Mock 2for **Senior six** 2014
Beginning of term 2 exams
P 510/1,
Physics Paper 1
Time 2h 30 min

INSTRUCTIONS

Answer 5 questions including at least 1 but not more than 2 from each of sections A, B and C.

Assume where necessary:

Acceleration due to gravity, *g*	=	9.81 m s^{-2}
Density of water	=	1000 kg m^{-3}
Electron charge, *e*	=	1.6×10^{-19} C
Gas constant, *R*	=	8.31 J mol^{-1} K^{-1}
Specific heat capacity of water	=	4200 kg^{-1} K^{-1}
Radius of the earth	=	6.4×10^{6} m

SECTION A

1. (a) (i) What is meant by dimension of a physical quantity? (01 mark)

(ii) The velocity, v of waves of wave length, λ on the surface of a liquid of surface tension, γ and density, ρ is given by

$$V^2 = \frac{\lambda g}{2\pi} + \frac{2\pi\gamma}{\lambda\rho}$$

Where, g is the acceleration due to gravity. Show that the above equation is dimensionally consistent. (04 marks)

(b) (i) Define Young's modulus and work hardening. (02 marks)

(ii) Describe an experiment to determine Young's modulus of a wire. (06 marks) (c)(i) Derive an expression for the energy stored in a unit volume of a stretched elastic material giving your result in terms of Young's modulus, *E* and the strain of the material. (04 marks)

(ii)The rubber cord of a catapult has cross sectional area of $1mm^2$ and total un stretched length of 10.0 cm. it is stretched to 12.0 cm and then released to project a mass of 50 g. calculate the velocity of projection taking Young's modulus for rubber as 5.0×10^8 N m^{-2}. (03 marks)

2 (a) What is simple harmonic motion and give two example of such a motion.

b). A volume, *V* of air at pressure, *P* is contained in cylindrical vessel of cross sectional area, A by a frictionless and air tight piston of mass *M*.

(i) Show that on slight forcing down the piston and releasing it, the piston oscillates with a period, $T = \frac{2\pi}{A}\sqrt{\frac{MV}{P}}$ (05 marks)

(ii) Verify that the expression for *T* in b (i) above is dimensionally consistent. (02 marks)

C. A particle of mass 4 kg moving along the x-axis under the action of the force $F = -\frac{\pi^2}{16}x$ in newtons. When t=2 s, the particle passes through the equilibrium position and when t=4 s the speed of the particle is 4 m s^{-2}. Find

(i) The amplitude of the motion (04 marks)

(ii) The displacement, *x* at time, *t*. (02 marks)

d(i) Explain why oscillations ultimately die out when a particle is given a slight displacement. (02 marks)

(ii) On the same axes sketch graphs to show the variation of potential and kinetic energy with displacement for a mechanical oscillating system.(02 marks)

3a(i) Briefly explain stable and unstable equilibrium of a body. (03 marks)

(ii) A horizontal rod AB is suspended at the end by strings. The rod is 0.8 m long and a mass of 5 kg is attached 0.6 m away from A so that a body attains horizontal equilibrium. Find the tension in each string. (04 marks)

b(i) Define surface tension and free surface energy (02marks)

(ii) Show that surface tension and free surface energy are numerically equal (03 marks)

(iii) Derive an expression for pressure difference between the pressure inside and outside an air bubble of radius R in a liquid of surface tension, $\boldsymbol{\gamma}$. (04 marks)

(c) Two soap bubbles of radii 1.5 mm and 2.5 mm coalesce under isothermal conditions. If the surface tension of the soap solution is 2.5×10^{-2} N m^{-1}, calculate the excess pressure inside the resultant bubble. (04 marks)

4. a) Define the following;

i. Gravitational potential at a point
ii. Parking orbit
iii. Escape velocity (03 marks)

b(i) A rocket of mass, $\boldsymbol{m}_r$ is fired from the earth's surface so that it just escapes from the gravitational influence of the earth. Show that the escape velocity $V_{esc}=(2gR_e)^{1/2}$ where g is the acceleration due to gravity and R_e is the radius of the earth. (04 marks)

(ii) Deduce its numerical value (02 marks)

(ii) Account for the moon not having an atmosphere (03 marks)

C(i) Explain the energy changes which occur when a pendulum is set into motion (illustrate your answer) (03 marks)

d) A simple pendulum of length 0.5 m has a bob of mass 0.2 kg, it is displaced from its mean position P to position Q so that the string makes an angle of 60^0 with the vertical. Calculate the;

(i) Maximum potential energy of the bob

(ii) Loss in potential energy when the angle made by the string with the vertical turns to 30^0.

SECTION B

5. a) (i) Explain what is meant by a change in temperature of 1^0C on the scale of a platinum resistance thermometer. (2 marks)

(ii) Draw a well labelled diagram of a platinum resistance thermometer together with a circuit in which it is used. (4 marks)

(iii) Give two advantages of this thermometer. (2 marks)

b) The resistance R_θ of platinum varies with temperature θ in ^{0}C as measured by a constant volume thermometer according to the equation:

$R_\theta = R_0(1 + 800\alpha\theta - \alpha\theta^2)$, where α is a constant. Calculate the temperature on the platinum scale corresponding to 300^0C on the gas scale. (5 marks)

c) The volume of some air at constant pressure and also the length of an iron rod are measured at 0^0C and again at 100^0C with the following results:

	$\theta(^0C)$	$100(^0C)$
Volume of air (cm)	28.5	38.9

Length of rod (cm)	100.0	100.2

Calculate,

(i) the absolute zero of this air thermometer scale. (4 marks)

(ii) the length of the iron rod at this temperature if its expansion is uniform according to the air scale. (3 marks)

6. a) Define the following terms:

(i) thermometric property (1mark)

(ii) a fixed point (1mark)

b) (i) Outline the steps involved in establishing a thermodynamic scale of temperature. (4marks)

(ii) Explain why two thermometers may give different values of the same unknown temperature. (3marks)

c) (i) Describe with the aid of a labelled diagram how a constant-volume gas thermometer may be used to measure temperature. (6marks)

(ii) State any three corrections that need to be made when using the thermometer in (c) (i) above. (3marks)

(iii) State and explain the sources of inaccuracies in using mercury-in-glass thermometers. (2marks)

7. a) (i) Give the difference between *heat capacity* and *specific heat capacity* of a substance, and explain why water is used in a car radiator other than any other liquid. (4marks)

(ii) Write down the measurements that need to be made in the determination of the specific heat capacity of a solid by the method of mixtures, pointing out the quantities to be given to you and the precautions to be taken. (3marks)

b) (i) With reference to an electrical thermometer, outline the steps involved in setting up a Kelvin scale of temperature. (4 marks)

(ii) The resistance of the element of a platinum resistance thermometer is 4.00 Ω at the ice point and 5.46 Ω at the steam point. What temperature on the platinum resistance scale would correspond to a resistance of 9.84 Ω? (3 marks)

c) (i) State Newton's law of cooling. (1 mark)

(ii) Outline the steps involved in verifying Newton's law of cooling. (5marks)

SECTION C

8 (a) With the aid of a labelled diagram and relevant equation, describe Millikan's experiment for determining the charge on an electron. (5 marks)

(b) An oil drop carried a charge 24e and is between two plates 4 mm apart. The drop falls under gravity with a velocity of 6.0×10^{-4} m s^{-1} and a p.d of 1600V applied between the plates makes the drop to rise with a steady velocity *v*. If the viscosity of air is 1.8×10^{-5} Ns m^{-2} and the density of oil is 900 kg m^{-3},
Calculate

(i) the radius of the drop (3 marks)

(ii) the value of *v* (3 marks)

(c) (i) State and derive Bragg's law of X-ray diffraction . (5marks)

(ii) A second order diffraction image is obtained by reflection of rays at atomic planes of a crystal for a glancing angle 11.4°. If the atomic spacing of the planes is 2.0×10^{-10} m, calculate the wavelength. (3 marks)

9.(a) (i) Distinguish between thermionic and photo electric effects. (2 marks)

(ii) Write down Einstein's equation for the kinetic energy of electrons due to photo electric emission. (1 mark)

(b) Explain what is meant by the following terms as applied to a photo emissive surface:

(i) work function (1 mark)

(ii) stopping potential and (1 mark)

(iii) threshold frequency (1 mark)

c) Cesium has a work function of 1.9 eV. Find the stopping p.d when the metal is illuminated by light of wave length 4.5×10^{-7}m (4 marks)

d) (i) Draw a labelled diagram to show the essential parts of a cathode ray oscilloscope. (4marks).

