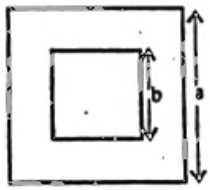
PAPER II PART A - STRUCTURED ESSAY

(1) Figure shows a thin, uniform metal sheet of side a with a square hole of side b in it. a and b are of the order of a few centimetres. a,b, thickness (t) and the mass (m), of the sheet ae to be measured as accurately as possible.



(a) What is the best laboratory measuring instrument that can be used to measure ? *(one line)*

(b) An important check has to be made before taking a measurement using the above instrument. What is it ? *(one line)*

(c) You are givena vernier caliper to measure a and b .

Which partof the caliper would you utilize to

(1) determine a: .....

(2) determine b: .....

(d) What is the most suitable laboratory measuring instrument that can be used to measur m ? *(one line)*

(e) Write down an expression for the density of the metal in terms of m,a,b,and t. *(one line)*

(f) The thickness t was measured at five different places of the sheet and the values obtained are given below.

1.10 mm, 1.11 mm, 1.12 mm, 1.11 mm

(i) What is the least count of the measuring instrument used ? *(one line)*

(ii) Calculate the mean thickness of the sheet. *(one line)*

(iii) Up to how many decimal places would you give the answer calculated above ? Explain why ? *(2 lines)*

(g) To determine the volume of the sheet a student suggests to immerse the sheet in water and measure the volume of water displaced. state why this is not so accurate as compared to the value calculated using a,b, and t. *(one line)*

. You are asked to find the specific latent heat of fusion of ice using the method of mixtures.

(a) Draw a labelled diagram of an experimental arrangement that you would use for this.

(b) (i) If the ice is available in the following three forms, which form would you think is the best for this experiment ?

One large cube : Small cubes : Ice in crcushed form.

(ii) Give one scientific reason as to why you have rejected each of the other two forms. *(3 lines)*

(c) What are the three measurements that you would propose to take before adding ice into water ? *(3 lines)*

(d) In this experiment, usually a certain experimental procedure is adopted to minimize the heat loss to surroundings. What is it ? *(2 lines)*

(e) State the other two measurements that you would take after mixing ice and water. *(2 lines)*

(f) In this experiment an accurate result cannot be obtained if a small quantity of water just sufficient to dessolve ice is used.

Give two reasons. *(2 lines each)*

(g) When calculating the specific latent heat *(L)* of fusion of ice using the data taken under (c) and (e) the temperature of ice is usually assumed to be 0 °C . If the actual temperature of ice is -2 °C , by what percentage the calculated value of *L* is deviated from the actual value due tothis assumption ? *(2 lines)*

Specific heat capacity of ice = $2.2 \times 10^3 \, J kg^{-1} K^{-1}$

3. You are provided with a convex lens, two pins which are mounted on stands and a screen.

(a) You are asked to determine the position of the real image of a pin formed by the convex lens, using the oth pin. Draw an experimental arrangement of the given apparatus that you would use of this purpose. Label t object pin as *O*, the image pin as *I* and the screen as *S*. Also mark the positions of the focal points. *(5 cm space available)*

(b) Write down the essential experimental steps that yourwould follow in the non - parallax method which is use to determine the posistion of the image in (a). *(4 lines)*

(c) In a smillar experiment when a certain concave lens is kept in contact with the convex lens a real image cou not be found for any location of the object pin.

(i) What is the reason for this ? *(one line)*

(ii) Draw a ray diagram to illustrate such a situation. *(7 cm space available)*

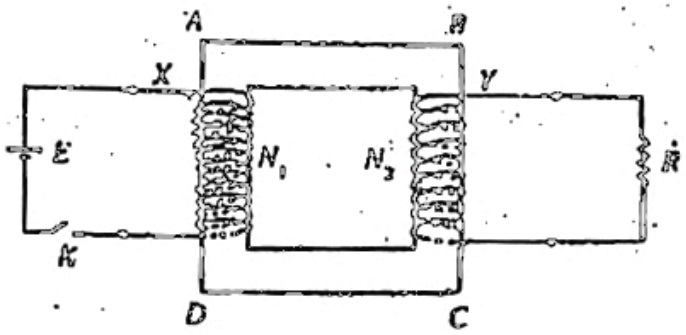
(d) Now if a suitable concave mirror is placed behind the lens combination mentioned in (c) above a real image found to appear at the same location of the object pin.

