FWC

தேசிய வெளிக்கள நிலையம் தொண்டைமானாறு
ஆறாம் தவணைப் பரீட்சை - 2024
National Field Work Centre, Thondaimanaru
6th Term Examination - 2024

பௌதிகவியல் - II
Physics - II

Gr. 13 (2024) | 01 | E | B

Part - II(B)
Essay Questions

- **Answer only four questions.**

05) (a)

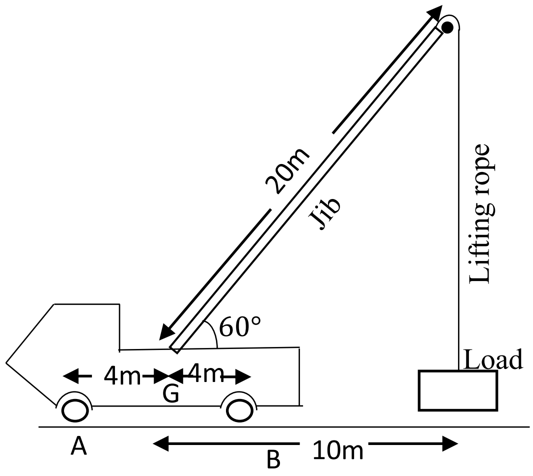


Figure (1)

Figure 1 shows the structure of a mobile crane, which is supported by two wheels located at points A and B. Mass of the base of this crane is $2.8 \times 10^4 kg$. Point G is the center of gravity of base (see the figure). The Jib has a uniform mass distribution, with a mass of $3 \times 10^3 kg$ and length of 20m. It is positioned at an angle of $60°$ with the horizontal.

(i) State the principle of moments for force equilibrium.

(ii) Calculate the forces acting on wheels A and B by the ground when a mass of $1.5 \times 10^4 kg$ is lifted from the ground.

(iii) Calculate the maximum load that can be lifted by the crane without causing it to overturn in the position shown in figure 1.

(iv) At what inclination to the horizontal must the jib be maintained when the load is raised above the value calculated in part a(iii) above? (Calculation is not required)

(b) Consider a case where the crane described in part a lifts a load of $2000kg$ a small distance above ground level. Consider this load displaced by a small velocity on a bar moving horizontally with a constant speed of $5ms^{-1}$. Refer to figure 2. Assuming that the load attains the velocity of the bar two seconds after it makes contact, answer the following questions.

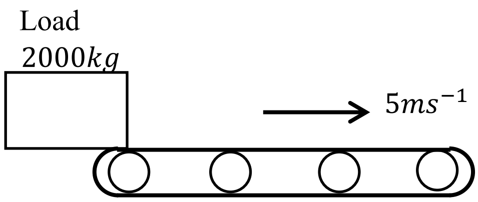


Figure (2)

(i) Find the magnitude of the horizontal force acting on the load during this period.

(ii) State how this force is generated?

(iii) Plot the force F acting on the load as a function of time t during the first three seconds from the moment it touches the bar. (During this period, the load remains in contact with the bar.)

(iv) Calculate the additional power that must be supplied to the bar by the external source to maintain its motion in the same direction due to the displacement of the load.

(c) Cranes use hydraulic modules or motor technology to lift loads. When lifting loads with motor technology, the load is raised by the cord wrapped around a drum connected to the motor's shaft as it rotates. See figure 3.

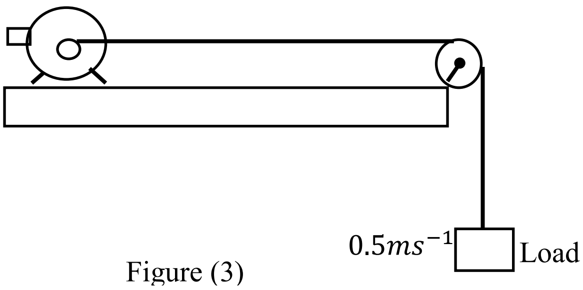


Figure (3)

(i) Find the torque exerted on the motor when a load of$1.5 \times 10^4 kg$ is lifted with a constant speed of $0.5ms^{-1}$. Take the diameter of the motor axis to be 1m.

