Kinetic Particle Model

Kinetic particle model = atomic theory.

- All matter made of tiny moving particles
  e.g. atoms or molecules
- Particles move in straight lines
- Elastically collide with each other and walls of container
  so KE is conserved
- As a gas, the distance between particles are large compared
  to their size
- Average Particle velocity (i.e. KE) is proportional to temperature

(Boiling vs. Evaporation)

Evap. = slow process. Boiling quick.

(Fig 10.5 BBB) Increasing T, avg speed increases

also, Increasing T, larger spread of molecule KE

Heat and Temperature

Internal Energy = KE + PE

$\uparrow$ $\propto$ Temp.

Phase diagram (Fig 10.15): E used to break inter-molecular bonds instead of increasing KE @ boiling point.

Zeroth Law of Thermodynamics

If object A is the same temperature as object B, and object B is the same temperature as object C, then object A is the same temperature as object C.

First Law of Thermodynamics

Energy cannot be created or destroyed in an isolated system. ← $-Q_{lost} = Q_{gained}$

(Types of systems)

Open: Energy / Mass can enter and exit

Closed: Mass stays same but energy can enter and exit

Isolated: Neither energy or mass can enter or exit

Second Law of Thermodynamics

The entropy of an isolated system always increases.

(Entropy)

Entropy is the measure of the disorder in a system.

Third Law of Thermodynamics

Entropy approaches a constant value as temperature approaches absolute zero.

Absolute Zero

Absolute zero is the theoretical temperature where there is no internal energy. It is equal to -273.15°C

To cool something, there needs to be an object that is colder for the heat to flow into. However, when cooling an object to absolute zero, there is no colder temperature than -273.15°C. Thus, it is theoretically impossible to achieve absolute zero temperatures.

(Celcius and Kelvin)

C and K share the same magnitude of their units (i.e. +1°C = +1K). Converting between the two requires this formula:

$$K = °C + 273$$
$$°C = K - 273$$

This means 0K is at absolute zero.

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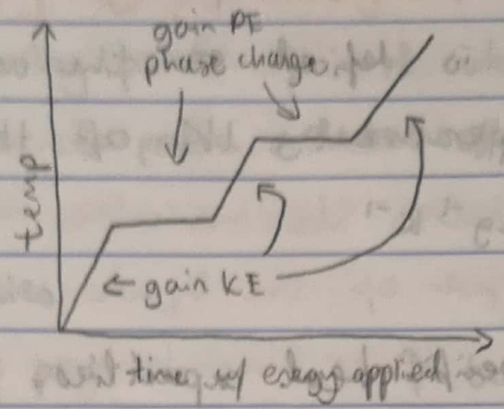


(Bathtub vs. Teacup)

Which has more energy, a fully filled 40°C bathtub or a fully filled 100°C teacup?

Answer: bath tub, because there are more molecules inside the bathtub compared to the cup even though for one molecule, the kinetic energy in the cup is higher than in the bath tub.

(Use Kelvin, not Celcius)

When comparing temperatures of substances, calculations must be done in K.

Specific Heat Capacity

Specific Heat Capacity is defined as the amount of energy which will raise temperature by 1K of 1kg of a specific material. Unit: $J\,kg^{-1}\,K^{-1}$

Table 10.1 lists specific heat capacities.

$$Q = mc\Delta T$$

where Q is energy (J)

m is mass (kg)

c is specific heat capacity ($J\,kg^{-1}\,K^{-1}$)

ΔT is change in temperature (K)

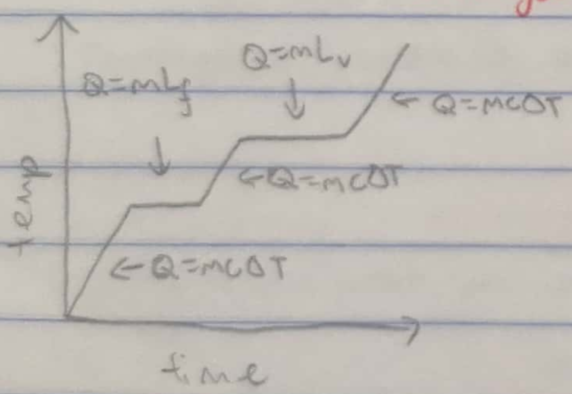
Process of Calorimetry

Use First Law of Thermodynamics:

$$-Q_{lost} = Q_{gained}$$

$$-(m_1 c_1 \Delta T_1) = m_2 c_2 \Delta T_2$$

Change of State



We cannot use specific heat capacity to calculate energy use when potential energy increases/changes. Use ~~specific h~~ latent heat of fusion (L_f, table 10.2) for solid $\leftrightarrow$ liquid and latent heat of vaporisation (L_v, table 10.2) for liquid $\leftrightarrow$ gas phase changes.

Changing Melting & Boiling Points

Melting and boiling points of most substances can be altered in order to produce a desired effect. This can be done using:

1. Adding impurities
   - ↓ melting point
     eg. saline solution to de-ice windows
   - ↑ boiling point
     e.g. cook pasta in salty water (quicker)

2. Increasing pressure
   - If liquid expands when frozen: ↓ melting point
   - If liquid contracts when frozen: ↑ melting point

   because: ↑ pressure pushes molecules closer together. If (l) contracts, increases T where molecules attract & solidify.

   - ↑ boiling point
     e.g. pressure cookers

Removing impurities or decreasing pressure has the opposite effect on melting and boiling points.

Evaporation

Liquids can change state without boiling. All molecules in the liquid do not contain the same kinetic energy; during evaporation, the molecules with greater energy near the surface of the liquid change state to gaseous form. The slower molecules get left behind.

Evaporation does not occur in a closed container as the system has reached an equilibrium where the rate of evaporation is equal to the rate of condensation. (Fig 10.16)

The Kinetic Model of Gases

Assumptions are made to simplify the motion of gas particles.

1. Gas particles are in constant random motion. They move at high speeds in straight lines unless they elastically collide (no loss in KE) with the walls of the container or other gas particles.
   - Explains why gases readily mix and fill containers.
2. Gas particles are separated by large distances compared with the particles' diameter, which is assumed to be negligible in size.
   - Explains compressibility and small density of gases
3. Intermolecular attraction is negligible ∵ distance.
4. Temperature is a measure of the average KE of the gas,

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(Pressure)

Pressure is defined as the force per unit area, or:

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

Where P is pressure (Nm^{-2}) or (Pa)

F is force (N)

A is area (m^2)

The Combined Gas Equation

Since

$V \propto \frac{1}{P}$ (Boyle's Law, $P_1V_1 = P_2V_2$),

$V \propto T$ (Charles' Law, $\frac{V_1}{T_1} = \frac{V_2}{T_2}$),

and $P \propto T$ (Amontan's Law)

Then:

$V \propto \frac{T}{P}$ and $\boxed{\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}}$

Where P and V can be in any unit as long as it is consistent, but T has to be measured in Kelvins. $1\,L = 10^{-3}\,m^3$

$1\,atm = 101.325\,kPa$

The Ideal Gas Equation

Because $P \propto N$ where N is the number of gas particles,

$$PV = kNT$$

Where k is Boltzmann's constant, $k = 1.38 \times 10^{-23}\,Pa\,m^3\,molecule^{-1}\,K^{-1}$

If N is changed to number of moles (n) then

$$PV = nRT$$

Where R is the Universal Gas constant, $R = 8.31\,Pa\,m^3\,mol^{-1}\,K^{-1}$

All variables are in standard units.

(Converting N to n)

Use $n = \frac{N}{N_A}$ to convert n to N.

