Do not write in this margin

Candidate's Name: PHYSICS
Signature: PAPER I
Subject .... Paper code ....../...

Random No.				
Personal Number				

Question 1

1 (a)(i) Is the way a derived quantity is related to the fundamental quantities of mass length and time. 01

(ii) $C = F / \frac{1}{2}(\rho V^2 A)$.

$[F] = MLT^{-2}$; $[\rho] = ML^{-3}$, $[V] = LT^{-1} \Rightarrow [V^2] = L^2T^{-2}$

$[A] = L^2$

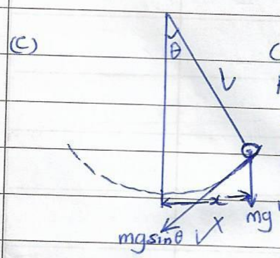
$\Rightarrow [C] = \dfrac{[F]}{[\rho]\times[V^2]\times[A]} = \dfrac{MLT^{-2}}{ML^{-3}\times(L^2T^{-2})\times L^2} = 1$

$\therefore$ C is a dimensionless constant. 04

(b)(i) S.h.m is the period motion of a body whose acceleration is directed towards a fixed point and is directly proportional to the displacement from the fixed point. 01

(ii) S.hm is — a periodic motion
- its acceleration is directed towards a fixed point.
- its acceleration is directly proportional to the fixed point.
-

(c)



Component of weight towards the equilibrium position $= mg\sin\theta$

Restoring force, $F = -mg\sin\theta$.

But $F = ma$; $\therefore ma = -mg\sin\theta$

For small angle, θ ; $\sin\theta \simeq \theta = \frac{x}{l}$

$\Rightarrow ma = -mg\frac{x}{l}$; $a = -\frac{g}{l}x$ with $a = -w^2x$

$\Rightarrow w^2 = \frac{g}{l}$ but w ~~...~~ $w = 2\pi f$

$4\pi^2 f^2 = \frac{g}{l}$; $f^2 = \frac{1}{4\pi^2}\cdot\frac{g}{l}$; $f = \frac{1}{2\pi}\sqrt{\frac{L}{g}}$ 06

(d) Clamp the spring on a retort stand.
Fix a horizontal pin at the free end of the spring to act as a pointer.
Place a vertical metre rule next to the pin and note its initial position.
Suspended a known mass, m to the free end of the spring.
Note and record the new position of the pointer.
Calculate the extension, e produced.
Repeat the procedure above for different values of masses and obtain corresponding values of extensions.
Plot a graph of e against m.
Calculate the slope, s of the graph.
Get the acceleration due to gravity, g from $g = ks$ where K is the known force constant of the spring. 06

Candidate's Name ....

Signature ....

Subject .... Paper code ..../......

Random No.					
Personal Number					

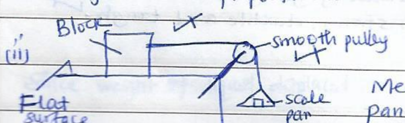
Question 2.

2 (a)(i) Surfaces have very small projections and when placed together, the actual area of contact is very small. The pressure at the points of contact is therefore high. The projections merge a little producing cold welds at these points.
The welds have to be broken for relative motion to occur. This explains the fact that friction opposes the relative motion between surfaces in contact.

When the area between the surfaces is changed, the actual contact area remains constant, hence no change in friction. This explains the fact that friction is independent of the area of contact provided the normal reaction is constant.

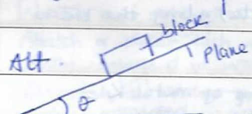
Increase in normal reaction increases the pressure at the welded points. This increases the actual area of contact to support a bigger load and friction increases. Hence friction is proportional to the normal reaction. 06

(ii)



Add small masses on a scale pan one by one until the block just starts to move.
Measure and record the total mass, m of the scale pan and its contents.
Limiting friction is got from mg. 04

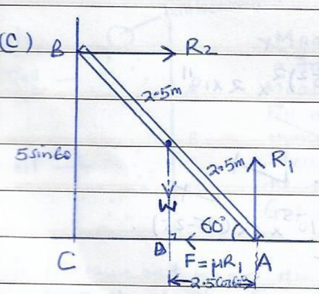
Alt.



