Part B – Essay

$g = 10\ N\,kg^{-1}$

❖ **Answer four questions only.**

(05) Some examiners states that the reason for most road accidents of motor vehicles is due to the lack of knowledge of the drivers regarding motion of motor vehicles.

(a) The mass of a bus without fuel and the passengers is 9920kg. Consider the average mass of one passenger is 80kg and the mass of a travelling bag is 20kg. 40 passengers with their 40 travelling bags get into the bus to go on a trip. At the beginning of the trip, the fuel tank is filled with $100l$ of fuel of density $800kgm^{-3}$.

(i) What is the mass of the fuel filled?

(ii) After filling the fuel, the bus is starting from rest and moves 200m during 10s with a constant acceleration. What is the constant acceleration?

(iii) When the bus is starting the journey, what is the effective force on the bus?

(iv) When the bus is moving on a horizontal road with $20ms^{-1}$ constant velocity, the force exerted by the engine is 10000N. What is the power of the engine?

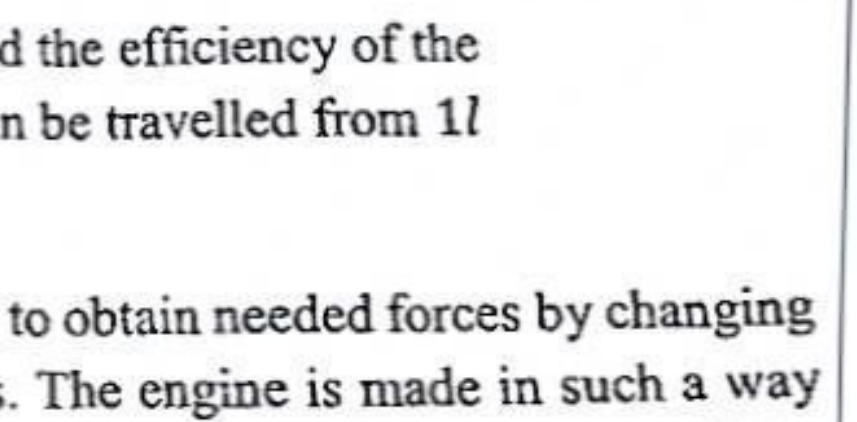
(v) When the bus is moving 1km distance, what is the energy exerted by the engine?

(vi) If the energy released by $1l$ of fuel is $1 \times 10^8 J$ and the efficiency of the engine is 30%, what is the distance, in km, that can be travelled from $1l$ of fuel?

(b) Motor vehicle companies are manufacturing engines, as to obtain needed forces by changing the gears, when driving in hilly and mountainous areas. The engine is made in such a way that it creates a large resistive force when a vehicle is moving down along a slope and the accelerator paddle is not being pushed down. Below table shows how this resistive force vary according to the gear for the above bus.

Gear	1	2	3	4	5	N
Resistive Force (N)		76800		4000		0

Above bus reaches the top a cliff and after that it starts to move down along a road of length $446.5m$ which is 30° inclined to the horizontal with $5ms^{-1}$ initial velocity. The descent starts in the 4th gear and pushing down the accelerator.



After moving 126.5m along the road, there is a horizontal bend of radius 8m at the end of the road and the driver sees a road sign which indicates to decrease the speed as there is a dangerous horizontal bend ahead. In the bend, the coefficient of friction between the tyres and the road is 1.25. Consider that, when the distance is at 126.5m the velocity of the bus is $28ms^{-1}$ and the total mass of the bus is 14000kg. $(\sqrt{5} = 2.2\ ,\ \sqrt{3} = 1.7\ ,\ \sqrt{2} = 1.4)$

(i) What is the acceleration when the bus travels 126.5m?

