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ACEITEKA MOCK
PHY (P510/1), 2024

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST: 2024

FOR ANY ADDITIONS PLEASE WHATSAPP 0754440607 THANKS Asuman.

PROPOSED

CANDIDATE'S NAME: MARKING GUIDE .... INDEX No. ....

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READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE USING THE ANSWER BOOKLET.

1. Use a blue or black ball pen.
2. List the question numbers in the order attempted, in the left-hand column of the box opposite.
   Do not list the multiple choice questions.
3. Write your answers on both sides of each sheet.
4. Do your rough work in this answer booklet. Cross through any work you do not want to be marked.
5. Do not tear any part of the answer booklet.
6. Check that you have written the information required on each additional answer booklet used. Tie all the booklets used together.
7. Do not share your work with another candidate or expose your work such that another candidate can copy from it.

Question number attempted	For Examiners use only	
	Marks	Examiners' initials
Total		

Write here the number of answer booklets you have used.	

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WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST:

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CANDIDATE'S NAME:............ INDEX No............

SUBJECT:............ PAPER:............ SIGNATURE............

SECTION A.

Question 1(a)

(i) Every body continues in its state of rest or uniform motion in a straight line unless acted on by an external force.

The rate of change of momentum is directly proportional to the applied force and takes place in the direction of the applied force.

For every action, there is an equal but opposite reaction.

03

Question 1(a)

(ii) From Newton's second law;

$$F \propto \frac{\text{change in momentum}}{\text{time taken}}$$

If a body is of mass, m moving at an initial velocity u and attains a final velocity, v for a time, t, then,

$$F \propto \frac{mv - mu}{t}$$

$$F \propto \frac{m(v-u)}{t}$$

02

$$F = \frac{km(v-u)}{t}$$

$$\text{but } a = \frac{v-u}{t}$$

$$F = kma$$

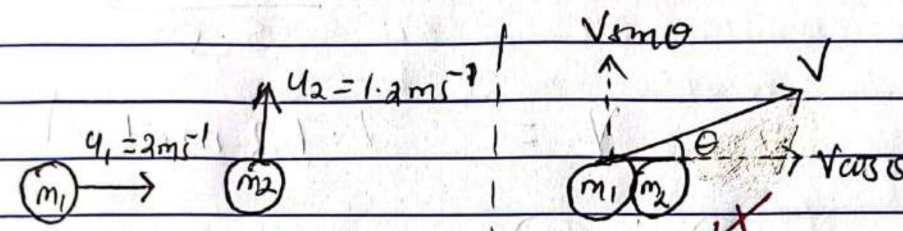
If $F = 1N$, $m = 1kg$, $a = 1ms^{-2}$, then $k = 1$

thus $F = ma$ #

Question 1(b)

(i) The principle of conservation of linear momentum states that for any two or more colliding bodies, the total momentum before collision is equal to the total momentum after collision provided no external forces act on them. (01)

(ii)



$m_1 = 2.5kg$ $m_2 = 3.0kg$

Before collision — After collision

Conserving momentum;

Horizontally;

$m_1u_{1x} + m_2u_{2x} = (m_1+m_2)V\cos\theta$.

$u_{1x} = 2, \quad u_{2x} = 0$

$2.5\times2 + 3.0\times0 = (2.5+3.0)V\cos\theta$

$5 = 5.5V\cos\theta$ — (1)

vertically;

$m_1u_{1y} + m_2u_{2y} = (m_1+m_2)V\sin\theta$

$u_{1y} = 0, \quad u_{2y} = 1.2$

$2.5\times0 + 3.0\times1.2 = (2.5+3.0)V\sin\theta$

$3.6 = 5.5V\sin\theta$ — (2)

$(1)^2 + (2)^2$

$5^2 + 3.6^2 = (5.5V)^2\cos^2\theta + (5.5V)^2\sin^2\theta$

$37.96 = (5.5V)^2(\cos^2\theta + \sin^2\theta)$

$\cos^2\theta + \sin^2\theta = 1$

$$37.96 = (5.5V)^2$$

$$5.5V = \sqrt{37.96}$$

$$5.5V = 6.161169$$

$$V = \frac{6.161169}{5.5}$$

$$V = 1.12\,ms^{-1}$$

② ÷ ①

$$\frac{5.5V\sin\theta}{5.5V\cos\theta} = \frac{3.6}{5}$$

05

$$\tan\theta = \frac{3.6}{5}$$

$$\theta = \tan^{-1}\left(\frac{3.6}{5}\right)$$

$$\theta = 35.8^\circ$$

∴ The magnitude of the final velocity of the particles is $1.12ms^{-1}$ at 35.8° to the horizontal.

Question 1(c)

(i) Intensity of gravity is a force acting on a 1kg mass placed in the gravitational field

Gravitational potential is the workdone in moving a 1kg mass from infinity to a point in the gravitational field.

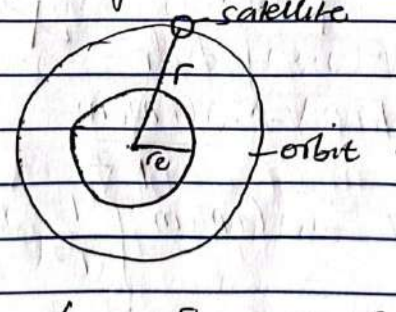
02

(ii) A body at the pole is practically stationary while towards the equator, the body also experiences the centripetal force. This brings about change in acceleration due to gravity, g

OR;

(ii) The Earth is not a perfect sphere. Therefore, all places on the Earth's surface are not at the same distance from the centre of the earth. A body at the equator is slightly further away from the centre of the earth compared to one at the poles, and hence feels a smaller gravitational acceleration. The nearer the place with respect to the centre of the earth, the greater the value of acceleration due to gravity. (03)

(iii) Consider a satellite of mass, m launched from the earth's surface of radius, re into an orbit of radius, r



Centripetal force, $F = \frac{mv^2}{r}$ — (1)

Gravitational force, $F = \frac{G M_e m}{r}$ — (2)

from (1) and (2)

$$\frac{mv^2}{r} = \frac{G M_e m}{r^2}$$

CANDIDATE'S NAME:.............................. INDEX No..............

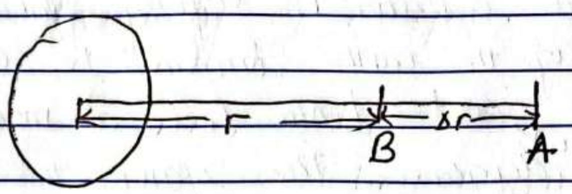
Do not write in this margin

SUBJECT:.............................. PAPER:.............. SIGNATURE..............

$$\frac{1}{2}mv^2 = \frac{GM_em}{2r}$$

Kinetic energy $= \frac{GM_em}{2r}$ — (2)

Consider a body of mass, m being moved from infinity at A to a point B through a small distance δr where B is at a distance r from the earth's centre.



For small workdone, $\Delta W = F \cdot \delta r$

Total work done;

$$\int \delta W = \int_{\infty}^{r} F\delta r$$

$$\int dW = \int_{\infty}^{r} F dr$$

$$W = \int_{\infty}^{r} F dr$$

$$F = \frac{GM_em}{r^2}$$

$$W = GM_em \int_{\infty}^{r} \frac{1}{r^2} dr = GM_em \left[\frac{-1}{r}\right]_{\infty}^{r}$$

$$W = GM_em \left(\frac{-1}{r} - \frac{1}{\infty}\right)$$

$$W = -\frac{GM_em}{r}$$

Potential energy = Workdone

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST: ____________ O&A

CANDIDATE'S NAME:... INDEX No.........................

SUBJECT:.. PAPER:................. SIGNATURE.........................

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Potential energy $= -\frac{GMem}{r}$

magnitude of P.E $= \frac{GMem}{r}$ — (4)

From eqns (3) and (4);

Potential energy $= \frac{GM_em}{r} = 2\left(\frac{GMem}{2r}\right) = K_e$

$\therefore$ Magnitude of P.E is equal to twice the Kinetic energy of a satellite

04

JULY/AUGUST:______

CANDIDATE'S NAME:.. INDEX No.......................

Do not write in this margin

SUBJECT:.................................. PAPER:................. SIGNATURE.......................

Question 2 a)

(i) Coefficient of viscosity is the frictional force in area of $1m^2$ of fluid when it's in a region of velocity gradient of $1s^{-1}$.