N_A is Avogadro's Constant, $N_A = 6.02 \times 10^{23}$

Temperature and Kinetic Energy

Use this equation to find E_k at a T or vice versa:

pressure $(P = \frac{1}{3}\rho v^2)$ density

$$\overline{E_k} = \frac{3}{2}kT$$

where $\overline{E_k}$ is the total E_k for all particles (J)

T is temperature (K)

k is Boltzmann's Constant

(Real Gases)

Gases in real life are often not ideal (ideal: consisting of single atoms only). Assumptions were made that gas particles' size and attractive force is negligible. However, in real life, $P \propto \frac{1}{T}$ as the molecules are pushed closer together, attractive F is greater and V of particles is significant compared to V of gas.

Under ~~of~~ the conditions of low temperatures or high pressures, a real gas deviates from the behavior indicated by the ideal gas equations.

Thermal Expansion of Solids

Linear thermal expansion: application p265

$$\Delta L = L_i \alpha \Delta T$$

where ΔL is change in length (m)

L_i is original length (m)

α is the coefficient of linear expansion ($m\,K^{-1}$)

ΔT is change in temperature (K)

ΔL of 1m of substance due to 1K ΔT

(Table 11.1)

Thermal Expansion of Liquids

Liquid thermal expansion:

$$\Delta V = V_i \beta, \Delta T$$

where ΔV is change in volume (L)

V_i is initial volume (L)

β is the coefficient of volume expansion ($~~m~~\,L\,K^{-1}$)

ΔT is change in temperature (K)

(Table 11.2)

Abnormal Expansion of Water

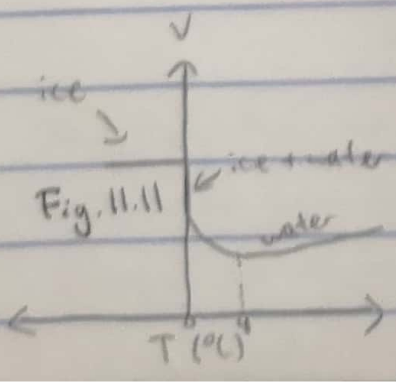

Fig. 11.11

Between 0°C and 4°C, water expands as T decreases. When it freezes at 0°C it undergoes considerable expansion.

Conduction

Metal feels colder than fabric because it is more thermally conductive. Similarly, a down blanket feels warmer than a polyester blanket because the air between the feathers is less thermally conductive.

Heat can only be conducted through a medium where there are particles i.e. s, l and g. Vacuum environments cannot conduct heat.

$$R = \frac{k\,|T_2 - T_1|\,A}{d}$$

Where R is the rate of heat transfer (W)

k is the thermal conductivity ($W m^{-1} K^{-1}$)

$|T_2 - T_1|$ is the difference in temperature (°C or K)

Table 12.1

A is the area (m^2)

d is the thickness (m)

Conduction - contact between two objects where energy transfer occurs

Magnetism & Electromagnetism

Diamagnetic - most common, weakly repelled by magnents
e.g. glass, Cu, Au and bismuth.

Paramagnetic - weakly attracted by magnents
e.g. Mn, Al and Pt

Ferromagnetic - strongly attracted to magnents
e.g. Fe, Ni, Co best examples

Field Lines
- Arrows from N to S
- Do not cross
- More closer together ↳ stronger field at point

(Magnetised?)

During crystallisation, metals that are magnetised have their magnetic domains oriented (Fig 25.5 R). Unmagnetised materials have randomly oriented magnetic domains, resulting in a net magnetic charge of zero.

(Soft vs. Hard)

Difficult to induce but retains magnetism : magnetically hard
Easy to induce but quickly loses magnetism : magnetically soft

(Demagnetisation)

Demagnetisation occurs with soft/hard ~~magnets~~ magnets when:
- heated to Curie Temperature (unique to every material)
- dropped or hammered

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(Cause of Magnetism)

Magnetism is caused by the spin of the electrons in the atoms.

Magnetic Fields

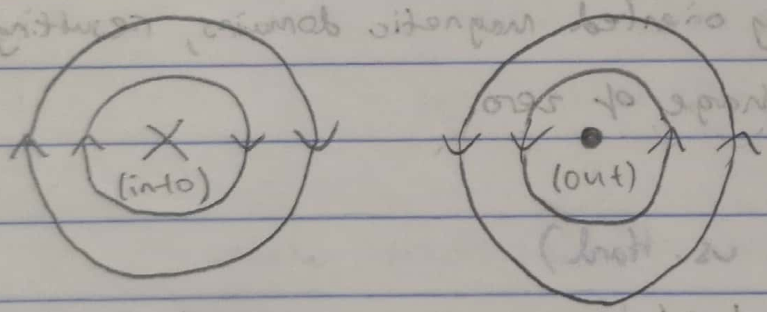
The magnetic field strength (B), measured in Teslas (T), is shown by the density of the field lines.

(Conventional Current)

Conventional current describes current flow from excess positive to excess negative.

Magnetic Field in a Wire

Field lines travel clockwise, axially to the wire.



Maxwell's Screw Rule

Point thumb (RH) parallel to wire. Direction to fingers is direction of field lines. Thumb = current, curl = field

- Field lines are concentric
- $B \propto \frac{I}{r}$ - current, - radius
- Current reversed, field direction reversed

$$B = \frac{k\,I}{r}$$

where B is magnetic field strength (T)

k is magnetic constant, $k = 2\times10^{-7}\ N\ A^{-2}$

I is current (A)

r is distance from centre of wire (m)

Solenoids / Multi-turn Coils

Inside coil, field lines add up through middle of coil.

Outside, field lines cancel out.

$$B = \frac{2\pi k N I}{L}$$

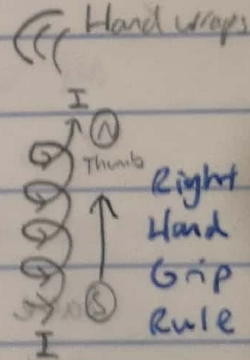
where N is number of turns

L is coil length (m), not wire length

To find direction of field: (RH Grip)

Point fingers along each coil wire in dir. of current

Thumb will point N



Right Hand Grip Rule

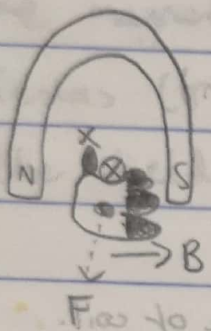
Forces on Current-Carrying Conductors

Use the right hand motor rule:

Point thumb in direction of current

Point fingers flat in field direction (external)

Force directed on wire away from palm.



RH Motor Rule

or Motor principle

← length of conductor in flux (m)

$$F = BIL\sin\theta$$

Where F is the EMF on the wire (N)

B is the field strength (T)

I is the current (A)

θ is the angle of the wire to the field

Parallel CCC's

Same direction of current: attractive force btw. wires

Opposite direction of current: repulsive force btw. wires

Recall $B = \frac{kI}{r}$, field of a CCC.

Let r = distance btw. two wires

Then $B = \frac{kI}{d}$

Force experienced by I_1 : $F_1 = B_2 I_1 L \sin\theta$

Then:

$$F = \frac{k I_1 I_2 L}{d}$$

where F is the force on both parallel wires (N)

Coils in Magnetic Fields

The total torque acting on a coil within a magnetic field is given by:

$$\tau = BAIN\cos\theta$$

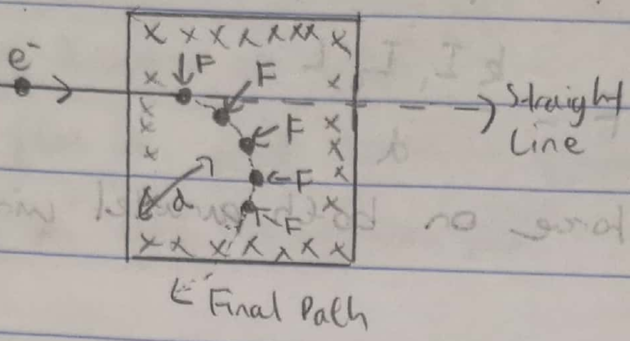
where τ is the torque (Nm)

A is the CSA (m^2)

N is the number of turns

θ is the angle

Moving Charges in Magnetic Fields



$$F = qvB$$

Where F is EMF causing e^- to turn (N)
q is charge of e^- (C)
v is velocity (ms^{-1})

$$r = \frac{mv}{qB}$$

Where r is radius of path (m)

(Right or Left Hand?)

