1a Measurements & units

2022年11月24日 11:07

Number Prefixes

Prefix	Meaning	10^x notation
T (*tera*)	1000 000 000 000	10^{12}
G (*giga*)	1000 000 000	10^{9}
M (*mega*)	1000 000	10^{6}
k (*kilo*)	1000	10^{3}
d (*deci*)	1/10	10^{-1}
c (*centi*)	1/100	10^{-2}
m (*milli*)	1/1000	10^{-3}
μ (*micro*)	1/1000 000	10^{-6}
n (*nano*)	1/1000 000 000	10^{-9}
p (*pico*)	1/1000 000 000 000	10^{-12}

SI Units

Quantity	Unit	Symbol
mass	kilogram	kg
length	metre	m
time	second	s
current	ampere	A
temperature	kelvin	K
Amount of substance	mole	mol
luminous	candela	cd

Significant figures

- Use the lowest significant figure of **data** in the calculation

Measuring length

Large objects (several metres)	Tape	Low precision ~ few mm to 1 cm
Medium (several centimetres)	Ruler	Medium precision ~ 1 mm
Small (several millimetres)	Vernier calipers	High precision ~ 0.1 mm
Small (several millimetres)	Micrometer	Highest precision ~ 0.01 mm

Measuring time

- Time intervals of seconds or minutes can be measured using a stopclock or stopwatch.
- When humans are involved measuring short time intervals (a few seconds or less) can be difficult – this is because of human reaction time (215 ms on average)
    - This can be overcome in two ways:
        - Automated timing
        - Measuring time of several repeats

1b Volume & density

2022年11月24日 11:07

Volume

- A measure of how much space an object takes up
- Volume units
  - SI unit = m^3
  - 1 litre = 10^{-3} m^3
  - 1 millilitre = 10^{-6} m^3 = 1 cm^3

Measuring volume

Liquid	Measuring cylinder
Regular solids	Calculated using mathematics
Irregular solids	Displacement
Large objects	Displacement can

Mass and weight

- Mass: a measure of the amount of substance in an object
- All objects are attracted to the Earth by gravity - the greater the mass of an object, the stronger the Earth's pull
- Weight: the Earth's gravitational force on an object
- All objects resist attempts to make them go faster, slower, or in a different direction - the greater the mass of an object, the stronger the resistance to change in motion

Measuring mass

A several grams	Balance
Kilograms	Newton scales

Density

- A measure of how much mass can fit in a volume.
- $\text{density} = \frac{mass}{volume}$ $\rho = \frac{m}{v}$
- SI derived unit of density = kg/m^3
- 1 g/cm^3 = 1000 kg/m

2a Speed, velocity & acceleration

2022年11月24日 11:07

- Speed: How fast something is moving
  - average speed $= \frac{distance\ moved}{time\ taken}$
- Velocity: The speed of something in a particular direction
  - average velocity $= \frac{displacement}{time\ taken}$
- Acceleration: A measure of how fast something changing its velocity (vector)
  - average acceleration $= \frac{change\ in\ velocity}{time\ taken}$ $a = \frac{v - u}{t}$

2b Motion graphs

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	Distance time	Speed time
Horizontal line	Stationary	Moving at constant speed
Straight line	Moving at constant speed	Constant acceleration
Curve	Accelerating	Changing acceleration
Gradient	Speed	Acceleration
Area	/	Distance traveled

2c Forces

2022年11月24日 11:07

Gravity

- Gravitational force: Pull of Earth on an object with mass
- Gravity properties
  - All masses attract each other
  - The greater the masses the stronger the force
  - The closer the masses the stronger the force

Gravitational field

- A region around a mass in which another mass experiences a force due to gravitational attraction
- Gravitational field strength of Earth = 9.8 N/kg

Weight

- $\text{weight} = \text{mass} \times g \quad W = mg$
- A gravitational force

Force

- Force: A push or pull exerted by one object on another
  - Measuring forces - spring balance
- Resultant force = the result of adding all the different forces acting on a body
- 1 newton = the force required to give a mass of 1 kg an acceleration of $1 m/s^2$

Further effects of forces

- Motion change (speed or direction)
- Shape change
- Volume change

1st law of motion

- If no resultant external force are acting on a body, it will
  - If at rest, remain at rest
  - If moving, keep moving at constant speed in a straight line

2nd law of motion

- $\text{resultant force} = \text{mass} \times acceleration \quad F = ma$

Inertia

- The resistance to change in velocity of an object is called inertia
- The larger the mass, the larger the inertia
- Mass = resistance to change in motion

2d Friction

2022年11月24日 11:07

Friction

- A force that tries to stop two surfaces sliding past each other

Causes of friction

- Roughness of surfaces
- Deformation of surfaces
- Bonding of surfaces

2 types of friction

- Static friction
    - Occurs when the objects are stationary
    - Larger than dynamic friction
    - Does not cause heating
- Dynamic friction
    - Occurs when the objects are moving
    - Smaller than static friction
    - Causes heating from KE

Free fall

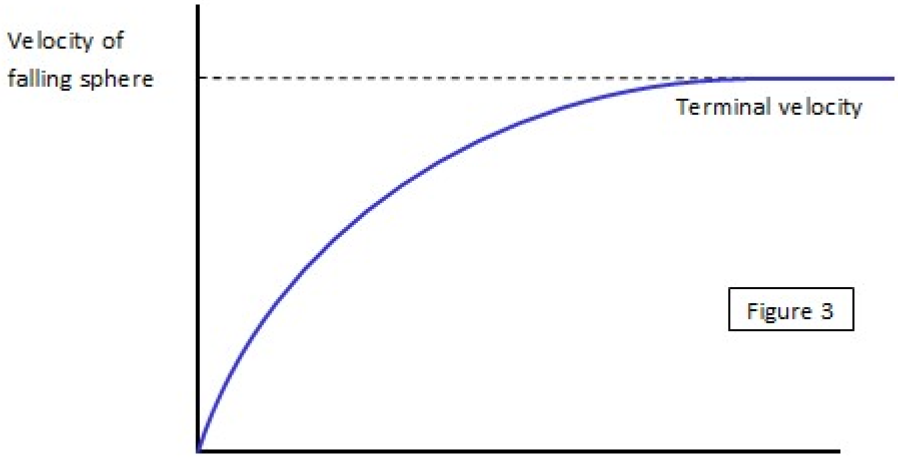
- No air resistance
- Objects accelerate at a constant rate, pulled by the earth's gravity
- Acceleration of free fall = 9.8 m/s^2

Drag

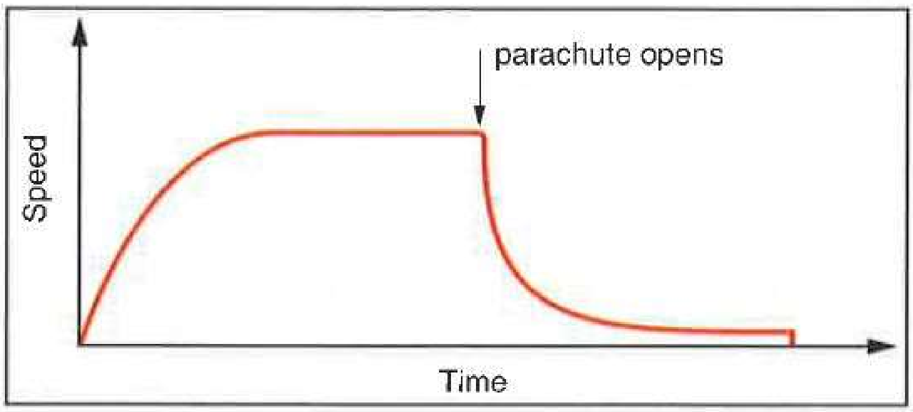
- Factors increasing drag (fluid friction)
    - Increase the surface area perpendicular to the direction of travel
    - Increase the speed of travel
    - Increase viscosity (how easily a fluid flows)
- Air resistance = a type of friction

Terminal velocity

- Start initially with free fall briefly
- Air resistance increase because speed increase
- Resultant force get smaller
- Acceleration decrease
- Air resistance become as big as the weight
- Force is balanced so there is no acceleration
- Speed is constant
- Air resistance is not increasing anymore because speed is not increasing (Reach terminal velocity)
- Same to other situations moving through a fluid - resistance increase until the maximum speed is reached
- Graph gradient not bigger than 9.8 m/s^2

- 

Parachute

- Increase surface area
- Air resistance bigger than the weight
- Upward resultant force
- Decelerating
- Air resistance get smaller because speed decrease
- Resultant force get smaller
- Deceleration get smaller
- Air resistance become as big as the weight
- Speed become constant
- Hit the ground - stop
- 

A speed–time graph for a falling parachutist.

2e Momentum

2022年11月23日 22:48

What is momentum

- $momentum = mass \times velocity\ (p = mv)$
- Unit of momentum = kg m / s
- A vector quantity

Newton's 2nd law

- $F = \frac{mv - mu}{t} \left(\text{resultant force} = \frac{\text{change in momentum}}{\text{time taken}}\right)$

Impulse

- $\text{resultant force} \times \text{time} = \text{change in momentum}$
- $\text{impulse} = \text{force} \times \text{time}$
- Impulse is **numerically equal** to change in momentum
- Impulse unit = **Ns**
- Change in momentum unit = kg m s^{-1}
- Seat belt:
  - With no seat belt the person would not start to change their momentum until they hit the dashboard or windscreen
  - Come to stop quickly
  - Large change of momentum in a short time = large resultant force = large injury (f = $\frac{\Delta mv}{t}$)
  - With the seatbelt they will have a slower change in momentum
  - They will experience a smaller resultant force and so less injury

Conservation of momentum

- Law of conservation of momentum
  - When two or more objects act on each other, their total momentum remains constant, providing no external forces act on them
- Total momentum before = total momentum after
- Elastic collision: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
- Stick together (inelastic collision): $m_1u_1 + m_2u_2 = (m_1 + m_2)v_{1+2}$
- Explosion: two moments add up to 0

2f Vectors

2022年11月23日 23:13

Scale drawing

1. Choose a scale (e.g. $1\ \mathrm{N} = 1\ \mathrm{cm}$)
2. Carefully draw your vectors at the correct angles
3. Complete the parallelogram
4. Draw the diagonal
5. Measure the diagonal and convert
6. Measure the angle of the diagonal

2g Circular motion

2022年11月23日 23:37

Centripetal force

- The force required to move an object in a circular path
- Act at right angles to the direction of motion

Factors affecting centripetal force

- Force ∝ Mass
- Force ∝ Speed
- Force ∝ $\frac{1}{\text{Radius}}$
- $F = \frac{mv^2}{r}$

Why there is a centripetal force

- The velocity is changing because the direction is changing
- There is acceleration
- So there is a resultant force
- Centripetal force is the resultant force

Motion

- Force stop - moving in straight line
- Accelerating
  - Constant speed
  - Direction changing

3a Moment

2022年11月24日 0:06

Definition

- The turning effect of a force
- $moment\ of\ a\ force\ about\ a\ point\ =\ force\ \times perpendicular\ distance\ from\ the\ pivot\ point$
- Moments have a direction - clockwise or anticlockwise

Equilibrium

- Principle of moment
    - If an object is in equilibrium, the sum of the clockwise moments about a point is equal to the sum of the anticlockwise moments about the same point
    - Point can be taken anywhere on the object
- Conditions for equilibrium
    - The sum of the forces in any direction must be equal to the sum of the forces in the opposite direction
    - The sum of the clockwise moments must be equal to the sum of the anticlockwise moments about a point
    - If the first condition does not apply the object will accelerate (F = ma)
    - If the second condition does not apply the object will rotate

Centre of gravity / mass

- Centre of mass: the point of an object where you can take all of the mass to act from
- Centre of gravity: the point of an object where you can take all of the weight to act from
- Not in the same place: the strength of gravity across the object is different, so centre of gravity changes

Finding the centre of gravity

- Plumb line
    1. Hang object by first pivot
    2. Use a plumb line suspended from the same point from the hole
    3. Draw first line by sketching the plumb line
    4. Hang object and the line by second pivot, draw the second line
    5. Ideally draw 3 lines
    6. Intersection of lines is the centre of gravity
- Centre of gravity is in a vertical line with the pivot
    - No perpendicular distance - no moment

Stability

- Three types of equilibrium: stable, unstable, and neutral
- Stable
    - Object returns to its equilibrium position if displaced a little
    - Wide base, low centre of gravity
    - Tilted for a certain angle before centre of gravity cross the pivot point and topple
- Unstable
    - Object does not return to its equilibrium position if displaced
    - Topple immediately after being tilted
- Neutral
    - Stay in place when left alone
    - Stay in the new position when moved
    - The object's centre of mass is always exactly over the point which is its 'base'.

Testing the principle of moments

- The two conditions of equilibrium must both apply
- Moment taken from various points to check (at least 2, best if 3)

3b Stretching and compressing

2023年1月24日 19:46

Elastic and plastic

- Elastic materials
  - Return to their original shape and size after being stretched or squashed or bent
  - Stop being elastic if bent or stretched too far, either break or become permanently deformed
- Plastic materials
  - Does not return to its original shape after being stretched or squashed or bent

Stretching a spring experiment

- When mass is added to a spring it pulls down with its weight due to the gravitational pull of the Earth
- Load
  - The weight of the mass acting down on the spring
- Extension
  - The change in length of the spring
- Limit of proportionality
  - Stops being straight
  - Up to it the graph is linear and the spring follows Hooke's law
- Elastic limit
  - Where the curve goes from curving a bit to curving more
  - Up to it the spring will return to its original length if the load is removed
  - If unloaded after the point the spring will be permanently stretched
- Graph plotted as extension on y-axis and load on x-axis
- *Graph is a straight line and pass through the origin

Spring constant

- Up to the limit of proportionality, Force ∝ Extension (obey Hooke's law)
- Equation
  - $\text{load} = \text{spring constant} \times \text{extension}$
  - $F = k \times x$
- Spring constant k tells us the stiffness of the spring
  - A spring with a larger spring constant will need a large force to produce a small extension
  - Units N/m

3c Pressure

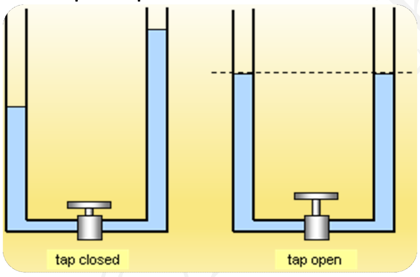
2023年1月24日 19:46

Pressure

- $P = \frac{F}{A}$
    - $P \propto F$ (force between the surfaces)
    - $P \propto \frac{1}{A}$ (the area of contact between the two surfaces)
- Measured in N/m^2 = Pa (area have to be m^2 to use Pa)

Pressure in liquids

- $P = \rho gh$ (use SI units, density of water = 1000kg/m^3)
- $Pressure\ at\ a\ depth = density\ of\ liquid \times g \times depth$
- Properties
    - Increases with depth
        - The deeper in the liquid the higher the weight of the liquid above so higher pressure
        - The pressure at a certain depth in the liquid is the same at all points at that depth
    - Increases with density
        - The denser the liquid the greater the pressure at any given depth
    - Acts equally in all directions
        - The liquid pushes on every surface in contact with it no matter which direction the surface is facing
    - Finds its own level
        - In the u-tube the pressure of the right is higher than the left due to the higher column
        - The liquid flows from the right to left until the pressure and the level are the same when the tap is opened

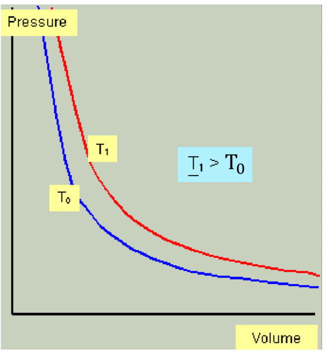


Gas pressure and volume

- The behaviour of a fixed mass of gas depends upon its pressure, volume and temperature
- A change in any of these three things affect the others

Link between pressure and volume

- Boyle's Law
    - The pressure of a fixed mass of gas is inversely proportional to its volume as long as the temperature remains constant
    - $Pressure = \frac{constant}{volume}$
    - $p_1V_1 = p_2V_2$
- Graph
    - Lines on the graphs are isothermals
        - Join points of equal temperature
    - For two different temperatures $T_1 > T_0$:



Explaining Boyles's law

- Gas molecules constantly strike and bounce off the walls of the container
- The force of these impacts causes the pressure
- If volume is halved, there are twice as many molecules in 1 m^3
- So there are twice as many impacts each second in 1 m^2
- So pressure is doubled

4a Work and energy

2023年1月25日 18:44

Work

- Work is done whenever a force makes something move
- Measured in J
- $Work\ done = Force\ used \times Distance\ moved\ in\ the\ direction\ of\ the\ force$
- $W = Fd$
- The force is not necessarily the resultant force
- *Convert mass to weight

Work and energy

- When work is done energy must be transferred from one energy store to another
- Work is a direct result of the energy transfer so work is also measured in Joules
- Work done = energy transferred
- Moving objects store energy

Energy stores

- Kinetic energy
- Gravitational potential energy
- Elastic potential energy
- Chemical energy
- Electrostatic energy
- Nuclear energy
- Thermal energy

Energy pathways

- Energy is transferred from one to another
- Four pathways
  - Mechanically, by a force moving something
  - Electrically, by a current
  - By heating because of a temperature difference
  - By radiation such as light waves and sound waves

Conservation of energy

- Energy can be stored or transferred, but it cannot be created or destroyed
- When one form of energy is transferred from one store to another the overall amount of energy remains the same
- Energy in the universe can never be exhausted even though it may become very spread out

Energy transfer

- No energy transfer is 100% efficient
- Lost energy is not destroyed but no longer available in a form that can be easily used
- Most transfers lose some energy to a thermal store
  - Transferred by heating to thermal store of the surroundings and become no longer useful

4b PE & KE

2023年3月1日 20:02

Potential energy

- If an object is in a state where it could do a work if released then it has potential energy so it is an energy store
- Gravitational potential energy (G.P.E.) calculation
    - $Gravitational\ potential\ energy = mass \times g \times height$
    - $G.P.E. = mgh$
- Force needed = mg
- Distance = h
- The object will release the energy taken to get it up when it falls to the ground

Kinetic energy

- When something is moving it has energy
- This type of energy is called the kinetic energy of the object
- Factors affecting the amount of kinetic energy
    - Mass
    - Speed
- Formula
    - $Kinetic\ energy\ (k.e.) = \frac{1}{2}mv^2$

Changing PE to KE

- Free fall
    - When an object falls to the ground all its potential energy is mechanically transferred to kinetic energy if ignoring friction with the air
    - When it hits the ground, this kinetic energy is transferred by sound and mechanically by a force to thermal energy