(07)

(ii) Increase in temperature of a gas increases the kinetic energy hence the molecules move faster. This causes the molecules to frequently collide thus increasing transfer of momentum hence increasing the viscosity of a gas.

(03)

Question 2(b)

(i) Consider a steel ball bearing of radius r and density, ρ falling through a liquid of density σ and coefficient of viscosity, η

U - upthrust
F - viscous drag
W - Weight.

At terminal velocity;

$$W = U + F$$

$$m_b g = m_l g + 6\pi\eta r V_t$$

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

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

(04)

$$V_t = \frac{4\pi r^3 g(\rho-\sigma)}{3 \times 6\pi\eta r}$$

$$V_t = \frac{2gr^2(\rho-\sigma)}{9\eta}$$

V_t is the terminal velocity.

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST: ____________

CANDIDATE'S NAME:.. INDEX No.....................

SUBJECT:.................................... PAPER:............... SIGNATURE.....................

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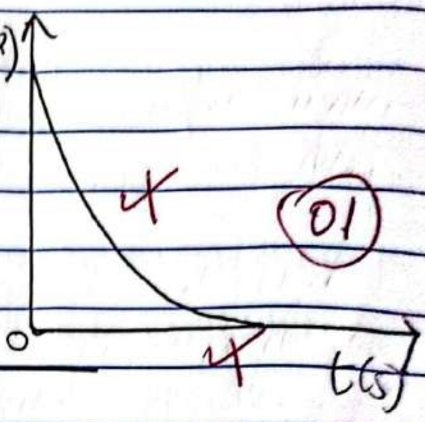
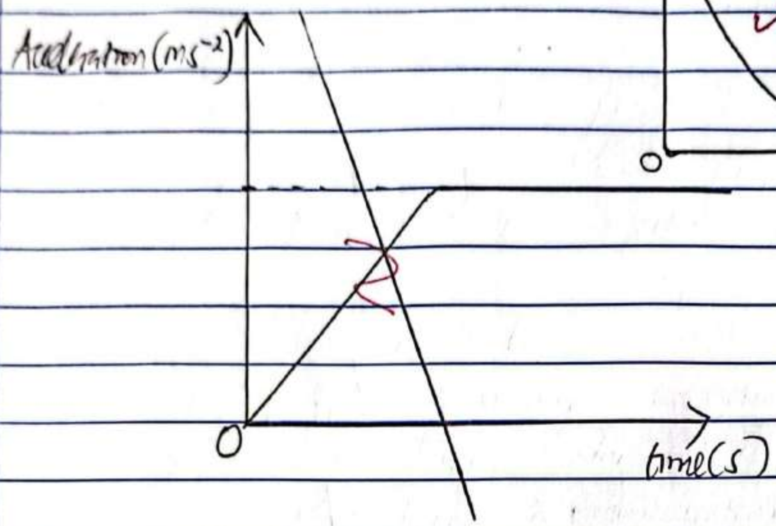
Question 2 (b)



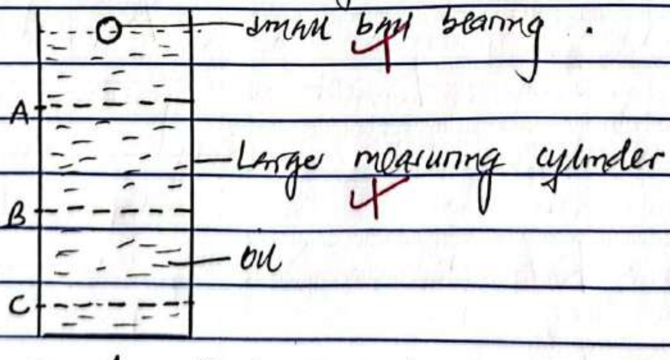
(ii)



~~(iii)~~ Question 2(c)

(i) Stoke's law states that the viscous force depends on the coefficient of viscosity, velocity of the body and the radius of the body. 01

(ii)



The diameter, d and hence radius, r of the ball bearing is measured using a micrometer screw gauge.

Densities of the ball bearing and liquid ρ and σ respectively are obtained.

Three reference marks A, B, and C at equal distances are made on the sides of a tall transparent measuring cylinder or tube.

filled with oil.

The ball is allowed to fall centrally through the oil.

The time t_1 and t_2 taken for the ball to fall from A to B and from B to C respectively are measured and noted.

When $t_1 = t_2 = t$, the terminal velocity, V_t is obtained from;

$$V_t = \frac{AB}{t} = \frac{BC}{t} = \frac{AC}{2t} \quad \text{—— } (1)$$

Coefficient of viscosity, η is then calculated from stoke's law using;

$$V_t = \frac{2gr^2(\rho-\sigma)}{9\eta}$$

$$\eta = \frac{2gr^2(\rho-\sigma)}{9V_t}.$$

06

~~(ii)~~ Question 2(d)

(i) Bernoulli's principle states that for streamline motion of an incompressible non-viscous fluid, the sum of pressure at any part plus the kinetic energy per unit volume plus potential energy per unit volume there is always constant.

07

(ii) It is not advisable to stand by the road side when a fast moving trailer is passing because when a stream of fast moving air blows between a person and the trailer, it creates a low pressure in between and higher pressure out. This causes the trailer and the person come closer hence a person falls into ... accidents. 03

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST:________

CANDIDATE'S NAME:.. INDEX No.....................

Do not write in this margin

SUBJECT:.................................... PAPER:............... SIGNATURE......................

Question 3(a)

Elastic limit is the point beyond which a material doesnot regain its original shape and size when applied force is removed.

Proportional limit is the point beyond which the extension of a material is not proportional to the applied force but the material is elastic.

02

Question 3(b)

(i) Wire Y has a smaller crosssectional area because it produces a larger extension for the same force applied on wire X since extension is inversely proportional to the crosssectional area of a material

02

(ii)

The original length, lo of the iron wire is determined.

The diameter, d of the iron wire is obtained by measuring using a micrometer screw gauge at three different points and taking the average.

The crossectional area, A of the iron wire is then determined from $A = \frac{\pi d^2}{4}$.

The slope, S of the graph for X would then be determined.

The value of young's modulus, E is got from;

$$E = \frac{S l_o}{A}$$

04

Question 3(c)

$\rho = 7800 kgm^{-3}$

$m = 16g = \frac{16}{1000} = 0.016 kg$

$l_0 = 250cm = \frac{250}{100} = 2.5m$

$e = 1.2mm = 1.2\times10^{-3} m$

$F = 80N$

(i)

$E = \frac{Fl_0}{Ae}$

but $A = \frac{V}{l_0}$

$V = \frac{m}{\rho}, \Rightarrow A = \frac{m}{\rho l_0}$

$E = \frac{Fl_0 \times \rho l_0}{me}$

$E = \frac{F\rho l_0^2}{me}$

$E = \frac{80\times 7800\times 2.5^2}{0.016\times 1.2\times10^{-3}}$

$E = 2.0313\times10^{11} Pa$ 03

(ii)

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

$F = \frac{EAe}{l_0}$

$= \frac{1}{2}\frac{EAe^2}{l_0}$

$A = \frac{m}{\rho l_0} = \frac{0.016}{7800\times2.5} = 8.205\times10^{-7}m^2$

CANDIDATE'S NAME:............ INDEX No............

SUBJECT:............ PAPER:............ SIGNATURE............

Do not write in this margin

$$\text{Energy stored} = \frac{EAe^2}{2l_0}$$

$$= \frac{2.0313\times10^{11}\times 8.025\times10^{-7}\times(1.2\times10^{-3})^2}{2\times2.5}$$

$$= (39.12\,J\times1.2\times10^{-3}$$

$$= 4.695\times10^{-2}\,J$$

(02)

Question 3(d)

(i) Relative density of a substance is the ratio of density of a substance to density of equal volume of water. (01)

(ii)

When in air, the sinker and weight W are attached to the meter rule as shown above.

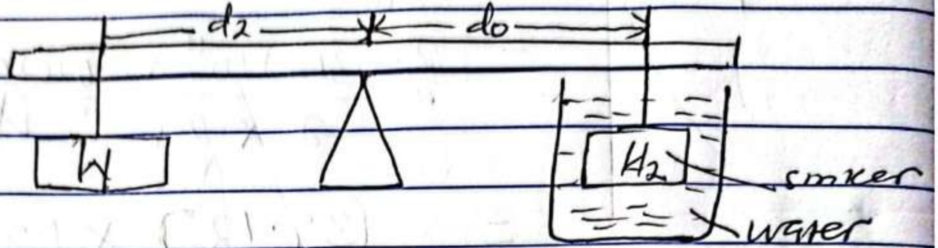
The weight is adjusted until the metre rule balances horizontally.