All rules to do with hands have been using the right hand. This is because the RH thumb points in the direction of conventional current (opposite to e^- movement).

The LH can be used instead to find the direction of e^- flow. All hand rules are compatible.

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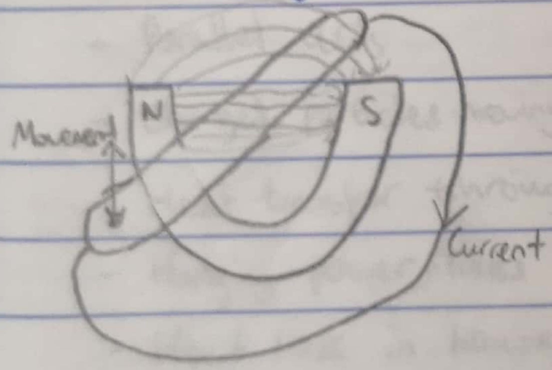
Electromagnetic Induction

Faraday's Law states that when a magnetic field in the region of a conductor changes, an EMF is induced across the ends of the conductor. If the conductor is made part of a complete circuit then an induced current will flow.

Lenz's Law states that when an EMF is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced EMF is such that it produces a current whose magnetic field opposes the change which produces it.

Faraday's Law



$EMF = BLv\sin\theta$

Where EMF is induced voltage

L is length of conductor in field

v is relative velocity

Magnetic flow in a conductor, in a closed circuit, gives current.

Magnetic flow in a conductor, in an open circuit, gives EMF across the conductor.

Lenz's Law

Mag. flux → EMF → Current → Magnetic Field

opposes

Transformers

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

Where V_p is AC across primary coil
V_s is AC across secondary coil
N_p is number of primary turns
N_s is number of secondary turns.

If $N_p > N_s$, transformer is step-down (reduce AC voltage)
If $N_s > N_p$, transformer is step-up (increase AC voltage)

The current changes along with the voltage as energy is not created nor destroyed.

$$V_p I_p = V_s I_s$$

Paper A

Term I
Exam Content

Recall & Explain (Part A) KCU 1

defn. - Field Lines N–S
rel. - Mag. domains, dia-, ferro-, paramag.
rel - Current, mag. fields, movement

- 1^{st}, 2^{nd} laws of Thermodynamics defn.
- Thermal Expansion defn.
- Thermal Energy, E_k, E_p, temperature rel.

Very in-depth explanation required
Summary of content

Compare & Explain (Part A) KCU 2

- Magnet attracting iron
- Liquid ⟷ gas energy change
- Compare galvanometer & electric motor
- (Compare temp. change & phase change)

Conclude & Recommend (Part A) EC 2

- Parallel cc's
- Charged particles moving through fields
- Heat transfer through windows
- Hanging power lines
- Heat loss in houses
- Transformers

to conclude, remember to justify your recommendations. justify mathematically and assume, compare values.

Paper B

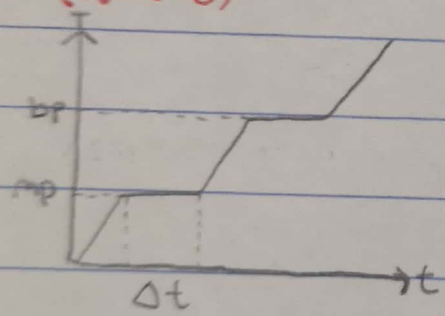
Term I

Exam Content Ctd.

Apply & Calculate (Part B) KCU3

- Field strength of wire $B = \frac{kI}{r}$ kg ↓
- Find c to identify substance $Q = mc\Delta T$
- Field strength of a solenoid $B = \frac{2\pi k N I}{L}$
- P, V, T relationships $P_1V_1 = P_2V_2$, $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
- Field strength at a point due to 2 wires
- Calorimetry with phase changes $Q_{lost} = Q_{gain}$
- Force on conductor in magnetic field $F = BIL \sin\theta$
- Calorimetry with ice

IP (Part B)



Can find: mp, bp, c (w/ power, mass & ΔT)
L_f, L_v (w/ power, mass)

- Charles' Law experiment $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (use kelvin)
- Electromagnet - vary N or I, measure F

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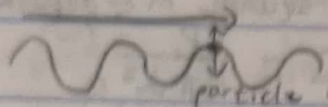
Basics of Sonic

Types of waves: wave propagates this way

Transverse



- Particles move ⊥ to wave's movement

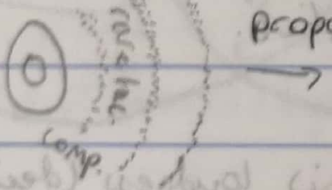
  e.g. water waves, skipping ropes

Longitudinal

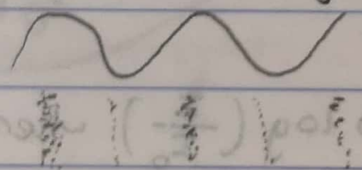
- Particles move ∥ to wave's movement

  e.g. sound

Sound is made of alternating bands of high pressure air (compressions) and low pressure air (rarefactions).



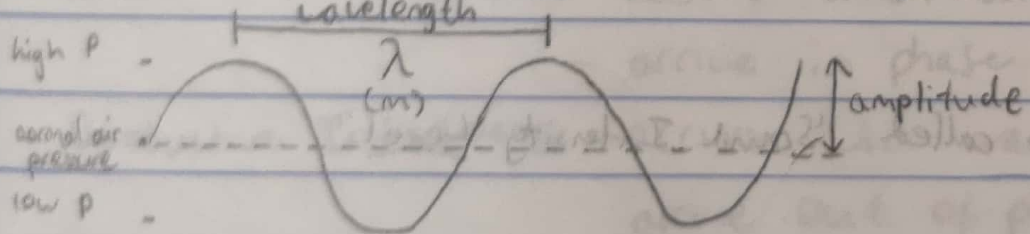
propagates spherically away from source



← representation

← molecules

However, sometimes ~~so~~ sound is represented as a transverse wave to make it easier to visualise.



FREQUENCY (f)

Measured in Hertz (Hz)

1 Hz = 1 wave per sec.

(A4 = 440 Hz)

Velocity of a wave: $\underset{(ms^{-1})}{v} = \underset{(s^{-1})}{f}\underset{(m)}{\lambda}$

In air, $v_s \approx 340 ms^{-1}$ (at 0°C, $331 ms^{-1}$; at 20°C, $344 ms^{-1}$)

Formula for v_s of air @ T: $v_T = 331\sqrt{\frac{T}{273}+1}$

v_s depends on density; metals ↑ v_s than ~~so~~ fluids

Period (T)

measured in (s)

time for a wave to move past a point

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

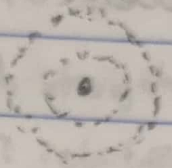
When waves travel through different surfaces, its frequency remains the same but its wavelength changes.

How Loud Things Are

Intensity: I (Wm^{-2}) → energy per second ← Power (P)
per square m ← depends on dist.

$$SA_{sphere} = 4\pi r^2 \quad \therefore \underset{(Wm^{-2})}{I} = \frac{\underset{(W)}{P}}{4\pi \underset{(m)}{d^2}}$$

inverse-square relationship



spherical propagation away from source

$I_0 = 10^{-12}\ Wm^{-2}$ is the lowest intensity sound the human ear is able to detect. Changes in intensity can be picked up more easier at lower intensity levels than high.