4c Efficiency and power

2023年3月2日 19:39

Device

- A machine or object that transfers energy from one form into another

Efficiency

- Calculation
  - $efficiency = \frac{Useful\ work\ done}{Total\ energy\ input} = \frac{Useful\ energy\ output}{Total\ energy\ input} = \frac{Useful\ power\ output}{Total\ power\ input}$
- Most of the remaining energy is wasted as heat or sound

Power

- The rate at which work is done and energy is transferred from one form to another
- Measured in Joules per second or Watts (W)
- Factors
  - How much energy is given
  - How much time is taken
- The more powerful a person or a machine is, the less time they take to convert a given amount of energy
- Calculation
  - $Power\ (W) = \frac{Energy\ transferred\ (J)}{Time\ (s)} = \frac{Work\ Done\ (J)}{Time(s)}$

4d Energy for electricity

2023年3月2日 19:39

Thermal power stations

- Generators are turned by the turbines blown round by a high pressure steam to generate electricity
- Water is heated in a boiler to produce the steam
- The thermal energy comes from burning fossil fuel or from a nuclear reactor
- Cooling towers
  - The steam is cooled and condensed after it has passed through the turbines so that it can be fed back to the boiler
  - The steam is cooled by a heat exchanger into which flows cool water from the cooling towers

Nuclear power stations

- A nuclear reaction releases energy, which makes steam and drive the turbine to turn the generator
- Pros
  - Existing supplies of radioactive fuel are readily available and relatively easy to use
- Cons
  - Difficult to dispose radioactive waste
  - Safety concerns regarding release of radiation

Alternatives

- A more economical and efficient use of fuels
- The use of better materials to insulate buildings so that less energy is needed to heat them
- Research into alternative energy sources

Wind energy

- Numerous wind turbines are positioned in designated areas and each has its own generator inside
- As the wind blows the propeller blades turn the generator producing electricity
- The housing turns to face the wind to maximise speed of the propeller blades
- Pros
  - No fuel is required and running costs are minimal after initial set-up costs
- Cons
  - Large, windy areas of land are required
  - Winds are variable = unreliable
  - Noisy and can spoil the landscape

Wave energy

- As waves approach the shore, the water level rises and falls.
- This motion can be used directly to move a ‘duck’ system up and down, and convert this to rotational movement which is used to drive a turbine and thereby generate electricity
- Wave machine - alternative
  - As wave approaches the water level rise in a vertical air chamber.
  - Air is forced out past the turbine, rotating the turbine
  - As the wave pass the water level falls
  - Air is drawn into the air chamber causing the turbine to rotate in the opposite direction
  - The turbine drives the generator
- Pros
  - Set-up costs are relatively low compared to fossil fuel / nuclear power stations
  - Relatively low maintenance costs
- Cons
  - Wave power cannot produce large amounts of energy at present
  - Difficult to build

Tidal energy

- As tidal waters come in, they are held in an area behind a barrage, raising the water level by several metres
- When the gate is open GPE of water turns into kinetic energy, so it turns the turbine and generates electricity
- Pros
    - Set-up costs are relatively low when compared to fossil fuel/nuclear power stations
    - Running costs relatively low
- Cons
    - Tidal power restricts entry to the river for shipping and fishing, and affects local habitats + prevent fish from migrating
    - Few areas of the world are suitable

Hydroelectric energy

- It uses falling water from a reservoir to drive turbines and generate electricity
- To create a reservoir a river has to be dammed
- The water falls through giant tunnels or pipes and exits through turbines as it leaves the reservoir through the dam, so it turns the turbines which drive the generator and produces electricity
- Pros
    - Minimal running cost
- Cons
    - Higher initial set-up costs than other alternative energy sources
    - Large areas of land have to be flooded, and dams do restrict the flow of water, which changes habitats and displace people, causes environmental damage because plants and animals are killed
    - Few areas of the world are suitable

Geothermal energy

- Water is pumped down to the hot rocks in pipes.
- The high temperature causes the water to turn into steam, which comes back up to the surface to rotate a turbine and hence drive a generator which produces electricity.
- Pros
    - No fuel required
    - Minimal running cost
- Cons
    - High initial installation costs
    - Deep drilling is difficult and expensive

Solar energy

- The Sun produces solar radiation which contains several different forms of energy
- Types of solar panels
    - Solar thermal panels that contain a series of water pipes which provide hot water.
    - Solar electric panels which contain photovoltaic cells that convert light into electricity
    - Some solar panels combine both thermal and electric panels to maximise efficiency
- Pros
    - Low running cost
    - No fuel required
- Cons
    - Variable amount of sunshine in some countries → unreliable
    - Solar panels are expensive and must be large to deliver enough power, occupying a lot of space

Sun

- Energy from the sun is responsible for most of our forms of energy we use for generating electricity on Earth
- The energy released from the Sun and other stars is due to nuclear fusion
- Nuclear fusion is the process by which nuclei of lighter elements join together to form a heavier nucleus.

Evaluating

- Fossil fuels
    - Non-renewable
    - Reliable
    - Damages the environment
        - Global warming
    - Energy originally from the sun
- Nuclear power
    - Non-renewable
    - Reliable
    - Damages the environment
        - Nuclear waste
    - Energy not originally from the sun
- Wind power
    - Renewable
    - Not reliable
    - No damage to the environment
    - Energy originally from the sun
- Wave energy
    - Renewable
    - Not reliable
    - No damage to the environment
    - Energy originally from the sun
- Tidal energy
    - Renewable
    - Reliable
    - Damages the environment
        - Stops fish from migrating but no pollution
    - Energy not originally from the sun
        - Tidal is caused by the moon
- Hydroelectric energy
    - Renewable
    - Reliable
    - Damages the environment
        - Fill the valley with water
        - Kill plants in the valley before
    - Energy originally from the sun
        - Water is from the river, river is from the rain, rain is from sun evaporating water
- Geothermal energy
    - Renewable
    - Reliable
    - Damages the environment
        - Drilling the ground may cause problems
        - Some rocks may contain heavy metal and contaminate water if water is not in pipes
    - Energy not originally from the sun

5a Moving particles

2023年3月19日 11:16

States

- Solid
  - Particles held closely together by strong intermolecular bonds
  - Particles vibrate on the spot, cannot change position
  - Fixed shape and volume
- Liquid
  - Particles can move freely as the intermolecular bonds have been broken
  - Particles slide past each other and undergo frequent collision with each other
  - Takes the shape of its container; fixed volume (large force of repulsion between particles)
- Gas
  - Particles are widely spaced
  - Move around rapidly and undergo high speed collisions with each other
  - Fill any space available (no fixed shape or volume)

Kinetic theory

- Matters are made up of tiny particles which are constantly in motion
- The particles attract each other
- Heating a substance it increases the internal energy of its particles
  - Internal energy = kinetic energy + potential energy of the molecule
  - They gain more kinetic energy when heated because they move more
  - There will also be an increase in potential energy due to the bonds and separation between the molecules

Brownian motion

- Robert Brown
- Observed a weak solution of milk and later pollen grains in suspension with a high-powered microscope
- The milk particles and the pollen grain showed a violent and random motion with an equal chance of moving in any direction
- Caused by collision with other particles
- Increases as the size of the particles decreases
  - Lower mass increases the impact on their velocity when the collide with other particles
- Increases as the temperature increases
  - More kinetic energy so move faster
  - Collide more often and stronger

5b Temperature

2023年3月19日 11:16

Temperature

- A measure of how hot or cold something is
- Factors
  - The amount of thermal energy absorbed by the objecct
  - The nature of the object and its mass
- At a molecular level it is the result of the motion of the particles of the substance
  - Increases as the energy of particle motion increases

Energy and temperature

- The temperature of two objects determines the direction of the transfer of heat energy between them
- The bigger the difference in temperature the greater the transfer of heat
- Objects at the same temperature have the same average kinetic energy per particle

Celsius

- Fixed points
  - Melting point of water = 0℃
  - Boiling point of water = 100℃

Kelvin

- Absolute zero
  - 0 K or -273℃
  - No further heat can be extracted
  - All movements of the particle stops (particles have minimum kinetic energy)
  - The lowest temperature possible to reach
- 0℃ = 273 K (temperature in Celsius = temperature in Kelvin - 273)

5c Heating solids liquids

2023年3月19日 11:16

Expansion of solids

- Explanation
  - When a material gets hot it expands
    - The molecules in it are moving about more vigorously because it has more KE and so need more room
  - As a solid is heated the molecules vibrate more violently and the solid expands in all directions
- The amount of expansion depends on:
  - What material it is
  - How big the temperature rise is
  - How long it was to start with
- Bimetallic strip
  - Bends with the metal that expands more on the outside
- Glass beaker
  - Shatter if plunged into cold water after being heated
  - Outside of the glass cools rapidly so it tries to shrink
  - The inside is still hot so it does not shrink
  - The outside glass contract so it shatters

Expansion of liquids

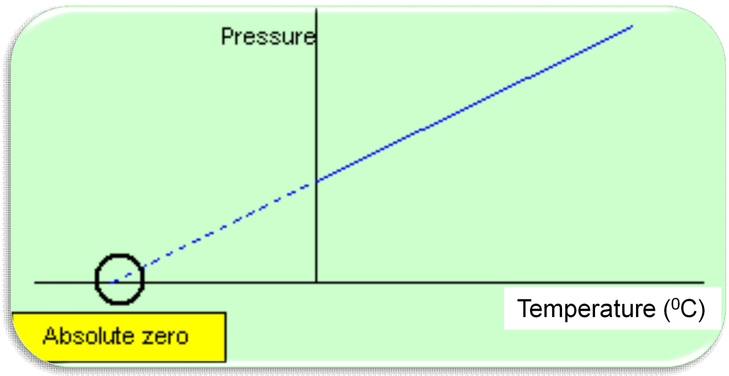
- Explanation
  - All liquids expand more than solids
  - The volume of the liquid gets greater as it is heated
  - The greater the rise in temperature the more it expands
  - The actual change in shape of the liquid depends on the shape of the container that it is in

Expansion of gases

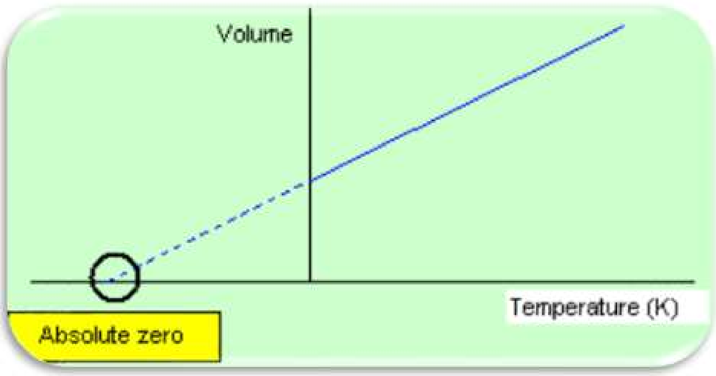
- Explanation
  - When the gas is heated the molecules in the gas move round faster
  - They are being given energy in the form of heat so they gain kinetic energy
  - The molecules bang into each other and into the walls of the container more violently and more often
  - This increases the pressure and so the gas tries to expand

The pressure law

- For a fixed mass of gas at constant volume, the pressure is directly proportional to the Kelvin temperature
- Equations
  - $\frac{\text{Pressure (Pa)}}{\text{Temperature (K)}} = \text{constant}$
  - $\frac{\text{Pressure 1}}{\text{Temperature 1}} = \frac{\text{Pressure 2}}{\text{Temperature 2}}$
  - $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
- Absolute zero
  - It is the temperature where the gas molecules have their minimum energy
  - Pressure is zero at absolute zero
    - The molecules have stopped moving
    - No velocity so no kinetic energy
- Graph

- 

<u>The expansion of gas / Charles' law</u>

- Equations
  - $$\frac{\text{Volume of a gas}}{\text{Absolute temperature of a gas}} = \text{constant}$$
  - $$\frac{\text{Volume 1}}{\text{Absolute temperature 1}} = \frac{\text{Volume 2}}{\text{Absolute temperature 2}}$$
  - $$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$
- As long as the pressure of the gas is kept constant
- Graph
  - 

<u>Explaining Boyle's law</u>

- Gas made up of moving particles constantly moving about and hitting the wall of their container
- They change their momentum when hitting the wall of the container so there must be force exerted on the wall of the container
- Force is exerted on the wall of the container creates the pressure
- If volume of gas is halved, there will be twice as many particles per cubic metre
- Twice as many impacts with wall, so pressure doubles

5d Heat transfer

2023年3月19日 11:16

Conduction

- Thermal conduction occurs best in solids
- Metals are materials which are good conductors of heat
- Process
  - As the temperature of a solid is increased, the particles vibrate with higher amplitude and faster, so they gain more kinetic energy
  - The increase in kinetic energy is passed onto adjacent particles through collision, causing them to vibrate more
  - In this way heat is passed from one end of the solid to the other
- Conduction in metals
  - Metal atoms exist as positively charged metal ions in a regular lattice structure
  - The ions are surrounded by negatively charged electrons
  - Some of the electrons are delocalised and are able to move within the metal
  - Vibrating atoms / ions can transfer energy to free moving electrons by collision
  - When these electrons move through the metal and collide with other electrons / atoms in colder regions, they transfer their kinetic energy, which heats up the colder regions
  - Thermal energy are rapidly transferred in this way

Conductors and insulators

- Transfer of heat occurs very quickly in metal but much slower in non-metals
- Non-metals are therefore used as insulators
- Metals > non-metals > liquids > gases

Convection in water

- Process
  - When the beaker is heated the glass conducts heat into the water which is heated
  - When heated, the water expands and becomes less dense
  - It rises up to surface as the cooler water sinks to displace it
  - The result is a circulating stream called a convection current
  - The heated water that rises has particles with more kinetic energy which vibrate more
  - As they rise the pass on their energy to other parts of the water
  - 

Convection in air

- Convection in atmosphere
  - Warm air in land is heated by the sun so it expands and become less dense
  - Warm air rises above equator and displaced by cooler, denser air sinking to the north or south
  - Result in huge convection currents in the Earth's atmosphere
  - Cause winds across all oceans and continents
- Sea breeze
  - Land heats up more quickly than the sea during the daytime (water has a high specific heat capacity)
  - Warm air rises above the land and is displaced by cooler air moving in from the sea
- Land breeze

- The sea stays warmer than land at night because land cools down quickly (water has a high specific heat capacity)
- Warm air rises above the sea and is displaced by cooler air moving out from the land

Using convection at home

- Radiator
    - The hot radiator gives out heat to the surrounding air as the air molecules collide with the surface of the radiator.
    - As the air becomes hotter it expands and becomes less dense
    - The less dense hot air rises towards the ceiling and displaces the cooler air near the ceiling
    - The cool air gradually falls to take the place of the hot air near the radiator
    - As the cooler air molecules collide with the surface of the radiator, they gain heat and the cycle starts again
- Hot water system
    - Cold water in the storage tank sinks to the boiler, where it is heated
    - The heated water rises to the top of the storage tank to displace the colder water, forming an convectional current
    - The tank is insulated to reduce thermal energy losses by conduction and convection
    - The header tank provides the pressure to push the water out of the taps

Radiation

- Radiation is the transfer of heat by infrared waves
- Can travel through the vacuum (how heat and light from the Sun reaches the Earth)
- Travel at the speed of light in a straight line
- Heat up things that absorb them
- Thermal radiation is a mixture of different wavelengths
    - Mainly infrared waves but very hot objects also emits waves with shorter wavelengths which may include visible light waves
- Transfer
    - An object warmer than the surroundings emits more infrared radiation than it absorbs
    - An object colder than the surroundings absorbs more infrared radiation than it emits
- Emitters and absorbers
    - The temperature remain constant if the object absorbs and emits radiation at the same rate
    - How well the surfaces emit infrared radiations
        - Matt black > white > silver
    - Light, shiny surface = good reflector = poor absorber and emitter
    - Dark, matt surface = poor reflector = good absorber and emitter

5e Liquids & vapours

2023年5月7日 19:20

Evaporation process

- The molecules in a liquid are in a state of continuous motion
- Some moving faster than others
- In the middle of the liquid they collide with each other but at the surface of the liquid some of them have more kinetic energy and can escape from the liquid altogether
- Only the surface molecules evaporate, no bubbles of gas formed in the body of liquid

Methods to accelerate evaporation

- Increase the temperature
  - More of the particles have enough energy to escape
- Increase the surface area
  - More molecules are close to the surface
  - Only surface particles can escape so more particles can now escape into air
- Blow air across the surface
  - The moving air carries escaping water molecules away before many of them can return to a liquid

Boiling

- A very rapid form of evaporation
- Bubbles of gas form deep in the liquid
- They expand, rise, burst, and release large amounts of vapour
- Occur at one precise temperature for a liquid (the boiling point)

Pressure's effect on boiling temperature

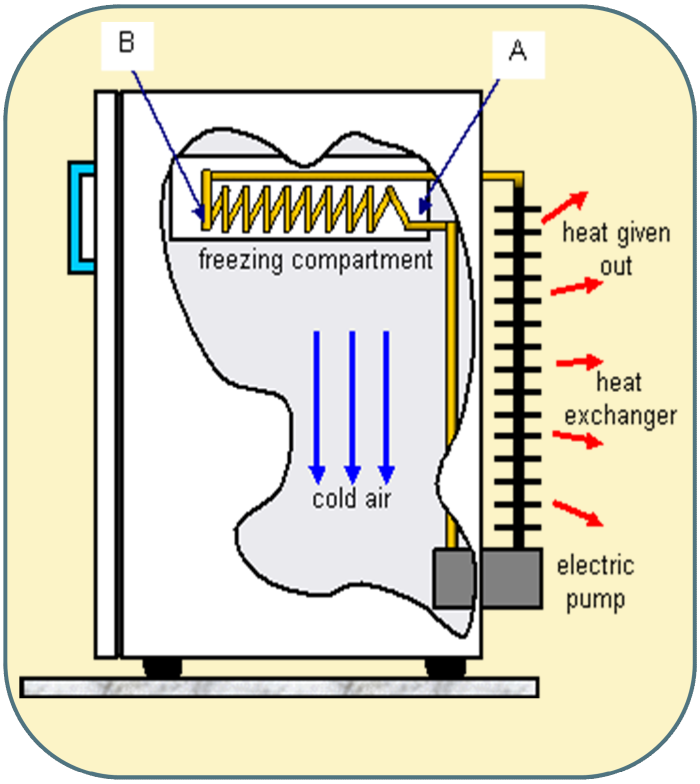
- The pressure of vapour in the bubbles is the same as the air pressure above the surface of the liquid
- Increased pressure raises the boiling point
- Decreased pressure lowers the boiling point

