PASS A'LEVEL

Friday, June 5, 2020

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YOUR GUIDE AWAY FROM SCHOOL

SOLUTIONS TO PHYSICS (APHY 003)

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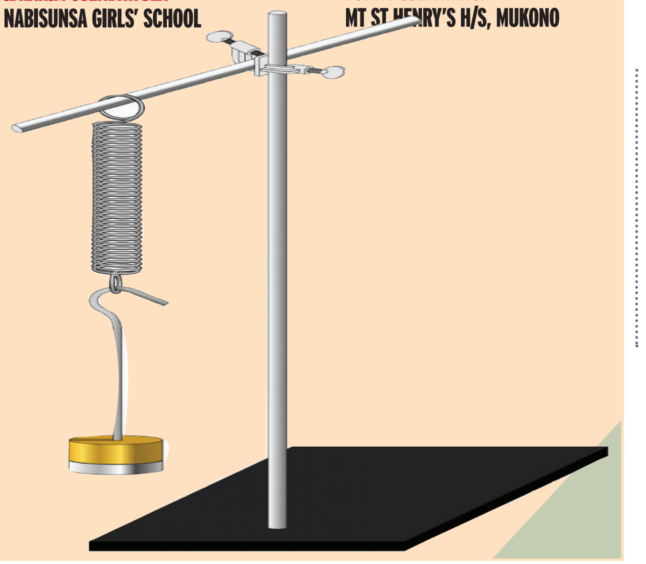


(1) (a) (i) Fundamental quantities are quantities which cannot be expressed in terms of any other quantities using any mathematical equation.
Examples include; mass, length and time.

Derived quantities are quantities which can be expressed in terms fundamental quantities of mass, length and time.

OR. Derived quantities are those physical quantities which can be obtained by combining the fundamental quantities mathematically.
Examples include; acceleration, speed, power, force, etc.

Note: Physical quantities that are not related to mass, length and time are called dimensionless or non - dimensional quantities. Examples include; relative density, refractive index mechanical advantage, etc.
Read about Dimensions of a physical quantity.

(ii) To show that an equation is dimensionally consistent (a correct equation) the units / dimensions on the left hand side (LHS) should balance with those on the right hand side (RHS).

Note: ALL correct equations should be dimensionally consistent but not all dimensionally consistent equations are correct.

From the equation, $V=\sqrt{\frac{Y}{\rho}}$,

LHS: $[velocity]=[V]=LT^{-1}$

RHS;

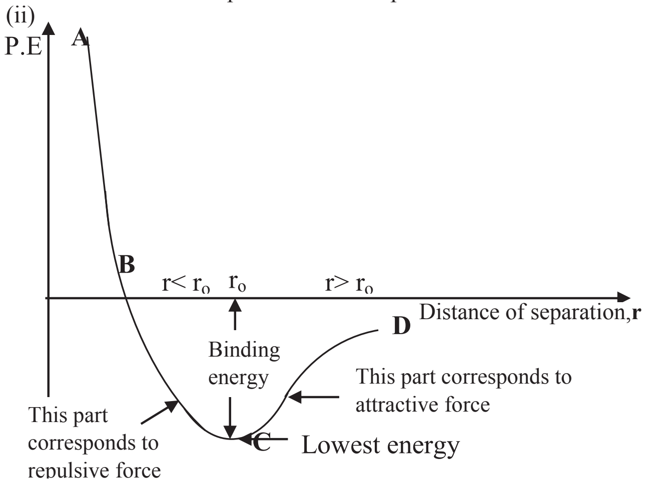
$[\text{Young's modulus}]=[Y]=ML^{-1}T^{-2}$ and $[density]=[\rho]=[ML^{-3}]$

$$\sqrt{\frac{[\text{Young's modulus}]}{[\text{density}]}}=\sqrt{\frac{ML^{-1}T^{-2}}{ML^{-3}}}=\sqrt{L^{(-1+3)}T^{-2}}=\sqrt{L^2T^{-2}}=LT^{-1}$$

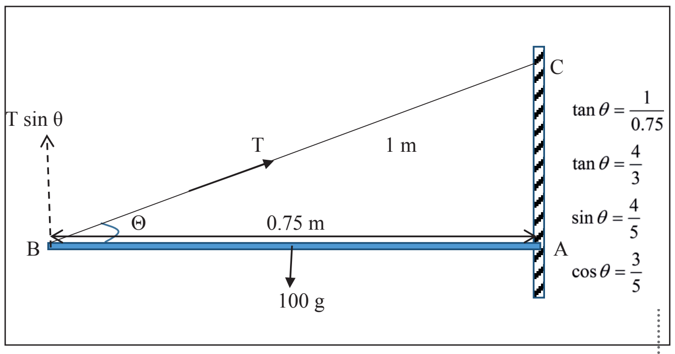
Since dimensions on the RHS (LT^{-1}) = dimensions on the LHS (LT^{-1}), then the equation is dimensionally consistent.

(b) (i) Intermolecular forces are forces of attraction or repulsion which act between neighbouring particles such as molecules. These forces arise from the potential energy of the molecules, and the thermal energy of the molecules which is kinetic energy of the molecules and it depends on the temperature of the substance.

(ii)



Along part AB, the potential energy ,P.E is positive and along BCD, P.E is negative.
For distance $r < r_o$, repulsive forces exceed attractive forces between the molecules. At $r = r_o$, the attractive forces and repulsive forces balance. The potential energy is, therefore, minimum at $r = r_o$, which corresponds to equilibrium separation of molecules, at absolute zero, where the thermal kinetic energy is zero. For $r > r_o$, attractive forces exceed repulsive forces so that molecules return to equilibrium position when slightly displaced from it. So the molecules of a solid oscillate about their equilibrium or mean position.



(i) Taking moments about A

$$100\times9.81\times\frac{0.75}{2}=T\times0.75\sin\theta$$

$$T=\frac{100\times9.81\times0.375}{0.75\times\frac{4}{5}}$$

$$T=613.125N$$

(ii)

$$BC=\sqrt{1^2+0.75^2}=1.25m$$

$$extension, e=1.25-1.23=0.02m$$

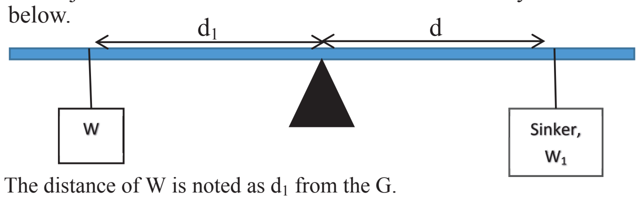
$$A=\frac{\pi d^2}{4}=\frac{\pi}{4}(0.8\times10^{-3})^2=5.027\times10^{-7}m^2$$

$$\text{Young's modulus, E}=\frac{F/A}{e/lo}=\frac{613.125\times1.23}{0.02\times5.027\times10^{-7}}$$

$$=7.5\times10^{10}Nm^{-}$$

2. (a) (i) Relative density is the ratio of the mass of any volume of a substance to the mass of an equal volume of water.
OR: Relative density is the ratio of density of a substance to the density of water.

