C12 Motion in a circle

A moon is in circular orbit around a planet. Explain why the *path of the moon is circular* [2]

- Gravitation forces provides centripetal force
- Due to velocity of moon is perpendicular to gravitational forces
- Gravitational forces are constant therefore magnitude of centripetal forces are constant

Explain, with reference to gravitational field lines, why the gravitational field near the surface of the Earth is approximately constant for small changes in height [3]

- The lines are radial
- near the surface the lines are (approximately) parallel
- parallel lines so constant field strength
- constant field strength hence constant acceleration of free fall

Centripetal acceleration in causing circular motion basics :

- Force of constant magnitude
- Force always perpendicular to the direction of motion
- Magnitude of velocity does not change

Describe how the two forces acting on the object give rise to this centripetal acceleration, when object rests on the surface of the Earth at the equator

- Two forces are gravitational force and (normal) contact force
  #Gravitational force on object is greater than the contact force
- Gravitational force and normal contact force are in opposite directions, and their resultant causes the centripetal acceleration

C13 Gravitational Fields

Gravitational field line

State how the direction of the electric field at the surface of the Earth compares with the direction of the gravitational field

- Same direction

Explain, with reference to gravitational field lines, why the gravitational field near the surface of the Earth is approximately constant for small changes in height [2]

- change in height negligible compared with radius (of Earth)
- (so) field lines are (effectively) parallel

State a similarity between the gravitational field lines around a point mass and the electric field lines around a point charge.[1]

- (both have) radial field lines

Gravitational field strength

Explain why there is a point where resultant gravitational field strength due to Earth and Moon is zero

- Field due to Earth and Moon have equal magnitude
- Field due to Earth and Moon are opposite direction

Gravitational potential

Similarities and differences between gravitational potential and electrical potential

Similarities	Differences
- inversely proportional to distance (from point) - points of equal potential lie on concentric spheres - zero at infinite distance	- gravitational potential is (always) negative - electric potential can be positive or negative

Explain why the gravitational potential energy is negative [3]

- potential energy is zero at infinity
- gravitational forces are attractive
- work must be done on the rock to move it to infinity

Explain why, at the surface of the sphere, the gravitational potential is always negative

- g is always attractive
- Force is always in opposite direction to displacement

Geostationary orbit Qs
Explain why the path of moon is circular

- Gravitational force provides centripetal force
- Velocity is perpendicular to resultant force
- Resultant force is constant

State conditions that must be met for the orbit to be geostationary

- Direction must be from West to East
- Must be above equator
- Orbit period must be 24 hours

C14 Temperature & C16 Thermodynamics

Temperature
State the reason why two objects that are at the same temperature are described as being in thermal equilibrium

- No net thermal energy is transferred between them

Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules

Type of thermometer to use with each type of temperature measurement:

Thermocouple- utilises change in emf to measure temp
Thermistor- resistance
Liquid in glass- density

(b) Suggest suitable types of thermometer, one in each case, to measure

(i) the temperature of the flame of a Bunsen burner,

thermocouple ..... [1]

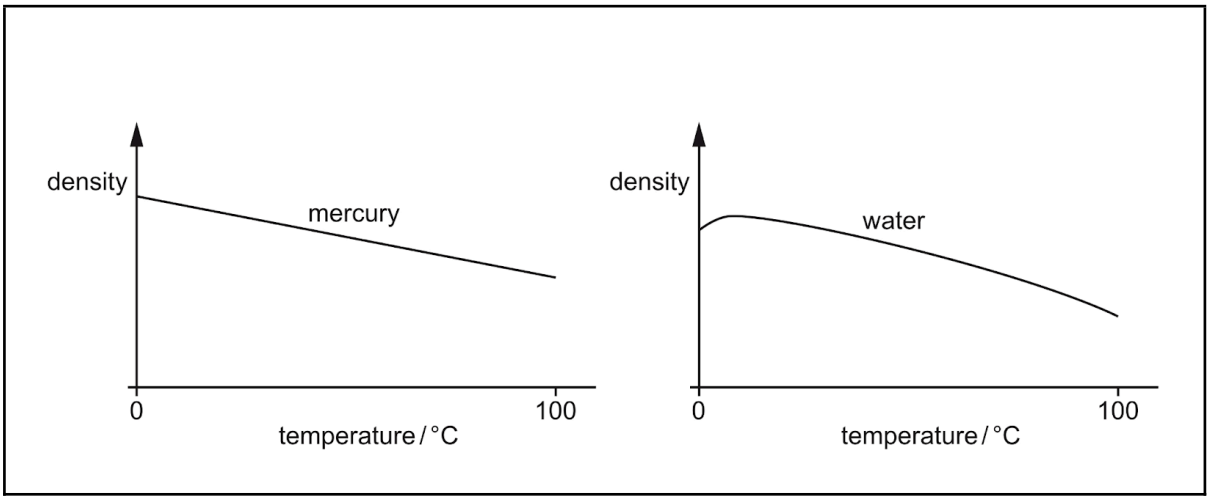
(ii) the change in temperature of a small crystal when it is exposed to a pulse of ultrasound energy.

thermistor / thermocouple ..... [1]

What makes thermodynamic temperature unique:
Does not depend on the property of any particular substance (lowest temperature is 0K)

Temperature measurement and Thermometer:
4 Uses property of substance that changes with temperature

- Density of liquid
- Volume of gas at a constant temperature
- Resistance of a metal
- EMF of a thermocouple thermometer



Suggest why, for measuring temperature over this temperature range:

i) Mercury is a suitable liquid

- Linear

ii) Water is not suitable liquid

- Not linear
- Different temperatures have same density

Suggest one change that could be made to the design of the thermometer that would enable it to give a more accurate measurement of temperature

- Use a liquid with a lower specific heat capacity than mercury
- Use a smaller mass of mercury

Explain why liquid-in-glass thermometer does not provide a direct measurement of thermodynamic temperature

- depends on properties of real substance - not absolute scale
- 0°C is not absolute zero

Specific heat

The specific latent heat of vaporisation is much greater than the specific latent heat of fusion for the same substance. Explain this, in terms of the spacing of molecules [1]

- (much) greater increase in spacing of molecules (for vaporisation compared with fusion)

First law of thermodynamics Qs

(b) The state of an ideal gas is continuously changed according to the cycle ABCDA shown in Fig. 3.1.

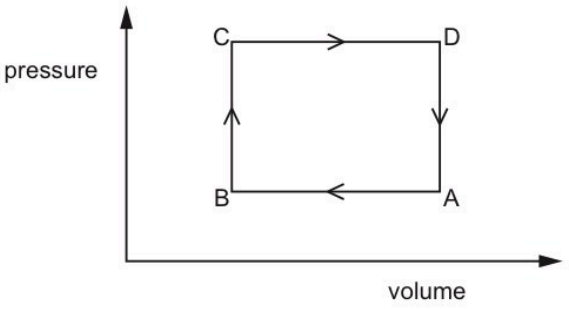


Fig. 3.1

(i) Complete Table 3.1 for the changes A to B and B to C by placing two ticks (✓) in each row.

Table 3.1

change	change in internal energy			work done on gas		
	decrease	no change	increase	negative	zero	positive
A to B	✓					✓
B to C			✓		✓	

[4]

$\Delta U = W + q$ $W = p\Delta V$

A → B U↓ W↓ W↓ V↓ volume ↓ work done on system +ve

B → C $\Delta U = 0 + q$ W = 0 ↑ p↑ doesn't affect

U↑ pressure ↑ temp. ↑ q↑

1st Law of Thermodynamic

(ii) Use the first law of thermodynamics to describe and explain the energy transfers associated with one complete cycle ABCDA.

