H2 Physics Explanations

Syllabus document

https://www.seab.gov.sg/docs/default-source/national-examinations/syllabus/alevel/2024syllabus/9749_y24_sy.pdf

Measurement

- Explain why … helps improve reliability

Reliability is linked to percentage uncertainty
Marks:

- Give definition/formula: % uncertainty = absolute uncertainty / data value (given graph, the best data point would be the one with the largest data value)
- Larger data value reduced % uncertainty

- Explain which quantity has the greatest contribution to the uncertainty of some variable.

See expression of variable. “Quantity is raised to the power of xxx, so it contributes greatest to the uncertainty of the variable.”

- How does taking many readings and taking average help to reduce random error?

- Absolute uncertainty is the same
- Percentage uncertainty is calculated by dividing absolute uncertainty over a larger measurement
- % uncertainty is reduced

- Sometimes qn ask u to suggest another method to increase accuracy of measurement.

They actually mean accuracy as precision :<

Kinematics

- Acceleration changed from + to - in the same instant. Why is this not possible?

2 accelerations in the same instant -> 2 net forces -> impossible

- Explain how the path taken by the particle can be considered parabolic.

Parabolic motion conditions:

1. Constant acceleration (like in kinematics)
    a. Prove that the resultant force has constant magnitude and direction. Eg weight and electric force have constant magnitude and direction, so the net force has constant mag and dir.
2. One component of velocity is in dir of acceleration, one perpendicular component of velocity has no acceleration.

Forces

- Previous calculations show that the object is not in rotational equilibrium. However, *when in use*, the object is in equilibrium. Explain why.

Think: what wasn't considered in previous calculations?
Eg (weight of jib, counter jib, masses at bottom)

These cause moments about pivot → help cause object to be in equilibrium

- What are the origins of upthrust

1. Upthrust originates from the pressure difference between top and bottom of the body.
2. (why is there pressure difference) As pressure increases with increasing depth, bottom is at larger depth, so upward **force** on bottom is higher than downward **force** on top
3. **Link pressure to force:** Upthrust is product of pressure difference and cross sectional area.

- Show upthrust = value. **Explain your working.**

Upthrust = weight of fluid displaced

- Given that there are 3 forces, 1st force is vertical, 2nd force has both vertical and horizontal components, explain why the 3rd force cannot be vertical if the object is in equilibrium.

2nd force has e.g. leftwards horizontal component of force. For the object to be in equilibrium, net force = 0N. Hence the 3rd force needs to have a rightwards horizontal component.

Alternatively, say vector sum must be 0. Then draw the triangle.

- Why small objects in circular motion can be dangerous for satellites

“Dangerous for satellites” <- collision <- force <- N2L <- momentum <- p=mv <- high velocity

- Why is speed of molecule vibration lower than speed of sound in gas

speed of sound in gas is speed of energy transfer while speed if vibration is speed of oscillation

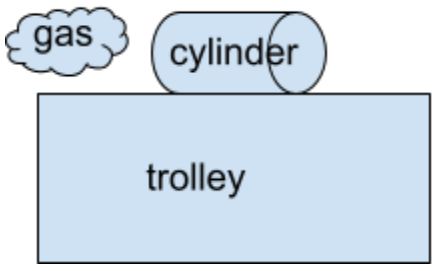
- Origin of energy transfer in sound waves?

mechanical energy of vibrating object

- Origin of restoring force on a molecule as it vibrates?

Gas has weight, and can exert pressure. Pressure difference exerts restoring force.

- Origin of force that accelerates trolley, using Newton's laws? [3]



Thinking: I need to use N2L and N3L. N2L is for a single body, N3L is for 2 bodies. Identify these 2 bodies. Trolley+cylinder system and exerted gas from the cylinder.

1. ORIGIN of force exerted on gas: N2L > Gas in cylinder has rate of change in momentum, so leftward force is exerted on gas
2. N3L: equal and opp rightward force on trolley
3. N2L: trolley accelerates

- Suggest and explain direction of reaction force, given that there is tension and weight.

Horizontal: there is a horizontal component of tension. Weight only has a vertical component.
Vertical: (*from the previous part, calculated W, need to calculate if T_y = W). Sum of upward tension … smaller than weight, so reaction force has an upward vertical component.

Dynamics

- What happens to force on a propelled object when fluid is ejected out, and compressed air occupies more space?

Gas occupy more space -> vol increase -> pV=nRT -> *pressure decrease* -> p=F/A -> force by air on fluid decrease -> force on propelled object decrease

- Explain how momentum is conserved in the collision of the sphere with the ceiling
    1) Identify the system: ceiling and sphere
    2) Keywords: equal and opposite
    3) Critical details: direction of momentum change

System comprises of ceiling and sphere
Upward gain of momentum by ceiling is equal and opposite to downward loss of momentum by sphere
Rightward gain of momentum by ceiling is equal and opposite to leftward loss of momentum by sphere
If little marks no need to write about forces

- Why is it not possible for both items to stop at the same instant?

Initial momentum is …
If both stop at the same time, momentum will be zero.
This violates POCOM

- Given a v-t graph, explain which curve corresponds to a body with smaller mass.

Forces → momentum
N3L → equal and opposite forces → time of collision is the same → impulse = force x time → equal and opposite change in momentum → smaller mass, so larger change in velocity

WEP

- By considering TRANSFORMATION of energy, explain the motion of a truck moving up an incline with the same engine force.

⭐ transformation of type of energy into another type VS transfer of energy = work done
Chemical E (not WD by engine) → KE → GPE + Thermal E (not WD done against resistive forces)

- Explain whether work done by motor is positive or negative

Method 1) Consider directions of force and displacement
Method 2) Conservation of energy

Circular Motion

- Object tied to string in circular motion. As the object undergoes circular motion, the string wraps around a pole. Explain why the string may snap.

Formula: $Fc=mv^2/r$

1m – Radius decreases, velocity increases (by common sense) => centripetal force increases
1m – String breaks when tension exceeds breaking point of string

- State (in terms of forces) condition that's necessary for uniform CM

(uniform CM = constant linear velocity, so no force that's parallel to linear velocity)
Resultant force is perpendicular to linear velocity and directed towards the centre of the circular path.

- Object moves in a circular path at *constant speed*. Explain why it has acceleration.

Direction of velocity constantly changes -> velocity changes -> acceleration is rate of change of velocity -> there is acceleration

- Use Newton's laws of motion to explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle. [3]

Qn analysis: (1) uniform speed + (2) circle. Separate.

- * Must explain the origin of acceleration. Which is change in velocity.
- Force towards centre of circle ← acceleration towards centre of circle (N2L) ← change in velocity towards centre of circle ← linear velocity is tangential to circular path ← change in velocity is perpendicular to the direction of its motion ← uniform speed
- Need to qualify by saying "**as the body has uniform speed**, change in velocity…". Basically u need to start with question's given cause/scenario.

- Standard Fc explanation
  - (Dir) Initially, B is perpendicular to the initial direction of motion of electrons (not motion). So Fb perpendicular to v.
  - (Dir) This occurs throughout its time in the B field
  - (Mag) V and Fb remains constant throughout, so uniform CM

Remember: 💫 time element for direction + 💫 phrase "*direction* of motion"

- Parabolic motion

Also focus on direction and magnitude: direction of force is perpendicular to initial direction of motion and is constant, so object undergoes parabolic motion.

- Proven that an object with initial velocity x will not be in circular motion at the top of the circle. Is this conclusion the same or different with a larger mass?

Conclusion same. Acceleration is independent of mass.

- Car undergoing CM turns right. Why does it tilt to the left?

Protip: if rlly dk what to write, just write smth provides F_c
[separate wheel from car body]
Wheel → friction provides for rightward F_c
Car → inertia, tends to continue moving straight

- Effect when angular speed inc

Assume radius unchanged in chain of reasoning, although end goal is effect on radius :p

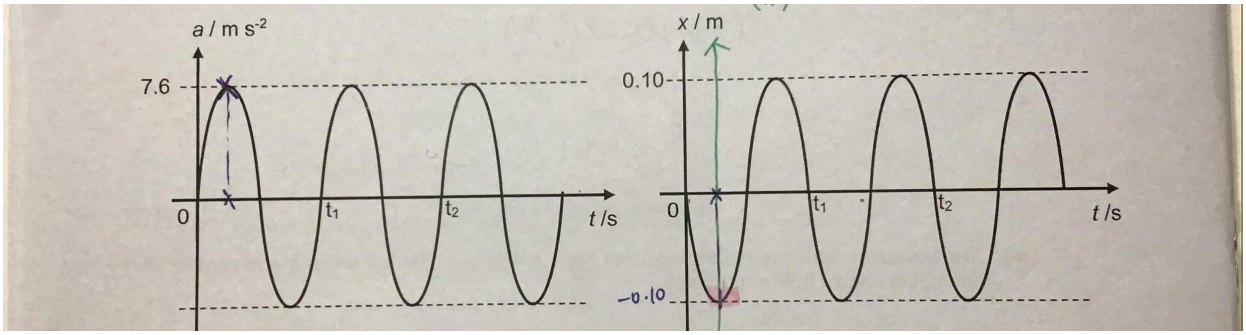
- Explain why water leaves washing machine through holes

Must generalise your explanation to all hole positions

At holes, there is no NCF. Radial component of the weight of water is insufficient to provide for required centripetal force.

Oscillations

- State and explain features of the graph showing that the motion is simple harmonic.



Evidence: shape of graphs
Acceleration and displacement are opposite: one is (sine), other is negative (sine)
Acceleration and displacement are directly proportional: both are (sine)

- MUST START FROM GRAPH !!! Eg **not straight line graph** → a and x not directly proportional

- Explain how the expression shows SHM. [3m]

[2m] definition of SHM
[1m] variables (representing ω^2) are constants, so … is constant

- F=-kx. How does this prove SHM?

F is proportional to acceleration, a. Hence acceleration is proportional to displacement.

  - Past mistake: never define a as acceleration.

- What does driver driven amplitude-frequency graph show?

Shows resonance in forced oscillation.

