Provincial Department of Education

Northern Province

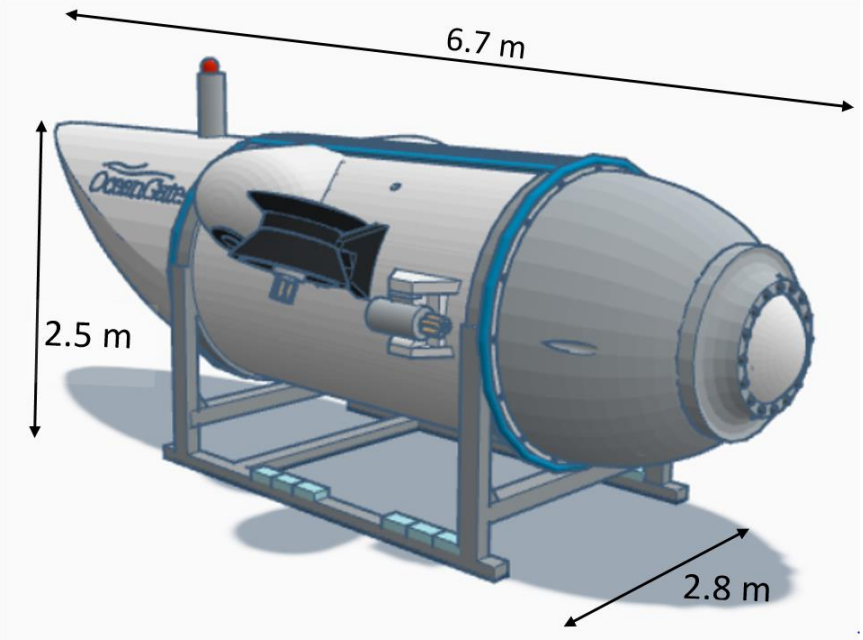
Pilot Paper – December 2023

Physics - II (B)

Grade- 13 (2023 Batch)

Select the questions according to the instruction given in part **ii** (A) **Front side**

5. The world knows the meaning of "Explosion", but there is an incident which taught us the meaning of "Implosion". A submersible named as "Titan" which is produced and operated by Ocean Gate, designed for transporting paying customers (tourists) to the wreckage of *Titanic* Ship which lies at a depth 4000 m below from sea level. Titan was 6.7 m × 2.8 m × 2.5 m and weighed 6350 kg. It can carry maximum payload of 350 kg of 5 tourists(each person has 70kg).

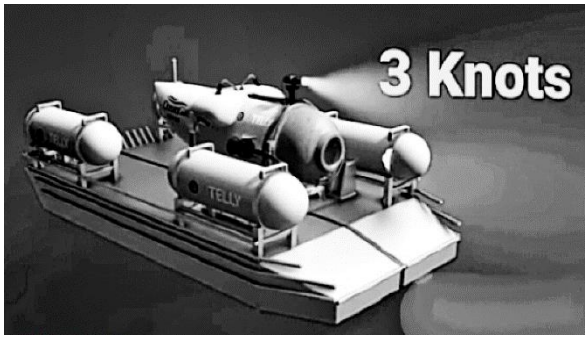


The effective volume of Titan is 25 % of the total space occupied by the above given dimension. It has a compartment called as "Ballast tank" which controls its movement upward or downward and provides hydrostatic stability . The maximum volume occupied by this tank is 10 m^3. To get upward thrust water in the ballast tank is pumped out and air is filled . To get downward thrust water is pumped into the ballast tank and air is pumped out. Initially 34000 N upward thrust is produced. A volume of 0.18 m^3 Oxygen gas at 1 atm is in the submersible for the passengers to breath. This gas is enough for 98 hours for the crew members. Its body is made of Steal , Aluminum , Titanium and carbon fiber to avoid the strain due to the high pressure in the sea water.

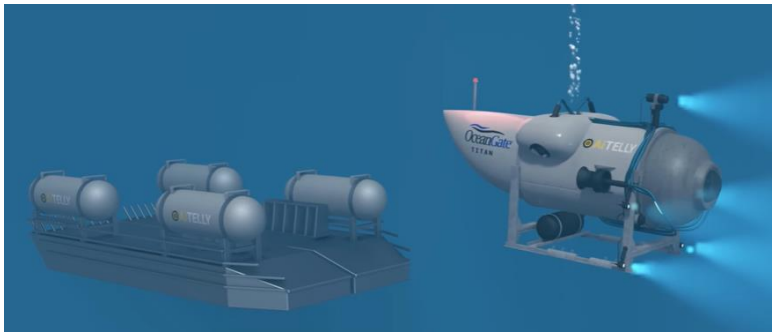
The following steps were planned to follow by the Ocean Gate company to operate this submersible.