- more w.d. by gas in CD than AB – due to higher P during CD
  - ↳ no wd. on gas in BC and DA, so overall gas does work
- change in internal energy = 0
- input of thermal energy [3]

[9]

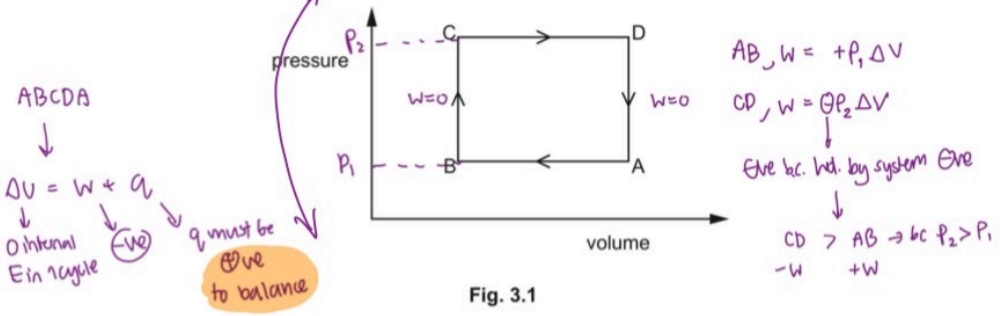


Fig. 3.1

<u>Summary for these kind of question</u>

*** For Ideal gas ***

If there are changes but **<u>V is constant</u>**

- W = 0
  - If **P increases** → T increases and q is +ve → U = +ve
  - If **P decreases** → T decreases and q is -ve → U = -ve

<u>Reason</u>: Because when V is constant, pressure is increased by **increase in collisions** between particles and container (system)

- Hence, each particles must have more (kinetic) energy than before
- So, it means that thermal energy is added (+q) to supply those increasing of kinetic energy

If there are changes but **p is constant**

- If V increases → W is -ve
  - Because V increases = Workdone <u>by</u> system = -ve
  - q = -ve
- If V decreases → W is +ve
  - Because V decreases = Workdone on system = +ve
  - q = +ve

Workdone comparison

- If $\Delta V = 0 \rightarrow W = 0$
- If $\Delta V \neq 0 \rightarrow$ use $W = p\Delta V$ for comparison

C15 Ideal gases

Mole: amount of substance containing as many particles as there are number of Carbon-12 atoms in 12 grams of carbon

Avogrado's number: number of atoms in 12g of Carbon

Activity - rate at which nuclei decay
Decay constant- probability that a nuclei will decay per unit time

State the assumptions of Kinetic Theory of Gases:

- **Volume of molecules negligible compared to volume of container**
- **Time of collisions negligible compared to time between collisions**
- **There are no forces of attraction or repulsion between molecules (except during collisions) [→ this means no Ep]**
- All collisions are perfectly elastic (no loss of Ek)
- Molecules are in continuous random motion

Ideal gas = Constant volume = No work done so $\Delta U = q$

- The gas at the surface of a star has a very high pressure

Use the basic assumptions of the kinetic theory to suggest why, in practice, a gas at the surface of a star is unlikely to behave as an ideal gas

- High pressure = particles are very close together
- Force between particles is not negligible

Explain how movement of the gas molecules causes pressure in the container [3]

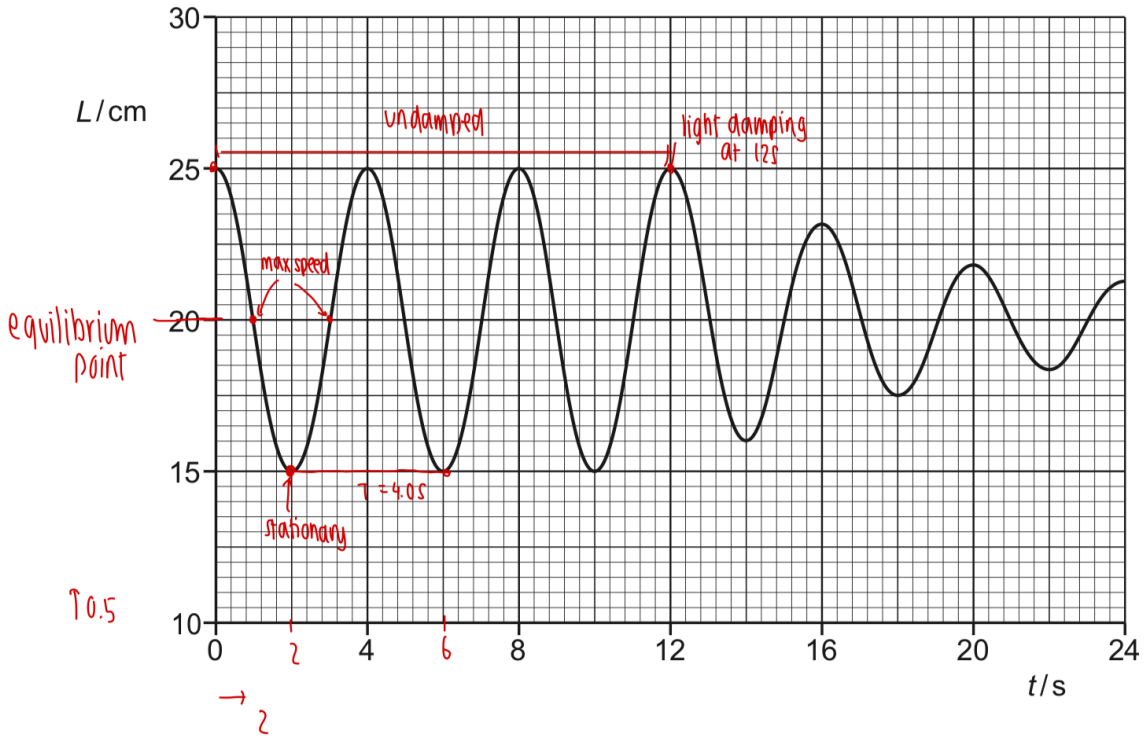
- molecule collides with wall
- momentum of molecule changes during collision (with wall)
- force on molecule so force on wall
- many forces act over surface area of container exerting a pressure

→(Newton 2nd and 3rd law)

C17 Oscillations

Describe the interchange between the potential energy and the kinetic energy of the oscillations (in case if no damping)

- Sum of potential energy and kinetic energy is constant
- At maximum displacement, **potential energy is maximum** and kinetic energy is 0
- At 0 displacement, potential energy is 0 and **kinetic energy is maximum**



How graph shows that the motion of pendulum is SHM

- straight line(constant gradient) through origin shows that a is proportional to x
- negative gradient shows that a is in opposite direction to x

4 A trolley on a track is attached by springs to fixed blocks X and Y, as shown in Fig. 4.1. The track contains many small holes through which air is blown vertically upwards. This results in the trolley resting on a cushion of air rather than being in direct contact with the track.

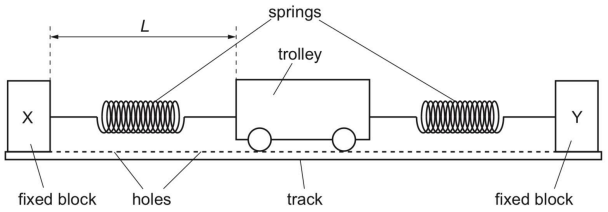


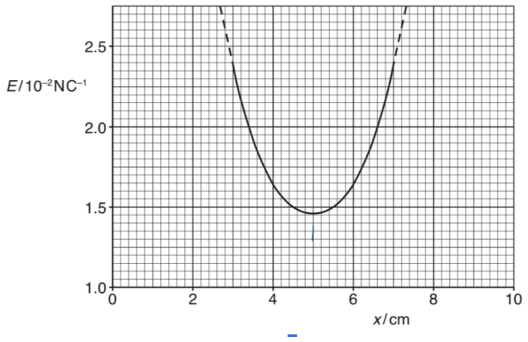
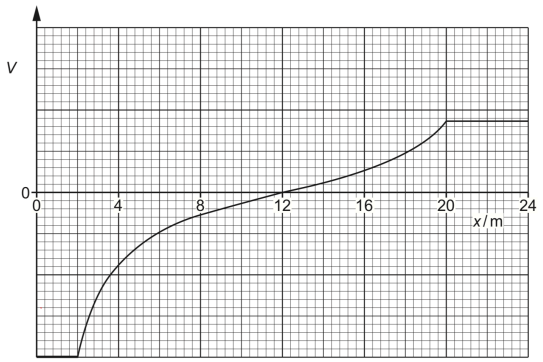
Fig. 4.1

The trolley is pulled to one side of its equilibrium position and then released so that it oscillates initially with simple harmonic motion. After a short time, the air blower is switched off. The variation with time *t* of the distance *L* of the trolley from block X is shown in Fig. 4.2.

