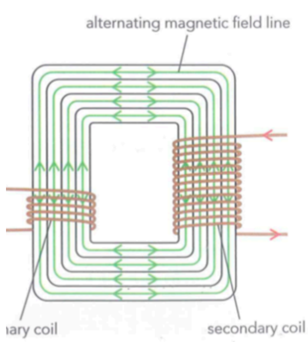
$$\boxed{\frac{N_P}{N_S} = \frac{V_P}{V_S}}$$

Step-up transformer: A transformer which increases the voltage of an a.c. supply; $N_P < N_S$

Step-down transformer: A transformer which decreases the voltage of an a.c. supply; $N_P > N_S$

Only a.c. current can use transformer

1. **Alternating/changing current** in **primary coil** produces a **changing magnetic field**
2. This changing magnetic field transfers to **second coil** through **iron core**
3. Causes **changing magnetic flux** in second coil/ **cut** by secondary coil
4. Which **induces alternating current** in second coil



Power in ideal transformer(100% efficiency):

$$(P_{in} = P_{out})$$

$$V_P I_P = V_S I_S$$

<u>Possible reasons for efficiency less than 100%:</u>

Magnetic field leakage

Heat in coils

Eddy current in core

Sound from coil/core

Chapter 22. The Nuclear Atom

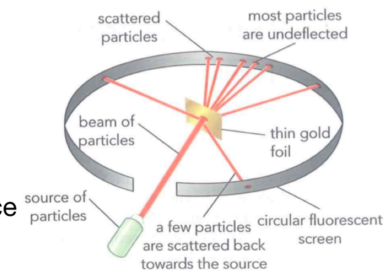
Atom (neutral) structure: a **positively** charged **nucleus**(nucleons: **proton(+) & neutron(0)**) + **negatively** charged **electrons** in orbit around the nucleus

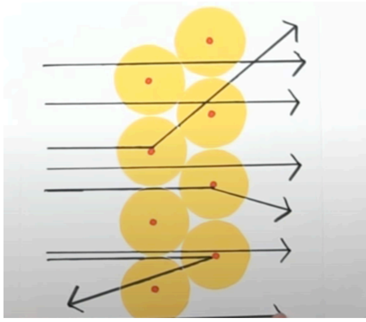
Ionization:when an atom becomes electrically charged by losing or gaining **electrons**; gain: negative ion, lose: positive ion

The radius of the nucleus is a lot smaller than the radius of the entire atom. Almost all the mass of the atoms lies in the nucleus.

Alpha particle scattering experiment

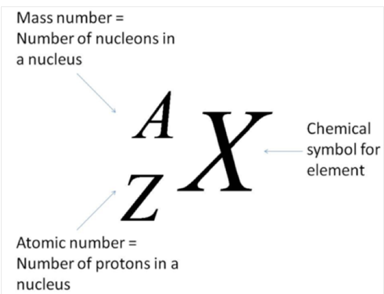
- The tiny core of concentrated charge at the heart of an atom is atom's nucleus
- Most of the mass of an atom is concentrated in the central nucleus;
- The nucleus is positively charged;
- A very small nucleus surrounded by mostly empty space





Particle	Position	Charge/C	Relative charge	Mass/kg	Relative mass
proton	in nucleus	$+1.6 \times 10^{-19}$	+1	1.67×10^{-27}	1
neutron	in nucleus	0	0	1.67×10^{-27}	1
electron	orbiting nucleus	-1.6×10^{-19}	−1	9.11×10^{-31}	$\frac{1}{1836}$ (practically zero)

Nuclide notation:



Nucleon number = relative mass
Proton number = relative charge

Atoms of the same element have the same number of protons. Isotopes are forms of an element's atom with the same number of protons but a different number of neutrons.

nuclear fission: splitting of nuclei $^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{92}_{36}\mathrm{Ba} + ^{141}_{56}\mathrm{Kr} + 3\,^{1}_{0}\mathrm{n} + \text{energy}$

nuclear fusion: joining of nuclei $^{2}_{1}\mathrm{H} + ^{2}_{1}\mathrm{H} \rightarrow ^{3}_{2}\mathrm{He} + ^{1}_{0}\mathrm{n}$

total mass always decreases

Chapter 23. Radioactivity

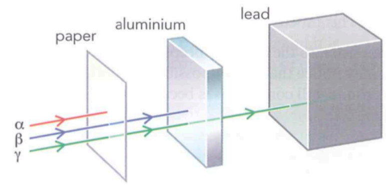
Radioactive decay is the spontaneous transformation of an unstable nucleus (usually **isotopes** with excess of **neutron**) into a more stable one by the release of radiation. It is a random and in all direction.

