IDEAL GASES (30 Jan – 3 Feb)

1. initial pressure, $P = (A+h)\rho g$
   final pressure, $P' = (A+h/2)\rho g$

$$\frac{V'}{V} = \frac{P}{P'} = \frac{A+h}{A+h/2} = \frac{A+h}{\frac{1}{2}(2A+h)}$$

2. pV=NkT
3. translational KE = 3/2 kT (for an ideal gas molecule, independent of mass)

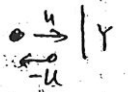
4. (a) It is a perfectly elastic collision.

(b) (i) Time taken between the collision,

$$T = \frac{\text{Distance travelled}}{\text{speed}} = \frac{2l}{u}$$

Frequency, $f = \frac{1}{T} = \frac{u}{2l}$

(ii) Change of momentum of 1 molecule



$= -mu - mu = -2mu$

Total rate of change of momentum of 1 molecule

= Total no. of collision per sec × change of momentum

$= f \times (-2mu)$

$= -2muf$

Mean force acting on molecule $= -2muf$

Mean force exerted on face Y $= 2muf$

(iii) Mean pressure exerted on face Y

$$= \frac{\text{Mean force on } Y}{\text{Area}}$$

$$= \frac{2muf}{l^2} = \frac{2mu}{l^2}\left(\frac{u}{2l}\right) = \frac{mu^2}{V} \quad \text{where } V = l^3$$

(c) 'C_{rms}' is the root mean square speed of the molecules which is the square root of the average of the square of the speeds of the molecules.

(d) $P = \frac{1}{3}\rho C_{rms}^2$

$= \frac{1}{3}\frac{M}{V} C_{rms}^2$ where M = mass of gas.

From the ideal gas eqn: $PV = NKT$

$PV = NKT$

$\frac{1}{3} M C_{rms}^2 = NKT$

$M C_{rms}^2 = 3NKT$

Mean translational K.E of the gas

$= \frac{1}{2} M C_{rms}^2 = \frac{3}{2} NKT$

5(a) In an ideal gas, PV=nRT. Since V=const, P/T=const for a fixed mass of gas. From the graph, a straight line passes through the origin implies that $P \propto T$. Hence, the gas behaves like an ideal gas.

(b) (i) PV=nRT; $(124.5 \times 10^{-3})(1.0 \times 10^{-3}) = n(8.31)(300)$; $n = 0.05$
(ii) n = M/Mr; $M = nMr = 2.0 \times 10^{-4}$ kg

(c) (i) W = 0, vol is fixed.
(ii) inc in U = $3/2\ nR\Delta T = 3/2\ (0.05)(500 - 300) = 125$J
(iii) $\Delta U = Q + W$; $125 = Q + 0$; $Q = 125$J

(d) Total mass of hydrogen + helium in mixture = 2.0×10^{-4} kg
Mass of hydrogen gas in mixture = 1.0×10^{-4} kg (since equal masses of each gas)
No. of moles of hydrogen = M/Mr = $(1.0 \times 10^{-4}) / (2.0 \times 10^{-3}) = 0.050$ mol
No of moles of helium = M/Mr = $(1.0 \times 10^{-4}) / (4.0 \times 10^{-3}) = 0.025$ mol
Total no. of moles of gas = 0.050 + 0.025 = 0.075
PV = nRT; $P(1.0 \times 10^{-3}) = (0.075)(8.31)(300)$; $P = 1.87 \times 10^5$ Pa

(f) gradient of graph = nR/V, where R/V = const.
as n increases, gradient increases. Hence, graph is steeper.

THERMODYNAMICS (4 – 7 Feb)

1. $P_S = P_{water} + P_{heat\ loss}$

$2500 = \frac{mc\Delta\theta}{t} + P_{heat\ loss}$

$P_{heat\ loss} = 2500 - \frac{(1)(4000)(80)}{200}$

$= 900\ W = 0.90\ kW.$ (C)

2. cooling - heat released, lost to surrounding (C)

3. No heat loss ⇒ adiabatic (D)

4. Heat at constant rate ⇒ const. P.

(i) Heat supplied to raise temp from 53→63K

$= mc\Delta\theta = Pt.$

$\therefore m(1610)(10) = P(160)$

$\Rightarrow P = 100m$ W.