Apart from the quantities, describe what may be deduced from the graph about the motion between time t = 0 and t =24 s.

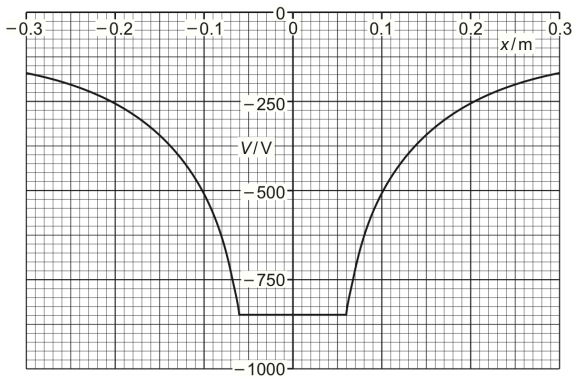
- Initial pull was to the right
- Distance from X to trolley at equilibrium is 20cm
- Period is 4.0 s
- Initial motion is undamped
- Motion becomes damped from 12s
- Damping is light
- Maximum speed at 1s, 3s,

C18 Electric fields

Electric field strength against x	Electric potential against x
	
• Charges A and B have same magnitude because minimum is at the midpoint • Charges A and B have opposite charge because field does not become zero/field does not change direction	• Charge A is negative charge with radius 2.0 m • Charge B is positive charge with radius 4.0m • Spheres carry opposite charges • Magnitude of charges on the spheres are equal and opposite

- The flat part is where the charge is inside the sphere
- The curve part is where the charge is outside the sphere

Radius = 0.060m



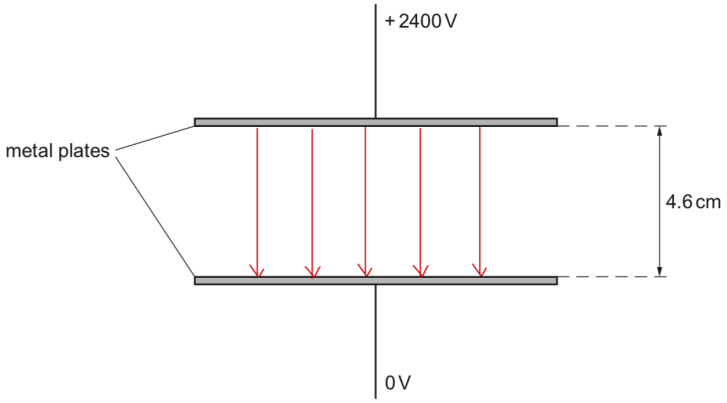


Fig. 4.1

The plates are separated by a distance of 4.6 cm. The plates are in a vacuum.

(i) On Fig. 4.1, draw five lines to represent the electric field in the region between the plates. [3]

What does the direction of field lines indicate in an electric field:
Direction of force on a positive charge

Why may a charge be considered a point charge:

- Field lines are radial/ normal to the surface
- Field lines appear to originate from the centre of the sphere

State the relationship between electric potential and electric field strength:

- Field strength is equivalent to the potential gradient but in the opposite direction at a point

Two spheres are identical; both spheres have the same charge.
Two spheres are now released simultaneously so that they are free to move.
Describe and explain the subsequent motion of the spheres.

- Force is repulsive so spheres move apart
- Force is in direction of motion so speed increases
- Potential energy converted to kinetic energy so speed increases
- Force decreases with distance so acceleration decreases
- Momentum is conserved at zero so velocities are always equal and opposite

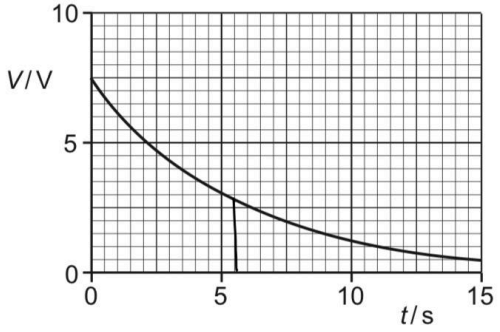
C19 Capacitance

State functions of capacitors in electric circuits
- Smoothing
- Timing // Time delay
- Block d.c.
- Energy storage for surge protection / temporary power supply
- Tuning (adjusting frequency)
- Oscillator

Explain how the plates could act as a capacitor [2]
- potential difference applied between the plates
- causes energy to be stored (between the plates)

State why capacitors store energy but not charge:
- Equal and opposite charges on the plates so no resultant charge
- Positive and negative charges separated so energy is stored

State how speed of charging/ discharging can be increased: หาก่อน



Explain the shape of the line in the graph representing the variation of V with t
- P.d. across resistor = p.d. Across capacitor
- Current in the resistor is proportional to p.d. across it
- Current causes capacitor to lose charge
- Charge on capacitor proportional to p.d. so p.d. decreases

Explain whether reducing separation of the plates results in an increase or decrease in energy stored in the capacitor
- oppositely charged plates attract, so energy stored decreases

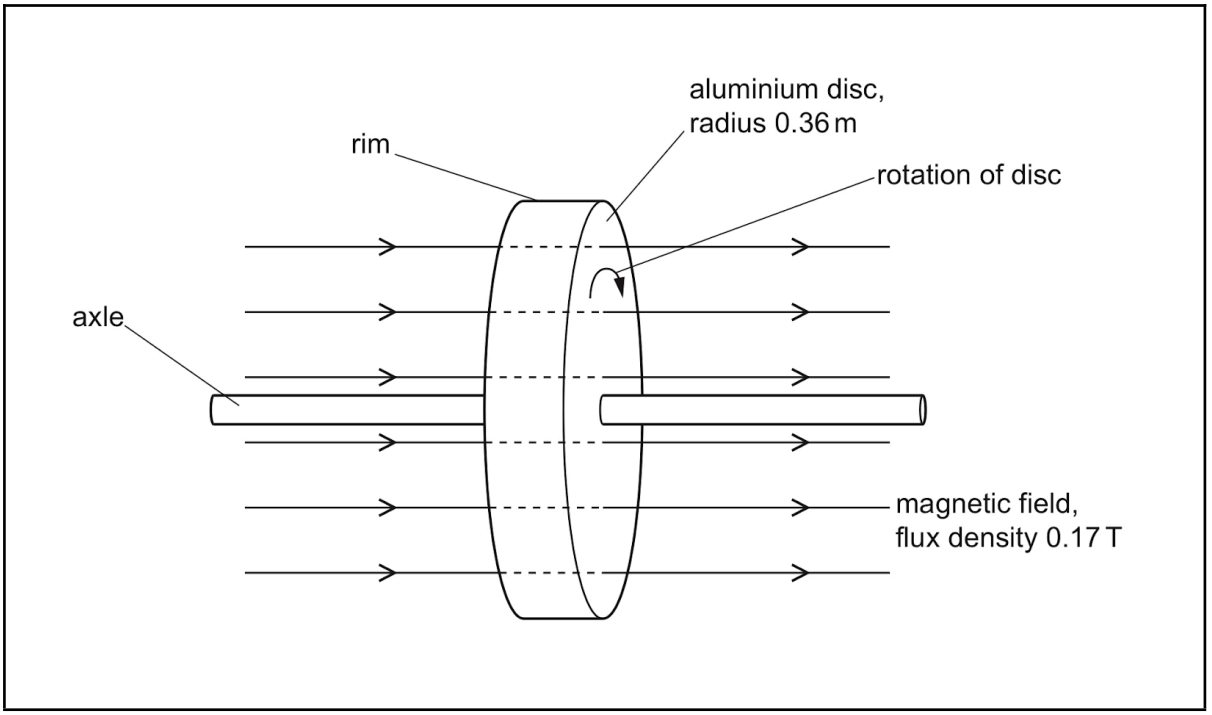
C20 Magnetic fields

State the **two** conditions that must be satisfied for a copper wire, placed in a magnetic field, to experience a magnetic force. [2]