(ii) What is a time base in an oscilloscope? Sketch a graph showing the variation of time-base voltage with time. (3 marks)

e) A cathode ray oscilloscope has its Y-sensitivity set to 10 V cm^{-1}.
A sinusoidal input is suitably applied to give a steady trace with the time base set so that the electron beam takes 0.01 s to traverse the screen. If the tract seen has a total peak to peak height of 8 cm and contains 3 complete cycles, what is the r.m.s voltage and frequency of the input signal? (3 marks)

10. (a) (i) With the aid of a labelled diagram, describe how an *X* -ray tube works. (5 marks)

(ii) How do *X* - rays differ from beta particles? (2 marks)

(iii) Distinguish between *X* - rays *production* and *cathode ray production*. (2 marks)

(b) A beam of cathode rays is directed midway between two parallel metal plates of length 4.0 cm and separation 1.0 cm. The beam is deflected through 10.0 cm on a fluorescent screen placed 20.0 cm beyond the nearest edge of the plates when a potential difference of 200V is applied across the plates. If this deflection is annulled by a magnetic field of flux density 1.14×10^{-3} T applied normally to the electric field between the plates, find the charge to mass ratio of cathode rays. (6 marks)

(c) With the aid of a labelled diagram, describe and give the theory of a fine beam tube for measuring the charge to mass ratio of cathode rays. (5 marks)

End

Solutions

1 (a) (i) Dimensions of a physical quantity is the way the quantity is related to the fundamental quantities of mass, length and time.

(ii) $V^2 = \frac{\lambda g}{2\pi} + \frac{2\pi\gamma}{\lambda\rho}$

For the left hand side, LHS; $[V^2] = (LT^{-1}) = L^2T^{-2}$

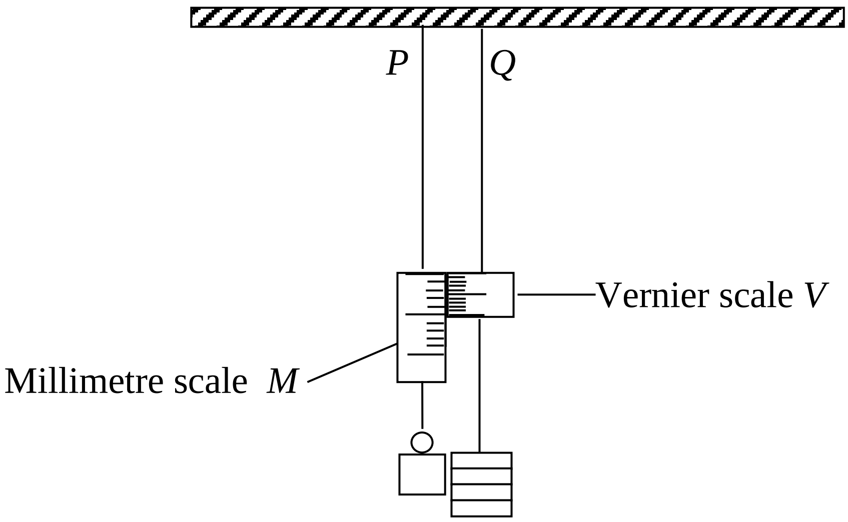
For the right hand side, RHS; $\left[\frac{\lambda g}{2\pi}\right] = [\lambda] \times [g] = L \times LT^{-2} = L^2T^{-2}$

Again for RHS; $\left[\frac{2\pi\gamma}{\lambda\rho}\right] = \frac{[\gamma]}{[\lambda]\times[\rho]} = \frac{MT^{-2}}{L \times ML^{-3}} = L^2T^{-2}$

Since the dimensions on LHS are equal to the dimensions on RHS the equation is dimensionally consistent

(b) Young's modulus is the ratio of tensile stress to tensile strain.

Work hardening refers to the rearrangement of crystals imperfections or dislocations prohibiting plastic flow leading to increased stress.

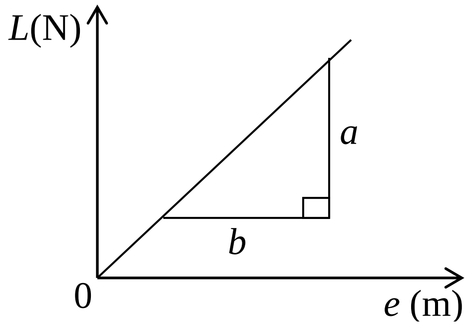


Two long thin identical wires of same materials and length, *P* and *Q* are suspended side by side from a common rigid support .
Wire *P* is kept taut by weight *W* attached to its end to remove kinks and carries a scale *M* graduated in millimetres.
Wire *Q* carries a vernier scale *V* alongside scale *M*.
The original length *l* of the test wire is measured from the support to the vernier scale using a ruler.
The diameter *d* of the test wire is also determined by measurements at several points of the wire, and the average calculated, hence the cross-sectional area *A*.

$$A = \pi\left(\frac{d}{2}\right)^2$$

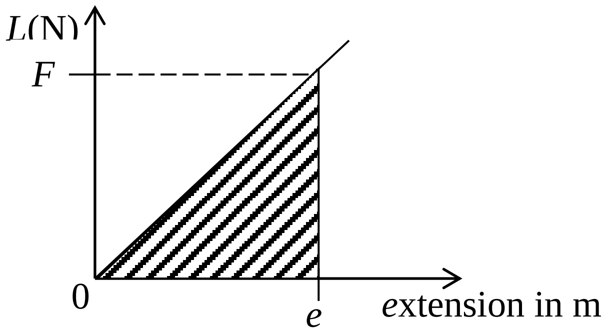
Various known weights/loads *L* are added to the free end of *Q* and the corresponding extension *e* caused read from the vernier scale and recorded.
After each reading the weights are removed to check that the wire returns to its original reading showing that the elastic limit has not been exceeded.
The results are tabulated including values of *L* , in newtons and extension, *e*, in metres.

A graph of L against e is plotted and its slope $\frac{a}{b}$ determined.



Using $L = \frac{EA}{l}e$ the slope $\frac{a}{b} = \frac{EA}{l}$ i.e. $E = \frac{4l}{\pi d^2}\frac{a}{b}$ substituting is done and a value for E calculated.

(c) (i) consider a material of length l, cross-sectional area A, being stretched by force F by extension e.



Energy stored i.e. work done in stretching wire, = area under the graph with the e axis.

Energy $= \frac{1}{2}Fe$

Energy per unit volume $= \frac{\frac{1}{2}Fe}{Al} = \frac{1}{2} \times \frac{F}{A} \times \frac{l}{e} \times \frac{e}{l} \times \frac{e}{l}$

Energy per unit volume $= \frac{1}{2} \times \left(\frac{e}{l}\right)^2$ using $E = \frac{Fl}{Ae}$

Energy per unit volume $= \frac{1}{2}E(\text{strain})^2$

(c) (ii)work done $= \frac{1}{2}Fe = \frac{EAe^2}{2l} = \frac{1}{2}mv^2$

$$v^2 = \frac{EAe^2}{ml}$$

$$v = \sqrt{\frac{EAe^2}{ml}}$$

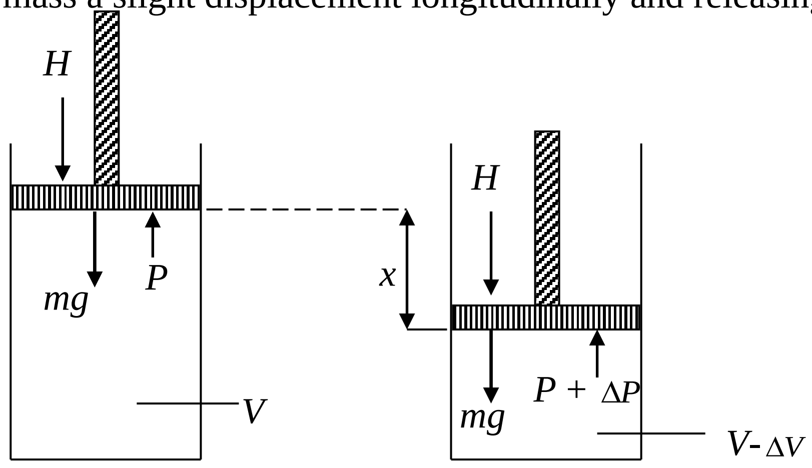
$$v = \sqrt{\left(\frac{5.0\times10^8\times1.0\times10^{-6}\times(0.02)^2}{\frac{50}{1000}\times\frac{10}{100}}\right)} = 6.325 \text{ m s}^{-1}.$$

2. (a) Simple Harmonic Motion is the motion whose acceleration is directed towards a fixed point and is directly proportional to the displacement from the fixed point.