The distances d_1 and d_0 are measured and recorded.

If W_1 is the weight of the sinker in air, then taking moments about the pivot;

$$W_1 d_0 = W d_1$$

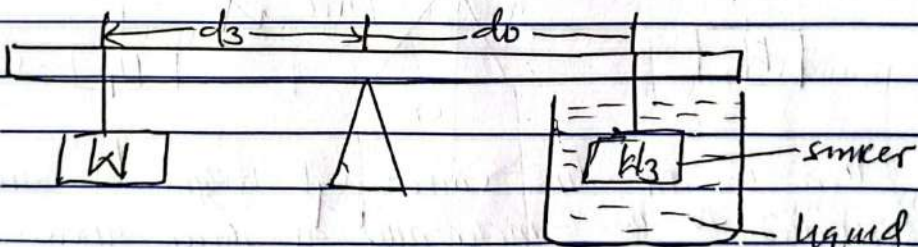
$$W_1 = \frac{W d_1}{d_0} \quad \text{——} (1)$$



The sinker is then immersed in water in a beaker while keeping do constant.
The position of the weight W is adjusted until balance is restored.
The distance d_2 is measured.
If W_2 is the weight of the sinker in water, then taking moments about the pivot gives;

$W_2 d_0 = W d_2$

$W_2 = \frac{W d_2}{d_0}$ ——— (2)



The sinker is then immersed in a liquid in a beaker while keeping do constant.
The position of weight W is adjusted until balance is restored.
The distance d_3 is measured.
If W_3 is the weight of the sink in the liquid, then taking moments about the pivot, then

$W_3 d_0 = W d_3$

$W_3 = \frac{W d_3}{d_0}$ ——— (3)

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST:__________

CANDIDATE'S NAME:.. INDEX No.......................

Do not write in this margin

SUBJECT:.................................... PAPER:................ SIGNATURE..........................

But Relative density = $\frac{\text{Apparent loss of weight of sinker in liquid}}{\text{Apparent loss of weight in water}}$

$$= \frac{W_1 - W_3}{W_1 - W_2}$$

$$= \frac{W\frac{d_1}{d_0} - W\frac{d_3}{d_0}}{W\frac{d_1}{d_0} - W\frac{d_2}{d_0}}$$

$$R.D = \frac{d_1 - d_3}{d_1 - d_2}$$ #

where $d_1 > d_2 > d_3$.

06

CANDIDATE'S NAME:.. INDEX No........................

SUBJECT:........................ PAPER:.................. SIGNATURE..........................

Do not write in this margin

Question 4(a)

(i) SHM is the periodic motion whose acceleration is directly proportional to the displacement from a fixed point and is directed towards that point.

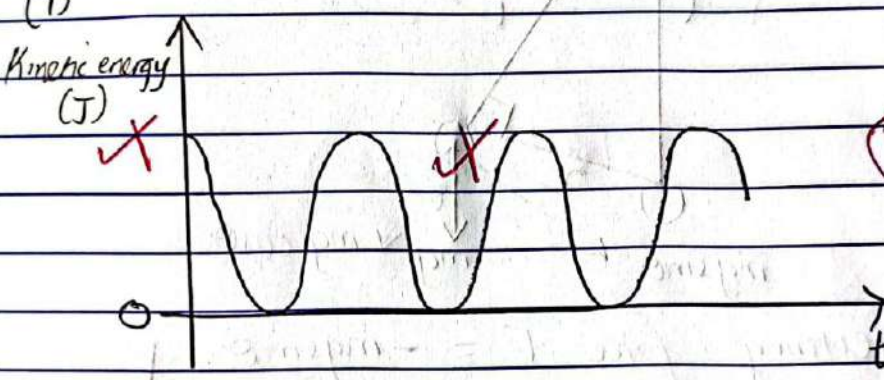
01

(ii) Amplitude is the maximum displacement of a particle from the fixed point.
Period is the time taken to complete one oscillation.

02

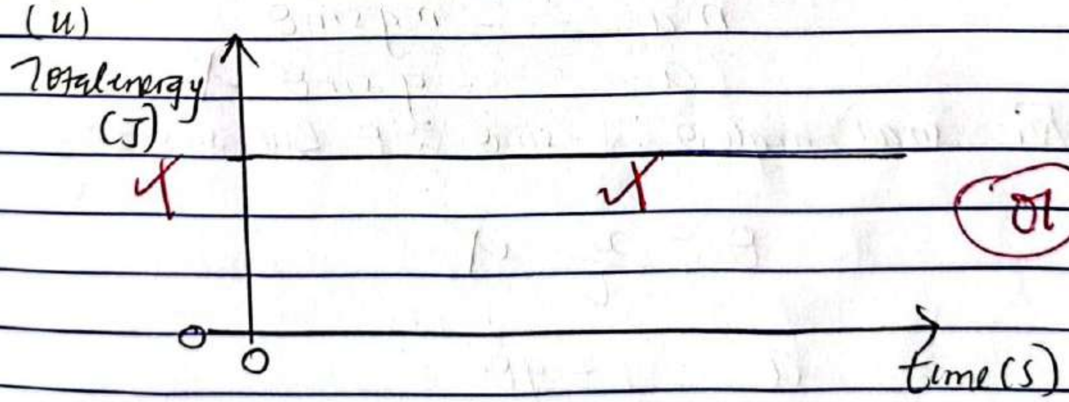
Question 4(b)

(i)



01

(ii)



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CANDIDATE'S NAME:............................ INDEX No.....................

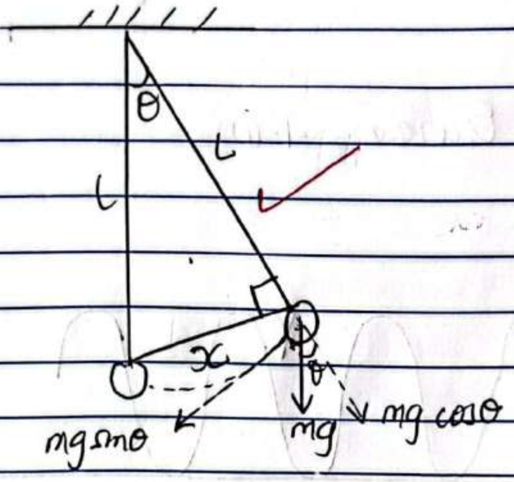
SUBJECT:.................... PAPER:.............. SIGNATURE......................

Do not write in this margin

Question 4(c)

Consider the motion of a pendulum of mass m suspended at the end of a light inextensible string of length, L which is fixed at the other end O.

Assume that the bob is given a small displacement x and at that point, the string makes an angle, θ with its equilibrium vertical position as shown below;



the restoring force $F = -mg\sin\theta$
but $F = ma$

$$ma = -mg\sin\theta$$
$$a = -g\sin\theta$$

For small angle θ; $\sin\theta \approx \theta$ But $\sin\theta = \frac{x}{L}$

$$\theta = \frac{x}{L}$$

$$a = -g\theta$$
$$a = -\frac{gx}{L}$$
$$a = -\left(\frac{g}{L}\right)x$$

but $a = -\omega^2 x$

$$\omega^2 = \frac{g}{l}$$

$$\omega = \sqrt{\frac{g}{l}}$$

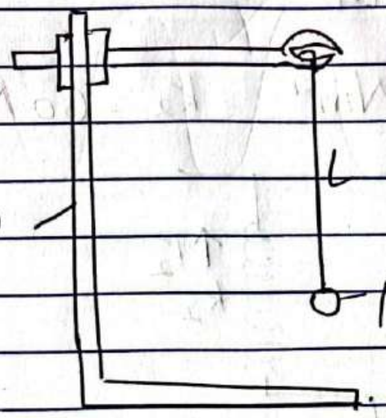
Period, $T = \frac{2\pi}{\omega}$

$$= \frac{2\pi}{\sqrt{\frac{g}{l}}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

06

(ii)



