G.C.E. (Advanced Level) Examination - August 2011
PHYSICS - II
Three hours

Answer all four questions. PART A - Structured Essay $[g = 10\ N\ kg^{-1}]$

01. Figure 1 shows a spherometer used in a laboratory. Number of divisions in the circular scale is 50. Linear progress made by the circular scale on the vertical scale in two complete rotations is 1 mm.

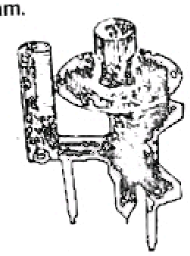


Figure 1

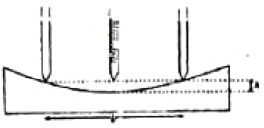


Figure 2

Spherometer is used to determine the radius of curvature of the curved surface of a plano-concave lens. In such a determination, spherometer is placed on the curved surface of the lens as shown in figure 2. After obtaining the measurements h and b which are shown in the figure, the radius of curvature (R) can be determined by the following formula.

$$R = \frac{b^2}{6h} + \frac{h}{2}$$

(*a*) What is the least count of this spherometer?

(*b*) Before placing the spherometer on the curved surface, it has to be adjusted by placing it on a flat glass plate. How do you experimentally make sure that the tip of the screw just touches the glass plate?

(*c*) Then the spherometer is placed on the curved surface of the lens.

(i) What adjustment would you make before taking the next measurement in order to determine h?

(ii) What is the reading that you would take from the spherometer after the above mentioned adjustment?

(*d*) After extensive use, the reading taken from the vertical scale may not be so accurate in some spherometers. what is the reason for this?

(*e*) In order to determine R you need to measure the mean distance between the spherometer legs.

(i) What measuring instrument would you use to determine b?

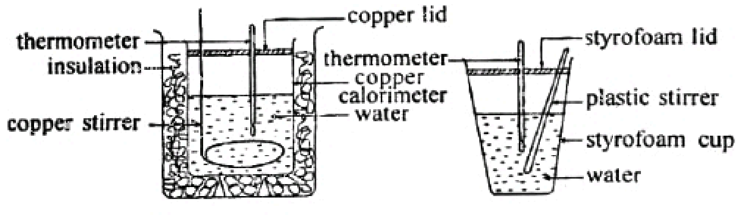
(ii) What experimental steps would you follow in order to determine b?

(*f*) Give another use of a spherometer except the measurement of radius of curvature.

(g) Suggest a method to further decrease the least count of the spherometer given above.

02. The material called Styrofoam, Rigifoam or polystyrene is widely used for making disposable cups. The thermal conductivity of this material is less than 0.0001 times that of copper while its specific heat capacity is about 4 times that of copper.

In order to investigate the suitability of using a styrofoam cup instead of a copper calorineter in heat experiments, a student selected the 'experiment of determination of specific heat capacity of iron in the form of iron balls using method of mixtures', and arranged two experimental setups to perform the experiment, one using a copper calorimeter and the other using a Styrofoam cup. The figure shows his experimental arragement.



After taking the required initial temperature and mass measurements, he added iron balls heated to 100°C to the water in the calorimeter / Styrofoam cup and obtained the necessary temperature and mass measurements. The readings he obtained are shown below.

	Experiment with copper calorimeter	Experiment with Styrofoam cup
Mass of the empty vessel with stirrer	100g	10g
Mass of the vessel with water and stirrer	150g	60g
Initial temperture of water	30 °C	30 °C
Maximum temperature of water after adding iron balls	45 °C	47 °C
Mass of the final system	300 g	210g

(*a*) (i) Calculate the amount of heat absorbed by the calorimeter with stirrer (Take specific heat capacity of copper as 375 J kg^{-1} K^{-1}).

(ii) Using the data obtained with the copper calorimeter, show that the specific heat capacity of iron is 450 J kg^{-1} K^{-1}. (Specific heat capacity of water is 4200 J kg^{-1} K^{-1})

(b) Taking the specific heat capacity of iron as 450 J kg^{-1} K^{-1}, calculate the amount of heat absorbed by the styrofoam cup. (Assume that heat lost to surroundings from the Styrofoam cup and heat absorbed by the plastic stirrer are negligible.)