Weak radiation that can be detected from external sources is called background radiation. Sources of background radiation include:

(a) Radon gas(in the air)
(b) Rocks and buildings
(c) Food and drink
(d) Cosmic rays

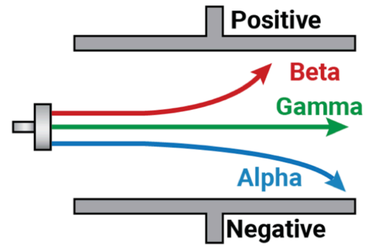
Measurement of radiation: Geiger counter

The three types of nuclear emission



- Alpha:
  - A heavy nucleus emits an alpha particle (helium nucleus).
  - The nucleus changes to that of a different element **according to the following equation:** $^{A}_{Z}X \rightarrow \; ^{A-4}_{Z-2}Y + \; ^{4}_{2}\alpha$
  - They are highly ionising and weakly penetrating. **They are stopped by a sheet of paper.**
  - **They are slightly deflected by electric and magnetic fields.**
- Beta:
  - A neutron turns into a proton and emits a beta particle (electron)
  - The nucleus changes to that of a different element **according to the following equation:** $^{A}_{Z}X \rightarrow \; ^{A}_{Z+1}Y + \; ^{0}_{-1}e^{-}$
  - They are moderately ionising and moderately penetrating. **They are stopped by a thin sheet of aluminium.**
  - **They are greatly deflected by electric and magnetic fields.**
- Gamma:
  - After a previous decay, a nuclei with excess energy emits a gamma particle.
  - Gamma particles are a form of electromagnetic radiation.
  - They are lowly ionising and highly penetrating. **They are stopped by many centimetres of lead.**
  - **They are not deflected by electric and magnetic fields.**

α particle has the greatest ionising effect because it has larger k.e., and more charge



The **half-life** of an isotope is the time taken for half the nuclei to decay, or the time taken for the activity to halve.
Background radiation has to be **subtracted** before attempting to perform half-life calculations

Uses of radioactivity:

- Smoke detectors
  Long half life alpha emitters are used in smoke detectors. Alpha particles cause a current in the alarm. if smoke enters the detector, some of the alpha particles are absorbed and the current drops triggering the alarm.
- Thickness monitoring
  Long half life beta emitters can be used for thickness monitoring of metal sheets.
  A source and receiver are placed on either side of the sheet during its production.
  If there is a drop or rise in the number of beta particles detected, then the thickness of the sheet has changed and needs to be adjusted.
- Diagnosis and treatment
  Short half life gamma emitters such as technetium-99m are used as tracers in medicine as they concentrate in certain parts of the body.
  The half life must be long enough for diagnostic procedures to be performed, but short enough to not remain radioactive for too long.
  Other gamma emitters such as cobalt-60 can be used to destroy tumours with a high dose of radiation.
- Sterilisation of equipment
  Gamma emitters are used to kill bacteria or parasites on equipment so it is safe for operations.

Exposure to radiation can destroy living cell membranes by ionisation, causing the cells to die, or damage DNA which causes mutations that could lead to cancer.