$\rightarrow F = BILsin\theta$

1. Must be current in wire
2. Wire must be at non-zero angle to the magnetic field

Lenz's law Qs



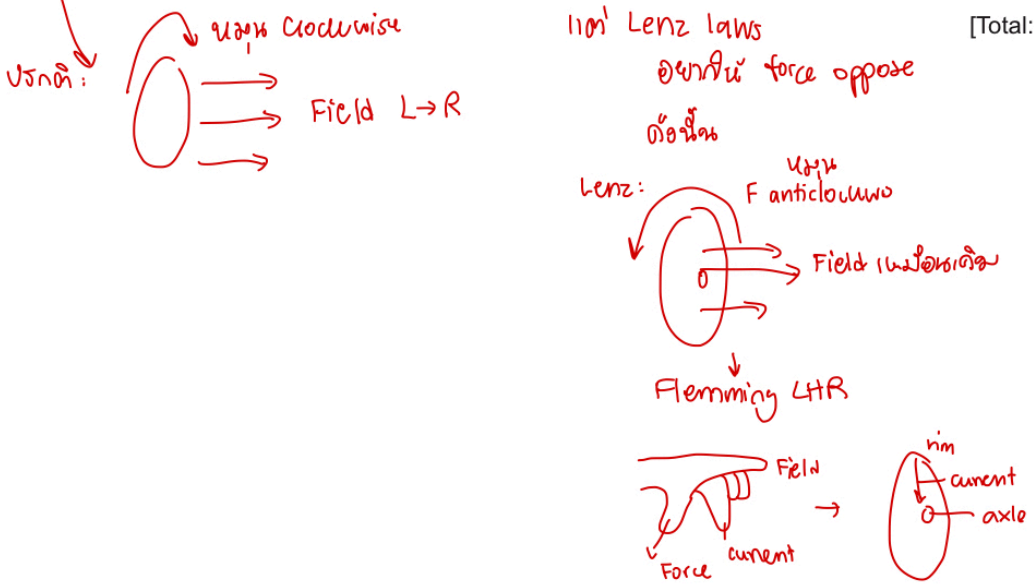
(c) The axle and the rim are connected into an external circuit that enables the energy of the rotation of the disc to be stored for future use. The direction of rotation is shown in Fig. 6.1.

Use Lenz's law of electromagnetic induction to determine whether the current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

- current in disc is perpendicular to magnetic field
- Force opposes rotation of the disc
- LHR indicates current is from rim to axle

[3]

[Total: 10]

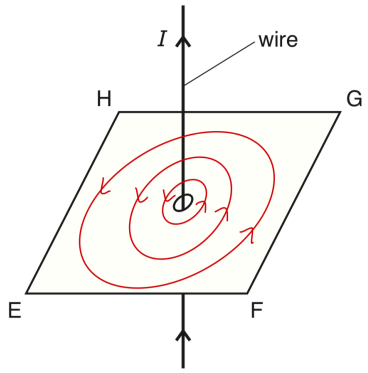


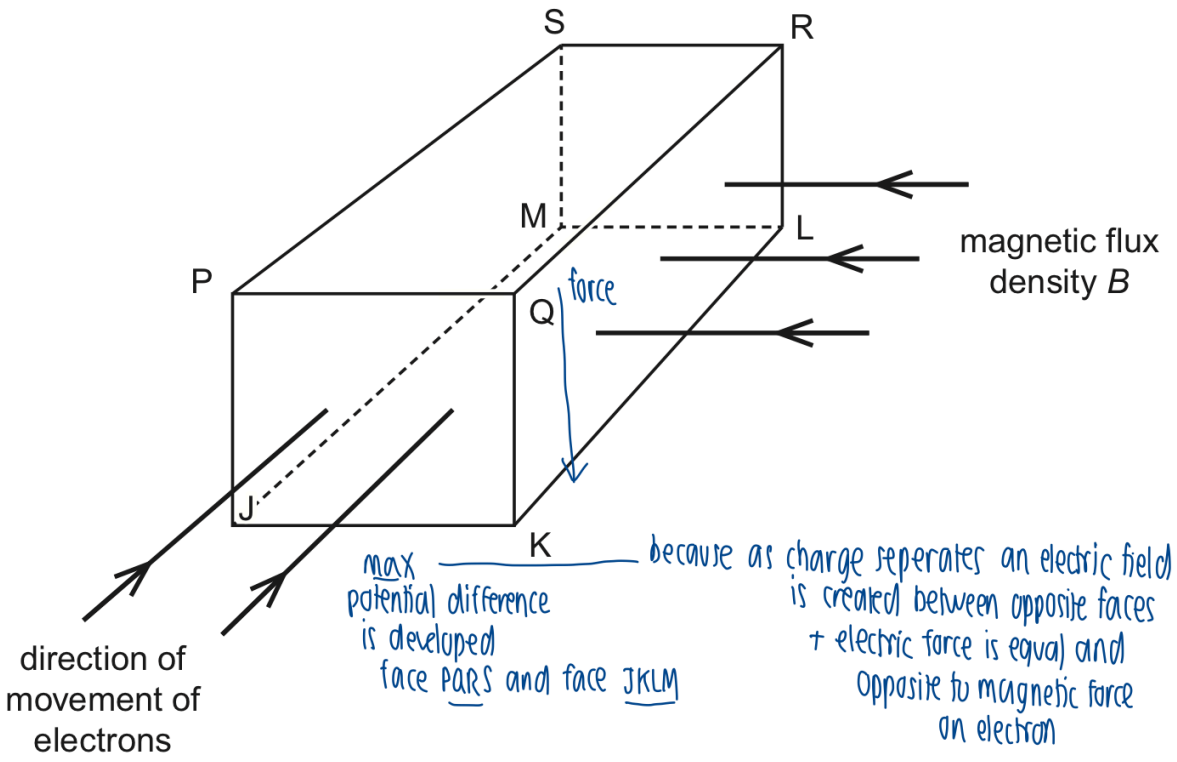
State and explain the effect on the coil of connecting the terminals together during the change in magnetic flux density

- Change in magnetic flux linkage induce emf in the wire
- Induced emf causes current to flow into the coil
- Flowing current in the coil generates a magnetic field
- Opposite side of coil force inward

Explain why the electrons follow a circular path when inside the region of the magnetic field. [3]

- Electric force is perpendicular to the velocity / direction of motion
- magnetic force **provides the centripetal force** or force perpendicular to motion causes circular motion
- magnitude of force (due to the magnetic field) is constant or no work done by force or the force does not change the speed

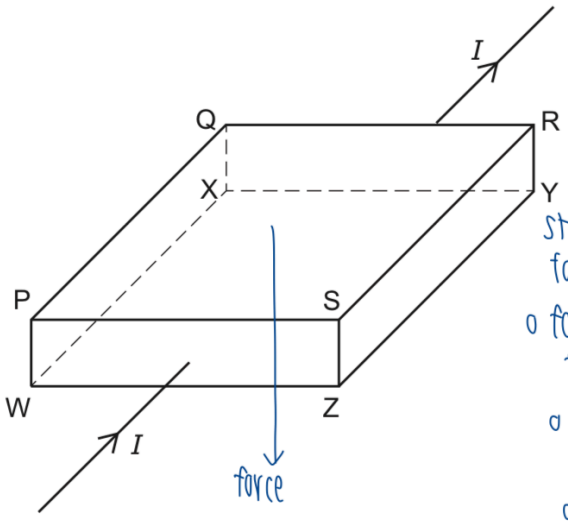




max potential difference is developed face PQRS and face JKLM

because as charge seperates an electric field is created between opposite faces + electric force is equal and opposite to magnetic force on electron

Fig. 6.1 shows a thin slice of semiconducting material used in a Hall probe.