- Car on road. When the car travels at a certain speed over a series of speed bumps, the vertical oscillations of the car suspension system can be very large. Explain why.

Identify the driver & the driven.

- Driver = normal contact force by road
- Driven = car suspension system

Explain resonance:

- Frequency of driver (ncf) matches natural frequency of driven (car suspension system)
- Resonance occurs
- Maximum energy transfer
- Maximum amplitude of oscillation

- Sand on oscillator. Fnet=W. Does amplitude change if sand is changed to pebbles?

a=g
SHM $a=-\omega^2 x$
(support) $g=-\omega^2 x$
(reasoning) g is independent of mass
(claim) amplitude won't change

Superposition

- Explain what is a stationary wave [3m]

1. Wave → (SHM) particles oscillate about an equilibrium position
2. Stationary → Waveform does not travel and there is no energy transfer
3. Stationary → There are nodes where particles have 0 disp and antinodes where particles have max amplitude of vibration

- Explain formation of a stationary wave

Use the context of the experiment given !!!:
- Incident wave from (xxx) travels and gets reflected at (xxx) (eg free end reflection)

Conditions:
- The 2 waves are coherent/same v and f, and have the same amplitude. They travel in opposite directions, overlap and superpose, forming stationary wave.

- What are the conditions required for *observable* interference pattern

1. Coherence (same speed and frequency)
2. Equal amplitudes (good contrast)
3. For transverse waves, they must either be unpolarized, or polarised in the same plane

- Explain why 2 waves of different intensity cannot form a stationary wave with zero amplitude at its nodes.

- Different intensities => different amplitudes
- Link to resultant displacement (vector sum): difference of amplitudes is not zero OR no complete destructive interference at nodes.

- v=fλ. A stationary wave doesn't have speed. By reference to the formation of a stationary wave, explain the significance of fλ.

Dunno? Issokay just spam formation of wave first.
When 2 coherent waves of the same amplitude, frequency travel at the same speed in opposite directions and overlap, a stationary wave is formed.

If the v doesnt belong to stationary wave, then whose speed is it?
V is the speed of the progressive waves that make up the stationary wave.

- Explain the effect of changing string to one of different material/diameter.

Change in wtv → change mass per unit length of string → change source, change frequency → speed of wave depends on tension & mass per unit length → speed changes

v depends on medium, f depends on source

- Explain if pressure change at displacement antinodes is maximum or minimum

Pressure at displacement antinodes is minimum (pressure node)
Particles surrounding disp antinodes have similar amplitudes
Hence their separation (btw immediate surrounding particles and particle at antinode) remains the same

- (pipe experiment) Speed measured is an underestimate. This cannot be attributed to uncertainty of measurement. Explain what caused the underestimate.

There is end-correction.
Underestimate => calculated v < actual v => calculated λ < actual λ
Antinodes/nodes at the ends are further than the ends of the pipe

- Explain what is meant by Rayleigh's criterion [2]

1m - meaning: 2 patterns are just distinguishable
1m - condition: the central max of 1 source coincides with the first minimum of the other source

- [Double slit, given intensity graph] Explain how interference patterns are formed on screen. [2]

1m - normal explanation: waves diffract at slits, are coherent, overlap and superpose at screen
1m - reference graph, explain how maximas and minimas are formed: maximas formed when waves meet in phase, constructive interference; minimas formed when waves meet antiphase, destructive interference

- Explain why in intensity graph of double slit, maximas are not of same intensity

Theoretically: double slit by itself -> constant intensity
Actually: double slit + single slit

Slit has finite slit width. There is diffraction at each slit (single slit diffraction). As angle of diffraction increases, intensity decreases.

- Explain why bright fringes are produced. [2]

1m – basic topic keywords: light beams **overlap** and **superpose**
1m – they have a phase difference that is a multiple of 2π, constructive interference

- Before: source
- During: path difference
- After: phase difference
- If u write about path difference being multiple of wavelength, u must bring in the phase difference of source. Can just write the end point: phase difference.

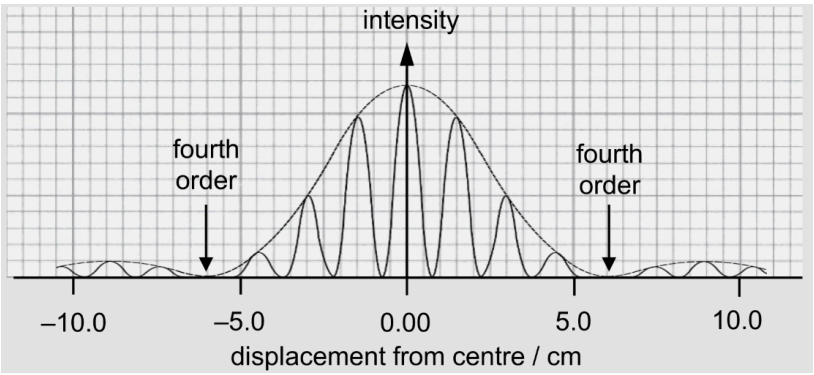
VS explain why *a* bright fringe is produced: phase difference = 2π (not a multiple because only 1 point).

- Show width of central fringe = …

Sin theta approx = tan theta, where theta is small

- *THIS ONLY APPLIES TO DOUBLE SLIT INTERFERENCE!!! FOR SINGLE SLIT, USE ARC LENGTH FORMULA.*

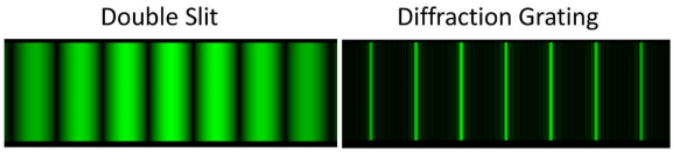
- Explain why in intensity graph of double slit, there is a missing fringe



1. Same idea as above: Finite slit width, there is single slit diffraction. As angle of diffraction increases, intensity decreases.
2. Extra: 4th maxima from double slit interference coincides with minima from single slit interference -> resultant intensity = 0

If given an empty space above lines, u are expected to do working or draw something. Working: find distance of 4th maxima from double slit interference from central max, using previous part's results about fringe separation. Find distance of single slit diffraction minima from central max, using previous part's results about central fringe width.

- Why is it better to use diffraction grating than double slit to determine wavelength
  Grating gives sharper, brighter maximas -> higher contrast and sharpness -> more accurate data



- Why need single slit for light to pass through before passing through double slit
  Single light source > makes light passing through slits in double slit coherent

- Explain why intensity at a point is zero although there are 4 rays reaching it

Destructive interference > waves are antiphase (π phase difference)
Address the "4 rays" ← 2 waves are antiphase, the other 2 waves have same path difference, so they are antiphase too.

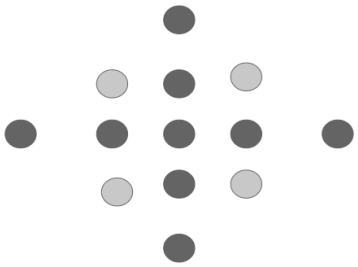
- Describe how resultant amplitude changes (two source interference)

if you are given the phase difference at the initial point, you are expected to give quantitative!!! numerical!!! answers!!!
eg at point P, phase difference = 8pi → it's the 4th maxima → draw out lines and count → there are ___ maximas and ___ minimas

- Describe how diffraction takes place at a grating

Grating has multiple slits. Diffraction takes place when light passes through each slit.

- There are 2 perpendicular multiple slit gratings. Explain formation of criss cross pattern and difference in intensities of maximas.



Horizontal slits → vertically spread maximas
Vertical slits → horizontal maximas

- First grating produces horizontal/vertical maximas
- Each maxima then acts as a light source for the 2nd grating
- Maximas in the corners are of lower intensity than maximas in the middle portion because the former were diffracted 2x while the latter were diffracted 1x.

- Multiple slit grating is rotated. Will this affect the position of the central maximum?

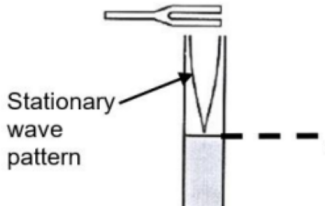
Multiple diffraction = Single slit + Double slit
Single slit is always central max, double slit central is either max or min ← depending on constructive or destructive interference ← depending on phase difference ($\phi_{total} = \phi_{source} + \phi_{path} + \phi_{others}$) ← depending if path difference got change

- Path difference between light from adjacent slits remains 0
- Position of central max is unchanged

- Describe how sound travels in water.

Sound is a longitudinal wave.
Energy is transferred via changing pressures (varying rarefactions and compressions).

- How does stationary wave pattern illustrate a longitudinal wave [2]



Pattern: **(lateral) displacement of wave that is left and right of the axis represents vertical vibrations of air particles that are along the axis.**

- Air particles, not sound particles (sound is a wave! Not a particle! It transfers energy through the medium, in this case air)
- Lateral is <->

Definition: vibrations of air particles are parallel to direction of energy transfer.

- Compare and contrast stationary wave with progressive wave

	Progressive wave	Stationary wave
Energy	Energy is transferred in the direction of wave propagation	Energy is not transferred
Amplitude	All particles on the wave oscillate with the same amplitude	Amplitude of particles vary from 0 amplitude at nodes and maximum amplitude at anti nodes
Wavelength	Wavelength is the distance between 2 adjacent particles that are oscillating in the same phase	Wavelength is twice the distance between adjacent nodes or antinodes
Phase angle	All particles within one wavelength are oscillating at different phases	Particles within an intermodal segment are oscillating in phase ; particles in adjacent intermodal segments oscillate anti phase.

WAPE: wavelength, amplitude, phase, energy

Temperature and Ideal Gases

- Explain what is meant by an ideal gas
- It obeys pV=nRT
- Define the variables in eqn: p = pressure of gas, blabla, T = thermodynamic temperature of the gas

- How does volume of gas provide evidence that gas is ideal

Vol_{gas} < vol occupied → gas molecules are far apart → negligible IMF → ideal

- Why is the mean velocity of a gas zero

(vector kinda question)

- Velocity is a vector quantity, has magnitude and direction
- Gas has continuous random motion → equal probability of moving in any direction
- Mean velocity in 1 dir is equal and opp to mean velocity in opp dir, cancel each other

- Explain what is meant by thermal equilibrium (3 things)

When objects are in thermal contact, there is no net transfer of thermal energy and they are at the same temperature.