Cooling by evaporation

- The fastest liquid molecules at the surface leave the liquid in evaporation
- Temperature relates to internal energy, if internal energy decrease temperature decrease
- The average kinetic energy of the liquid molecules decreases so the internal energy decrease so temperature of the liquid falls

Refrigerator

- Heat pump
- In a refrigerator, heat is removed from the surroundings at one point (the freezing compartment) and given out to the surroundings at another (the heat exchanger)
- A volatile liquid evaporates through a small hole into the coils because of the low pressure
- As it does so it cools down taking heat from its surroundings and so the freezing compartment gets colder.
- The electric pump then forces this cold vapour into the heat exchanger coils where it is compressed and turns back into a liquid getting hotter in the process
- This means that the liquid is now hotter than the outside of the fridge, giving out heat to the surroundings
- The whole cycle is then repeated

- 

<u>Condensation (of water vapour)</u>

- As warm, moist air rises it cools
- It is unable to hold so much water so the water vapour condenses as millions of minute droplets (clouds)
- As more condenses the cloud cannot support itself and so the water falls to the ground as rain

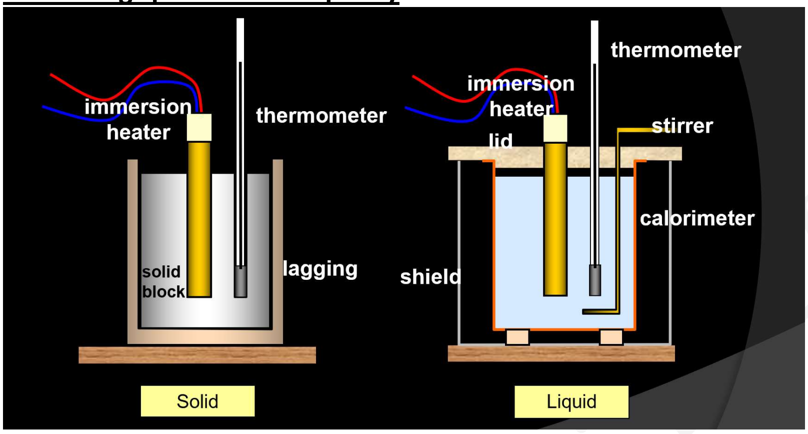
5f Specific heat capacity & latent heat

2023年5月7日 19:20

Specific heat capacity

- The energy needed to raise the temperature of 1kg of an object by 1℃
- A measure of how much heat energy a material can hold
- Specific to that material
- Energy transferred = mass × specific heat capacity × temperature change
- $\Delta E = mc\Delta T$
- Unit = J/kg℃
- Specific heat capacity of water = 4200 J/kg℃

Measuring specific heat capacity

- 

- Energy = Power ✕ Time
- Rearrange the formula
- Make no allowance for any thermal energy lost to the container or the surroundings
- So only approximate value of specific heat capacity
- Calorimeter
    - Low specific heat capacity
    - Reach same temperature as water quickly
    - Less heat transferred by conduction to the calorimeter
    - Shiny - poor absorber of heat radiation
    - Reduce heat loss by radiation

Latent heat

- The amount of energy used to change the state of a substance, without a change in temperature
- Latent heat of fusion
    - The thermal energy a substance needs to gain to change from solid to liquid or given out to change from liquid to solid
- Latent heat of vapourization
    - The thermal energy a substance needs to gain to change from liquid to gas or given out to change from gas to liquid
- Unit = J/g, kJ/kg, etc.

6a Waves

2023年5月7日 19:20

Type of waves

- Transverse wave
  - The oscillation of particles is perpendicular to the direction of wave travel
- Longitudinal wave
  - The oscillation of mechanical particles is parallel to the direction of the translation of energy (direction of wave travel)
  - Have compressions = the particles are squeezed together, and rarefactions = the particles are most spaced out

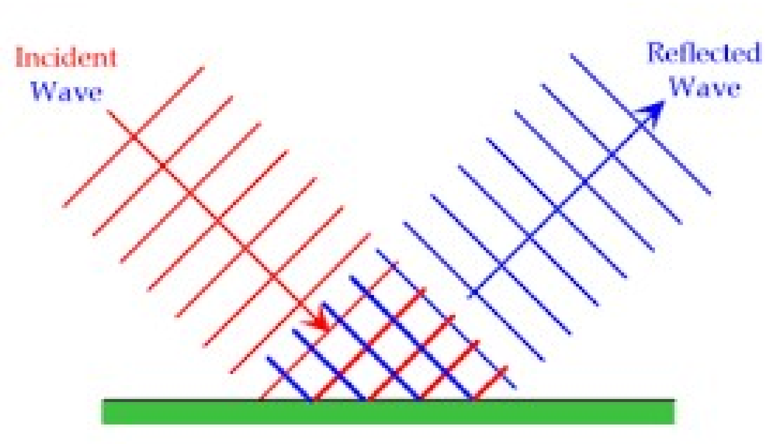
Key terms

- Amplitude
  - The distance of the peak above the centre line or the distance of the trough below the centre line
  - Measured in metres
- Wavelength
  - The distance from peak to peak or trough to trough
  - Measured in metres
- Frequency
  - The number of complete waves per second
  - Measured in Hertz (Hz)
- Speed
  - The distance the wave travels in one second
  - Measured in metres per second (m/s)

Wave formula

- Wave Speed = Frequency * Wavelength
- $v = f\lambda$
- Unit = m/s

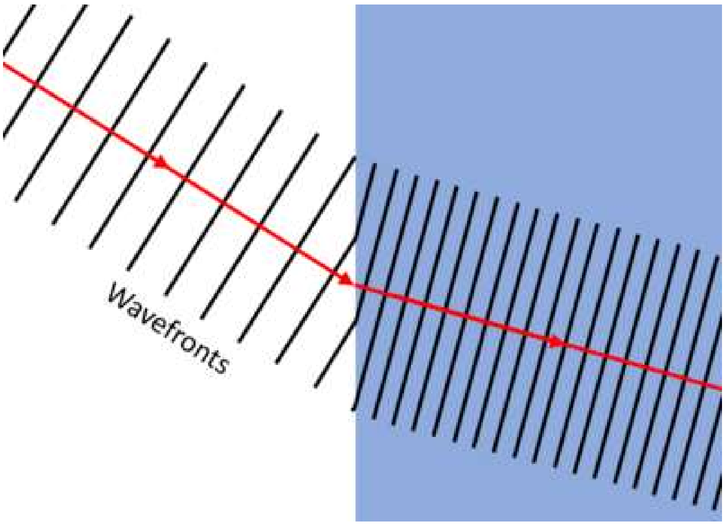
Reflection

- 

- i = r

Refraction

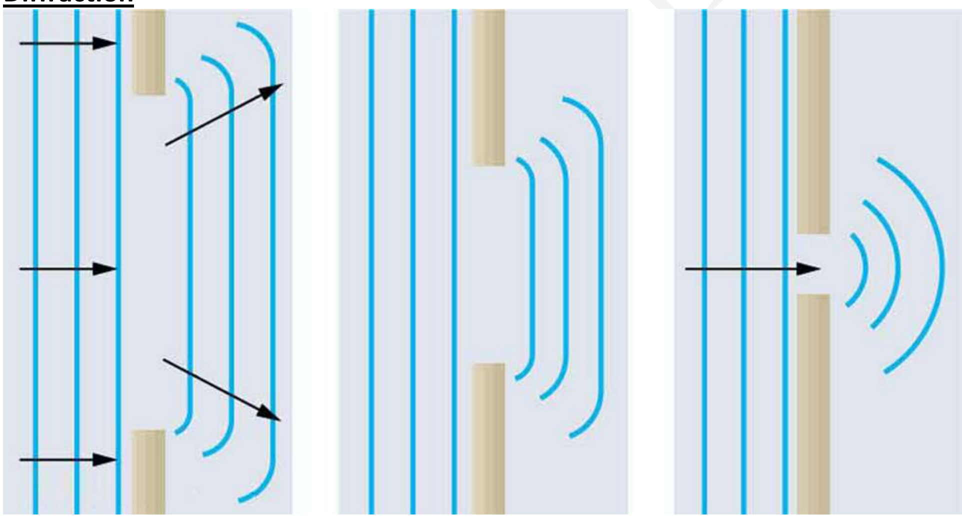
- Cause
  - Refraction means the change of direction of waves when they change speed
  - Refraction usually occurs when a wave moves from one medium to another because of a

    difference of wave speed in the two media
    - If a wavefront approaches at an angle to the surface separating the media, the edge which hits first will slow down / speed up first, causing a change in direction at the wavefront
    - Frequency does not change because number of waves per second is the same so only wavelength change
- Slow to fast = away from normal
- Fast to slow = bend toward the normal
- 

Refraction in ripple tank

- The deeper the water, the faster the waves travel
- So waves will refract (change direction) when they enter deeper or shallower water at an angle

Diffraction

- 
- The waves bend round the sides of an obstacle or spread out as they pass through a gap
- Only significant of the size of the gap is about the same as wavelength
- Wider gap = less diffraction
- Longer wavelength = more diffraction

6b Sound Waves

2023年5月11日 19:00

Sound Waves

- Longitudinal
- Produced when objects vibrate
  - e.g. when a tuning fork hit on a hard surface

How does sound travel in air

- The vibration travel in the same direction as the wave travels
- At some points the air molecules are pushed together increasing pressure (compression)
- At other points the air molecules are further apart decreasing pressure (rarefaction)
- As a result the sound wave travels through the air
- The air particles vibrating backwards and forwards at the frequency of the sound

How do we hear sound waves

- Sound waves carry energy through the air causing other objects such as eardrums to vibrate
- The vibrations are converted to electric signals and carried to the hearing centre in our brain via the auditory nerve

How sound waves travel in solids, liquids and gas

- A medium is needed to transmit sound waves
- The particles making up solids are very close together, so they can transfer sound energy from particle to particle very quickly by collision
- In liquids the particles are relatively close together, so they can also transfer sound waves from particle to particles fairly quickly by collision
- However, in gases the particles are widely spaced, therefore it takes longer for the sound waves to pass from particle to particle by collision
- The more dense the medium, the faster the sound waves travel through it
- Speed of traveling in mediums
  - Gas / air = 340 m/s
  - Liquid / water = 1500 m/s
  - Solid = 5000 m/s

Diffraction of sound

- Sound waves can still be heard even when they cannot travel in a straight line from where they are produced to our ears
- This is because they can be diffracted
- If there were no diffraction there would be areas where sound waves cannot reach
- Size of gap
  - Small gap = large diffraction
  - Large gap = small diffraction

Reflection

- Law of reflection
  - Angle of incidence = angle of reflection
  - i = r
- Normal
  - Line that is perpendicular to the surface
- Reflect best on flat, hard surfaces
  - Soft surfaces absorb the sound wave rather than reflecting it

Echoes

- Made when a sound wave reflects off a hard surface such as a brick wall

- Hearing a reflected sound a short time after the original sound
- Slower because there is a longer distance to travel

Characteristics of sound waves

- Same characteristics as other types of wave, e.g. frequency, amplitude, wavelength
- A microphone can be used to convert the sound wave into an alternating voltage
- The voltage can be displayed on a cathode ray oscilloscope (CRO)

Loudness and pitch

- Amplitude
    - Measure of energy carried by the wave
    - The greater the amplitude the more energy it carries and the louder the sound
    - Doubling the amplitude means that four times as much energy is delivered (squared relationship)
- Frequency
    - All sounds are made by objects vibrating
    - The faster that an object vibrates, the higher the pitch of the sound produced and the greater the frequency
    - Low frequency, long wavelength = low pitch
    - High frequency, short wavelength = high pitch

Range of human hearing

- 20-20000 Hz
- The frequency range for normal human conversation is centred around 800Hz
- As we get older we lose the ability to detect the higher frequency sounds, so the range decreases with age
- Sounds with frequencies above 20,000Hz cannot be heard by humans (but can be heard by some other animals) and are known as ultrasound
- Dogs can hear frequencies up to 45,000H

Uses of ultrasound

- Echo sounder
    - Ships use echo sounders to send ultrasound down towards the sea bed
    - Measures the time taken for each echo to return
    - Find the depth of the sea
- Test for metal flaws
    - A pulse of ultrasound is sent through the metal by a transducer
    - If there is a flaw (tiny gap) in the metal two reflected pulses are picked up by the detector
    - The pulse reflected from the flaw returns first, followed by the pulse reflected from the far end of the metal
    - The pulses can be displayed using an oscilloscope
    - The trace on the screen is a graph showing how the amplitude (strength) of the ultrasound varies with time
    - Determine time taken for the echo from the front and back of the bubble
    - Distance = speed of ultrasound waves in metal (5000 m/s) * time taken to return
- See baby in a womb
    - A transmitter sends pulses of ultrasound into the mother's body
    - The transmitter also acts as a detector and picks up pulses reflected from the baby and different layers within the body
    - The signals are processed by a computer into an image on a screen
    - Using ultrasound is better than X-rays
        - X-rays can cause cell damage
        - Ultrasound can distinguish between different layers of soft tissue which X-rays cannot

7a Light rays & reflection

2023年6月8日 18:53

Ways to represent waves

- Waves
    - Useful for showing:
        - Amplitude
        - Wavelength
- Wavefronts
    - Useful for showing:
        - Wavelength
        - Direction
- Rays
    - Useful for showing:
        - Direction

Features of light

- Light is a form of radiation
    - Spreads out from its source in all directions
    - Rays are used to show the direction of travel of the light
- Light travels in straight lines
    - Travel in the shortest + straightest path between two points
- Light transfers energy
    - Things that produce light use energy
    - Light itself is a form of energy
    - When light moves around is being transferred
- Light travels as waves
    - Some experiments in physics can only be understood if light behaves likes waves e.g. refraction and diffraction
- Light behave as particles
    - Some experiments in physics can only be understood if light behaves likes particles
    - The particles of light are called photons
- Light can travel through empty space
    - Light waves do not need a material to travel through
    - They can pass through a vacuum
- Light is the fastest thing there is
    - No physics experiment has ever measured or recorded a speed faster than the speed of light
    - The speed of light is very fast - 300 000 000 m/s ($3*10^8$ m/s)

Wavelength and colour

- Light come in many colours
- Different colours correspond to different wavelengths
- When all different wavelengths are present at the same time the light appears as white
- Some sources of light are not quite white e.g. tungsten lamp / the Sun is slightly yellow
- Lasers
    - Special in that they can produce light of a very pure single wavelength
- Light of a single wavelength = monochromatic
-

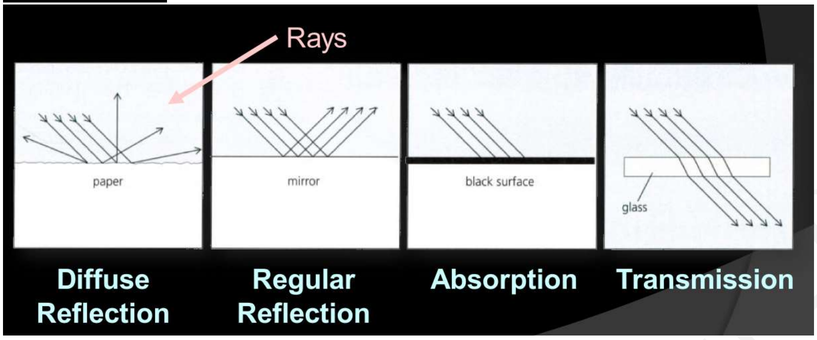
Colour	Wavelength/nm	Frequency/Hz
Red	700	4.3×10^{14}
Orange	620	4.8×10^{14}
Yellow	580	5.2×10^{14}
Green	530	5.7×10^{14}
		14

Blue	475	6.3×10^{14}
Indigo	450	6.7×10^{14}
Violet	400	7.5×10^{14}

How are things seen

- Light must enter eyes to see things
- Some objects produce their own light = luminous
  - e.g. the Sun, light bulb, candle, laser
- Most objects do not produce their own light = non-luminous
  - Reflect light from luminous objects or other non-luminous objects
- Rays of light in sky
  - Visible because they are reflecting off the particles of dust / moisture
  - Bounce into our eyes

Ray diagrams

- 

Reflection in plane mirrors

- Plane mirror
  - A flat mirror that reflects light regularly
  - i.e. all the waves reflect in the same direction
- Best visualised using rays because we are only interested in directions
- In terms of incident rays and reflected rays
- Normal line = a line at right angles (90°) to the surface.
- The angle of incidence is the angle between the incident ray and the normal
- The angle of reflection is the angle between the reflected ray and the normal

Laws of reflection

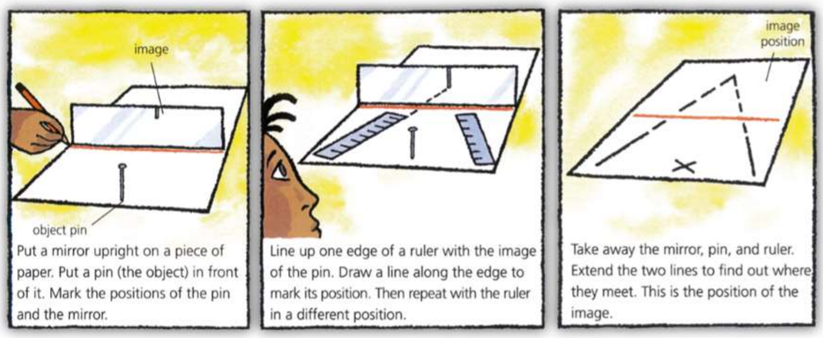
- $\boxed{\text{angle of incidence, i} \ = \text{angle of reflection}, r}$
- $\boxed{\text{the incident ray, reflected ray and normal all line in a plane}}$

Virtual image

- Virtual image = a reflected image of an object seen in a mirror
- Cannot be projected on a screen
- Light rays do not pass through the image
- (Can be) laterally inverted - appear back to front
- Size and position
  - The image is the same size as the object
  - The image is as far behind the mirror as the object is in front
  - Equivalent points in an object and image pass through the mirror at right angles

Find virtual image

- Put a mirror upright on a piece of paper
- Put a pin (the object) in front of it
- Mark the position of the pin and the mirror
- Line up one edge of a ruler with the image of the pin and draw a line along the edge to mark its position

- Repeat with a ruler in another position
- Take away the mirror, pin and ruler
- Extend the two lines to find out where they meet
- Meeting point = position of the virtual image
- 

7b Refraction

2023年6月8日 18:53

Refraction of light

- Refraction
  - The bending of light as it passes between two different media, e.g. water and air
- (Best visualised using rays, best understood using wavefronts, in terms of incident and refracted rays)

Why lights refract

- Light is made of tiny waves
- When the waves travels in different substances it travels at different speeds
- When a light beam passes from one medium to the other at an angle one side of the beam is slowed first, making the beam bend