(i) Where should the centre of curvature of the mirror be situated for this to happen ? *(one line)*

(ii) In such an arrangement the distances to the object pin and to the concave mirror from the le combination are found to be 20 cm and 10 cm respectively. If the radius of curvature of the conca mirror is 20 cm, calculate the focal length of the lens combination. *(3 lines)*

(iii) If the focal length of the convex lens is 20 cm what is focal length of the concave lens ? *(3 lines)*

4.



In the diagram shown X and Y are two coils of N_1 and N_2 turns respectively and $ABCD$ is an iron core.

(a) (i) If the key K is closed suddenly, an instantaneous current will flow through the resistor R. Expla why? *(4 lines)*

(ii) Indicate the direction of this current in the above diagram.

(iii) State the law which determines the direction of this current.(No marks will be given for mathematic formula only.) *(3 lines)*

(iv) What is the main purpose of the iron core $ABCD$? *(one line)*

(b) If now an a.c, source voltage of V_1 is connected across the coil X instead of the battery and the key, and the resistor R is removed so that the arrangement becomes a transformer, write down expression for the voltag V_2, developed across the coil Y in terms of V_1, N_1 and N_2 *(one line)*

(c) In usual tranformers, power losses in the iron cores due to eddy currents are reduced by using specially made cores.

(i) To achieve low losses, what type of iron core is used ? *(one line)*

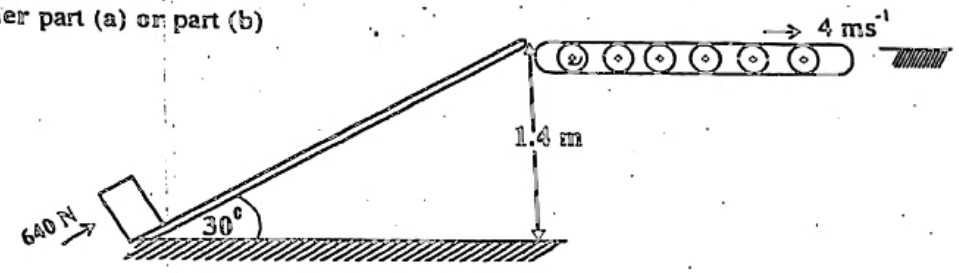
(ii) Explain how the eddy currents are minimised in th ironcore mentioned in (c) (i). *(3 lines)*

(d) (i) What type of transformer is suitable for spot welding ? *(one line)*

(ii) Give the reason for your choice. *(2 lines)*

1. Answer either part (a) or part (b)

(a)



A box of mass 100 kg is to be raised to a vertical height of 1.4 m by pushing it up an inclined plane and then to be transferred over to a horizontal moving conveyor belt, as shown in the figure, It is found that a minimum force of 640 N is necessary to move the box along the inclined plane which make an angle 30° with the horizontal.

(i) What is the totla work done by the above applied force in pushing the box up the inclined plane.

(ii) What is the corresponding increase in the potential energy of the box ?

(iii) If the value obtained in (i) is different from (ii), explain the reason for it'

(iv) Calculate the coefficient of friction between the box and the inclined plane.

(v) At the top of the inclined plane the box is transferred instantaneouslywith a negligibly small speed on to the belt which is moving horizontally at a constant speed 4 ms^{-1}. The box acquires speed of the belt 2 s after it touches the belt.

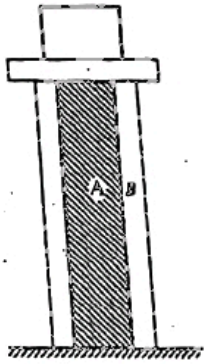
(a) What is the change in momentum of the box along the horizontal direction ?

(b) calculate the magnitude of the force acting on the box during the 2 s, in order to acquires the above momentum. Explain how does this force originate.

(c) What is the magnitude of the external force which should act on the belt in order to it movingat constant speed during the above mentioned 2 s.