Sound intensity is objective. However, it is not a good indication of "loudness" which is subjective.

Loudness: $\underset{(dB)}{L} = 10 \log\left(\frac{I}{I_0}\right)$ where L is loudness (decibels, dB)
L compares the intensity logarithmically to the lower threshold of the ear.

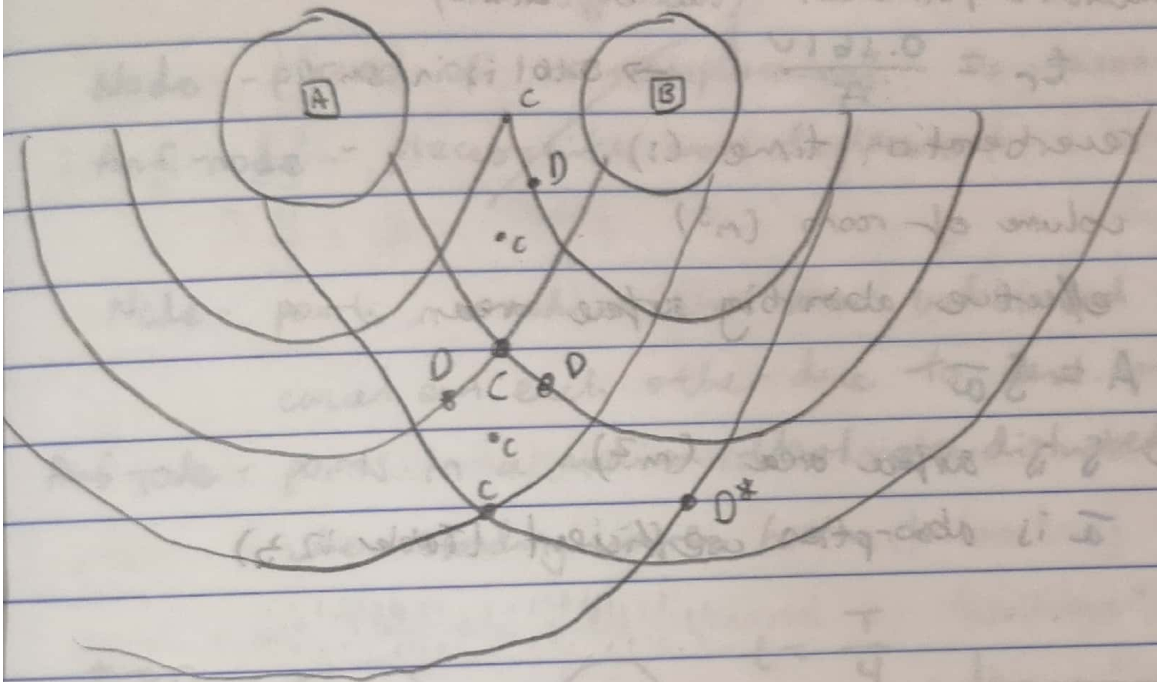
Loudness is also called "Sound Intensity Level."

Humans can hear between 20Hz to 20000Hz.

Interference & Reflection

Hard surfaces reflect waves in the same phase, as the particles in the rigid surface do not move.

Soft surfaces reflect waves out of phase, switching compressions and rarefactions.



Path Difference: Physical distance of point away from sources.

$PD = n\lambda \rightarrow$ constr.

$PD = \frac{n\lambda}{2} \rightarrow$ destru.

Constructive Interference occurs when waves from 2 sources arrive in phase (points labelled C)

Destructive Interference occurs when waves from 2 sources arrive out of phase (points labelled D)

Reverberation Wub-Wub

Reverberation Time is the time that it takes from a note to end to when its echoes cannot be heard (usu. < 60 dB).

Depends on size, shape and nature of surfaces.

Semi-accurate formula: (Sabine's Formula)

$$t_r = \frac{0.161V}{A} \quad \rightarrow 0.161 \text{ is in } sm^{-1}$$

where t_r is reverberation time (s)

V, is volume of room (m^3)

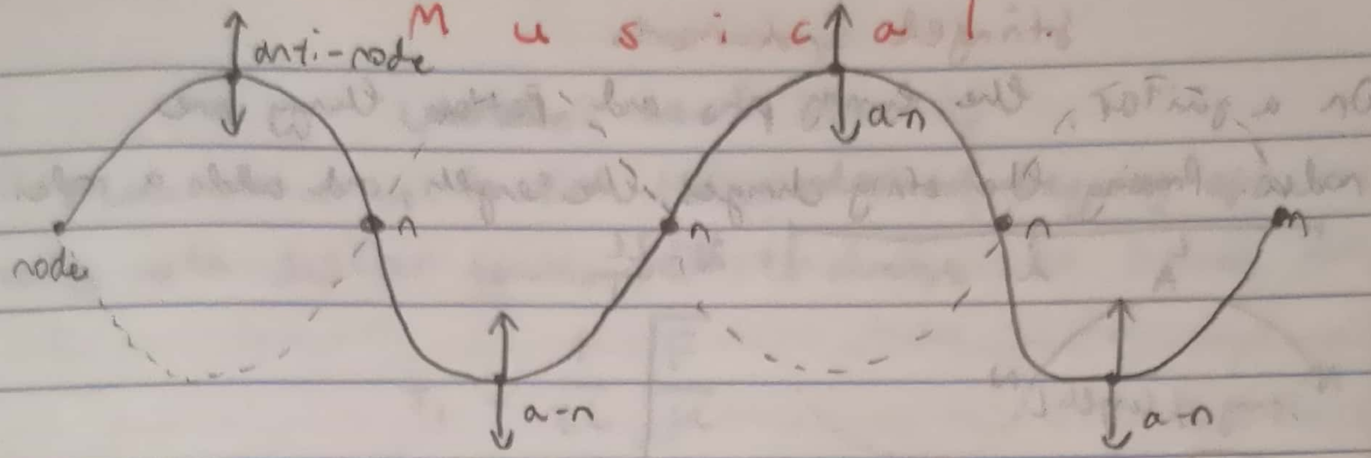
A is effective absorbing surface area

$\hookrightarrow A = S\bar{a}$

where S is surface area (m^2)

$\bar{a}$ is absorption coefficient (Table 17.3)

