3. Thermal Physics

Date No.

Matter and Heat

- As heat ↑, average kinetic energy of particles ↑
- particles move about more in liquids and gases, vibrate more rapidly in solids
- Solids $\underset{\text{freezing}}{\overset{\text{melting}}{\rightleftharpoons}}$ Liquids $\underset{\text{condensation}}{\overset{\text{evaporation / boiling}}{\rightleftharpoons}}$ Gas

→ closely packed together	→ relatively close together	→ far apart
→ vibrate in fixed positions	→ can move about (low speed)	→ can move about quickly
→ orderly arrangement	→ random arrangement	→ random arrangement
→ dense	→ less dense	→ extremely low density

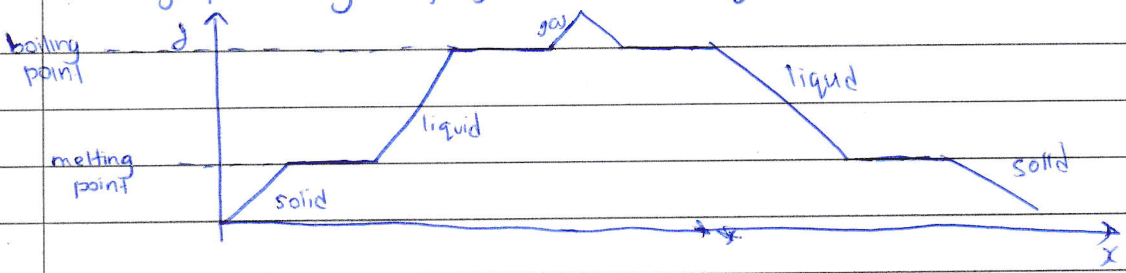
- Note that sublimination is solid to gas, reverse subliminaction is gas to solid
- Basic unit of heat is J (joules)

Flow of Heat Energy

- Energy moves from an area of high to low energy
- The larger the difference (Δ), the faster the flow of energy

Changes in State

- Initially, energy is used (when heating) to ↑ average K.E of particles, but at the melting/boiling point, that energy is used to break intermolecular forces, rather than ↑ average K.E a.k.a temperature
- So for a graph showing temp (y) vs time (x), we get this



- Similarly, when condensing/freezing, energy released by the formation of intermolecular forces offsets the temperature reduction, hence temp does not change
- NOTE: ~~Spefic~~ specific latent heat of vapourisation or fusion (for solid to liquid) is the amount of energy needed to ~~conve~~ convert 1 kg of solid / liquid → liquid / gas without changing the temperature (J/kg)

Evaporation

- liquid → gas without boiling [gas is water vapour not steam]
- the particles at the surface of a liquid with the highest K.E ~~break the in~~ are able to move away from the liquid as gases, leaving the particles with the lowest K.E behind [these are those with low temp]
- ∴ evaporation of sweat is cooling as "hotter" particles leave (higher K.E particle) and "colder" particles remain

- Factors affecting Evaporation
  ① Temp → higher temp, higher rate of evaporation → ↑ K.E of particles, weakens intermolecular forces
  ② S.A → ↑ S.A, more particles at surface, ↑ ava particles that can breakoff, ↑ evaporation
  ③ Humidity → ↑ Humidity, ↓ evaporation, as lower rate of diffusion of escaping particles
  ④ Wind → ↑ wind, ↑ evap, remove higher K.E particles faster, other high K.E particles can escape fa

Changing m.p and b.p

M.p

→ ↑[impurities], ↓ m.p

→ ↑ presure, ↓ m.p

B.p

→ ↑[impurities] ↑ b.p

→ ↑ presure, ↑ b.p

Expansion and Contraction

- As ↑ K.E, particles move further apart, meaning the substance as a whole expands, ↑ volume
- Similarly, as ↓ K.E, particles move closer together, ↓ volume [Contraction]
- Expansion and Contraction depends on material and the actual temperature change

Conduction

- Heat flows through solids through conduction
- When heat is supplied to a solid, the particles near the source gain K.E and vibrate at a higher frequency, they collide with neighbouring K.E, triggering further vibration and spreading vibrations throughout the solid. This increases the average K.E of the solid particles, ↑ temperature

- Metals are good conductors of heat as they have free moving electrons that can collide with each other to transfer energy through the solid faster than colliding particles do
- Non-metals have no free moving charged particles, so they do not conduct heat as well
- ∴ they are used as insulators
- Liquids and gases have no free moving charged particles and their particles are ~~far~~ further apart, hence poor conductors. Gases are good insulators