To melt solid, heat required = mL

$Pt = mL$

$100m(240) = mL$

$\Rightarrow L = 24000$

$= 2.4 \times 10^4\ J\,kg^{-1}$

(ii) Energy supplied to raise temp of liquid

$= mc\Delta\theta = Pt$

$c_l = \frac{(100m)(200)}{m(73-63)}$

$= 2000\ J\,kg^{-1}K^{-1}$

5.

An adiabatic change is a change where no heat flows into or out of the system.

For an **ideal gas**, the internal energy is the ***total kinetic energy*** of the gas molecules, while for a **real gas**, the internal energy is the ***sum of the kinetic and potential energy*** of the gas molecules in a system.

The ***intermolecular forces*** between molecules in a real gas gives rise to the potential energy of the molecules, while in an ideal gas, these forces do not exist, hence there is no potential energy.

The specific latent heat of vaporization is larger than the specific latent heat of fusion because:

1) more energy is required to increase the average separation between the molecules (i.e. increase in the potential energy of the system)
2) more energy is required to do work to expand the gas against the molecules in the atmosphere.

i) According to 1st Law of Thermodynamics:

$\Delta U = Q + W$, where W = work done ON the system.

Isothermal heating -> $\Delta U = 0$

Hence: $Q = -W$

(i.e. Heat supplied to the system = Work done BY the system).

Hence, **gas expands**.

ii) Final pressure for each change:

i) Compressed isothermally to half its initial volume;

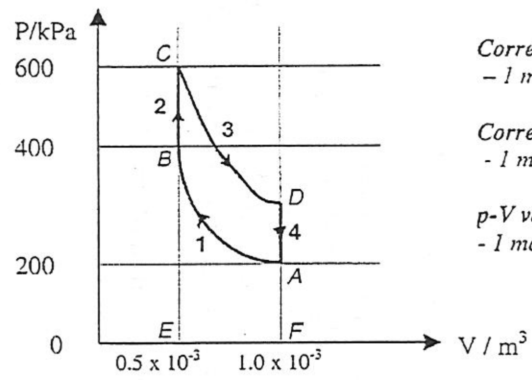
Since T = constant, $P_1V_1 = P_2V_2$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right) = (200x10^3)(2) = 400kPa$$

ii) Heated at constant volume to 450 K

Constant volume, $\frac{P_2}{P_3} = \frac{T_2}{T_3}$

$$P_3 = P_2\left(\frac{T_3}{T_2}\right) = (400x10^3)\left(\frac{450}{300}\right) = 600kPa$$



Correct shape
- 1 mark

Correctly labeled process change 1, 2, 3 & 4
- 1 mark

p-V values for process 1 and 2
- 1 mark

iii) Thermal efficiency =

$$\frac{(\text{work done by the gas}) - (\text{work done on the gas})}{\text{work done by the gas}}$$

Work done BY the gas = area EBCDAF
Work done ON the gas = area EBAF

OR

Thermal efficiency = $\frac{area(ABCD)}{area(EBCDAF)}$

WAVE (8 – 11 Feb)

1. Refer to notes.

2. Intensity , $I = ka^2$ = Power/Area $= P/4\pi r^2$

   Hence a α 1/r

   $a = k\,(1/r)$

   $y = m\,x$

Hence it's a straight line passing through the origin.