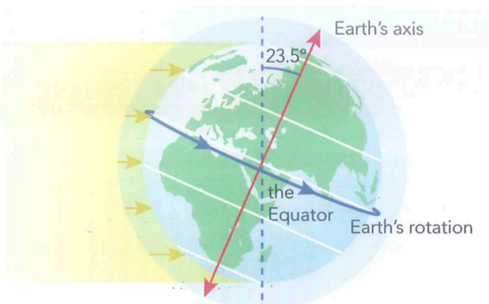
Safety measures include:

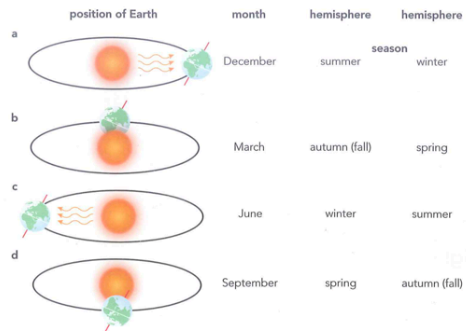
- Minimising the time of exposure to radiation. For example, radioactive tracers with a short half life should be used.
- Keeping as big a distance from the radioactive source as possible. They should be handled using tongs and held far away from people.
- Using shielding against radiation, such as the concrete shielding around a nuclear reactor. Radioactive sources must also be kept in a lead-lined box.

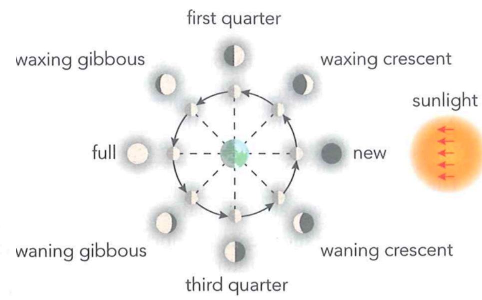
Chapter 24. Earth and Solar System

Earth, Sun and Moon

1. Day and night <u><= ***Earth spin*** *on its axis.*</u> 2. Years <u><= ***Earth*** *rotates around* ***Sun***</u> 3. Months <u><= ***Moon*** *rotates around* ***Earth***</u>







<u>What causes seasons?</u>

The spin axis of Earth is ***<u>tilted</u>***.

Rays from Sun strikes the position ***<u>at different angles</u>***

Rays from Sun strikes the position ***<u>different number of hours per day</u>***

Solar system:

Sun: 99.8% mass

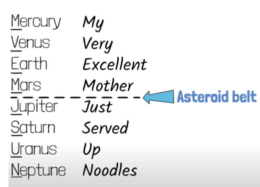
Eight planets: **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune**

Minor(dwarf) planet; Moons: orbits *<u>planet</u>*;

Asteroids and meteoroids; Comets

<u>(outer => less attraction => smaller orbital speed => larger period)</u>

Inner four: *<u>small & rocky</u>* ||asteroid belt|| outer four: *<u>giant & gaseous; why?</u>*



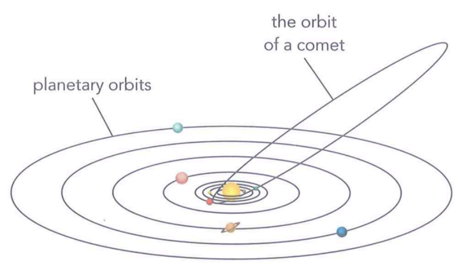
- Gravity pull mass together => form accretion disk
- Closer to the Sun, higher gravitational pull, interstellar of gas and dust **<u>density</u>** higher => ***rocky planet***
- Intense **<u>heat</u>** forced some of lighter materials further away = ***gas giants***

2. Gravitational field strength (g): gravitational force per unit mass

Gravity points towards center

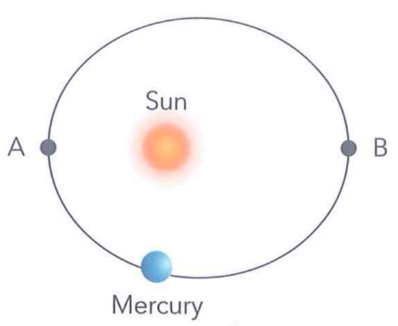
Directly proportional to m

Inversely proportional to r^2



g around planet, depends on distance from Sun: d↑=> g↓
g around surface, depends on mass, radius of planet.