The apparatus is set up as shown above.
The length, l of the peddulum is measured.
The bob is displaced through a small angle and allowed to oscillate
The time, t for 20 complete oscillations is noted
The experiment is repeated for different values of L and the results are tabulated including values of T for one oscillation and T^2.
A graph of T^2 against l is plotted

and a straight line through the origin is obtained.
The slope, S of the graph is calculated.
The acceleration due to gravity, g is obtained from,

$$T^2 = \frac{4\pi^2 L}{g}$$

$$T^2 = \left(\frac{4\pi^2}{g}\right) l$$

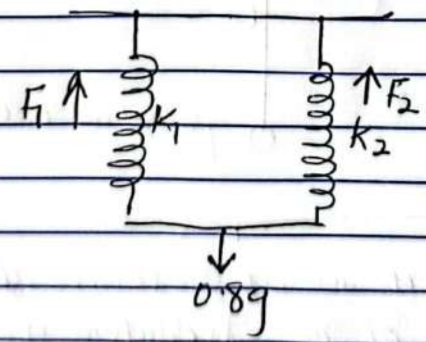
04

The slope, $S = \frac{4\pi^2}{g}$

Thus $g = \frac{4\pi^2}{S}$ #

Question 4(d)

$K_1 = 120\,Nm^{-1}$ $K_2 = 60\,Nm^{-1}$



$F_1 = -K_1 x$, $F_2 = -K_2 x$

Restoring force $F = F_1 + F_2$

$F = -K_1 x - K_2 x$

$F = -(K_1 + K_2)x$

but $F = F_1 + F_2 = 0.8g$

$x(K_1 + K_2) = 0.8g$

$x(120 + 60) = 0.8 \times 9.81$

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST:

O&A

CANDIDATE'S NAME:.................................... INDEX No......................

SUBJECT:.................................... PAPER:.................. SIGNATURE..........................

Do not write in this margin

$$180x = 0.8 \times 9.81$$

$$x = \frac{0.8 \times 9.81}{180}$$

$$x = 0.0436\,m$$

03

(ii) Tension, $F_1 = K_1 x$

$= 120 \times 0.0436$

$5.232\,N$

Tension $F_2 = K_2 x$

$= 60 \times 0.0436$

$= 2.616\,N$

02

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST: ________

CANDIDATE'S NAME:.. INDEX No.......................

Do not write in this margin

SUBJECT:.. PAPER:................. SIGNATURE..........................

SECTION B

Question 5(a)

(i) The intermolecular forces of attraction between molecules of the gas are negligible.

The volume of the molecules is negligible compared to the volume of the container.

The molecules of the gas perform perfectly elastic collisions.

The duration of a collision is negligible compared to the time between collisions.

02

(ii) The intermolecular forces of attraction between molecules of the gas are negligible.

The volume of the molecules is negligible compared to the volume of the container.

01

(iii) The intermolecular forces of attraction are appreciable.

Because of intermolecular forces of attraction, the molecules approaching the walls of the container exerts less pressure, P than the bulb pressure.

This accounts for the term $\frac{a}{V^2}$

The volume of the molecules is appreciable compared to the volume of the container.

Because of intermolecular forces of repulsion, there is a definite volume called co-volume surrounding each molecule and therefore, the free volume of movement of the molecules is less than the volume of the container, V by b

This accounts for the term b.

03

WAKISSHA JOINT MOCK EXAMINATIONS
JULY/AUGUST:__________

O&A

CANDIDATE'S NAME:.. INDEX No.........................

SUBJECT:... PAPER:.................. SIGNATURE..........................

Do not write in this margin

Question 5(b)

$T_2 = 147°C = 147+273 = 420K$

$T_1 = 0°C = 0+273 = 273K$

$\rho = 1.5 kgm^{-3}$

From $P = \frac{1}{3}\rho \overline{c^2}$

At $0°C$

$T_1 = 273K$

$P_2 = 1 \times 10^5 Nm^{-2}$

$$\sqrt{\overline{C_1^2}} = \sqrt{\frac{3P}{\rho}}$$

$$\sqrt{\overline{C_1^2}} = \sqrt{\frac{3 \times 1 \times 10^5}{1.5}}$$

$$\sqrt{\overline{C_1^2}} = 4.472 \times 10^2 ms^{-1}$$

05

but $\sqrt{\overline{C^2}} \propto \sqrt{T}$

$$\frac{\sqrt{\overline{C_1^2}}}{\sqrt{\overline{C_2^2}}} = \frac{\sqrt{T_1}}{\sqrt{T_2}}$$

$$\frac{4.472 \times 10^2}{\sqrt{\overline{C_2^2}}} = \frac{\sqrt{273}}{\sqrt{420}}$$

$$\sqrt{\overline{C_2^2}} = \frac{4.472 \times 10^2 \sqrt{420}}{\sqrt{273}}$$

$$\sqrt{\overline{C_2^2}} = 5.55 \times 10^2 ms^{-1}$$

CANDIDATE'S NAME:.. INDEX No......................

SUBJECT:.. PAPER:.................. SIGNATURE........................

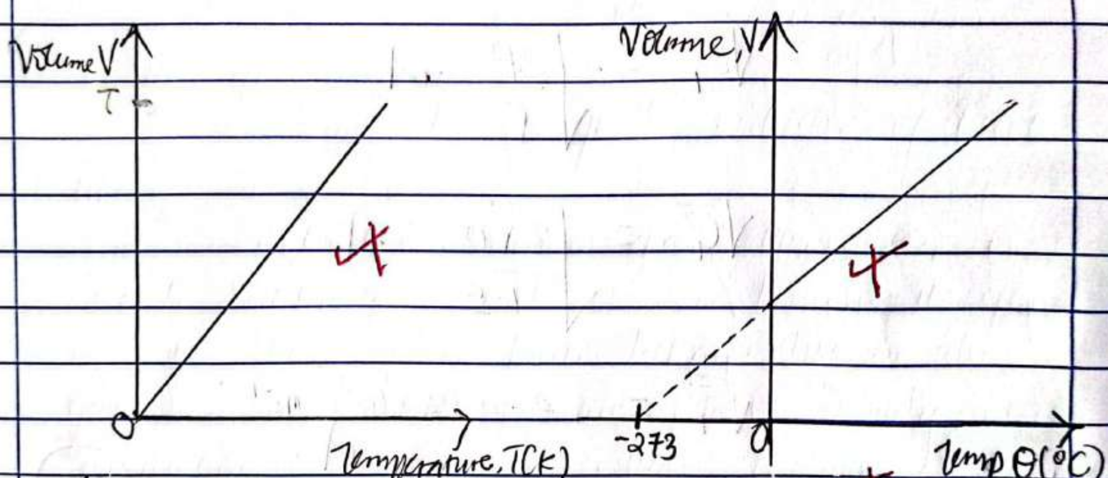
Do not write in this margin

Question 5 (c)

(i) When the temperature of the gas increases, the average kinetic energy of the gas molecules increases and the number of collisions made with the container persecond increases. The rate of change of momentum of the gas molecules during collision also increases hence pressure of a fixed mass of a gas in a closed container increases.

02

(ii)



When a gas is cooled, the average kinetic energy of the gas molecules decreases thus the internal energy of the gas molecules also decreases.

There is a point at which the gas molecules have zero kinetic energy, that is, at -273°C or 0K, a gas liquefies before reaching zero kelvin.

Therefore the volume of the gas is not actually zero as it appears on the graphs above. This implies that the graphs above are theoretical at low temperature.

04

JULY/AUGUST: ________ O&A

CANDIDATE'S NAME:.. INDEX No.....................

SUBJECT:.................................... PAPER:............... SIGNATURE.......................

Do not write in this margin

Question 5 (d)

$V_1 = 400cm^3$

$T_1 = -129^\circ C = -129+273 = 144K$

$T_2 = -136^\circ C = -136+273 = 137K$

$V_2 = ?$

$\gamma = 1.40$

From $TV^{\gamma-1} = K$

$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$144 \times (400)^{(1.40-1)} = 137 \times V_2^{(1.40-1)}$

$144 \times 400^{0.40} = 137 V_2^{0.40}$

$\frac{144 \times 400^{0.40}}{137} = V_2^{0.40}$

$11.5469 = V_2^{0.40}$

$V_2 = (11.5469)^{1/0.40}$

$V_2 = 453.068\ cm^3$

03

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST: ____________

CANDIDATE'S NAME:.. INDEX No......................

SUBJECT:.. PAPER:................ SIGNATURE..........................

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Question 6(a)

(i)

A good thermometric substance should expand uniformly.

A good thermometric substance should be easily seen.