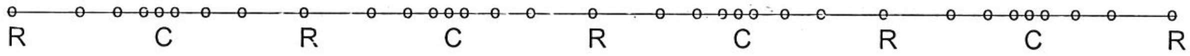
3. $f = 1/T = 1/0.8$

   phase diff = time delay / period x $2\pi = 0.2 / 0/8 \times 2\pi = \pi/2$

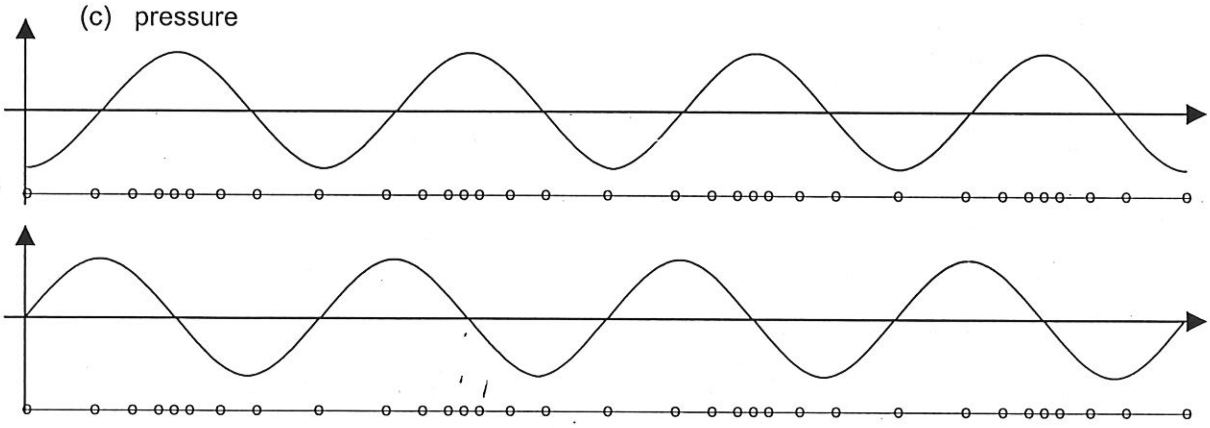
4. The power of the light produced = 10% of 100 = 10W
   The power is assumed to spread uniformly in all directions, therefore the power is distributed over an area of $4\pi\, r^2$, which is $5.0 \times 10^{13}\,cm^2$.
   So the power entering the eye is $0.5 \times 10 / 5.0 \times 10^{13} = 1 \times 10^{-13}$W (this is a very small amount of power and it is amazing that our eyes are so sensitive!!!)

5(a) The wavelength is longitudinal as the direction of travel of the wave is parallel to the direction of vibration of the atoms.

(b) Figure 2



(c) pressure



(d) $v = f\lambda = \lambda / T$. The wave speed is a constant while the atoms oscillates with SHM and hence their speeds is constantly changing periodically.

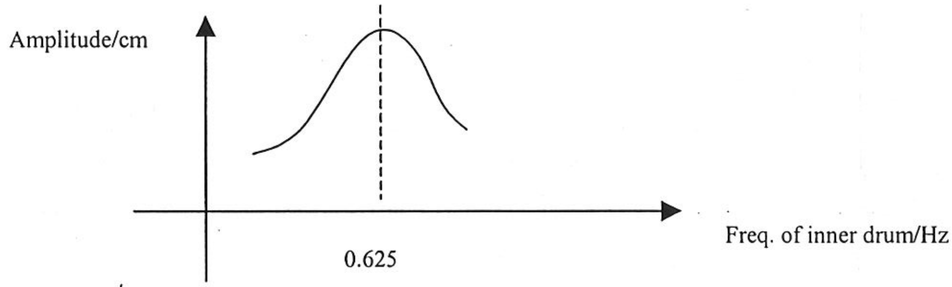
OSCILLATIONS (12 – 14 Feb)

1. Period , $T = 0.2s \times 2 = 0.4$ s
   $r = 1.0$ m
   Speed, $v = r\omega = r\,(2\pi f)$
   $= 1.0 \times 2\pi \times (1/0.4)$
   $= 1.6\ ms^{-1}$