Examples:

- motion of a simple pendulum which has been slightly displaced and released;
- motion of a liquid in an open U-tube after a slight displacement by briefly blowing gently in one limb;
- motion of a frictionless piston in an enclosed gas cylinder at constant temperature after forcing the piston against the gas and releasing it;
- motion of a mass suspended at one end of a clamped spiral spring after giving the mass a slight displacement longitudinally and releasing it.

(b) (i)



At equilibrium   After a slight displacement

ΔP is change in pressure; ΔV is change in volume.
At equilibrium, $HA + mg = PA$, where A is piston area.
After a slight displacement, $HA + mg = (P + \Delta P)A$.
Restoring force, $F = (P + \Delta P)A - PA$.
Using Newton's 2nd law, $F = ma$.
$ma = -\{(P + \Delta P)A - PA\} = -A\Delta P$ the negative sign is because

acceleration a is in opposite direction to that of displacement x.

$a = \frac{A}{m}\Delta P$

but from Boyle's law, $P_1V_1 = P_2V_2$.

$PV = (P + \Delta P)(V - \Delta V)$

$PV = PV + V\Delta P - P\Delta V - \Delta P\Delta V$

But $\Delta P < P$, $\Delta V < V$ and $\Delta P\Delta V \approx 0$

$\frac{V\Delta P}{V} = \frac{P\Delta V}{V} \Rightarrow \Delta P = \frac{P\Delta V}{V}$

Again $\Delta V = xA$.

$\therefore a = -\frac{A}{m}\left(\frac{PxA}{V}\right)$

$a = -\frac{PA^2x}{mV}$

Since $\frac{PA^2}{V}$ is a constant, $a \propto x$, and is always directed towards a fixed point thus the motion is Simple Harmonic.

From $a = -\frac{PA^2x}{mV}$, comparing with $a = -\omega^2 x$,

$\omega^2 = \frac{PA^2}{mV}$

$\left(\frac{2\pi}{T}\right)^2 = \frac{PA^2}{mV}$ Hence $T = \frac{2\pi}{A} \times \sqrt{\frac{mV}{P}}$

(ii) $T = \frac{2\pi}{A} \times \sqrt{\frac{mV}{P}}$

$[L.H.S] = [T] = T$

$[R.H.S] = \frac{1}{[A]} \times \left[\frac{mV}{P}\right]^{\frac{1}{2}}$

$[R.H.S] = \frac{1}{L^2} \times \left(\frac{ML^3}{ML^{-1}T^{-2}}\right)^{\frac{1}{2}}$

$[R.H.S] = \frac{1}{L^2} \times \left(\frac{L^4}{T^{-2}}\right)^{\frac{1}{2}} = \frac{1}{T^{-1}} = T$

Since $[L.H.S] = [R.H.S]$ the equation is dimensionally consistent.

(c) $F = -\frac{\pi^2}{16}x$..(1)

$m = 4$ kg, $F = -\omega^2 x$ from $-a = -\omega^2 x$......................................(2)

Comparing (1) with (2) $4\omega^2 = \frac{\pi^2}{16}$

$\omega^2 = \frac{\pi^2}{16 \times 4} = \frac{\pi^2}{64}$ hence $\omega = \frac{\pi}{8} = 0.393$ rad

Assume $x = A\sin(\omega t + \Theta) = A\sin(\frac{\pi}{8}t + \Theta)$ where Θ is phase angle.

When $t = 2$ s, $x = 0$

$0 = A\sin(\frac{\pi}{8} \times 2 + \Theta)$

$0 = \frac{\pi}{4} + \Theta$ i.e. $\Theta = -\frac{\pi}{4} = 0.785$ rad

When t $= 4$ s, $v = 4$ m s^{-1}

$v = A\omega\cos(\omega t + \Theta)$

$v = A \times \frac{\pi}{8} \times \cos(\frac{\pi}{8}t - \frac{\pi}{4})$

$4 = A \times \frac{\pi}{8} \times \cos(\frac{\pi}{8} \times 4 - \frac{\pi}{4})$

$4 = A \times \frac{\pi}{8} \times \cos(\frac{\pi}{4})$

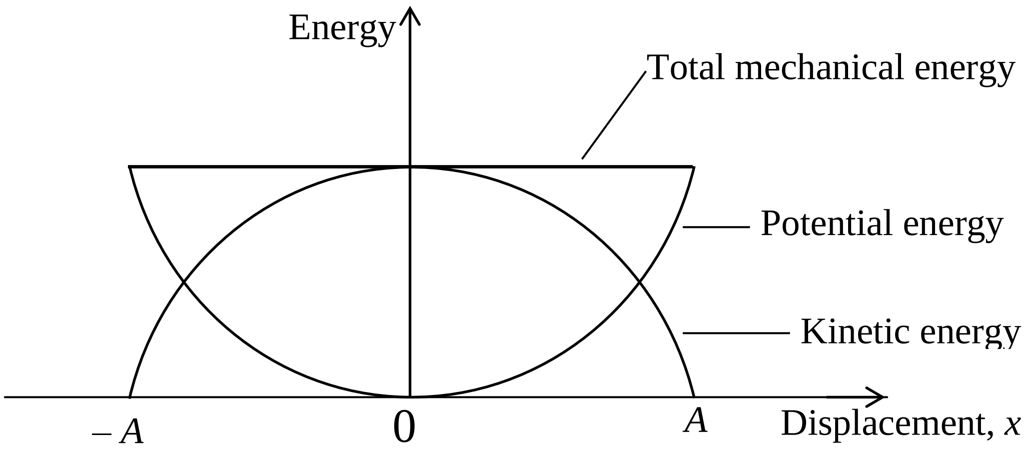
$A = \left(\frac{64}{\pi\sqrt{2}}\right)$ in metres

(ii) $x = A\sin(\omega t - \Theta)$

$x = \left(\frac{64}{\pi\sqrt{2}}\right)\sin(\frac{\pi}{8}t - \frac{\pi}{4})$

(d) (i) The oscillations eventually die out when a particle is highly damped depending on the air resistance. This leads to loss of energy to the surroundings and the amplitude of oscillation decreases.

(ii)

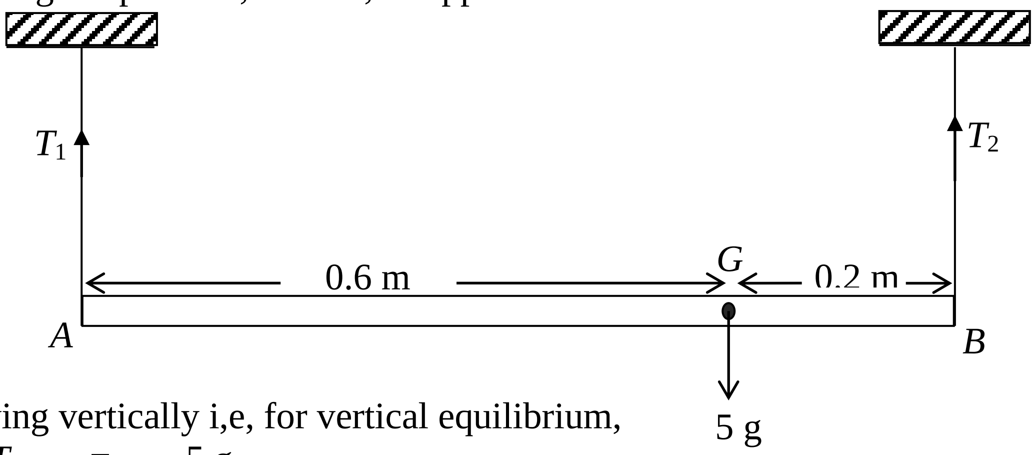


3. (a) (i) Free surface energy is the energy required to create a liquid surface of one unit area (of 1 m^2). Or potential energy per unit area of a liquid surface.

I. For stable equilibrium, when a body is slightly displaced/tilted, its centre of gravity is raised and on releasing the body it returns to its original position.

II. For unstable equilibrium, when a body is slightly displaced/tilted, its centre of gravity is lowered and when it is released it does not return to its original position, instead, it topples over.