Factors affecting Conduction

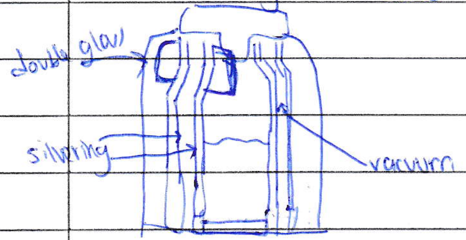
1) Material → metal/non-metal, ~~state of matter~~
2) State of Matter
3) S. A$_v$ → larger S.A, more particle collisions between surface of material and heat source, ↑ rate of collisions
4) Temperature Difference → ↑ Δ temp, ↑ rate of conduction

Convection

- transfer of heat through fluids (gases and liquids)
- It is reliant on the ability of particles to move about in gases and liquids
- When heat is applied, particles have ↑ K.E and move further apart, increasing volume, ∴ ↓ density [∴ ↑ T, ↓ density of a fluid]
- Therefore, as less dense fluids rise, the hot fluid rises, displacing the cooler fluid higher up, which falls due to it's relatively higher density
- This is applied in air conditioning units; the units are placed high such that the cooler air they circulate sinks to displace the ~~cooler~~ hotter air below, causing it to rise and be cooled above.
- Sea and Land Breezes - the land gains and loses heat faster than the sea. During the day, the land is hotter, so the air above is hotter and rises, hence the cool, less dense, air from the sea moves in ~~from the sea~~ to displace it (sea breeze). The reverse applies for the night (land breeze)
- Convection is affected by

Radiation

- type of electomagneticradiation, caneven work in a vacuum
- Good radiators/ absorb and emit heat better → dull black surfaces absorb and emit radiation faster than shiny white surfaces
- Shiny, white/bright surfaces reflect radiation away better
- This is why radiator fins are black and firefighting suits are shiny suits
- The rays that cause the most heating are the infored rays (IR), λ > than visible light
- Vacuum flasks
  - → has a vacuum portion so no heat loss by conduction or convection can occur
  - → silvering reduces radiation by reflecting any radiation back
  - → double glass reduces heat loss by conduction



Density

→ SI unit is kg/m^3

→ $\frac{\text{mass}}{\text{volume}}$, we find mass using a mass balance and volume through water displacement

remember, read at the bottom of the meniscus

→ NOTE: pressure diff at a depth is P = density (kg/m³) x 10N/kg x depth(m)

Motion and Energy

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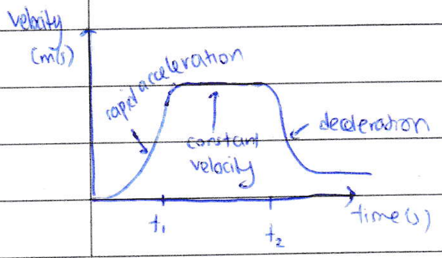
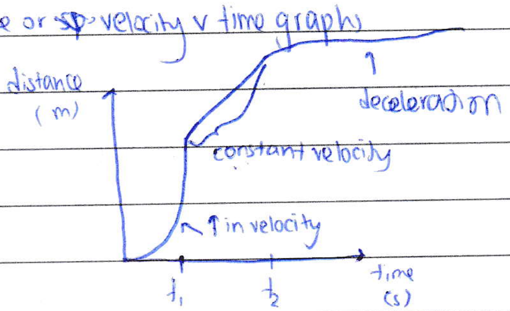
Kinematics

- Speed (m/s) = $\frac{\text{Distance (m)}}{\text{time (s)}}$
- Speed is scalar, so it only has a value, but without a specified direction component
- Velocity is a vector; it has a scalar (speed) and direction
- Velocity is only constant in a straight line, if there is a change in direction while the same speed is maintained, velocity changes
- Acceleration (m/s²) = $\frac{\text{change in velocity (m/s)}}{\text{time (s)}}$, so 2 m/s² means that every second, ↑ velocity by 2 m/s
- We can plot distance v time or ~~sp~~ velocity v time graphs





- for a graph ~~of velo~~ $v = f(t)$ [velocity as a function of time], $\int f(t)\,dt$ = total distance covered
- for ~~s (displacement)~~ Distance $) = f(t)$, ~~$\int s\,dt$~~ the gradient at any point is equal to the velocity ~~at a~~
- The gradient on a $v = f(t)$ graph is equal to the instantaneous acceleration
- Note that displacement (s) is a vector quantity

SUVAT

1) $v = u + at$
2) $v^2 = u^2 + 2as$
3) $s = \left(\frac{u+v}{2}\right)(t)$
4) $s = ut + \frac{1}{2}at^2$
5) $s = vt - \frac{1}{2}at^2$

v = velocity (m/s)
u = initial velocity (m/s)
s = displacement (m)
a = acceleration (m/s²)
t = time (s)

Inertia and Newton's First Law

- Newton's First Law (N_1) → When all forces are balanced (no resultant force), an object at rest stays at rest, and an object in motion moves at a constant speed in a straight line
- Inertia is a reluctance to stop or start moving
- Objects with higher masses have higher inertia