A good thermometric substance should have a high boiling point

A good thermometric substance should have a low melting point

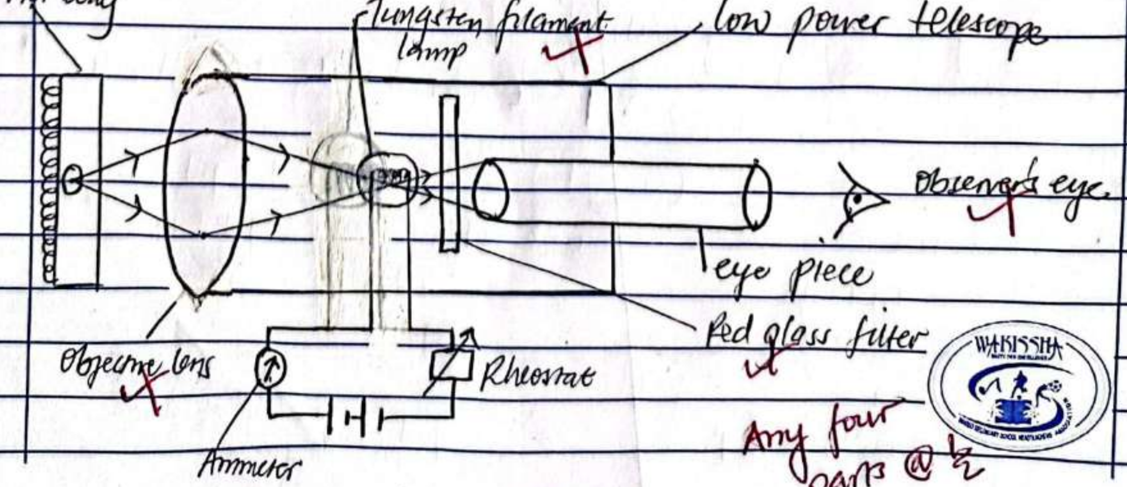
A good thermometric substance should not wet the glass walls. Any 4 @ ½

It should be a good conductor of heat 02

(ii)

A constant volume gas thermometer is used to calibrate other thermometers because the gas in the hard glass bulb behaves like an ideal gas and therefore its pressure varies linearly with temperature at constant volume making it very accurate. 02

Question 6(b)



The filament lamp is placed at the principal focus of the objective lens.

The body whose temperature is required is focused by the objective lens so that its image lies in the plane of the filament.

The light from both the filament and the hot body passes through the red glass filter to the observer's eye.

If the hot body is brighter than the filament, the filament appears dark on the bright background.

If the filament is brighter than the hot body, the filament appears bright on the dark background.

The filament current is adjusted using the rheostat until the filament light merges as nearly as possible into its background.

The temperature of the hot body is then equal to that of the filament.

The temperature is read off from the ammeter which is calibrated to read directly in temperature in °C.

06

Question 6 (c)

(i) Latent heat of fusion is the quantity of heat required to convert a given mass of a solid at its melting point into liquid at constant temperature.

01

(ii) To melt 1kg of a solid substance, heat energy is only required to break the intermolecular forces of attraction between solid molecules whereas to vaporise 1kg of the same liquid substance, heat energy

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST:

CANDIDATE'S NAME:.. INDEX No.........................

Do not write in this margin

SUBJECT:.. PAPER:................. SIGNATURE.........................

is required to break the intermolecular forces of attraction between liquid molecules and to do work against external atmospheric pressure during expansion to vapour, hence the specific latent heat of vaporisation is greater than specific latent heat of fusion of the same substance.

03

Question 6(d)

Case 1:

$m_i = 50g = 0.05kg$ $\quad m_w = 200g = 0.2kg$

$\theta_1 = 0°C$ $\quad \theta_3 = 70°C$

$\theta_2 = 40°C$ $\quad \theta_2 = 40°C$

Assuming no heat losses to the surroundings;

Heat lost by the water from 70°C to 40° + Heat lost by the flask from 70°C to 40°C = Heat gained by ice at 0°C + Heat gained by ice in warming from 0°C to 40°C

$m_w c_w(\theta_3-\theta_2) + C_f(\theta_3-\theta_2) = m_i l_f + m_i c_i(\theta_2-\theta_1)$

$c_i = c_w = 4200\,Jkg^{-1}K^{-1}$

$0.2 \times 4200(70-40) + C_f(70-40) = 0.05L_f + 0.05 \times 4200(40-0)$

$25200 + 30C_f = 0.05L_f + 8400$

$16800 + 30C_f = 0.05L_f$ — ①

Case 2:

$m_i = 80g = 0.08kg$ $\quad m_w = 0.2 + 0.05 = 0.25kg$

$\theta_2 = 10°C, \theta_3 = 40°C$

$0.25 \times 4200(40-10) + C_f(40-10) = 0.08L_f + 0.08 \times 4200(10-0)$

$31500 + 30C_f = 0.08L_f + 3360$

$28140 + 30C_f = 0.08L_f$ — ②

② − ①

$11340 = 0.03L_f$

$L_f = 3.78 \times 10^5\,Jkg^{-1}$

06

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST:________ Q&A

CANDIDATE'S NAME:............ INDEX No............

SUBJECT:............ PAPER:............ SIGNATURE............

Do not write in this margin

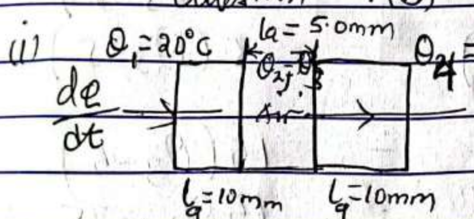
Question 7 (a)

(i) Thermal conductivity is the rate of heat flow through a conductor per unit cross sectional area per unit temperature gradient. (01)

(ii) Metals have free electrons. When a metal is heated, the electrons at the hot end gain more energy and transfer energy as they collide with atoms in solid lattice. The mechanism of heat transfer by atomic vibrations also occurs in the metal. (03)

Question 7 (b)

(i)



The temperatures of the inner surfaces are θ_2 and θ_3.

$$\frac{dQ}{dt} = \frac{K_g A(\theta_1 - \theta_2)}{l_g} = \frac{K_a A(\theta_2 - \theta_3)}{l_a} = \frac{K_g A(\theta_3 - \theta_4)}{l_g}$$

$$\frac{dQ}{dt} = \frac{K_g A(20 - \theta_2)}{10 \times 10^{-3}} = \frac{K_a A(\theta_2 - \theta_3)}{5 \times 10^{-3}} = \frac{K_g A(\theta_3 - 5)}{10 \times 10^{-3}}$$

$$\frac{K_g A(20 - \theta_2)}{10} = \frac{K_g A(\theta_3 - 5)}{10}$$

$$20 - \theta_2 = \theta_3 - 5$$

$$\theta_3 + \theta_2 = 25 \quad \text{--- (1)}$$

$K_a = 0.02\,Wm^{-1}K^{-1}$

$K_g = 0.6\,Wm^{-1}K^{-1}$

$$\frac{K_a A(\theta_2 - \theta_3)}{5\times10^{-3}} = \frac{K_g A(\theta_3 - 5)}{10\times10^{-3}}$$

$$\frac{0.02A(\theta_2 - \theta_3)}{5\times10^{-3}} = \frac{0.6A(\theta_3 - 5)}{10\times10^{-3}}$$

$$0.02\times10\times10^{-3}A(\theta_2-\theta_3) = 0.6\times5\times10^{-3}A(\theta_3-5)$$

$$0.02\times10(\theta_2-\theta_3) = 0.6\times5(\theta_3-5)$$

$$0.2\theta_2 - 0.2\theta_3 = 3(\theta_3 - 5)$$

$$0.2(\theta_2-\theta_3) = 3(\theta_3-5)$$

$$\theta_2 - \theta_3 = 15(\theta_3 - 5)$$

$$\theta_2 - \theta_3 = 15\theta_3 - 75$$

$$15\theta_3 + \theta_3 - \theta_2 = 75$$

$$16\theta_3 - \theta_2 = 75 \quad \text{--- (2)}$$

from (1) $\theta_2 = 25 - \theta_3$

$$16\theta_3 - 25 + \theta_3 = 75$$

$$17\theta_3 = 100$$

$$\theta_3 = \frac{100}{17}$$

$$\theta_3 = 5.88\,^\circ C$$

$$\theta_2 = 25 - 5.88 = 19.12\,^\circ C$$

∴ the temperatures of inner surfaces are $19.12\,^\circ C$ and $5.88\,^\circ C$.