- rate of energy transfer from A to B = rate of energy transfer from B to A

- Explain qualitatively how molecular movement causes the pressure exerted by a gas. [3m]

Quantitative alternative = derivation of pv=1/3Nm<c2>

1. Molecular movement: Gas molecules collide into walls and rebound

Think: Pressure=Force/Area → Force is related to momentum

2. There is a change in momentum, leading to force exerted on the inner wall by each molecule. [SINGLE molecule]
3. There are many molecules, giving rise to many impulses and averaged out to give the force.

- State improvements to equation of state (1 for ⅓, 2 for adding <>)

$pV=nmc^2 \rightarrow pV=\frac{1}{3}nm\langle c^2\rangle$

Adding ⅓: Takes into account the 3 dimensional movement of molecules
Adding <>: Takes into account the different speeds of molecules due to constant random motion and removes assumption that all molecules have the same speed c

- Given the speed of molecules increase after volume of gas decreases, use kinetic theory of gases to explain why there is increase in thermodynamic temperature.

Speed increases → Average KE of gas particles increases → By kinetic theory, average KE of atoms is proportional to thermodynamic temp (½m<c2>=3/2KT) → temp increases

- Previous part calculated c_{rms} of all atoms, another part calculated c_{rms} using speeds of 4 atoms. Explain why there is a difference in values.

There is a spectrum of speeds, the sample size of 4 atoms is too small.

- State the 5 assumptions of kinetic theory of gases

1. (1 – finding impulse) Perfectly elastic collisions between molecules and walls
2. (1 – finding time) Duration of collision is negligible compared to the time between collisions
3. (2 – N molecules & 3 – accounting for all directions) There are **many** gas molecules in **constant random motion**
4. (Ideal gas) Volume of molecules is negligible compared to the volume occupied by gas
    a. Qn specifies in relation to the separation of particles: separation of particles is much larger than size of particles
5. (Ideal gas) There are negligible intermolecular forces of attraction

- Actual pressure is higher than theoretical pressure. Identify and explain which assumption is no longer applicable.

Assumptions 1-3 shouldn't be broken. Break either 4 or 5.
Assumption 4 broken: non-negligible volume of particles → frequency of collisions increase (analogy: footballs in field vs footballs in a basket → pressure increase
Assumption 5 broken: non-negligible FOA → repulsive forces between particles → increase force and thus pressure on walls of container

- Is 1/2m<c2>=3/2kT applicable to ideal gas

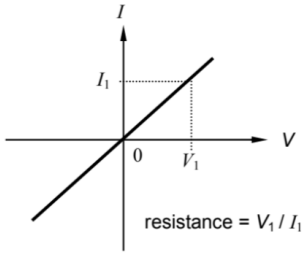
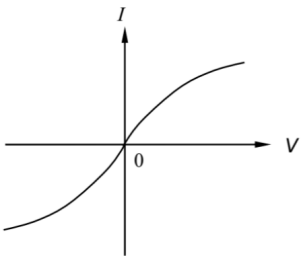
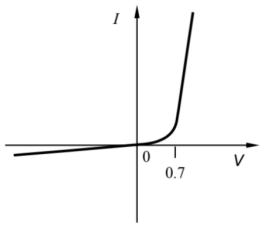
Yes. Ideal gas obeys pV=nRT and kinetic theory of gases.

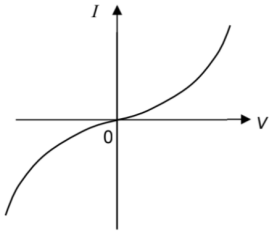
- Average distance:

pV=nRT -> find N -> **average (cubic) volume occupied by one particle** = V/N -> **average separation between particles** = cube root of V/N.

- phrasing: "ave separation is 2 orders of magnitude larger than size of particle"

D.C. Circuits

Graph	Explanation
 Metallic ohmic resistor	Constant temp Constant magnitude of vibration of lattice ions Constant freq of collisions Constant resistance
 Filament lampS (ASS !! 🍑🍑)	- When v increases, energy converted from electrical energy to other forms of energy such as heat, per unit charge, increases OR when I increases, heating effect > Temperature increases - As temp increases, n is constant. - Increased amplitude of vibration of lattice ions (main pt) > increased frequency of collisions between lattice ions & free e^- - More difficult for e to pass through - R increased
 Semiconductor diode Exponential	- Temperature increase > n (mobile charge carriers) also increases (both grp 4 metal) - Amplitude of vibration blah blah - This outweighs the increase in obstruction to flow of free electrons - R decreases Also a semiconductor

 Negative temperature coefficient (NTC) thermistor / LDR (opposite of filament lamp)	

- Given I-V graph, explain how R changes

R is reciprocal of gradient of straight line from origin to a point on the graph

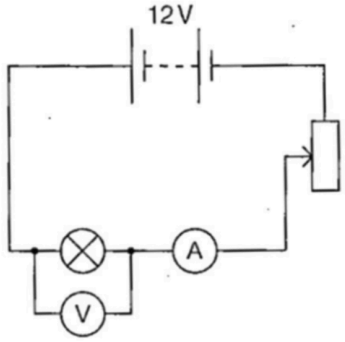
- Use energy considerations to distinguish between EMF and PD

Just state definitions separately.

- Distinguish between resistance and resistivity

- State definitions separately
- 补充: Resistivity relates to the material, while resistance relates to the object, which includes material and dimensions

- Explain why the pd across the lamp cannot range from 0-12V.



Cannot be 0V -> Lamp has non zero resistance / By potential divider rule, V lamp = R_{lamp}/R_{lamp} + $R_{resistor}$. For V_{lamp} to be 0V, $R_{resistor}$ must be infinite. But it has finite R.
Battery has internal resistance -> cannot be 12V

- Suggest an advantage of using a potentiometer <u>to measure voltages</u> as compared to using a voltmeter.

Purpose: to measure voltages. So discussion cannot be about cheaper price etc

- Difference: Under balanced conditions, potentiometer does not allow current to flow through the secondary circuit, *whereas* a voltmeter with finite resistance allows current to flow through it.
- Implication: Using potentiometer does not affect voltage measurements while using voltmeter affects it.

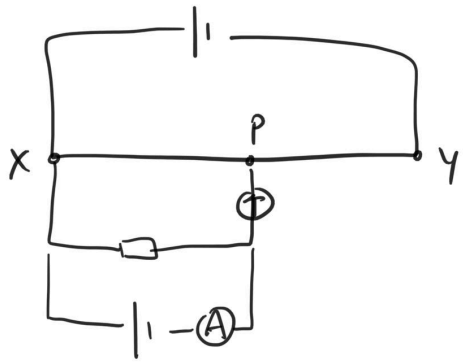
- The EMF in the bottom loop is too small, causing balance length to be short. Suggest how to increase balance length.

Method 1) Add resistor in series to the top loop > Decrease $V_{potentiometer}$ according to potential divider rule > pd per unit length decreases > balance length increases

Method 2) (want to decrease V, so decrease R) ($R = \frac{\rho L}{A}$)
Use thicker wire. R decreases as wire is made of the same material, resistivity is constant.

Not recommended: Method 3) make the emf of the driver cell smaller. A bit no brainer.

- How does the balance length XP change when the cross sectional area of XY increases?



Thought process:
R_{XY} decreases > R_{XP} decreases > $R_{lower\ loop}$ constant > UBC, R_{XP} must = $R_{lower\ loop}$ > Balance length increases

Presentation:
Resistance XY decreases (Length XY, and resistivity same)
Link resistance to balance length: pd per unit length decreases (length XY constant)
Balance length increases

- How does the balance length XP change when the ammeter has internal resistance? (same circuit as above)

Lower loop: increased total R > decreased current
$V_{XP} = V_{terminal} = V_{external\ R} = V_{4ohms}$
V_{4ohms} decreased > V_{XP} decreased > pd per unit length decreased > balance length increased

- Why can't balanced conditions be achieved if the polarities of the driver and bottom cells are opposite.

Qn type: Why ___ cannot occur
Ans technique: Assuming it can occur, blabla. But there is a contradiction.

For balance conditions to be achieved, $V_{top\ loop} = V_{bottom\ loop}$
Based on the polarity of the driver cell, potential of ..(point) > potential of .. → $V_{top\ loop}$ is positive/negative
Based on polarity of the bottom cell, potential of .. > potential of .. → $V_{bottom\ loop}$ is negative/positive
Hence $V_{top\ loop}$ =/= $V_{bottom\ loop}$
So balanced conditions cannot occur

- Explain why the thermistor should be kept cool to prevent thermal runaway.

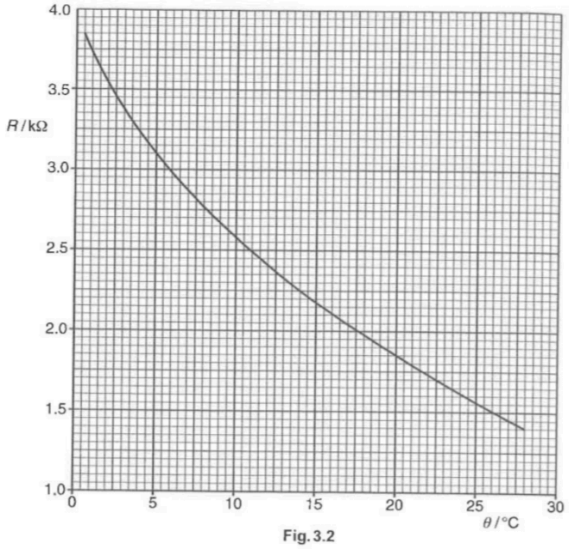


Fig. 3.2

- Observation from graph

If not kept cool -> R of thermistor decreases

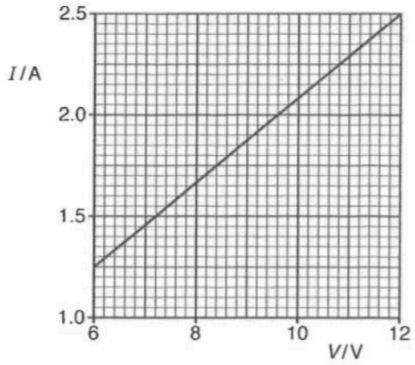
- Link to whole circuit

Cuz EMF is constant, total resistance decreases, current increases.