(ii) A metre rule is balanced horizontally on a knife edge.
- The position of the balance point on the metre rule is marked as G.
- The knife edge is now fixed at point G.
- A sinker of weight W_1, is hung at a constant distance d from the pivot.
- A weight W of any suitable mass is hung on the opposite side and adjusted until the metre rule balances horizontally as shown below.

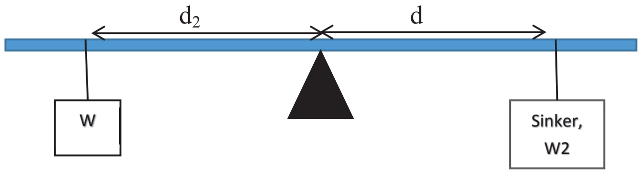


The distance of W is noted as d_1 from the G.

$$W_1d=Wd_1$$

$$W_1=W\frac{d_1}{d}$$

- The sinker is then immersed in water in a beaker while d kept constant.
- The position of the weight W is adjusted until the balance position is restored.
- The distance d_2 of the weight W from the pivot is measured.

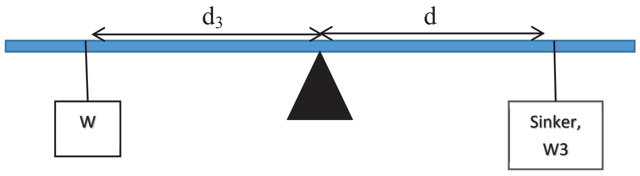


- If W_2 is the weight of the sinker in water, then taking moments about the pivot gives;

$$W_2d=Wd_2$$

$$W_2=W\frac{d_2}{d}$$

- The sinker is then immersed in a liquid in a beaker while keeping d constant.
- The position of the weight W is adjusted until balance position is restored.
- The distance d_3 of the weight W from the pivot is measured.



- If W3 is the weight of the sinker in water, then taking moments about the pivot gives;;

$$W_3d=Wd_3$$

$$W_3=W\frac{d_3}{d}$$

By definition,

Relative density =

$$\frac{\text{apparent loss of weight of the sinker while in liquid}}{\text{apparent loss of weight of the sinker while in water}}$$

$$=\left(W\frac{d_1}{d}-W\frac{d_3}{d}\right)\Big/\left(W\frac{d_1}{d}-W\frac{d_2}{d}\right)$$

$$=\frac{d_1-d_3}{d_1-d_2}\quad,\quad \text{where } d_1>d_2>d_3$$

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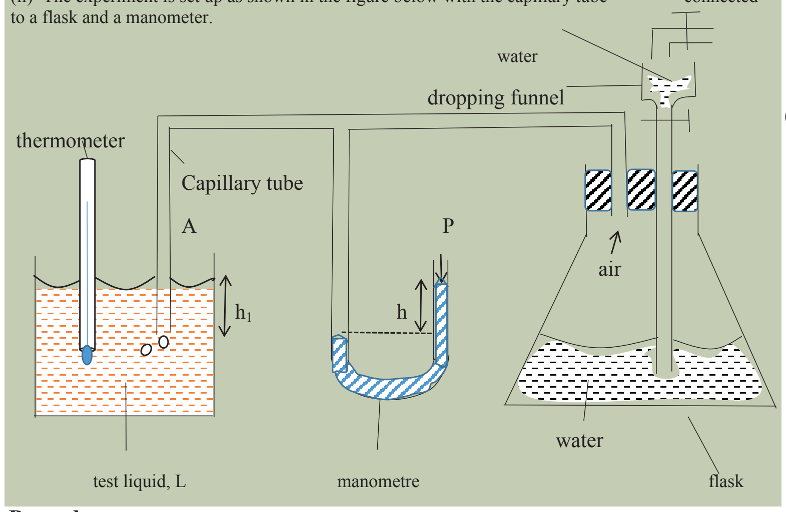
Note: The advantage of this method is that relative density can be determined even when the weights are not known.

(b) (i) Surface tension is a tangential force acting perpendicular to one side of an imaginary line of length one metre drawn in the liquid surface.
OR: Surface tension is the force per unit length acting normally to one side of an imaginary line drawn in the liquid surface.

$$[\text{surface tension}] = \frac{[force]}{[length]} \Rightarrow [\gamma] = \frac{MLT^{-2}}{L} = MT^{-2}$$

(ii) The experiment is set up as shown in the figure below with the capillary tube connected to a flask and a manometer.



Procedure:
- The pressure in the flask is increased gradually by allowing drops of water to slowly fall down through the funnel. This is done while observing the levels of mercury in the manometer.
- As a result, a bubble forms slowly at the end of the tube A.
- The maximum pressure difference, h is noted on the manometer.
- The depth, h_1 of the end of the capillary tube below the specimen is recorded.
- The radius, r of the capillary tube is determined by measuring its diameter by using a traveling microscope.

If P = atmospheric pressure, ρ = density of liquid in manometer, σ = density of the test liquid and r = radius of the orifice of the capillary tube , A, then;
Excess pressure inside the bubble is;

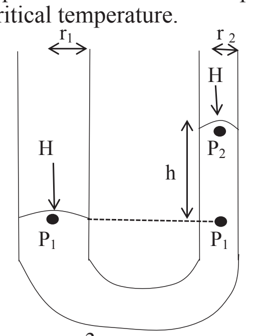
$$\frac{2\gamma}{r} = (P + h\rho g) - (P + h_1\sigma g)$$

$$\gamma = \frac{rg}{2}(h\rho - h_1\sigma),$$

Since all these quantities are known, then surface tension, γ is calculated.

Note: The experiment can be repeated for various temperatures, θ, of the test liquid and in each case, the value of the surface tension γ , is calculated. Then those values can be used to determine the variation of surface tension with temperature.

(iii) When the temperature of a liquid is increased, the average kinetic energy of its molecules increases. The intermolecular forces of attraction between the molecules decrease. Hence surface tension of a liquid decreases as the temperature increases and varnishes at the critical temperature.