Where does this force come from ?

b) A vertical support is made of two solid co-axial metal cylinders *A* and *B* each of length 5 m as shown in the figure. The inner cylinder *A* is of radius 10 cm and the outer cylinder *B* has an internal radius of 10 cm and an external radius of 15 cm . The lower end of the support is fixedrigidly to the houizontal floor and a horizontal plate of negligible mass is placed on the upper end. A weight of 2.2×10^6 N is kept on the plate and the plate remains horizontal.



The young's modulii of the materials of A and B are 1.0×10^{11} N m^{-2} and 1.2×10^{11} N m^{-2}, respectively.

(i) What is the ratio of the forces acting on *A* and *B* ?

(ii) What is the decrease in length of the support due to the weight that is placed on the plate ?

(iii) Suppose at a time when the weight is not present on the plate, the temperature of the support has gone up by 20 °C . Calculate the increase in th lengths of *A* and *B* under this situation.

Linear expansivitiesofthe materials of A and B are 2.0×10^{-5} C^{-1} and 1.0×10^{-5} C^{-1} respectively.

(iv) Now if the weight (2.2×10^6 N) is brought back on to the plate while keeping the temperature of the support at the value mentioned in (iii), show that the length of the support again becomes 5 m.

[If your expressions in (iv) above contain terms such as $(5 + \Delta l)$ and if Δl is less than 0.005 m you may neglect Δl]

2. Usingdimensional analysis show that the visous force F acting on a sphere of radius a moving with a veloc in a liquid of coefficient of viscosity η isgiven by

$$F = k\eta aV$$

where k is a constant.

A sample of muddy water from a river iscollected to a tall glass vessel and allowed to sediment at time $t=0$ It be assumed that the mud particles attain their terminal velocities within a negligible short time. Assume th t muddy water contains equal numbers of spherical particles of all sizes and initially the are distributed unifor the volume.

(i) Derive an expression for the terminal velocity V of a mud particle of radius a and density ρ moving d~v water of density σ and coefficent of viscosity η.

(ii) If $\rho = 2500\ \text{kg m}^{-3}$, $\sigma = 1000\ \text{Kg m}^{-3}$, $\eta = 8 \times 10^{-4}\ \text{N s m}^{-2}$ and the height of water in the vessel is calculate the time taken to sedmient all th particles with $a = 8 \times 10^{-6}$ m. Assume that there are no colli- n particles inside the vessel.

(iii) Repeat the calculation in (ii) for particles having radius $a = 3 \times 10^{-6}$ m.

(iv) Once the sedimentation of particles having $a = 8 \times 10^{-6}$ m is over what fraction of particles with $a = 3$ can be found inside that sedimented layer.

3. State Newton's Law of coolig

(i) A vessel of water kept in a room of temperature $30\,^{\circ}\text{C}$ is to be heated to $100\,^{\circ}\text{C}$.

(a) When an immersion heater of 420 W was used to boil the vessel of water it was found temperature of water had not increased beyond $90\,^{\circ}\text{C}$. Explain the reason for it.

(b) Calculatethe wattage of an immersion heater which is just capable of increasing the temperature o water to $100\,^{\circ}\text{C}$. Assume that the evaporation of water from the surface is negligible.

(ii) In a practical situation

(a) State whether the assumption made in (i) b is valid specially when the temperature of water i cl $100\,^{\circ}\text{C}$.

(b) briefly explain whether the wattage calculated in (i) b issufficient to increase the temperature of w $100\,^{\circ}\text{C}$.

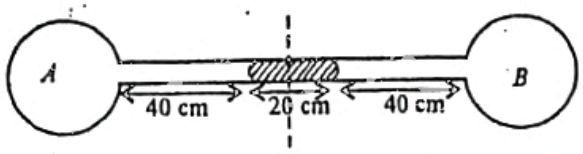
(c) briefly explain whether the Newton's Law of cooling can be applied when there is evaporatio from the surface.

(d) If the 420 W immersion heater and another immersion heater having a wattage equal to calculated in (i) b are used together to heat the water calculate the rate at which the water boi the vessel.

(e) in order to perform the calculation in (ii) d above is it necessary to make the assumption state in Explain your answer.