Wave properties change

- Frequency is the same in refraction (number of waves per second is the same)
- $c=f\lambda$, if the speed decreases and the frequency stays the same the wavelength gets smaller

Direction change

- Fast to slow = bend towards the normal
- Slow to fast = bend away from the normal

Refractive index

- The speed of light in different substances is measured in terms of the refractive index of a substance
- refractive index = $\frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$
- The bigger the refractive index of a substance the larger its bending effect

Snell's law

$\frac{\sin i}{\sin r} = \frac{n_2\,(\text{refractive index of medium 2})}{n_1\,(\text{refractive index of medium 1})}$ (=n or $\frac{1}{n}$)

- $n_{substance} = \frac{C_{vacuum}}{C_{substance}}$

Dispersion / refraction of light through a glass prism

- When light passes from air to glass it refracts because the speed of light is slower in glass than air
- Sides of a prism are not parallel
- When light is refracted it comes out in a different direction (deviated)
- Only prism
  - In rectangular glass blocks there is 1 clockwise + 1 anticlockwise bend, wave entering and leaving are parallel
- White is a mixture of all the colours in the rainbow
- Different colours travel at different speeds in glass
- They refract by different amounts and disperse (spread out) into a range of colours called a spectrum
- Violet refracts most, red refracts the least (draw these in ray diagrams)

Total internal reflection

- Light must pass from medium where it travels slower to medium where it travels faster
- At angles smaller than critical angle the ray splits into a refracted ray and a weaker reflected ray
- At the critical angle the refraction becomes so great that the refracted ray is parallel to the surface (r=90)
- At angles greater than the critical angle there is no refracted ray, all the light is reflected

- This is called total internal reflection
- Critical angle
    - The angle of incidence that gives an angle of refraction of 90°
    - $\sin c = \frac{1}{n}$

Reflecting prisms

- Inside faces of prisms are being used as mirrors
- Total internal reflection occurs because the angle of incidence is greater than the critical angle
- All the light is reflected

Optical fibres

- Very thin flexible rods made use of special glass or transparent plastic
- Light put in one end is total internally reflected along the fibre until it comes out on the other end
    - Prevents escaping
- Although some light is absorbed by the fibre the light comes out almost as bright as it goes in even if the fibre is several km long
- Transmission of data
    - Communications for sending large amounts of digital information around the world quickly
    - Signals are coded and sent along the optical fibres as pulses of laser light
    - Less booster stations are needed than electrical cables
- Endoscopes
    - for looking into a body
    - Light travels down one set of fibres then back up another set of fibres

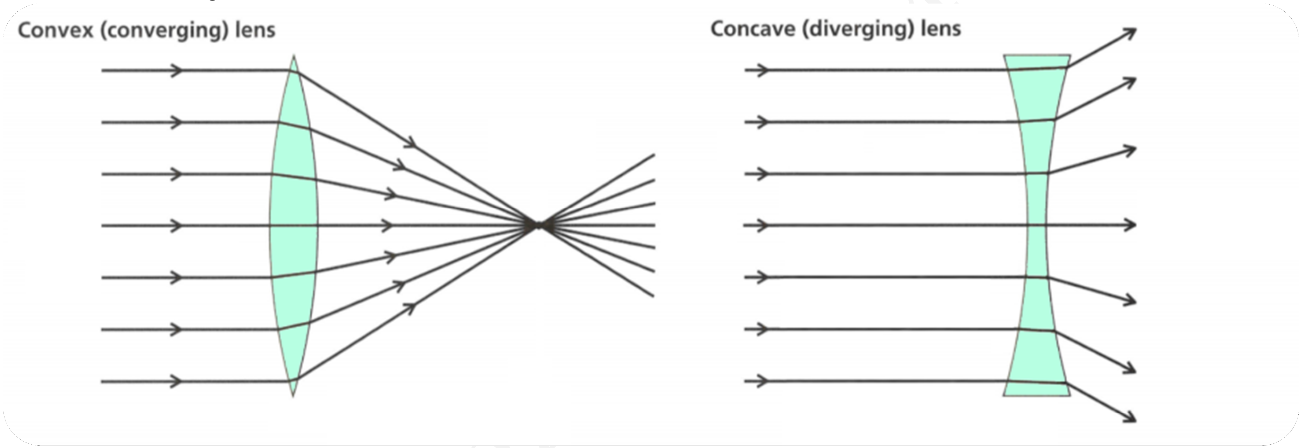
7c Lenses

2023年6月10日 16:50

Lenses

- Use the refractive properties of glass to bend light

Types of lenses

- Convex lenses
  - Thick in the middle
  - Thin at the edge
  - Converge rays (focus)
  - Real image at the focus
- Concave lenses
  - Thick at the edge
  - Thin in the middle
  - Diverge rays (spread out)
  - Virtual image at the focus
- 

Real images formed by convex lenses

- Light from a long distance (further than the principal focus) passed through a convex lens forms a real image that is inverted (upside down)

Properties of image

- If the object is closer to the lens than the principal focus then the rays diverge and a virtual image is formed.
- The virtual image appears larger, i.e. magnified compared to the object
- Real / virtual + upright / inverted + diminished / enlarged

Defects in vision

- The lens in the human eye is flexible
  - Can be made thicker or thinner to change the focal length
  - Focus light onto the retina at the back of the eye.
- With many people the movement of the lens is not enough to focus the light on the retina
- They have to wear another lens (in spectacles or contact lenses) in front of the eye to fix the problem

Correct short sight

- Short sight (myopia) = the lens cannot be made thin enough for looking at distant objects.
- The rays are bent inwards too much.
- They converge before they reach the retina
- To correct the fault a concave (diverging) lens is placed in front of the eye.
- Increase focal length of the eye

Correct long sight

- Long sight (hyperopia) = the lens cannot be made thick enough for looking at close objects
- The rays are not bent inwards enough.
- When they reach the retina they have still not met
- To correct the fault a convex (converging) lens is placed in front of the eye
- Reduce focal length of the eye / put image further away from eye

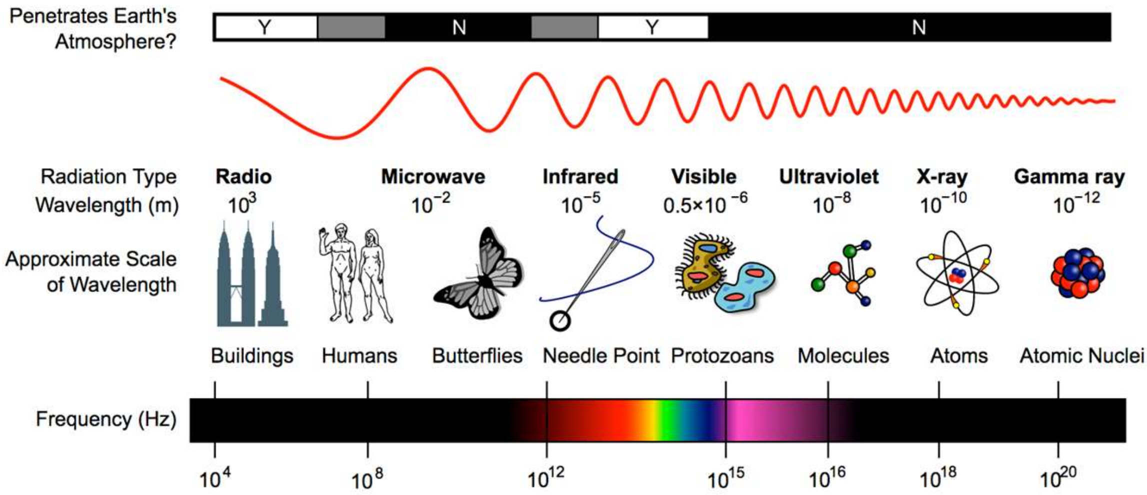
7d E-M waves

2023年9月15日 19:37

Same characteristics of electromagnetic waves

- Can travel in vacuum
- Travel at the speed of light, 3×10^8 m/s
- Transverse waves
    - Oscillations of particles are right angles/perpendicular to direction of travel
- Transfer energy
    - A source loses energy when it radiates electromagnetic waves
    - A material gains energy when it absorbs them

Electromagnetic spectrum

- The full range of electromagnetic waves
- Different electromagnetic waves have different frequencies and hence different energies
- This also means they have a range of wavelengths
- 

Radio waves

- Source
    - Stars emit radio waves naturally
        - Can be detected by radio telescopes
    - Produced artificially by making an electric current oscillate in an antenna
- Long and Medium Waves
    - Diffract around hills so signals can be received even if the direct route is blocked and can be received over long distances
- VHF (Very High Frequency) and UHF (Ultra High Frequency) Waves
    - VHF = stereo radio, UHF = TV broadcasts
    - Shorter wavelengths → do not diffract around hills
    - Need straight path between transmitter and receiver

Microwaves

- Shortest wavelengths of all radio waves
- Uses
    - Used by mobile phones, Wi-Fi, beaming TV, data and telephone signals to and from satellites / across country to transmit data
    - Heating
        - Microwave produce a heating effect when absorbed
        - Absorbed by water and food and can be used to heat them
        - Water absorbs microwaves of one particular frequency
        - Microwave ovens have microwaves that penetrate deep into food and heat up water

inside it

Infrared radiation and light

- All hot objects will emit some amount of infrared radiation due to the motion of their atoms / molecules
- Most radiate a wide range of wavelengths
- As objects are heated it emits more infrared radiation
- As being heated the wavelength becomes shorter and can be seen by the eye
  - Around 700℃ → red hot object
  - Around 1000℃ → the object becomes white hot

Infrared radiation uses

- Security alarms and lamps
  - People emit more infrared radiation than the surroundings
  - Can be switched on by the motion sensors that pick up the changing pattern of infrared caused by an approaching person
- Photographs can be taken with infrared at night
  - People emit more infrared radiation than the surroundings
- Transfer data along optical fibres for telephone and data networks
- Infrared pulses are used by TV remote controllers to transmit signals

Ultraviolet radiation

- Very hot objects, like the Sun, emit radiation beyond the visible part of the spectrum
  - Higher frequency and shorter wavelength
- Release ionising radiation
  - This has more energy than visible light and can ionise atoms in cells
  - Damage living cells, penetrate the skin and cause skin cancer if too much penetrates
  - Can damage retina in the eye and cause blindness

UV radiation uses

- Tanning salons to tan people
- Sterilizing to kill bacteria
- Fluorescence
  - Some materials fluoresce when they absorb UV
    - Convert their energy into visible light and glow
  - Security marker pens contain special ink that is normally invisible
    - Ink fluoresces and glows when UV light is shone on it
  - Also used to spot fake notes
    - Parts of a fake note glow a different colour compared with genuine note

X-rays

- X-rays are produced when very fast moving electrons lose energy quickly
  - e.g. in an X-ray tube electrons are collided with a metal target
- X-rays & gamma rays are high frequency and have a very short wavelength
  - Can penetrate through the human body but are stopped / slowed down by dense materials such as lead
  - Shorter wavelength = more penetrating, can only be slowed down by dense materials
  - Longer wavelength ones cannot pass through bones so they can be used for showing them on an X-ray photograph
- Very high energy and exposure to them can cause damage to living cells and cause cancer / mutations
  - Emit ionising radiation

X-ray uses

- Can be used to take photographs showing bones
  - They can pass through flesh but absorbed by the bones so they show up on an X-ray photograph

- Can reveal flaws in metals / things in luggage
- Treat cancer by using concentrated beams of X-rays to destroy abnormal cells

Gamma rays

- From radioactive materials
- Produced when the nuclei of unstable atoms break up or lose energy
- Tend to have shorter wavelengths than X-rays because the energy change to produce them is greater
- Similar to X-ray uses and damage
    - Can be used to treat cancer / taking X-ray type photograph
    - Used for sterilizing food and medical equipment because they kill harmful bacteria

7e Sending signals

2023年9月15日 23:26

Telecommunication system parts

- An encoder
  - Change information into signals that we can send
  - Encoded into electronic signal / digital signal / flashes of light
- A transmission path
  - Wires / optical fibres / radio waves / infrared waves
- A decoder
  - Decode electrical signal into sound / other useful information

Telephone example

- The encoder will be the microphone turning the incoming information (speech) into electrical signals which can be transmitted
- The signals pass along the transmission path (wires) to the decoder (the earphone)
- The decoder turns the electrical signals back to useful information (speech)

Types of signals

- Changes in voltage
- Changes in the intensity of a beam of light
- Changes in the strength or frequency of radio waves

Analogue digital signals comparison

- Analogue signals
  - Can have any value within a certain range
  - Values can be varied smoothly and continuously over the range
  - The waveform in the information follows the original waveform exactly
- Digital signals
  - The original waveform is sampled at regular intervals
    - Sampling = conversion of an analogue signal into a digital signal
  - Digital signals can only take certain values within a certain range

Advantages of digital transmission

- Noise
  - Attenuation happens
    - Attenuation = signals lose power as they travel along
  - They are also affected by noise (electrical interference)
  - To restore their power and quality, digital pulses can be amplified by regenerators
    - Regeneration = removal of noise from a signal
  - Analogue data can also be amplified but the noise is also amplified so the signals have lower quality when reaching their destination

Sending signals without wires

- Use UHF (ultra-high frequency) radio waves or microwaves to carry the signals
- RFID
  - Radio Frequency Identification, around 14 MHz
  - Used in shops and libraries for identifying which good are being sold or taken
  - A tag or sticker on the product contains a tiny chip to emit data signals
  - Contactless debit and credit cards work this way.
- Satellite phones
  - Around 1600 MHz
  - Work in areas too remote for ordinary mobile phones.
  - Some communicate via satellites in geostationary orbits

    - Others via a network of satellites in low orbits around the earth
- Bluetooth
    - Around 2400 MHz
    - Uses radio waves to link fixed and mobile devices over short distances
        - Typically up to about 10 m, less if walls are present
    - Wi-Fi works in a similar way to Bluetooth
- Mobile phones
    - 4G is around 2600 MHz
    - Linked by a network of masts
    - Use microwaves with wavelengths of a few centimetres, so only need a short antenna inside them
    - Signals are weakened by walls

Optical fibres

- Used by cable TV, high speed broadband and telephone networks for transmission
- Signals are encoded into light by an LED (light-emitting diode) / laser diode and sent along the optical fibres
- Light is total internally reflected along the fibre until it comes out on the other end
- Light is decoded by a photodiode at the receiving end and turned back to electrical signals
- Thinner and lighter than electrical cables
- Carry more signals with less attenuation over long distances and not affected by interferences

8a Electric charge

2023年9月18日 19:15

Charges in an atom

- An electron has a negative charge that is of the same size (magnitude) as the positive charge of a proton
- Neutrons has no electric charge
- As an atom has the same number of electrons and protons it is uncharged

Static and current electricity

- Static electricity
  - The situation when electric charges remain stationary on an object
  - Occurs best with insulators
- Electric current
  - Occurs when electric charges are moving from one place to another
  - Occurs best with conductors

Electrical conductors and insulators

- Electrical conductors
  - Materials through which electric current flows easily
  - All metals are conductors
    - They lose their outer shell electrons
    - The free moving electrons can easily move about and allow charge to flow through the structure
- Electrical insulators
  - Have a very high resistance to the flow of electric current
    - They strongly hold onto their electrons so the electrons can't move about

Charging materials using friction

- When certain insulating materials are rubbed against each other they become electronically charged
- Electrons are rubbed off one material onto the other
- The material that gains electrons become negatively charged
  - e.g. Polythene
- The material that loses electrons is left with an equal positive charge
  - e.g. Perspex

Law of charges

- Like charges repel, unlike attract

Attraction of uncharged objects

- A charged object will attract an uncharged object close to it
- Positive + uncharged
  - e.g. positively charged rod + aluminium foil
  - Electrons in the foil are pulled towards the rod
  - The part closer to the rod become negatively charged, while the part further away is positively charged
  - The closer part is attracted to the rod while the further part is repelled
  - The attraction is stronger because the attracting charges are closer than the repelling ones
- Negative + uncharged
  - Electrons pushed away
  - Other is similar

Detect charge

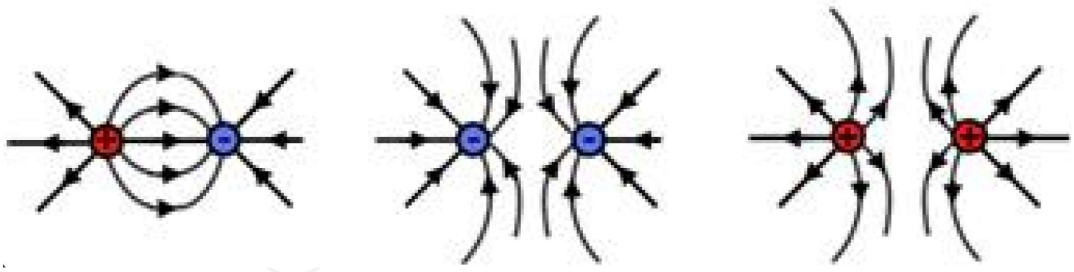
- Gold leaf electroscope - measure static electricity and charge

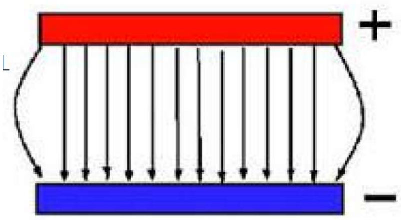
- A metal disc is connected to a narrow metal plate and a thin piece of gold leaf is fixed to the plate
- When a charge is put on or near the disc at the top it spreads down to the plate and leaf
- This means that both the leaf and plate will have the same charge
- Similar charges repel each other and so the leaf rises away from the plate
- The bigger the charge the more the leaf rises

<u>Unit of charge</u>
- Electric charge in a solid is carried by electrons
- One electron has a very tiny charge and so for practical measurement of electric charge we use units called coulombs
- A coulomb= an amount of electric charge
- One coulomb is the charge of roughly $6*10^{18}$ electrons
- The charge of 1 electron is $1.6 * 10^{-19}$ C

<u>Electric field</u>
- When an electric charge is placed near another electric charge it experiences a force
- An electric field exists around all electrical charges
- The electric force does not require contact between the two charges, it acts through space
- The region of space where an electric charge experiences a force due to other charges is called an electric field

<u>Diagrams</u>
- Arrows are defined to show what would happen with a positive charge
- Arrows closer together in the centre = stronger field

- 

<u>Charged plates</u>
- Positive charge attracted to negative plate
- Same strength throughout the field (same distance between the lines)
- 

<u>Van de Graaff generator</u>
- Becomes positively charged by removing electrons
- A person touching the dome of the Van de Graaff generator will also lose electrons and become positively charged
- The person, their head, and each of the hair strands are all positively charged
- The hairs will repel from the head and from every other strand of hair
- Hair stick out from the head in all directions