$r_1 = \frac{10}{2} mm = 5.0\times10^{-3} m$, $r_2 = \frac{3}{2} mm = 1.5\times10^{-3} m$, $\theta = 120^0$,

$\rho = 1.36\times10^4 kgm^{-3}, \gamma = 0.4 Nm^{-1}$

Let P_1 = pressure just below the surface of mercury in the larger tube
P_2 = pressure just below the surface of mercury in smaller tube
H = atmospheric pressure.

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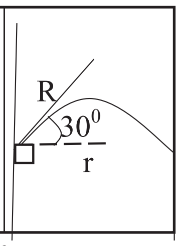
(i) $F\gamma = 2\pi R\gamma$, But $r = R\cos\theta$
Where; R= radius of curvature of surface and r radius of capillary tube.

$$F_\gamma = \frac{2\pi r\gamma}{\cos\theta}$$

$$F_\gamma = \frac{2\times3.14\times5.0\times10^{-3}\times0.4}{\cos30^0}$$

$$F_\gamma = 0.015\text{N}$$



(ii) $P_1 - H = \frac{2\gamma\cos\theta}{r_1} \Rightarrow P_1 = \frac{2\gamma\cos\theta}{r_1} + H........(i)$

Similarly, $P_2 - H = \frac{2\gamma\cos\theta}{r_2} \Rightarrow P_2 = H + \frac{2\gamma\cos\theta}{r_2}$

Also $P_1 = P_2 + h\rho g \Rightarrow P_1 = H + \frac{2\gamma\cos\theta}{r_2} + h\rho g.....(ii)$

$(i) = (ii)$

$$\frac{2\gamma\cos\theta}{r_1} + H = H + \frac{2\gamma\cos\theta}{r_2} + h\rho g$$

$$h\rho g = 2\gamma\cos\theta\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$h = \frac{2\gamma\cos\theta}{\rho g}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$h = \frac{2\times0.4\cos120^0}{1.36\times10^4\times9.81}\left(\frac{1}{5.0\times10^{-3}} - \frac{1}{1.5\times10^{-3}}\right)$$

$$h = 0.0014m$$

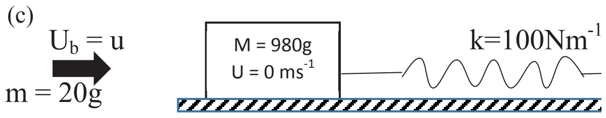
Difference in mercury levels = 0.0014 m

3. (a) Everybody remains in its state of rest or uniform motion in a straight line unless an external force acts otherwise.
- The rate of change of momentum of a body is directly proportional to the applied force and acts in the direction of the force.
- For every action, there is an equal and opposite reaction

(b) The rocket exerts a strong force on the burning gases, expelling them downwards. The exhaust gases also exert an equal and opposite force on the rocket, which propels the rocket to move forward.

Read about conservation of linear momentum.

(c)



Let; m = mass of the bullet.
M = mass of the wooden block,
V = common velocity of the bullet and block after collision.

(i) Elastic potential energy of the compressed spring

$$E.P.E = \frac{1}{2}Kx^2 = \frac{1}{2}\times100\times(4.8\times10^{-2})^2 = 0.115J$$

(ii) Kinetic energy gained by block and bullet = Elastic potential energy

$$\frac{1}{2}(m+M)V^2 = \frac{1}{2}Kx^2$$

$$\frac{1}{2}(0.02+0.98)V^2 = 0.115$$

$$V = \sqrt{0.23} = 0.48ms^{-1}$$

Using conservation of momentum;

$$mu_1 + Mu_2 = (m+M)V$$

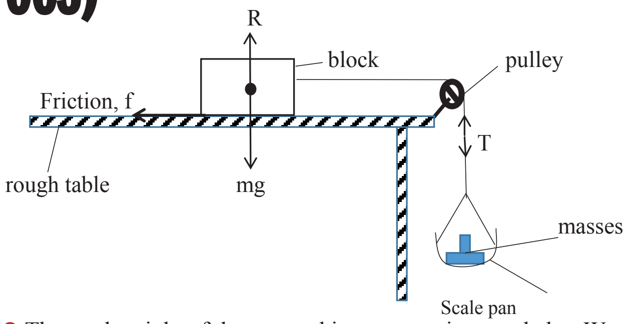
$$0.02u + 0.98\times0 = (0.02+0.98)\times0.48$$

$$u = 24ms^{-1}$$

$\therefore$ velocity of bullet just before collision is 24 ms-1

(d)(i) Frictional force between two surfaces opposes their relative or attempted motion.
- Frictional force is independent of the area of contact but depends on the nature of the surfaces in contact provided the normal reaction is constant.
- Frictional force is directly proportional to the normal reaction.

(ii) The block is weighed and its mass recorded as m.
- A light string is attached to the block resting on the table and passes over a pulley to support a scale pan at its free end.
- Small weights are carefully added into the scale pan until the block just begins to move.



- The total weight of the pan and its contents is recorded as W.
- Under these conditions, the limiting frictional force, F = W.
- The co-efficient of friction, μ is then calculated from;

$$\mu = \frac{F}{R} = \frac{W}{mg}$$

- The experiment may be repeated for more values of W and the average values of μ calculated.

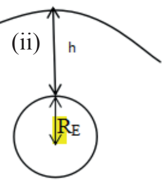
Alternatively;
- The experiment may be repeated for more values of m (obtained by adding known masses to the block) and the corresponding values of W determined.
- A graph of W against m is plotted and it is a straight line through the origin.

The slope of the graph gives the value of the co-efficient of static friction, .

Read about determination of the coefficient of dynamic/ kinetic/sliding friction.

4. (a) (i) Escape velocity is the vertical velocity that a body should be given at the surface of a planet (such as Earth) so that it just escapes from the gravitational attraction of the planet.
OR: Escape velocity is the minimum velocity with which a body is projected in order that it may escape the earth's gravitational pull.