2. Displacement $X = X_o \cos \omega t$ (Given that displacement starts from max. displacement when t = 0)
Velocity, $V = -X_o\omega \sin \omega t$ (Graph X)
Acceleration $= -\ X_o\omega^2 \cos \omega t$ (Graph W)

3. Period, $T = 0.4$ s
Angular frequency, $\omega = 2\pi f = 2\pi\,(1/0.4) = 15.7\ rads^{-1}$

4(a)(i)
When the system oscillates freely after being displaced from its equilibrium position, the number of cycles its makes per unit time is known as the natural frequency.
(ii) From $T = 2\pi\sqrt{(M/K)}$, $K = 4\,(\pi^2/T^2)M$
$= 4\,(\pi^2/1.6^2)\,40 = 6.2 \times 10^2\ Nm^{-1}$
(b)(i) The rotating drum exerts a periodic force on the system. As a result, the system undergoes forced oscillation. Its amplitude reaches a maximum when the periodic force exerted by inner drum is 1.6 s, the natural period of the system.
(ii) No. of revolution per second = 1/1.6 = 0.625 Hz
(iii)

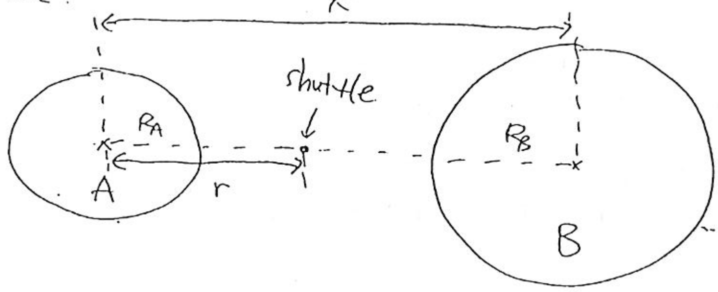


(iv) Since $T \propto \sqrt{M}$, without the concrete, the natural period is shorter. Hence, natural frequency is increased and this may lead to unwanted resonant effects when the drums are spinning at high speeds during the spin part.

5(a) The amplitude of oscillation decreases with time.
(b)(i) $T/4 = 0.2 \times 10^{-3}$ s
$f = 1/T = 1250$ Hz
(ii) $a_{max} = \omega^2(\text{amplitude})$
$= [2\pi\,(1250)]^2\,(6.0 \times 10^{-3})$
$= 3.7 \times 10^5\ ms^{-2}$
(c) (i) f decreases. No change in amplitude. Graph shifts to left.
(ii) Sharper response. Larger peak. Graph shifts to right.
For both graph C and D, the graph starts at the same point at f = 0.
(d) Natural frequency of oscillation of H atom in HCl molecule.
$f = c/\lambda = 3.0 \times 10^8 / 3.5 \times 10^{-6} = 8.57 \times 10^{13}$ Hz
$f = (1/2\pi)\sqrt{(K/M)}$
$K = 4\pi^2 f^2 M$
$= 4\pi^2 (8.57 \times 10^{13})^2\,(1.7 \times 10^{-27}) = 493\ Nm^{-1}$

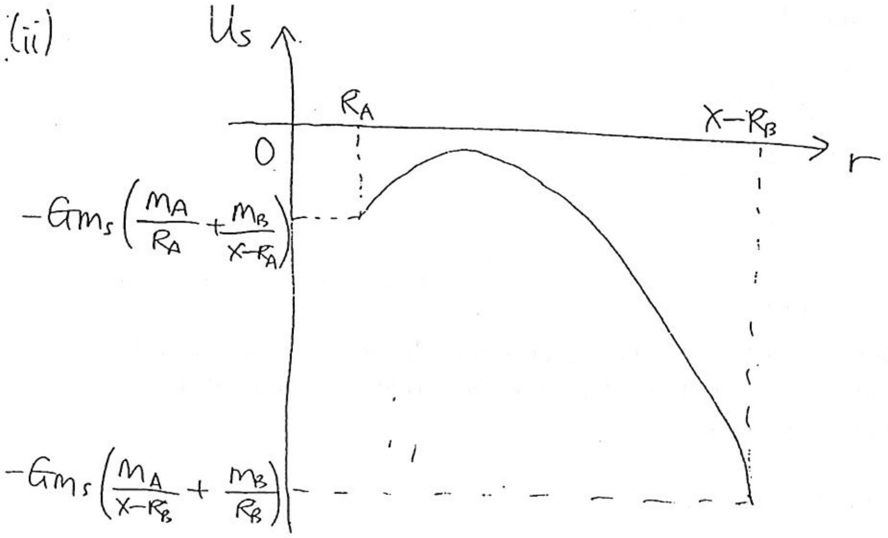
6. (a) -1.77×10^9 J (1) of work is done by external agent moving 1kg of mass from infinity to a point on Jupiter's surface (1)