(c) In heat experiments where Styrofoam cups are used the amount of heat absorbed by the cups can be neglected com pared to copper calorimeters. Justift this statement using the results obtained under (a) (i) and (b) above.

(d) State a practical advantage of using a Styrofoam cup com pared to a copper calorimeter in this expriment.

(e) A copper calorimeter cannot be replaced by a Styrofoam cup in the verification of Newton's law of cooling. Give two experimental reasons for this.

(i) ....

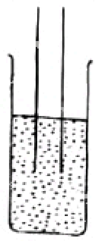
(ii) ....

3. (a) When a tuning fork is at resonance with a tube with one end closed, what is the type of the wave being produced in the tube? Longitudinal or transverse? Travelling or standing?

(b) You are provided with a set of tuning forks of frequencies (f) 288 Hz, 320 Hz, 362 Hz and 480 Hz, a suitable glass tube, a glass jar and other necessary items to determine the speed of sound (υ) in air using a graphical method.

(i) What is the purpose of immersing the tube in water?

(ii) Inside the tube shown in the diagram, draw the wave pattern of the mode of vibration that you would setup for taking data. Clearly indicate the end correction (e) in the diagram.



(iii) Which tuning fork would you select first to take data? Give the reason for your selection.

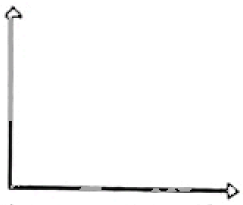
(iv) Calculate the minimum length of the glass tube required to take data using the given set of tuning forks? Take the value of υ in air as 345.6 m s^{-1}.

(v) Obtain the necessary equation in terms of f and the resonance length l to determine υ and e by plotting a graph.

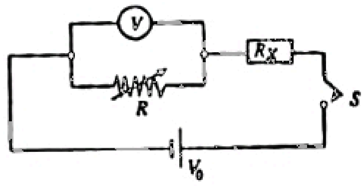
(vi) If you are asked to use another tuning fork in addition to the tuning forks given in (b) above to do the experiment, which one out of the given set below would you select considering the requirement to have a uniform distribution of points on the plot?

f(Hz)	288	320	341.3	362	406.4	426.6	480
$\frac{1}{f}(Hz^{-1})$	3.5×10^{-3}	3.1×10^{-3}	2.9×10^{-3}	2.8×10^{-3}	2.5×10^{-3}	2.3×10^{-3}	2.1×10^{-3}

(vii) Draw a rough sketch of the graph that you would expect in this experiment in the following figure. Label the axes. The dependent variable should be on the vertical axis.



(viii) If the room temperature was uniformly increasing during the period of data taking, draw the curve that you would expect theoretically on the same figure above. Label it as curve - 2.



A student is asked to find the value R_x of an unknown resistor connected to the circuit shown, using a graphical method. R is a variable resistance provided by a resistance box. V is the reading of the voltmeter Connected across R. The internal resistance of the voltmeter is large. Tow new dry cells of voltage 1.5 V each is used to provide a voltage V_0 of 3 V. Assume that the internal resistance of such a dry cell battery is negligible.

(a) Indicate the polarity of the voltmeter by labeling its terminals with + and - signs.

(b) In order to plot a graph, the student is asked to take severel voltmeter readings (V) by varying the resistance R.

(i) Write down an expression relating V, R, V_0 and R_x

(ii) Rearrange the variables in order to plot a straight line graph with $\frac{1}{V}$ on the Y axis.

(iii) Draw a rough sketch of the expected curve. Label the axes.

(iv) How would you find the value of R_x from the graph?

(v) How would you find the voltage V_0 of the battery using the graph?

(c) You are given that the internal resistance of the voltmeter is 1500Ω and the value of R_x is of the order of 100Ω. Of the following ranges given, indicate with a tick (✓) the range of values that you would choose for R in order to obtain the straight line graph.

25 Ω - 500 Ω (..........)
25 Ω - 1500 Ω (..........)
25 Ω - 200 Ω (..........)

Give the reason for your choice.

(d) (i) How would you check experimentally whether the data have been affected by the possible run-down of the battery?

(ii) If you have discovered that the battery has run-down, how would you desing another battery which lasts longer time, using new 1.5V cells to give 3V, before repeating the experiment. (If necessary you may also draw a diagram to illustrate the answer.)