The mass, m of the block is measured and recorded.
The block is placed on a horizontal surface. The surface is gradually tilted until the block just starts to move.
The angle, θ between the plane and the horizontal surface is measured and recorded.
Limiting friction = mg sinθ. 04

(b) When a vehicle moves on a rough surface, friction between the tyre and the surface causes heating, so the temperature of the air inside the tyre increases. The kinetic energy of the air molecules in the tyre increases leading to increased pressure inside the tyre and the tyre may burst. 04

(c)



$(\uparrow)$: $R_1 = W = 20g$ ——(i)

$(\rightarrow)$: $R_2 = \mu R_1$; $R_2 = 20g\mu$ ——(2).

$\overset{\frown}{A}$: $R_2 \times \overline{BC} = W \times \overline{AD}$

$20g\mu \times 5\sin 60^\circ = 20g \times 2.5\cos 60^\circ$

$\mu = \dfrac{2.5\cos 60^\circ}{5\sin 60^\circ}$

$\mu = 0.289$ 04

(e) Friction is used in
- generation of static friction
- lighting of a match box

(first two) 02

- writing
- walking
- hydraulic brake systems in vehicles.

20

Do not write in this margin

Candidate's Name ....

Signature .... | Random No. | | | | | |

Subject .... Paper code ..../..... | Personal Number | | | |

Question 3

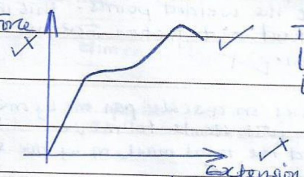
3 (a) Elastic limit is a point below which a material regains its original shape and size when the deforming load is removed.

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

(b)(i) When a wire is stretched elastically, energy changes from PE → KE → PE. No heat is produced ~~and~~ so ME is conserved.

(ii) When a wire is stretched plastically, energy changes from PE → KE → Heat → PE. Mechanical energy is not conserved.

(c)



The wire undergoes both elastic and plastic deformation.
It has a high value of young's modulus.
~~It is also stiff, strong, ductile and tough.~~

(d)(i) Metal L; since it has a small slope (stress-strain ratio) along the linear part of the graph.

(ii) Metal L; since it has a small plastic region than that of metal K.

(iii) Metal L; since it can withstand a small stress (breaks easily at a small stress).

(e)(i) $\alpha = \frac{l}{L\Delta\theta} \Rightarrow e = \alpha L \Delta\theta$; e = extension

Force, $F = \frac{eAE}{L}$ $\therefore F = \frac{\alpha L \Delta\theta AE}{L}$

$F = \alpha \Delta\theta AE$

$F = 1\times10^{-5} \times (75-25) \times \pi (1\times10^{-2})^2 \times 2\times10^{11}$

$F = 3.142\times10^{4}\,N$

(ii) Energy stored in the wire $= \frac{1}{2}Fe = \frac{1}{2}F\alpha L\Delta\theta$.

$= \frac{1}{2} \times 3.142\times10^{4} \times 1\times10^{-5} \times 1 \times (75-25)$

$= 7.855\,J$.

Do not write in this margin

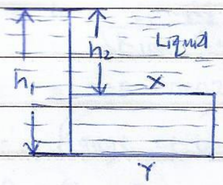
Candidate's Name ....

Signature .... | Random No. | | | | |

Subject .... Paper code ..../...... | Personal Number | | | |

Question 4

(a) Archimedes's principle states that when a body is wholly or partially immersed in a fluid, it experiences an upthrust that is equal to the weight of the fluid displaced. 01



Pressure at a depth, $h_1 = (h_1 \rho g + H)$

Force on Y, $F_Y = (h_1 \rho g + H)A$

Pressure at a depth, $h_2 = (h_2 \rho g + H)$

Force on X, $F_X = (h_2 \rho g + H)A$

Resultant upward force = upthrust $= F_Y - F_X = (h_1 - h_2)\rho g A$

Weight of solid = weight of liquid displaced = mass of liquid displaced × volume of liquid displaced × acceleration due to gravity.