(ii) In question (c)(i) above, find the motor's output power in kW.

(iii) What will be the efficiency of the motor if the magnitude of the frictional torque acting on it is 1000 Nm?

06) Visual angle is the angle a viewed object subtends at the eye. The apparent size of the object depends on the visual angle. The visual angle depends on the size and distance of the object. Since the angle subtended by the microorganism at the eye is too small, it cannot be seen by the naked eye. Therefore, microscopes are used to observe microorganisms by increasing the visual angle. Likewise, for observing large objects in the vast universe, such as planets and stars that are far away, telescopes are used to increase the visual angle.

(a) (i) State two factors which are depends on visual angle.

(ii) Objects that are the same height but at different distances from the eye appear to be the same height. Draw the ray diagram and explain why images appear this way by indicating the visual angle.

b) i) Define the angular magnification of a simple microscope when it is in normal adjustment.

ii) Draw the ray diagram for the normal adjustment of a simple microscope and derive an expression for the angular magnification.

iii) A simple microscope has a convex lens with a focal length of $5cm$. What is the angular magnification in normal adjustment if the least distance of distinct vision is $25cm$?

c) i) Define the angular magnification of a compound microscope.

ii) Draw the ray diagram for the normal adjustment of a compound microscope and derive an expression for the angular magnification, assuming the image distance from the objective is l.

iii) Find the magnification of the microscope if $l = 20.2cm$ and the focal lengths of the objective and eyepiece are $2mm, 2.5cm$, respectively.

iv) The viewer said that the image was not clear when viewed through the eyepiece. What type of defect might the viewer have?

v) To observe the object clearly, the eyepiece should move a minimum distance of $\frac{175}{81\times 11}cm$. What is the shortest distance for the patient?

vi) The patient mentioned above moves the eyepiece to obtain the abnormal adjustment of the microscope. Find the distance between the objective and the eyepiece now?

07)

(a) (i) Define surface tension

(ii) A bubble of radius r formed in a liquid. The excess pressure of the bubble is given by $\Delta P = \frac{2T}{r}$. Where T is the surface tension of the liquid. Show that the equation $\Delta P = \frac{2T}{r}$ is dimensionally correct.

(iii) A capillary tube with a radius r is vertically immersed in a liquid with a surface tension T and a contact angle $\theta(> 90°)$.

(1) Draw the position and shape of the meniscus in the tube from the liquid's surface.

(2) Indicate the contact angle θ in the figure drawn above.

(3) Find the radius of liquid crescent R in terms of r and ρ if distance for meniscus from the liquid surface is h and density of liquid is r, θ .

(4) Show that the excess pressure of the meniscus, ΔP is given by $\Delta P = \frac{2T\cos(180-\theta)}{r}$

(5) From the result in Question 4 above, find an expression for h in terms of T, r, ρ, g and θ

(b) A horizontal U-Shaped tube contains a liquid X of density $\rho = 800kgm^{-3}$ one end of the tube is open to the atmosphere. In the other part, a capillary tube with a radius of $r = 0.5mm$ is fixed horizontally, as shown in fig(1). A soap film is formed at its end. A pump is attached to the upper end of the U - shaped tube using a rubber tube to change the shape of the soap film.

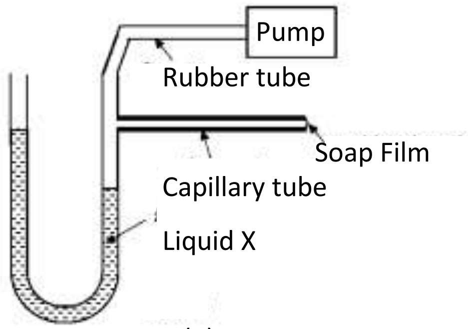


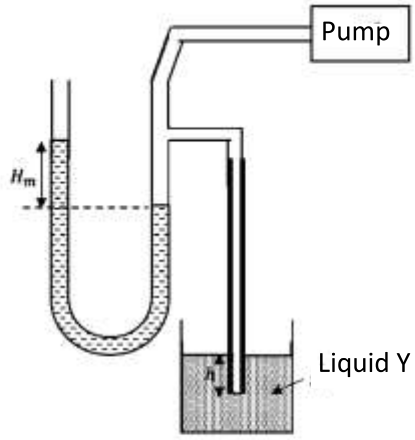
Figure (1)