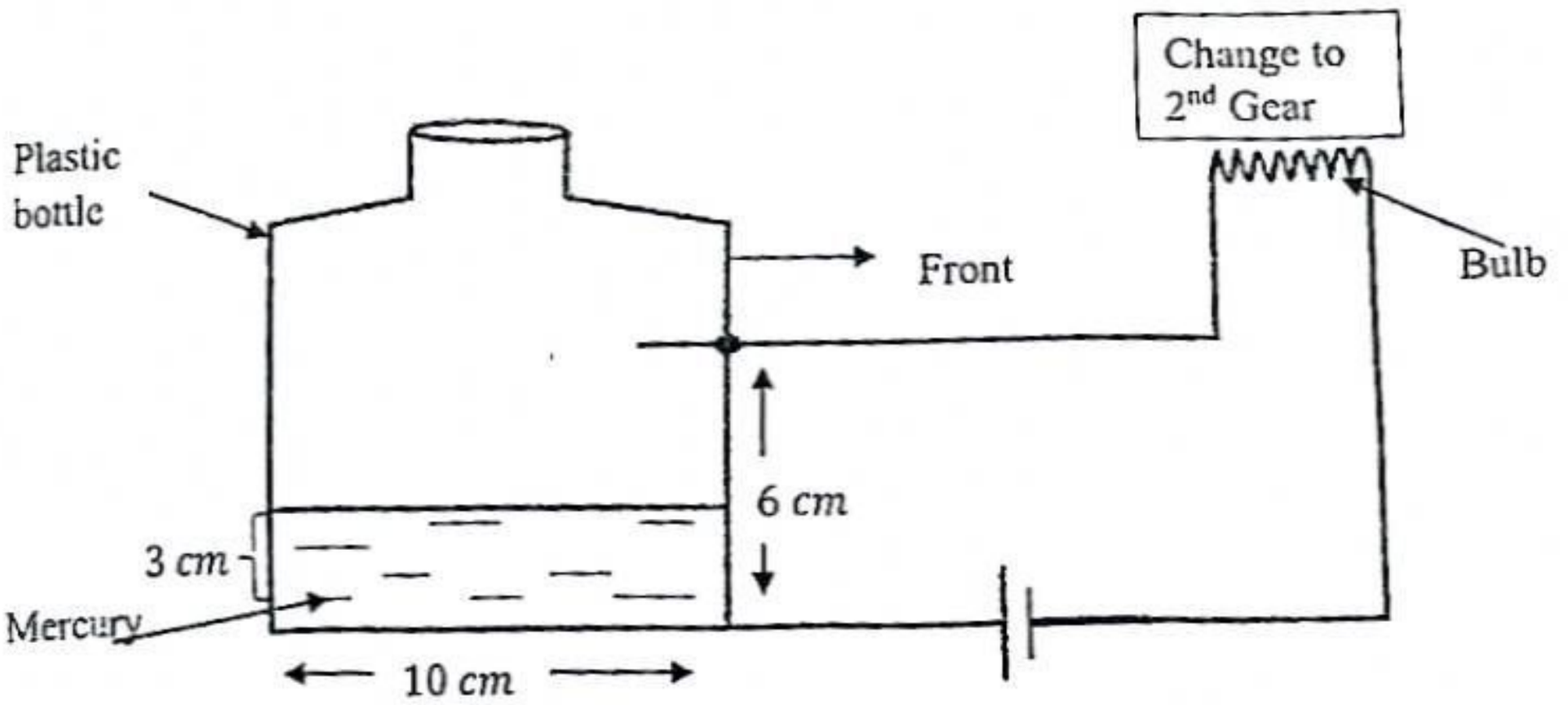
(ii) After seeing this road sign, the driver completely releases the accelerator and applies maximum brake force of 70000N. The remaining distance is travelled in the 4^{th} gear. The resistive force created due to the other parts, except the resistive force of engine. is 10000N. What is the deceleration of the bus? What is the velocity of the bus when it reaches the bend?

(iii) What is the maximum velocity that the bus can travel on this horizontal bend without having an accident?

(iv) Show that above bus will have an accident.

(v) An examiner says that, if the driver changed to the 2^{nd} gear at the moment he saw the road sign and even if the brake were not applied, that the bus would not have had the accident. If it is so, what is the deceleration? What is the velocity near the bend?

(c) A student creates a small circuit to inform the driver to change the gear to the 2^{nd} when he is moving in an inclined plane.



When the bus is stopped on a horizontal road, this apparatus is fixed horizontally. If the bus is moving to the downward on an inclined plane having θ angle to the horizontal, what is the minimum value needed for $\tan\theta$ to light the bulb?

(06) An endoscope is a medical device used to see inside of the human body. It works by using a lens which focuses an image into an optical fiber which transports the image using total internal *reflection*, to the exit face where a virtual image can be seen.