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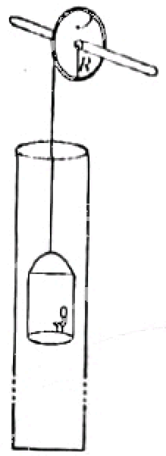
Answer all four questions. PART - B $[g = 10\ N\ kg^{-1}]$

05. A capsule which is free to move through a vertical cylindrical tube as shown in figure can be used to rescue a person trapped in an underground mine. A wire, one end of which is fixed to a pulley of redius R, and wrapped around the pulley, is used to hang the capsule. Assume that the mass of the wire and the friction between the wire and the pulley are negligible. The pulley is free to rotate about a horizontal axle. Answers to the following questions should consist of only relevant quantities represented by the given symbols. (g = gravitational acceleration)



(a) For this part assume that the mass of the pulley and the frictional force against the rotational motion of the pulley are negligible.

(i) If the capsule of total mass M is released from rest, use the law of conservation of energy to obtain an expression for the speed of the capsule after it has moved down a depth h.

(ii) Find the angular speed of the pulley after the capsule has moved down the depth h.

(b) If the mass m of the pulley is not negligible and the moment of inertia of the pulley about the rotating axis is $\frac{1}{2}mR^2$, repeat parts (a) (i) and (a) (ii) neglecting the frictional forces.

(c) Under practical situations the mass m of the pulley and the friction against the rotational motion are not negligible. Assume that the friction exerts a constant frictional torque, τf, against the rotational motion of the pulley.

(i) What is the work done against the frictional torque (τf) when the pulley has rotated by an angle θ_0 in redians?

(ii) Answer parts (a) (i) and (a) (ii) under these conditions.

(iii) After moving down a depth h_0 the capsule reaches the bottom of the tube and stops. However, the pulley keeps rotating against the frictional torque. Use the law of conservation of energy to find the number of turns (n) that the pulley would rotate further after the capsule has stopped.

(d) A person of mass m_0 gets into the capsule When it is at the bottom of the tube. Find the external torgue (Je) that must be applied on the pulley to rotate it at a constant angular speed while raising the capsule. Assume the conditions given in part (c) for this.

06.

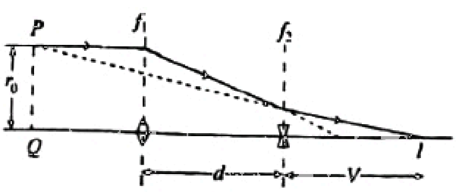


Figure (1) shows a zoom lens arrangement used in a camera. It consists of a convex lens of focal length f_1 and a concave lens of focal length f_2 separated by a variable distance d. The purpose of a zoom lens is to vary the effective focal length of the lens combination significantly with a small variation of d thereby providing variable magnification of the object.

(a) What is the inequality that should be satisfied by d and f_1 in order to form a real image at I?

(b) The lens combination forms an image I at a distance V to the right of the concave lene. Derive an expression for V in terms of f_1, f_2 and d.

(c) (i)

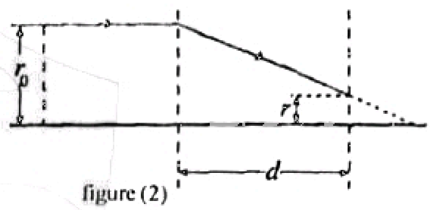


figure (2)

To determine the effective focal length of the combination, consider a parallel ray incident on the convex lens at a distance r_0 from the principal axis. Show that the distance r from the optical axis to this ray at the point it enters the concave lens is give by $r = \frac{r_0(f_1 - d)}{f_1}$. Use the geometry of the diagram in figure (2) to obtain your experssion.

(ii) If the ray shown in figure (1) that emerges from the concave lens and reaches the final image I is extended backward to the left of the concave lens, it will eventually meet the incident ray at point P. The distance from the final image I to the point Q is the effective focal length f of the lens combination.

Show that this focal length is given by $f = \frac{f_1 f_2}{f_2 - f_1 + d}$

(**Hint** : Use the results obtained in (b), (c) (i) above, and geometry to obtain your expression.)

(iii) f_1 = 12.0 cm, f_2 = 18.0 cm and the separation d is adjustable between 0 and 4.0 cm, find the minimum and maximum focal lengths of the combination.