(i) Obtain an expression for R in terms of H, T, ρ and g, where R is the radius of soap film and H is the height difference between the liquid levels in U - shaped tube.

(ii) Draw the graph representing the variation of R and H.

(iii) Determine the surface tension of the soap solution if maximum value obtained for $H_{max} = 4cm$

(c) Now, the capillary tube is immersed vertically to a depth h in a vessel containing liquid y. When the pressure is increased by the pump, the maximum liquid level difference in the U - shaped tube is observed as H_m. The values of H_m obtained for two different parameters are as follows.



Figure

$h(cm)$	$H_m(cm)$
1	3
5	8

(i) Find the density of liquid y.

(ii) Determine the surface tension of the liquid y.

(iii) Draw the graph representing the variation of H_m with h.

(iv) Can the above method be used to find the surface tension of an opaque liquid? Give reason.

08) (a) State Gauss's Theorem.

(i) A long straight cylindrical conductor with radius a is placed horizontally and has a linear charge density of $+\lambda$.

(1) Define linear charge density.

(2) Obtain an expression for the electric field intensity E at a point that is a distance $r(r \geq a)$ from the central axis in terms of λ, r and $\in_0$. Where $\in_0$ is the dielectric constant of the vacuum.

(3) Draw the graph representing the variation of electric field intensity € with respect to the distance (r) from the axis of the conductor.

(ii) An electron is placed at a point that is a distance r from the axis of the charged conductor described in question (i) above. The charge and mass of the electron are e and m respectively.

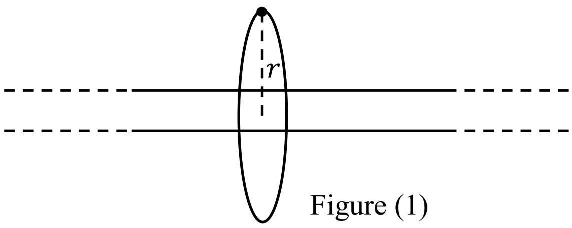


Figure (1)

If the electron moves in a circular path with a radius r centered on the axis of the conductor, find the following (neglect the effects of gravity)

(1) Copy Figure 1 onto your answer script, indicate the force acting on the electron, and obtain the magnitude of the force in terms of $\lambda, r, \in_0$ and e

(2) Obtain an expression for the angular velocity of the electron in terms of $\lambda, r, \in_0$, e and m

(3) Write the expression for the tangential speed of electron in term of $\lambda, r, \in_0$, e and m.

(4) Evaluate the period of the electron. (Take $\pi = 3$)

Mass of the electron $m = 9 \times 10^{-31} kg$

Charge of the electron $e = 1.6 \times 10^{-19} C$

Linear charge density in SI units $\lambda = 6 \times 10^{-15}$

Dielectric constant in vacuum $\epsilon_0 = 9 \times 10^{-12} Fm^{-1}$

Distance from the axis $r = 5 \mu m$

(b) The electron specified in question (a) (ii) above now starts moving with a speed V, making an angle θ with the horizontal at a distance r from the conductor.

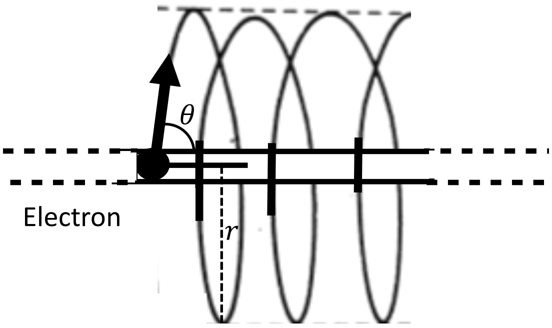


Figure (2)

i) State the arguments for an electron moving in a helical path.