Step **(I)** Titan submersible is brought by the mothership (Polar Prince) to the dive site near the Titanic's wreckage which is above the place of the sea bed at which wreck of Titanic lies. During this job breaking ice berg and launching the Titan submersible into the sea are also done by the mother ship.

Step **(II)** The Titan is fixed with a small platform as shown in the figure and four cylinders which provide thrust also fixed with the platform. Titan submersible is directed to the sea bed with the help of platform with a velocity of $V_1 km/h$



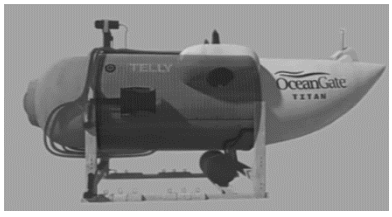
Step **(III)** The Titan submersible is separated from its platform. Then it travels with $V_2 km/h$ towards the wreckage of Titanic



Step **(IV)** Having reached the place at which Titanic wreckage lies, the passengers would view the wreckage of Titanic .

But unfortunately the submersible has under gone an implosion due to the high pressure . All the passengers are dead after the catastrophic implosion of the vessel.

The thrust due to the difference of the up thrust and the weight of the submersible only will be considered for the following questions. Ignore any effect due to the platform of the submersible.



Before the implosion

After the implosion

(a) (i) State the principle of floatation

(ii) Draw the model of the submersible on to your answer sheet and mark all the forces which act on it when it is totally submerged.

(iii) Explain the motion of the submersible by comparing the forces act on it for the following instances (without calculation)

(1) When the Ballast tank is completely filled by water

(2) When the Ballast tank is completely filled by air.

(b) (i) Find the effective volume of Titan submersible

(ii) If the density of sea water is 1200 kgm^{-3} find the up thrust when it is completely submerged.

(Iii) If the submersible is allowed to move freely when it is totally submerged and the ballast tank is completely filled by air then find the magnitude and direction of the acceleration

(iv) What is the mechanism which is used to move the submersible down ward direction?

(v) a) Find the volume of water which is added into the ballast tank to balance the initial up ward thrust acts on the submersible.

b) Find the magnitude and direction of acceleration of the submersible when the ballast tank is completely filled by sea water

(vi) Calculate the hydraulic pressure on the sea bed where the wreckage of Titanic lies (ignore atmospheric pressure)

(vii) If temperature is constant calculate the volume of O_2 gas at the pressure calculated in the part (vi)

(viii) Calculate the required volume of O_2 in one hour for one person in the submersible at atmospheric pressure

ix) The submersible can travel from the sea bed to the sea level with a velocity of $5km/h$. Find the minimum volume of O_2 required at atmospheric pressure during coming back to the sea level.

(c) In rockets, its propulsion system also uses thrust as the submarine to take satellite to the space. Draw a simple diagram to show how thrust given by the propulsion system acts on the space craft for each of the following instance and mark the thrust. Consider only one thrust for each instance.

(1) When the Chandrayaan-3 space craft which carries Vikaram Lander and Pragnayan rover is launched from the earth

(2) When the Vikram Lander is lowered from high elliptical orbit to low elliptical orbit near the moon surface

(3) When the Vikram lander moves horizontally (parallel to the moon surface) for 32 seconds at an altitude of 30 km from the moon surface.

6. (A) Write down an expression for the speed of transverse wave along a stretched wire and hence show that the speed of the wave V is given by $V = \sqrt{\frac{T}{A\rho}}$ where T is the tension, A is the area of cross section of the wire and ρ is the density of the material of the wire.

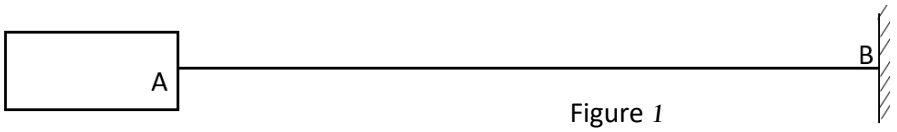


Figure *1*

one end A of a wire AB is attached to a vibrator of frequency f and the other end B is attached to a fixed support as shown in the figure 1. When the length of the wire is l it resonates with the vibrator in its fundamental mode.