M u s i c a l

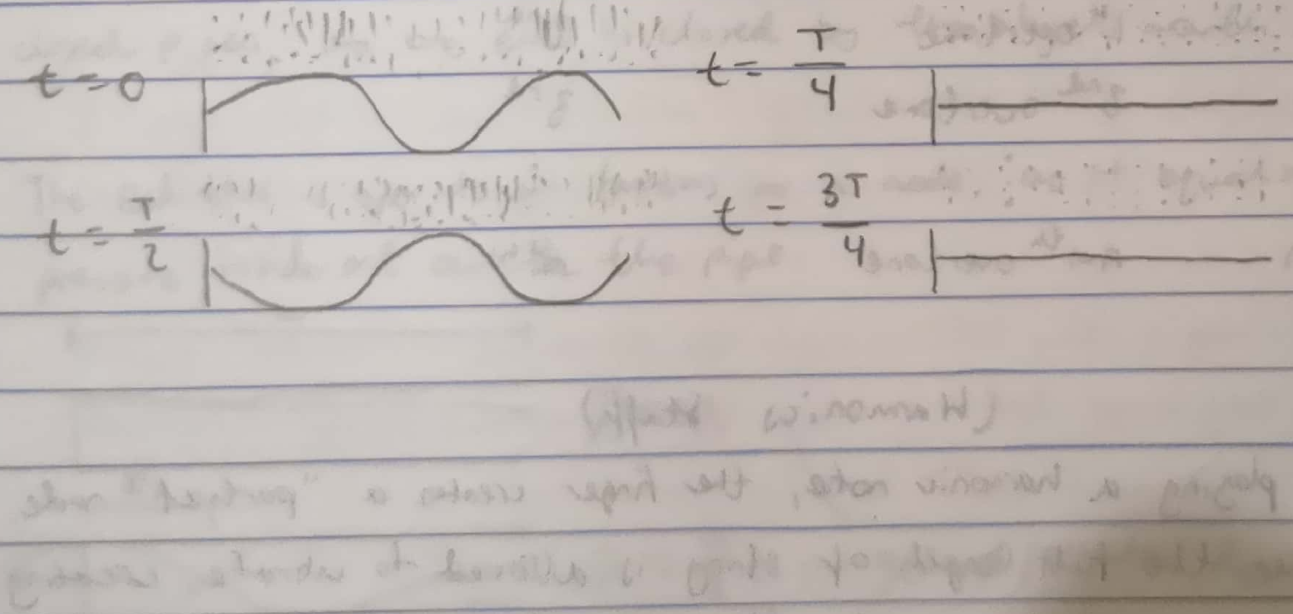


Node - places of no displacement ha-haaaaaa

Anti-node - places with most displacement

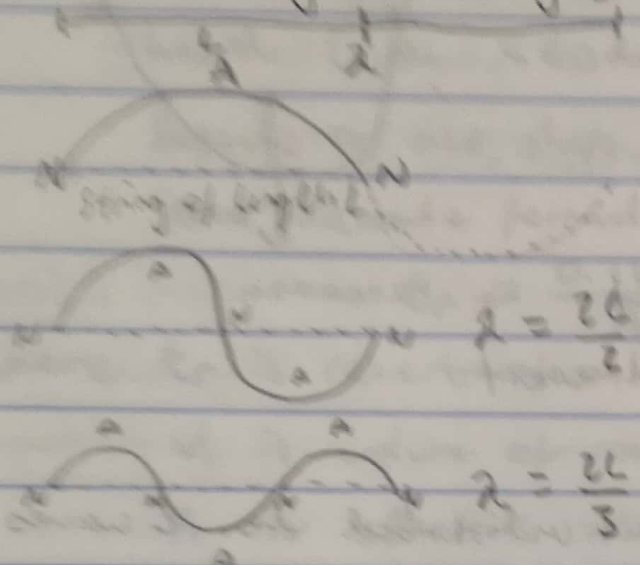
Node - points in a medium that remain undisturbed when 2 waves cancel out each other due to dest. interference.

Anti-node - points in a medium that are disturbed the most when standing waves form.



Stringed Instruments

On a guitar, the tuning pins and bottom thingy are nodes. Pressing the string changes the length, and adds a node.



$\lambda = \frac{2L}{1}$

$\lambda = \frac{2L}{2}$

$\lambda = \frac{2L}{3}$

general formula: $\lambda = \frac{2L}{n}, \; n \in J$

$f_n = \frac{vn}{2L} \therefore f_n = nf_1$

$f_1 = \frac{v}{2L}$

n	name of overtone	name of harmonic
1	fundamental	1st
2	1st overtone	2nd
3	2nd overtone	3rd
⋮	⋮	⋮
n	n-1th overtone	nth

(Harmonics Stuff)

When playing a harmonic note, the finger creates a "partial" node. However, the full length of string is allowed to vibrate, creating an overtone that is louder than the fundamental tone.

(Mersenne's Law)

This law allows us to find the fundamental frequency of strings with different tensions and thicknesses.

$$f_1 = \frac{1}{2L}\sqrt{\frac{F}{\mu}}$$

where F is the tension in the string (N)

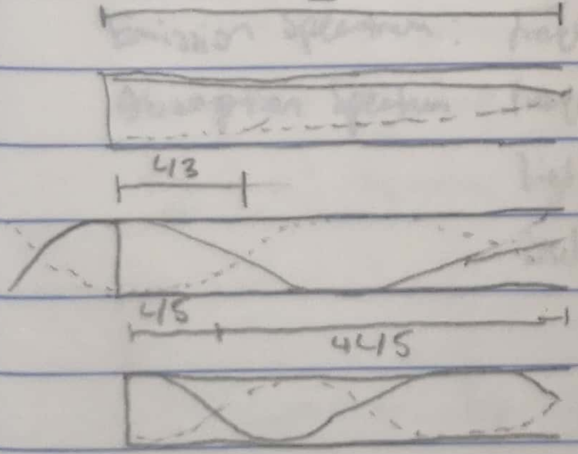
μ is the mass per unit length of the string ($kg\,m^{-1}$)

$$\mu = \frac{m_{string}}{L}$$

Closed Pipes

A closed pipe is one that is sealed at one end and open at the other. Brass instruments and any instruments involving breathing are closed pipes, as one end is closed by the player's mouth.

The end that is open to air functions as a node, as it equalises the pressure inside and outside the pipe.



$\lambda = 4L$

$\lambda = \frac{4}{3}L$ — general formula: $\lambda_n = \frac{4L}{2n-1}$

$\lambda = \frac{4}{5}L$

Modern Physics - History / Intro

α-particle : He^{2+} ion

Ernest Rutherford's gold foil experiment determined that instead of a "plum pudding" model where they are electrons interspersed in positively-charged matter, there exists a nucleus of positive matter surrounded by electrons.

This model has problems: the electrons would get to the nucleus of the atom and spiral faster. This would increase the frequency emitted, but was never observed. Furthermore, a collision of e^- and nucleus would make the atom unstable.

It also did not explain the specific absorbed frequencies in the sunlight's absorption spectrum.

Emission Spectrum: frequencies of light emitted when a gas is excited.
Absorption Spectrum: frequencies of light absorbed by a gas with white light shining through. The "gaps" in the spectrum indicate the gas' composition.

Balmer's Equation

Johann Jakob Balmer created an empirical equation for the ~~frequencies~~ wavelengths of hydrogen's emission spectrum:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

where λ is the wavelength (m)

R_H is Rydberg's constant ($R_H = 1.097 \times 10^7 \, m^{-1}$)

n_f is the final energy level

n_i is the initial energy level

For the Balmer Series, $n_f = 2$ and $n_i = 3, 4, 5$ or 6 with the longest wavelengths corresponding with the smallest n_i.

For the Lyman Series, $n_f = 1$ with n_i increasing after 1.

For the Paschen Series, $n_f = 3$ with n_i increasing after 3.

"1 2 3 → L B P"

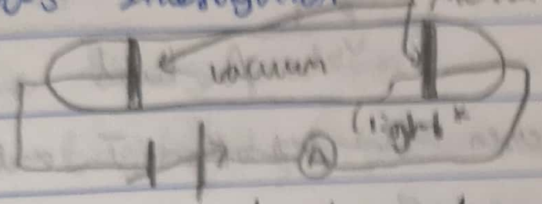
Photoelectric Effect

Discovered: UV light in, current in receiver.