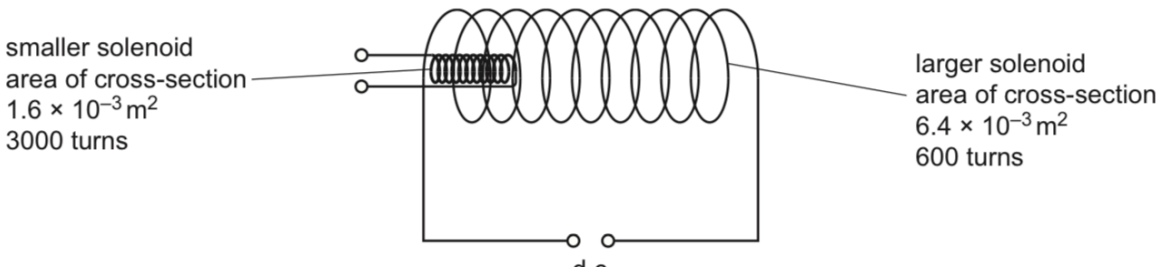
steady V_H is developed between faces PQXW and SRYZ :
- force on charge carriers is perpendicular to both B-field and current
- as charge carriers are deflected to one side, an E-field is set up
- F_E and F_B on charge carriers are equal in magnitude but in opposite directions

Fig. 6.1 (not to scale)

Current I passes through the slice in the direction shown.

The slice is placed in a uniform magnetic field of flux density B, so that two of its faces are perpendicular to the magnetic field.

6 A small solenoid of area of cross section $1.6 \times 10^{-3}\,m^2$ is placed inside a larger solenoid of area of cross-section $6.4 \times 10^{-3}\,m^2$, as shown in Fig. 6.1.



The terminals of the smaller solenoid are connected together. The smaller solenoid is then removed from inside the larger solenoid.
With reference to magnetic fields, explain why a force is needed to remove the smaller solenoid.[3]

- change of flux (linkage) in smaller solenoid induced e.m.f. in smaller solenoid
- (induced) current in smaller solenoid causes field around it
- the two fields (interact to) create an attractive force

Two long parallel current-carrying wires are placed near to each other in a vacuum. Explain why these wires exert a magnetic force on each other [3]

- current in wire creates magnetic field around wire
- each) wire sits in the magnetic field created by the other
- (for each wire,) current / wire is perpendicular to magnetic field (due to other wire), (so) experiences a (magnetic) force

Suggest why Hall probes are usually made using semiconductors rather than metals [2]

- Semiconductors have a smaller n
- Therefore V_H for semiconductors is larger so more easily measured

Suggest, with reference to the equation of Hall voltage, $V_H = B\frac{I}{ntq}$ why the slice of the material used in Hall probe is thin [2]

- $V_H \propto \frac{1}{t}$
- so t needs to be small for V_H to be large enough to measure

A loosely coiled metal spring is suspended from a fixed point, as shown in Fig. 9.1.

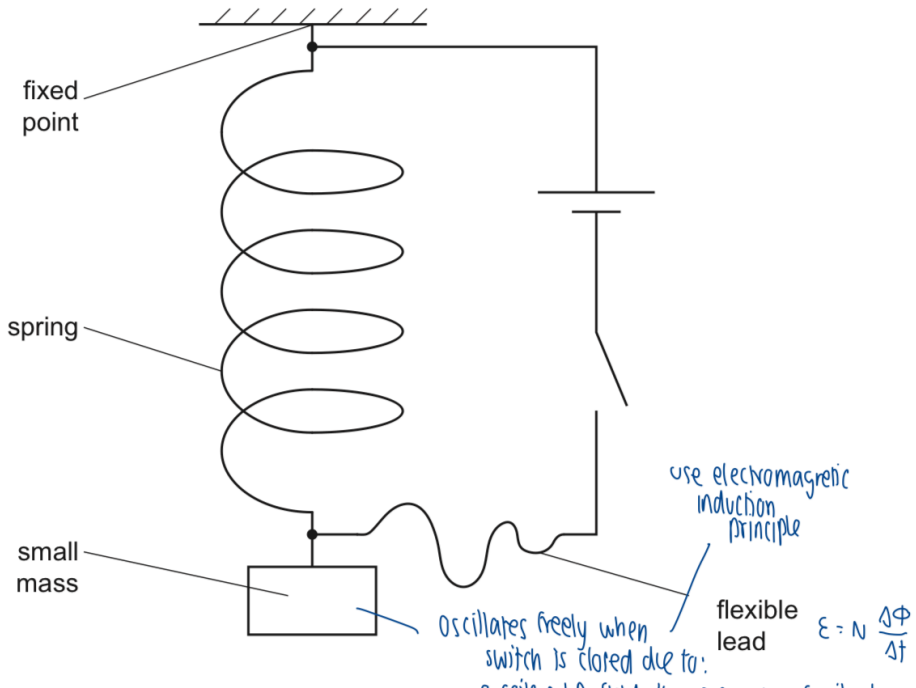


Fig. 9.1

Electrical connections are made to the ends of the spring by means of a flexible lead.

The length of the spring is measured before the switch is closed and then again after the switch is closed.

change in length of the spring because:
- B-field around each coil is circular
- current in coils interacts with B-field to exert force on coil
- force is normal to both coil and B-field (force parallel to axis of coil)
- force between coils are attractive so spring contracts

Electromagnetic induction questions [2-4]

- Conductor cuts through B-field lines OR direction of B-field through a coil changes
- This **causes change in magnetic flux** → which causes work to be done (this work is then transformed into electrical energy), inducing e.m.f

Why induced e.m.f is not constant [2]

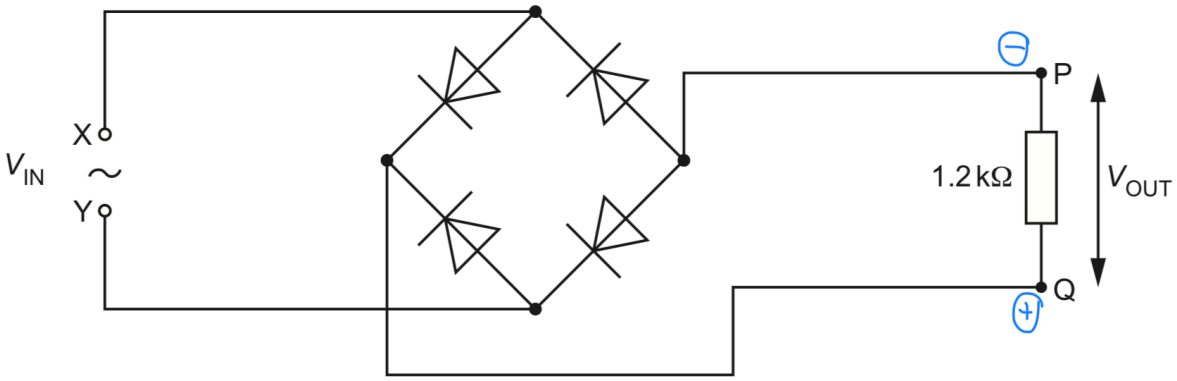
- Rate of change of magnetic flux is not constant
- Induced e.m.f is proportional to rate of change of magnetic flux

Describe velocity selection using electric and magnetic fields:

- Electric and magnetic fields are at a normal to each other
- Velocity of the particle is at a normal to both fields
- Force due to fields in opposite direction

- Forces are equal for particles at a particular speed

C21 Alternating currents

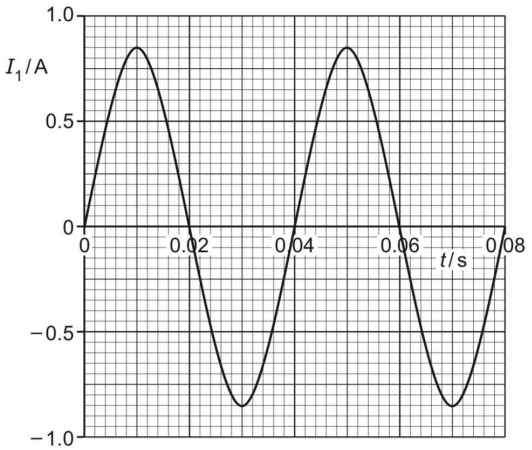


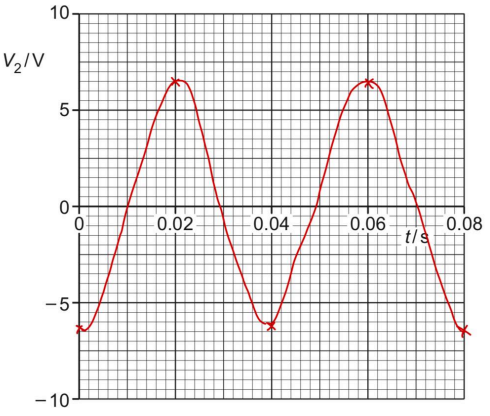
- Rectifier Bridge provides full-wave rectification
- connect capacitor parallel to output circuit/resistor to smooth