(a) Draw the corresponding wave pattern and obtain an expression for the frequency f in terms of l , the tension in the wire T , cross sectional area of the wire A , density of the material of the wire ρ .

(b) Now suppose that the wire AB is connected to a second wire BC, made of the same material as that of AB. The wire BC has the same length l but twice the diameter that of AB. The Composite wire is attached to the vibrator and the fixed support as shown in the figure 2 .

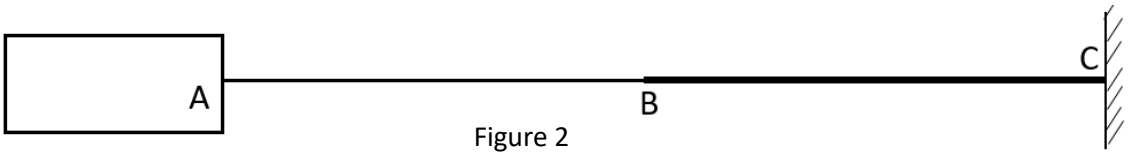


Figure 2

(i) If n_1 and n_2 are the number of loops formed in the wire AB and BC such that the point B being a node when the wire is set to vibrate with the same vibrator. Find the ratio of $\frac{n_1}{n_2}$.

(ii) Find the least number of loops that could be formed in the composite wire that vibrates as mentioned in the above part.

(B) The sound intensity is defined as the sound energy passing unit area , perpendicular to it, per unit time .When the sound waves travel through air the respective sound intensity at a point is given by the equation $I=2\pi^2\rho A^2 V f^2$ where A , V, and f are the displacement amplitude , speed and frequency of the wave respectively and ρ is the density of the air. The variation in pressure , as similar to the variation in displacement , are created in the air when the sound waves travels through air according to the symbols given above the amplitude of pressure P_m , is related to the displacement amplitude by the equation $P_m = 2\pi\rho V f A$. Ear drum of the human ear is sensitive to the pressure variation . The threshold of hearing and threshold of the pain for the human ear at the frequency of 3.3 kHz are 10^{-12} Wm^{-2} and 1 Wm^{-2} respectively . The sound intensity level β is expressed as $\beta = 10 \log_{10} (\frac{I}{I_0})$ (Take π = 3)

(1) Write down the units of sound intensity and sound intensity level

(2) A point source emits sound of power 48 x 10^{-6} W . Find the sound intensity and the sound intensity level at a point which is 20 m from the point source.

(3) The outer part of the human ear can be treated as a organ pipe closed at one end at the ear drum and open to the atmosphere at the other end. State whether the maximum change in pressure occurs at the ear drum or at the opening of the ear?

(4) (i) According to the given symbol , show that the pressure amplitude will be given as $P_m = \sqrt{2\rho VI}$

(ii) If ρ = 1.2 kgm^{-3} , V = 340 ms^{-1} find the minimum pressure amplitude that will make the sensation of hearing $(\sqrt{51} = 7.14)$

(iii) Find the minimum force that should be exerted on the ear drum membrane of 5 mm^2 area.

7. (a) (i) Three capillary tubes are immersed partially in three liquids A, B and C in vertical position. Their angle of contacts are 0^0 , 90^0 and 120^0 respectively. Draw the shape of liquid levels at outside of the capillary tube and inside of the capillary tube , and the shape of meniscus for each tube . Draw and show the surface tension clearly which acts on the liquid and the corresponding angle of contact.

(ii) A capillary tube of internal radius r is immersed in water partially under the atmosphere in vertical position. Write down an expression for the capillary rise h in the tube in terms of T, ρ, g and r . Where T is the surface tension of water , ρ is the density of the water and g is the gravitational acceleration. The angle of contact between the water and the material of the tube is zero.

(iii) In plants capillary action helps bring water up into the roots. The surface tension and the density of water are 7.2 x 10^{-2} Nm^{-1} and 1000 kgm^{-3} respectively. Find the capillary rise in such a vertical root having radius 50 μm. The angle of contact between the water and the root is zero.

(b) (i) Give an equation which relates the excess pressure (ΔP) , the radius of curvature of the liquid surface r and the surface tension T which acts along the surface when the liquid surface contacts only one side with air .