Double-Slit Experiment

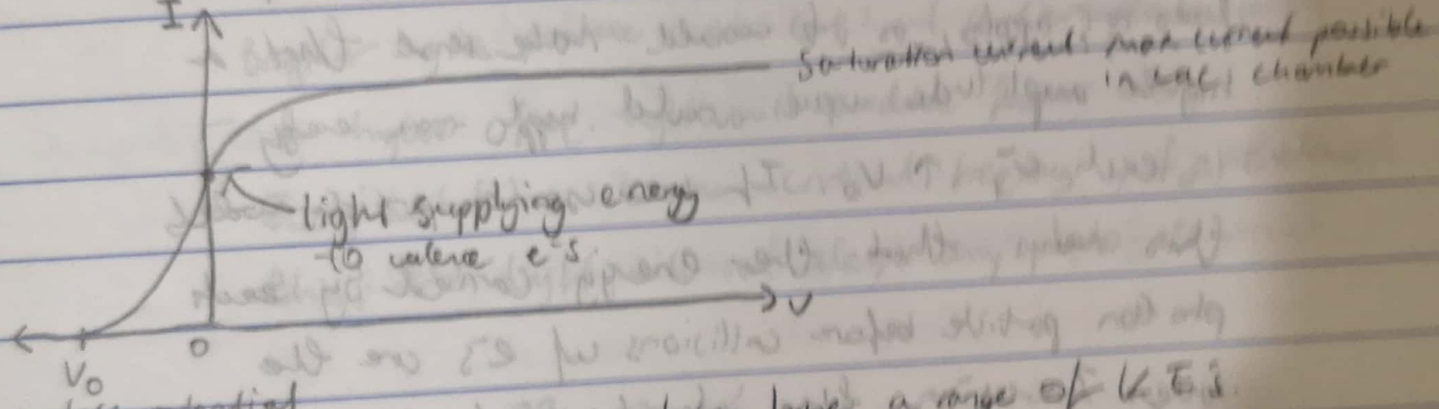
Two slits placed in front of sodium lamp. Resulting image: light and dark bands caused by constr. & destr. interference. This suggests light is a wave.

Lenard's Investigation



Without voltage from the battery, the electrons travelled across the vacuum chamber when a light was shone against the plate.

This suggests the light gave the e's energy



e's leaving metal plate have a range of K.E's.
If e^- does not have enough energy from light, does not escape.
If e^- does have energy but not enough KE, doesn't move.
e^- requires more KE to travel to collector plate.

$$E_p = qV \qquad E_k = \frac{1}{2}mv^2$$

where E_p is electrical potential energy
q is charge
V is voltage (potential diff.)

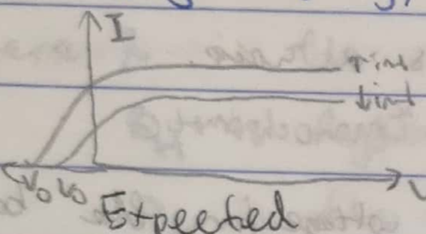
@ cutoff potential, $qV = \frac{1}{2}mv^2$ for most energetic e's.

ctd.

We can write this as:

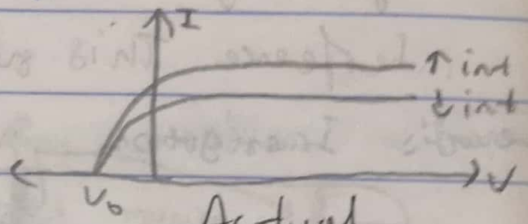
$$E_{k\,max} = qV_0$$

Changing Frequency, Intensity & Surface



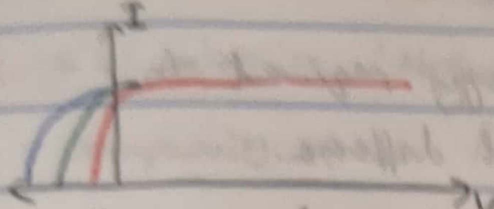
↑ Intensity

Expected

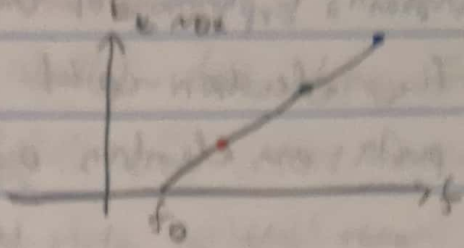


Actual

Increasing the intensity increases the saturation I and I at no voltage, but the cutoff potential stays the same. This means the wave model for the ~~electron~~ photon does not apply, as it would make sense that a higher amplitude wave would supply more energy to each e^-, ↑ V_0. If we use a particle model, this means that the energy carried by each photon particle before collisions w/ e^-s are the same. Increasing the intensity actually increases the amount of photons sent, not their individual energies.



↑ Frequency



Increasing frequency (E of photon)
~~increases~~ decreasing V_0 and increasing $E_{k\,max}$.

(Section Summary)

Wave theory predicts:

- Brighter lights produce more and faster photo-electrons
- A higher frequency light will not change anything

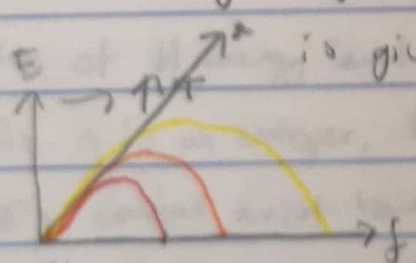
Lenard's Results show:

- Brighter lights produce more but not faster photo-e's
- A higher freq. light will produce faster e's.
- Every metal has its own critical frequency, f_0. Below this, the light will not release any photo-e's.

UV Catastrophe – ??

Black body: object that absorbs and re-emits all radiation it is given

theory & practice for black body radiation disagree.



* expected curve of wave model

Planck proposed that energy was emitted in short bursts instead of one continuous stream called energy quanta.

$$E = hf$$

where h is Planck's constant, $h = 6.63 \times 10^{-34}$

f is frequency

Einstein's Explanation of the Photoelectric Effect.

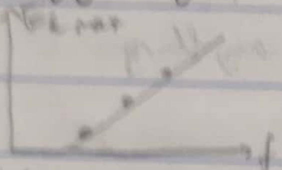
The electron-volt (eV) is the energy required to push an electron over 1V of potential difference.

$$1eV = 1.6 \times 10^{-19} J$$

Requirements for Einstein's Model

1. A photon gives all its energy to an e^-.
2. An e^- must take energy from one photon at a time.

The work function (W) is a measure of ~~the metal's~~ the energy required for an e^- to escape its metal's nucleus.



$$E_{k\,max} = hf - W$$
$$y = mx + c$$

Millikan's experiments confirmed Einstein's prediction.

Applications

Common uses: photoelectric light meters, solar panels

$$m_{e^-} = 9.104 \times 10^{-31} kg$$

Bohr's Model of the Atom

1. e⁻s exist in "stationary states" (energy shells) where they are unexplainably stable. Any permanent change in their motion must consist of a complete transition from one state to the other.
2. No radiation is emitted from an atom in a stationary state. A transition between states will cause an emission/absorption of radiation (photon). The photon's frequency is:

$$hf = E_1 - E_2$$

where E_1 and E_2 are the energy states.

3. An e^- in a stationary state has an angular momentum of a multiple of $\frac{h}{2\pi}$.

Coulomb's Law $$F_C = \frac{kZe^2}{r_n^2}$$

where F_C is the electrostatic attractive force (N)

k is Coulomb's constant, $k = 8.988 \times 10^9\ Nm^2C^{-2}$

Z is the atomic number of the atom

e is the fundamental charge, $e = 1.6 \times 10^{-19}$ C

n	1	2	3	4	5
	L	B	P	B	P
	Lyman	Balmer	Paschen	Brackett	Pfund

Radius of H energy level $r_n = n^2 \times 5.3 \times 10^{-11}$

As n is an integer, there are only set radii possible. e⁻s cannot exist between these positions.