(ii)



Let M_e = mass of the Earth
M_s = mass of the satellite

By Newton's law of gravitation, $F = \frac{GM_eM_s}{R^2}$

Centripetal force, $Fc = M_s\omega^2R$

For satellite to be maintained in motion;

$$\frac{GMeMs}{R^2} = Ms\omega^2R$$

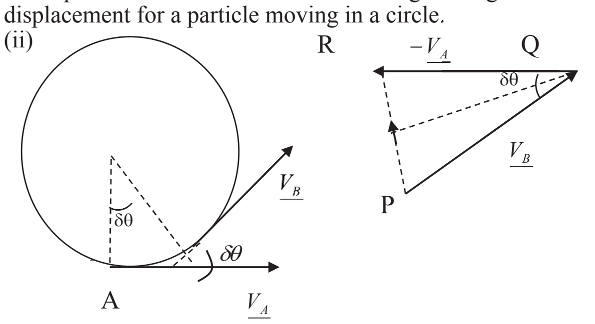
$$R^3 = \frac{GMe}{\omega^2} = \frac{g\text{Re}^2}{\left(\frac{2\pi}{T}\right)^2} = \frac{9.81\times(6.4\times10^6)^2\times(24\times3600)^2}{4\pi^2}$$

$$R = 42.35\times10^6m$$

$$h = 42.35\times10^6 - 6.4\times10^6 = 35.95\times10^6m$$

(b) (i) Angular velocity is the rate at which the line joining the particle to the centre of the circle sweeps an angle about the centre
Or: Angular velocity is the rate of change of angular displacement for a particle moving is a circle.
Centripetal acceleration is the rate of change of angular displacement for a particle moving in a circle.

(ii)



Suppose that during time δt a particle moves from A to B so that its velocity vector changes from $\underline{v}_A$ to $\underline{v}_B$. Then the change in velocity is $\underline{v}_B - \underline{v}_A$, which is the vector PR in the diagram on the right. If δt is small, the angle AOB; i.e., $\delta\theta$, which is equal to PQR is also small, so that the angle RPQ tends to a right angle. This means that the change in velocity, PR, is towards O, the centre of the circle.
Thus, the acceleration is towards the centre of the circle.

$$\text{Acceleration, } a = \frac{\text{Change in velocity}}{\text{Time}} = \frac{PR}{\delta t}$$

But $PR = 2v \sin\frac{1}{2}\delta\theta$

Since $\delta\theta$ is small, $\sin\frac{1}{2}\delta\theta = \frac{1}{2}\delta\theta$

i.e. $PR = 2v.\frac{1}{2}\delta\theta = v\delta\theta$

Thus $a = \frac{v\delta\theta}{\delta t}$

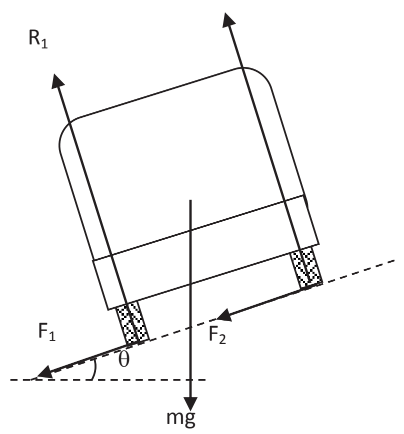
In the limit, as $\delta t \to 0$, $a = \frac{v d\theta}{dt} = v\omega$

But $v = r\omega$

$\therefore$ $\mathbf{a = \frac{v^2}{r}}$ or $\mathbf{a = r\omega^2}$

Thus, if a particle of mass m moves in a circle at a uniform speed v, the centripetal force on it is $ma = m\frac{v^2}{r}$ or $mr\omega^2$

(c)



Let F_1, F_2 be the frictional forces and R_1, R_2 the normal reactions.

Then $F_1 + F_2 = \mu(R_1 + R_2)$

$$\therefore (R_1 + R_2)\cos\theta = \mu(R_1 + R_2)\sin\theta + mg \,..(1)$$

$$\frac{mv^2}{r} = (R_1 + R_2)\sin\theta + \mu(R_1 + R_2)\cos\theta \,....(2)$$

$$\text{From}(1): \quad R_1 + R_2 = \frac{mg}{\cos\theta - \mu\sin\theta} \,.........(3)$$

$$\text{From (2)}: \quad R_1 + R_2 = \frac{mv^2}{r(\sin\theta + \mu\cos\theta)} \,.......(4)$$

$$\text{From (3) and (4)}: \quad \frac{v^2}{r(\sin\theta + \mu\cos\theta)} = \frac{g}{\cos\theta - \mu\sin\theta}$$

$$\therefore v = \sqrt{\frac{gr(\sin\theta + \mu\cos\theta)}{\cos\theta - \mu\sin\theta}} = \sqrt{\frac{9.81 \times 60(\sin 24^0 + 0.25\cos 24^0)}{\cos 24^0 - 0.25\sin 24^0}}$$

$$= 21.46\, ms^{-1}$$

(d) (i) Hooke's law state that the extension of a wire is directly proportional to the applied force provided that the elastic limit is not exceeded; i.e., $F \; \alpha \; e \;\Rightarrow\; F = k \; e$

(ii) Diameter of the material in form of a wire
- Original length of the wire
- Extension caused in the wire
- Cross sectional area of the wire

Read about the experiment of verifying Hooke's law.

(iii) Limitations of Hooke's law
- It ceases to apply past the elastic limit of a material. If the material is stretched past its elastic limit, it causes permanent deformation.
- The wires should be long enough such that measurable extensions are produced.
- The wires should be thin such that there is no need of use of bigger stretching masses (in case the wire is thick) which are difficult to handle.
- Wires used must be identical to eliminate errors that would result due to any changes in position resulting from bending the rigid support as well as errors due to changes in temperature.

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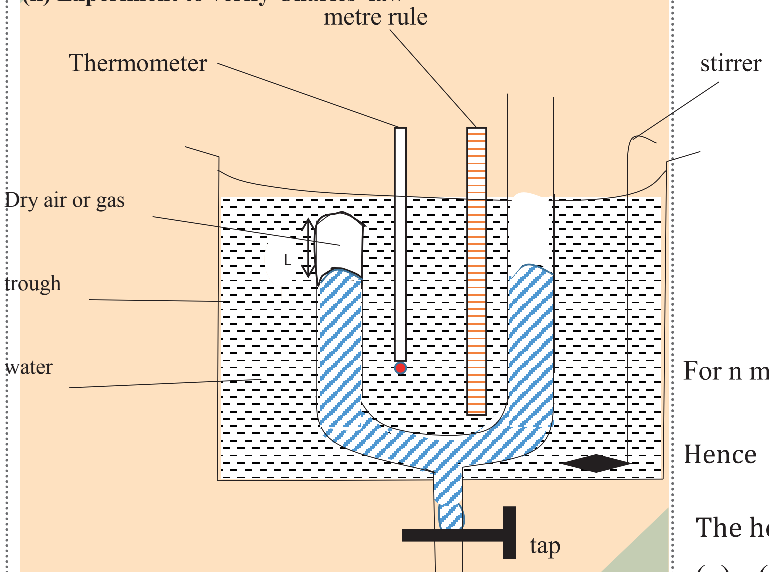
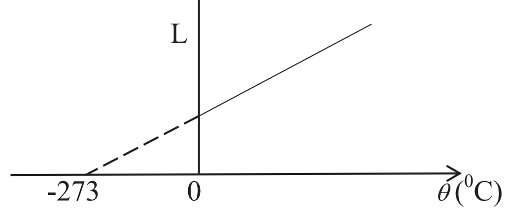
5. (a) (i) Charles' law states that the volume of a fixed mass of a gas at a constant pressure is directly proportional to the absolute temperature.