Momentum

- Momentum (in $kg\,ms^{-1}$) = Mass (kg) x velocity (ms^{-1})

- $F = ma = m\left(\frac{v-u}{t}\right)$

Change in momentum $= \frac{mv-mu}{t} = \frac{\text{momentum after} - \text{momentum before}}{\text{time needed for change}}$

- Momentum is always conserved
  - Total Momentum before event = Total Momentum after
- Force (N) = rate of change of momentum = ~~Na~~ $\frac{mv-mu}{t}$

Newton's Second Law

- f (N) = mass (kg) × acceleration (ms^{-2}) = ma

Forces

- For an object to start moving, there must be a net (resultant) force
- e.g for a car, the forwards thrust (forwards force) must be more than friction (backwards force) for there to be a resultant force

Drag

- ↑ speed, ↑ drag (in fluids)
- ↑ area, ↑ drag → ∴ sports cars streamlined

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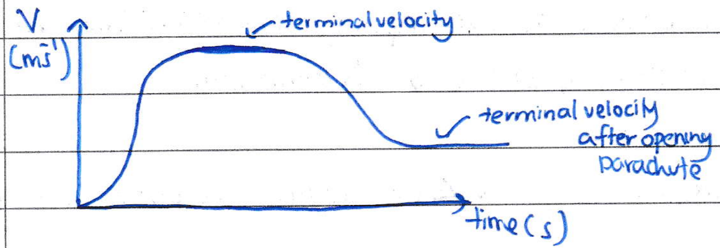
Gravity

- Mass is the measurement of how heavy something is in kg (constant irrespective of gravitational field strengt
- Weight is equal to mass times gravitational field strength → $W = mg$
- Gravitational field strength = 10 N/kg

Free fall and Terminal Velocity

- In freefall, at the start, moving objects have greater ~~ar~~ force ~~enea~~ downwards (weight), than air resistance, resulting in downwards acceleration (as resultant force is downwards)
- However, ↑ ~~sp~~ velocity, ↑ air resistance, reducing acceleration till weight = air resistance, when forces are balanced and there is no resultant force
- Hence, terminal velocity (constant) is reached
- For a skydiver, he hits terminal velocity, but then opens his parachute (change in shape and area, ↑ drag), which increases the air resistance, due to higher surface area, thus the resultant force is upwards, slowing the diver until the forces are balanced again
-



Newton's Third Law

- For every action, there is an equal and opposite reaction
- 

→ Totally balanced at rest

Work Done

- When a force is applied over a distance, work is done and energy is transfered
- e.g, pushing an object is a transfer of energy, chemical energy in food → kinetic energy
- Work done (energy transfered in joules) = force (N) × distance (m) = fd

Power

- Rate of doing work
- $P (W) = \frac{WD (J)}{time (s)}$

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Kinetic Energy and Gravitational Potential Energy

- Kinetic energy is the energy of a moving object
- KE(J) = $\frac{1}{2}mv^2$ (useful shorthand, if v becomes 2V, KE → ~~K~~ 4 KE)
- This explains why ~~spe~~ stopping distances increase so much with speed
- The K.E must be converted to heat energy of brakes + tyres

  $\therefore \quad \frac{1}{2}mv^2 = \underset{\uparrow \text{ braking by tyres}}{F} \times d \leftarrow$ braking distance

- d must increase proportionatally when v increases, ∴ doubling v quadruples braking distance
- Gravitational Potential Energy is the energy an object has due to its height
- GPE = mgh
- GPE becomes K.E when an object falls, but some may be lost as heat due to air resistance
- set $\frac{1}{2}mv^2 = mgh \rightarrow \quad v^2 = 2gh$
- In car crashes, K.E is converted into other forms fast, rate of momentum change large, ∴ large forces.
- Crumple zones on cars at the front and back crumple on impact, convert K.E into changing shape of the front and back ↑ impact time, ↓ force as ↓ Δ momentum
- air bags prevent us from hitting hard surfaces
- seat belts stretch to increase time until stop, ↓ Δ momentum and belt stretching absorbs K.E
- side impact bars divert K.E away from passengers

Principle of Energy Conservation and Energy Forms

- Energy can be changed from one form to another, but cannot be created or destroyed
- Thermal, kinetic, GPE, elastic potential, electrical energy, sound, light, nuclear
- In a large number of cases, energy is wasted in the form of heat
- Energy efficiency = $\frac{\text{output}}{\text{input}} \times 100\%$