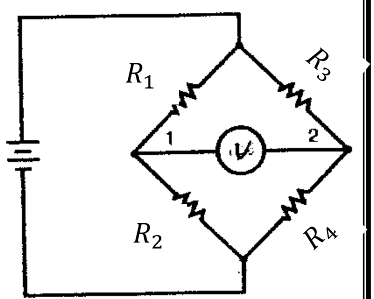
ii) Derive an expression for the displacement d of the electron during one complete cycle in terms of T and , where T is the orbital period of the electron.

iii) Obtain an expression for the period of the electron. From this, Show that T is independent of θ.

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

(A)

(a) (1) I. Obtain an expression relating R_1, R_2, R_3 *and* R_4 when the center-zero galvanometer shows zero deflection in the Wheatstone bridge.

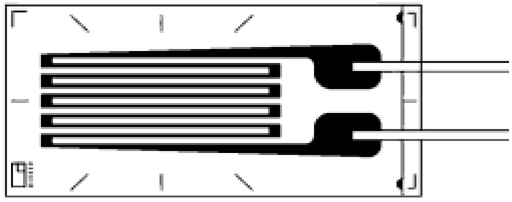


II. Write down the equation for the resistance of a conductor, relating it to its length and cross-sectional area.

III. A string with a particular resistance (R) is stretched under a force. Show that the resistance of the string is proportional to the square of its length.

(2) A student plans to design a strain gauge capable of measuring the stretch of a string by obtaining voltmeter readings using the Wheatstone bridge described in part (1) and monitoring changes in the string's resistance due to stretching.

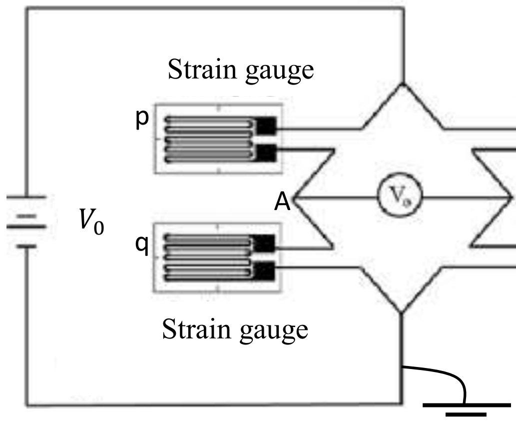
Strain gauge



A wire of 1 m in length, with a cross-sectional area of $1mm^2$ and a resistivity of $5 \times 10^{-7}\Omega m$ is folded into $10m$ segments and rigidly connected to a hard plastic board as shown in the figure.

I. Find the resistance of $1m$ length wire.
II. Find the resistance of the $1\ m$ length wire when the strain gauge expands by $1mm$
III. Calculate the increase in resistance (r) of the strain gauge due to expansion.

(3) Four identical strain gauges $p, q, r, and\ s,$ are connected to the bridge circuit, as shown in the figure. Assume that the resistance of each gauge is$R$. Gauges p and s are connected to a material that undergoes the same expansion. Gauges q and r does not free expansion. Wheaton bridge is connected to A cell of electromotive force V_0 and negligible internal resistance. Resistance increases due to the expansion of $p\ and\ s\ is\ r$.



a) The potential at Point A in terms of $V_0, r\ and\ R$.

b) Find the potential at Point B in terms of $V_0, r\ and\ R$.

c) Calculate the voltmeter reading using the results obtained in parts (a) and (b) above.

d) What is the voltmeter reading if the strain gauges $p\ and\ s$ show a $1\ mm$ extension?

e) What is the expansion in the strain gauges if the voltmeter shows a $50\ mV$ reading?

f) To observe the expansion of a bridge, two strain gauges P and S are rigidly attached to the bridge, while R and S are free. When the extension increases (i.e., when the voltmeter reading rises above $0.7V$), a warning signal is emitted. Draw a circuit diagram to illustrate how to use a red LED.