8b Current, potential difference & resistance

2023年10月23日 22:46

Current

- An electric current = a flow of charge
  - Current = $\frac{\text{Charge}}{\text{Time}}$
  - $I = \frac{Q}{t}$
  - Charge = Current × Time
  - 1A is a coulomb (about $6*10^{18}$) of electrons flowing round the circuit every second
- Measured in amps by an ammeter
  - Ammeter is connected in series with the circuit

Electric current formation

- Electric current = a flow of charge
- In a metal the charge will be carried by electrons
- The force from a voltage supply (e.g. a battery or cell) act on electrons which are free to move causing the movement of charge
- There must also be a complete circuit from one terminal to the other
- The electrons flow from the negative terminal to the positive terminal (opposite to conventional current)
- The electric current is not used up by the components in a circuit but it transfers energy from the voltage source to the various components making up the circuit

Voltage

- A measure of the energy carried by the charge (current) flowing within the circuit
- Formula
  - $Voltage = \frac{Energy\ transferred\ (Work\ done)}{Charge}$
  - $V = \frac{W}{Q}$
  - Unit = volts = joule per coulomb
- The electromotive force and potential difference is measured in volts
  - The voltage of a power supply is an electromotive force (convert other forms of energy into electrical energy)
    - Electromotive force = maximum potential difference
    - Potential difference always add up to EMF
  - The voltage across a circuit component is a potential difference (converting electrical energy into other forms)

Measuring voltage

- Using a voltmeter
- Connected in parallel to the circuit
- Voltmeter measures the loss of energy per unit charge of the electricity between two points

Resistance

- The property of a material which restricts the flow of electricity
  - Higher resistance = more energy needed to be spent for the current to pass through it
  - Spent energy is transferred to another form e.g. heat / light
- Unit = Ohm (Ω)
- Cause
  - As an electric current flows, electrons move through a conductor
  - Moving electrons collide with the atoms of the conductor
    - More difficult for the current to flow

Ohm's law

- $V = IR$
- For a fixed temperature, the current flowing through a resistor is directly proportional to the potential difference across the resistor

Resistance and heating effect

- There is a heating effect whenever a current flows in a resistor
  - This principle is used in heating elements and in light bulb with filaments
- Occurs because electrons collide with atoms as they pass through a conductor
  - The electrons lose energy, the atoms gain energy and vibrate faster
  - Vibrating faster = higher temperature
- Smaller current = smaller heating effect

Factors affecting resistance

- Type of wire
  - Different materials have different resistivity
  - e.g. nichrome wire has more resistance than a copper wire of the same size
- Length of the wire
  - Longer wires = higher resistance
  - The electrons collide with atoms more in a longer wire than in a shorter wire → electrons lose more energy and become slower
  - Double the length = double the resistance
- Cross sectional area of the wire
  - Thinner wire = higher resistance
  - A thin wire has fewer electrons to carry the current than a thick wire
  - Halve the cross sectional area = double the resistance
- Temperature of the wire
  - Metal: higher temperature = higher resistance
    - Atoms vibrate more and take more space
    - Electrons collide with the atoms more often which reduces their speed
  - Semiconductors: higher temperature = lower resistance
    - Heating = more electrons start to conduct electricity

Resistivity

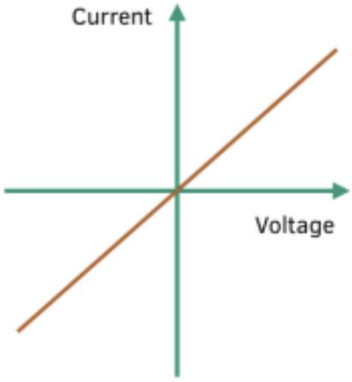
- The resistance between two opposite faces of a $1m^3$ specimen of the material
- Unit for resistivity = Ωm
- Symbol = ρ
- $\rho = \frac{RA}{L}$
- $R = \frac{\rho L}{A}$

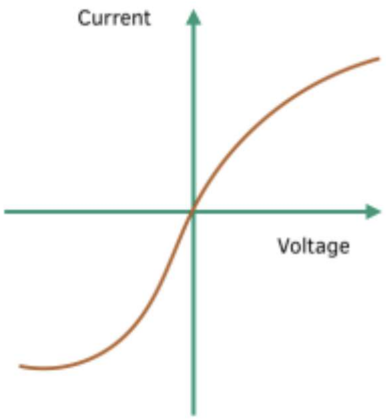
Types of resistors

- Resistors
  - Specially made to provide resistance
  - Reduce the current in simple circuits
  - Keep currents and p.d.s at the levels needed for other components in more complicated circuits so they work properly
- Variable resistor / rheostat
  - Vary the current in many different circumstances
  - e.g. increasing brightness, increasing volume
- Thermistor
  - Higher temperature = lower resistance
  - Contain semiconductor materials
    - As temperature increase more electrons will start to conduct electricity
- Light-dependent resistor (LDR)

- Higher light intensity = lower resistance
- Diodes
  - Extremely high resistance in one direction but a low resistance in the other direction
  - Allow the current to flow in one direction only
  - Used in electronic circuits

Current voltage graphs

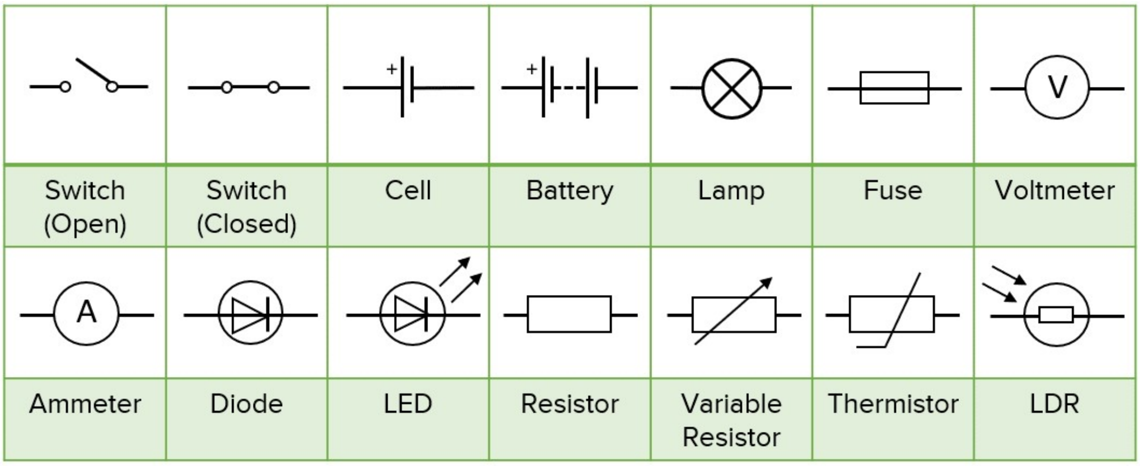
- Ohmic conductors
  - Resistance remains constant as long as its temperature remains constant
  - Current is directly proportional to voltage
  - e.g. resistor
  - 

- Non-ohmic conductors
  - As the current increase the temperature rises and the resistance goes up
    - Gradient decreases = resistance increases
      - $Gradient = \frac{1}{Resistance} = \frac{I}{V}$
  - Current is not proportional to voltage
  - e.g. filament lamp
  - 

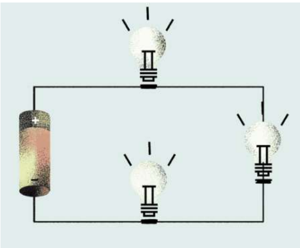
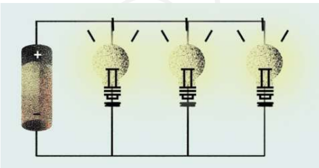
8c Series & parallel circuits

2023年10月23日 22:46

Electrical symbols

- 

Series and parallel circuits

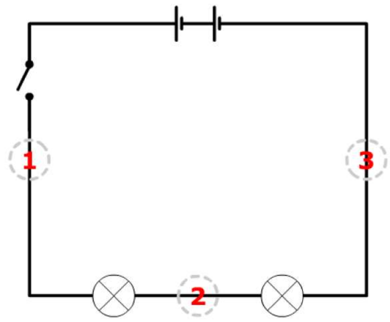
- Series circuit
  - Consists of a string of two or more components, connected end to end
  - e.g.
    - 
    - If one lamp goes out, the other goes out as well because the circuit is broken
    - Lamp glow dimly because they share the voltage from the battery
- Parallel circuit
  - Consists of two or more components attached along separate branches of the circuit
  - e.g.
    - 
    - Each gets full potential difference from the battery because each is connected directly to it → glow brightly
    - If one lamp goes out the other keeps working because it is still part of an unbroken circuit

Parallel circuit advantage

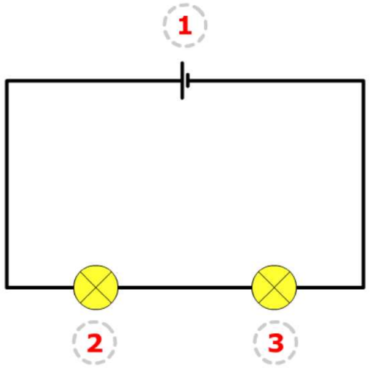
- The components can be individually controlled, using their own switches
- If one component stops working the others will continue to function
- All bulbs can get the normal brightness / correct voltage / voltage of the power supply

Properties

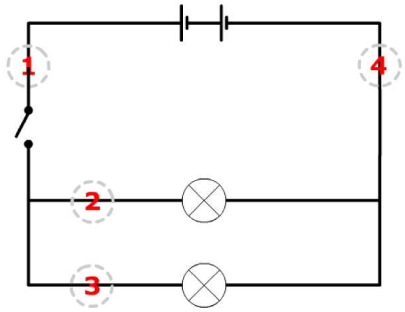
- Series
  - Current
    - The current is the same at all points

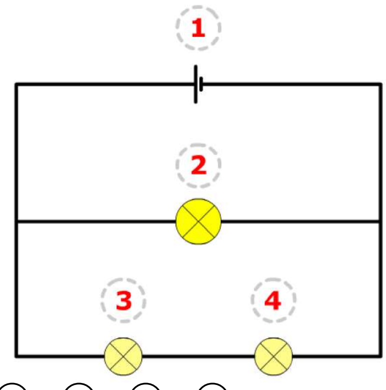
- 

- ① = ② = ③

• Voltage
  - The sum of potential differences across the components is equal to the total EMF of the power supply
  - 

  - ① = ② + ③

• Parallel circuit
  • Current
    - The current splits up
      ▪ Some of it going one way and the rest going the other
    - Total current in the circuit = sum of the currents in the branches
    - 

    - ① = ② + ③ = ④
  • Voltage
    - Total voltage of a parallel circuit has the same value as the voltage across each branch
    - 

    - ① = ② = ③ + ④

<u>Series and parallel resistors</u>

• Two resistors in series

    - $R = R_1 + R_2 = R_1 + R_2 + R_3$
- Two resistors in parallel
    - $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
    - $R = \frac{R_1 R_2}{R_1 + R_2} = \frac{R_1 R_2 R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3}$
    - R = effective resistance of the two resistors in parallel
- Two resistors in series always have a greater resistance than either of the resistors on their own
- Two resistors in parallel always have a lower resistance than either of the resistors on their own

8d Power & mains electricity

2023年10月23日　　22:46

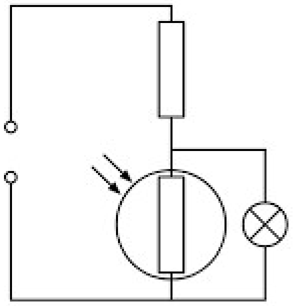
Diodes

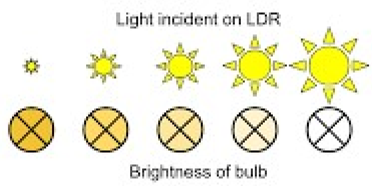
- Only let current flow in one direction in a circuit
  - When a diode is forward biased it has extremely low resistance and current can flow
  - When a diode is reverse biased it has an extremely high resistance and current cannot flow
- Used to control current flow

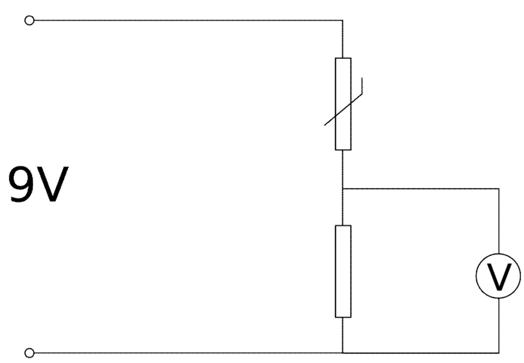
Light-emitting diodes (LED)

- Works the same as a regular diodes
- Gives off light when a current flows in the forward direction
- Very efficient as turning electricity into light
  - A very tiny amount of current is needed to produce a bright light
- Often used in electronic circuits as output devices

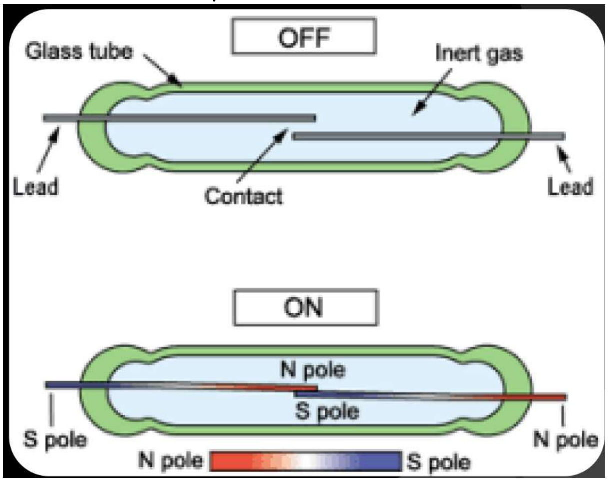
Potential divider

- An arrangement in a circuit that delivers only a proportion of the voltage from the battery
- Uses
  - LDR
    - When it is bright the LDR has a low resistance - small potential across lamp → lamp off
    - When it is dark the LDR has a high resistance - large potential across lamp → lamp is on
    - 



  - Thermistor
    - When it is cold the thermistor has a high resistance - small potential across buzzer
    - When it is hot the thermistor has a low resistance - large potential across buzzer → buzzer turned on
    - 

Reed switch

- Consists of a glass tube with two iron reeds sealed inside it
- If the iron is unmagnetised there is a gap between the reeds and no current can flow
- If a magnet is brought near the reed switch it magnetises each iron reed
- The two iron reeds are attracted to each other, and they bend to touch each other
- The circuit is completed and current can flow
- 

Reed relay (see 9b)

- A reed switch put inside a coil of wire (an electromagnet) then it can be operated by the current in the coil
- A small current in the coil can switch on a larger current in the reed switch

Electrical power and energy equation

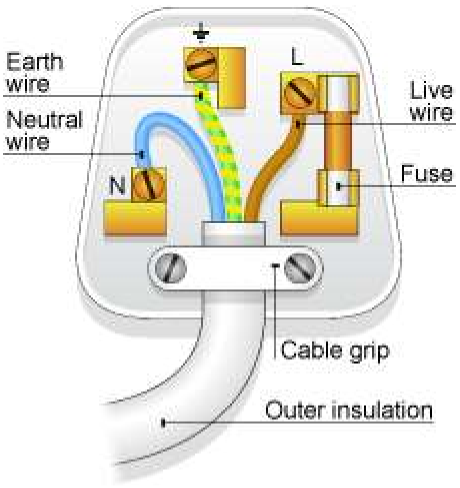
- $P = VI = I^2R = \frac{V^2}{R}$
- $E = P \times t = V \times I \times t$

DC & AC current

- Direct Current (DC)
  - Provided by individual cells and batteries which have a positive and negative terminal
  - Provide electricity flowing in one direction.
- Alternating Current (AC)
  - Domestic electricity supplies are provided as AC
  - Change the direction of current 50 times a second, giving it a frequency of 50 Hertz

Three core cable

- The live wire
  - Goes alternatively negative and positive
  - Making the alternating current flow back and forth in the circuit
- The neutral wire
  - Completes the circuit
  - Stays at a potential difference of zero
- The earth wire
  - Included for safety
  - At zero volts

- 

Metal casing

- Metal encasing of electrical appliances should be connected to the earth wire
- If the live wire breaks and touches the metal casing, the earth wire provides a low-resistance path for the current,
    - Causing the fuse to blow and turning the circuit off.
- In the absence of an earth wire, anyone touching the casing of the faulty appliance would receive an electric shock
    - Current would pass through them to Earth

Double insulation

- Outer casing is composed of a double layer of insulator
- The electrical parts are insulated and cannot come into contact with the user
- People cannot receive an electric shock even if the wires inside become loose and touch the outer casing
- These appliances do not need an earth wire

Fuse

- When the current is too high the fuse wire begins to heat up, glows and then melts → 'blown'
- The melting of the fuse breaks the circuit and cuts the electrical supply to the appliance → the cable does not catch fire
- Placed in the live wire
- (Often replaced by circuit breakers nowadays)
- Power of the fuse
    - A bit higher than the power of the normal circuit

Residual current device / RCD

- Compares the current in the live and neutral wires ← should be the same
- If they are not the same there is residual current (current flowing to earth) → the device breaks the circuit
- A reset button can be pressed as soon as the fault in the circuit has been fixed
- Does not protect against a short circuit ← fuse / circuit breaker needed

Causes of residual current

- The live wire being cut → in current leaking away to earth
- Device failure, such as a bulb blowing → leaks current temporarily just prior to the bulb blowing

Advantages over a fuse

- An RCD does not have to be replaced when it stops the circuit
- A fuse does not detect differences in current between the live and neutral wires - it only detects the flow of excess current
    - A fuse will not detect a leakage of current to Earth.