Electricity

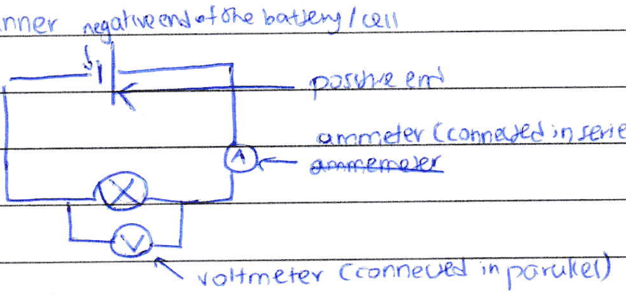
Electrostatics

- We can charge insulators with static electricity
- By rubbing an insulator against a surface, friction results in the movement of electrons between the surface + insul
- When we rub polyethene with a cloth, electrons (e^-) from the cloth move to the polyethene, giving it a negative charge. It will therefore attract positively charged objects and repel negatively charged objec
- Acetate is the reverse; it loses electrons and therefore becomes positively charged
- PROTONS ARE LOCALISED!! Only e^- move.
- Paint Spraying → spray nozzle positively charged, ∴ charge transfered to droplets, all ~~p~~ +ve, hence repel each other, larger S. A painted. Object to be painted is made negatively charged.
- Dust Extraction → positively charged wires ~~stretche~~ stretched across chimneys, induce ionisation of dust particles, making them positively charged (as e^- in particles repelled out), thus repelled by wires towards earthed plates.

- Dangers → If enough e^- build up on something, some e^- may be pulled though the air, generating sparks, could start a fire. To prevent charge build up, we "earth" objects so the charge can flow into the ground ~~+ to preven~~

Electrical Currents

- electrical Conductors allow for the flow of a current though them → e.g all metals (Cu, Al)
- Insulators ~~do not~~ cannot carry a current, due to a lack of delocalised electrons → e.g. plastics, rubber
- The current is an expression of the rate at which charge flows through a circuit
- $\therefore$ Current (I) = $\frac{\text{Charge (C)}}{\text{time (s)}}$
- 1 C is an expression of the charge generated by 6.24 x 1018 electrons
- We draw circuits in this manner



- Voltage = Joules per coulomb
  = Current × Resistance

R is in ohms (Ω)

$$V = IR = \frac{J}{C} \longrightarrow R = \frac{V}{I}$$

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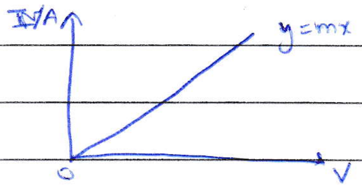
Voltage Graphs

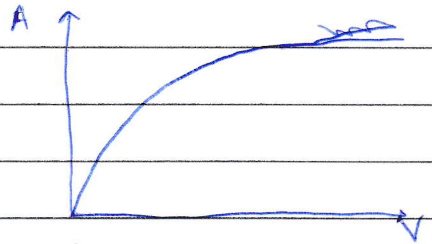
- $y = I\ (A)$, $x = V\ (V)$
- Gradient $= \frac{I}{V} = \frac{1}{R}$
- Fixed Resistor



→ constant gradient ∴ $\frac{1}{R}$ constant, hence R constant

→ All ohmic conductors (fixed resistors) display this

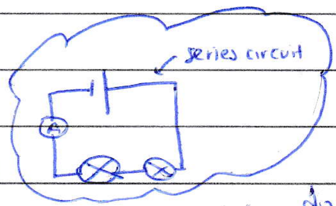
- Filament lamp



→ ↑ current, lamp gets hotter, ↑ resistance, ∴ $\frac{1}{R}$ ↓ in size, so graph flattens

Circuits

① Series

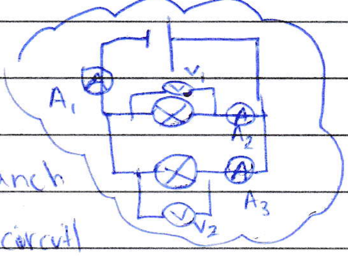


→ same current flows through each part

→ if one part of the circuit breaks, the overall flow of $\bar{e}$ is disrupted, circuit becomes incomplete, ∴ connected appliances do not function ~~receive no electricity~~

→ ∴ if one lamp breaks, the others stop working

② Parallel



→ branches off from main circuit

→ current split depending on resistance in each branch

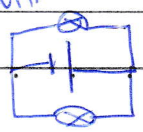
→ Σ current in each branch = current in main circuit

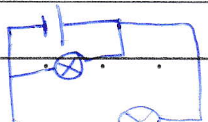
→ e.g $A_1 = A_2 + A_3$

→ Voltage across each branch is the same as the total voltage → $V_1 + V_2$ = battery voltage