(ii)



Resolving vertically i,e, for vertical equilibrium,

$T_1 + T_2 = 5$ g

Taking moments about A $5\,g \times 0.6 = T_2 \times 0.8$

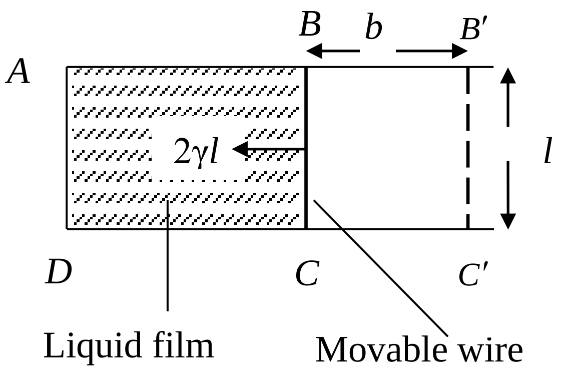
$$T_2 = \frac{5g \times 0.6}{0.8} = \frac{5 \times 9.81 \times 0.6}{0.8} = 36.79\text{ N}$$

$T_1 + T_2 = 5 \times 9.81$

$T_1 + 36.79 = 49.05$

$\mathbf{T_1 = 12.26\ N}$

(b) (i) Surface tension is the force per unit length acting in the surface of a liquid at right angles to one side of an imaginally line drawn in the surface.
OR Surface tension is the tangential force acting per unit length perpendicularly to an imaginally line drawn in the surface.



Consider a rectangular loop ABCD with BC able to slide along AB' and DC'. If BC slides to position $B'C'$ through a small distance b under isothermal conditions, new film A$B'C'$D is formed.

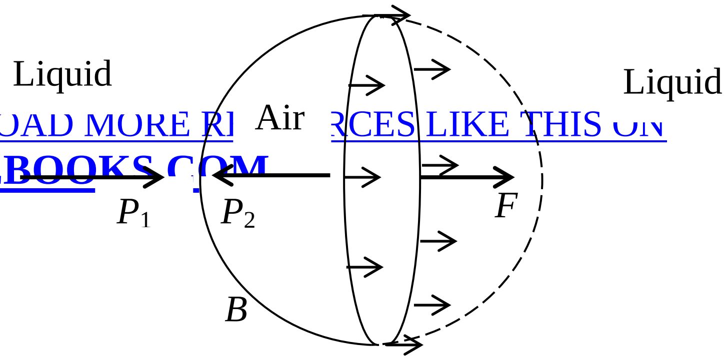
Work done, $W = 2\gamma lb$

$W = \gamma A$, where $A = 2lb$

$$\therefore \quad \gamma = \frac{\text{work done}}{\text{increase in area}} = \sigma$$

$$\gamma = \sigma$$

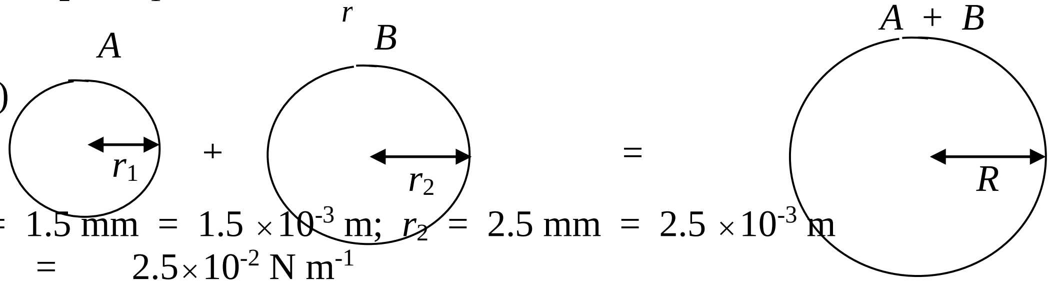
(iii) Consider an air bubble formed inside a liquid;



P_1 is liquid pressure at depth of the air bubble.
P_2 is the air pressure inside the air bubble.
F is the surface tension force.
r is the radius of the bubble.
For horizontal equilibrium of forces on the bubble;
$F + P_1A = P_2A$ where A is the perpendicular area of bubble to the horizontal direction in which the pressures are acting.

$$2\pi r\gamma + P_1\pi r^2 = P_2\pi r^2$$
$$(P_2 - P_1)\pi r^2 = 2\pi r\gamma$$
$$P_2 - P_1 = \frac{2\pi r\gamma}{\pi r^2}$$
$$P_2 - P_1 = \frac{2\gamma}{r}$$

(c)



$r_1 = 1.5$ mm $= 1.5 \times 10^{-3}$ m; $r_2 = 2.5$ mm $= 2.5 \times 10^{-3}$ m
$\gamma = 2.5\times10^{-2}$ N m^{-1}

Using the principle of conservation of surface energy,
$$2\times4\pi r_1^2\gamma + 2\times4\pi r_2^2\gamma = 2\times 4\pi R^2\gamma$$
$$R^2 = r_1^2 + r_2^2$$
$$R = \sqrt{(r_1^2 + r_2^2)}$$
But $$P_2 - P_1 = \frac{4\gamma}{R}$$
$$P_2 - P_1 = \frac{4\gamma}{\sqrt{(r_1^2 + r_2^2)}}$$

$P_2 - P_1 \quad = \quad \frac{4\times 2.5\times 10^{-2}}{\sqrt{(1.5\times 10^{-3})^2 + (2.5\times 10^{-3})^2}} \quad = \quad 34.30 \text{ N m}^{-2}$

4 (a) (i) Gravitational potential at a point is the work done to move a unit mass of 1 kg from infinity to the point in the gravitational field.

(ii)A parking orbit is the path taken by a satellite revolving round the earth in the same direction as the direction of rotation of the earth and with the same angular velocity so that it stays over the same place on the earth while the earth rotates about its axis.

(iii) Escape velocity is the minimum velocity with which a body must be launched from the surface of a planet so as to just escape completely from the gravitational influence of the planet.

(b) The total work done to move a body/rocket from the earth's surface, ($r = R_e$) to infinity, ($r = \infty$), so that it escapes is given by;

$$\int dw = \int_{R_e}^{\infty} \frac{GM_e m_r}{r^2}\, dr$$

$$W = GM_e m_r \left[\frac{-1}{r}\right]_{R_e}^{\infty}$$

$$W = \frac{GM_e m_r}{R_e}$$

In order for the body to escape it must have at least this amount of kinetic energy at launching.

$\therefore \tfrac{1}{2} m_r v^2 = \frac{GM_e m_r}{R_e}$ where v is velocity of escape.

$v^2 = 2\times \frac{GM_e}{R_e}$ Hence $v = \sqrt{\frac{2GM_e}{R_e}}$

But when the body is on the eart's surface, $GM_e = g R_e^2$

$$v = \sqrt{\frac{2gR_e^2}{R_e}} = (2gR_e)^{\frac{1}{2}}$$

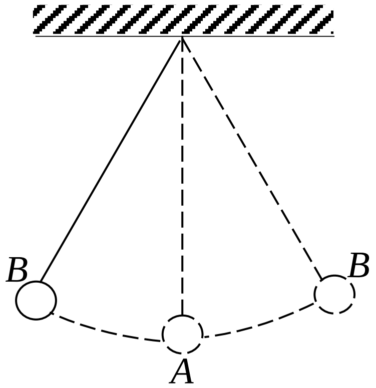
(ii) $v = (2gR_e)^{\frac{1}{2}}$

$g = 9.81 \text{ m s}^{-2}$, $R_e = 6.4 \times 10^6$ m

$v = (2\times 9.81\times 6.4\times 10^6)^{\frac{1}{2}} = 1.12 \times 10^4 \text{ m s}^{-1}$

(iii) The gravitational attraction of the moon is so small. The escape velocity at the moon's surface is less than the mean square velocity of molecules of gases. Therefore it cannot hold gases onto its surface.