Safety precautions

- Never use electrical appliances in the bathroom
- Never overload circuits
- Never use an appliance with a frayed or damaged cable
- Never touch electrical plugs or sockets with wet hands
- Never insert objects into wall sockets
- Never place objects on top of an electric cable

9a Magnets

2023年11月22日 15:27

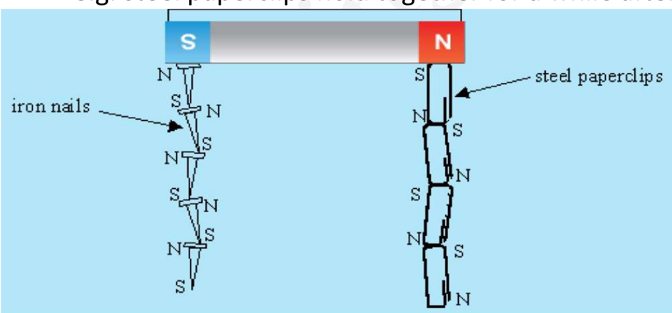
Magnetic materials

- Materials which can be magnetised and is attracted to magnets
- All strongly magnetic materials e.g. steel contain iron / cobalt / nickel
- Strongly magnetic metals = ferromagnetics

Poles

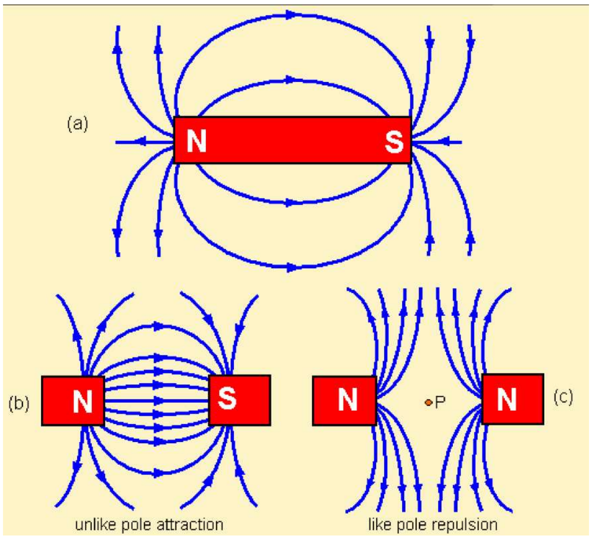
- The places where the magnetism of the magnet is greatest (where the magnetic forces are from)
- The Earth exerts forces on poles of a magnet
    - When a magnet bar is suspended one pole will point to the north and the other pole points to the south
    - North-seeking / south-seeking pole
- Like poles repel; unlike poles attract
- The closer the poles, the greater the force between them

Induced magnetism

- The bar magnet induces magnetism to materials such as steel and iron when placed nearby them
    - Attracted to magnets because they themselves become magnetised
- The induced pole nearest the magnet is opposite to the pole at the end of the magnet
    - Attract together as unlike poles attract
- Magnetically soft / hard
    - Iron = magnetically soft
        - It is easy to magnetise but also loses its magnetism easily
        - Used for making electromagnets so it can be switched on / off easily
        - e.g. iron nails fall apart immediately after the magnet is removed
    - Steel is said to be magnetically 'hard'
        - Difficult to magnetise but do not easily lose their magnetism
        - Used for making permanent magnets so it is difficult to demagnetise
        - e.g. steel paperclips hold together for a while after the magnet is removed
    - 

Magnetic fields

- The area around a magnet where its magnetism can be felt
- If a compass is put into the magnetic field it will point along the direction of the magnetic field
- Neutral point
    - When two magnetic fields overlap they may cancel out at some place
    - A point where the resultant magnetic force is zero

- 

- Arrow = effect on north pole

<u>Investigating magnetic field</u>

- Iron filings method
  - Place a sheet of paper on top of a bar magnet and sprinkle iron filings thinly and evenly onto the paper from a container of iron filings
  - Tap the paper gently with a pencil and the filings should form patterns of lines of force
  - Each filing turns in the direction of the field when the paper is tapped
- Plotting compass method
  - Lay the bar magnet on a sheet of paper
  - Starting near one pole (N end here)
  - The positions of the ends (S and N) of the compass are marked by a pencil
  - Compass is then moved so that the S end is at where the N end used to point to
  - The new position of N end is marked
  - Repeat processes of marking the dots
  - Join the dots and this gives the plot of the magnetic field lines

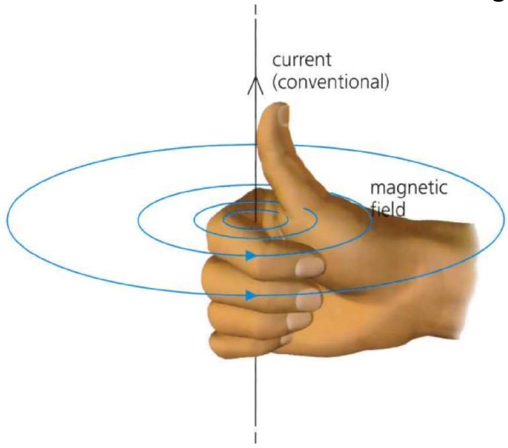
9b Electromagnets

2023年11月22日 15:28

Magnetic field around a wire

- When a current flows through a wire a magnetic field is created around the wire
- Properties
  - The magnetic field line are circles
  - The magnetic field is stronger closer to the wire
  - Larger currents produce stronger magnetic fields

Right-hand grip rule

- With the thumb of your right hand pointing in the direction of the current, your fingers will curl in the direction of the magnetic field
- Reversed current direction = reversed magnetic field direction
- 

Magnetic fields from solenoids / electromagnets

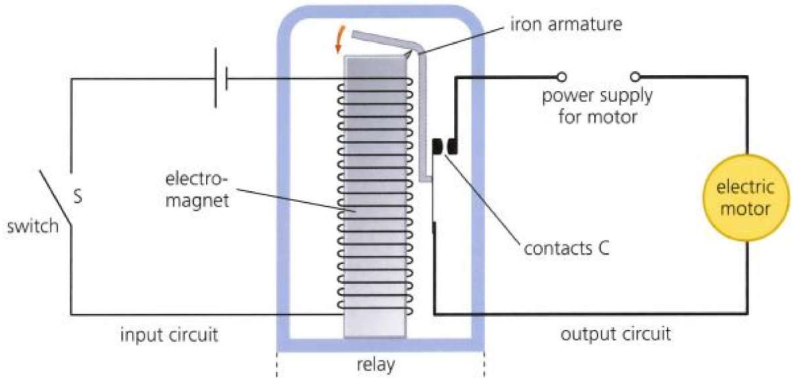
- An electromagnet can be made by wrapping a length of insulated wire into a coil and connecting it to a source of electricity
  - A current produces a stronger magnetic field if the wire it flows in is wound into a coil
- Same field shape to bar magnet with poles at the end
  - Right-hand grip rule for solenoids
    - Align your right hand around the solenoid so that your fingers curl in the direction of the (conventional) current
    - Your thumb now points to the North pole of the solenoid
- If the current direction is reversed, the North and South poles swap ends

Increasing electromagnet strength

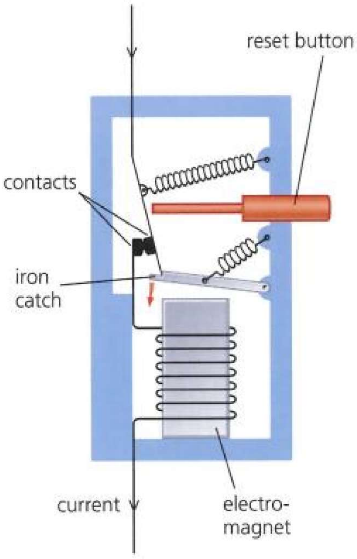
- Increasing the current
- Adding a soft iron core (the core is magnetised by the current flowing around the coil)
- Increasing the number of coils of wire
- Bringing the poles closer together

Electromagnetic relay

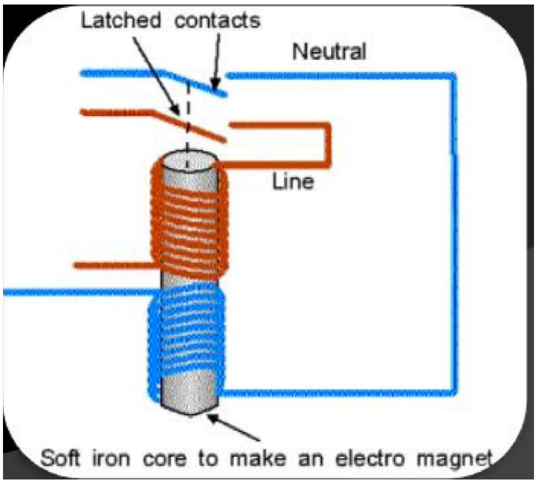
- When the switch is closed a current is passed through the coil so the core becomes magnetised
- The core then attracts the iron armature, which is pivoted, causing it to close the contacts → the current can flow in the output circuit as it is now a closed circuit
- When the current is switched off, the iron armature loses its magnetism and the contacts are released → the current is switched off in the output circuit as the circuit is broken
- Can be used as remote switch switching on a secondary circuit carrying a larger current

- 

Electromagnetic circuit breaker

- If the current flowing around the circuit becomes too high, the magnetic field in the coil pulls the iron catch
  - Allows the contacts to separate and breaks the circuit
- The system can be reset manually but will always switch itself off if a fault is detected
- 

Electromagnetic RCD

- The coil of the live wire is wound the opposite way around to the neutral wire so the direction of the magnetic field is opposite as well
- This means that if the current is the same in both coils there will be no resultant magnetic field
- If one coil has a larger current passing through it than the other there will be a resultant magnetic field and the contacts will be attracted and break the circuit
- 

The motor effect

- A wire carrying an electric current in a magnetic field experiences a force and the wire moves
  - No force is produced if the wire is parallel to the magnetic field

- Why does the wire move
  - When a current passes along a piece of wire, it establishes a magnetic field around the wire
  - If this wire is then placed between the North and South poles of a magnet, the two field overlap
  - In some places the two fields are in the same direction so they reinforce each other, resulting in a very strong magnetic field
  - In other places, the fields are in opposite directions so they cancel out each other and the resultant magnetic field is much weaker
  - The wire experiences a force pushing it from the stronger part of the magnetic field to the weaker part
- Fleming's left hand rule

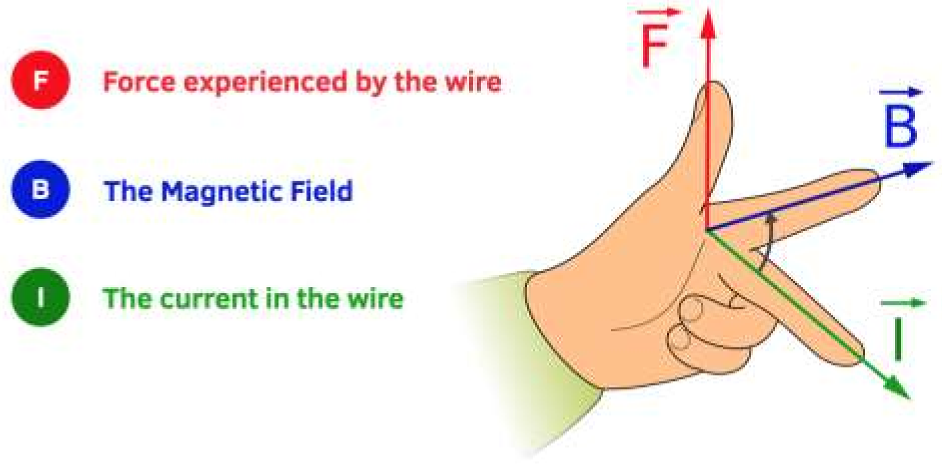


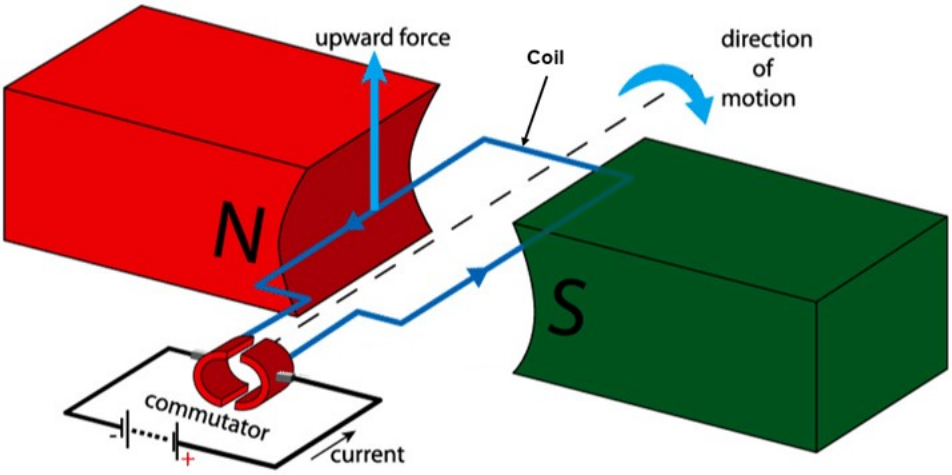
Fig 1. Fleming's Left Hand Rule.

Turning effect on a coil of wire

- The current flows in opposite directions along the two sides of the coil
- So one side is pushed up and the other side is pushed down → turning effect on the coil

Simple D.C. motor

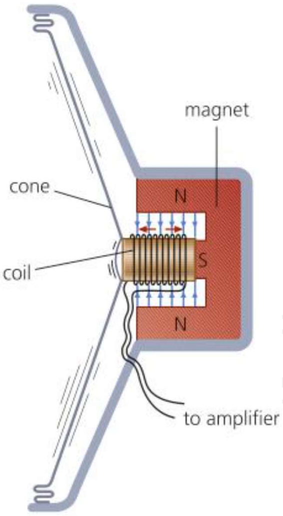
- Coil made of insulated copper wire, free to rotate between poles of magnet
- Coil horizontal = forces furthest apart + maximum turning effect on the coil
  - Eventually come to rest in the vertical position with no changes to forces + no turning effect
- The commutator / split-ring
  - Rotates with the coil, and the brushes make electrical contact with the commutator / split-ring
  - As the coil rotates to vertical position the current alternates direction → forces changes direction and push the coil further forward until it is vertical again
  - Without the commutator the motor would come to rest (no perpendicular distance = no moment for turning)
  - Alternates the current every 180° of rotation
- Brushes
  - Two contacts which rub against the commutator and keep the coil connected to the battery
  - Allow current to flow through so the coil can rotate
- Curved pole = keep magnetic field radial

- 

Factors increasing the turning effect

- Increasing the current
- Using a stronger magnet
- Increasing the number of turns on the coil

Moving coil loudspeaker

- The cylindrical magnet produces a strong radial magnetic field perpendicular to the wire of the coil
- The coil is free to move backwards and forwards
- The loudspeaker is connected to an amplifier which gives out alternating current
- When a constantly varying current, in both size and direction, is passed through the coil, the magnet is pushed in and out
- This causes the flexible speaker cone or diaphragm to move in and out (vibrate), producing the sound waves that we hear
- 

9c EM Induction

2024年1月10日 18:51

Electromagnetic induction in a moving wire

- When a wire is moved across a magnetic field a small emf (voltage) is induced in the wire due to the wire cutting the magnetic field lines
- If the wire / coil is part of a circuit them the emf causes a current to flow

Factors increasing the current induced in the moving wire

- Moving the wire faster
- Using a stronger magnet
- Increasing the length of wire in the magnetic field (e.g. more turns on the coil)

Electromagnetic induction in a coil

- When a magnet is moved in and out of a coil a small emf (voltage) is induced in the coil due to the coil cutting the magnetic field lines
- If the coil is part of a circuit then the emf causes a current to flow

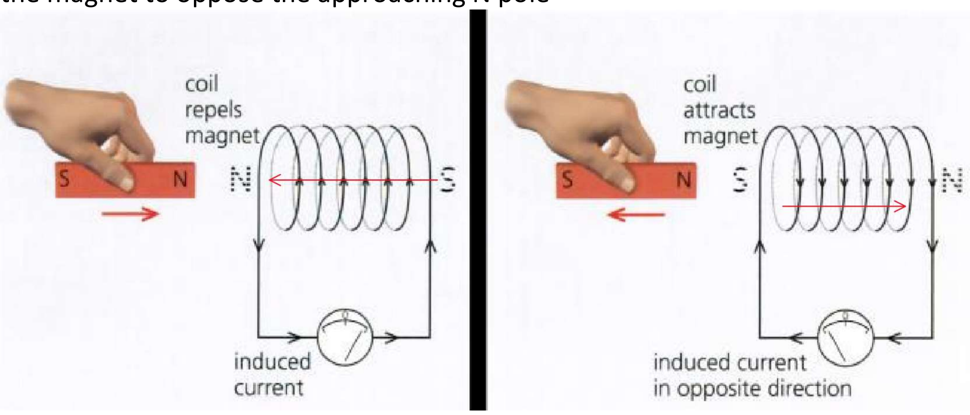
Factors increasing the current induced in the coil

- Moving the magnet faster
- Using a stronger magnet
- Increasing the number of turns in the coil

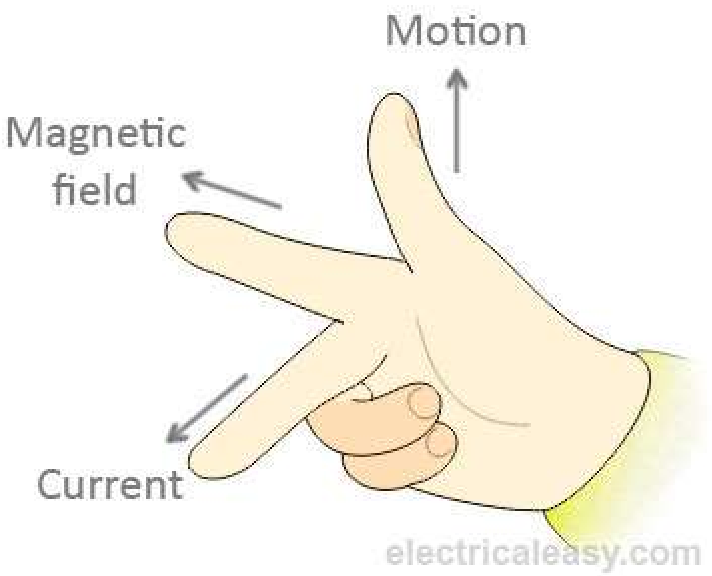
Faraday's Law

- The induced emf in a conductor is proportional to the rate at which magnetic field lines are cut by the conductor
- Stopping the induced emf
  - There is no motion
  - Motion is parallel to the magnetic field lines
  - No field line cut = no induced emf
- Reversing the induced emf
  - Reversing the direction of motion
  - Reversing the magnetic field direction

Lenz's law

- An induced current always flows in a direction which that it opposes the change that produced it
  - (stop / reduce induction)
- e.g. when N pole of magnet is pushed towards the coil the coil forms an N pole at the side closer to the magnet to oppose the approaching N pole
- 

Fleming's right hand rule

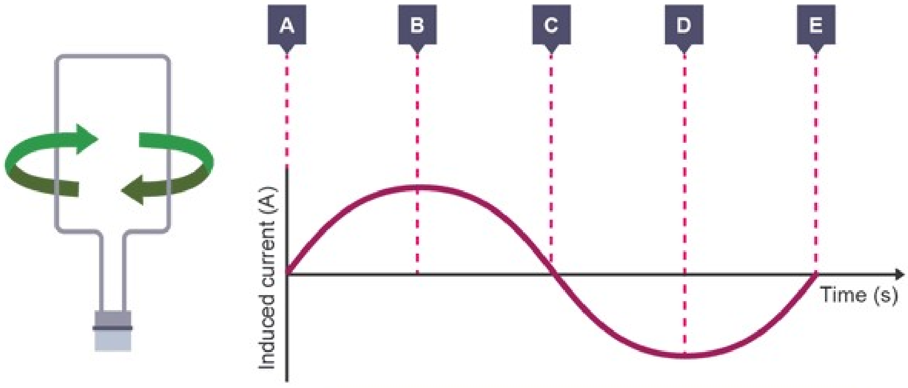
- 

- (When a current causes a motion = left hand rule, motion causes current = right hand rule)

Using left hand rule + Lenz's law to work out direction
- e.g. the upward motion produces a current
- The induced current is in the magnetic field, so there is a force on the wire (normally given by left hand rule)
- The force must be downward to oppose the motion from Lenz's Law
- Use the direction of force and the left-hand rule to work out the direction of the induced current
- (This gives the same answer as the right-hand rule!)