Specific latent heat of vaporisation of water $= 2.27 \times 10^{6}\ \text{J kg}^{-1}$

4. Clearly identifying each symbol write down the ideal gas equation.



Two identical glass bulbs A and B each having a volume of $50\ \text{cm}^3$ containing dry air at $27\,^{\circ}\text{C}$ are cor ec gass tube of length 100 cm and cross sectional area $1\ \text{cm}^2$. When the system is held horizontally, the 2 mercury column contained in the tube is found to be at the middle of the tube as shown. When the sy vertically, the top of the mercury column is found to be at the middle of the tube.

(i) Find the pressure inside the bulbs, when the system is in the horizontal position, in cm of mercury.

(ii) In the vertical position, when the lower half of the system is maintained at a certain temperature, T, the mercury column moves up so that the bottom of the column is at the middle of the tube. What is the value of T ? Neglect the expansion of the glass and mercury.

(iii) Suppose the bulb A contains dry air and B contains air with saturated water vapour, and the mercury column is still found to be at the middle when the system is kept at the horizontal position. Now if the temperature of the system is lowered from 27 °C to 12 °C the mercury column will move by 1.5 cm from its initial position. Calculate the mass of water vapour which wil get condensed in the bulb at 12 °C . Assume that the water vapour behaves as an ideal gas

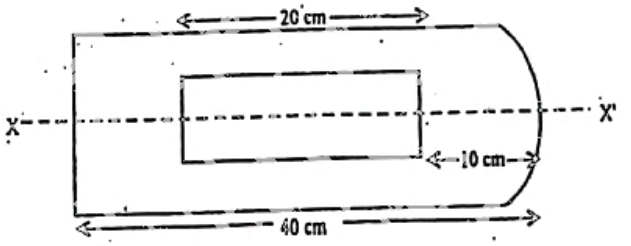
molecular mass of water = 18 g

gas constant R = 8.3 J. $mol^{-1} k^{-1}$

Saturated vapour pressures of water at 27 °C and 12 °C are 4.0×10^3 N m^{-2} and 1.5×10^3 N m^{-2} respectively.

5. Answer either part (a) or part (b)

(a) Cross section of a cylindrical glass rod of length 40 cm having a flat surface at one end and a convex surface at the other end, is shown in the figure. A cylindrical cavity of length 20 cm is located at the center of the rod. Refractive index of glass = 3/2.



(i) A narrow monochromatic beam of parallel light enters through the flat surace along the axis XX' and converges to a point outside the cylinder, at a distance 10 cm from the convex surface. What is the radius of curvature of the convex surface ? State clearly the formula and the sign convention that you have used.

(ii) If a small light bulb is placed at the center of the cavity, what is the position of the image of the light bulb if it is viewed through the convex surface ?

(iii) Where should the light bulb be located inside the cavity in order to obtain a parallel beam of light through the convex surface ?

(b) ' Angular magnification is a better measure compared to linear magnification in determining the magnification produced by an optical instrument. ' Briefly explain the above statement.

(i) A student constructed a refracting telescope using a cardboard tube and two convex lenses of focal length 100 cm and 20 cm. He observed the image of a distant building with the telescope in normal adjustment. calculate the magnifying power of the telescope. Derive any formula that you may use.

(ii) Later he has converted the instrument into a terrestrial telescope in normal adjustent by placing another convex lens of focal length 8 cm between the objective and eye piece while keeping the distance between the objective and the eye piece as shout as possible.

(a) Why is it convenient to use the arrangement mentioned in (ii) over the one given in (i) to view the distant building ?

(b) What is the distance between the image formed by the objective and that formed by the lens of focal length 8 cm ?

(c) Trace the paths of two rays coming from the top of the distant building through the terrestrial telescope to the eye.

(d) Calculate the distance between the objective and the eye piece, and the magnifying power of this terrestrial telescope.

6. Once the end correction is neglected, the resonant frequencies, f, of a uniform pipe of length L closed at one end can be written as $f = \frac{nV}{4L}$

Where V is the velocity of sound in air, and n can take values 1, 3, 5, 7 and so on.

Similarly if the pipe is open at both ends, the resonant frequencies, f', are given by

$f' = \frac{n'V}{2L}$ Where n can take values 1, 2, 3, 4 and so on.

(i) In both cases, show that the above formulae are true for the respective fundamental notes and the firs overtones.