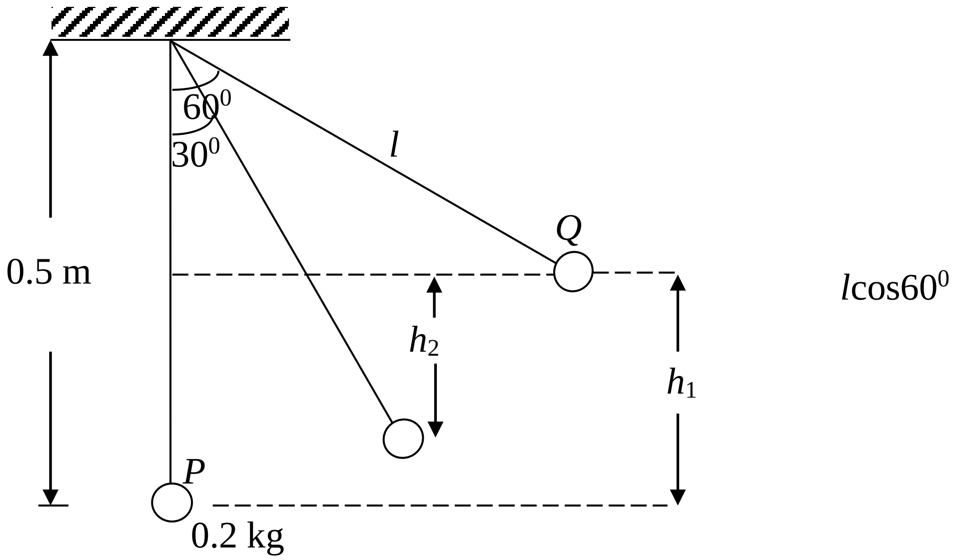
(c) (i)



- When the pendulum bob is at position B on the left, it possesses maximum potential energy p.e. and zero kinetic energy k.e;
- Between B and A its k.e. decreases at the expense of p.e. (air resistance assumed negligible).
- At A it possesses maximum k.e. and minimum or zero p.e.
- Between A and B on the right, p.e.increases at the expense of k.e.

At B on the right, it possesses maximum p.e. as before on the left and zero k.e.

(d) (i)



Maximum potential energy, $p.e._{max} = mgh_1$

But $h_1 = l - l\cos60^0 = l(1 - \cos60^0)$

$p.e._{max} = mgl(1 - \cos60^0) = 0.2 \times 9.81 \times 0.5(1 - 0.5)$

$p.e._{max} = 0.4905$ J

(ii) Loss in p.e. i.e. $p.e._{loss} = mgh_2$

$h_2 = l\cos30^0 - l\cos60^0 = l(\cos30^0 - \cos60^0)$

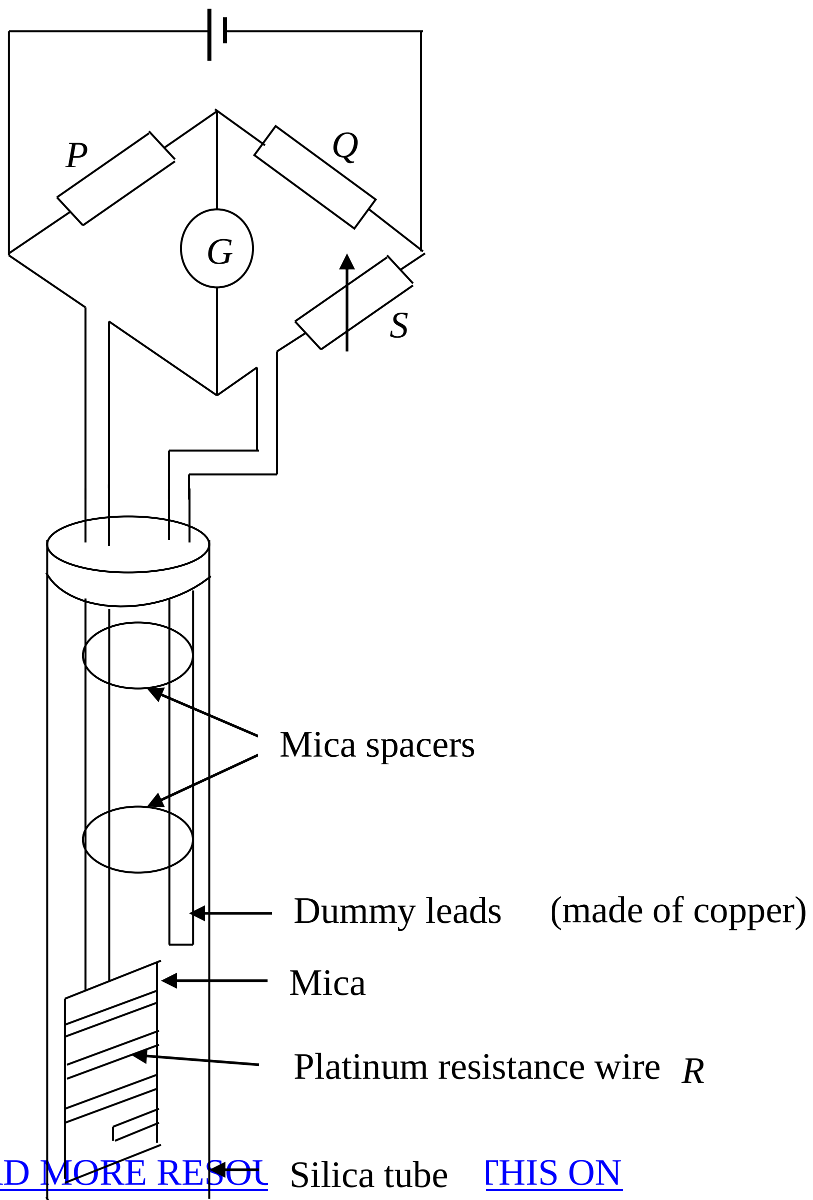
$p.e._{loss} = mgh_2 = mg\,l(\cos30^0 - \cos60^0)$

$p.e._{loss} = 0.2\times9.81\times0.5(0.866 - 0.5)$

$p.e._{loss}$ = 0.359 J

5. a) (i) A change in temperature of 1^0C is the fractional increase of resistance per temperature coefficient of resistance.

(ii)



(iii) Advantages of the resistance thermometer:

- It has a wide range (- 250^0C to 1500^0C)
- It is fairly accurate

b) $R_{300} = R_0(1 + 2400000\alpha - 90000\alpha) = R_0(1 + 2310000\alpha)$

$R_{100} = R_0(1 + 800000\alpha - 10000\alpha) = R_0(1 + 790000\alpha)$

$$\theta = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100 = \frac{R_0(1+2310000\alpha) - R_0}{R_0(1+790000\alpha) - R_0} \times 100$$

$$\theta = \frac{2310000\alpha}{790000\alpha} \times 100 = 292^0\text{C}$$

c) (i) $V_\theta = V_0(1 + \alpha\theta) \Rightarrow 38.9 = 28.5(1 + 100\alpha)$

$$-\frac{1}{\alpha} = -\frac{1}{30649 \times 10^{-3}} = -274^0\text{C}$$

(ii) $l_\theta = l_0(1 + \alpha\theta) = 100(1 - 3.649 \times 10^{-3} \times 1)$

$l_\theta = 99.64$ cm

6. a) (i) Thermometric property is the property of a substance that changes linearly and continuously with temperature and can be measured accurately.

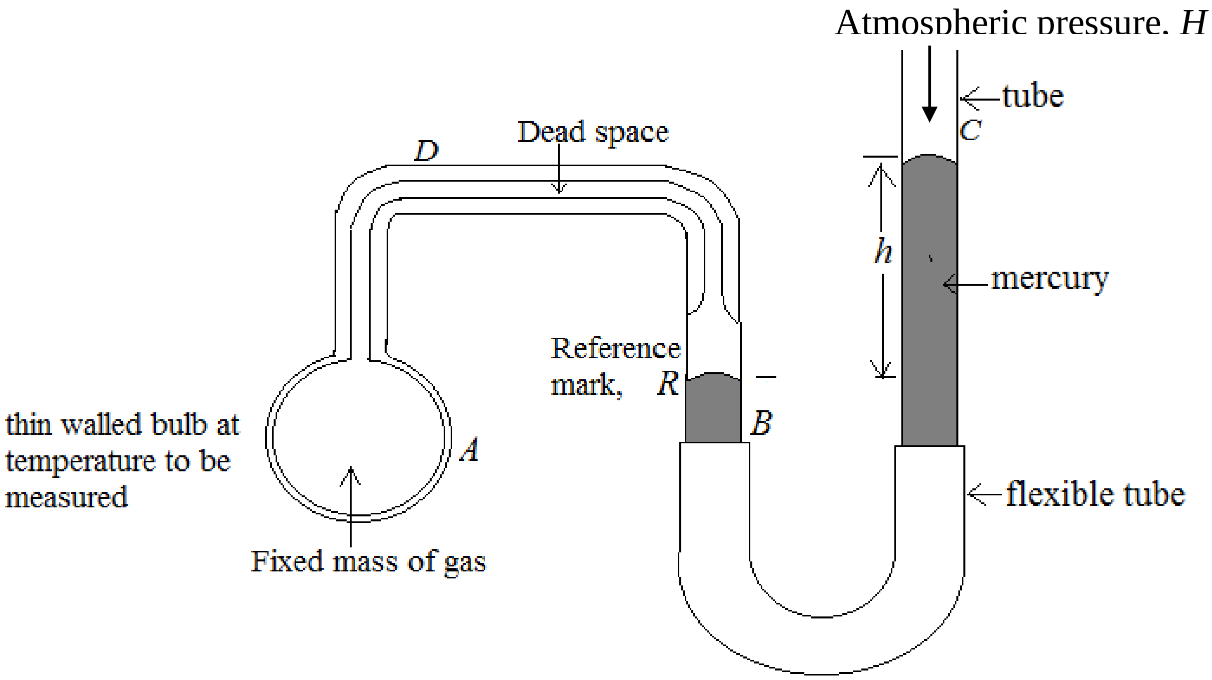
(ii) *A fixed point is the single temperature at which it can confidently be expected that a particular event always takes place*, e.g. change of state, i.e. melting of ice or boiling of water under specific conditions.

b) (i) Obtain a thermometric property e.g. pressure P of a gas at constant volume; measure the value of the property P_θ at an unknown temperature θ. Measure the value of the property P_{tr} at triple point of water.