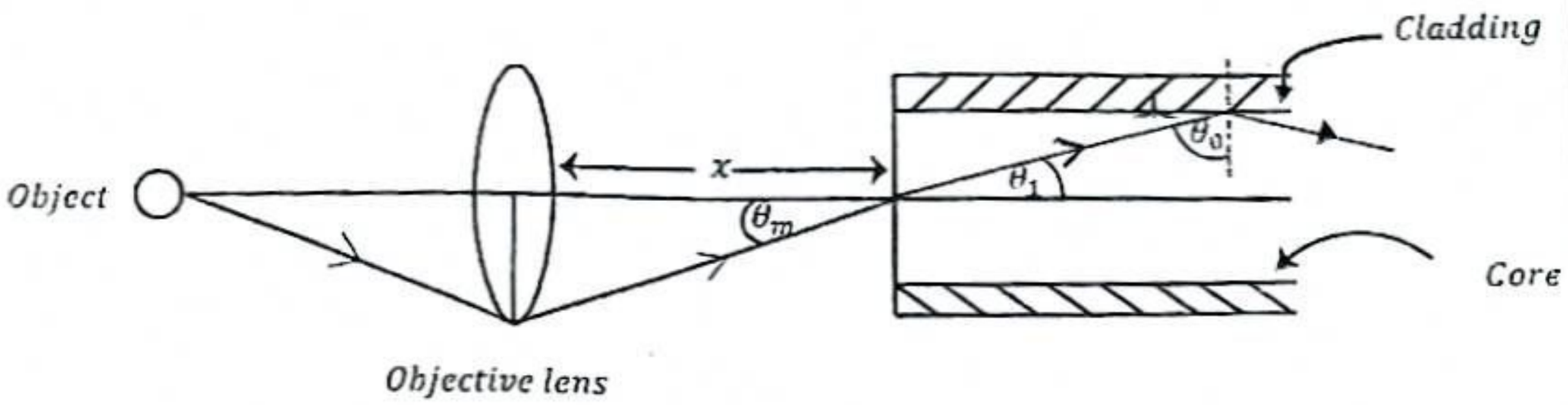
(a) i) Write down the definition of refractive index (n) of a medium by using the velocity of light in the relevant medium (V) and the velocity of light in vacuum (Vc).

ii) What is the critical angle?

iii) Obtain an expression for the critical angle when a light ray passing from a medium of refractive index 'n' to the air.

iv) What is the total internal reflection?

(b) This endoscope consists of a lens that collects and focus the light rays from the object being imaged and a fiber that transports the rays (via total internal reflection) to the eye piece. The refractive index of fiber's core is 1.6 and the refractive index of the cladding is 1.5



Figure(1)

(i) What is the critical angle (θ_c) of the fiber?

(ii) Calculate the angle θ_1

(iii) What is the maximum angle (θ_m) for the light rays incident on fiber's face to be totally internal reflected?

(iv) If the lens has a diameter of 4mm, calculate the distance x, shown in the figure. Round off your answer into <u>one</u> decimal.

(v) If the focal length of this objective lens is 0.7mm and it is capable of properly focusing an object which is in front of the objective lens, what is the distance the object should be placed from the lens?

(c) Assume the light ray incidents, on the cladding as shown in figure (2).

(i) Calculate the minimum angle which can be taken for θ. The refractive index outside the cladding is 1.2.

(ii) If the smallest outside radius permitted for a bend in the fiber if no light is to escape is

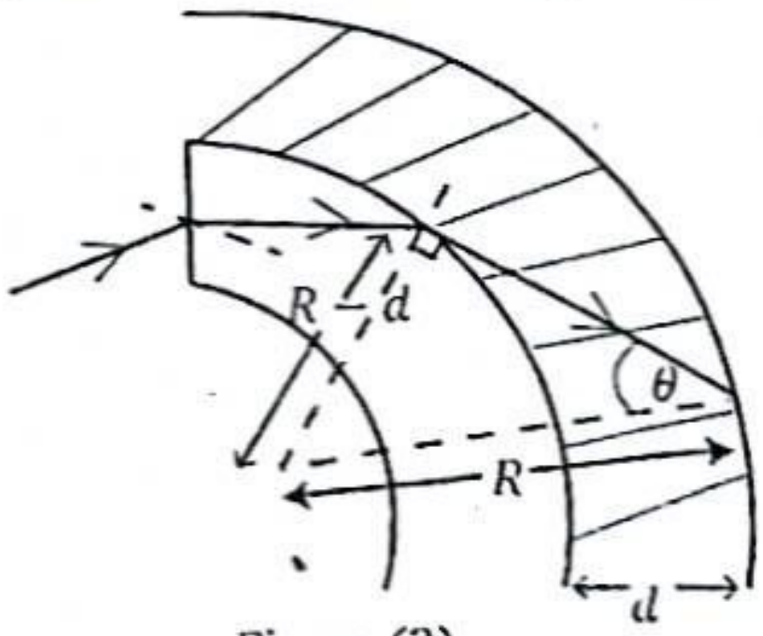


Figure (2)

$2 \times 10^{-2} m$, find the thickness of the cladding.

(d) Figure (3) shows that the distribution of light within the acceptance cone at the entry face of a fiber will be uniformly distributed over the exit face of the fiber.