→ If one lamp stops working, ~~the circuit can't~~ the circuit is not broken

→ Examples of parallel circuits





Resistors

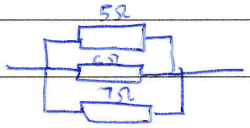
- When resistors are in series, total resistance = Σ resistance of each resistor

e.g

total resistance = $7+6+5 = 18\Omega$

- In parallel, we use this formula → $\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots \frac{1}{R_n}$

e.g



65

$\frac{1}{R_t} = \frac{1}{5} + \frac{1}{6} + \frac{1}{7}$

$= \frac{42+35+30}{210}$

$= \frac{107}{210}$

$\therefore R_t = \frac{210}{107} \approx 1.96$ or so $\Omega = 1.96\Omega$

Power and Energy

- Power (P) = Voltage (V) × Current (I)

$P = VI$

why? → $V = J/\text{coulomb}$

$I = \frac{\text{coulomb}}{\text{second}}$

- P is in watts
- To find energy transfer, we multiply P by t

$E = VIt$

as $P = \frac{J}{\text{second}}$ ∴ $E = J$ from $P \times t$

$VI = \frac{J}{\text{coulomb}} \times \frac{\text{coulomb}}{\text{second}}$

$= J/\text{second} = \text{power}$

- E is also = Volts × ~~cob~~ coulombs transfered

as

$= JC^{-1} \times Cs^{-1} \times s$

$= C \times JC^{-1}$

$=$ ~~C×V~~ $V \times C$

Transformers

- use a.c current under a magnetic field
- can produce different output voltages depending on the number of coils on the input and output centres (primary and secondary coils)
- $$\frac{\text{Voltage on primary}}{\text{Voltage on secondary}} = \frac{\text{coils on primary}}{\text{coils on secondary}}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

- If $N_s > N_p$, $V_s > V_p$, so the transformer is a step up transformer
- If $N_s < N_p$, $V_s < V_p$, so the transformer is a step down transformer
- If a transformer is 100% efficient → Power from primary = Power from secondary

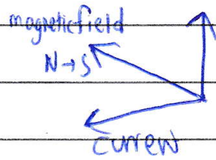
$$V_p I_p = V_s I_s$$

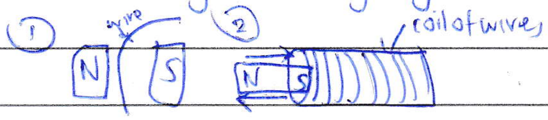
Power Generation

Electromagnetic Induction

→ creation of a potential difference across a conductor that is experiencing a change in magnetic field

→ This is produced by moving a wire within a magnetic field according to Flemming's right hand rule



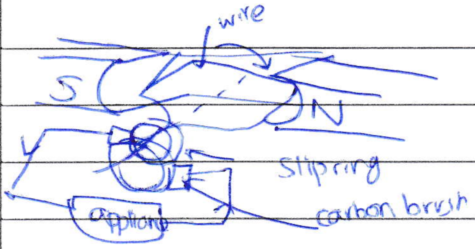


- by cutting though ~~an elect~~ magnetic field, e's in the wire/conductor ~~can~~ are given the energy to move

→ The voltage and current generated can be ↑ by ① using a stronger magnet
② moving the wire faster/magnet faster
③ ↑ ~~coils~~ turns on a coil
④ cross sectional area increase ~~increase~~ in the coil

- If wire/magnet moved back and forth, alternating current produced

A.C Generators



- As the coil is rotated 360°, the current flows forwards, then backwards, e.t.c for as long as the coil is turning
- High currents when the wire is perpendicular to field

Important Equations for Electricity

$V = IR$

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

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

$E = VIt = P \cdot t$

$E = V \times C$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}$$

$P = VI$

$P = I^2R$

$P = \frac{V^2}{R}$

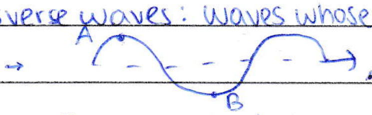
$\frac{V_p}{V_s} = \frac{n_p}{n_s}$

$V_p I_p = V_s I_s$

Waves

Wave Nature

- waves allow for the transfer of energy without net movement of matter
- Transverse waves: waves whose oscillations are perpendicular to the direction of travel

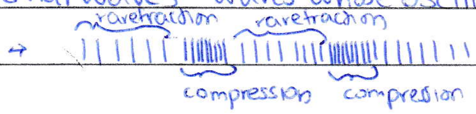


→ e.g $y = \sin x$

- In water waves, A is crest, B is trough

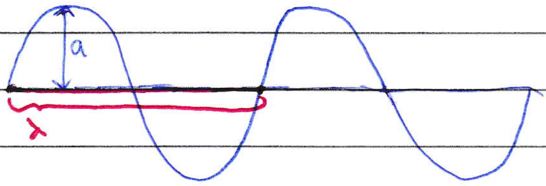
→ E.g. light, electomagnetic radiation, some types of seismic waves

- Longitudinal waves: waves whose oscillations are ~~perpendicular~~ parallel to the direction of travel