(iv) Do your results justify the purpose of the zoom lens? Give reasons for you answer.

07. (a) A capillary tube of internal radius r is immersed vertically in water under atmospheric pressure. Show that the value of the capillary rise h in the tube is given by $h = \frac{2T}{\rho g r}$ where T is the surface tension of water and P is the density of

water. Take the contact angle between water ρ and the material of the tube to be zero.

(b) In plants, water ascends through capilliaries known as xylem tubes. When answering parts (b) (i) and (b) (ii) consider a xylem tube having both ends open to atmospheric pressure.

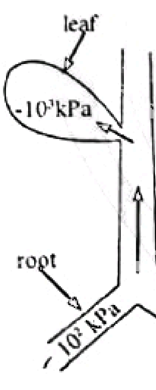
(i) Calculate the height to which water rises in such a capillary of radius 100μm. (Surface trnsion of water = 7.2×10^{-2} Nm^{-1}, density of water = 10^3 kg m^{-3})

(ii) Water rises up to a height of even 100 m in tall trees. If water goes up the xylem tubes due to capillary action alone, calculate the Internal radius of a capillary that would raise water by 100 m to the top of a tree.

(c) However scientists have never found such small capillaries calculated in (b) (ii) above in tree xylem. Therefore capillary action cannot be solely responsible for water getting to the top of trees.

To explain how water ascends from roots to leaves, scientists use the concept known as the water pressure (water potential per unit volume.) At standard temperature and pressure, pure water is given a water pressure of zero. Adding solute molecules to the water has the effect of lowering the water pressure, i.e. making it negative. When water evaporates from leaf tissues it raises the solute concentration of water in leaves. This results the water pressure of leaves to be relatively low compared with the water pressure at roots. This water pressure gradient pushes the water up from roots to leaves.

(i) The figure shows a root and a leaf of a tree. If the water pressures of the root and the leaf are -10^2 kPa and -10^3 kPa respectively, estimate the height of the water column that can be sustained by this pressure difference. Neglect the surface tension of water.



(d) (i) Assuming the water flow in the xylem tube (internal radius = 100μm) to be streamilned, use the Poiseuille's equation to determine the average speed of rising water. Neglect the weight of the rising water column. Viscosity of water = 10^{-3} Pa s. Take the length of the xylem tube to be equal to the height calculated in (c) (i) above.

(ii) Calculate the power needed to raise this water column up in the xylem tube. (Take π= 3)

08. Use of satellites is expanding due to many applications in areas such as communication, meteorology, defence and scientific exploration about the earth as well as the outer space. Satellites are placed on certain orbits depending on their applications. The gravitational force provides the required centripetal force to maintain a satellite in an orbit.

Geosynchronous satellites orbit the earth with a period of 24 hours, thus matching the period of the earth's rotational motion. **A geostationary satellite (GSS)** is a Geosynchronous satellite in an approximately circular orbit on the plane passing through the earth's equator (0° latitude) that appears motionless in the sky, to a ground observer. The idea of a GSS was first proposed by the science friction writer Arthur C. Clarke. Communication satellite and weather satellites are often given Geostationary orbits as they can continuosly observe the same areas on the earth. GSS use directional antennas for communication with ground stations. There are also several disadvantages of a satellite being operated as a GSS. The number of satellites that can be maintained in Geostationary orbits without interfering one another is limited. An electromagnetic (EM) signal emitted from a ground station, travels at the speed of light (3×10^8 ms^{-1}). Due to the great distance to the satellite a significant time delay is introduced between the original signal emitted from an earth station and the signal receiced by another station after travelling via a satellite. Furthermore, due to the greater height, the clarity of pictures of the earth taken by GSS are poor, especially at locations away from the equator. Another problem would be the damage caused by the EM radiation from the sun when a GSS comes closer to the sun especially when the sun passes through the equatorial plane at late March and late September.