$= A\rho \times (h_1 - h_2) \times g$

$= (h_1 - h_2)\rho g A$.

Since weight of liquid displaced is equal to upthrust, Archimedes's principle is verified. 04

(b) Weigh and note the weight, W_1 of the test solid in air.

Attach a sinker such as a stone to the test solid and weigh and note their weight, W_2 when fully immersed in water.

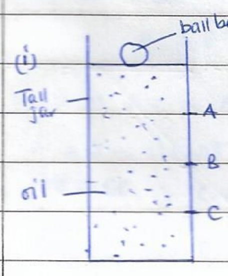
Detatch the sinker from the test solid and note the weight, W_3 of the sinker when fully immersed in water.

Get the weight of solid in water $= W_2 - W_3$

$R.D$ of solid $= \frac{\text{weight in air}}{\text{upthrust in water}} = \frac{W_1}{W_1 - (W_2 - W_3)}$.

Density of solid $= (R.D \times 1000)\ kgm^{-3}$. 04

(c) (i)



Mark three points A, B and C on one side along a vertical line of a transparent tall vessel.

Measure and record the distances $\overline{AB}$ and $\overline{BC}$

Fill the jar with oil and allow the ball bearing to fall centrally through the oil.

Measure and record the times, t_1 and t_2 the ball bearing takes to fall from A to B and from B to C.

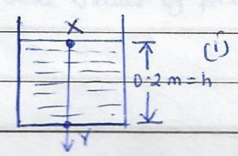
Get the terminal velocity of the ball bearing from $V_0 = \frac{\left(\frac{\overline{AB}}{t_1} + \frac{\overline{BC}}{t_2}\right)}{2}$. 04

(ii) Measure and record the diameter and hence radius, r of the ball bearing.

Note the density, δ of oil and ρ of the ball bearing.

Get η from $\eta = \frac{2r^2 g(\delta - \rho)}{9\eta}$ 02

(d)



(i) PE at X = KE at Y

$mgh = \frac{1}{2}mV^2$

$V = \sqrt{2gh}$; $V = \sqrt{2 \times 9.81 \times 0.2}$; $V = \cancel{3.98}$ $1.98\ ms^{-1}$ 02

UGANDA NATIONAL EXAMINATIONS BOARD
NOVEMBER - DECEMBER, 2020

Do not write in this margin

Candidate's Name ....

Signature ....

Random No.					
Personal Number					

Subject .... Paper code ..../......

(ii) Rate of mass flow = cross-sectional area x velocity x density.

$= \pi r^2 \times v \times \rho$

$= \pi (2.5 \times 10^{-3})^2 \times 1.98 \times 1000$

$= 0.0389 \ kgs^{-1}$

Candidate's Name ....

Signature ....

Random No.				
Personal Number				

Subject .... Paper code ..../.....

Question 5

5(a) Temperature of 60°C means that if the values of resistance at 0°C is R_0; at 100°C is R_{100} then at 60°C, the value of resistance is R_{60}.

$$\Rightarrow \theta = \left(\frac{R_{60} - R_0}{R_{100} - R_0}\right) \times 100°C.$$ 02

b(i) $E_\theta = 20\theta - 0.02\theta^2$; $\frac{dE_\theta}{d\theta} = 20 - 0.04\theta = 0$; $\theta = \left(\frac{20}{0.04}\right) = 500°C$

$\therefore$ Range of temperature $= (0 - 500\ °C)$ 03

(ii) $\theta = \left(\frac{E_\theta - E_0}{E_{100} - E_0}\right) \times 100\ °C \Rightarrow \theta = \frac{E_\theta}{E_{100}} \times 100\ °C$.

$E_\theta = 6.5mV$; $E_{100} = [(20 \times 100) - (0.02 \times 100^2)] = 1800mV$.