Use $T = \frac{P_\theta}{P_{tr}} \times 273.16$ to calculate values for the temperatures in kelvin.

(ii) Different thermometers use different thermometric properties and these properties vary differently with varying temperature. Thermometers will always agree at fixed points.

c) (i)



The bulb containing the gas is immersed in the fluid/enclosure whose temperature is to be measured. Time is allowed for the gas to acquire the temperature of the fluid. The flexible/rubber tube is adjusted to bring mercury level to fixed volume mark R. the difference in mercury levels, h is measured and recorded. The gas pressure $P = H \pm h$, and it is calculated using density of mercury and acceleration due to gravity. The bulb is then immersed in an ice-water mixture and pressure P_0 obtained. It is then immersed in steam from boiling water at standard atmospheric pressure and pressure P_{100} also obtained.

The unknown temperature θ in ^{0}C is calculated by substitution in

$$\theta = \frac{P_\theta - P_0}{P_{100} - P_0} \times 100$$

(ii) Corrections that need to be made when using the thermometer in c(i):

- The dead space to be made narrow;
- The gas bulb to be made of hard glass (pyrex);
- The manometer tubes to be widened.

c) (iii)

- Non-uniformity of the bore of the capillary tube which may make the mercury rise in the bore non-uniform; factory error.
- The gradual change in the zero reading position due to bulb shrinkage resulting in non-uniform scale; old age.
- The mercury in the stem not being at the same temperature as that of the bulb leading to non-uniform expansion; bulb immersed, while stem not immersed.

7, a) (i) Heat capacity is the amount of heat required to raise the temperature of a substance by 1^{o}C or 1K while the specific heat capacity is the amount of heat required to raise the temperature of 1 kg of a substance by 1^{0}C or 1K.

Water has got a *high specific heat capacity*. It is therefore used in car radiator as a coolant because it can absorb a lot of heat from the engine before its temperature rises to boiling point, thereby keeping the engine cool for a long time unlike other liquids which would quickly heat up to boiling point and rapidly boil away.

(ii) The measurements to be made are:

- Mass of solid
- Temperature of hot solid
- Mass of calorimeter and stirrer
- Mass of liquid
- Initial temperature of liquid and calorimeter
- Final steady temperature of mixture

Given quantities:

- Specific heat capacity of liquid
- Specific heat capacity of copper.

Precautions:

- Calorimeter to be securely lagged/insulated

- Calorimeter to be placed just under the steam jacket for the specimen to be slid directly into the liquid.

b) (i) The silca tube of the platinum electrical thermometer connected to an electric circuit is immersed in the fluid of unknown temperature and the resistance R_θ of the platinum wire determined. The resistance of the wire at triple point of water R_{tr} is also determined. By substituting in the equation $T = \frac{R_\theta}{R_{tr}} \times 273.16$ a value for the unknown temperature T in Kelvin is calculated. Various other temperatures are likewise determined setting up a Kelvin scale of temperature.

(ii) $R_0 = 4.00\ \Omega$, $R_{100} = 5.46\ \Omega$. $R_\theta = 9.84\ \Omega$; $\theta = ?$

Use $\theta = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100$

$$\theta = \frac{9.84 - 4.00}{5.46 - 4.00} \times 100 = \frac{5.84}{1.46} \times 100 = 400^0\text{C}$$

c) (i) *The rate of loss of heat is directly proportional to the excess temperature over the surroundings*.

(ii) Note the temperature of a cooling liquid e.g. water, at 2 minute intervals starting from about 80^0C to about 40^0C.

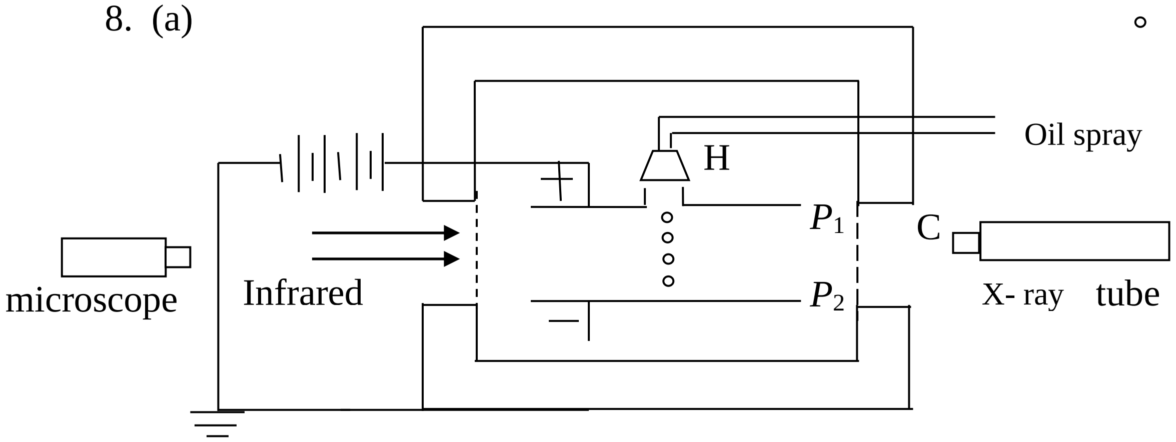
Plot the cooling curve.

Determine the rates of cooling at various points on the curve and record them against the excess temperatures over the surroundings.

Plot a graph of rate of cooling against excess temperature over the surroundings.

A straight line graph through the origin verifies the law.

8. (a)



The oil drops acquire chare through friction or by exposure to X-rays.
The intense light illuminated to the chamber is for observing the oil drop through a travelling microscope.
A suitable drop is selected and its terminal velocity, v_o, determined by measuring the distance it falls through in a measured time, when there is no p,d applied across plates P_1 and P_2 , hence;

Weight = viscous force + up thrust .... (1)

$$\frac{4\pi r^3 \rho\ g}{3} = 6\pi r\eta\ v_o + \frac{4\pi r^3 \sigma\ g}{3}$$

$$\frac{4\pi r^3}{3}(\rho - \sigma)g = 6\pi r \eta\ v_o \quad \text{.. (2)}$$

A *known p.d,V* is then applied between P_1 and P_2at a known distance of separation, *d* apart so that the drop rises up with terminal velocity, v_1
i.e. $mg + F_r = F_e + U$
v_1 is determined,

$$\frac{4\pi r^3 \rho\ g}{3} + 6\pi r\eta\ v_1 = qE + \frac{4\pi r^3 \sigma\ g}{3}$$

$$\frac{4}{3}\pi r^3(\rho - \sigma)g + 6\pi r\eta\ v_1 = qE \quad \text{... (3)}$$

Substitute for $r = \left[\frac{9\eta v_0}{2g(\rho-\sigma)}\right]^{\frac{1}{2}}$ in (3) and rearrange;

$$\boldsymbol{q} = \frac{6\pi\eta d}{V}\left[\frac{9\eta v_0}{2g(\rho-\sigma)}\right]^{\frac{1}{2}}(v_0 - v_1) \quad \text{.. . (4)}$$

Where ρ = density of oil(given)
E = $\frac{V}{d}$,electric field intensity
η = coefficient of viscosity of air(*given*); hence the value of charge *q* can be calculated by substitution in the above expression, (4).

(b) q = 24 *e*, p.d. = 1600 V, *d* = 4 mm = 4×10^{-3} m,
$v_o = 6.0 \times 10^{-4}$m s^{-1}.