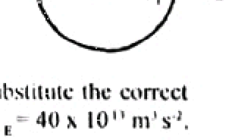
Low Earth Orbit Satellites (LEOS), typically operating at the heights of 160-2000 km from the **surface of the earth** with shorter periods, have become popular in recent years. Their orbits could be on any plane passing through the centre of the earth. However, for continuous data acquisition pertaining to a specific location (eg: observation of weather over a given country) a system of a group of LEOS is needed. Some advantages of a LEOS are the use of simple non-directional antennas, reduced time delay for EM signals, higher clarity pictures of the earth and less EM radiation from the sun. Also, it needs less energy and resources to place a satellite into a Low Earth Orbit and need less powerful amplifiers for successful communication. A polar satellite which passes over the poles of the earth is a special case of LEOS. Hubble space telescope is another example of LEOS.

For scientific exploration of outer space, experiments are conducted in observatories placed on the orbits which are far away from the earth. There are five specific locations called Lagrange points or L-Points where satellites could be placed to perform such experiments. Satellites placed at L-points appear stationary relative to the sun-Earth system. The following figure shows two of the L-points called L_1 and L_2. When the earth orbits the sun with a period of 1 year, satellites placed at L_1 and L_2 also move with the sun-Earth system but the relative locations of them remain the same. There are four satellites at the vicinity of L_1 and three satellites including the latest Planck Space Observatory have been placed at the vicinity of L_2. L_2 is especially useful for observation of outer space because, the earth partially blocks solar radiation falling towards the satellite at L_2 throughout the motion. (Radius of the earth is 6.4×10^6m).

(a) What is the value of the period of a GSS?

(b) Draw a 3 -dimensional digram of the orbit of a GSS around the earth. Clearly indicate the geometrical North, South and the equatorial plane of the earth.

(c) Give an example for a LEOS.



(d) Obtain an expression for the radius r of a GSS in terms of universal gravitational constant G, mass of the earth M_E and the period T of GSS. Substitute the correct numerical values in the expression $GM_E = 40 \times 10^{13}$ m^{3}s^{-2}. No need to simply the answer.

(e) Calculate the time delay in receiving an electromagnetic test signal emitted from a ground station to a GSS located 36000 km vertically above it, if the signal is received again by the same station.

(f) International space station orbiting around the earth is in an orbit with a radius of 6700 km inclined to the equatorial plane. Calculate its period. Is this a GSS or LEOS? Give the reason for your answer.

$(\sqrt{67^3} = 67^{\frac{3}{2}} = 548.4;$ Take π^2 as 10)

(g) Give three advantages of LEOS.

(h) Why is the location L_2 bet ter for placing an outer space observatory?

(i) Calculate the angular speed (ω) of the planck Space Observatory in units of rad year^{-1}.

(j) Write down an equation for the orbital motion of the Planck Observatory in terms of mass of the sun (M_s), mass of the earth (M_E), distances from the earth to the sun (R) and to the satellite (r), ω and G. Neglect the effect of other planets and the moon.

(k) Periods of satellites around any object, in general, should increase with the distance from the centre of the object. Satellites at L_1 and L_2 are at different distances from the sun but have equal periods. Explain the reason for this.

09. Answer either part (A) or part (B) only.

(A) The circuit shown in figure 1 has three inputs A, B and C and voltages V_A, V_B and V_C of either zero or 7 V can be applied be tween the inputs and the common grounded line XY.

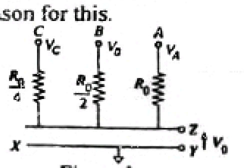


Figure 1

(a) If a zero voltage is applied (i. e. $V_A = V_B = V_C = 0$) to all three inputs by grounding each input terminal as shown in figure 2, find

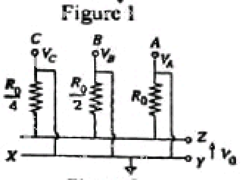


Figure 2

(i) the equivalent resistance across ZY.

(ii) output voltage V_0.

Now copy the table given below onto your answer script and complete the row 1 (i. e. V_0 value) of the table.

Important : All calculations and corresponding circit diagrams nust be shown clearly in order to earn marks for the parts (b), (c) and (d).

	V_C (volt)	V_B (volt)	V_A (volt)	V_0 (volt)
Row 1	0	0	0	
Row 2	0	0	7	
Row 3	0	7	0	
Row 4	0	7	7	
Row 5	7	0	0	
Row 6	7	0	7	
Row 7	7	7	0	
Row 8	7	7	7	

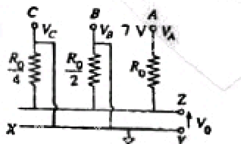


Figure 3

(b) Now the A input is connected to 7V and B and C inputs are grounded as shown in figure 3. Calculate the new value of V_0 and nence fill in the row 2 of the table.