(ii) The capillary tube mentioned in the part (a)(ii) is kept vertically in air. A height of water column trapped in the capillary tube is h' and the radius of the meniscus at the bottom of the water column is r'. Draw the shape of the lower meniscus of water column for each of the following instances.

(a) h' = h

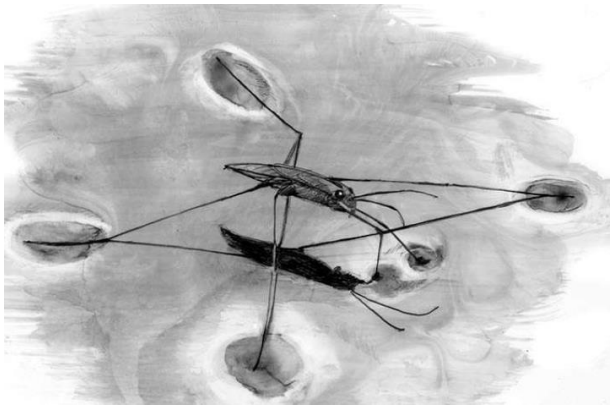
(b) h' < h

(c) h' > h

(iii) Find the maximum value of h' in terms of h

(iv) Sketch a graph for the variation of r' (y-axis) with h' (x - axis)

(c) Surface tension allows Water striders to walk on the water surface



When the strider sits on the water surface the surface is lowered a little bit. The legs of the insect does not wet due to the wax layer on the legs. The weight of the insect is W and the radius of all the legs is r_0 . Consider the six legs only contact with water surface. The surface tension of the water is T and the angle of contact between the legs and the water is θ.

(i) Take each leg of the strider as a vertical cylinder and find the resultant which acts on a leg by water in terms of T , r_0 and θ

(ii) If the strider is in equilibrium , obtain an expression for W in terms of T, r_0 and θ

(iii) If the surface tension of the water is 7.2×10^{-2} Nm^{-1} , r_0 = 0.1 mm and $\theta = 30^0$ then find the mass of the strider in mg (milli gram)

(iv) Calculate the maximum mass of the such strider which has the same dimension as mentioned in part (c)(iii) to sit on the surface of the water without immersing ?

8. (a) A rectangular coil ABCD is placed in between two permanent magnets as shown in the figure 1. A current I flows through it. The magnetic flux density in between the poles is B. AB = a and BC = b,

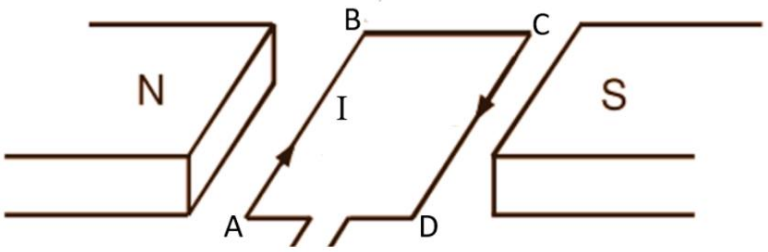


Figure 1

(I) Write an expression for the magnetic force F which acts on AB

(ii) Obtain an expression for the torque (τ) which acts on the coil ABCD in terms of the given quantities.

(iii) Write the expression obtained in part (a) (ii) if the coil has N turns.

(b) Now the coil with N turns has turned through θ as shown in the figure 2.

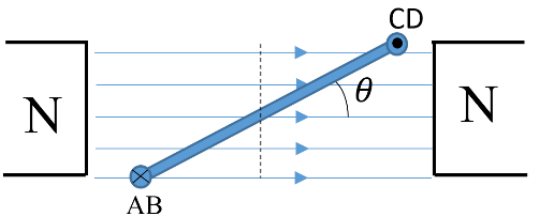


Figure 2

1. Obtain an expression for the torque which acts on the coil.

2. Draw the two positions of the coil separately when maximum torque acts on the coil and minimum torque acts on the coil according to the figure 2.

3. If θ increases beyond 90^0 and the the direction of the current is unchanged then , explain the subsequent motion of the coil.

(c) Moving coil galvanometer is an instrument which is designed such that the angle of deflection of the rectangular coil is directly proportional to the current through it.

(i) Draw the radial magnetic field lines used in the galvanometer.

(ii) What are the two main parts which are needed to produce radial magnetic field?