3. Elliptical orbits

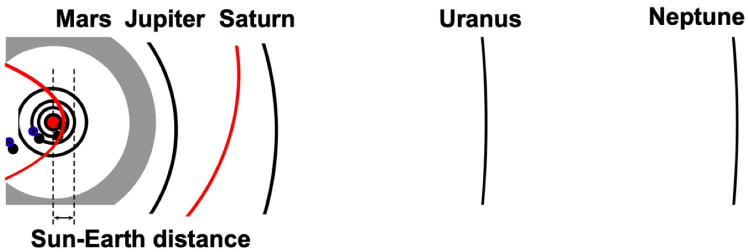


No friction in space => energy conservation
From A -> B, k.e. -> g.p.e, slows down. At A: <u>max</u> speed
From B -> A, g.p.e -> k.e., speeds up. At B: <u>min</u> speed

KEY EQUATION

$$\text{average orbital speed} = \frac{2 \times \pi \times \text{orbital radius}}{\text{orbital period}}$$

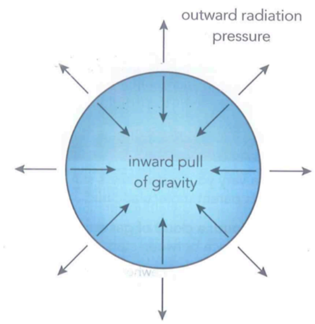
$$v = \frac{2\pi r}{T}$$



$R\uparrow \rightarrow v\downarrow;\ \ R\uparrow \rightarrow T\uparrow$

Chapter 25. Stars and the Universe

The Sun



Size: Medium size

Elements: 75% H, 24% He, 1% the rest(O, C)

Spectrum: IR, visible light, UV

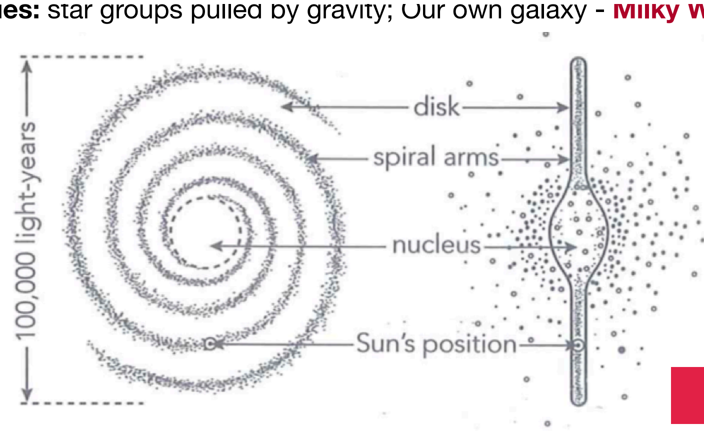
Nuclear fusion in core: H => He (hydrogen fuses to helium)