(c) (i) Draw the circuit-diagram similar to figure 3 connecting the inputs A and C to ground and input B to 7 V.

(ii) Find the value of V_0 and fill in the row 3.

(d) Draw the circuit diagrams corresponding to the situations depicted in rows 4 and 5 of the table, find the values of V_0 and fill in the corresponding rows.

(e) (i) Hence deduce V_0 values for the rest of the input voltage combinations of the table and complete the V_0 column of the table.

(ii) If the voltages 7V and 0 are considered to represent binary 1 and 0 respectively, explain the function of the above circuit given in figure 1.

(B) (a) Figure 1 shows I - V characteristics of a light emitting diode (LED) for two different temperatures.

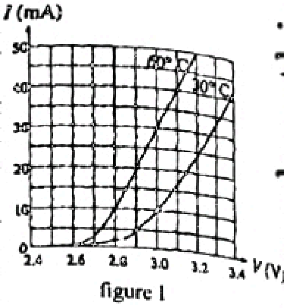


figure 1

(i) Suppose the LED at a 30°C room temperature is connected to a 3 V battery as shown in figure 2. According to the I - V characteristics, it will draw a 10 mA current. After some time, if the LED reaches a temperatire of 60 °C due to its heat dissipation, what will be the current through the LED?

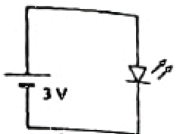


figure 2

(ii) Why would a current through a semiconductor device depend on the temperature?

(iii) It is possible to control the current through the LED by connecting a resistor in series. Calculate the value of the resistor that would limit the current through the LED (at 30 °C) to 10mA, when connected to a 9V battery.

(iv) With a resistor having the value calculated in part (iii) above, suppose the temperature of the LED goes above 30 °C and the current through the LED reaches 10.3 mA. Calculate the voltages across the resistor and the LED under this condition. When this happens, will the power dissipated in the LED increase or decrease? Justify your answer. If the current futher increases due to higher LED temperature, what will happen to the voltage drops across the resistor and the LED?

(b) Figure 3 shows a circuit commonly used for providing a constant current to a device such as an LED (marked as D in the figure.)

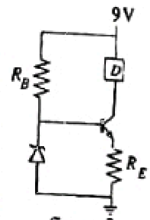


figure 3

(i) If the value of R_B is 3000Ω, and the voltage drop across the Zener diode is 3 V, calculate the current through the Zener diode. (Assume that the base current is negligible.)

(ii) If the voltage across the base-emitter junction of the transistor is 0.7V, calculate the value of R_E that will make the collector current 10mA. (Assume that the emitter current is equal to the collector current.)

(iii) If the LED in part (a) above is used as the device D, calculate the voltage across the collector and emitter terminals of the transistor (V_{CE}). (Assume that the LED temperature is 30 °C.)

(iv) Assume that the graph in figure (4) represents the I_C - V_{CE} curve for the transistor for the releveant I_B value.

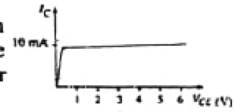


figure 4

Copy this graph to your answer script and mark the operating point (V_{CE}, I_C) as point A

(v) If the LED temperature now increases, indicate on the graph with an arrow which way the operating point will move.

(vi) Now suppose two identical LEDs, connected in series, are used as the device D. Calculate the new V_{CE} value and indicate the operating point of the transistor in the graph as point B.

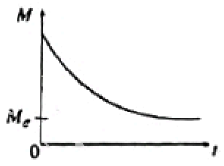
10. Answer either part (A) or part (B) only.

(A) A closed transparent chamber of volume 1 m³ contains air at 30 °C and 80% relative humidity. Air inside the chamber is first dride by means of an equipment (dehumidifier) which removes moisture without changing its temperature so that the absolute humidity of the air is dropped to 50% of its initial value. Absolute humidity of air saturated with water vapour at 30 °C is 30g m^{-3}.