What is meant by the root mean square of AC:
The direct current that produces the same heating effect as the ac

What is meant by smoothing of AC:
Reduction in variation of output voltage/ current by adding a single capacitor connected in parallel to a load with resistance R

Relationship between V-t (voltage-time) and I-t (Current-time) graph





Use the laws of electromagnetic induction to explain the shape of this graph (on the right)

- Magnitude of V is <u>proportional to</u> the rate of change of magnetic flux
    - V is proportional to gradient of I-t curve

- V is maximum when gradient of I-t graph is steepest
- V = 0, when gradient of I-t graph is maximum
- V changes signs when sign of gradient of I-t curve change

C22 Quantum physics

Wave-Particle Duality

Photoelectric effect:

- Phenomenon of wave-particle duality where light behaves both as a waves and photons

- Each electron absorbs A photon - so frequency > threshold frequency will emit a photoelectron

change	Maximum speed/Ek max of electrons	Rate of emission of electrons
Increased intensity of incident radiation at constant frequency	no change - because each photon have same energy	Increase - because more number of photons emitted per unit time
Increased frequency of incident radiation at constant intensity	Increase - because greater photon energy (and same work function)	Decrease - because lower number of photons emitted per unit time

Evidence for the photoelectric effect + Briefly describe two phenomena associated with the photoelectric effect that **cannot be explained using a wave theory of light (i.e. can be explained by using photoelectric effect//photon model of light):**

- **Max energy depends on frequency**
- **Max energy does not depend on intensity**
- Rate of emission depends on intensity
- **Electrons are not emitted when frequency of photon < threshold frequency of material**
- **Emission of electrons are instantaneous**
- Increasing frequency at constant intensity decreases the rate of emission of electrons

Explain why most of the emitted electrons will have a speed lower than Vmax. [1]

- energy is required to bring electron to the surface

Explain how photoelectric effect provides evidence for the existence of photons

- electron needs a minimum energy to escape or electron emitted if energy in packet is enough
- energy must be absorbed in packets that are related to frequency
- intensity relates to number of packets (not to energy in packet)
- electron absorbs only a single whole packet

(b) Electromagnetic radiation of a varying frequency f and constant intensity I is used to illuminate a metal surface. At certain frequencies, electrons are emitted from the surface of the metal. The variation with f of the maximum kinetic energy E_{MAX} of the emitted electrons is shown in Fig. 7.1.

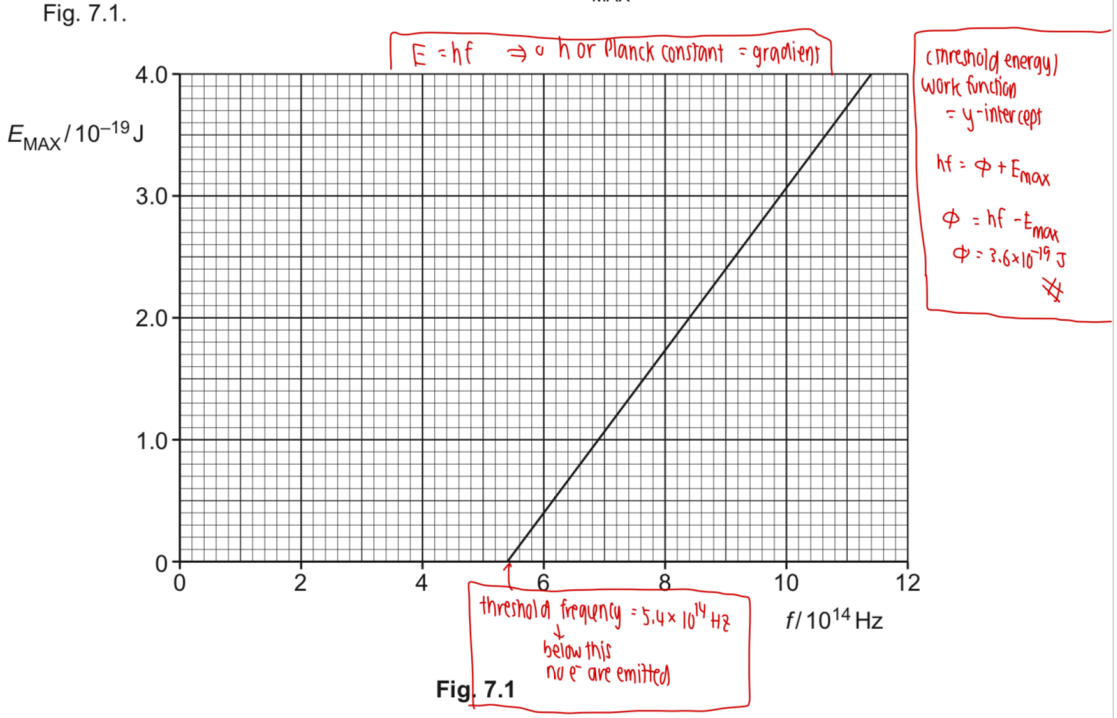
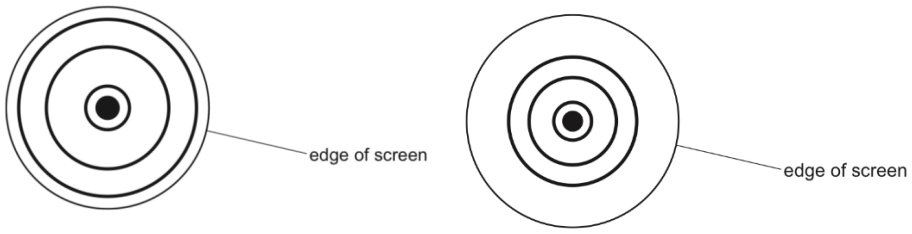


Fig. 7.1

Electron diffraction

Aka de Broglie wavelength

Electrons accelerate through a p.d. , pass through a thin crystal and are then incident on a fluorescent screen. The pattern is observed on the fluorescent screen below:



Thin crystal causes diffraction because:

- spacing between atoms ≈ wavelength of electron OR
- diameter of atom ≈ wavelength of electron

Phenomenon = electron diffraction

Nature of electrons = moving electrons can behave as wave (Beam spreads out indicating diffraction)

Lower accelerating voltage = Increase diameter of the rings

Higher accelerating voltage = Higher momentum = decrease diameter of the rings = decrease in $\lambda_{de\ Broglie}$

Line spectra

Emission spectra

Evidence for discrete energy levels

- Energy of photon has a corresponding to a single frequency
- Change in energy level emits a single photon
- Discrete frequency comes from discrete energy gaps
- Photon energy = difference in energy levels
- Discrete energy changes = discrete energy gaps

Absorption spectra

Production:

- A beam of white light pass through a cloud of cool gas
- Light of certain wavelengths are mission
    - *Continuous spectrum* contain all the colours
    - Dark-lines at certain wavelength
        - Why?: (ans in the absorption spectra block)

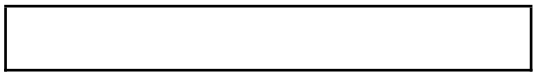
A beam of white light passes through a cloud of cool gas. The spectrum of the transmitted light is viewed and contains a number of dark lines