→ e.g sound waves, some seismic waves

- Principles



a = amplitude

λ = wavelength (m)

f (frequency) = hertz (Hz)

$$f = \frac{1}{\text{time for one wave to complete 1 cycle (s)}}$$

$$\therefore f = \frac{1}{\text{time period}}$$

$$\text{time} = \frac{1}{f}$$

NOTE: 1 Hz means 1 wave per second, similarly, 2 Hz means 2 waves per second

→ the speed of a wave = $\frac{\text{distance covered}}{\text{time}}$

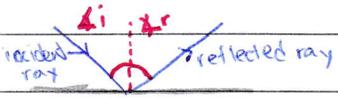
→ velocity also = $v = f\lambda$

= frequency (Hz) × wavelength (m)

Wave Behaviour + Optics

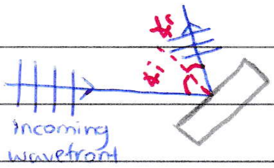
- Reflection (no change in speed, wavelength or frequency)

(a) for light waves



→ we find that the angle of incidence = angle of reflection

(b) for wavefronts



→ same rule applies, ∡i = ∡r

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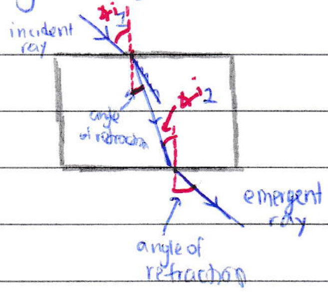
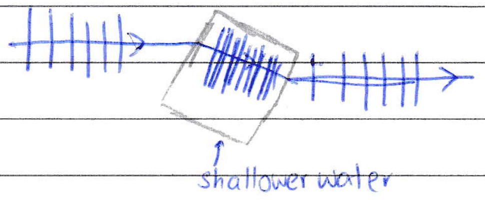
○ Refraction (↓ speed and wavelength for entering dense/shallower area)

(a) light waves



(b) ~~for~~ wavefronts



→ incident ray parallel to emergent ray

→ shallow water ↓v, ↓λ of wavefront

→ deeper water ↑v, ↑λ of wavefront

→ for entering denser substance,
$\measuredangle i_1$ > angle of refraction (1)

→ for exiting dense substance, entering less dense substance
$\measuredangle i_2$ < angle of refraction

→ Why do v and λ decrease?

○ upon entering a denser medium, the waves bunch up (↓λ), but the frequency stays constan

○ As we can see from $v = f\lambda$, to compensate for ↓λ, v must also decrease
[and $f = \frac{v}{\lambda}$]

○ The Doppler Effect

→ when the source of a wave moves towards an observer, the observed wavelength decreases and the observ frequency increases

→ when the source moves away from an observer, the observed wavelength increases and the observed frequency decreases

→ e.g. a police car's sirens sounds high pitched when near us (due to lower observed wavelength and higher observed frequency) but becomes low pitched as it moves away (as ↑ observed wavelength, ↓ observed frequency)

→ When we compare the absorption spectrum of the sun and a distant star, we find that the latter has more absorption of wavelengths corresponding to red (high λ). This is explained by the Doppler effect, as we are further from the source, we obtain higher observed wavelengths, lower observed frequencies.

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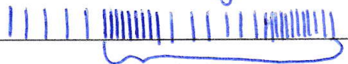
Sound Waves

- they are longitudinal waves consisting of compressions and rarefactions



λ (start of one compression/rarefraction till end of next compression/rarefraction)

- speed of sound = 330ms^{-1}
- Need a material to travel through, need medium to pass oscillations through
- Order of speed of sound in different states → solid > liquid > gas
- NOT IN BMAT SYLLABUS (but interesting) → oscilloscopes use a microphone to track air pressure and shows its oscillations, creating a waveform that is ~~ar~~ transverse analogue of a sound wave
- When sound waves are reflected by hard surfaces, they prod~~uce~~ve echoes
  - → 

    ∴ $\text{speed of sound} = \frac{2 \times A}{\text{time to hear echo}}$
  - → Remember to multiply distance by 2
  - → this principle is used in echosounders in ships → sound waves used to estimate depth → but remember this 2(depth) is the dist travelled
- Ultrasound
  - → bats use~~d~~ ~~a~~'ultrasound to send out sound pulses and use the reflections to "see"
  - → scanning the womb - reflected sound waves analysed by computer to prod image
    - unlike x-rays, no damage and can distinguish between diff layers of soft tissues

AY.