Energy levels of H $$E_n = \frac{-2.17 \times 10^{-18}}{n^2}\ J$$

or

$$E_n = \frac{-13.6}{n^2}\ eV$$

ground state	$n = 1$
1st excited state	$n = 2$
2nd excited state	$n = 3$
⋮	⋮

Ionisation energy: energy req. to remove e^- from atom ($n = \infty$)

Fundamental Forces

Gravity $F = \frac{Gm_1m_2}{r^2}$ nucleons - p^+'s and n^0's

Electrostatic $F = \frac{kq_1q_2}{r^2}$

Strong Nuclear

- Force that acts over ~~the~~ small distance in nucleus ($\approx 10^{-15}$ m) to hold nucleons together against repulsive electrostatic forces exerted between p^+s.
- If p^+'s are too far apart, electrostatic F overcomes strong nuclear F → nucleus breaks up.

too many n^0's

- If nucleons are too close, strong nuclear F has repulsive effect. Both repulsive → nucleus breaks up.

too few n^0's

- some number of p^+ and n^0 will create stable arrangement
- as $\# p^+ \uparrow$, more n^0 than p^+ required not 1:1 → "stable"

Radioisotopes

- Isotopes that are unstable

e.g. ^{12}C stable, ^{14}C and ^{15}C unstable

Binding Energy

- E required to overcome strong nuclear F and pull nucleus apart into seprate nucleons

Atomic Mass Unit (amu)

- $\frac{1}{12}$ of the mass of a ^{12}C nucleus

$1 \text{ amu} = 1.661 \times 10^{-27}$ kg

$m_p = 1.007276$ amu

$m_n = 1.008665$ amu — n^0 a bit heavier than p^+

Mass Defect

- There is a difference, for example, in the mass of a He^{2+} nucleus and the mass of $2p^+ + 2n^0$.
- Mass is always conserved, except now
- Mass defect is the difference between the mass of a nucleus and the mass of its nucleons.
- The binding energy needs to be added to seprate the nucleus. This is essentially "adding mass".

Mass - Energy Equivalence

- Binding energy is calculated with:

$$\underbrace{E}_{\substack{\text{binding E} \\ (J)}} = \underbrace{m_D}_{\substack{\text{mass defect} \\ (kg)}} \underbrace{c^2}_{\substack{\text{speed of light} \\ (3 \times 10^8 \, ms^{-1})}}$$

$m_D = 1 \text{amu} \rightarrow E = 1.49 \times 10^{-10}$ J $= 931$ MeV

Binding Energy per Nucleon

- Binding E ÷ no. of nucleons
- Nuclei with mass no. ≈ 60 are most stable as they have greatest avg. ~~bing~~ binding E per nucleon
- Mass no. > 60 → avg. binding E per nucleon ↓

Radioactive Decay

- Occurs when nuclei of radioisotopes break down into smaller nuclei, releasing radiation.
- The resulting atom formed is called a "decay product" or "daughter nucleus".
- e.g. ^{210}Po decays into ^{206}Pb.

Decay Chain / Series

- Sequence of elements formed during radioactive decay

Half-life $t_{1/2}$

- Time taken for half of the atoms in a sample to undergo radioactive decay.
- Decay equation:

$$\frac{\text{amt sample left}}{\text{Original sample amt}} = \frac{1}{2^n}$$

where n is no. of elapsed half-lives

$t, t_{1/2}$ same unit

N, N_0 same unit

or:

$$N = N_0 e^{-\lambda t}$$

N: mass left after time t (kg / no. of nuclei)

N_0: Original mass / amt nuclei (kg / no. of nuclei)

λ: decay constant, $\lambda = \frac{\ln 2}{t_{1/2}}$, in t^{-1} units

Radiation

Example decay equation: 228+4=232

$${}^{232}_{90}Th \rightarrow \underbrace{{}^{228}_{88}Ra + {}^{4}_{2}He}_{88+2=90}$$

${}^{4}_{2}He$ – helium nucleus

emits α particle – stopped by 1 sheet of paper

228+0

$${}^{228}_{88}Ra \rightarrow \underbrace{{}^{228}_{89}Ac + {}^{0}_{-1}e}_{89-1=88}$$

${}^{0}_{-1}e$ – one electron

emits β^- particle

$88p^+, 140n^0$ $89p^+, 139n^0$

~~One neutron has turned into a proton by emitting~~ its negative charge (emits β^-)

β^+ particle - positron (${}^{0}_{1}e$)

When β^- and β^+ come into contact, they annihilate each other and emit photons.

γ particle - high-energy photon

Transmutation Process

Particle	Symbol	Mass	Charge
Electron/beta particle	${}^{0}_{-1}e$	0	-1
Neutron	${}^{1}_{0}n$	1	0
Photon / gamma ray	${}^{0}_{0}\gamma$	0	0
Proton	${}^{1}_{1}H$	1	1
Positron	${}^{1}_{0}e$	0	1
Alpha particle	${}^{4}_{2}He$	4	2
Neutrino	${}^{0}_{0}\nu$	0	0

EEI Ideas

- Sound
- Electromagnetism
- Thermal (but easily influenced by ext factors)
- Light (learn next term)

Paper A

Ch17/18, 21/22

Exam Content Term 2

K&A 1 - Reproduce and Interpret

- emission & absorption spectrum
- mass defect
- half life & decay constant
- quantisation of energy
- sound intensity, intensity level & loudness
- standing waves in open & closed pipes
- temp. & speed of sound in air

mathematical relationships
definitions
explain concepts

2A's

K&A 2 - Comparison & Explanation

- Lenard's results in photoelectric experiment
- Fundamental forces
- mass before/after fission
- penetrating & ionising power
- isotopes vs. ions
- sound barrier
- timbre
- f and λ through different media
- speed of light vs. speed of sound
- tension vs. pitch

explain phenomena

2A's, 2B's, 4C's, 2D's

Paper B

Exam Content Term 2 Wk. 30min

IA P3 - Analysis and Identification

Choose ONE and set a time limit

Two datasets:

1. Acceleration
   - Graphs, most likely L & t
2. Photoelectric Effect Results
   - f of light, v_0, $E_{k\,max}$
   - $E = hf - W$

Work with multiple results from one dataset.

Fallback: compare relationships w/ two variables scatterplot

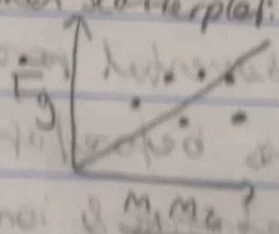
Identify / justify w/ reference to data: relationships, patterns, trends, errors, anomalies

Calculate constants, then compare to accepted val.

e.g. $F_g = \frac{Gm_1m_2}{r^2}$

F_g	m_1	m_2	r	$\frac{m_1m_2}{r^2}$
·	·	·	·	·
·	·	·	·	·
·	·	·	·	·

Then scatterplot:



$y = mx$

$\Downarrow$

$F_g = G\frac{m_1m_2}{r^2}$

$\therefore G$ = gradient of line of best fit

~~absolute error~~

rel. error $= \frac{G - G_{ac}}{G}$

-1
$\lambda, \quad v - \frac{\circ}{P}$

same criteria in EC Chemistry

EC2 - Exploration & Recommendation

Choose ONE stimulus. — 5min

1. p 577-582, "Who will pay for a nuclear future?"
2. Attached ~~to~~ in email

KEA1 - Linking & Application

8C's, 4B's, 2A's

- intensity w/ power
- String length, frequency
- Intensity level of intensity
- Fundamental freq
- Recep time
  time taken to travel & come back
  eg. $v_s = 300ms^{-1}$, $t_{rec} = 5sec$
  sound travels = 1500m
  distance = 750m
- threshold freq. given W
- energy/mass comparisons
- $E = hf$
- Nuclear eqn's i.e. α emission
- $E = m_0 c^2$
- Balmer's eqn

Term 4

Medical Physics

Ultrasound - high frequency sound

IMAGING

Ultrasound - looking for echoes or reflections at every change in medium/tissue → wavelength changes ($v = f\lambda$)

- transmit pulses of sound in (mirror)
- transmitter is also reciever
- picks up reflected waves

No known adverse effects

X-Ray - looking for shadow

- X-Rays go through body and hit detector
- leaves "shadow" exposing detector

Doppler Ultrasound - detects blood flow direction

- bunched up reflections indicate blood flow towards transmitter
- spaced out reflections indicate blood flow away transmitter

For an object to be detected via ultrasound, the wavelength needs to be shorter than the object. Otherwise, resolution too small

$\downarrow \lambda$ means $\uparrow f$. 20kHz → 75mm, too small

1.2MHz → 1.2mm, 3.5MHz → 0.43mm resolutions.

old.