(ii) Explain why radial magnetic field is used here.

(d) Electric motor is an instrument which converts electrical energy into mechanical energy. The rotating part of the motor is called "armature".

(i) What is the main part of a DC electric motor which is used to make complete rotation of the rectangular coil ?

(ii) Copy the figure 1 onto your answer sheet and complete the diagram by using the part mentioned in (d)(i) with the DC power supply.

(iii) Give reason for using a carbon brush.

(iv) In practice, the armature of the DC motor has multiple coils wrapped around a cylindrical form and the part mentioned in (d)(i) is divided into several equal number of segment pairs as shown in the figure 3. Give reason for this.

(v) What is the structural difference between a DC motor and a DC generator ?

Figure 3

9(A) (a) (i) Write an equation for a conductor which shows the variation of resistance with temperature and identify the notations you used in this equation.

(ii) When temperature increases

(a) Conductor (b) Semiconductor

Sketch separate graphs for each which shows the variation of resistance with temperature.

(b) Thermistor is an electric instrument which is made by semiconducting material. It is used as sensor of temperature changes. The variation of electrical resistance of a thermistor is shown in the figure 1. A circuit of thermistor with 5kΩ resistance and a battery of emf 9 V is shown in the figure 2. The internal resistance of the battery is negligible and voltmeter is ideal. A student plans to measure temperature by using this circuit.

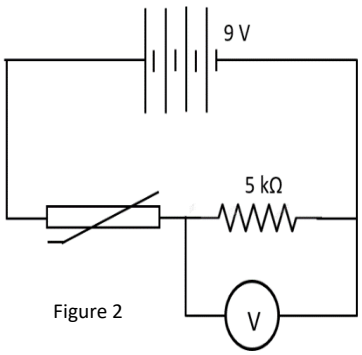


Figure 2

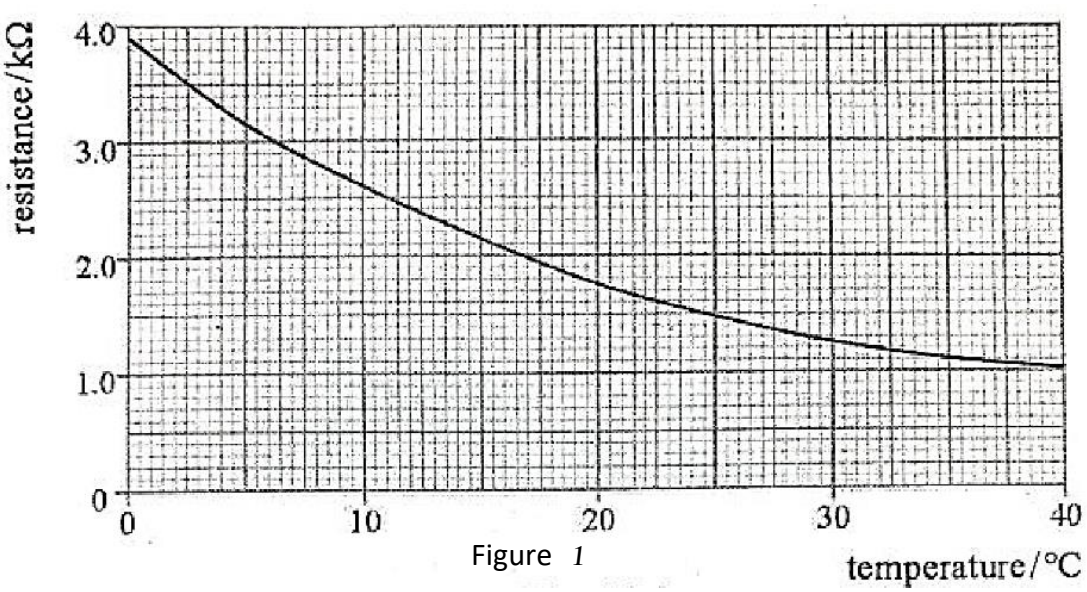


Figure *1*

(i) What is the purpose of using constant resistance (5 kΩ) with thermistor ?

(ii) What is the value of resistance of the thermistor at 30 ^{0}C ? Calculate the voltmeter reading at this temperature.

(iii) Find the corresponding temperature at which the voltmeter reads 6 V.

(vi) How would the temperature be measured by using the circuit in the figure 2.

(c) (i) Define the term "Electro motive force " (E) of a cell.