$\theta = \left(\frac{6.5}{1800} \times 100\right) = 0.361°C$ 04

c(i) Total heat energy supplied to a system is equivalent to the sum of the change in internal energy and work done by the system. 01

(ii) From first law of thermodynamics, $\Delta Q = \Delta U + \Delta W$.
At constant volume, $\Delta W = 0$; $\Delta Q = \Delta U = nC_V\Delta T$
At constant pressure, $\Delta W = P\Delta V$; ~~$\Delta Q = nC_p\Delta$~~ $\Delta Q = nC_p\Delta T$.

$\Rightarrow nC_p\Delta T = nC_V\Delta T + P\Delta V$.

For an ideal gas, $PV = nRT$; $P(V+\Delta V) = nR(T+\Delta T)$
$\therefore P\Delta V = nR\Delta T$.

$\Rightarrow nC_p\Delta T = nC_V\Delta T + nR\Delta T$

$\therefore C_p = C_V + R \Rightarrow C_p - C_V = R$. 05

(d) $\Delta Q = \Delta U + \Delta W$; $nC_p\Delta T = nC_V\Delta T + \Delta W$

$\Rightarrow \Delta Q = nC_p\Delta T$; $3\times10^4 = n \times 29.1 \times (323 - 273)$; $n = 20.6$

$\Rightarrow \gamma = \frac{C_p}{C_V}$; $C_V = \frac{C_p}{\gamma} = \left(\frac{29.1}{1.4}\right) = 20.8$

$\Delta U = nC_V\Delta T$; $\Delta U = 20.6 \times 20.8 \times (323 - 273)$; $\Delta U = 21424J$

$\Rightarrow \Delta Q = \Delta U + \Delta W$

$3\times10^4 = 21424 + \Delta W$; $\Delta W = (3\times10^4 - 21424) = 8576J$. 04

e) A reversible process is one that can take place in the reverse direction through the same values of pressure, volume and temperature in small steps. 01

20

UGANDA NATIONAL EXAMINATIONS BOARD
NOVEMBER - DECEMBER, 2020

Do not write in this margin

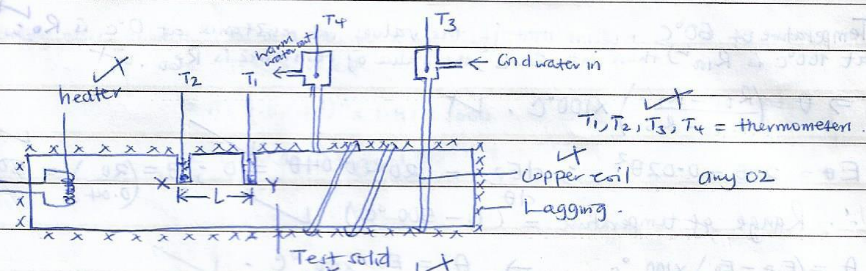
Candidate's Name ....

Signature .... Random No.

Subject .... Paper code ..../..... Personal Number

Question 6

6(a)



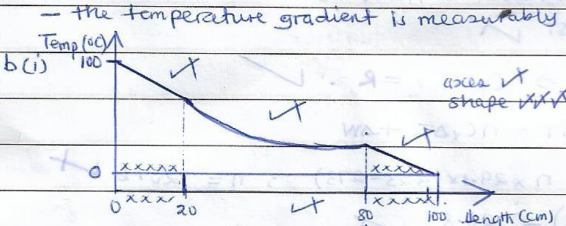
02

Measure and record the length, L between the holes X and Y.
Insert thermometers T_1 and T_2 in ~~Y~~ and X and fill X and Y with oil to ensure good thermal contact for T_1 and T_2.
Lag the solid well and allow water to flow at a constant rate through the copper coil from a constant head tank.
Switch on the electrical heater until a steady state condition is reached at which all the four thermometers T_1, T_2, T_3 and T_4 indicate steady temperatures.
Read and record their corresponding temperatures θ_1, θ_2, θ_3 and θ_4 respectively.
Rate of heat flow through the solid, $\frac{dQ}{dt} = KA(\theta_2 - \theta_1)$ where A is the cross-sectional area and K is the thermal conductivity of the solid.
At steady state condition, heat supplied is used to raise the temperature of the flowing water and is given by $\frac{dQ}{dt} = mc(\theta_4 - \theta_3)$ where m is the mass flowing persecond and c is the specific heat capacity. 05