(a) Calculate the absolute humidity of dried air.
The dehumidifier is then removed and the chamber with dried air is used to study the drying of paddy. For this, 750g of wet paddy is introduced into the chamber at time t = 0. The initial omisture content of the paddy sample amounts to 20% of its initial mass. paddy sample is kept on the pan of an electronic balance placed inside the chamber and its mass can be read from outside.

(b) Find the mass of the moisture present in the given paddy sample before placing it in the chamber.

(c) As the paddy dries, the variation of its mass (M) with time (t) as displayed by the electronic balance is shown in the figure.



(i) Give a reason
(1) for the shape of the curve,
(2) as to why the mass attains a equilibrium value M_e after some time.
(ii) What is the relative humidity of air inside the chamber when the mass of paddy reaches M_e?
(iii) Calculate the equillibrium mass M_e.
(iv) Calculate the remaining moisture content in grammes of the paddy sample when its mass becomes M_e.

(d) If the percentage moisture content of the paddy sample is to be reduced to 10% what should be the minimum volume of the chamber that has to be employed with dried air prepared in the same manner as given at the beginning of this question?

(e) Atmospheric air heated to higher temperature (without using a dehumidifier) can also be used for drying. If the closed chamber of 1 m^3 is filled with air which was originally at 30 °C and relative humidity 80% now heated to 70 °C to perform this study calculate.

(i) the initial relative humidity of heated air inside the chamber before introducing the paddy sample.
(ii) expected value of M_e.
Assume that the temperature of air inside the chamber is maintained at 70 °C throughout the time of the study. Absolute humidity of air at 70 °C saturated with water vapour is 216 g m^{-3}.

10. (B) In the medical imaging technique called positron Emission Tomography (PET), a patient is injected with a radioactive isotope that decays by emitting positrons (β^+ or e^+) to a blood vessel. Next, the radiation coming out of the body is detected by detectors placed around the patient. Using this information, an image is constructed by a computer, which shows the concentration of that isotope in different regions of the body.

Suppose a patient is injected with 20 pico grams of ^{15}O-water (water prepared by replacing ^{16}O atoms by ^{15}O atoms). ^{15}O atoms decay by emitting positrons with a half life ($T_{\frac{1}{2}}$) of 2 minutes. (1 pico gram = 10^{-12} gram.)

(a) (i) The activity of a radioactive sample that has an N number of atoms is given by the formula $A = \frac{0.7N}{T_{\frac{1}{2}}}$.

Calculate the activity (in Bq) of the amount of ^{15}O- water injected, at the time of injection. (Take the mass of one ^{15}O- water molecule as 2.8×10^{-26} kg).

(ii) Calculate the activity (in Bq) inside the brain due to ^{15}O decay, after 2 minutes of the injection. Assume that 10% of the injected water reached the brain of the patient during that period.

(iii) Due to the naturally present radioactive isotopes (such as ^{14}C) in the body, there is an activity of about 10^4 Bq in the body of a normal person. Show that, 40 minutes after giving the above injection, the activity due to ^{15}O decay in the body of the patient will become less than the naturally present activity. (Take $2^{20} = 10^6$)

(iv) What could be the advantage of using an isotope with a very short half-life?

(b) Inside the body, the positrons emitted by the decaying ^{15}O atoms interact with electrons in the body to produce two gamma rays according to the reaction $e^+ + e^- \rightarrow 2\gamma$. These gamma rays can be detected by detectors placed outside the body.

(i) If an electron (β-) emitting isotope is used instead of a positron (β+) emitting isotope, explain why no radiation will come out of the body of the patient.

(ii) If a gamma ray has an energy E, the magnitude p of its momentum is given by $p = E/c$ where c is the speed of light. Using the law of conservation of momentum, show that both gamma rays in the above reaction must have the same energy and that they will be travelling in opposite directions. (assume that both e^+ and e^- have zero momentum.)

(iii) Both e^+ and e^- have the same mass. In energy units, this mass is 511ke V. How much is the energy of one gamma ray in the above reaction?

(c) The maximum dose of radiation a patient could get from an ^{15}O- water injection can be estimated by assuming that all the gamma rays produced are absorbed by the body of the patient. If the weight of the patient mentioned above is 51.1kg, calculate this maximum dose (acerage over the body) he could receive from the injection of 20 pico gram ^{15}O- water, in Gy. (1 ke V = 1.6×10^{-16}J and 1 Gy = 1 Jkg^{-1})

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