(ii) Show that product of E I is equal to the power delivered by a cell when current I is drawn from the cell by using this definition .

(iii) A cell of emf E is charged by a charger and a current I flows through the cell. What is represented by the product EI ?

(iv) A car battery of emf 12 V and internal resistance 0.060 Ω is charged by a charger battery of emf 14 V and internal resistance 0.10 Ω as shown in the figure 3. The battery is charged for four hours and a constant current 12. 5 A flows through the cells during this period

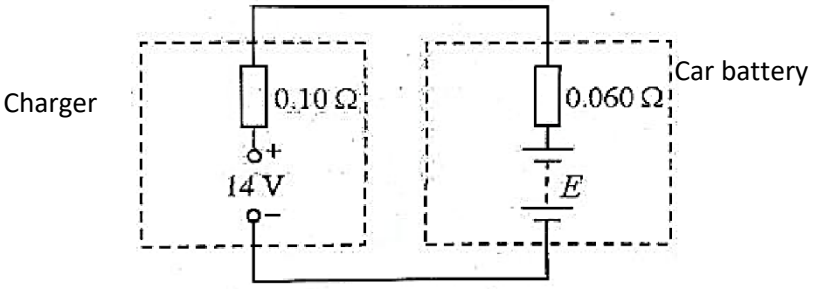


Figure *3*

Find the followings

(1) The amount of charge flows through the car battery

(2) The power provided by the charger battery

(3) The total power dissipated as heat in the circuit

9(B) FET (Field Effect Transistor) is used in modern electronics devices mostly and it has three terminals semiconducting device. Its function is different from bipolar junction transistor (BJT). There are two main types of Field effect transistor. One is Junction field effect transistor(JFET) and the other one is Insulated Gate field effect transistor (IGFET). Each type is further classified into p-type and n- type. The figure 1 shows the cross sectional view of n- channel JFET and its symbol.

(a) Identify the terminals D, G and S.

(b) What is the charge career which contributes to the current flow through the transistor shown in the figure 1 ?

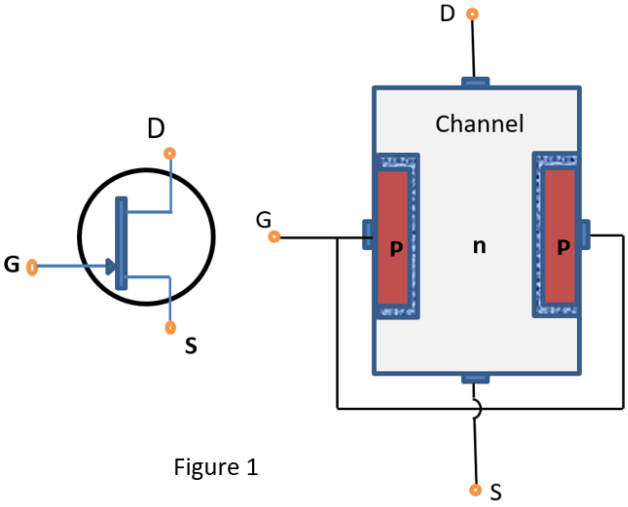


Figure 1

(c) The potential difference between D and S (V_{DS}) is kept at zero and the terminals S and G are kept in reverse bias. The magnitude of the potential difference between G and S (V_{GS}) is increased gradually.

(i) Give the reason why the thickness of the depletion layer is uniform throughout the channel in this situation .

(ii) Give the reason why the thickness of the depletion layer increases .

(d) Now, the potential difference between G and S is kept at zero ($V_{GS} = 0$) while the potential difference between D (higher potential) and S (lower potential) is increased gradually.

(i) For a small value of V_{DS} the channel width is uniform and the drain current (I_D) varies linearly with V_{DS}. Give reason for this .

(ii) For a large value of V_{DS} the channel width becomes non uniform and the drain current (I_D) varies non linearly with V_{DS} . Give reason for this .

(iii) What is meant by pinch off voltage (V_p) ?

(iv) From the figure 2 and figure 3 , find out pinch of position and the cut off position of the channel?