Explain why these dark lines occur

- Photon absorbed by electron and electron excited
- Photon energy equal to difference in (energy of two) energy levels
- Photon energy relates to a single wavelength / single frequency
- Electron de-excites and emits photon in all direction
  #when electrons excited, photons are emitted in all directions

Explain why there is a single frequency of electromagnetic radiation that corresponds to each of transitions in line spectra

- Transition photon with energy equal to difference energy between 2 levels
- Energy of radiation corresponds to energy of photon



Electrons are now *accelerated through a greater potential difference* between the cathode and anode

Suggest and explain the change in the pattern on the fluorescent screen
(use $\lambda=h/mv$)

- The diffraction pattern gets smaller
- Produce central blob and concentric rings
- Smaller diameter of diffraction pattern
    - Greater p.d. so electrons to have greater momentum
    - Greater momentum so decrease in de Broglie wavelength
    - Lower wavelength causes smaller diffraction angle
        - Smaller angle of intensity maxima for each order
        - Decrease in fringe spacing in diffraction pattern

8 Fig. 8.1 shows the lowest four energy levels of an electron in an isolated atom.

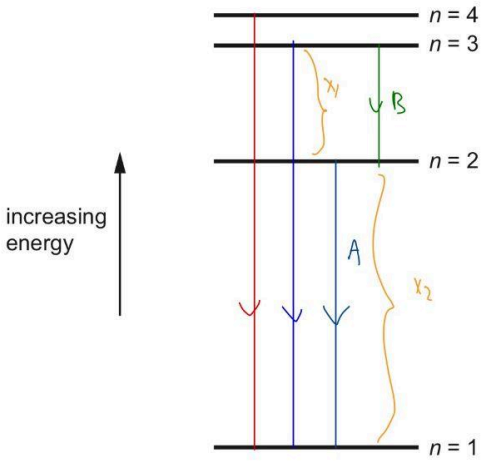


Fig. 8.1

Fig. 8.2 shows the lines in the emission spectrum of the atom that correspond to the transitions of the electron from $n = 3$ to $n = 1$ and from $n = 4$ to $n = 1$.

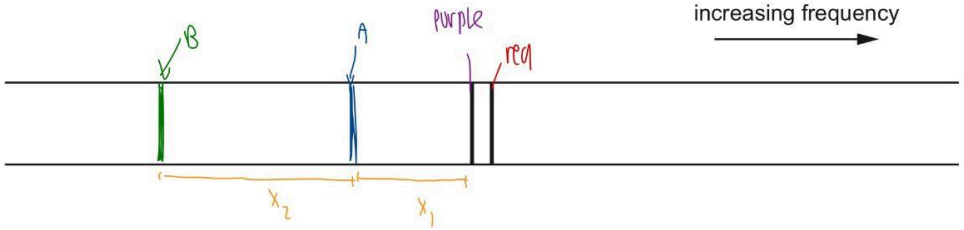


Fig. 8.2

(a) Explain, with reference to photons, why there is a single frequency of electromagnetic radiation that corresponds to each of these transitions.

- transition emits 1 photon with energy equal to the difference in energy between 2 levels (ΔE)
- frequency of radiation corresponds to energy of photon ($E = hf$)

..... [2]

(b) (i) On Fig. 8.2, draw a line that corresponds to the transition of the electron from $n = 2$ to $n = 1$. Label this line A. [2]

(ii) On Fig. 8.2, draw a line that corresponds to the transition of the electron from $n = 3$ to $n = 2$. Label this line B. [2]

The frequency of radiation represented by line A is f_A.
The frequency of radiation represented by line B is f_B.
The energy of the ground state ($n = 1$) is E_1.

Determine an expression, in terms of f_A, f_B, E_1 and the Planck constant h, for the energy E_3 of the energy level $n = 3$.

$E = hf$

$E_3 = E_1 + hf_A + hf_B$

$\therefore E_3 = E_1 + h(f_A + f_B)$

Suggest an explanation why people are not observed to diffract when they walk through a doorway [1]

- (de Broglie) wavelength (of human) negligible compared with width of doorway

Appearance of a visible line emission spectrum:
Mostly dark background with coloured lines

Evidence for discrete energy levels

- Energy of photon has a corresponding frequency
- Change in energy level emits a single photon
- Discrete frequency comes from discrete energy gaps
- Photon energy = difference in energy levels
- Discrete energy changes = discrete energy gaps

Energy level

Explain how the emission spectrum provides evidence for the existence of discrete energy levels for the electron in a hydrogen atom

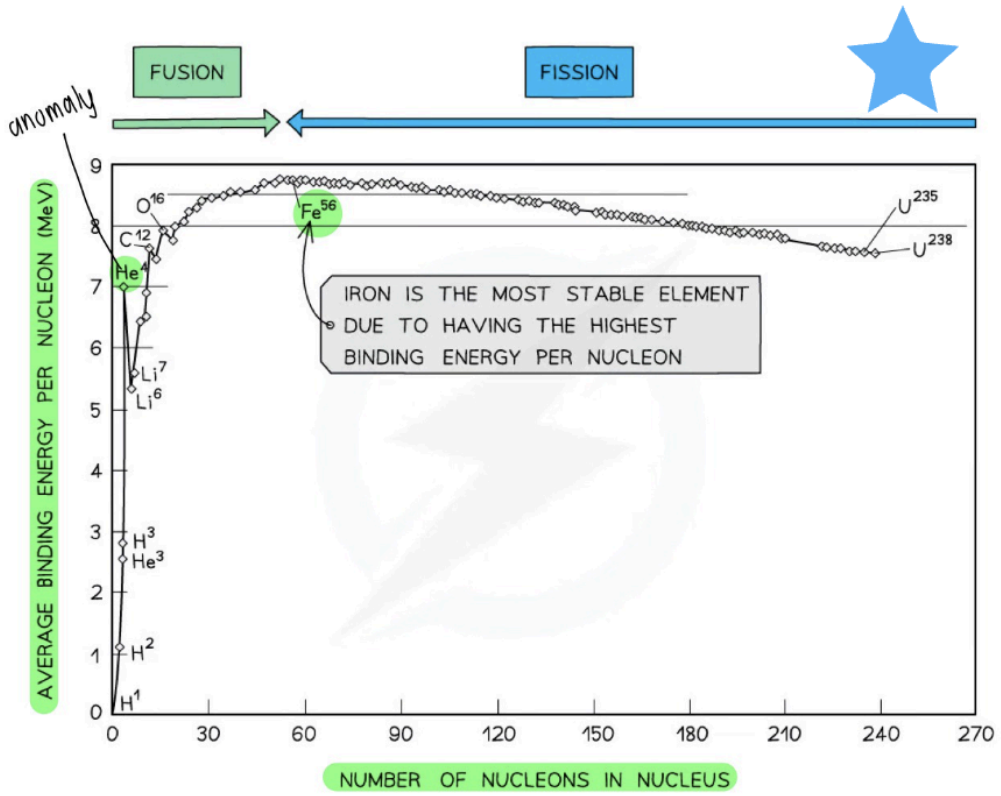
- Energy of photon has corresponding frequency
- Change in electron energy level emits a single photon
- Photon energy = different in energy levels
- Discrete frequencies must have come from discrete energy levels

Calculation of energy level

$E_1 - E_2 = hc/\lambda \rightarrow$ "*difference in energy level* is equal to *photon energy*"

- E_1 = higher energy level (less negative) , E_2 = lower energy level (more negative)

C23 Nuclear physics



Lower BEN(binding energy per nucleon) = Less stable and weak electrostatic forces

Explain, with reference to the random nature of radioactive decay, **why the activity of the substance decreases with time**

- Every (undecayed) nucleus has the same probability of decay
- Fewer (undecayed) nuclei remaining (with time), so fewer will decay in given time interval

Binding energy

$$^{15}_{6}C \rightarrow {}^{15}_{7}N + {}^{0}_{-1}\beta + {}^{0}_{0}\bar{\nu}.$$

State and explain how the mass of the products of the decay must compare with the mass of the carbon-15 nucleus

- For the reaction to occur, energy is released

- Energy release comes from fall in mass so total mass of products must be less than mass of carbon-15

Count rate of decay

State, with reasons, whether a radiation detector ***placed near*** to the sample of Carbon-11 indicates a measured ***count rate from the sample that is less than, the same or greater than the activity of sample***

- Less than
    - sample emits in all directions but detector only captures emissions in one direction
    - some emissions are absorbed (by air / detector window) before reaching detector
    - some emissions are scattered within the sample
    - simultaneous arrival of multiple particles only registers once
    - some particles may reach detector but not cause ionisation
    - Self-absorption within the source
    - Dead-time / inefficient of detector

Half-life

The activity of the sample after a time of 1.0 half lives is found to be greater than the expected 2.6MBq.