At balance $\frac{dQ}{dt} = \frac{KA(\theta_2 - \theta_1)}{L} = mc(\theta_4 - \theta_3)$ from which K is got. 05

(ii) – the rate of heat flow through the conductor is measurable.
– the temperature gradient is measurably steep.

b(i)



(ii) For the first and last 20cm of the bar, no heat is lost and so the rate of heat flow is uniform. For the middle 60cm, heat is lost to the surrounding and so the rate of heat flow is not uniform. 03

(c)(i) $Q_c = Q_b + Q_s$: $\frac{K_cA(100-\theta)}{L_c} = \frac{K_bA(\theta - 0)}{L_b} + \frac{K_sA(\theta - 0)}{L_s}$; θ = temp. of the junction

$\frac{385A(100-\theta)}{0.4} = \frac{108A\theta}{0.1} + \frac{50A\theta}{0.5}$; $962.5(100-\theta) = 1080\theta + 333.3\theta$

$\therefore \theta = 40.5°C$. 04

(ii) Heat current in the copper rod = rate of heat flow = $\frac{K_cA(100-\theta)}{L}$

$= \left(\frac{385 \times 2 \times 10^{-4} \times (100 - 40.5)}{0.4}\right) = 11.5\ Js^{-1}$ 02

20

Do not write in this margin

Candidate's Name ....

Signature ....

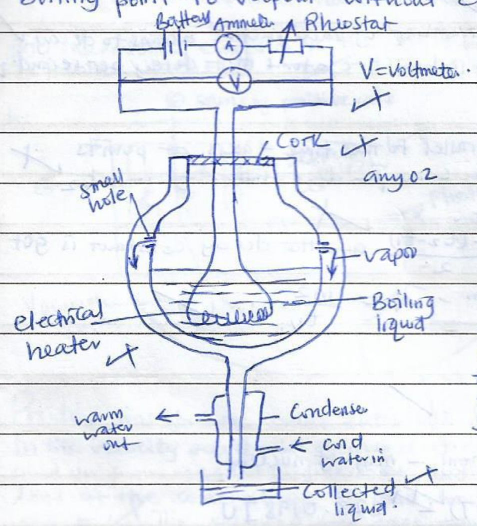
Subject .... Paper code ..../......

Random No.				
Personal Number				

Question 7

7(a) Is the quantity of heat required to change a 1kg mass of a liquid at boiling point to vapour without change in temperature. 01

(b)



Power is switched on and the liquid heated until it boils. A stop clock is started and the mass, m_1 collected is noted together with the time, t taken. The ammeter reading, I_1 and voltmeter reading V_1 are noted.

At steady state, $I_1V_1t = m_1L_v + h$ — (i)

The rheostat is adjusted to obtain new ammeter reading I_2 and voltmeter reading, V_2 and the mass, m_2 collected in the same time, t also noted.

Hence $I_2V_2t = m_2L_v + h$.

Specific latent heat of vaporization L_v is got from $L_v = \frac{(I_2V_2 - I_1V_1)t}{m_2 - m_1}$ 05 07

where h = heat lost to the surrounding.

(c) Contrary to the method of mixtures, in the continuous flow method;

- cooling correction is not required
- heat capacity of the apparatus is not required
- heat losses are accounted for. (first 3) 03
- heat loss is minimized by the vacuum.

(d) (i) ~~$Pt = mL_v + h$~~ ; L_v = specific latent heat of vaporization.

$L_v = \frac{(P_1 - P_2)t}{m_1 - m_2}$; $L_v = \frac{(12-7)(30\times60)}{(8.6-5)\times10^{-3}}$ $\therefore L_v = 2.5\times10^6\ J\,kg^{-1}$ 03

(ii) $P_1t = m_1L_v + h$; $h = P_1t - m_1L_v$

$h = (12\times30\times60) - (8.6\times10^{-3}\times2.5\times10^6)$

$h = 100J$

Power loss $= \frac{h}{t} = \left(\frac{100}{30\times60}\right) = 0.056 W$ 03

(e) Evaporation causes the most energetic molecules at the liquid surface to escape. The molecules that remain are those with low kinetic energy. Since KE of the molecules is directly proportional to temperature, the liquid cools. 03

20

Do not write in this margin

Candidate's Name ....