(ii) Experiment to verify Charles' law



- Dry air is trapped in the closed limb of a U shaped tube with a T- junction that carries the tap.
- The set up of the apparatus is as shown in the figure above.
- Some mercury from the tube is either run out by opening the tap or more is added into it through the open end so as to bring the mercury columns in the two limbs to the same level. This ensures that the pressure of the trapped gas or air is equal to the atmospheric pressure.
- The length, L of the trapped air and the temperature, θ in ^{0}C, of the water in the trough are measured and recorded.
- Several values of L and θ are obtained by passing steam through the water in the trough to vary the temperature of the trapped air. This is done while stirring and in each case, the mercury columns are levelled as before.

A graph of L against θ is plotted. It is linear and passes through the origin.



The graph shows that L is proportional to temperature. Since L is proportional to volume, this shows that V is proportional to temperature, thus verifying Charles' law.

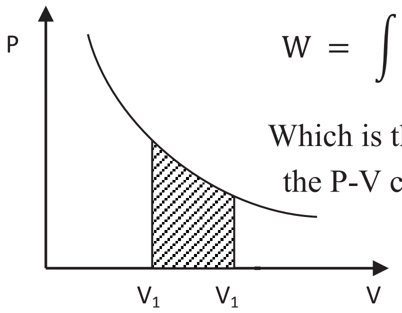
Read about verification of Boyle's law and Pressure law.

(b) (i) Conditions for an Isothermal Process:
- Thin-walled, highly conducting vessel surrounded by a constant temperature bath.
- The process must occur very slowly to allow transference of heat to maintain a constant temperature at every instant.

Read about conditions for adiabatic process.

(ii) Suppose a gas expands by, δV, at a pressure P. The work done, $\delta W = P.\delta V$

The total work done in expanding from V_1 to V_2 is



$$W = \int dW = \int_{V_1}^{V_2} PdV$$

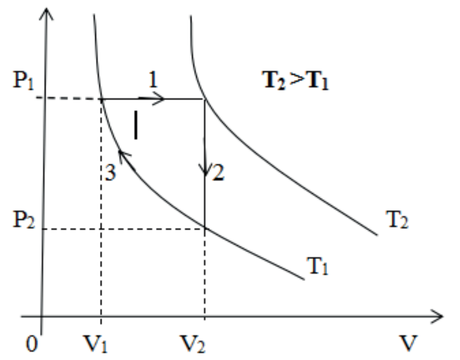
Which is the shaded area on the P-V curve shown.

For n moles of gas, $P = \frac{nRT}{V}$

Hence $W = \int_{V_1}^{V_2} PdV = \int_{V_1}^{V_2} nRTdV = nRT\log_e\left(\frac{V_2}{V_1}\right)$

The heat required, $Q = W = nRT\log_e\left(\frac{V_2}{V_1}\right)$

(c) (i)



(ii)

Note that $P_1 = 1.5 \times 10^5$ Pa , $T_1 = 273 + 27 = 300$ K, and $V_2 = 2V_1$

Process 1; Represents expansion of the gas at constant pressure (isobaric process) to twice its original volume.
Process 2; Represents the cooling of the gas from T_2 to T_1 at constant volume. (Isovolumetric process)
Process 3; Represents an isothermal compression of the gas back to its original volume.
The work done W, by the gas during the cycle is given by;

$$W = W_{12} + W_{23} + W_{31},$$

where W_{12}, W_{23} and W_{31} are the work done in the processes 1, 2 and 3 respectively.

$$W_{12} = P_1(2V_1 - V_1) = P_1V_1 = nRT_1 \text{ --------------(i)}$$

$$W_{23} = \int_{2V_1}^{V_1} PdV = nRT_2 \ln\left(\frac{V_1}{2V_1}\right) = -2RT_2 \ln 2 \text{ ------(ii)}$$

$W_{31} = 0$ (Since there is no change in volume of the gas.

Thus; $W = 2RT_1 - 2RT_2 \ln 2 = 2R(T_1 - T_2 \ln_2)$...(iii)

To find T_2, using process 1,

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, $P_1 = P_2, V_2 = 2V_1$ So, $\frac{V_1}{T_1} = \frac{2V_1}{T_1}$, from which

$T_2 = 2T_1$

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Therefore substituting in (iii) gives;

$$W = 2R\ (T_1 - 2T_1 \ln 2) = 2R\,T_1(1 - 2\ln 2)$$
$$W = 2 \times 8.31 \times 300\ (1 - 2\times 0.693)$$
$$W = -1.925 \times 10^3\ \text{J}$$

(d) Consider two ideal gases 1 and 2.

Let P_1 and P_2 be the pressure of the gases 1 and 2 respectively.

Also let V_1 and V_2 be the volume of the gases 1 and 2 and also

let; N_1, and N_2 be the respective numbers of molecules of gases 1 and 2.

Using the kinetic theory, we can write as below;

$$P_1V_1 = \frac{1}{3}N_1 m_1\overline{c_1^2} \quad \text{and} \quad P_2V_2 = \frac{1}{3}N_2 m_2\overline{c_2^2}$$

If their pressures, volumes and temperatures are the same, then;

$$P_1 = P_2 = P \quad \text{and} \quad V_1 = V_2 = V$$

$$PV = \frac{1}{3}N_1 m_1\overline{c_1^2} = \frac{1}{3}N_2 m_2\overline{c_2^2}$$

or
$$\frac{2}{3}N_1\left(\frac{1}{2}m_1\overline{c_1^2}\right) = \frac{2}{3}N_2\left(\frac{1}{2}m_2\overline{c_2^2}\right)$$

Since $\frac{1}{2}m\overline{c^2} = \text{constant}$, then $\frac{1}{2}m_1\overline{c_1^2} = \frac{1}{2}m_2\overline{c_2^2}$