- Effect on thermistor

Increased current causes increased heating effect, temp increases even more, resistance of thermistor decreases even more.

- Show that I is proportional to V



If I is proportional to V => I=kV
Calculate a few values of k, show that k is constant
Do NOT create equation !

- Explain why internal resistance can be considered negligible.

Must compare between external resistance and internal R: external R is much much greater than internal R

- Explain why the lamp lights up almost instantaneously even though drift velocity is low.

(basis: there are ALR electrons present in the light)

Even though drift velocity is low,

e field is set up almost instantaneously (signals to e to move)

the electrons in the lamp start drifting (not moving cuz it was alr moving in brownian motion) almost instantaneously

- If question says electrons in the *wire*, say electrons immediately move from wire to lamp

- Explain why there are some electrons with speeds higher than drift velocity.

There is a large number of electrons

There is a spectrum of speeds.

- Explain how “6V, 1W” provides information about the normal operation of the electrical device.

The optimal pd to use is 6V. Power dissipated at 6V is 1W.

- How does efficiency change when internal resistance is much lower than resistance of load

must write about the extreme

useful power approaches 0 → efficiency approaches 0

- Why no current

Electrons moving randomly → average velocity = 0 → no net flow of charge (I=Q/t) → current

- Why current is greatest when current is first switched on
- Consider the effects of flowing current (resistance!)

Current flows > metal ions in lattice in filament vibrate at greater amplitude > more difficult for electrons to flow > increase R

- Similar: when I is first switched on, resistance is low (atoms haven't had the chance to vibrate) > power dissipated is high (P=V2/R) > blown bulb

First Law

- Explain what is meant by internal energy of an ideal gas

Ideal gas has no potential energy
Internal energy of ideal gas is the sum of random distributions of kinetic energies due to random motion.

- (△U=W+Q) How does one variable change given info about other 2 variables?

- Rearrange equation, make the variable in question the subject
- Explain changes in the other 2 variables
  - △U: [△T->△*microscopic* KE. shorten: △U is proportional to thermodynamic T] + [change in separation, IMF->change in PE]
    If △T not given -> use pV=nRT deduce
  - $W_{on\ system}$: Gas expands/contracts (against external force) OR liquid->gas, vapor pushes back atmosphere
  - $Q_{to\ system}$: *sudden* event (no time for heat exchange with surrounding)/perfectly insulated system -> Q=0
- State signs of the variables, deduce sign of variable u wanna find

- Use first law to explain why specific heat capacity is larger for xx scenario, why lv>lf etc

Key terms: specific heat capacity, specific latent heat of wtv
Hence focus on Q

- Melting/vaporization: change in state, no change in temperature, no change in KE
- For vaporization:
  - U: greater increase in separation of molecules, greater increase in PE, greater increase in U
  - W: greater increase in volume, greater work done by gas
  - Q is larger

- Explain why internal energy is proportional to thermodynamic temperature of an ideal gas

Internal energy = (is the total random distributions of) microscopic KE + PE
As there are negligible IMF between ideal gas molecules, PE is 0
Internal energy is solely equal to kinetic energy.
By kinetic theory, mean KE is proportional to thermodynamic temperature of gas

- Why can water evaporate at any temperature, even below boiling point?

temperature is the AVERAGE ke
there is a SPECTRUM of kinetic energies
Some water particles have higher ke, sufficient to turn into gas at temperatures below b.p.

- Why gas moving as a whole does not affect kinetic energy

Bulk speed does not affect microscopic ke which is only affected by random motion

- Scenario: ideal gas in container with piston. Explain, *in terms of the motion of ideal gas molecules*, why the temperature of the gas decreases when the gas expands against atmospheric pressure. [3]

- Gas molecules transfer kinetic energy to atmosphere via outward moving piston during collision
- Gas molecules lose kinetic energy
- (kinetic theory) mean kinetic energy is proportional to thermodynamic temperature so temp decreases

- Explain, in terms of collisions of molecules with walls of container, why an expansion results in decrease in kinetic energy. [2]
- **Gas does positive work on container walls**
- Gas particles lose kinetic energy as they transfer KE to container

- What are 2 assumptions for temperature to be constant (no change in internal energy) and for gas to be contracting ($WD_{on}>0$)?

$Q_{to\ gas}$ <0 (gas is losing heat) (alas, this is not an assumption)

1. Compression is done slowly ← so that heat is transferred. If dowan heat to be transferred, compression/expansion should be done quickly.
2. Walls of container are good conductors of heat, so gas can easily transfer heat to the atmosphere, with the container acting as a middleman.

- An explosion is represented on a p-V graph as a curve. Why is it not appropriate?

Nature of event. Pressure at different points of gas is <u>not uniform</u>, is undefined, cannot be represented as a point/curve.

- Given p-V graph, explain why a process is isothermal

Product of p and V is constant. (pV=nRT). Not asking for 1st law.

- Combination of first law and electricity:

A metal wire is connected to a power supply.
As metal wire is being heated and increasing temp, U increases, q <0 (heat to system is not chemical energy in battery to electrical energy in wire; not energy conversion. Heat to system is heat **lost to surrounding air)**, w>0
As metal wire is being heated but has constant temp, U is constant, q<0 (still losing heat to air), w>0

Gravitational Fields

- Suggest why Newton's law of gravitation can be used

Masses can be assumed to be *point masses.*

- Explain why gravitational potential is negative

- Establish reference point: At infinity, potential is zero, and is highest.
- As a small test mass is moved from infinity to a point, in order for it to experience no change in kinetic energy, an external force is exerted on it, and is equal and opposite to gravitational force.

- The displacement is opposite to the external force, so work done by external force per unit mass and thus gravitational potential is negative.

- Explain why an astronaut in a spacecraft orbiting the Earth experiences weightlessness.

Think of related terms: apparent weightlessness, a=g, only weight acts on body, N=0
true weightlessness: no W acting on body
apparent weightlessness: only W acting on body, N=0

- (system) Gravitational force provides for required centripetal force.
- Both astronaut and spaceship are freefalling towards earth.
- (astronaut) (since a=g,) Only weight acts on the astronaut. Normal contact force = 0.

- Explain why near Earth, gravitational field strength is equal to acceleration of free fall.

During free fall
Net force = gravitational force
By N2L, F_{net}=ma
ma=F_g
a=F_g/m

Use definition of gfs: g is gravitational force per unit mass
g=F_g/m

Hence a=g

- Explain why near Earth, gravitational field strength is constant

Use formula! g=$\frac{GM}{(r+h)2}$ (h=height above earth)
Near earth, h is MUCH smaller than r. r+h ≈ r. Hence g constant.

- Rocket is on the surface of the planet, and it accelerates away from the planet that is isolated in space. Calculated g at surface to be 1.67Nkg-1. Rocket is fired for 15 seconds, mass is lost as exhaust. Explain whether actual acceleration is smaller or bigger than calculated acceleration.

In calculations, weight = mass x g. Assumed g to be constant. However, g is inversely proportional to r^2.
As r increases, g decreases, weight decreases.

- The gravitational force is very large. Why does this force have negligible effect on the motion of the sun?

N2L: Fnet=ma.
Mass is very large compared to force, so acceleration is negligible.

- Can xxx gas be found on the surface of planet?

If can be found on planet → didn't escape → actual speed < escape (minimum) speed
If cannot find → speed > escape speed
Speed can be compared by comparing thermodynamic temperature (rmb kinetic theory, T direct proportional to speed)

- Explain why potential-distance graph has a maximum point

- Eqn for *net* potential
- Describe shape: as dist increases, potential increases then decreases

- Explain why potential-distance graph is asymmetrical

- "Neutral point"
- Potential gradient=0
- gfs = 0
- $g_1 = g_2$
- Write eqn
- Compare mass of planets, see where neutral point is closer towards (closer towards smaller mass)

- Why can resultant g be 0

G due to planet 1 is equal and opposite to g due to planet 2
Resultant g is 0

- Using answer to previous part, explain why orbit around X is *better* than Y?

Angular velocity of orbit around X and around Y are the same -> satellite, X & Y are in a straight line

Read question to see what the purpose of the satellite is

Eg satellite's purpose is to observe the sun. orbiting around the sun is better than orbiting around earth so it can observe the sun at all times (fulfill its purpose). Versus if it orbits around earth, it cannot view the sun sometimes (mission failed).

- ⭐ How does radius change if total energy decreases? [2m]

Energy is scalar. Sign is part of magnitude. Total energy decreases -> magnitude of E_T increases (write this)

Use formula of E_T to get answer: $E_T = ½ E_p = -GMm/2r$
Radius decreases

- ⭐ How does speed change if total energy decreases? [2m]

Either: Use previous part about radius decreases
Use formula of E_k: $E_k = -½ E_p = GMm/2r$
Radius decrease → E_k increases (explanation) → speed increases

Or: Use relationship to get answer: $E_T = -Ek$
Decrease in E_T → E_k magnitude increases (explanation) → speed increases

- ⭐How does potential energy change if radius decreases?

Use formula $E_P = -GMm/r$
Magnitude of E_P increases, E_P becomes more negative, E_P decreases.

- ⭐How does kinetic energy change if radius decreases?

E_k=-½ E_p = GMm/2r
E_k becomes more positive, increases.

- Explain the effect on speed if there is resistive force.