(ii) A uniform pipe closed at one end resonates at the frequency of 210 Hz. When both ends of the pipe are open it resonates at 840 Hz.

(a) Neglecting end corrections, calculate the minimum pipe lengthe which statisfies the abov conditions. (Velocity of sound in air is 340 m s^{-1})

(b) Under this situation, for which tones do 210 Hz, and 840 Hz, correspond to?

7. Answer either part (a) or part (b)

(a) A resistor network consisting of three series connected resistors R_1, R_2 and R_3 is placed across a 300 V supply with R_1 adjacent to the positive end A and R_3 adjacent to the negative end D. The junction between R_1 and R_2 and that between R_2 and R_3 are denoted by B and C respectively. Two electrica appliances S_1 and S_2 connected between B and D, and C and D draw currents of 10 mA and 20 mA respectively.

(i) If the 300 V supply delivers 50 mA to the network and the voltages across BD and CD are 200 V and 150 V respectively, find the values of the resistor. R_1, R_2 and R_3.

(ii) Calculate the internal resistances of S_1, S_2.

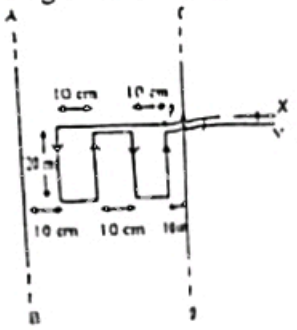
(iii) If S_1 is disconnected what will be the voltage appearing across S_2 and the current drawn by S_2?

(iv) For S_2 to operate properly, the input power given to it must lie between ±5% of the rate 3W value. When S_1 is removed, verify whether S_2 will continue to work properly or not.

(b) Write down Biot - Savart law in the form of a mathematical expression clearly identifying all the symbols you have used. Show in a diagram the directions of all the variables associated with the expression.

Write down an expression for the magnetic flux density B at a point which is situated at a distance from a thin straight conductor of infinite length carrying a current I.

A wire XY bent to form two rectangular loops as shown in the figure and carrying a current of 10 A placed symmetrically between two long straight parallel wires AB and CD so that their long sides ru parallel to AB and CD. All wire secions of XY, which are parallel to the two long wires have a length o 20 cm and a separation of 10 cm as indicated on the diagram. Assume all the wires lie on the same plane.



(i) If the wire AB carries a current of 20 A in the upward direction ($\overrightarrow{BA}$) find the magnitude and the direction of the resultant force exerted on the wire XY by the magnetic field due to the current in wire AB.

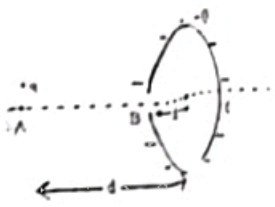
(ii) Is the actual magnitude of the resultant force acting on XY equal to the value calculated in (i)? Explain your answer.

(iii) Now in addition to the wire AB, the wire CD also carries a current of 20 A but in the opposite direction ($\overrightarrow{CD}$) find the magnitude of the resultant force acting on the wire XY by the magnetic fields due to the currents in AB and CD. You may arrive at your answer even without a calculation but in such cases a brief explanation is required.

(iv) Comment on the resultant magnetic field produced by the pair of wires belonging to XY which lie the right of point P.

$$\frac{\mu_0}{4\pi} = 1.0 \times 10^{-7}\ \mathrm{T\,m\,A^{-1}}$$

8. A charge Q is distributed uniformly over a thin spherical shell of radius R. Use the Gauss' theorem to show that the electric field intensity any where outside the shell is the same as if the charge Q were concentrated at the center of the shell. Find the electric Field intensity inside the shell.



A particle of charge +q is released from rest from point A towards a uniformly charged thin spherical shel of radius R carrying charge $-Q$. As shown in the figure the particle is initially at a distance d from the center of the shell, and when released it rou the two small holes situated dia metrically opposite sides of the surface of the shell, without shell.

(i) What is the electric potential energy of the charged particle

(a) When it is at point A and (b) When it reaches the center

(ii) What is the kinetic energy of the particle when it is at the center of the shell?

(iii) How far from the center of the shell does the particle come to rest again?

(iv) State whether the velocity of the particle will increase, decrease, or remain constar A to B, B to C, and beyond C.