Generators
- All generators generate electricity using electromagnetic induction
- When a generator is turned it induces an emf which can make a current flow
- Typically produce alternating current
- A.C. generators = alternators

Simple A.C. generator
- Structure
    - A coil made of insulated copper wire and rotates inside a magnet
    - Slip rings are fixed to the coil and rotate with it to make electrical contacts
    - Carbon brushes rub against the slip ring and provide the generated power to the outside circuit
- Explanation
    - When the coil is rotated it cuts the magnetic field lines and an emf is generated which makes a current flow in a circuit
    - As the coil is rotates each sides moves upward and downward repeatedly through the field lines, so current also flow backwards and forwards
        - Direction changes every 180° of rotation
    - The maximum output voltage will be when the coil is parallel to the field
    - This happens because the coil is cutting the field lines at the greatest rate at this point
    - Minimum magnitude of voltage is when the coil is perpendicular to the magnetic field so the direction of motion is parallel to the field lines and there is no emf induced
- Power output

- 

The current-time graph for a simple a.c. generator

Increasing the maximum emf

- Increasing number of turns on the coil
- Increasing the area of the coil by increasing coil length + radius
- Stronger magnet
- Rotating coil faster
- (Faster rotation also increases the frequency which in UK is 50 Hz)

9d Transformers

2024年2月5日 14:03

Transformers explanation

- Transformers are made by wrapping two coils of wire around a soft iron core
- An alternating current can then be passed through the primary coil and sets up an alternating magnetic field in the core
- The secondary coil is positioned near to the primary coil, so that it can pick up the changing magnetic field in the iron core
- As the changing field cuts through the wires of the secondary coil, a voltage is induced across the secondary coil.
- Both the size and direction of this induced voltage changes as the voltage applied to the primary coil changes.
- So when the secondary coil is connected to a complete circuit, an alternating current flows through the secondary coil
- $\frac{input\ voltage}{output\ voltage} = \frac{number\ of\ turns\ on\ primary\ coil}{number\ of\ turns\ on\ secondary\ coil}$ / $\frac{V_p}{V_s} = \frac{N_p}{N_s}$

Types of transformers

- Step-up transformer
  - Low → high voltage
  - Greater number of turns on the secondary coil than primary coil
  - Used in power stations to increase the voltage
- Step-down transformer
  - High → low voltage
  - Fewer number of turns on the secondary coil than primary coil
  - Used by chargers, computers, and other electronic equipment to reduce voltage

Power through a transformer

- Assuming 100% efficiency: $P_{in} = P_{out}$
- So $V_p \times I_p = V_s \times I_s$
- Increase in voltage = decrease in current in the same proportion

How is efficiency increases

- Coils are made from thick copper wire
  - Very little resistance
  - Hardly lose any energy due to electrical heating
- The primary and secondary coils are linked by an iron core
  - The iron core concentrates the field lines around the coils
  - Maximising the number of field lines from the primary coil which cut the secondary coil
- The iron core is laminated
  - This means that it consists of several layers of thin insulated iron sheets, which have a high resistance.
  - Lamination reduces any currents induced in the core when the changing magnetic field from the primary coil passes through it

Reduce energy loss in the national grid

- All cables have resistance and so as the electricity passes through them it will lose energy as heat in the cable
- The energy lost in a power cable: $P=I^2R$
- The power loss depends on the resistance of the cable and so to reduce this power loss the resistance of the cable must be as small as possible
  - Using thicker cables → too heavy
  - Using material which is a better electrical conductor such as gold or platinum → much too

expensive

- So changing the resistance is not a practical idea, but the current passing through the cable can be altered using a transformer
- Electricity is transmitted at low current and very high voltage to keep the power loss as small as possible
- Electricity generated in a power station as 25000 V (25kV) is stepped up to 275 kV or 400 kV for transmission across large distances
- Near towns, villages and industrial sites there are transformers that step down the voltage ready for use

10a Atoms

2024年3月3日 21:10

Plum pudding model

- J. J. Thomson discovered electron in atoms in 1897
- Electrons has a negative charge so an atom must also contain positive so it becomes neutral
- He proposed that the atom must be made of a positively charged sphere which contained the negatively charged electrons

Rutherford's nuclear model

- Alpha scattering experiment
  - In 1911, Ernest Rutherford's team carried out experiments in which positively charged alpha particles were fired at a thin sheet of gold
  - The experiment had to take place in a vacuum or the air would absorb the particles
  - The gold also had to be very thin or the alphas would not get through
  - Rutherford expected all of the particles to pass straight through or deflected slightly
  - In fact: most of the Alpha particles went straight through, a few were deflected slightly but very few were deflected through large angles (> 90°)
- Rutherford concluded that all of the positive charge and most of the mass of the atom was contained in a tiny nucleus at the centre, the electrons orbit the nucleus
  - Most of the particles went straight through because they never went near the nucleus because most of the atom is empty space
  - The small deflections were caused by the particles travelling close to the nucleus and being repelled
  - The large deflections were caused by particles travelling almost directly towards the nucleus and being repelled away by the concentrated charge

Atom structure

- A central nucleus made up of protons and neutrons
- Electrons orbit around the nucleus at high speed
- Protons and neutrons are called nucleons
- They each is about 1800 times more massive than an electron so virtually all of an atom's mass is in the nucleus
- Electrons are held in orbit by forces f attraction between opposite charges

Isotopes

- All atoms of the same element have the same number of protons. However, atoms may have different numbers of neutrons
- Atoms of the same element with different numbers of neutrons are called isotopes of that element

10b Nuclear radiation

2024年3月3日 22:37

Causes of instability of a nucleus

- A nucleus with more than 82 protons
- A nucleus with an atomic mass of more than 200
- An unstable ratio of neutrons to protons - this can be caused by too many or too few neutrons in the nucleus

Ionizing radiation

- Atoms are neutral as they have the same number of protons and electrons
- Ionizing radiation caused the atom to lost (or gain) electrons making the neutral atom into a charged ion, it has been ionised
- There are three types of ionizing radiation:
  - Alpha (α)
  - Beta (β)
  - Gamma (γ)

Alpha radiation

- Formed when an unstable nucleus decays and emits an alpha particle
- The particle emitted is composed of two protons and two neutrons
- Alpha particles have an atomic mass of 4 and a relative charge of +2
- When a nucleus emits alpha radiation, it changes into a more stable isotope of a different element
- ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$
- The radiation may produce another radioisotope that decays
- Each individual step is known as an alpha decay

Alpha radiation properties

- Strongly ionising
- More kinetic energy and more charge than beta particles
- Very likely to collide with atoms as they pass through a substance
- As an alpha particle ionizes an atom it loses some of its (kinetic) energy
- After many thousands of ionizations the (kinetic) energy of the alpha particle is low enough for electrons to attach to themselves and one atom of helium is created
- As alpha particles are very ionizing and large, they collide easily with atoms in a substance, producing many ionizations in a short distance, quickly losing their (kinetic) energy
- They only travel around 3-5 cm in air and are stopped by skin or a piece of paper

Beta radiation

- Beta radiation consists of free, high energy electrons
- Beta particles are made when a neutron changes into a proton and an electron
- The proton stays in the nucleus and the electron is emitted as a beta particle
- The mass of a beta particle is negligible, so when a beta particle is emitted, it does not alter the atomic mass of the nucleus
- Change the charge of the nucleus by +1 as beta particles have a relative charge of -1
- ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta$

Beta radiation properties

- Beta radiation is moderately ionizing as beta particles are less likely to collide with atoms in a substance than alpha particles
- Ionizes by transferring energy to outer electrons which then leave their orbits
- Beta particles have a very low mass and high speed, so they collide less easily than alpha particles with atoms in a substance and so have a greater range than alpha particles and are considerably more penetrating

- Travel up to 10m through the air, and through some obstacles, such as pieces of paper
- They are stopped by a 5mm thick layer of aluminium

Gamma radiation

- Gamma rays = electromagnetic waves and have the highest frequency and shortest wavelength of all the seven types of electromagnetic wave
- When a radioactive nucleus emits an alpha or beta particle, the protons and neutrons in the newly formed nucleus are often in an excited, unstable state
- A gamma ray is then emitted from the newly formed nucleus, reducing the energy level and increasing the stability of the nucleus
- Gamma rays have 0 mass and 0 charge as it is an E-M wave
- When a gamma ray is emitted from an atom, it has no effect on either the atomic mass or atomic number.
- ${}^{A}_{Z}X \rightarrow {}^{A}_{Z}X + {}^{0}_{0}\gamma$

Gamma radiation properties

- The gamma rays are weakly ionising, as they tend to pass through a substance rather than collide with its atoms.
- When gamma rays do collide with an atom, energy is transferred to an electron which leaves its orbit.
- Gamma radiation has no mass and travels at the speed of light, so gamma rays collide infrequently with atoms in a substance
- Gamma rays have a greater range, and more penetrating than alpha or beta particles.
- They can travel long distances through the air
- Can travel through pieces of paper and aluminium foil, several cm of lead or several metres of concrete are needed to stop the passage of gamma rays

Effect of E-M fields

	Electric field	**Magnetic field**
Alpha	Small deflection	Small deflection
Beta	Large deflection	Large deflection
Gamma	No deflection	No deflection

- Electric field
  - Alpha particles are bent slightly towards the negative terminal of an electric field
  - Beta particles are bent strongly to the positive terminal of an electric field
  - Gamma rays are not affected by an electric field
- Magnetic field
  - Both Alpha and Beta particles are reflected at right angles to a magnetic field. Alpha and Beta particles will move in opposite directions according to Fleming's left hand rule
  - Gamma rays are not affected by a magnetic field

Danger of ionising radiation

- Cause immediate damage such as radiation burns but possibly its long term effects are even more serious
- High amounts of radiation can kill cells directly
- Leukaemia
- Cancer and genetic damage
  - Cancer can be caused by exposure to radiation because radiation can damage DNA leading to mutations
  - Cancer cells grow rapidly and can develop into tumours

Safety precautions

- If you are under 16 do not use the sources
- Never handle a source directly
- Always use tongs or tweezers

- Keep as far away from a source as possible
- Never open a sealed radioactive source
- Keep a record of the use of any radioactive source
- Always return the source to its lead container after use
- Keep the sources locked away in a secure cupboard when not in use
- Report any accidents immediately
- Never point a source towards anyone, including yourself

<u>Measuring ionising radiation</u>

- Geiger-Müller counter
- Inside the tube, radiation ionizes molecules of an inert gas
- These ions and the electrons produced are attracted to the electrodes within the device
- This creates a pulse of current which is detected by the counter

<u>Background radiation</u>

- Low level radiation present all around us. It comes from a variety of natural and artificial source
- Because of background radiation a Geiger counter set up anywhere on Earth will always register a count
- We must correct the count by subtracting the background radiation
- Because the emission of backgrounds counts is a random process, we need to take a count of at least 60 seconds and divide it by 60 to get an average background count
- Corrected count = Total count - background count

10c Radioactive decay

2024年3月3日 23:16

Activity of a source

- The activity of a source tells us the number of its nuclei that decay in unit time
- Since each decay produces ionising radiation, the activity of a source also tells you the number of ionising particles that it emits in unit time
- SI unit of activity is the Becquerel (Bq)
- 1 Bq = an activity of 1 decay per second 1 Bq = 1 s^{-1}

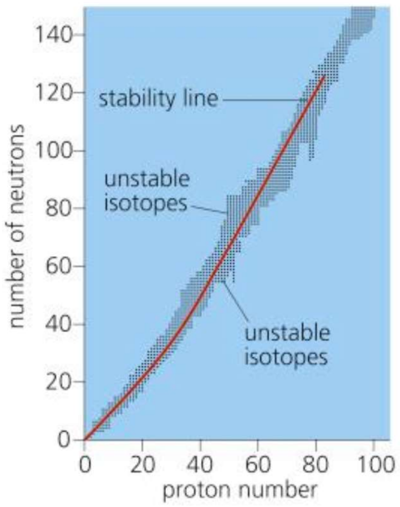
Radioactive decay

- Radioactive decay is a process by which the nucleus of an atom becomes more stable by emitting particles and energy
- A random and spontaneous process
- The rate of decay cannot be changed externally in any way

Half-life

- The average time taken for the activity of a sample of radioactive material / to drop to half its original value / time taken for half of the nuclei present to decay is called the half-life of the source (T)
- Depends only on the material of the source and different radioactive isotopes have different half-life

Stability of nucleus

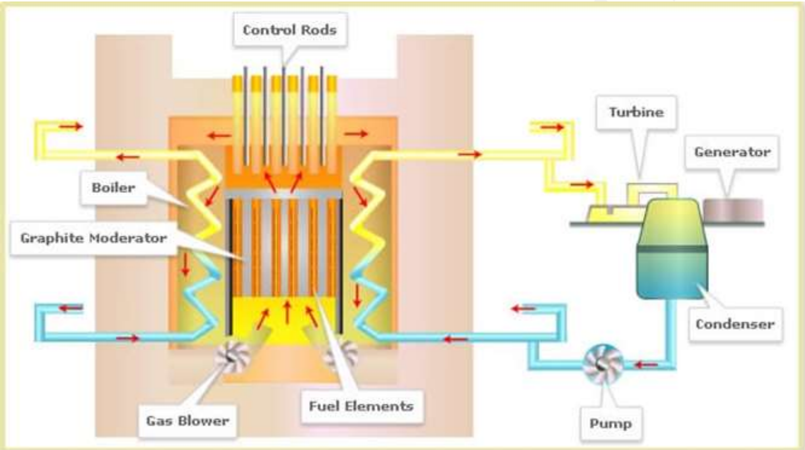
- Some proportions of neutrons to protons are more stable than others in a nucleus
- Stable isotopes lie along the stability line
- Isotopes above the stability line have too many neutrons to be stable
    - Decay by beta- emission to reduce the number of neutrons
- Isotopes below the stability have too few neutrons to be stable
    - Decay be beta+ emission to increase the number of neutrons
- The heaviest isotopes (proton number > 83) decay by alpha emission
- 

10d Nuclear energy

2024年3月9日 17:27

Nuclear fission
- In uranium 235 nucleus there are 92 protons and 143 neutrons
- If we fire another neutron at this nucleus, it becomes unstable
- In the end the nucleus splits in half

Chain reaction
- The neutrons from the fission of one nucleus go on and may split other uranium nuclei if conditions are right
- These fissions then produce more neutrons that split more nuclei and so on
- Only get a chain reaction if there is enough uranium 235 atoms and it is in the right shape
- Otherwise too many neutrons will escape from the outside and the reaction will stop
- The smallest amount of uranium needed to keep a chain reaction going is called the critical mass

Nuclear fission reactor
- The core of the reactor contains the uranium fuel that is held in thousands of metal tubes in a large block of graphite
- Coolant (carbon dioxide gas) is blown through the reactor core under pressure to absorb and take away the heat energy produced by the fission reactor
- This gas is then passed over tubes containing water, giving out its heat and turning the water into high temperature steam
- Steam is then used to drive turbines and generators
- The whole reactor core is contained in a steel pressure vessel and then surrounded by a thick layer of concrete to protect the workers from radiation
- 

Why is energy produced
- When the nucleus splits we get two smaller nuclei, two or three neutrons and some energy
- This energy appears as heat due to the kinetic energy of the smaller nuclei and the neutrons
- The energy is produced because the mass of the uranium nucleus plus the mass of the incoming neutron is slightly greater than the masses of the particles formed after fission

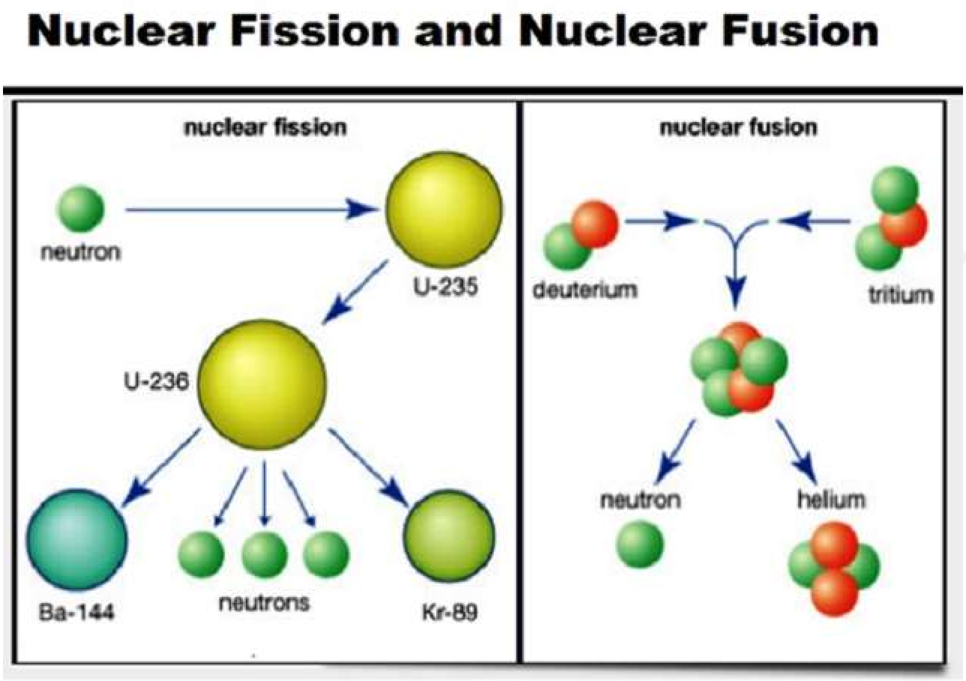
Nuclear fusion
- Two light nuclei are be joined together to form a heavier nucleus, releasing energy
- The fuel could be heavy hydrogen (deuterium), extracted from sea water
    - One in 6700 of the hydrogen atoms in sea water is deuterium
- Gives an almost unlimited energy source for the foreseeable future
- Difficult to do because both the nuclei are positive so they need to be very close together so that the strong nuclear force becomes greater than the electrostatic repulsion
- Need to make them collide at very high speed by raising the temperature of the gas to over 100 million °C (several times hotter than the centre of the Sun)