(i) Before p.d. is applied; weight = up thrust + viscous force

$$\frac{4}{3}\pi r^3(\rho - \sigma)g \quad = \quad 6\pi r\eta\, v_o$$

$$r^2 \quad = \quad \frac{9\eta v_o}{2(\rho - \sigma)g}$$ assume the density of air is negligible,

$$r \quad = \quad \sqrt{\frac{9\times 1.8\times 10^{-5}\times 6.0\times 10^{-4}}{2\times 900\times 9.81}} \quad = \quad 2.346\times 10^{-6}\text{ m.}$$

(ii) When p.d. is applied;

Electric force + up thrust = weight + viscous force

$$6\pi r\eta \quad (v_o + v_1) \quad = \quad qE$$

$$v = \frac{qE}{6\pi r\eta} - v_o$$

$$v \quad = \quad \frac{24\times 1.6\times 10^{-19}\times 1600}{6\times 3.14\times 2.364\times 10^{-7}\times 1.8\times 10^{-5}\times 4\times 10^{-3}} - 6.0\times 10^{-4}$$

$$v \quad = \quad \frac{6.144\times 10^{-15}}{3.2067\times 10^{-13}} - 6.0\times 10^{-4}$$

$$v \quad = \quad 1.916\times 10^{-2} - 6.0\times 10^{-4} \quad = \quad 1.856\times 10^{-2}\text{ m s}^{-1}$$

(c) (i) Bragg's law states that the maximum intensity of diffraction occurs when the path difference of the X-rays equals an integral multiple of the wavelength of the x-ray produced.

Or $2d\sin\theta \quad = \quad n\lambda$

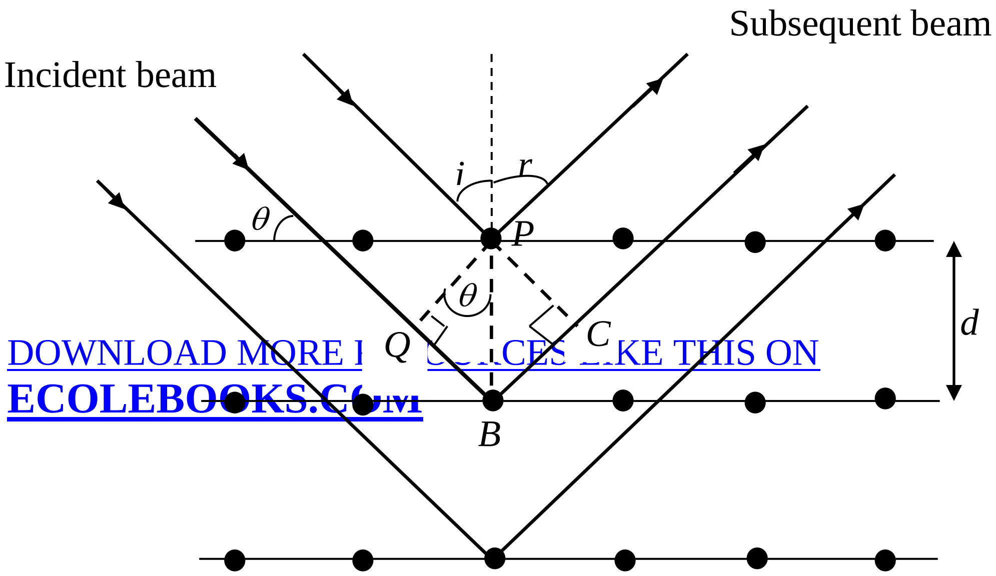
where, d is interplanner spacing,

θ is angle of diffraction (glancing angle),

n is order of diffraction,

λ is wavelength of the X-rays

Consider planes of atomic spacing, d.



Constructive interference occurs when the wave fronts are in phase such as along AP or PC. The path difference between X-rays scattered by atoms in two consecutive planes is equal to AB + BC $= d\sin\theta + d\sin\theta = 2d\sin\theta$
But constructive interference takes place if the path difference is integral multiple of the wavelength
i.e. $2d\sin\theta = n\lambda$ where n is an integer.

(ii) $n = 2$, $\theta = 11.4^0$, $d = 2.0\times10^{-10}$ m, $\lambda = ?$

$$2d\sin\theta = n\lambda$$

$$2\times2.0\times10^{-10}\sin11.4^0 = 2\times\lambda$$
$$\lambda = 2.0\times10^{-10}\times1.977\times10^{-1}$$
$$\lambda = 3.953\times10^{-11}\text{ m}$$

Question 9

(a) (i) Thermionic effect is the process by which electrons are emitted from a metal surface due to the heating effect of a low voltage supply while photo electric effect is a process by which electrons are emitted from a clean metal surface when irradiated with a radiation of high enough frequency.

(ii)

Energy of incident photon = Work function = Maximum k.e. of emitted electron

$$E = W_o + \text{k.e}_{max} \text{ or}$$
$$hf = W_o + \frac{1}{2}mv_{max}^2$$

(b) (i) *Work function* is the minimum amount of energy necessary to take a free electron out of the metal surface against attractive forces of the surrounding positive ions.

(ii) *Stopping potential* is the minimum negative p.d. required to prevent the most energetic electrons from reaching the anode.

(iii) *Threshold frequency* is the minimum frequency of the incident radiation below which no photo electric emission can take place irrespective of the intensity of the incident radiation.

(c) $W_o = 1.9 \text{ eV} = 1.9\times1.6\times10^{-19}$ J, $\lambda = 4.5\times10^{-7}$ m

From $hf = W_o + \text{k.e}_{max}$, and also k.e. $= eV_s$

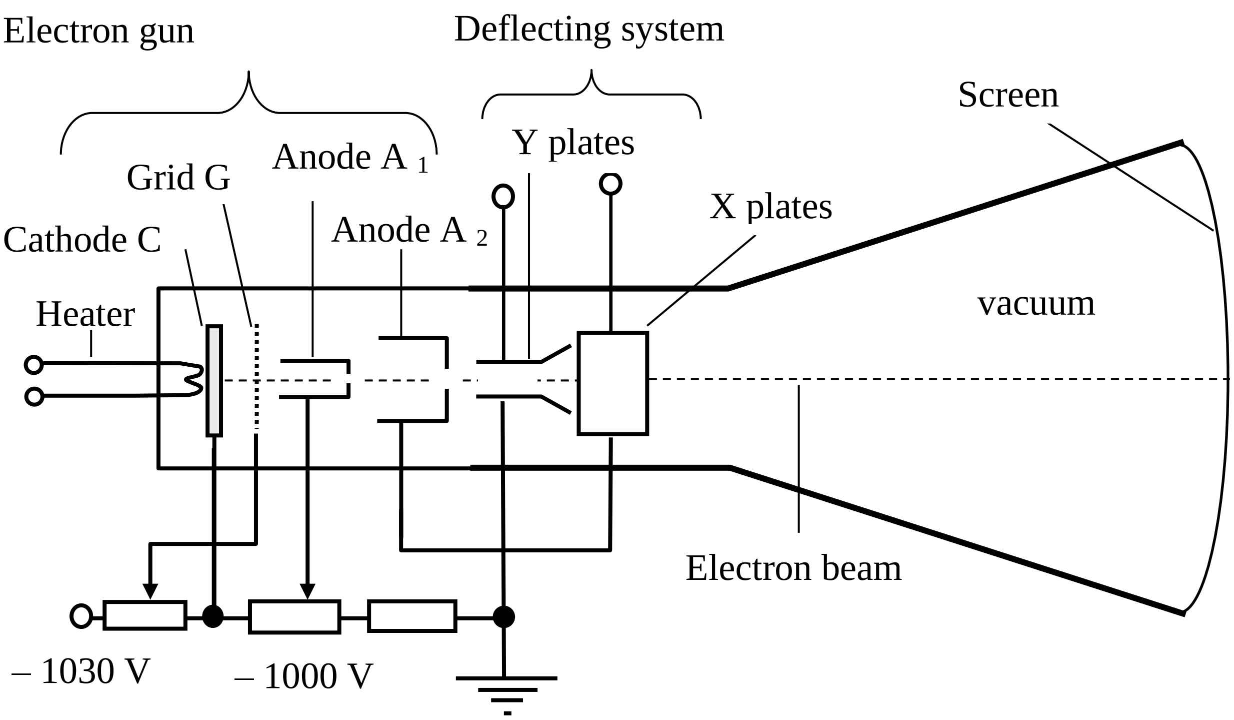
$h\frac{c}{\lambda} = W_o + eV_s$, where c is the velocity of light, V_s is the stopping potential.