(b)



(i) $$U_s = -\frac{Gm_A m_s}{r} - \frac{Gm_B m_s}{X-r}$$
$$= -Gm_s\left(\frac{m_A}{r} + \frac{m_B}{X-r}\right) \quad (1)$$

(ii)



shape of graph showing clearly maximum for U_s (1)
asymmetry of graph (1)
labels on axes (1)

(iii) F_s is gradient of graph of U_s against r (1)
$\Rightarrow$ F_s decreases as shuttle leaves surface of planet A to zero at some point in its trajectory and increases from that point till it reaches surface of planet B. (1)

6. (c)(i) graitational force by Earth on S_1 = centripetal force required to keep S_1 in circular orbit around Earth

$$\Rightarrow \frac{GMm}{a^2} = \frac{mv^2}{a} \text{ (1)} \Rightarrow E_k \text{ of } S_1 = \frac{1}{2}mv^2 = \frac{GMm}{2a} \text{ (1)}$$

$$= -\frac{1}{2}U_{S_1}, \text{ where } U_{S_1} = -\frac{GMm}{a} \text{ (1)}$$

(ii) $$E_{S_1} = E_{k,S_1} + U_{S_1} = -\frac{GMm}{2a} \text{ (1)}$$

(iii) 1. At A, $$E_{S_2} = E_{S_1} = -\frac{GMm}{2a}$$

$$\Rightarrow \frac{1}{2}(2m)v_A^2 - \frac{GM(2m)}{a} = -\frac{GMm}{2a} \text{ (1)}$$

$$\Rightarrow v_A = \sqrt{\frac{3GM}{2a}} \text{ (1)}$$

2. At C, $$\frac{1}{2}(2m)v_C^2 - \frac{GM(2m)}{2a - \frac{a}{2}} = -\frac{GMm}{2a} \text{ (1)}$$

$$\Rightarrow v_C = \sqrt{\frac{5GM}{6a}} \text{ (1)}$$

7.

(i) Find the potential difference between the two plates.

$E = \frac{V}{d}$, $V = Ed = (5.0\times10^{3})(1.0\times10^{-2})$ [1]

$= 50\ V$

(ii) For an electron which just enters the field as shown in the figure, draw a diagram to show the electrostatic force acting on the electron and the direction of the electric field. Determine the magnitude of this force. Hence find the acceleration of this electron.

Electric force, $F_E = qE$ [3]

$= (1.6\times10^{-19})(5.0\times10^{3})$

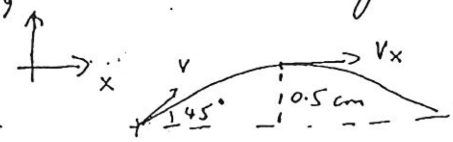
$= 8.0\times10^{-16}\ N$

Acceleration of e^-, $a = \frac{F_E}{m_e}$

$= \frac{8.0\times10^{-16}}{9.1\times10^{-31}} = 8.78\times10^{14}\ ms^{-1}$

7. (iii) What maximum speed can this electron have to avoid striking the upper plate? Ignore fringing of the field. [3]

To avoid striking the plate, the maximum height is 0.5 cm, ie 0.005 m



$V_y = 0$

At max. height, $V_y = 0$

$V_y^2 = U_y^2 + 2as$

$U_y^2 = 2(8.78 \times 10^{14})(0.005)$

$U_y = 2.963 \times 10^6$

V: maximum speed to avoid hitting the plate.