Inward gravity = outward radiation pressure → **Stable star**

light year: the **distance** that light travels through **space** in one year

$$3.0 \times 10^8 \times 365.25 \times 24 \times 3600 = 9.5 \times 10^{15}\, m$$

Galaxies: star groups pulled by gravity; Our own galaxy - **Milky way**

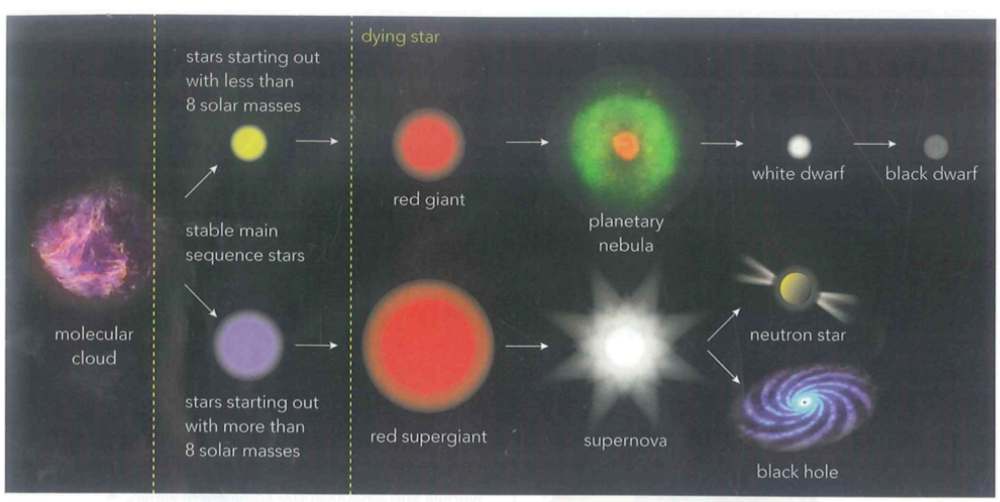


diameter: 100,000 lys

200 **billion** stars

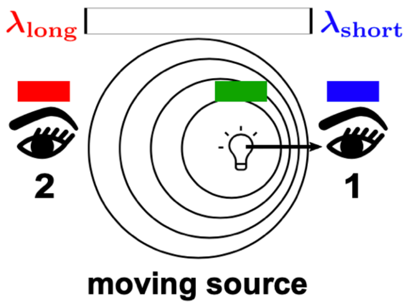
g.p.e->k.e.->heat(collide)

Cold and dense **molecular nebula** collapse due to gravity, increasing temperature forms **protostar** => **Stable Star**(inward gravity balances outward radiation pressure, hydrogen fusion begins)



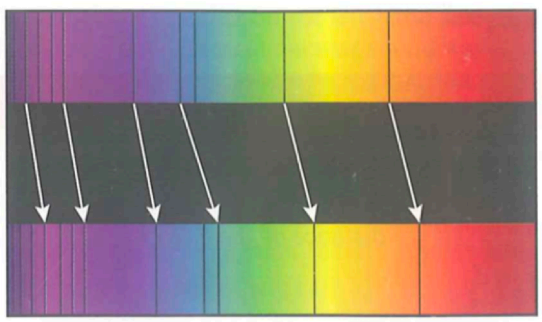
Stable star becomes dying star(red giant/supergiant when hydrogen in the core is used up)

Redshift: an increase in the observed wavelength of electromagnetic radiation emitted from receding stars and galaxies



Source moving away: $\lambda_o > \lambda_s$ wavelength(λ) ↑ redshift

v ↑ => redshift(z) ↑



Most of distant galaxies **redshifted**

=>they are ***moving away*** from us!!!

The big bang theory:

~13.8 billion years ago, the universe(space, time, matter, energy) expands from an initial state of unimaginably high density and temperature.

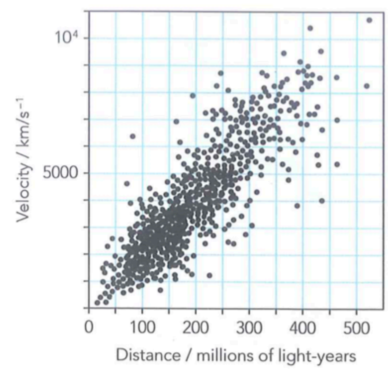
Hubble's law:

$$v = H_0 d$$

V: recession speed; d: distance from galaxy to us

H_0: Hubble constant = 2.2×10^{-18} /s

The ratio of the speed that galaxy is moving away from us to its distance from us



Estimate the age of universe.

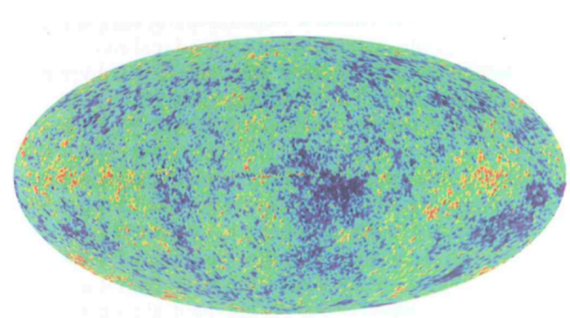
$$t_{universe} = \frac{1}{H_0} = 4.55 \times 10^{17} s = 14.4 \text{ billion years}$$

$\frac{1}{H_0}$: **Hubble time**

Cosmic Microwave Background Radiation(CMBR)

this radiation(light) formed shortly after big bang has been ***expanded*** into the ***microwave*** region of the electromagnetic spectrum as the Universe expanded

Cosmic Microwave Background radiation(observed at all points in the universe) (***T = 2.726 k***)



Supernova — measuring distance
distance of a far galaxy d can be determined using the brightness of a supernova in that galaxy