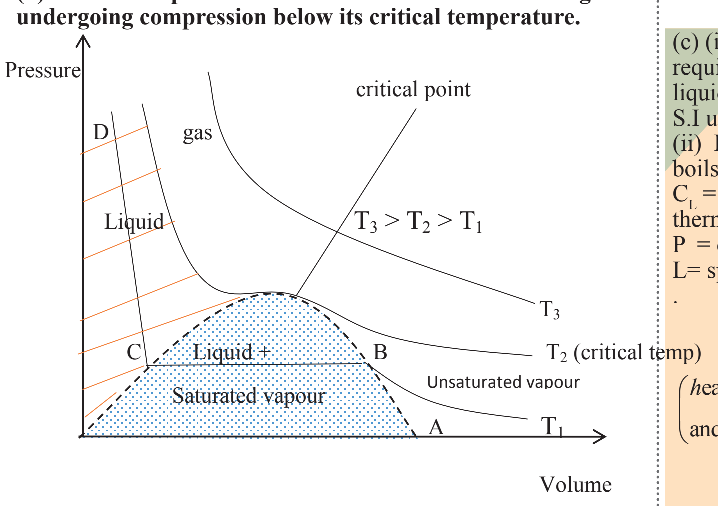
And so $N_1 = N_2$

Thus equal volumes of ideal gases existing under the same temperature and pressure contain equal number of molecules, hence the Avogadro's hypothesis.

Read about the derivation of $P = \frac{1}{3}\rho\overline{c^2}$

6. (a) (i) A saturated vapour is a vapour that is in dynamic equillibrium with its own liquid.
Read about:
- Difference between saturated, un saturated and super saturated vapours.
- Saturated vapour pressure (SVP) and boiling
- Effect of temperature and volume on saturated vapour pressure.
- Determination of SVP by the dynamic method.

(ii) Sketch of a pressure versus volume curve for a real gas undergoing compression below its critical temperature.



Note: Critical temperature is a temperature above which the gas can not be liquefied, no matter how high the pressure is or by mere compression.

(iii) Explanation of the graph.
- At temperature above critical point the gas obeys Boyle's law and no change of gas to liquid occurs.
- At temperatures below critical temperature (AB), the gas exists as an unsaturated vapour at low pressures.
- At higher pressures (BC), some of the vapour condenses and we have liquid plus saturated vapour but pressure remains constant as volume reduces
- At much higher pressures (CD), all the vapour condenses into a liquid and there is a very small change in volume for a large pressure increase.

(b) (i) Dalton's law of partial pressures states that total pressure of a mixture of gases which do not interact chemically is equal to the sum of the partial pressures of the constituent gases.

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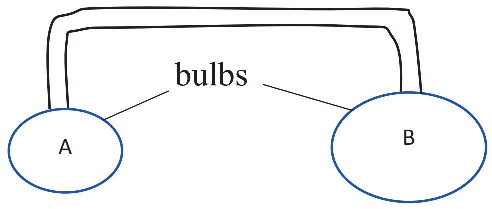
Note: Partial pressure is the pressure a gas would exert if it alone occupied the volume containing the mixture.



Let n_A and n_B be the number of moles of the gas in the bulbs A and B respectively.

$$\text{Initially;}\quad n_A = \frac{P_1V_A}{RT_1}\ ; \quad n_B = \frac{P_1V_B}{RT_1}$$

$$\text{Total number of moles;}\quad n_T = \frac{P_1V_A}{RT_1} + \frac{P_1V_B}{RT_1};$$

$$V_A = V_B = V \qquad n_T = \frac{2P_1V}{RT_1}$$

After immersing one of the bulbs in a bath of temperature T_2, then;

$$n_A = \frac{P_2V}{RT_1}; \quad n_B = \frac{P_2V}{RT_2}; \quad n_A = n_B = n$$

$$\Rightarrow \frac{2P_1V}{RT_1} = \frac{P_2V}{RT_1} + \frac{P_2V}{RT_2}$$

$$\frac{V}{R}\left(\frac{2P_1}{T_1}\right) = \frac{V}{R}\left(\frac{P_2}{T_1} + \frac{P_2}{T_2}\right)$$

$$\frac{P_2}{T_2} = \frac{2P_1}{T_1} - \frac{P_2}{T_1} \Rightarrow \frac{P_2}{T_2} = \frac{2P_1 - P_2}{T_2}$$

$$\Rightarrow T_2 = \frac{P_2T_1}{2P_1 - P_2}$$

(c) (i) Specific latent heat of vapourisation is defined as the heat required to change a one kilogram mass of a substance from liquid to vapour at constant temperature.
S.I units = Jkg^{-1}.

(ii) Let: M = original mass of liquid, m = mass of liquid that boils off,
C_L = specific heat capacity of the liquid, C = heat capacity of thermos flask ,
P = electrical power of heater, t = total time supplied,
L= specific latent heat of vapourisation,
. $\theta_1 = 28^0\ \text{C}$ and $\theta_2 = 78^0\ \text{C}$

$$(\text{Heat supplied by the heater}) =$$
$$\left(\begin{array}{l}\text{heat required to heat the liquid}\\ \text{and flask from } 28^0\text{C to } 78^0\text{C}\end{array}\right) + (\text{heat used to boil off the liquid})$$

$$Pt = M\,C_L(\theta_2 - \theta_1) + C\,(\theta_2 - \theta_1) + mL$$

Then $\quad Pt = (M\,C_L + C)(78 - 28) + mL$

$\therefore \quad mL = Pt - (Mc + C)(78 - 28)$

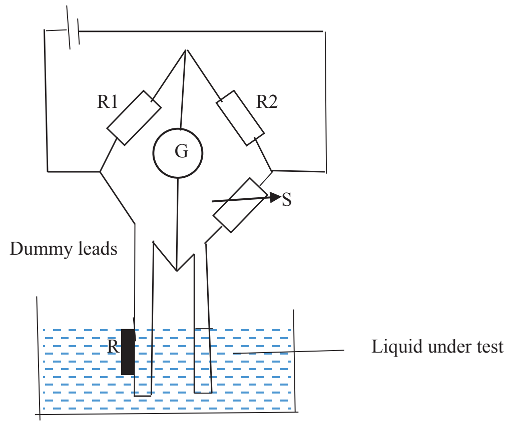
$= (500 \times 10 \times 60) - (2 \times 2500 + 840) \times 50$

$= 3.0 \times 10^5 - 2.92 \times 10^5 = 8 \times 10^3$

$\therefore \quad m = \frac{8\times10^3}{8.54\times10^3} = $ **0.937 kg**

Assumptions:
- ✓ No heat is lost to the surroundings.
- ✓ The heat capacity of the heater is negligible
- ✓ The liquid vapour escapes from the flask

(d) Measurement of temperature using platinum resistance thermometer.