(B) (a)

(i) Identify each terminal of the 741 operational amplifier (OP AMP) circuit symbol as shown in figure 1.

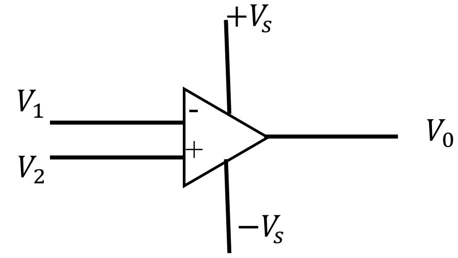


Figure (1)

(ii) Write the expression for the voltage gain (A) of the OP AMP using the symbols of the potentials specified in Question (i) above.

(iii) Draw the characteristic graph of an OP AMP, and indicate each region on the graph.

(iv) Give one use of an open-loop operational amplifier.

(b) Write down the golden rules.

(i) The 741 op-amp amplifier circuit is shown in figure 2. Identify the circuit.

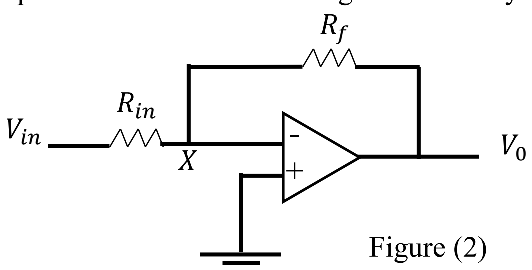


Figure (2)

(1) What is the potential at point ?

(2) Write the current through the resistance R_{in} in terms of V_{in} and R_{in}

(3) Write the current through the resistance R_f in terms of V_o and R_f

(4) Show that the voltage gain (A) of the circuit in figure (2) is $\left(-\frac{R_f}{R_{in}}\right)$ by using results obtained from questions (2) and (3) above.

(ii) The model of the volume control unit of a radio is shown in Figure 3

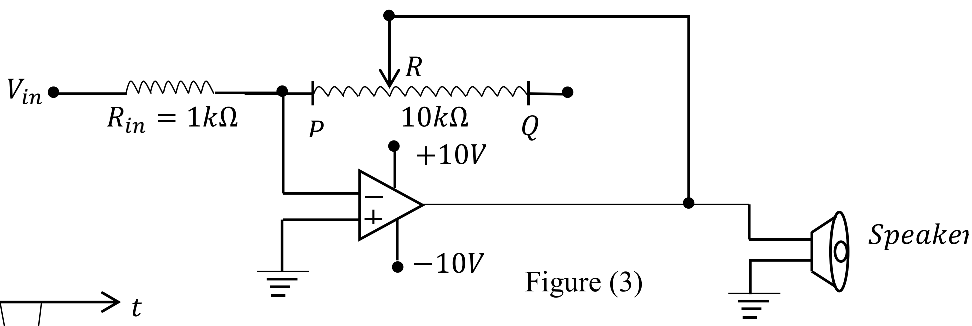


Figure (3)

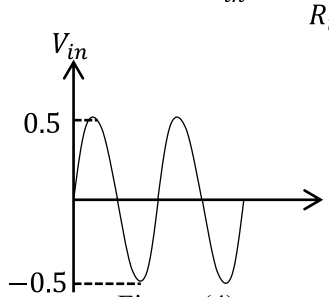


Figure (4)

The resistances of part PQ and R_{in} are $1k\Omega$ and $10k\Omega$, respectively, and the supply voltage of the amplifier is $\pm 10V$. The voltage delivered to the speaker is changed as the terminal R moves along PQ.

(1) What is the suitable laboratory equipment for part PQR?