Equations

$v = f\lambda$

$E = hv$ ← frequency

↑ 6.63×10^{-34}

$f = \frac{1}{\text{time period}}$

$\text{time period} = \frac{1}{f}$

The Electromagnetic Spectrum

Basics

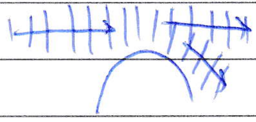
- transverse waves (can be reflected and refracted)
- travel at $c = 3 \times 10^8$ m/s in a vacuum
- transfer energy

Spectrum

- In order of frequencies, with decreasing wavelengths
  radiowaves, microwaves, infared radiation, visible light, UV, X-Rays, Gamma Rays
- ∴ gamma rays have the highest frequencies and lowest wavelengths, whereas radiowaves have the lowest frequencies and highest wavelengths
- higher frequencies mean greater energy, ↑danger (as $E = h \times f$)
- long wave radiowaves, radio transmitters, short wave radiowaves, TV waves/broadcasts

Types

① Radiowaves



→ used in radio broadcasts, can bend (diffract) around hills

→ low wave, short wave → TV

→

② Microwaves

→ micowave ovens

→ communications with satellites, radar

→ absorbed easily by H_2O molecules, can be dangerous

③ Infa-red Radiation

→ emitted by warm objects, heating effect

largest wavelength of visible light (re

→ ↑ heat, ↑ infa-red produced, at 700°C, shortest wavelengths ~~of IR prod~~ " hence object can glow red hot

→ used in thermographs + heaters

→ can be absorbed by skin cells, internal heating could damage cells (e.g. denaturing of proteins)

④ Visible Light

→ only part of the spectrum we can see

→ Red (700nm) – Violet (400nm)

⑤ Ultraviolet (UV)

→ produced by the sun
→ harmful to the skin in excess → skin cancer + damage retina
→ but helps skin produce vitamin D
→ usually, ozone layer helps to absorb some of the UV emitted by the sun
→ some chemicals fluoresce when they absorb UV, convert energy into visible light and glow

⑥ X-Rays (#1 applications clear from the name)

→ ~~product~~ produced by X-ray tube
→ short λ very penetrating
→ can damage cell DNA, mutations can develop
→ however can also kill cancer (by initiating apoptosis)

⑦ Gamma (γ) Radiation

→ produced by radioactive material
→ V. high penetrating power, only lead can stop it
→ used in sterilisation of medical equipment + external beam therapy in cancer (using Co-60)

Radioactivity

Atomic Structure

- atoms consist of protons, neutrons and electrons
- ~~apr~~ In the model of the atom, we find neutrons and protons in the nucleus, with electrons found in concentric, circular shells surrounding the nucleus
-

	proton	electron	neutron
charge	+1	-1	0
mass	1	5×10^{-4}	1
location	nucleus	electronshells	nucleus

- atomic number = number of protons, atomic mass = number of protons + neutrons
- ~~We can~~ isotopes; atoms of an element with the same number of protons and neutrons but a different number of neutrons
- Ions are formed from the gain or loss of electrons.
  - → If enough energy is supplied, ~~e~~ electrons can move out of an atom, making it a cat
  - → If there are strong electrostatic forces of attraction between an atom and a free electron, the electron can move into the atom's valence shell, making it an anion
  - → anions → -vely charged, cations, +vely charged

Radioactive Decay

- sometimes, we can have atoms with unstable nuclei ~~which~~
- this unstable nucleus can undergo decay, and as it does, it emits radiation
- the frequency at which this happens is random, it is also spontaneous
- There are 3 main types of radiation - alpha (α), Beta (β) and gamma (γ) radiation

α radiation

- the emission of an alpha particle stabilises the nucleus
- the original nucleus is the parent nucleus, any new nuclei are daughter nuclei, decay prods are daughter nucle + part
- An α particle is a particle made of 2 protons and 2 neutrons ($^{4}_{2}He$ / $^{4}_{2}\alpha$) (∴ ↓ p by 2, ↓ mass by 4)
- Ionisation ability: high, due to high charge density
- Penetration: low penetration (stopped by paper, skin or 6cm of air)
- e.g. $^{238}_{92}U \longrightarrow \underline{^{234}_{90}Th} + ^{4}_{2}\alpha$

  ↖ bear in mind that the daughter nuclei will correspond to a new element
- deflected in a magnetic field.
- speed is 0.1 × speed of light = 0.1c

B radiation

- emission of B particle stabilises the nucleus
- In beta decay, a neutron is converted into a proton, electron and antineutrino
- The beta particle is ~~an~~ the electron ($^{0}_{-1}B$ / $^{0}_{-1}e$)
- NOTE, $\bar{\nu}$ is antineutrino
- Ionisation ability: ~~high, but~~ weak lower ~~by~~ than α
- Penetration: relatively high penetration, but can be stopped by 3mm of Al(s)
- E.g. $^{234}_{90}Th \longrightarrow ^{234}_{91}Pa + ^{0}_{-1}B$ [mass same, ↑ proton no by 1]
- speed varies between 0.5c and 0.9c
- deflected in a magnetic field