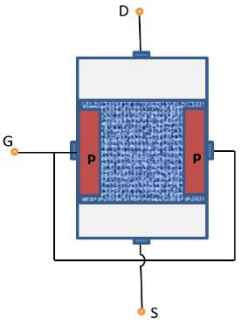


Figure 2

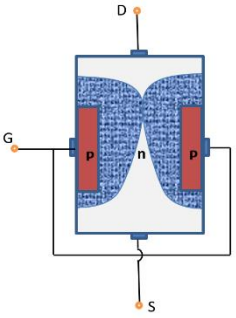


Figure 3

(e) After the channel of JFET is reached the pinch off position, if V_{DS} is increased further the drain current essentially becomes constant. This constant current is called as saturation current .

(i) Give the necessary condition at which the transistor is in saturation region in terms of V_{GS} , V_{DS} and V_P

(ii) The saturation current I_D is given by $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_p}\right)^2$

where I_{DSS} is the saturation current when $V_{GS} = 0$. Why the saturation current becomes zero when the channel is cut off.

(iii) Find the saturation current when V_{GS}= -3 V from the figure 4.

($V_{GS(off)} = V_P$)

(iv) An amplifier circuit of JFET is shown in the figure 5. The saturation current in this circuit varies according to the graph shown in the figure 4. Find the least value of V_{DD} to be acted the JFET in saturation region. (D is connected to the resistor 560 Ω)

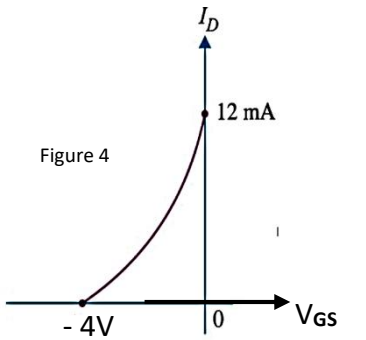


Figure 4

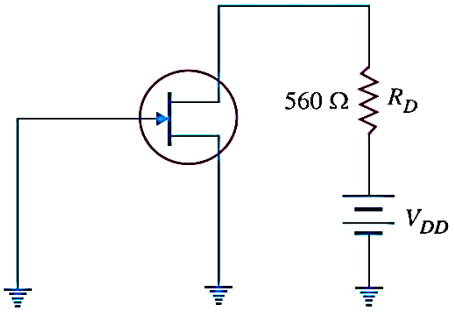


Figure 5

(f) Give two advantages of JFET compared to BJT.

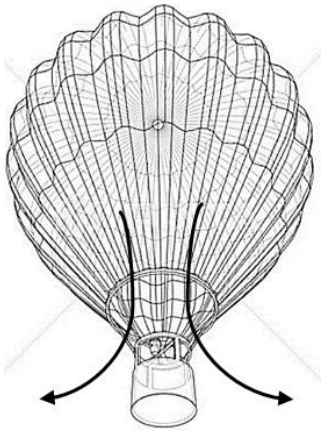
10 (A) (a) Using the ideal gas equation and kinetic theory for gases obtain expression for

1. Density of gas ρ in terms of pressure P , absolute temperature T , universal gas constant R and molar mass M
2. Mean kinetic energy of a gas molecule in terms of absolute temperature T and Boltzmann constant k

(b) A hot air balloon may be taken to hold 900 m^3 of air as its maximum. The air in the balloon, occupying its maximum volume may be assumed to be at a temperature of 127 ^{0} C and at this temperature its density is 0.84 kg m^{-3}. During heating process the pressure inside the balloon remains unchanged at the atmospheric pressure. Under the conditions in which it is heated , the air has a specific heat capacity of 1000 J kg^{-1} K^{-1}. Find the followings. (Boltzmann Constant =1.38 x10^{-23} JK^{-1})

a. The mass of air , m , in the balloon at 127^0 C
b. The heat energy required to raise the temperature of air 127 ^{0} C if the initial temperature of it is 7 ^{0} C.
c. The density of air at 7 ^{0} C.
d. Volume of air at 7 ^{0} C.
e. The mean kinetic energy of an air molecule at 127 ^{0} C.
f. The percentage change in the mean kinetic energy of the gas molecule when the temperature is increased from 7 ^{0} C to 127 ^{0} C.

(c) (i) (1) Identifying symbols, state first law of thermodynamics



(2) Why does the internal energy of a system of ideal gas depend only on its temperature

(ii) Suppose that the air which was originally within the balloon mentioned in part (b) spills out during the heating process so that volume of balloon remained unchanged. Given that atmospheric pressure is 1 x 10^5 Pa. Find

1. The work done on the atmosphere during the process
2. The change in internal energy of the mass m of air when heated from its initial temperature 7 ^{0}C to the final temperature

10 (B) X rays are produced whenever high energy electrons impinge on a metal target. The figure 1 shows an X –ray tube that is used to produce X – ray .