06

(iii)

For air

$$\frac{dQ_a}{dt} = \frac{K_a A(\theta_2 - \theta_3)}{l_a}$$

$$= \frac{0.02A(19.12 - 5.88)}{5\times10^{-3}}$$

$$= 52.96A$$

$$\frac{dQ_g}{dt} = \frac{K_g(A)(20-\theta_2)}{l_g}$$

$$= \frac{0.6A(20 - 19.12)}{10\times10^{-3}}$$

$$= 52.8A$$

$$\frac{\frac{dQ_a}{dt}}{\frac{dQ_g}{dt}} = \frac{52.96A}{52.8A} = \frac{331}{330} = 1.003$$

$$\frac{dQ_a}{dt} : \frac{dQ_g}{dt} = 331 : 330$$

03

Question 7(c)

(i) Stefan's law of black body radiation states that the total power radiated per unit surface area of a black body is directly proportional to the fourth power of its absolute temperature.

01

WAKISSHA

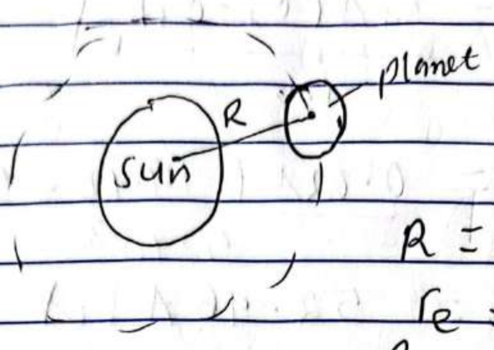
JULY/AUGUST: ____________

CANDIDATE'S NAME:.. INDEX No.......................

Do not write in this margin

SUBJECT:.............................. PAPER:................ SIGNATURE..........................

(ii)



$R = 40 r_e$

$r_e = 1.5 \times 10^{11} m$

$R = 40 \times 1.5 \times 10^{11} m$

$R = 6 \times 10^{12} m$

$T_s = 6000 K$

$T_p = ?$ $\quad r_s = 7 \times 10^{8} m$

At radiative equilibrium;
Power received by the effective area of the planet = power radiated by the planet.

Solar power x area of planet = power radiated by planet

$$\frac{4\pi r_s^2 \sigma T_s^4}{4\pi R^2} \times \pi r_p^2 = 4\pi r_p^2 \sigma T_p^4$$

$$\frac{r_s^2 T_s^4}{4R} = T_p^4$$

$$T_p^4 = \left(\frac{r_s}{2R}\right)^2 T_s^4$$

$$T_p^4 = \left(\frac{7 \times 10^8}{2 \times 6 \times 10^{12}}\right)^2 \times 6000^4$$

06

$$T_p = \sqrt[4]{\left(\frac{7 \times 10^8}{12 \times 10^{12}}\right)^2 \times 6000^4}$$

$T_p = 45.82 K$

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST: ______

O&A

ANDIDATE'S NAME:........................ INDEX No........................

UBJECT:........................ PAPER:................ SIGNATURE........................

Do not write in this margin

SECTION C

Question 8(a)

Half life is the time taken for half the original number of atoms of a radioactive substance to decay.
Decay constant is the fraction of a radioactive atoms which decay per second.

02

Question 8(b)

$t_{1/2} = 4.5 \times 10^9$ years

$t = 4.0 \times 10^9$ years

$A = \lambda N$, $N = N_0 e^{-\lambda t}$

Percentage of ^{238}U found undecayed today $= \frac{N}{N_0} \times 100\%$

Where N is the number of atoms present
N_0 is the original number of atoms.

$N = N_0 e^{-\lambda t}$

$\lambda = \frac{\ln 2}{t_{1/2}}$

$\lambda = \frac{\ln 2}{(4.5 \times 10^9 \times 365 \times 24 \times 3600)}$

$\lambda = 4.884 \times 10^{-18}\ s^{-1}$

$N = N_0 e^{-(4.884 \times 10^{-18} \times 4.0 \times 10^9 \times 365 \times 24 \times 3600)}$

$= N_0 e^{-0.616081296}$

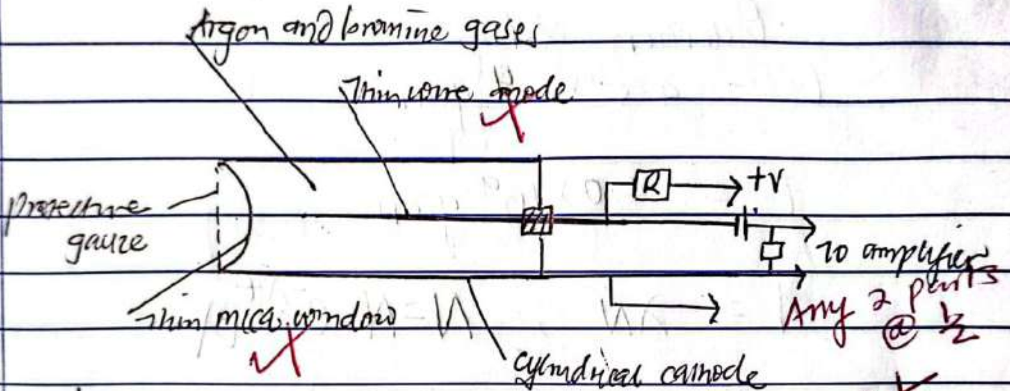
$N = 0.540 N_0$

Percentage of ^{238}U found on earth un-decayed $= \frac{0.540 N_0}{N_0} \times 100\%$

$= 54\%$

04

Question 8 (c)



When ionising radiations enter the tube, ion-pairs are produced through collisions with argon gas.

The electrons produced are accelerated towards the anode and more ion pairs are produced through repeated collisions.

The electrons produced produce more ion pairs resulting into gas amplification or an avalanche.

On reaching the anode, a discharge occurs and cause a current pulse through R.

The voltage pulse which develops is amplified and operates a counter which registers passage of ionisation. The tube is quenched for the next count.

The positive ions which would have caused secondary discharge on reaching the cathode are slowed down by collisions with bromine gas molecules.

06

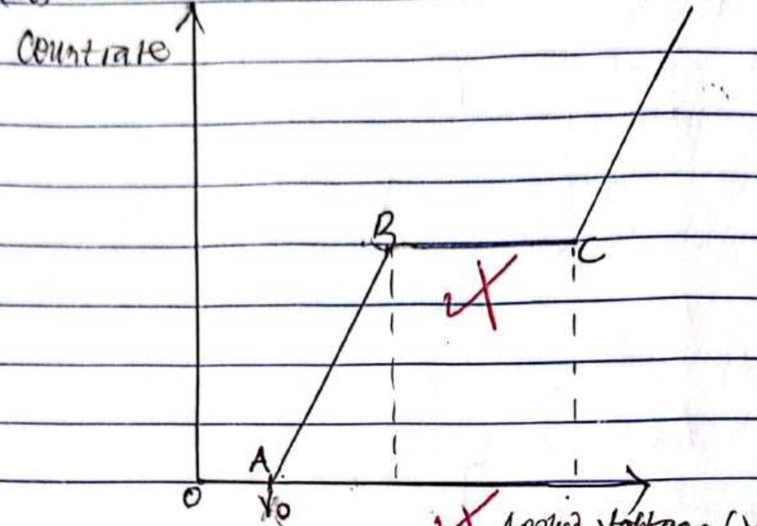
CANDIDATE'S NAME:............ INDEX No............

Do not write in this margin

SUBJECT:............ PAPER:............ SIGNATURE............

Question 8 (c)

(ii)



Vo - Threshold voltage

Between O and A, no count rates are recorded at all since the amount of electron amplification is not enough to give pulses of suffucient magnitude to be detected. Between A and B, not all the ions reach the electrodes hence only some of the freed electrons give pulses of suffucient magnitude to be recorded but their number increases with applied voltage. Between B and C, the count rate is constant. A full avalanche is obtained along the entire length of the anode and all particles whatever their energy produce detectable pulses.
Beyond C, the count rate increases with voltage due to incomplete quenching and unmonitored multiplication of ions occurs.

03

(iii) The G.M tube is operated in region BC (plateau region) because all the particles in this region produce sufficiently high voltage pulse for counting although their initial ionization may be different.

02

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST: ____________

O&A

CANDIDATE'S NAME:.. INDEX No.........................

SUBJECT:.. PAPER:.................. SIGNATURE..........................

Do not write in this margin

Question 8 (d)

Radio carbon (carbon-14) forms radioactive carbon dioxide which may be taken in by living plants during the process of photosynthesis.