$U_y = V \sin 45^\circ$

$\therefore V = \frac{U_y}{\sin 45^\circ} = \frac{2.963 \times 10^6}{\sin 45^\circ}$

$= 4.191 \times 10^6 \approx 4.19 \times 10^6 \, ms^{-1}$

8. (a) (i) $q = 3.2 \times 10^{-19} C$

$m = 6.7 \times 10^{-27}$ kg

$V = 3.0 \times 10^7 \, ms^{-1}$

$\mu = 50 \times 10^{-6} T$

force on a charge due to a magnetic field, $F_B = Bqv \sin\theta$ $(\theta = 90^\circ)$

$= Bqv$

$= (50 \times 10^{-6})(3.2 \times 10^{-19})(3.0 \times 10^7)$

$= \underline{4.8 \times 10^{-16} N}$

(ii) F_B: Centripetal force on the charge

$4.8 \times 10^{-16} = \frac{mv^2}{r}$

$r = \frac{6.7 \times 10^{-27} \times (3.0 \times 10^7)^2}{4.8 \times 10^{-16}}$

$= 12.56$ km

$\approx \underline{12.6 \text{ km}}$

8. b) $F = Bqv = \frac{mv^2}{r}$

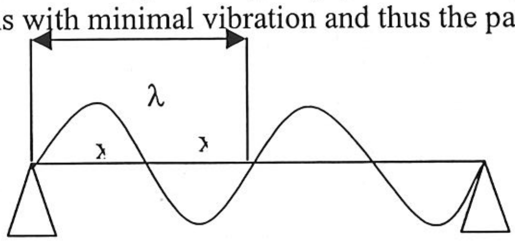
V: speed of particle

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

when v decreases due to atmosphere, while m, B, q are constant, the radius of the path will decrease.

SUPERPOSITION (22 – 28 Feb)

1. When the wavelength is 2x, the papers are sitting at the nodes as shown below. Nodes are positions with minimal vibration and thus the papers will remain on the wire



2. The transparent plastic introduced a path difference of one and a quarter of a wavelength. Thus the central maximum is also shifted one and a quarter of a wave away to the right.

3. Diffraction grating , $d\sin\theta = n\lambda$

$\sin\theta = n\lambda/d$

When d changes to d/2 , the new angle of the orders are given by $\sin\theta = n\lambda/(d/2) = 2n\lambda/d$
Hence all the angles of the diffraction order will be increased.

4(a) P & Q have a phase difference of π or 180°

(b)

- Along XY, path difference of signal = 0
- Phase difference of signals = π
- Destructive interference occurs.

(c)
Twice amplitude => constructive interference
Either
Path difference = $\lambda/2$ = 150 m
Hence ship moved $\lambda/4$ = 75 m
OR
Along PQ, stationary wave is set up.
Move $\lambda/4$ = 75 m from node to antinode.
(d) From (C), distance between successive dips = 150 m
No. of dips = 30,000/150 = 200

5 (a) (i) $d\sin\theta = 2\lambda$ (2nd order)

$\theta = 163.7^\circ - 126.4^\circ = 36.3^\circ$

$d = 1/4.5\times10^5$ m

$\lambda = \dfrac{\sin(36.3^\circ)}{2(4.5\times10^5)} = 6.58\times10^{-7}$ m

(ii) It involves smaller fractional error in θ hence λ.

(b) $\theta = 30^\circ \Rightarrow \sin\theta = 0.5$.

alternate slits become opaque $\Rightarrow$ d has doubled.