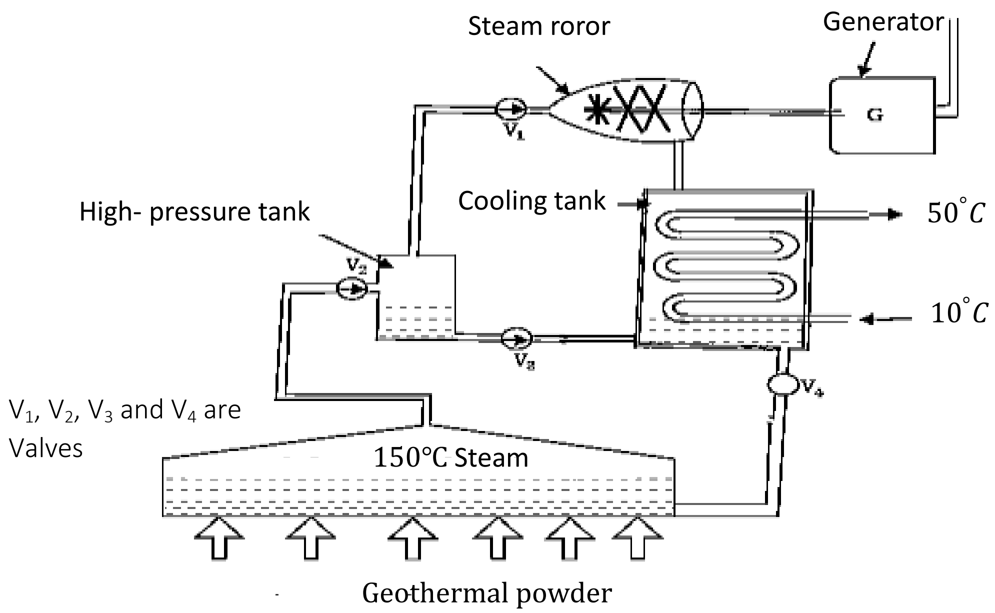
(2) Calculate the maximum and minimum voltage gain of the amplifier.

(3) Calculate maximum and minimum voltage delivered to the speaker when $V_{in} = -0.5V$

(4) Draw the voltage variation obtained at the speaker when the voltage signal shown in figure 4 is given to the input of the amplifier. (Assume that the resistance of part PQR is maintained at a constant value.)

10) **Answer either Part (A) or Part (B) only**

(A) Countries such as the USA fulfill 26% of their electric energy needs with geothermal power. Additionally, hot water produced from this is be used to meet the hot water needs of city residents. A simple diagram of a geothermal power plant is shown in the figure.



As shown in the figure, the water inside a buried tank ET is heated to 150°C and converted into steam. This steam is stored in a high-pressure tank ST and undergoed compression. When the valve opens, the high-pressure steam exits and collides with the rotor blades (T) at $1000\, m/s$. Due to this, 80% of the kinetic energy is converted to the rotor as rotational kinetic energy.

Remain water and steam sending to cooling tank. Water enters at 10°C, cools the steam to 50°C and leaves as hot water at 50°C. It helps meet the hot water needs of the city residents.

(I) Consider a generator with a power output of $100\, MW$ and an efficiency of 100%. Answer the following questions.

1) Gives the two uses of geothermal power plant.

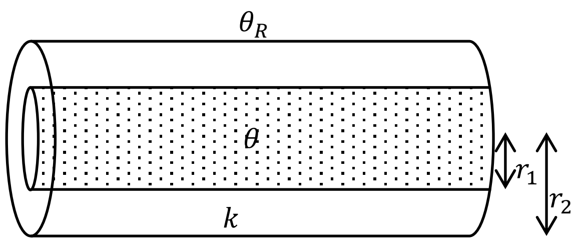
2) Find the mass of steam that contacts the steam rotor.

3) Find the heat energy required to produce the steam in the calculation from question (2) above.
4) Where does the plant obtain the heat energy it needs?
5) The thickness of the ET wall is 10 cm, and its thermal conductivity is $400Wm^{-1}k^{-1}$ If the external temperature is $200°C$ and the internal temperature is $150°C$, find the heat flow rate through a unit area.
6) Find the minimum area of the ET wall required for the efficient operation of this geothermal plant.
7) What is the advantage of this geothermal plant.
8) Gives two actions to increase the power generated by this geothermal plant.