γ radiation

- emission of γ radiation stabilises the nucleus (no change in no of protons, neutrons or electrons)
- emitted as a photon, specifically low wavelength, high frequency electromagnetic radiation
- accompanies α or B decay usually, or emitted when particles and antiparticles meet
- Ionisation ability: very weak
- Penetration: extremely high, can be reduced only by lead

Background Radiation

- There is a small amount of radiation around us all the time, this is the background radiation
- Can come from radon gas seeping out of rocks or from space (cosmic radiation)

Applications and Hazards of Ionising Radiation

Medicine

- Tracers: I-125 tests thyroid function, I-131 kills thyroid tissue, Technetium-99 (Tc-99) emits γ radiation, which can be traced by a gamma camera (also low ionisation)
- sterilisation: γ rays used to sterilise surgical equipment
- cancer: Co-60 produces γ radiation used to kill cancer cells

Date No.

Industry

- testing for cracks / leaks in pipes → use an isotope with short life and is a ~~beta~~ beta emitter (α cannot leave ground, γ would pass through the pipes all the time). Detection of radiation at a point shows the point of a leak

Radioactive Dating

- Using $^{235}_{92}U$ or $^{14}_{6}C$, we can see how old certain items are by comparing the count numbers / number of ~~atoms~~ unstable isotopes remaining ; we can use ~~the~~ half life to do this

rocks

once living material

Hazards

- ionising radiation can trigger a gain or loss of electrons in surrounding specie)
- can form unstable radicals (with an unpaired electron) which can damage DNA of cell) → mutations → can

Radioactive Decay and Half Life

- With a radioactive sample, we expect the number of unstable nuclei and the activity of these nuclei to decrease over time
- For example, take $^{131}_{53}I \longrightarrow ^{131}_{54}Xe + ^{0}_{-1}B$.
  - → if there are 2×10^8 atoms of ^{131}I-131 initially, after x minutes, we will have 10^8 atoms of I-1 and 10^8 atoms of Xe-131
  - → this time x is the half-life of I-131
- We can quantify the activity of a sample as the number of nuclei decaying per second, which is the becquerel (Bq)
- 1 Bq = 1 nuclei decaying per second
- Graphic representations of decay

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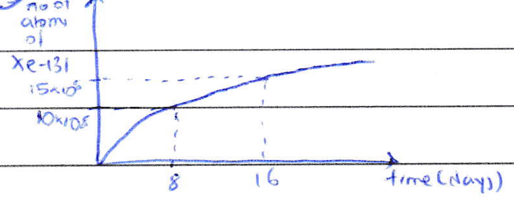

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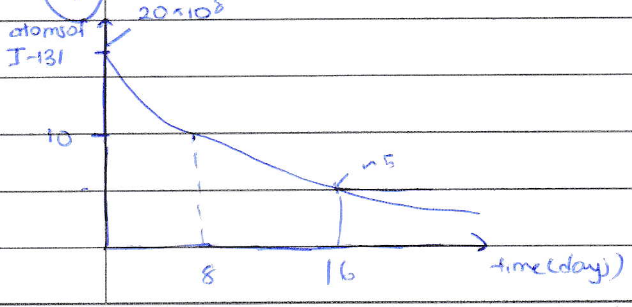

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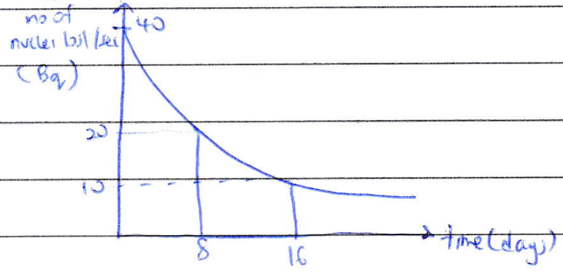

Nuclear Fission

- occurs when Uranium-235 or Plutonium-239 are bombarded with ~~sm~~ slow moving neutrons
- when a neutron penetrates an atom of U-235, the nucleus becomes very unstable, splitting into 2 nuclei and releasing 3 neutrons (sometimes 2)
- The splitting process is called fission
- The 3 neutrons released can start fission in other U-235 atoms, sparking a chain reaction
- Equations → $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{236}_{92}U \longrightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2^{1}_{0}n$
- In a reactor, control rods ~~slow down~~ absorb some neutrons to slow down the reaction

Nuclear Fusion

- small nuclei joining together to make a larger one
- e.g. fusion of hydrogen to form He → $^{1}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He$

  then

  $^{3}_{2}He + ^{3}_{2}He \longrightarrow ^{4}_{2}He + 2p$
- usually occur in stars, v. high temperatures + pressures needed for reaction to occur
- releases a huge amount of energy, even more than ~~fusion~~ fission reactions
- ~~no~~ little radioactive waste produced, lot of hydrogen that can be used as fuel
- used in hydrogen bombs, initially, fission produces the heat needed for fusion