When the plant dies, no fresh carbon is taken in and carbon-14 in the dead plant starts to decay by emission of beta particles.

Using a Geiger-Muller tube, the activity (A) of the dead plant (organic archaeological object) is determined.

The activity (A_0) of a similar object which is still living is measured.

Since the halflife, $t_{\frac{1}{2}}$ of radiocarbon is known, the time, t since the organic archaeological object died can be estimated from

$$A = A_0 e^{-\lambda t} \quad \text{where } \lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

03

CANDIDATE'S NAME:.. INDEX No..........................

SUBJECT:.................................... PAPER:............ SIGNATURE..........................

Do not write in this margin

Question 9 (a)

For every metal surface, there is a minimum frequency called threshold frequency below which no photoelectrons are emitted.

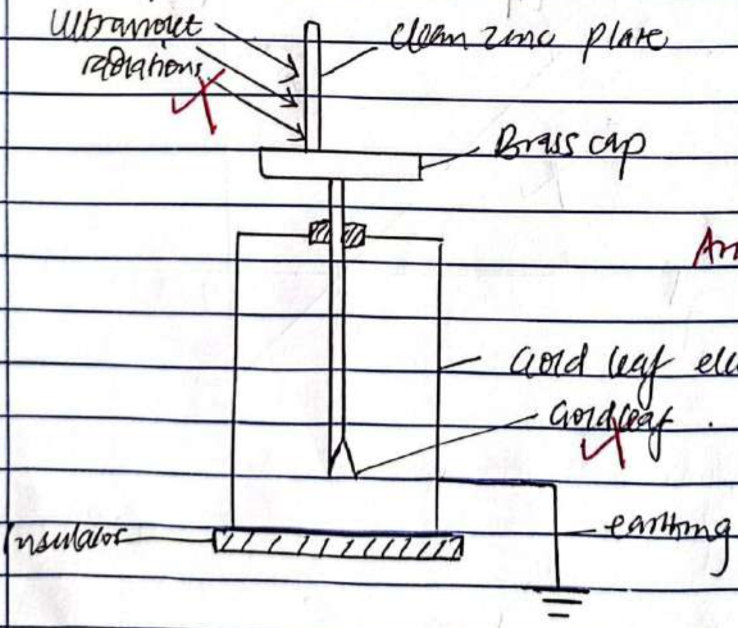
There is a negligible time lag between irradiation of the metal surface and emission of photoelectrons.

The number of photoelectrons emitted per second is directly proportional to the intensity of the incident radiation.

The kinetic energy of the emitted photoelectrons ranges from zero to a definite maximum and the maximum kinetic energy of the photoelectrons is directly proportional to the frequency of the incident radiation.

04

Question 9(b)



Any 2 parts @ $\frac{1}{2}$

A clean zinc plate is placed on the cap of a negatively charged goldleaf electroscope.

WAKISSHA JOINT MOCK EXAMINATIONS
JULY/AUGUST:

O&A

CANDIDATE'S NAME:............ INDEX No.............

SUBJECT:............ PAPER:............ SIGNATURE............

Do not write in this margin

Ultraviolet radiations are made incident on the clean zinc plate as shown above.
The divergence of the gold leaf is seen to decrease gradually. This means that the gold leaf is losing the negative charge through the zinc plate.
On recharging the gold leaf electroscope positively, the divergence of the gold leaf is seen not changing when the clean zinc plate is subjected to ultraviolet radiations.
That is because the clean zinc plate has lost the electrons by photoelectric effect thus it remains positively charged.

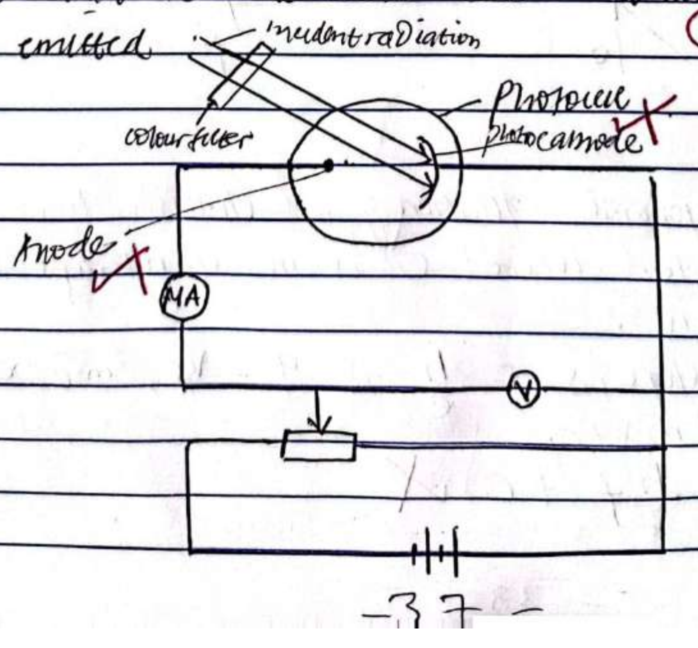
05

Question 9(C)

(i) Work function is the minimum energy required to liberate an electron from the bulk of the metal surface against attractive electrostatic forces of the nucleus.
Threshold frequency is the minimum frequency of the incident radiations below which no photoelectrons are emitted.

02

(ii)



Any 2 parts @ ½

CANDIDATE'S NAME:.. INDEX No.......................

Do not write in this margin

SUBJECT:.................................... PAPER:................ SIGNATURE.......................

The anode is made negative with respective to the cathode and the cathode is made positive with respective to the anode by the potential divider.

Radiation of known frequency, f is passed through a colour filter onto the photo cathode.

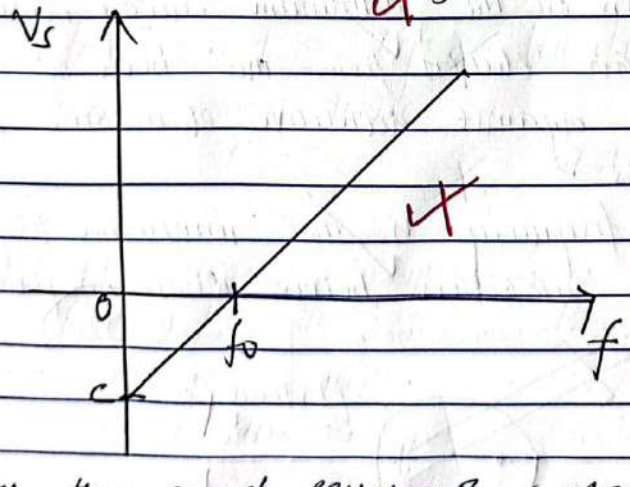
For each filter, the p.d is adjusted until the photocurrent through the micro ammeter is zero.

The stopping potential, V_s is noted.

The experiment is repeated with other filters to obtain several values of V_s and f for each colour filter.

A graph of stopping potential V_s against frequency, f of the radiations is plotted.

The slope, S of the graph is determined.



From the general equation of a straight line, $y = mx + c$, where c is the y-intercept, on the V_s-axis.

$m = \text{slope}, S = \frac{h}{e}$, $y = V_s$, and $x = f$

$y = mx + c$

$V_s = \frac{h}{e} f + c$

CANDIDATE'S NAME:.. INDEX No..........................

SUBJECT:.......................... PAPER:................ SIGNATURE..........................