- The platinum wire is put in ice and the variable resistor, S varied until galvanometer shows zero reading. At this point, if $R_1 = R_2$ then the resistance of the wire is equal to the resistance of S and is recorded as Ro.
- The platinum wire is now put in steam and the variable resistor, S varied until galvanometer shows zero reading. The resistance of the wire is equal to the resistance of S and is recorded as R_{100}.

The platinum wire is now put in contact with a body of unknown temperature (the liquid bath) and variable resistor, S varied until galvanometer shows zero reading. The resistance of the wire is equal to the resistance of S and is recorded as R_θ.
The unknown temperature θ of the liquid is determined from;

$$\theta = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100^0 C$$

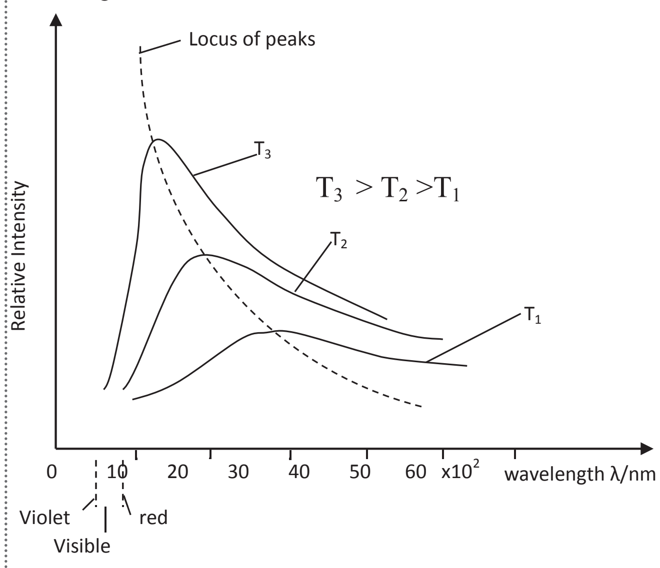
Read about how you can use the Kelvin scale to determine the temperature of a liquid bath using the platinum resistance thermometer.

7. (a) (i) Thermal conduction is the transfer of heat energy from the hotter regions to colder regions of a body without any net movement of the parts of the body itself.
(ii) Conduction in metals is mainly due to free moving electrons. When one end is heated, the free electrons gain thermal energy thereby increasing their velocities and thus kinetic energy as they drift from the heated end.
They dissipate some of this energy upon collision with the atoms in the lattice as they move towards the colder regions. This leads to increased vibrational energy of the atoms. This energy is therefore passed on from one atom to another thus leading to propagation of heat along the solid.
Also the fact that electrons are lighter and move very fast, transmission of heat energy is faster in metals than other poor conductors. This also explains why metals are better conductors than poor conductors.

(iii) Given; Area = $4\times10^{-4}m^2$, $l = 2\times10^{-2}$m, $\theta_2 = 60^0$C, $\theta_1 = 20^0$C

$$\text{From;}Q = \frac{kA(\theta_2 - \theta_1)}{l} \times t = \frac{400 \times 4\times10^{-4}(60-20)}{2\times10^{-2}} \times 2 \times 60 = 38400$$

(b) (i) A black body is the one that absorbs all radiations of all wavelength incident on it, reflects and transmits none..



(iii) At first the ball is invisible.
It becomes dull red, then bright red and finally less red, tending to white.
This is because as the temperature rises, the intensity of the shorter wavelengths increases more rapidly.

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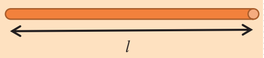
So the peak intensity shifts from the red end of the spectrum into the visible spectrum with other colours such as green and blue appearing.

(c) Given , diameter $=1.5\times10^{-2}m$,

length, $l=30\times10^{-2}$ m



Power radiated by filament $=1.81.8\times10^{3}W$

At equilibrium,

Power generated by filament = power generated by black body

$$1800=\frac{85}{100}\sigma A T^{4}$$

But $A=2\pi r l=\pi\times1.5\times10^{-2}\times30\times10^{-2}=0.01414\,m^{2}$

$$1800=\frac{85}{100}\times5.7\times10^{-8}\times0.01414\ T^{4}$$

$$T^{4}=2.628\times10^{12}\Rightarrow T=1273.2\ K$$

(d)

Let $m = 2.32\times10^{-26}$ kg, mean speed, $u = 500\ ms^{-1}$, $N=2\times10^{22}$ molecules

Change in momentum of each molecule $= mu-(-mu)=2mu$

Time taken to move from one end to another and back; $t=\frac{2l}{u}$

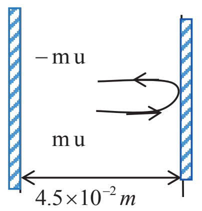
Rate of change of momentum at the wall;

$$=\frac{\text{change in momentum}}{\text{time between collissions}}=\frac{2mu}{2l/u}=\frac{mu^{2}}{l}=\textit{force on the wall}$$

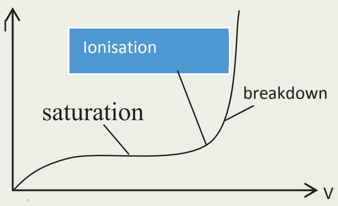
Pressure exerted by one molecule, $P=\frac{force}{area}=\frac{mu^{2}/l}{l^{2}}=\frac{mu^{2}}{l^{3}}$

Total pressure exerted by N molecules, P_T;

$$P_T=\frac{Nmu^{2}}{l^{3}}=\frac{2\times10^{22}\times2.32\times10^{-26}\times500^{2}}{(4.5\times10^{-2})^{3}}=1.273\times10^{6}\ Nm^{-2}$$



8 (a). (i)



(ii). The electrons, emitted from the cathode by photoelectric effect, are accelerated towards the anode.