- At these temperatures the gas becomes a plasma (a sea of electrons and ions)
- Difficult to contain such a high temperature

Nuclear fusion in stars

- The high temperature and the very strong gravitational pull keeps the hydrogen as a plasma and moving fast enough for fusion to take place
- However, the sun uses a different fusion reaction from the one we use on Earth and would not it suitable as its power output would be too low
- The reaction works for powering stars because they have a much larger amount of hydrogen than we could ever use on Earth

Examples

- 

10e Using Radioactivity

2024年3月9日 17:27

Smoke detectors

- A smoke detector uses americium-241 which emits alpha particles
- The alpha particles ionise the air within the detector and, as a result, a small current flows
- When smoke enters the detector, it absorbs the alpha particles which reduces the electrical current and triggers the alarm
- Alpha = best current + least penetrating and least range

Tracer

- Chemicals emitting beta or gamma radiation can be injected or swallowed
- The path of the radiation followed around the body as a medical tracer
- (Alpha radiation must never be used as tracer because of the ionising properties)
- Can be used to check the function of body organs / track a plant's uptake of fertiliser / detecting leaks

PET scan

- Positron Emission Tomography
- Using Gamma radiation to identify cancers and damaged tissues
- To produce a PET scan, the patient is injected with a form of glucose with radioactive fluorine (fluorine-18, half-life 110 min) attached to it
- The glucose is used in respiration, so it concentrates where respiration / metabolism is high
- Cancer cells and other cells which have high metabolic rates show up well with a PET scan as bright areas
- The PET scanner detects the gamma radiation emitted from the patient
- Damaged areas of the brain (as in the case of Alzheimer's disease) can be identified

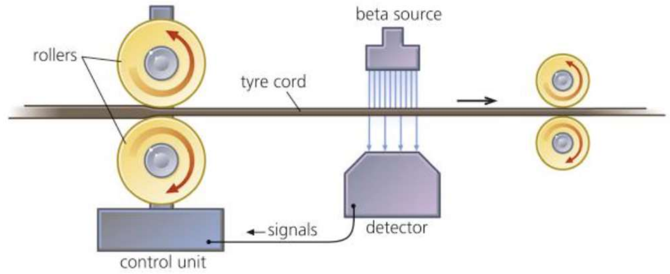
Cancer treatment

- In some cases, cancer can be treated by radiotherapy
- This involves gamma rays being used to kill the cancer cells
- Gamma rays can penetrate the body to reach the tumour
- The tumour is exposed to radiation at different angles
- This gives normal cells a low dose of radiation, while the tumour receives a high dose

Detecting leakage

- Adding a tracer to the fluid in the pipe
- Wherever the leak is, the radiation will build up
- Gamma radiation of a short half-life must be used to reduce the danger of a long term hazard

Measuring the thickness of material

- Beta for paper, gamma for metal
- Detector detects the amount of radiation pass through and determine the thickness
- 

Sterilisation

- Gamma radiation can be used to sterilise food or medical instruments
- Objects to be sterilised pass under the gamma radiation source and gamma rays pass through the

object

- Any microbes is killed as they pass through
- After sterilisation food can be left on display for longer
- Less likely that the price of food will be reduced before the 'sell by' date

11a The Earth & Moon

2024年1月31日 23:15

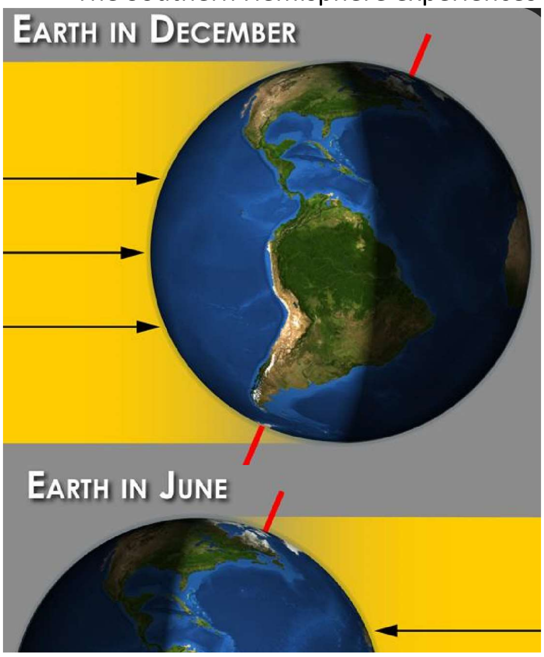
The Sun

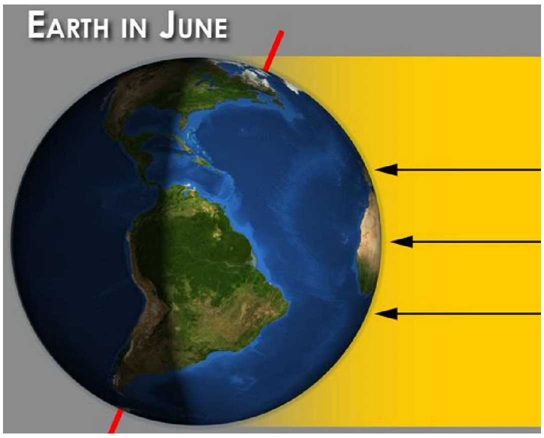
- A huge, glowing ball of gas called a star
- Medium size star
- Consisted mainly of hydrogen and helium
- Extremely hot, with a temperature of around 6000 K on the surface, rising to $1.5 * 10^7$ K in the centre
- Releases energy by nuclear fusion reactions in its core
- Releases all types of E-M radiation but mostly IR, visible light and UV

Day and night explanation

- The Earth rotates on its axis (tilted 23.5°) every 24 hours (1 day)
- At each moment half of the Earth is facing the sun and in sunlight (day), the other half is facing away from the sun and in shadow (night)
- In Summer the northern hemisphere is pointing towards the Sun so the length of the day is much greater than the length of the night
- In Winter the northern hemisphere is pointing away from the Sun so the length of the day is much shorter than the length of the night

Seasons explanation

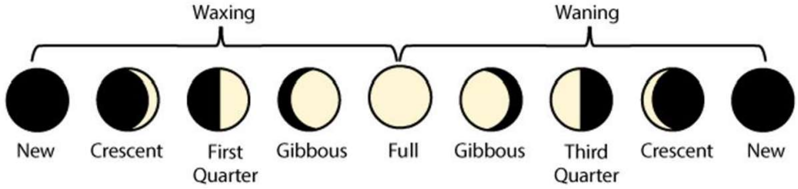
- Season happen at different times in different parts of the world
- The tilt of the Earth doesn't change as it rotates around the Sun but the part of the planet that gets the most direct sunlight does change
- The northern Hemisphere is tilted away from the Sun from September to March (next year)
    - The northern hemisphere doesn't get as much light and heat from the Sun and this causes autumn and winter
    - Sun is at a lower angle in the sky, the same amount of sunshine is covering a larger area in winter + the day is shorter so it is colder
    - The Southern Hemisphere is tilted towards the Sun so the southern half of the planet gets spring and summer
- From March to September, the Northern Hemisphere is tilted towards the Sun
    - The northern hemisphere gets more sunlight and experiences spring and summer
    - The sun is at a higher angle in the sky so the sunlight is concentrated onto a much smaller area in summer + the day is longer so it is warmer
    - The Southern Hemisphere experiences autumn and winter
- 

- 

Moon definition

- Natural satellite orbiting the Earth

Moon phases

- 

Moon phases explanation

- The shape of the Moon isn't changing throughout the month but our view of the moon does change.
- The Moon does not produce its own light, Sun is the only light source in our solar system → the Moon's surface reflects the Sun's light
- The Sun's light comes from one direction and always lights up the side of the Moon that is facing the Sun, the other side of the moon is dark
- On Earth, our view of the illuminated part of the Moon changes each night, depending on where the Moon is in its orbit around Earth
- When we have a full view of the completely illuminated side of the Moon = full moon
- But following the night of each full moon, as the Moon orbits around Earth, we start to see less of the Moon lit by the Sun
- Eventually, the Moon reaches a point in its orbit when we don't see any of the Moon illuminates and the illuminated
- side of the Moon is facing the Sun + the side facing Earth is dark. = new moon
- The Moon takes approximately the same amount of time to rotate once on its own axis as it does to orbit the Earth (27.3 days) so it always presents the same side to us

Orbital speed

- $v = \frac{2\pi r}{T}$ (v = orbital speed in metres per second, r = radius of orbit in metres, T = period of orbit in seconds)
- The time period is defined as the time taken to complete one orbit
- The radius is always taken from the centre of the object it is orbiting

11b The Solar System

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Solar system

- The Sun, the planets (including the Earth) in orbit around the Sun and other objects (asteroids, comets, dwarf planets) in orbit around the Sun
- The planets are not hot enough to give off their own light so we see them because they reflect light from the Sun
- The gravitational pull of the Sun keeps the planets in orbit
    - Gravitational force weakens with distance
    - $F \propto \frac{1}{r^2}$ (double distance = a quarter of the force)
- Everything orbiting the Sun orbits in an ellipse which does not have the Sun in the centre (many of the planets' orbits are almost circular with the Sun approximately at the centre)
- The planets' orbits are approximately in the same plane and all in the same direction

Mercury

- A smaller planet than the Earth and much hotter
- There is no atmosphere
- It is so hot that lead would melt in the mid-day sun
- Space probes show that its rocky surface is covered in craters, like our Moon

Venus

- A planet about the same size as the Earth
- Instead of air it is covered with clouds of sulfuric acid and lots of carbon dioxide
    - Keep it very hot as well as making it impossible to see any details of the surface from Earth
- Space probes show that the surface is covered with rocks
- Example of a greenhouse effect
    - The radiation from the Sun is trapped beneath the thick atmosphere causing the planet to heat up and make Venus the hottest planet

Earth

- The only planet in the Solar system where water can exist as a liquid
- Because of this it is the only planet in the Solar System that can support life

Mars

- The surface of Mars is a rocky, reddish desert with very strong winds blowing across it
- Thin atmosphere mainly carbon dioxide
- Covered with craters like the Moon, have polar caps
- There are also huge mountains and deep valleys which may have been made from water that once flowed there
- Volcanoes but none are active

Asteroid belt

- Between Mars and Jupiter there are a large number of tiny rocky planets called asteroids
- Dimensions ranging from a few kilometres to 1000 km
- It is possible that they are the remains of a large planet that broke up millions of years ago or they could be parts of a planet that never formed
- There is some evidence that around 65 million years ago an asteroid about 10 km across struck the Earth, may have caused the extinction of dinosaurs

Jupiter

- Jupiter is the largest planet (bigger than all the other planets put together)
- No solid surface, made of very solid, heavy gas + atmosphere is 90% hydrogen = gas giant
- The surface of Jupiter is covered with coloured bands

- The Great Red Spot = thought to be a huge storm that has been raging on the planet for hundreds of years
- One of Jupiter's moons, Io, has active volcanoes on it

Saturn

- Saturn is a very cold planet with a surface of heavy gas, gas giant
- Surrounded by very thin rings made by millions of pieces of ice ranging in size from grains to boulders
- Saturn has the lowest density of the planets and would float in water

Uranus

- Uranus is mostly hydrogen and helium, gas giant
- The majority of its mass may be due to ices like water, methane, ammonia
- It is unusual in that its axis of rotation is tilted at more than 90 degrees
- Has rings but much fainter ones that Saturn's

Neptune

- The farthest gas giant, mostly hydrogen and helium, and is very similar to Uranus
- It also has a faint ring system

Pluto

- Used to be considered as the outermost planet but now dwarf planets

Patterns for planets

- The further a planet is from the sun, the slower it travels, and the more time it takes to complete an orbit
    - Further away = weaker gravitational attraction = smaller centripetal force = less acceleration
- The further a planet is from the sun, the lower its average surface temperature
    - The intensity of Sun's radiation weakens with distance
- The mass, density and diameter of a planet affect the strength of gravity (so some gas giants have a low gravitational strength for their mass)

Comets

- Comets are made of frozen gases like carbon dioxide, methane, ammonia, as well as water and ice
- Dust particles and rocky materials are embedded in ice
- As a comet approaches the Sun, solar radiation melts the surface, vaporising molecules of dust and gas and creating the tail that comets are known for
- A comet's tail will always point away from the Sun, which means it doesn't always trail behind the comet

Comet orbits

- Comets have highly elliptical orbits, the Sun at a focus of the ellipse
- The gravitational force of the Sun provides an inward force to keep a comet in orbit
- Orbital speed is slowest furthest away from the Sun, which is where the gravitational pull is weakest → more GPE and less KE
- As the comet moves closer to the Sun the gravitational force will increase
- Also, the comet's GPE will transfer to KE as it moves closer to the Sun making it faster
- The total energy (GPE+KE) is constant (conservation of energy)
- Can leave the inner solar system when orbiting

11c Stars

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Light year

- 1 light year is the distance travelled by light in 1 year
- 1 light year = 9.5×10^{15} m / 9.5×10^{12} km (speed of light = 3×10^{8} m/s)
- For measuring distance between objects as the distance is so large that meter is too small for a unit of measurement
- e.g. *Proxima Centauri* = closest neighbouring star, 4.2 ly away

Galaxy

- Galaxy = a huge collection of gas, dust and billions of stars and their solar systems held together by gravity
- Between the stars in a galaxy is interstellar matter: gas (mostly hydrogen) and dust
- Our galaxy = the Milky Way, more than 100,000 ly across, at least 100 billion stars

Formation of a star

- Stars form in huge rotating clouds of gas and dust called a nebula
- Because of gravity, dense areas form and collapse inwards, rotating faster and faster
- More material is pulled in by gravity and the GPE of this material is converted to heat, creating a massive and hot protostar in the middle
- The gas in the protostar gets compressed and hotter until the pressure and temperature becomes high enough to start nuclear fusion so it becomes a star
- The new star will stabilise at a size where the inward force of gravity is being balanced by the outward pressure caused by the radiation emitted and the gas pressure from the hot expanding gases
- The remaining gas and dust forms an accretion disc around it
    - Grains of material are slowed by collisions and pulled into clumps by gravity
    - These clumps will become planets and moons
- The Sun's radiation drove off most of the gas from the inner planets so they are small and rocky
- It was cooler further out so the planets retained gas and became gas giants

Fusion power of the Sun

- When small nuclei fuse (join) together energy is released
- But nuclei are positively charged so they will repel each other
- To overcome the repulsion, they need to collide together at extremely high speeds
- This high speed is achieved by the very high temperature in Sun ($15 * 10^{6}$ K)
- Most of the Sun (& stars) is made of hydrogen nuclei and these are fused together to (eventually) make helium

Death of a star

- Sun
    - Eventually (in about 6 billion years) most of the hydrogen in the core of the Sun will be fused into helium
    - The outer layer of the Sun will expand to around 100 times it current size and cool down so it glows red → Red Giant
    - Over time the outer layer will drift off into space forming a planetary nebular and exposing the small hot, extremely dense core → White dwarf
    - White dwarf fuses helium before cooling to a Black dwarf
- Larger stars
    - Stars at least 10 times larger than the Sun
        - Becomes much larger Red Supergiant's when they run out of hydrogen in the core
        - Red Supergiant's collapses causing an enormous explosion called a supernova
        - The nebula from a supernova may form new stars with orbiting planets

    - The collapsed compressed core is so dense that the electrons and protons react to form neutrons and form a neutron star
- Stars at least 100 times larger than the Sun
    - When it collapses in a supernova the greater mass of the core becomes much more compressed with an even higher density and keeps on collapsing
    - The nebula from a supernova may form new stars with orbiting planets
    - Than a neutron star and becomes a black hole
    - Nothing can escape a black hole including light, but we can detect them when they get too close to another star or pass between us and a star

Formation of elements

- Originally the universe was just made of hydrogen
- During the life of a star all the elements up to iron are made by nuclear fusion inside the star
- Elements heavier than iron in the periodic table are only made in the massive release of energy in a supernova
- The nebula created by the supernova therefore has a mix of all the elements and can create new stars and planets

11d The universe

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Red shift

- Doppler effect
  - When something that emits waves is moving, the waves' frequency falls if the object is moving away and frequency increases if the object is moving closer
- Light from an object moving away from you is shifted towards to red end of the spectrum (red shift)
- Light from an object moving towards you is shifted towards the blue end of the spectrum (blue shift)
- The faster it moves the more the light is shifted towards that end of the spectrum so we can work out how fast something is moving by looking at the amount of red shift

Hubble's observation

- Light from distance galaxies is red shifted and the red shift increases with the distance of the galaxy
- So the galaxies are moving away from us, and the universe is expanding

The Big Bang Theory

- The Big Bang theory suggests that our universe began with a massive explosion (a Big Bang) throwing energy (gamma rays) out in all directions
- The universe, therefore, began in a very hot and very dense state, but has been expanding and cooling since

Evidence for the Big Bang Theory

- Hubble's measurements
  - Showed that the further away a galaxy is the greater the red shift and so the faster it is moving
  - It shows that the Universe is expanding so must have been smaller in the past (come from a point)
- Microwave radiation picked up by radio telescopes
  - Coming from every direction in space, has a particular frequency
  - May be the heavily red-shifted remnants of radiation from the Big Bang
  - Called cosmic microwave background radiation (CMBR)

Estimating the age of the Universe

- Hubble noticed that the further away the galaxies were, the greater the redshift
  - Speed = measured by change in wavelength due to redshift
  - Distance = measured by the brightness of a supernova in the galaxy
- A graph can be produced of this relationship
- The gradient of the graph = the Hubble constant, H_0
- $H_0 = \frac{speed\ galaxy\ move\ away\ from\ Earth}{distance\ from\ Earth} = \frac{v}{d}$
- The accepted value of $H_0 = 2.2 * 10^{-18}\ s^{-1}$
- If we assume that at the Big Bang all of the Universe was at the same point and that the Universe has separated at a constant rate: $time = \frac{distance}{speed}$, so Age of the universe $=$ time to separate $= \frac{d}{v} = \frac{1}{H_0}$
- Using $H_0 = 2.2 \times 10^{-18}\ s^{-1}$: $age\ of\ Universe = \frac{1}{2.2\times10^{-18}} = 4.55 \times 10^{17} s$ (14.4 billion years)