Do not write in this margin

When $V_s = 0$, $f = f_0$

$$0 = \left(\frac{h}{e}\right) f_0 + c$$

$$c = -\left(\frac{h}{e}\right) f_0$$

$$V_s = \left(\frac{h}{e}\right) f - \left(\frac{h}{e}\right) f_0$$

$$eV_s = h(f - f_0)$$

$$eV_s = hf - hf_0$$

$$hf = hf_0 + eV_s$$

This is the Einstein's equation of photoelectric emission

06

Question 9 (d)

$$W_0 = 4.0eV = (4.0 \times 1.6 \times 10^{-19})J$$

$$W_0 = hf_0 = \frac{hc}{\lambda_{max}}$$

$$W_0 = \frac{hc}{\lambda_{max}}$$

$$\lambda_{max} = \frac{hc}{W_0} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{4.0 \times 1.6 \times 10^{-19}}$$

$$\lambda_{max} = 3.094 \times 10^{-7} m$$

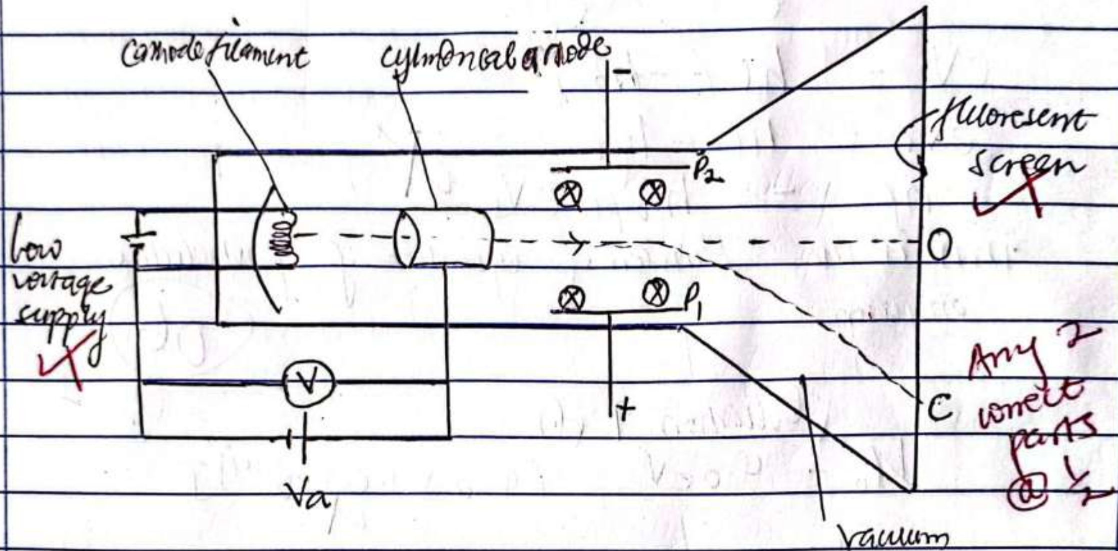
03

Question 10(a)

Specific charge is the ratio of charge of an electron to its mass.

Its unit is coulombs per kilogram (Ckg^{-1}) 02

Question 10(b)



The filament is heated by a low voltage supply and electrons are emitted thermionically.

The emitted electrons are accelerated towards the cylindrical anode.

With no electric and magnetic fields applied between plates P_1 and P_2, the electron beam strikes at point O on the screen.

Point O is then noted.

A magnetic field of intensity B is applied between plates P_1 and P_2 which deflects the electron beam to point C on the screen which is noted.

An electric field of intensity E is applied at right angles to the flux B between the plates and is adjusted until the position of the beam on the screen is restored to position O.

WAKISSHA JOINT MOCK EXAMINATIONS

JULY/AUGUST:_________

O&

CANDIDATE'S NAME:........................ INDEX No........................

Do not write in this margin

SUBJECT:........................ PAPER:.............. SIGNATURE........................

Do not write in this margin

The p.d, V and the plate separation, d ; and the velocity u of the electron beam are noted.

Electric force = Magnetic force

$Ee = Beu \Rightarrow E = Bu$

$u = \frac{E}{B}$ —(1)

Kinetic energy of the electrons, $\frac{1}{2}mu^2 = eVa$ —(2)

from (1) and (2)

$\frac{1}{2}m\frac{E^2}{B^2} = eVa$

$\frac{E^2}{2B^2Va} = \frac{e}{m}$

$\frac{e}{m} = \frac{E^2}{2B^2Va}$

but $E = \frac{V}{d}$

$\frac{e}{m} = \frac{V^2}{2B^2Vad^2}$

Thus e/m is the specific charge and can be determined by calculation

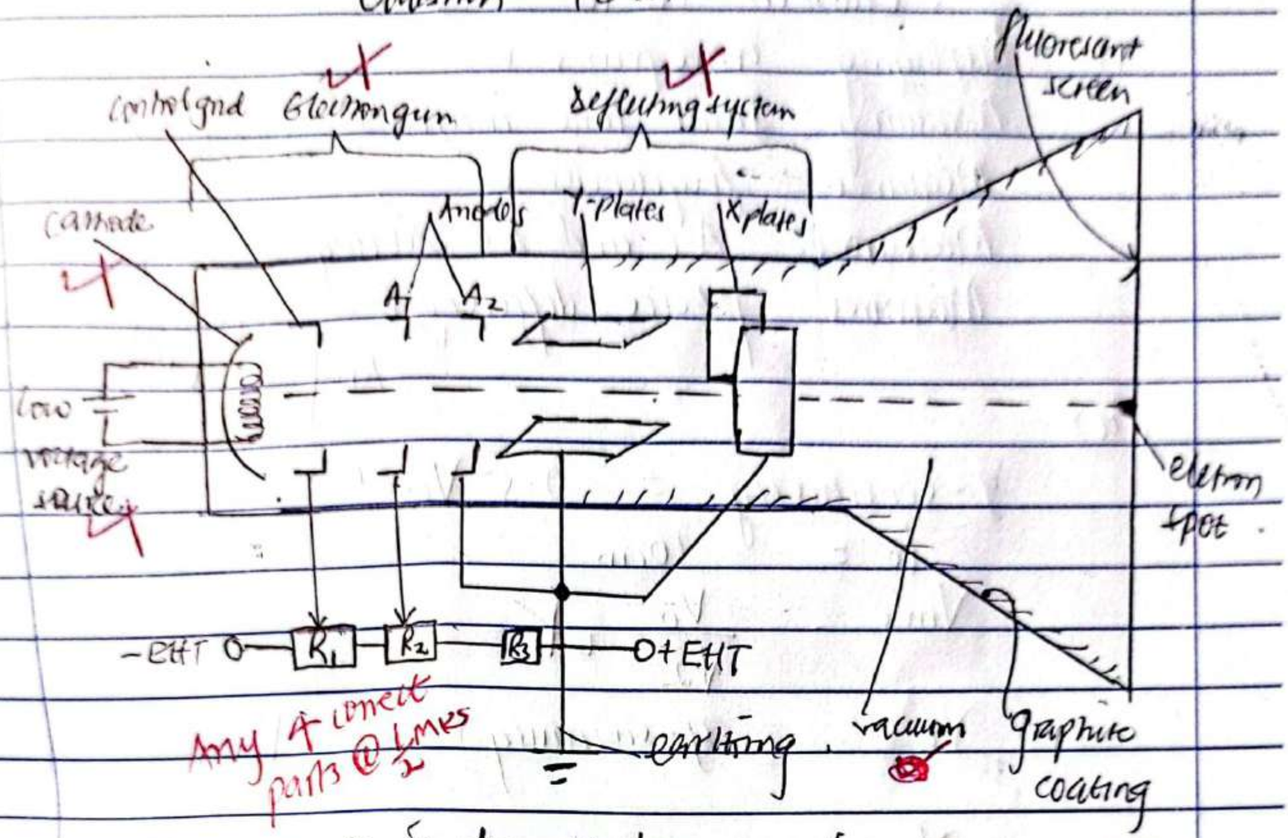
06

CANDIDATE'S NAME:.. INDEX No.....................

SUBJECT:.. PAPER:.................. SIGNATURE...............................

Do not write in this margin

Question 10(c)



The cathode is heated by a low voltage source and the electrons are emitted thermionically.

The emitted electrons are, are focused and accelerated by the anodes to the fluorescent screen.

The control grid controls the number of electrons reaching the screen hence the brightness of the electron spot.

On reaching the deflecting system, the Y-plates which are horizontal deflect the electron beam vertically and the X-plates which are vertical deflect the electron beam horizontally.

The electron beam strikes the screen and a bright electron spot is formed.

The vacuum prevents ionization of the air molecules by the electrons through collisions and the graphite coating shields electrons from external fields.

07

CANDIDATE'S NAME:.. INDEX No..................

Do not write in this margin

SUBJECT:.. PAPER:.................. SIGNATURE..................

Question 10 (d)

(i) Displaying waveforms
Measuring small time intervals
Measures frequencies
Measures AC and DC voltages.
Measures phase differences.

Any 2 correct @ 1mk

02

(ii)

$y\text{-sensitivity} = 0.5\ Vcm^{-1}$

$l_0 = 10cm$

$V_{rms} = \frac{V_0}{\sqrt{2}}$

$V_0 = (y\text{-sensitivity}) \times \frac{L_0}{2}$

$V_0 = 0.5 \times \frac{10}{2}$

$V_0 = 0.25\ V$

$V_{rms} = \frac{2.5}{\sqrt{2}}$

$V_{rms} = 1.768\ V$

03

— END —