Signature .... Random No.

Subject .... Paper code ..../..... Personal Number

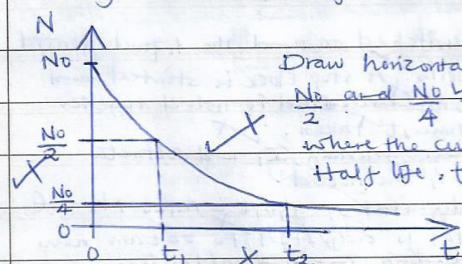
Question 8

8(a) Radioactive ~~day~~ decay is the spontaneous disintegration of the unstable nuclei of atoms accompanied by release of energy.

Half life is the time taken for half the number of radioactive atoms to decay.

Decay constant is the fractional number of radioactive atoms that decay per second.

(b)



Draw horizontal lines parallel to the time-axis at points $\frac{No}{2}$ and $\frac{No}{4}$. Note the corresponding times t_1 and t_2 where the curve is cut.

Half life, $t_{1/2} = \frac{t_1 + (t_2 - t_1)}{2}$ and the decay constant is got from $\lambda = \frac{\ln 2}{t_{1/2}}$.

C(i) Number of neutrons $= (227 - 87) = 140$

Mass defect = Mass of protons + Mass of neutrons − mass of nucleus.

$= [(87 \times 1.0073) + (140 \times 1.0087) - 223.0198]\,U$

$= (87.6351 + 141.281) - 223.0198$

$= (228.8531 - 223.0198)\,U$

$= 5.8333\,U$

(ii) The total mass of all the nucleons is greater than the mass of the nucleus. The difference in mass is the measure of the binding energy of the nucleus.

d(i) Quantum theory postulates that light energy exist in discrete units called quanta and that each quantum of energy, E is carried by a photon. When incident on a metal surface, each photon interacts with only one electron giving it all or none of its energy. If the energy is equal or greater than the work function of the metal, the energy is absorbed and an electron is immediately ejected. When the intensity of the incident radiation is increased, more electrons get ejected from the metal surface per second. Hence photo current $\propto$ to the intensity of the incident radiation.

(ii) Used to operate barglar alarms.
When an intruder intercepts infra-red radiation falling on a photo cell, current flowing in it is interrupted.
This sets off an alarm and sound is made.

Do not write in this margin

Candidate's Name ....

Signature .... Random No.

Subject .... Paper code ..../...... Personal Number

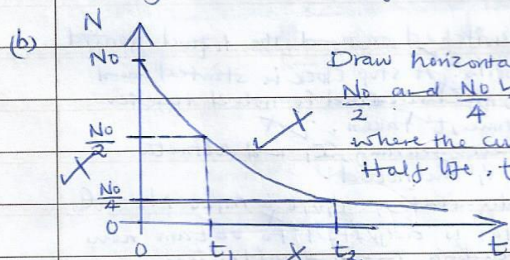
Question 8

8(a) Radioactive ~~day~~ decay is the spontaneous disintegration of the unstable nuclei of atoms accompanied by release of energy.

~~Half life~~ is the time taken for half the number of radioactive atoms to decay.

~~Decay~~ constant is the fractional number of radioactive atoms that decay per second.

(b)



Draw horizontal lines parallel to the time - axis at points $\frac{N_o}{2}$ and $\frac{N_o}{4}$. Note the corresponding times t_1 and t_2 where the curve is cut.

Half life, $t_{1/2} = \frac{t_1 + (t_2 - t_1)}{2}$ and the decay constant is got from $\lambda = \frac{\ln 2}{t_{1/2}}$.

C(i) Number of neutrons $= (227 - 87) = 140$.

Mass defect = Mass of protons + Mass of neutrons − mass of nucleus.