Since $\sin\theta \propto \frac{1}{d}$ as λ constant,

$\therefore \sin\theta' = 0.25 \Rightarrow \theta' = 14.5^\circ$

$\therefore$ New angle subtended $= 29.0^\circ$

4. (a) Process is called **photoelectric effect**

The cathode which is metallic is a good **reflector of** radiation and hence some of light (**photons**) incident on the cathode would have **reflected** from the surface instead of being absorbed by the electron. [1]

(b) No of electrons emitted from the tenth dynode
$= (2)^{10}$
$= 1024$ [1]

(c) Let
n_{10} : rate of photoelectrons emitted from the tenth dynode.
n_0 : rate of photoelectrons emitted from the cathode.

$$I = \frac{dq}{dt} = n_{10}e \quad [1]$$

$$7.2\times10^{-6} = n_{10}\, 1.6\times10^{-19}$$

$$n_{10} = 4.5\times10^{13}\ s^{-1} \quad [1]$$

$$\therefore\ n_0 = n_{10} \div 1024$$

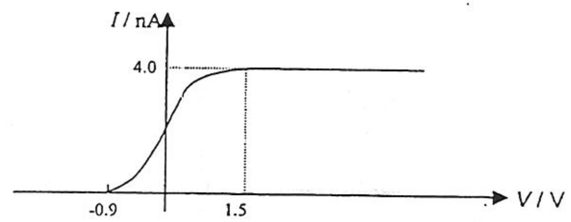
$$= 4.4\times10^{10}\ s^{-1} \quad [1]$$

(d) Power of the incident light
$= 3\, n_0\, h f = 3\, n_0\, h\, c/\lambda$ [2]

$$= 3\,(4.4\times10^{10})(6.63\times10^{-34})\left(\frac{3\times10^{8}}{365\times10^{-9}}\right)$$

$= 7.2\times10^{-8}$ W [2]

5(a)



(i) 1. Why are photoelectrons emitted with a range of energies ranging from zero to a maximum?

Electrons emitted from the surface will be emitted with the maximum energies.
Electrons emitted deeper from the surface will be emitted with energies less than the maximum due to collisions with atoms along the way to the surface thus losing energy. [1]

2. If the intensity of light is now doubled, how will the current and the maximum velocity of the electrons be affected by the intensity of light?

Increasing the intensity of light increases the number of incident photons and thus the number of photoelectrons that will be emitted. Saturation current doubles. [1]

Maximum velocity of the electrons are unaffected by the intensity of light. It is affected by the incident frequency of light and the work function of the metal. ($KE_{max} = E_{photon} - \phi$) [1]

3. Explain why the current remains at a value of 4.0 nA when V ≥ 1.5 V

Given a particular intensity of light, (i.e. a fixed wavelength and number of photons), there will be a maximum number of photoelectron that will be emitted. At 1.5V, all electrons emitted are collected. [1]

4. calculate the rate of incidence of photons on the emitter.

$$P = \frac{nhf}{t} \Rightarrow \frac{n}{t} = \frac{IS\lambda}{hc}$$

$$\frac{n}{t} = \frac{IS\lambda}{hc} = \frac{180\times0.45\times10^{-2}\times300\times10^{-9}}{6.63\times10^{-34}\times3.0\times10^{8}} = \underline{1.22\times10^{16}\ s^{-1}}$$ S: [1], A: [1]

(ii) From the graph,

1. explain why I is not zero even when V is zero,

There are electrons that are emitted in the direction of the collector. These electrons have kinetic energies and does not need an attractive potential of the collector to get collected reach the plate. [1]

5(a)

2. calculate the work function of the emitter,

$KE_{max} = 0.9 \times 1.60 \times 10^{-19}$ **Calculate KE_{max} : [1]**

$\phi = E_{photon} - KE_{max}$

$= hc/\lambda - KE_{max}$

$= (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/300 \times 10^{-9} - 0.9 \times 1.60 \times 10^{-19}$