Past mistake: resistive force → some KE used to do work against resistive force. Ur object of focus is KE, so it is wrong to link resistive force directly to KE. Besides, some PE also used to do work.
Strategy: link to total energy and radius
Resistive forces → decrease TE → decrease radius → increase KE → increase speed

  - Alternative qn phrasing: where is speed largest?
    - Don't use forces and v=$\sqrt{\frac{GM}{r}}$, cuz it doesn't explain shit
    - Use energy considerations to explain
      - Smallest radius
      - Potential energy most negative
      - Total energy is constant / total energy is conserved
      - Kinetic energy is largest so speed is largest

- What's a similarity and difference between gravitational and electric field strength (of a point charge)

Both field strengths are inversely proportional to the square of the distance from point mass/point charge.
Gravi potential is always negative while electric potential can have positive or negative values – because F_g always attractive while F_e can be attractive or repulsive

- What's a similarity and difference between gravitational potential produced by a point mass and electric potential produced by a point charge

Inversely proportional to distance from point mass/charge. Magnitude of both potentials decreases with increasing distance from …
Gravi potential <0, electric potential +/-

- Satellites lose energy as they travel. Why do they burn up?

Lose total energy -> speed increases -> increase resistive forces -> WD by resistive forces converted to thermal energy -> burnnn

- State what is meant by geostationary

Geostationary satellites are at a fixed point above the Earth's equator and appear stationary when viewed from a fixed point on earth.

- Why must geostationary satellites be placed above the equator?

1) Gravitational force on satellite is directed towards center of Earth so its center of orbit will be the center of Earth
2) If it's not above the equator, it will not be at a fixed point above the equator so not geostationary (use definition of geostationary)

- State advantages and disadvantages of geostationary orbits and polar orbits.

Geostationary is at equator, fixed point above Earth, rotates with earth, at high altitude.
Polar orbit is pole to pole, not at fixed point above Earth.

Geostationary advantage 1. Stationary above same spot above Earth -> no need to keep adjusting 2. Can view the whole Earth	Polar disadvantage 1. Not stationary above same spot -> need to be adjusted constantly 2. No one spot can be viewed continuously
Geostationary disadvantage 1. High altitude -> low spatial resolution 2. Delay in reception, lag time	Polar advantage 1. Low altitude -> greater spatial resolution 2. Reduced lag time

- Why does rate of loss of altitude increase over time

[idea: loss in energy due to *drag*]
Given: there is already loss of altitude -> decrease in r -> v=sqrt GM/r -> increase in velocity -> increase *drag* -> increase rate of energy loss -> increase rate of loss of altitude
[key links: radius > velocity > drag]

- Assumptions in calculations
    1) Assume mass is concentrated at center/distance between bodies is much larger than radius of body → point mass
    2) Assume an isolated system → no net external force
        - E.g. considering a system of a body and Earth. Assume isolated system, so no gravitational force exerted by sun or anything, only by earth
    3) Assume no air resistance → POCOE equation no need to account for work done against air resistance/drag
    4) Assume no rotation of Earth → so that speed of object at Earth's surface is only due to its own KE, none from Earth's rotation
        - Only works for objects projected *from* Earth, doesn't make sense to assume for objects that are hitting Earth

- Remember u cannot compare Fg and Fc

Fc is not an existing force, it is just a label. So, "weight is not sufficient to provide for Fc" and not "weight is less than Fc"

- Phrasing: potential gradient is numerically equal to gravitational field strength

- Explain how escape velocity of rocket changes as it moves from Earth to moon
- Versus explain difference in velocity/escape velocity when it's on earth and when it's on moon. ← this is comparing 2 points. But the above qn is about the *whole* journey. And an important position in the journey is the *neutral point*.
    - Past mistake: compared start and end points
- Draw graph of *net* potential-distance graph to help u.

- From earth to neutral point, net potential increases. GPE increases.
  - ❌ actual KE decreases → escape velocity decreases
  - ✔️ KE required to escape to infinity decreases → escape velocity decreases
    - Logic: from a point to infinity, it loses KE and gains GPE. Since GPE increases, gain in GPE is smaller, loss in KE is smaller, required KE is smaller.
- Do from neutral point to moon

- Use given net potential-distance graph to explain whether kinetic energy increases or decreases or remains constant when the body moves from the surface of B to A.

Two stars A and B are separated by a distance of 1.2×10^{10} m as shown in Fig. 5.1. x is the distance from the centre of star A, in the direction toward the centre of star B.

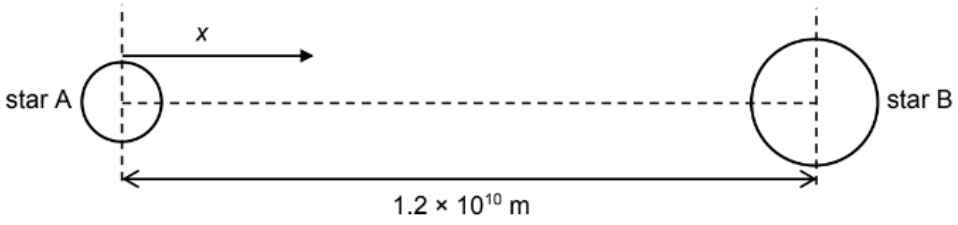
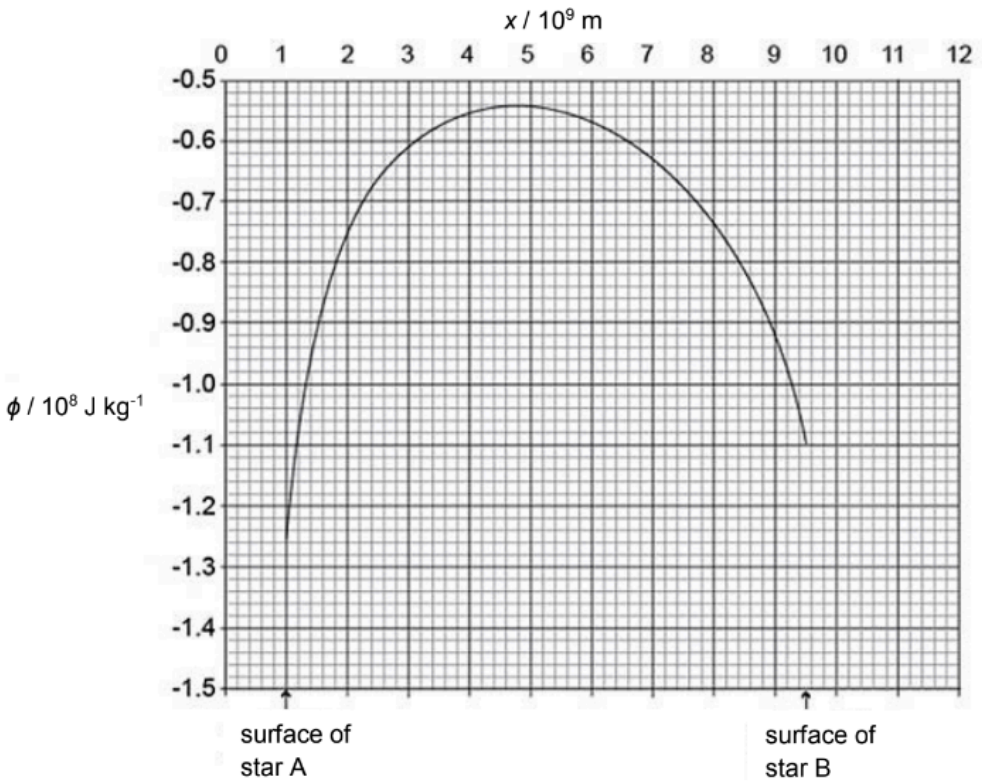


Fig. 5.1

The variation with x of the gravitational potential ϕ due to the two stars along the line joining their centres is shown in Fig. 5.2.



- Do NOT compare energy change of B to neutral pt with energy change of A to neutral pt. Do not bring in neutral point, overcomplication.

- Directly compare A versus B. A has smaller potential than B, so when body moves from B to A, electric potential energy decreases. POCOE → kinetic energy increases.

- A student calculates the change in KE of a satellite launched from Earth to its orbit using this derived expression: Fg=Fc → Ek=GMm/2r. Is the student correct?

❌ satellite was initially not in CM (not enough details)
✅ the expression assumes only Fg provides for Fc. But initially, the satellite was on Earth, so there are other forces that also act on the satellite, such as NCF.

Electric Fields

- Why can we assume that 2 charges are point charges

[compare size and distance]
Separation is much larger than radius

- What is an assumption

The test charge has no dimension and has an infinitesimally small amount of charge so that it does not affect the electric field we are measuring.

- Why does charge *appear* to be concentrated at center of spherical conductor

Electric field lines *appear* to originate from center

- Why a force on a charged particle may not be due to electric *field ← if not, then what field?*

Might be g force on mass in g field
Might be magnetic force if charged particle was moving at an angle to the magnetic field

- Why is the electric field strength zero within conductors?

Charges not moving > force=0 > E=F/q > E=0
Or Potential=constant (fact) > E=-dV/dr > E=0
Or If E=/=0 > charges will move > but charges in conductor are uniformly distributed, not moving > E=0

- Given graph of net E, explain whether spheres have same or opposite charges

C: charges are opposite
S: Net E is always positive (vector addition)
R: E due to each charge is positive → E is in same direction
(Link net to individual for such questions)

- Given graph of net V, explain whether spheres have same or opposite charges

C: opposite charges
S: Net V=0 at particular distance
R: Net V is scalar addition of individual potentials
+ charge always gives rise to + potential, – charge always gives rise to – potential

- Describe qualitatively the variation of acceleration

Look at mark allocation
2m = 2 regions of graph (↑&↓)

3m = 3 regions of graph (↑, –, ↓)
Unlike kinematics, just the direction of change is sufficient. Do not need rate of change (unlike kinematics).
Eg increase from minimum value, constant at minimum value, minimum at what distance

- State the relation between electric field strength E and potential V

E at a point is numerically equal to the potential gradient at that point (E=-dV/dr)

- A molecule comprising 2 charges. Previous parts ask to calculate electric force and force by 1 charge on the other. Explain why resultant force = 0.