$$eV_s = h\frac{c}{\lambda} - W_o$$

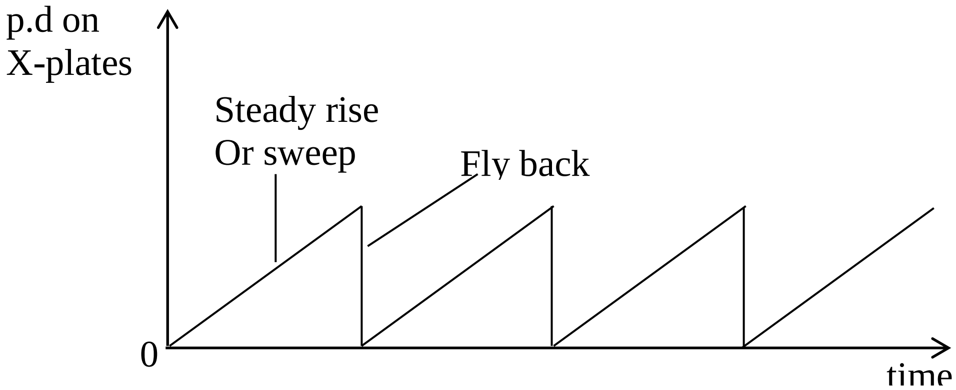
$$1.6\times10^{-19}V_s = 6.63\times10^{-34}\times\frac{3.0\times10^{8}}{4.5\times10^{-7}} - 1.9\times10^{-19} = 1.38\times10^{-19}$$

$$V_s = \frac{1.38\times10^{-19}}{1.6\times10^{-19}} = 8.625\times10^{-1}\text{ V}$$

(d) (i)



(ii) The time base provides a saw tooth p.d. that sweeps the electron spot from the left to the right of the screen at steady speed.



(e) Peak to peak voltage, $V = 10\times 8 = 80$ V

Therefore, peak voltage, $V_o = \frac{V}{2} = \frac{80}{2}$

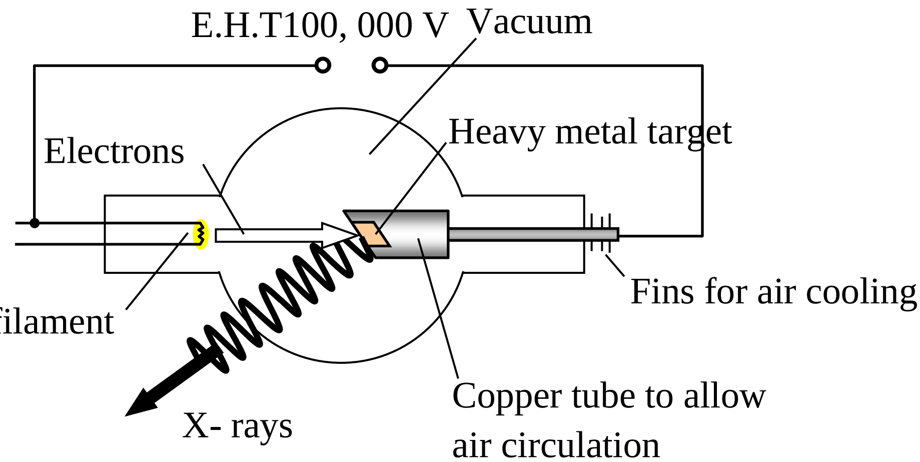
$V_o = 40$ V

But $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{40}{\sqrt{2}} = 28.28$ V

$f = \frac{1}{T}$ where T is period. Since 3 cycles took 0.01 s, $T = \frac{0.01}{3}$

$f = \frac{1}{0.01}\times 3 = 300$ Hz

10. (a) (i)



The electrons emitted thermionically by the heated tungsten filament are accelerated by the high anode voltage and travel in vacuum at high velocity towards the anode. They strike the target made of heavy metal of high melting point e.g. tungsten, placed on the anode, giving up their kinetic energy to the atoms of the target. Electron displacements in the shells closest to the nuclei of the atoms of the target take place and in the process, *X* - rays and a lot of heat are produced. Evacuation of the *X* - ray tube prevents the unnecessary collisions of the electrons with the air molecule which would result in loss of energy due to ionisation of the molecules of air.

(ii)

- *X* - rays are simply a flow of energy in form of electromagnetic waves while beta particles are particles having mass.
- *X* - rays originate from high energy changes in the electron structure deep inside the atoms while beta particles originate from the nucleus of unstable atoms as the atoms disintegrate in order to acquire more stable forms.
- *X* - rays carry no charge while beta particles are charged.

(iii) *X* - rays are produced by metal atoms when the metal absorbs energy from first moving electrons that cause electron displacements in shells closest to the nuclei of the atoms when electrons return to low energy levels giving out energy as *X* - rays, while cathode rays are emitted free electrons in the surface of hot metals and get accelerated by an anode nearby.

(b) $\frac{e}{m} = \frac{E}{B^2 r}$ where r is the radius of the curve taken by the electron in magnetic field, E is electric field intensity.

But $r = \frac{HK \times OL}{OG}$ where HK is the length of plates, OL is distance of screen from centre of plates, OG is electron displacement on screen.

$OL = 20.0 + 2.0 = 22.0$ cm $= 0.220$ m, $OG = 10.0$ cm $= 0.1$ m,

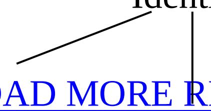
$HK = 4.0$ cm $= 0.04$ m, $B = 1.14$ T

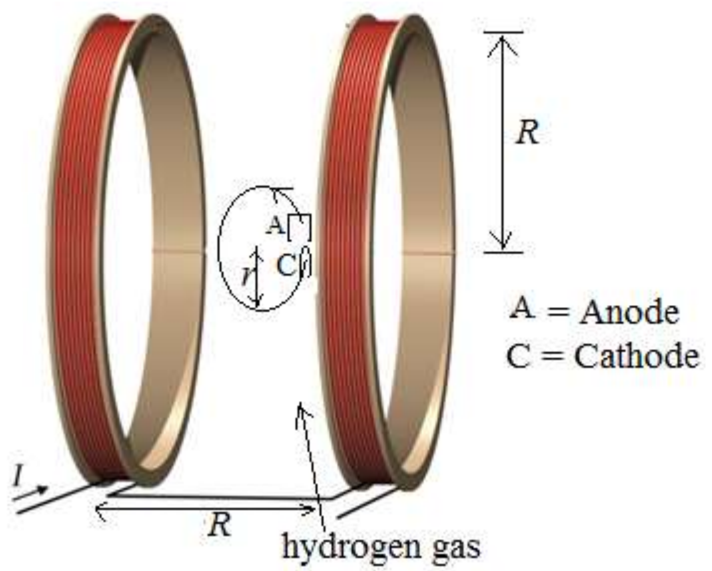
$$r = \frac{0.04 \times 0.22}{0.1} = 0.088 \text{ m}$$

$$E = \frac{200}{0.01} = 20{,}000 \text{ V m}^{-1}$$

$$\therefore \frac{e}{m} = \frac{20000}{(1.14 \times 10^{-3})^2 \times 0.088} = \frac{20000}{1.14 \times 10^{-6}} = 1.75 \times 10^{10} \text{ C kg}^{-1}$$

(c) Identical coils





Theory :

When current is switched on to flow through the cathode, the cathode gets heated up and emits electrons. Another *I* is also switched on to flow in the two identical coils of the tube, of known radius *R* and number of turns *N* producing a uniform magnetic field of density *B* between them. When a positive potential is applied at the anode A, the emitted electrons at the hot cathode are accelerated and get constantly deflected by the magnetic force to follow a circular path of radius *r*. *r* is measured using a travelling microscope and recorded. *The p.d V, applied between A and C, and the current I, flowing in the coils are also measured and recorded*.

Note that $eV = \frac{1}{2} mu^2$ .... (1)

Where *u* is the velocity of the electrons.

Again $Beu = \frac{mu^2}{r}$ (considering centripetal force on electrons).

$u = \frac{Bre}{m} \Rightarrow u^2 = \frac{B^2r^2e^2}{m^2}$ .... (2)

Substituting for u^2 in (1) and rearranging, $2V = B^2r^2\frac{e}{m}$

$\frac{e}{m} = \frac{2V}{B^2r^2}$ .... (3)

For Helmholtz coils, $B = \frac{0.72\mu_o NI}{R}$ .... (4)

Substitution for *N*, *I*, *R* and μ_o is made in equation (4) and a value of *B*, calculated. Finally substitution for *V*, *B* and *r* is made in (3) and the specific charge $\frac{e}{m}$ calculated. The experiment can be repeated by varying the current through the coils to obtain several values of $\frac{e}{m}$ so that an average value can be calculated.