$= 5.19 \times 10^{-19}$ J **Substitution: [1]**

$=$ <u>3.24 eV</u> **Answer: [1]**

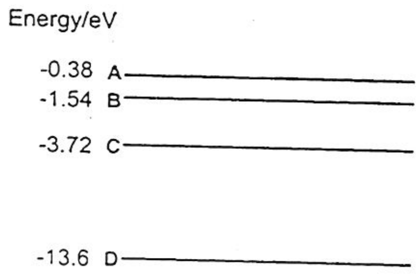
3. calculate the rate of emission of electrons when $V = 1.5$ V,

$$I = \frac{Q}{t} = \frac{ne}{t} \Rightarrow \frac{n}{t} = \frac{I}{e} = \underline{2.5 \times 10^{10}\ s^{-1}}$$ **Substitution: [1], Answer: [1]**

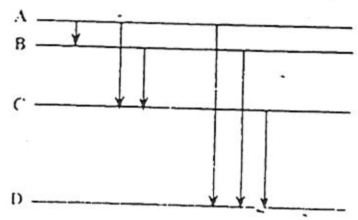
(iii) Comparing the answers from **(i) 4.** and **(ii) 3**, suggest a reason why the value of the rate of emission of electrons is to be expected.

Not all photons absorbed by the metal emitted a photoelectron. Some photoelectrons are re-absorbed back into the metal due to loss of energy during collision with atoms along the way. [2]

(b) The diagram shows four energy levels **A**, **B**, **C** and **D** within an atom. The outermost electron is at level **A**.



(i) Make a copy of the diagram. On it, show all the possible transitions between the four energy levels which result in photon *emission*.



Six emission lines representing three different series. Each line: [½]
(Total: [3])

(ii) Calculate the shortest possible wavelength of radiation emitted as a result of electron transition from level **A**. State the region of the electromagnetic spectrum at which the radiation will occur.

Shortest wavelength: largest energy difference (Transition: A to D)

$\Delta E = hc/\lambda$

$(E_D - E_A) = hc/\lambda$

$[(-0.38) - (-13.6)] \times 1.60 \times 10^{-19} = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / \lambda$ **Substitution: [1]**

<u>$\lambda = 9.40 \times 10^{-8}$ m</u> **Answer: [1]**

<u>UV region</u> (Correct region according to the answer found). **[1]**

NUCLEAR PHYSICS (7 – 14 Mar)

4(a) (i) $^{227}_{89}Ac \longrightarrow ^{223}_{87}Fr + ^{4}_{2}He$

(ii) Mass of Fr + He = (223.0198 + 4.0026)u = 227.0224 u

KE of product = Δmc^2 = (227.0278 – 227.0224)u c^2 = 8.07 x 10^{-13}J

= 5.04 MeV

(b) (i) Mass difference = (1.0073u)(87) + (223 – 87)(1.0087u) – 223.0198 = 1.7985u

(ii) Energy is required to break up the nucleus into its constituent components. This accounts for the mass of the constituent nucleons being greater than the nucleus.

(c) $^{223}_{87}Fr \longrightarrow ^{223}_{88}Ra + ^{0}_{-1}e$

(d) Since half life of actium isotope is much greater than that of the francium isotope, the concentration of francium will be constantly low as it quickly decays to Radium while Actinium decays slowly to form francium.

5(a) $$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{(90 \times 365 \times 24 \times 60 \times 60)} = 2.44 \times 10^{-10} s^{-1}$$

(b) For min no. of atoms to be present, we assume that one decay yields one alpha particle.

$A_0 = \lambda N_0$

10 x 10^{-3} / (5.1 x 10^{6} x 1.602 x 10^{-19}) = 2.44 x 10^{-10} x N_0

Hence, N_0 = 5.02 x 10^{19} atoms

(c) Alpha particle radiation is not penetrating, hence less harmful to the human body.

OR Having long half-life, it will have slow decay rate.

It will then be able to maintain a constant supply of power within the lifetime of the patient, so it does not need to be replaced.