Bcos of previous parts, need to address both electric force and force by charge.
Electric force equal and opposite, cancel yada yada (F_{net}=0, N2L, not N3L). And also force by 1 charge on other is an *internal* force, does not contribute to resultant force (N3L).

- Describe the path of the electron for minimum speed in previous part

Although path makes u think of complete motion, direction etc, qn only said that initially the electron was far away - so you don't know the direction of the whole motion.
Qn only wants path WHEN electron has MINIMUM SPEED – a point in time.

Ans: Electron crosses line between point charges at x=...

- Student thought Vx was constant. Are they correct?

1. Think of why student thinks that - list down formulas

Aaah they used formula for point charge

2. Why is it wrong? (wrong most of the time)

That only applies to isolated charges. Now there are >1 charges with interacting electric fields

- Explain quantitatively why only electric force, not gravitational force is taken into consideration
  Compare Fe and Fg > Fe much larger than Fg

- State 2 differences between forces experienced by a charged particle in an electric and magnetic field
  1) Electric force is parallel to electric field, magnetic force is perpendicular to magnetic field
  2) Electric force is independent of velocity (F=qE), magnetic force is dependent on velocity (F=Bqv)
     a) Use *general formula*

❌ electric force is inversely proportional to distance → this is only correct for 2 point charges, and the question (in this case) is about force experienced by a single charge in a field, so not applicable.

- There is a positively charged sphere and a negative point charge. Why is electric field strength larger in practice?

Positive charges on the sphere are redistributed such that there are more + charges on the right side of A.
Effective separation of charges increases.

Electromagnetism

- Why do conductors carrying currents in the same direction attract?

1. By RHGR: Magnetic flux density B at __ due to __ is perpendicular to __
2. From FLHR: direction of magnetic force F on __ is towards __
3. By N3L: magnetic force F on __ is towards __. Hence attraction between conductors.

- Why do charged particles moving in a magnetic field undergo circular motion?

Velocity is always perpendicular to magnetic force.
Magnetic force provides for required centripetal force, producing a constant changing of direction.

Electromagnetism

- Explain why particle undergoes circular motion in a magnetic field [2]
  - 1m – Fb provides for required Fc
  - 1m – why does Fb provide for Fc?
    - v is perpendicular to B field
    - ***(Condition for CM) Fb is perpendicular to v***
    - (Type of CM: uniform CM) v is constant, so magnitude of Fb is constant

- Why do charged particles moving at an angle into a magnetic field undergo a helical path?

1. CM

Component of velocity that is perpendicular to magnetic field results in CM

2. Speed perpendicular to plane of circle

Component of velocity that is parallel to the magnetic field does not experience magnetic force - is constant.

- Why do coils (like currents) attract

(FBI) Magnetic field of the 1st coil is normal to the current in the 2nd coil. This causes a force on the 2nd coil. By N3L, this leads to attraction.

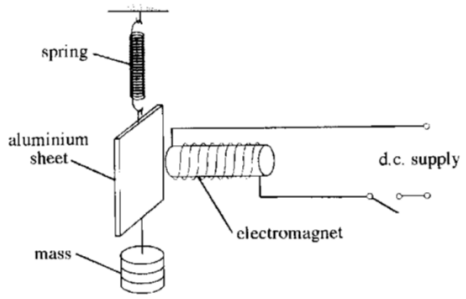
- Give 2 scenarios where a charged particle in a magnetic field does not experience a magnetic force
  1) Not moving
  2) Moving parallel to magnetic field

- Setup: 1 larger coil connected to electric supply, 1 smaller coil placed in the middle of the larger coil. What is assumed when u use the equation $B = \frac{\mu_0 NI}{2r}$ to calculate current induced in the smaller coil?

That equation refers to B at the *centre* of the larger coil. Assume that the B experienced by the smaller coil is this value throughout.

Electromagnetic Induction

- Lenz's law, POCOE (eg explain why oscillation is damped)



1) Change in factor affecting flux linkage (in above pic, is that the aluminium sheet cuts flux as it oscillates) → change in flux linkage → induce emf
2) induce current → sets up force on (object causing change in flux linkage, eg moving magnet) OR eddy currents formed
3) mechanical energy of oscillations converted to thermal energy (electrical potential energy → thermal energy)

- General Faraday and Lenz explanation

Change in factor affecting NΦ → change in NΦ → By Faraday's Law, there is an induced emf → if closed loop, there is an induced current → By Lenz's Law, to oppose the change in magnetic flux → an induced current flows in (dir) → to produce a magnetic field in (dir)

➢ Alternating current - explain why there is an emf induced

1) Primary

In primary coil: Alternating V > alternating I > alternating B (magnetic flux density) > alternating flux linkage

2) Threads through [link pri to sec]

Alternating flux linkage produced by the primary coil threads through the secondary coil

3) FL

By Faraday's Law, emf is induced in secondary coil

4) Same frequency

Induced emf has same frequency as alternating voltage supply

➢ Rotating coil - explain why flux linkage changes

Factor: angle between normal of plane of coil and B field changes

➢ Link induced emf to induced current

Complete circuit → current is induced
Material is made of electrical insulator → *high resistance* → no current induced

➢ Flux cutting

Wire cuts flux —> emf induced
direction of flux cutting changes —> direction of emf changes
skip change in magnetic flux linkage

➢ Soft iron core

Soft iron core concentrates B field in aluminium ring → increase magnetic flux in ring

- Use the laws of electromagnetic induction to explain the shape of your emf-t graph/explain the variation of emf induced

(given x-t graph, deduce shape of emf-t graph)
A lot of marks (eg 4m) - 2m is allocated for the 'specifics', so don't just stop at the general FL explanation

Method 1:

- (general FL explanation) Shape: sinusoidal — X varies sinusoidally > flux linkage varies sinusoidally > By FL > emf varies sinusoidally with time
- (specific) Exact shape
    - At t=..., x is max/min, flux = min/max, emf = 0
    - At t=..., x=0, flux=0, emf = max
    - when plane of coil is perpendicular to B field, flux=max, emf=0
    - When plane of coil is parallel to B field, flux=0, emf=0

Method 2: (using math)
X-t is cosine "__ varies with a cosine function" > flux-t is cosine "magnetic flux linkage experienced by __ varies with cosine function" > emf-t is sine "induced emf varies with sine function"

- Explain why magnitude of induced emf changes with time (context: magnet falling through coil)
    - = why emf is not constant
    - =/= why emf is increasing and decreasing at certain times (this requires details of direction)

Magnetic field of magnet is not uniform
Rate of change of flux is not constant

- Why is magnitude of maximum emf different when magnet is falling into coil VS when magnet is falling out of coil

Velocity increases (when dropping out of coil, time taken is shorter)
Magnitude of change in flux (area under graph) is constant

- Cutting magnetic flux - explain which side has higher potential

Conductor cuts magnetic field → By Faraday's law there is induced emf because there is rate of flux cutting → By FLHR electrons experience force in (dir) → accumulate (where)

- Given current against time graph of primary coil, explain why induced emf is largest at …

I-t graph = flux linkage-time graph
E=-d(flux linkage)/dt
(Graph) Gradient of tangent is largest → (definition) rate of change of magnetic flux linkage largest → induced emf largest

- There is a large coil connected to alternating current supply, and a small coil in it. Use Lenz's law to explain direction of induced current in small coil relative to direction of current in large coil. [4]

- *CHANGING* current in large coil induces emf. It is not current that induced emf.
- Notice that qn did not specify if current in the large coil increases or decreases. Conclusion differs for each scenario!
- There is no need to set up the direction of current in ur answer, just use it for thinking process.

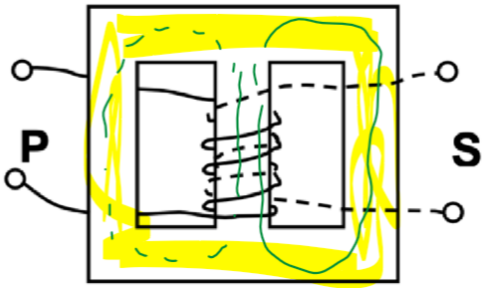
- If current in large coil increases > flux linkage increases > to oppose the increase in flux, current induced is opposite
- And vice versa

Alternating current

- [4m] state 2 causes of energy loss in a transformer, and how to reduce them

1) Magnetic flux leakage

Need to draw the new core



Primary and secondary coils are wound on each other

2) Resistive heating in wires/coils

Use coil of lower resistivity and thicker wires → Decrease resistance → $P=I^2R$ → Reduce power loss in coil

3) Heating of the core due to eddy currents

Laminate the core

Reduce size of eddy currents

Reduce heat loss due to eddy currents

4) Hysteresis loss

Use soft iron core instead of iron core

Easy to magnetize and demagnetize - *reduce* power loss

(if higher turns ratio, where turns ratio = $N_s/N_p = I_p/I_s$, I_s decreases, so power loss decreases)

- Given that $V=V_0$sin..t, and average I is 0, explain why there is a heating effect.

[Idea: instantaneous vs average]

Current is alternating > There is instantaneous current > although average current = 0 > there is instantaneous power dissipated as heat

- What is meant by an ideal transformer

[idea: power]

No power loss

- Explain distinction between rms and peak value of ac

Just give definitions

- Peak value is the max value in either direction in a periodic cycle

- In a circuit with a diode and battery, why is a resistor necessary?

[idea: heating effect due to current]

In forward bias > diode low R > high I > overheating

Resistor > increase R > decrease I > prevent overheating

- D.C. converter converts steady DC to AC before it goes to the transformer. Why is a D.C. converter required?

Transformer requires alternating current to work (emi shit)

Quantum

- *** state/describe/explain the photoelectric effect ***

Always the same thing no matter the marks!