However, because $E = hf \rightarrow f \propto E$, too high frequency could result in cell death so frequency is limited.

Additionally, because (with a high frequency) the waves ~~waves~~ have to distinguish between different groups of cells, more of the sound is absorbed which leads to a shorter penetration depth. However, the area that is penetrated has a higher resolution.

-

Scans of reproductive organs are always ultrasound to minimise the risk of altered meiosis inside gametes due to x-ray radiation.

Placing the transmitter close to the skin with ~~an a tran~~ an air gap creates a large echo off the skin because of the difference in density and acoustic properties between both mediums. Thus, a gel with similar acoustic properties (impedance) to skin is applied so the transition can be eased

Acoustic Impedance

The acoustic impedance (Z) of a material measures how readily sound will pass through it.

$$\overset{(kg m^{-2} s^{-1})}{Z} = \overset{(kg m^{-3})}{\rho}\, \overset{(ms^{-1})}{v}$$

where Z is acoustic impedance ($kg m^{-2} s^{-1}$)
ρ is density of the medium ($kg m^{-3}$)
v is the velocity of sound in material (ms^{-1})

Table 23.2 lists ρ and v for different materials.

Reflection of Ultrasound

The acoustic impedances of two adjoining tissues are used to calculate the intensity of the reflected pulse compared with that of the incoming one.

Fraction of intensity:

(larger difference in Z → larger reflection)

$$\frac{I_r}{I_0} = \frac{(Z_f - Z_i)^2}{(Z_f + Z_i)^2}$$

intensity of pulse reflected → I_r (Wm^{-2})
intensity of pulse incident → I_0 (Wm^{-2})
initial medium → Z ($kg m^{-2} s^{-1}$)
final medium → Z ($kg m^{-2} s^{-1}$)

Intensity of Ultrasound

Power levels of ultrasound imaging must be kept between 0.01 to 20 Wcm^{-2} to avoid cell/tissue death. 1 Wcm^{-2} is used to heat tissues for therapy and 10^3 Wcm^{-2} is used to destroy tissue. Multiple sources of ultrasound can be layered so that constructive interference is generated at the target location.

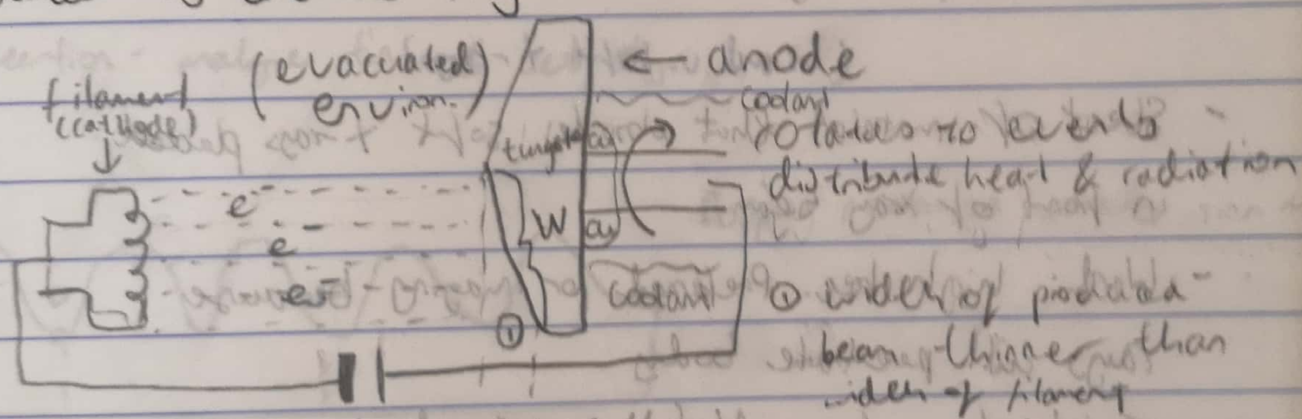
$^{99}_{42}Mo \rightarrow {}^{99m}_{43}Tc$ ($+ {}^{0}_{-1}\beta$ and ${}^{0}_{0}\bar{\nu}$). $t_{1/2}$ [illegible]

$^{99m}_{43}Tc \rightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$. $t_{1/2}$ [illegible]

$t_{1/2}$ [illegible]

X-Rays

- Electromagnetic waves w/ very short wavelength
- When passing through body, radiation absorbed and intensity reduced.
- Produced by cathode ray tube.



- W emits X-rays when striked by e^-. Melting point high enough (3400°C). However, W heats up a lot when hit (1% energy used converted into X-rays; 99% left converted to heat*).

* due to electron quanta - ~~one specific jump from top shell to bottom shell produces X-rays, the rest do not carry enough energy (multiple jumps).~~ ~~Bremsstrahlung (braking) radiation:~~ incoming e^- knocks out e^- in inner shell; difference in E emitted. If knocks out low level, X-ray produced as ΔE is high. See next page

- W anode surrounded by Cu (conductor) and cooled via coolant circulation pump.
- Anode rotates to distribute heat and radiation which prolongs life of anode.

* Also, Bremsstrahlung (Braking) radiation generates X-rays: e's slowed down by target (W) atoms. Some of e's KE converted to electromagnetic radiation → X-ray. Difference in energy produces different f X-rays.

(Hard v. soft X-rays)

- Sheet of material that absorbs soft X-rays placed in front of Xray beam.
- Hard: high freq. Preferred for imaging because rays will penetrate body
- Soft: low freq. Not ~~pro~~ preferred because rays will be absorbed, increasing dose.
- X-rays, when absorbed, ionise e's creating free radicals in body. Will damage DNA sequence; possibly transmitted to children if ~~g~~ gametes damaged

(kV & mAs)

↑kV	↑mAs
- More energy to e's	- More e's emitted
- more penetrating rays	- higher resolution image
- used for deeper parts	

Term 4 Exam Formulas required

$v = f\lambda$

$Z = \rho v$

$\frac{I_r}{I_0} = \frac{(Z_f - Z_i)^2}{(Z_f + Z_i)^2}$

$N = N_0 \left(\frac{1}{2}\right)^n \rightarrow n = \log_{1/2}\left(\frac{N}{N_0}\right)$ n is no. of $t_{1/2}$s elapsed

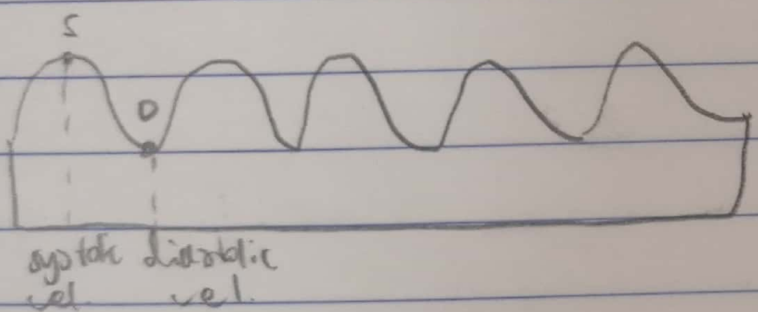
$N = N_0 e^{-\lambda t}$, $\lambda = \frac{\ln 2}{t_{1/2}}$

$\underset{Bq}{A} = \underset{s^{-1}}{\lambda} N$, A (Bq) decays·s^{-1}

$A = A_0 e^{-\lambda t}$, $\lambda = \frac{\ln 2}{t_{1/2}}$ $\left(\rightarrow \ln \frac{A}{A_0} = -\lambda t\right)$

$E = hf$

IP section - analyse time & activity



Doppler measures velocity