Suggest a possible reason for this. [1]

- daughter nucleus is unstable

C24 Medical physics

$$\alpha = \frac{I_R}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

$\alpha = 0$ $Z_2 \simeq Z_1 \rightarrow$ no reflection

$\alpha < 1$, $(Z_2 - Z_1)^2$ small = mostly transmission

$\alpha > 1$ $(Z_2 - Z_1)^2$ large = mostly reflection

Ultrasound

Explain the principles of the **generation** of ultrasound waves used in medical diagnosis [4]

- **Alternating p.d applied across piezoelectric crystal (which made of quartz), causing crystal to vibrate [2]**
- **Alternating p.d frequency matches natural frequency of crystal, producing resonance**
- **Due to natural frequency of crystal is in ultrasound range(>20000 Hz), it produces ultrasound**

Explain the principles of the **detection** of ultrasound waves used in medical diagnosis [3]

- piezo-electric crystal/transducer (emits a pulses of ultrasound)
- ultrasound incident on quartz crystal, causing crystal vibrate / resonate

- vibration produces (alternating) e.m.f. / p.d. across crystal

Explain the principles of the **use** of ultrasound waves used in medical diagnosis [6]

- Transducer(piezoelectric crystal) emits a pulses of ultrasound
- Pulse of ultrasound reflected at boundaries
- Reflected pulses detected by transducer
- Reflected signal processed and display

- Gel can be used as Z_{gel} similar to Z_{skin} so little(almost no) ultrasound is reflected
- Depth of boundary = time delay between transmission and receipt of pulse
- Nature of boundary = intensity of reflected pulse
    - Intensity of reflection depends upon acoustic impedance of two media at boundary

Explain why ultrasound used in medical diagnosis is emitted in pulses [2]

- allows the reflected signal to be distinguished from the emitted signal
- detection occurs in the time between emitted pulses
- (reflection of ultrasound) detected by same probe / transducer / crystal
- cannot emit and detect at same time (hence pulses)

The alternating voltage is now applied to a piezoelectric crystal in air
Explain what happens to the air surrounding the crystal [1]

- The crystal vibrates
- Which makes air to vibrate at the same frequency as it is in ultrasound range

Acoustic impedance

Why gel is applied to the surface of the skin during an ultrasound scan [2]

- without the gel most of the incident ultrasound is reflected from skin
- Z_{gel} similar to Z_{skin} ,so with gel, little(almost no) ultrasound is reflected//almost all of the incident ultrasound is transmitted into the body

By reference to specific acoustic impedance, explain why there is very little transmission of ultrasound waves from air to skin.

- Specific acoustic impedances of air and skin are very different
- Intensity reflection coefficient depends on difference between acoustic impedance
- Most ultrasound reflected so little transmission

	Ultrasound	X-rays
Method of production	vibrating quartz crystal	electrons hitting metal target
Detected wave	reflected	transmitted

X-rays

How X-rays are produced for use in medical diagnosis [3]

- Electrons are accelerated (by an applied p.d.)
- And electrons hit the (metal) target
- X-rays are produced when electron rapidly **decelerate** and transfer E_k into photons of EM radiation - photon energy depends on (magnitude of) deceleration
- (Range of decelerations causes continuous spectrum of energies of X-ray photons)

Explain why an aluminium filter may be placed in the X-ray beam when producing an X-ray image of a patient [3]

- (aluminium filter) absorbs (most) **low** energy X-rays
- X-ray beam contains many wavelengths
- so low energy X-rays are not absorbed in the body
- low energy X-rays can can cause harm but do not contribute to the image

Sharpness: ease at which edges can be distinguished
Contrast: difference in blackening between the darkest and lightest areas

Increase Hardness of x-ray = increase contrast

Increase hardness: increase accelerating pd
Increase intensity: increase current

Suggest two causes of lack of sharpness of an X-ray image [2]

- scattering of X-ray beam / no lead grid
- lack of collimation of beam / aperture large
- beam p.d. low / photon energy low / X-ray soft
- anode area large

	Linear attenuation coefficient, μ / cm^{-1}
bone	3.0
blood	0.23
muscle	0.22

Two X-ray images:

1. Equal thicknesses of bone and muscle
2. Equal thicknesses of blood and muscle

Explain why one of these images has good contrast, but the other does not [2]

- μ is very different for bone and muscle
- … so very different amounts of X-rays are absorbed // very different intensities transmitted so good contrast

OR

- μ is similar for blood and muscle
- similar amounts of X-rays absorbed so poor contrast // similar intensities transmitted so poor contrast

CT Scan

*****Outline briefly the principles of computed tomography (CT scanning). [5]**

- X-rays are used
- To produce a 3D image of an internal structure
- (Section is scanned)
- By first combining **multiple** X-ray images taken in the same section from **different angles** to obtain a 2D image of the section
- Then repeating this process along an axis and combining 2D images of multiple sections

State the purpose of CT scanning [1]

- to produce a 3-dimensional image of structure/body

Suggest an advantage and a disadvantage of CT scanning compared with single X-ray imaging for diagnosis

- Advantages: Produces 3D image
- Disadvantages: Much greater exposure to radiation

PET Scan

PET scan in nutshell

1) **Annihilation**

Radioactive tracer → Beta decay → Emit positrons → Positron annihilates with e^-

2) **Gamma photons production**

Two gamma photons are produced in opposite direction, because masses of antiparticles are converted to energy

Describe how gamma radiation is formed from the two particles in positronium. [2]

- 2 points, 1 mark:
  - Electron and positron interact
  - Positron is antiparticle of election
  - Annihilation occurs
- Mass of electron and positron converted into photon energy
- Energy, mass and momentum during annihilation are conserved

Explain how the gamma photons are used to produce an image [4]

- two gamma photons travel in opposite directions
- gamma photons detected (outside body / by detectors)
- gamma photons arrive (at detector) at different times
- determine location of production (of gamma)
- image of tracer concentration in tissue produced

Explain how the radioactive decay of fluorine-18 results in the emission from the body of the gamma-ray photons that are detected during a PET scan

- Positron and electron are interacting with each other
- Annihilation occurs
- Mass of particles become energy of photons

Positrons are not naturally present in the body
Explain how positrons come to be present in the body during PET scanning

- Introduction of tracer into the body
- Containing a beta+ emitter

C25 Astronomy and cosmology

Expanding universe

Emission spectra

Observed wavelength increases:

- Light is redshifted
- Star in galaxy is moving away from the Earth
- Universe is expanding
- Wavelength increases by doppler effect

1) **How emission spectra shows that universe is expanding**
    - Wavelength of spectral lines are greater than their known values
    - Redshift shows stars in distant galaxies moving away from Earth

2) **How expanding universe lead to Big Bang theory**
    - All parts of universe moving **away** from each other (receding from each other)
        - (Space between Earth and galaxies must be expanding)
    - **More distant** are moving away **faster** (More red-shift)
    - Matters must be very close / very dense in the past

Red-shift

1) **How scientist determine light from distant star has undergone redshift**
    - Examining lines in spectrum of light from star
    - Compare it with known spectrum

Calculate Hubble constant

(Large wavelength - small wavelength)/ large wavelength

$$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$

Then use, $V=H_0d$

Wein's displacement law

Explain how surface temperature of a distant star may be determined from the wavelength spectrum of light from the star

- Wavelength of peak intensity determined from spectrum of star
- Wavelength of peak intensity from object of known temperature is determined
- Wein's displacement law used ($\lambda_{max} \propto 1/T$)