1. Light shine on metal
2. If frequency exceeds threshold frequency
3. Electrons emitted

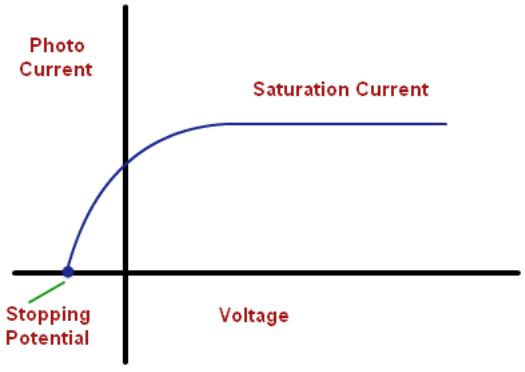
The photoelectric effect refers to the (3) emission of electrons from a metal surface when it is (1) irradiated with electromagnetic radiation with (2) frequency higher than threshold frequency.

- State in terms of energy changes, the required condition for electrons to be emitted [2]
    1) Energy of photon must exceed work function
    2) (Plonk equation that involves energy) Difference between energy of photon and work function is the maximum kinetic energy of photoelectron

- Explain in terms of energy changes of emitted electrons, why there is a minimum potential difference V_s to reduce current to 0

Stopping potential ← electron with highest KE is stopped
Electron with highest KE comes to a rest at xx electrode.
Other electrons with lower KE come to a rest before reaching that electrode.

- Why is current constant for V>0



The limiting factor is the rate of emission of photoelectrons at xx electrode, which is independent of V.

- Explain why photocurrent-time graph has positive values only, given that UV light is shone on 2 electrodes of different materials

Be concise! Only 1 electrode is emitting electrons. Based on qn, state which electrode has the lower work function energy and is the one emitting electrons.

- When wavelength of photons decreases, explain why photocurrent has both positive and negative values

Both electrodes emit electrons. Negative photocurrent is from the electrode with higher work function energy, since in the previous part shown than the electrode with lower work function energy gives positive photocurrent.

- With reference to photoelectric effect, explain meaning of threshold frequency

Threshold frequency is the minimum frequency such that photons have energy that exceed work function, so that photoelectrons are emitted.

- Why is the rate of electrons emitted way smaller than the rate of photons incident on metal target?

- Some electrons require energies higher than the energy of the photons
- Some photons reflect off
- Some photons absorbed as thermal energy by the metal
- Some photons are transmitted through the metal (if the metal is rly thin)

- Why do some emitted electrons have less kinetic energy than the maximum possible kinetic energy?

Electrons **below the metal surface** require some energy to be brought to the surface, so it requires more energy to be emitted.

- How does the photoelectric effect provide evidence for the particulate nature of light?

Need to give observations + dispel wave theory + explain particulate nature

Observation	Failure of wave theory	Particulate nature explanation
1. Time taken to liberate electrons Emission of photoelectrons is almost instantaneous upon irradiation of electromagnetic radiation on a metal surface, *provided that photons have energy exceeding work function energy, regardless of intensity.* Instantaneous vs delay	In low intensity light, electrons absorb energy over a period of time. They gain enough energy and are emitted after some delay.	Electrons interact with photons on a one-to-one basis, so emission is instantaneous.
2. Whether electrons are liberated No photoelectrons are emitted if their frequency is below threshold frequency, *regardless of intensity.* No vs yes	Even if the frequency is below threshold frequency, energy of electrons can accumulate over time and escape. There should be no threshold frequency	Work function energy is the minimum energy gained by electrons before it can escape. Energy of photons (hf) must exceed the work function (hf_0 where f_0 is threshold frequency) for photoelectrons to be emitted.
3. Factors affecting KE of electrons	**Higher intensity implies greater energy of photons (I=P/A = E/tA)**, so electrons should be emitted with	<u>Why dependent on frequency</u> Use equation: $E_{k\,max} = E_{photon}$ - work function

The maximum kinetic energy of photoelectrons is ~~dependent on frequency of light,~~ and independent of intensity. (choose 1 !!) Dependent and independent are opposite	greater kinetic energy. Max KE should depend on intensity and be independent of frequency.	= hf - work function Why independent of intensity Increased intensity implies a higher rate of emission of photons. When intensity is increased, as the energy of photons = hf, when frequency is constant, energy of photon is constant. Electrons interact with photons on a one-to-one basis, so no change in max ke.

- State phenomenon that gives evidence for the particulate nature of electromagnetic radiation : photoelectric effect
- State phenomenon that gives evidence for the wave nature of electromagnetic radiation (GENERAL!!!!) : diffraction
- State phenomenon that gives evidence for the particulate nature of electrons (PARTICLE !!!!) : electron diffraction
- Describe the main features of de Broglie's model of electrons

(electrons have wave properties)

- Each electron has a wavelength associated to it
- Plonk formula: wavelength = h/p

- Electrons shot through a single slit, forming interference patterns. State an aspect of the experiment that cannot be explained using the wave model.

Electrons can be counted discretely. (when electron gun shoots electrons one by one, you can see dots)

- State meaning of △momentum/position

Remember to state direction

(alphabet shows direction eg △x = x direction, △y = y direction)

- Why is energy of electron orbiting a nucleus negative
  - Electron is bound
  - **Work must be done to free the bound electron / ionize it**
  - Ref pt: Energy of electron is 0J when it is at the highest energy level of n=infinity

- Can an electron in the ground state absorb energy of xxx J?

(understand it as energy in the form of a photon)

- Calculate final energy
- Say whether final energy level is allowed

(for excitation due to photons, ALL of the photon's energy must be absorbed. But for electrons, part of the energy can be absorbed)

- If the amount of energy absorbed (from photon) exceeds ionization energy, it's allowed.

- How is an emission spectrum produced?

  Set up:
  - Production of hot gas: Voltage is applied across low pressure gas
  - Electrons collide with gas → gas becomes excited

Emission:
- Excited gas is unstable. When they transit to a lower energy state, they emit photons of specific frequency
- Discrete energy levels → only certain high to low energy level transitions are possible → E=hf → only certain frequency lines are present

- How is an absorption spectrum produced?

Set up:
- White light of all frequencies pass through a cool gas

Absorption:
- Gas absorbs photons with energies *exactly* equal to the difference between atom's energy levels
- Energy levels are discrete → only photons of certain frequencies are absorbed

Dark:
- When atoms transit back to ground state, photons of the same frequencies are emitted in all directions
- Dark lines corresponding to these wavelengths are formed on spectrum

- How does the line spectrum provide evidence for the existence of discrete energy levels of electrons in atoms

Line spectrum → photons → energy change → energy level
E=hf Ep=E change

Set up: Gas is heated, and gets excited, and when they de-excite, they produce photon, producing isolated coloured lines on dark background // White light is passed through cool gas, which absorb photons, producing dark lines against a continuous spectrum

Colored/dark lines are discrete → Each line corresponds to a specific wavelength → (Photons are emitted when electron transitions from high to low energy level / Photons are absorbed when electron transitions from low to high energy level) → E=hf → photons with specific energy are emitted/absorbed → discrete energy of photon corresponds to discrete energy change between energy levels → imply discrete energy levels in hydrogen and thus in atoms

- Why is line spectrum observed even though n is very large (close to infinity)

N is large → wavelengths are close → forms infinite continuum
Spectral lines (associated with transitions from a few lines above n=1) are distinctly separated

- Heisenberg uncertainty

(i) Find Δx of electron in an atom
(ii) Find Δv of electron in an atom
(iii) Given that diameter of nucleus is 10^4 times smaller than diameter of atom, why can't the electron be found in the nucleus?

$\Delta v = \frac{h}{\Delta x\,(m)}$ → (Δx) x 10^{-4} → (Δv) x 10^4 → calculate actual value using (ii) answer → **uncertainty of speed of electron in nucleus exceeds the speed of light** so it can't be found in the nucleus

- In an x-ray continuous spectrum, why is there a minimum wavelength / why is there a sharp cut-off at short wavelength?

(1) Set up
    - Due to *braking radiation*, when electrons decelerate, photons (x rays) are produced
(2) Process
    - Incident electron hits the target metal and stops in a *single* collision
    - *All* its KE is converted to a *single* photon
(3) ATQ
    - X ray has maximum energy
    - E=hc/lambda
    - X ray has minimum wavelength

(FYI) This happens rarely, so intensity is zero.

- Explain the continuous distribution of wavelengths

1m – "wavelength". Explain how x-ray photons are produced.
- Due to *braking radiation,* when electrons decelerate, photons are produced

1m – "continuous distribution".
- Incident electrons experience a distribution of deceleration
- Wavelength of photons depend of magnitude of deceleration
- There is continuous distribution of wavelengths of photons

- Explain why there are characteristic x-ray peaks

(electrons from electron gun hit metal target, knock off electrons in K, L, M shells)
(Outer) *Electrons in the target metal* de-excite, emitting photons.

- Explain why compared to the K series, other series of characteristic lines have longer wavelengths [2]

1m – how characteristic lines are produced
- When high speed electrons collide with target metal, inner shell electrons are knocked off, forming a vacancy that is filled by outer electrons. When outermost electrons transition to a lower energy state, they produce photons.

1m – why longer wavelength
- The vacancies produced are in shells that are above the K shell → smaller energy transitions → photons have less energy, larger wavelengths.