$= [(87 \times 1.0073) + (140 \times 1.0087) - 223.0198]\,U$

$= (87.6351 + 141.281) - 223.0198$

$= (228.8531 - 223.0198)\,U$

$= 5.8333\,U$

(ii) The total mass of all the nucleons is greater than the mass of the nucleus. The difference in mass is the measure of the binding energy of the nucleus.

d(i) Quantum theory postulates that light energy exist in discrete units called quanta and that each quantum of energy, E is carried by a photon. When incident on a metal surface, each photon interacts with only one electron giving it all or none of its energy.

If the energy is equal or greater than the work function of the metal, the energy is absorbed and an electron is immediately ejected.

When the intensity of the incident radiation is increased, more electrons get ejected from the metal surface per second. Hence photo current ∝ to the intensity of the incident radiation.

(ii) Used to operate barglar alarms.

When an intruder intercepts infra-red radiation falling on a photo cell, current flowing in it is interrupted.

This sets off an alarm and sound is made.

Candidate's Name ....

Signature .... Random No.

Subject .... Paper code ..../...... Personal Number

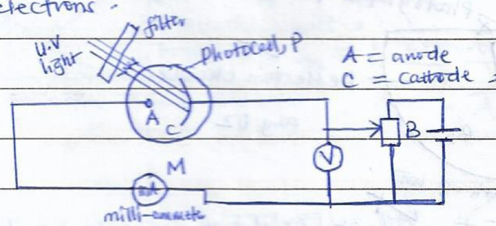
Question 10

10(a) (i) Is the frequency below which no photoelectric emission occurs however intense the incident radiation is.

Work function is the minimum energy required to liberate an electron from a metal surface.

(ii) When a metal surface is irradiated by an electromagnetic radiation, of high and enough frequency, the electrons there absorb the energy from the radiation as internal energy. If this energy is sufficient enough, the electrons overcome the inward attraction by the positive nuclei and are ejected as photo-electrons.

(b)



A = anode
C = cathode, V = Voltmeter.
B = Potential divider

Monochromatic U.V light is made to fall on the Cathode, C of the Photo Cell, P. The cathode is made positive with respect to the anode, A. The p.d between C and A is varied until the milli-ammeter, M just reads zero. The voltmeter reading is noted from the voltmeter and is the stopping potential of the metal.

c (i) The leaf falls. This is because electrons from the zinc plate are lost through photo-electric effect and electrons at the lower part of the electroscope move from the leaf through the cap to the zinc plate to replace the lost electrons. Hence the number of electrons at the lower part of the electroscope reduces, the force of repulsion the leaf and metal rod reduces and the leaf falls.

(ii) No effect is observed when infra-red radiation falls on the zinc plate. This is because infra-red radiation has a frequency below the threshold frequency required for photo-electric emission.

(iii) If uv light falls on the zinc plate connected to a positively charged electroscope, there is no change in the divergence of the leaf. This is because the electrons emitted by photo-electric effect are attracted back by the positively charged zinc plate.

(d) $hf = \frac{hc}{\lambda_1} = W_0 + \frac{1}{2}mV_{max}^2$; $\frac{hc}{\lambda_2} = W_0 + \frac{1}{2}mV_{max}^2$

When electrons just emerge from a metal surface ; $\frac{1}{2}mV_{max}^2 = KE_{max} = 0$

$\frac{hc}{6\times10^{-7}} = W_0$ — ①

When electrons get emitted, $\frac{1}{2}mV_{max}^2 = KE_{max} = 4\times10^{-20}$

$\frac{hc}{5.5\times10^{-7}} = W_0 + 4\times10^{-20}$ — ②

① in ② $\frac{hc}{5.5\times10^{-7}} = \frac{hc}{6\times10^{-7}} + 4\times10^{-20}$; $h = \frac{4\times10^{-20}\times10^{-7}}{\left(\frac{1}{5.5}-\frac{1}{6}\right)c}$

$h = \left[\frac{4\times10^{-27}}{\left(\frac{1}{5.5}-\frac{1}{6}\right)\times3\times10^{8}}\right] = 8.89\times10^{-34}\ Js$