(II) In the process of steam cooling, 10% of the thermal energy is lost as heat used for evaporation in a geothermal power plant.

1) Find the rate of water supply at 10°C to the cooling tank (CT).
2) What is the temperature of the water when it reaches the city if 30% of the heat is lost through the pipe while transporting the discharged water at $50°C$ to the city?

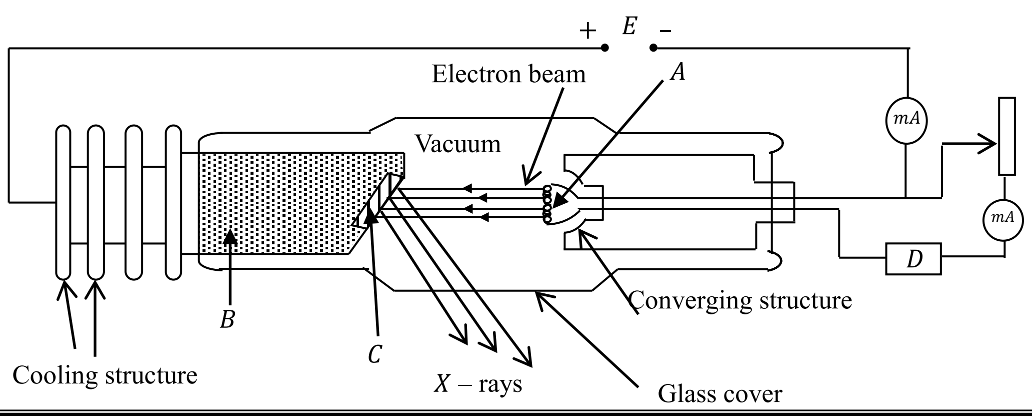
3)



Given the tube above used for transporting water at θ^0C, find the heat loss to the environment per unit length, where θ_R is the environmental temperature and k is the thermal conductivity of the material the tube is made of.

(B)

(a) Structure of modern ray-tube using for X-ray production is shown in the figure below.



(i) Name the parts A, B, C, D and E .

(ii)(1) What is the material used for part A?

(2) State two materials for used for part C.

(3) What characteristic should part C have?

(iii) Explain briefly the method of X-ray production.

(iv) What factor determine the rate of X-ray emission?

(v) What factor determine the frequency of X-ray?

(vi) What is the purpose of the X-ray tube vacuum?

(b) The voltage difference delivered to the X-ray tube is V; if the given energy is completely converted to X-ray photons,

(i) Give the expression for the maximum frequency (f max) of an X-ray photon in terms of the charge of the electron e, Planck's constant h, and V

(ii) Give the expression for the minimum wavelength (λmin) of an X-ray photon in terms of the speed of light in vacuum C, h, e and V

(iii) Draw a graph for variation of V with λ_{min}.

(c) The X-ray tube operates at a potential difference of $100\,kV$, with a current of $1.6\,mA$ flowing through it. If the efficiency of the X-ray tube is 1%,

i) Find the number of electrons that reach the target in 1s. (The charge of an electron is $e = 1.6 \times 10^{-19} C$)

ii) 1) What is the power supplied to the X-ray tube?

2) What is the rate of energy production of the X- ray?

3) What is the rate of heat loss?

iii) What is the minimum wavelength of the X-rays if all the input power is converted into X-ray photons? ($c = 3 \times 10^8 ms^{-1}, h = 6.6 \times 10^{-34} Js$)

(d) The photoelectric effect is the opposite of X-ray production. When a photon energy of $1.98\,eV$ is applied to a metal surface, photoelectrons are emitted with a maximum kinetic energy of $1.32\,eV$.

i) Find the work function $\emptyset$ of the metal material in joules.

ii) What is the value of stoping potential (V_s)?

iii) Find the threshold frequency (f_0) of the metal.