- How do changing factors affect x ray graph

(effects on intensity, minimum wavelength and characteristic wavelengths)

- Effects on intensity ($\propto \frac{Nphotons}{t}$)
    1) Temp of cathode inc → rate of emissions of *electrons* inc → rate of collisions of electrons with target metal inc → rate of x-ray photons produced inc

2) Accelerating voltage inc → speed of *electrons* inc → kinetic energy of electrons inc → rate of x-ray photons produced inc

- Effects on minimum wavelength
    - Need to explain the minimum wavelength before explaining effects on it

- Effects on characteristic peaks
    - Need to explain what the characteristic peaks refer to before explaining effects on it
    - "Electron energy levels in atom of metal targets are independent of …"

- Given graph of characteristic peak energies, asked to calculate energy of photons released from K transition of diff metals, then comment on elements in target metal

(1) DIR: what elements are present + (2) MAG: composition of elements

(1): match characteristic peak energy with calculated energy of photon
"Peak of <u>energy</u> __ is similar to/matches <u>energy difference of levels</u> in (metal)"

(2): see height of peaks
Peak of energy __ is higher than other peak → target contains more of (metal), less of (metal)

Nuclear

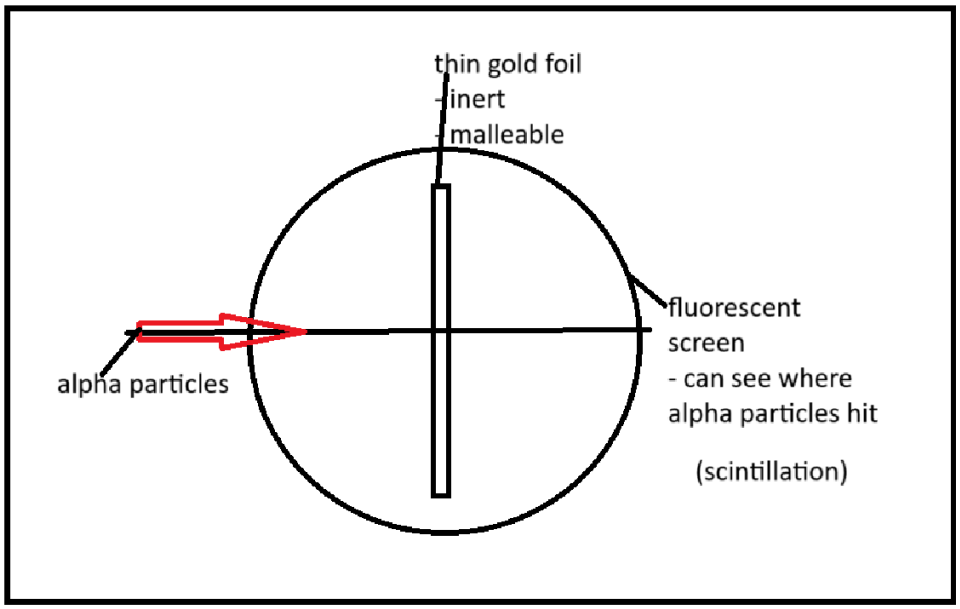
- Explain why the random nature of radioactive decay makes it difficult to measure the half life to a high degree of accuracy

1. Explain what is random (define)
2. Explain statistical meaning of random: after one half-life, it is not guaranteed that exactly half of the original atoms remain, but that this is just the most likely, and the average outcome.

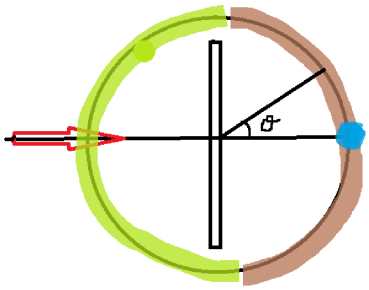
- Why should we use steep part of N-t graph to find half life

Key concept: random nature of decay
Random → a lot of fluctuations of graph → steep part use large decrease in N → decrease percentage uncertainty of half life

- Explain the set up of Rutherford's alpha scattering experiment



- How does Rutherford's experiment lead to deductions about the atom

Legend:	
Observations	Deductions
Most alpha particles were not deflected	- Nucleus is extremely small - Atom is mostly empty space
Some alpha particles were deflected at small angles	- Positively charged alpha particles were repelled by positively charged nucleus
Very few alpha particles were deflected through large angles	- Only a few alpha particles can go close enough to interact with nucleus - Nucleus has extremely small size - Gold nucleus remains stationary - Mass of atom is concentrated within a small volume

Qn: Explain results that suggest small size of nucleus compared to that of an atom

(1) Small size → θ=0, θ>90
(2) Compared to that of an atom → θ=0

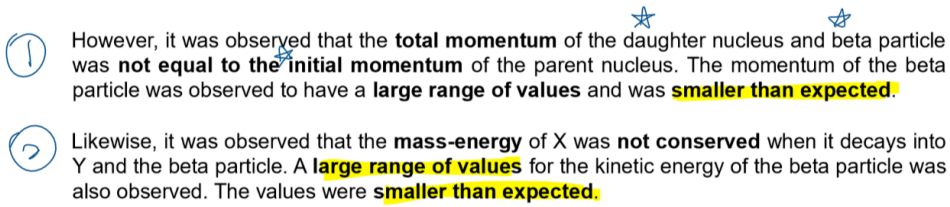
Qn: Explain results that suggest charge distribution
- Positive charge is concentrated within a small volume
- Use all 3 results. The positive charge affects all 3
- Mostly small deflections > small probability of getting close to the positive charge

Qn: Explain results that suggest mass distribution
- Mass is concentrated within a small volume
- Use large deflection result
- Nucleus remains stationary
- Nucleus is more massive than alpha particles

- By reference to binding energy per nucleon, explain why energy is released when fission occurs

BE per nucleon of pdts > BE per nucleon of rxts → pdts more stable than rxts → nucleon number conserved → total BE of pdts > total BE of rxts → energy released
*link per nucleon to total through conservation of nucleons!

- Explain the presence of neutrinos



Presence of neutrinos to enable principle of conservation of momentum and mass-energy.

  - POCOM: In a 2-particle system (daughter nucleus and beta particle), the ratio of speeds of the particles should be fixed.
  - POCOE: As the energy released per decay is constant, the speed of the beta particle should be fixed. (discrete value)
  - Graph shows that beta particles have a range of kinetic energy. This suggests there is a 3rd particle.

- Write essay on background radiation

20.5.11 Background Radiation

Background radiation is the ionizing radiation emitted from a variety of natural and artificial radiation sources. Primary contributions come from:

- Sources in the Earth. These include sources in our food and water, which are incorporated in our body, and in building materials and other products that incorporate those radioactive sources;
- Sources from space, in the form of cosmic rays;
- Sources in the atmosphere. One significant contribution comes from the radon gas that is released from the earth's crust and subsequently decays into radioactive atoms that become attached to airborne dust and particulates. Another contribution arises from the radioactive atoms produced in the bombardment of atoms in the upper atmosphere by high-energy cosmic rays.

Today, a small fraction of background radiation also comes from radioactive tools such as smoke detectors, from self-luminous dials and signs, from global radioactive contamination due to historical nuclear weapons testing, nuclear power station or nuclear fuel reprocessing accidents, and from normal operation of the nuclear power industry. Sometimes included in background radiation are routine medical procedures like x-ray imaging; this is purposeful diagnostic exposure which dwarfs all other human-caused background radiation in the population of the industrialized world.

- Identify assumptions from logic chain below:

Stationary parent nuclide and slow neutron (induced reaction)
Initial momentum = 0 ← assume slow neutron has no KE
By conservation of momentum, ← assume no net external force
$M_{daughter\ 1}\ v_{daughter\ 1} + M_{daughter\ 2}\ v_{daughter\ 2} = 0$ ← assume gamma photon has negligible momentum
Ratio of speed = …

- Why is it unlikely for daughter nuclide and alpha particle to go off in opposite directions?
  - Gamma photon is emitted
  - By conservation of momentum
  - As initial momentum = 0
  - Vector sum of momentums of daughter nuclide, alpha particle and gamma photon = 0
  - Momentum of gamma photon is non negligible
  - Unlikely for all 3 particles to move off in a parallel direction
  - Unlikely for the 2 particles to move in opposite directions

- Why is it better to measure samples with small decay constants if I'm doing graphical method

Long half life → activity doesn't change significantly during measurement

- Why should product be stable for graphical method analysis of count rate

Product should be stable so that count rate is only due to parent nuclide

- Why do u not need to consider background radiation

Count rate is significantly higher than BG radiation, BG radiation is insignificant

- What feature of the graph shows that decay is random

Graph has many fluctuations, jagged, not smooth

- Why is activity and measured count rates (accounted for the proportion thing in Geiger counter already) different
  - Background radiation adds to measured count rate

- Air absorbed some radiation
- Dead time of counter
- Products are not stable, decays, add on to measured count rate

- How does reading on Geiger Counter differ from the actual activity

Lower reading, because particles are emitted in all directions but only a proportion are detected by the counter.
Concept: only a fraction of particles are captured

- Effect of increased temperature on half life

No effect, rate of decay is independent of external physical and chemical factors

- Effect of increased temperature on measured count rate

❄️ rate of decay is random, effect cannot be predicted

- Why is the number of nuclei constant despite it being radioactive, given that it decays by the emission of gamma photons?

Decay by gamma radiation, no charge is taken away from nuclei, so proton number of nuclei stays constant.

- Why long half life good for space exploration

Reference length of space exploration. Long half life means power generated remains constant, lasts for space exploration

- Health effects

(commonly tested in data based qns)
___ is an ionizing radiation, damage to cells increases as exposure increases.

Data based question

- Helicopter, effect of air pressure

Helicopters push down air particles to generate thrust. Lower air pressure means less air particles per unit volume, so in atmosphere of lower pressure, helicopter rotor needs to be bigger

- Interpret equations correctly

Eg E = x/y (100) → value of E does not include %

- Disadvantage of driving in car with large deceleration when braking
  - Discomfort (brake too fast)
  - Tailgating vehicles cannot brake fast enough, accident

- Car braking system

Foot brake: hydraulic system, used for regular driving
Hand brake: mechanical system, used for parking
Should not use both brakes tgt, if not car will skid

- Energy

    - Renewable energy sources. Solar energy. Problem: intermittency, may not always have sunlight to provide solar energy
    - Changing system of providing electrical power to homes, skipping generator, go straight to homes → more efficient

- Temperature
    - Disadvantage of using a calibrated voltmeter to measure temperature: voltage and temperature may not vary linearly
    - Types of light bulbs (in order of increasing energy-efficiency): filament incandescent bulb, fluorescent bulb, LED

- Submarine. Disadvantages of increasing thickness of hull?
    - More expensive cuz more specialized materials needed to manufacture submarine
    - Increase circumference, increase drag, more power required

- Submarine. Why is actual power higher than calculated power required?
    - Efficiency is not 100%
    - Hull not smooth cuz covered by barnacles, irregularly shaped features such as fins and antenna, seawater flow is turbulent → increase drag