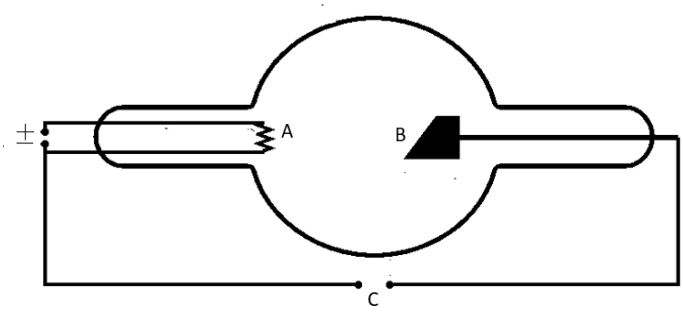


Figure 1

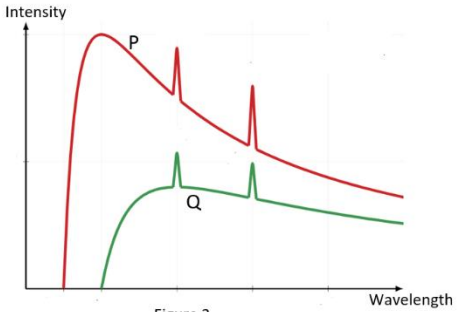


Figure 2

a) (i) (1) Identify the components A, B and C shown in the figure 1.

(2) State the purpose of having each of the components.

(ii) Explain how X rays are produced.

(iii) X- rays are emitted with different wavelengths (X - ray spectrum) . The minimum wavelength obtained in an X ray spectrum depends on the operating voltage .Two X ray spectra , P and Q , obtained with two operating voltages V_1 and V_2 ($V_1 > V_2$) are shown in the figure 2. Which curve corresponds to the operating voltage V_1 ? Give reason.

(iv) If the X ray tube is operated with an operating voltage of V. Show that the maximum velocity with which the electrons strike B, V_{max}, is given by $V_{max} = \sqrt{\frac{2eV}{m}}$ where e and m are charge and mass of an electron

(v) Obtain an expression for the minimum wavelength λ_{min} , in terms of e , speed of light c, operating voltage V and Planck's constant h.

(vi) Calculate λ_{min} for V = 100 kV, c = 3x10^8 m s^{-1} , h = 6.6 x10^{-34} J s and e = 1.6 x 10^{-19} C

b) The photoelectric effect can be introduced as the reverse effect of the production of X rays. In photoelectric effect electrons are emitted by the interaction of photon and matter. The setup used to study the photoelectric emission is shown in the fig 3.

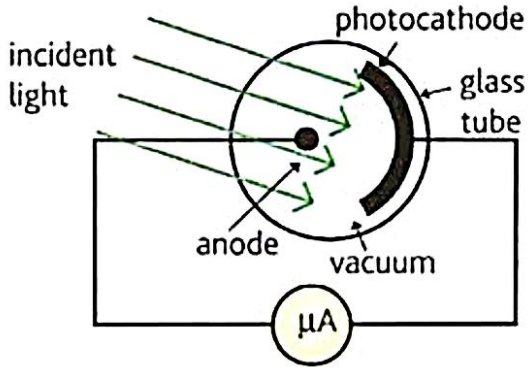


Figure 3

An evacuated glass tube contained a certain metal plate as its cathode. A metal terminal as the anode was a few milliammeters away. The cell was connected in series with a micro ammeter as shown.

(i) The microammeter reading was zero when the cell was illuminated with red light. When the cathode was illuminated with blue light of the same intensity , a non zero reading was observed on the micrometer .

(1) Using the photon theory of light , explain this observation.

(2) Why is it not possible to explain these observation using classical wave theory?

(ii) If the wavelength of the blue light is 430 nm , calculate the energy of a photon of this blue light .

(iii) If the work function of the metal is 2.25 eV , show the maximum kinetic energy of an electron emitted from this metal surface by the blue light is 0.64 eV

($h = 6.6 \times 10^{-34}$ J s , $c = 3 \times 10^{8}$ m s^{-1} and $e = 1.6 \times 10^{-19}$ C)