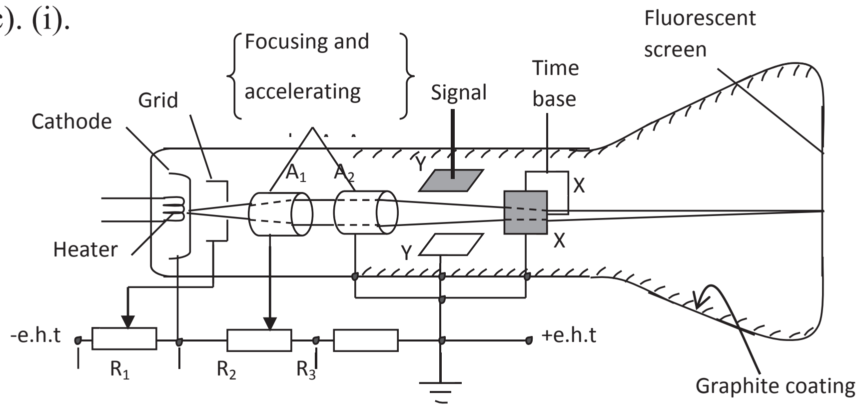
- As the p.d is increased more electrons reach the anode per second- This is depicted as increase in current.
- When all the available electrons per second are reaching the anode, there is no more increase in current. The current is said to be saturated.
- However, as the p.d is increased further, the electrons' kinetic energy is increased until they are able to ionize the gas atoms on their way.
- The ions so formed move to the cathode while the additional electrons join in the flight to the anode – This process of ionization leads to increase in current.
- The knocked–out electrons gain kinetic energy and produce more ions and electrons. Eventually, as the p.d is increased, a point is reached at which the current grows uncontrollably – This is a state of breakdown (avalanche)

(b) (i) C is a smoothening capacitor.

(ii) V_d decreases while V_L increases

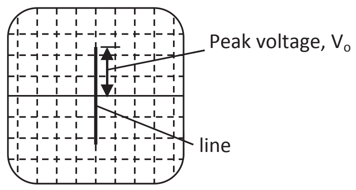
- When electrons, they ionise the mercury atoms
- The ions and electrons so formed make the valve a good conductor.
- This reduces the voltage drop across the valve and allows more of the voltage from the supply to appear across the load.

c). (i).



(ii). (ii)

- First an a.c voltage of known peak value, V_0 is connected to the Y-plates
- The time-base is switched off and the vertical line on the screen is centered.
- The length, l_0, of the trace on the screen is measured.



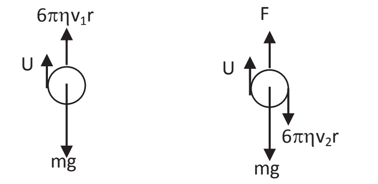
Now l_0 is proportional to twice the peak voltage, V0

The known a.c voltage is disconnected and replaced by the voltage V to be measured. The length l of the line is measured.

Now $l\propto 2V$ And $l_o\propto 2V_o$

$$\therefore\quad \frac{V}{V_o}=\frac{l}{l_o}$$

(d).



(i) *Before* (ii) *After application of the field*

Let F= electric force applied

U = up thrust

In case (i): $U+6\pi\eta r v_1= mg$........................... (1)

In case (ii): $U+F= mg+6\pi\eta r v_2$ .... (2)

Substituting for mg in Eq (2), we have

$F=6\pi\eta r(v_1+v_2)$; Recall that $F=qE=neE$

$$\therefore\quad n=\frac{6\pi\eta r}{Ee}(v_1+v_2)$$

$$=\frac{6\pi\times2.122\times10^{-5}\times6\times10^{-6}}{2\times10^{5}\times1.6\times10^{-19}}(12+4)\times10^{-5}$$

$= \mathbf{12}$

Also read about:

Millikan's oil drop experiment and how it is used to show that charge can be quantized

The use of the constant temperature bath, X-ray tube, lamp and microscopes in the experiment

The devices like the C.R.O, C.R.T, X-Ray tube and their applications.

The X-Ray emission spectra

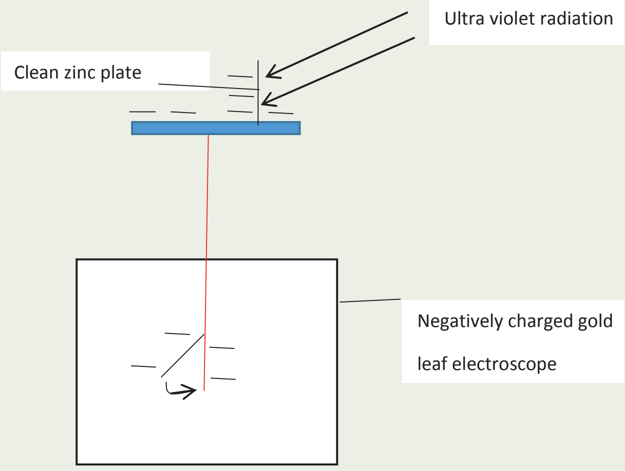
X-ray diffraction (Bragg's law and Laue's diffraction experiment)

Density of crystals (the formula $\frac{mx10^{-3}}{2d^{3}N_A}$; N_A); NA is Avogadro's constant

9(a) (i) Photoelectric emission is the emission of electrons from a metal surface when electromagnetic radiation of high frequency is incident on it.

(ii) For every metal, there is a minimum (threshold) frequency of incident radiation below which photoelectric emission will not take place.

- There is no detectable time lag between irradiation of the metal and emission of electrons.
- The number of electrons emitted per second (photocurrent) is proportional to the intensity of the incident radiation for a given frequency.
- Photoelectrons are emitted with kinetic energies ranging from zero to definite maximum which is proportional to the frequency of the incident radiation.



A clean zinc plate is placed on a negatively charged gold leaf electroscope. When ultra-violet radiation falls on the plate, the leaf collapses indicating that electrons are being lost by the plate. When the ultra-violet radiation is obstructed, the collapsing stops.

(c) (i) Using $hf_0=2.3x1.6x10^{-19}$; $f_0=\frac{2.3x1.6x10^{-19}}{6.6x10^{-34}}$

$$=5.58x10^{14}Hz$$

(ii) Here we shall use the Einstein's equation of photo electric emission

$$hf=hf_0+\frac{1}{2}mv^{2}$$

From this equation,

$$v=\sqrt{\frac{2h(f-f_0)}{m}}=\sqrt{\frac{2x6.6x10^{-34}(\frac{3x10^{8}}{5x10^{-7}}-5.58x10^{-14})}{9.11x10^{-31}}}$$

$$=2.479x10^{5}ms^{-1}$$

(iii)

Since the stopping potential stops the most energetic electrons, then

$eV_s=\frac{1}{2}mv^{2}$; V_s = stopping potential.

$$\Rightarrow V_s=\frac{mv^{2}}{2e}=\frac{9.11x10^{-31}x(2.479x10^{5})^{2}}{2x1.6x10^{-19}}=0.175V$$

More answers and questions next Friday