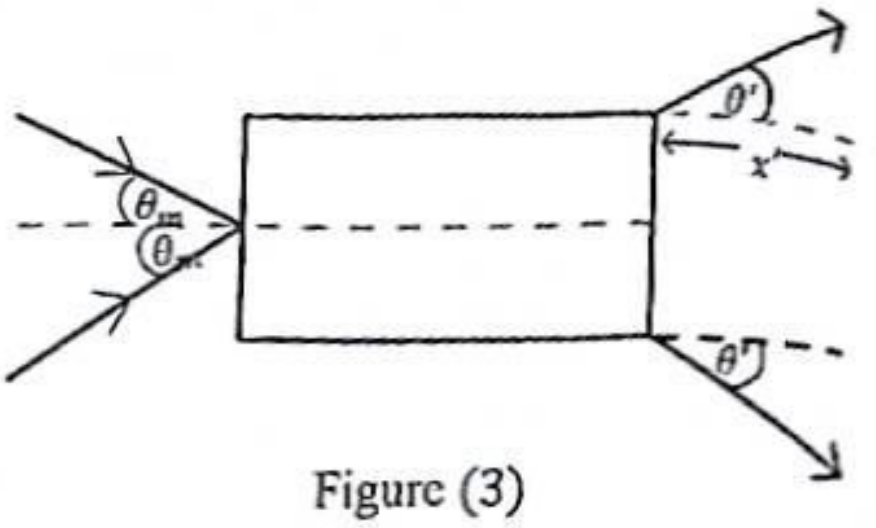


Figure (3)

(i) Find the value of θ' which is shown in figure (3) without calculation.

(ii) Write down the principle used to find the above angle.

(iii) If the x' distance in the above figure is $2mm$ and the diameter of the core of the fiber is $3mm$, calculate the illuminated area. ($\pi = 3$)

(e) Write down <u>one</u> practical application of the total internal reflection.

(07) Blood circular system is the most important system for the human beings and animals. It transports nutrient fractions, minerals as well Oxygen needed to respirate via blood. In this transportation process, the main power pump is the heart. The main factor for heart attacks is the blocking of arteries which carry blood out of the heart. Figure (1) shows how a liquid of high density blocks in an artery of a heart of a person who is not well.

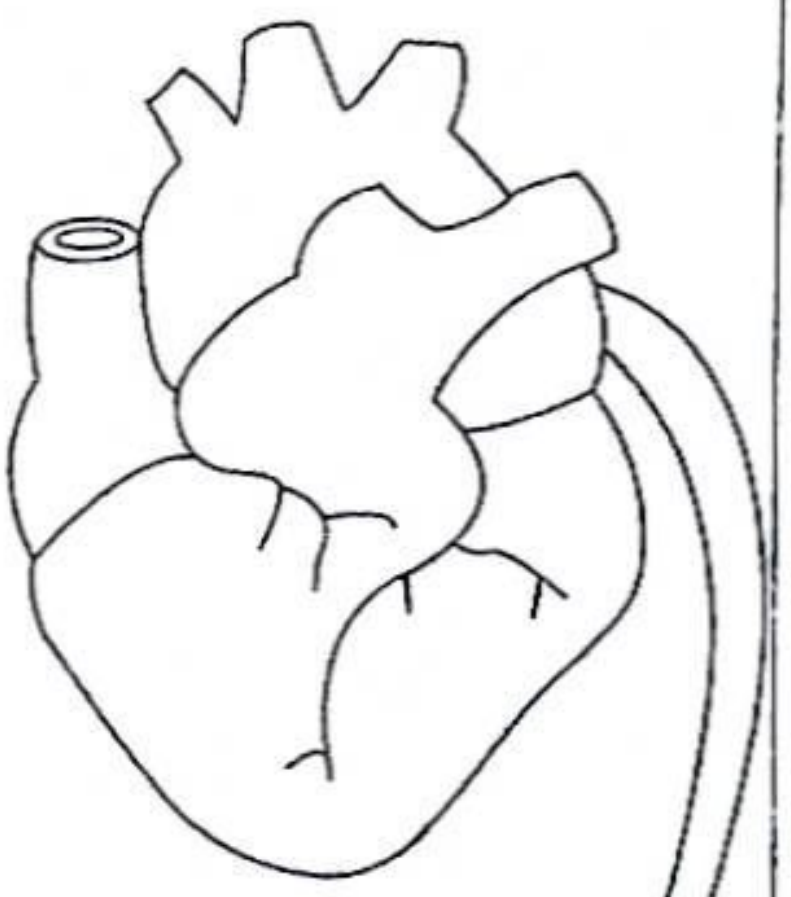


Figure (1)

Work done during one second by the heart of a person who is not well is 3W and the volume of heart chamber is from 600 cm^3 to 300 cm^3.

(i) Calculate the pressure inside the heart of this person during one second.
As shown in Figure 2, the height of the liquid portion of the blocked artery of the patient can be considered as the capillary rise in a capillary tube.

(ii) Define the surface tension (T).

(iii) If the internal radius of the tube is r, surface tension is T, the contact angle of meniscus A is θ and the contact angle of meniscus B is α, obtain expressions for the below given instances using the given symbols.

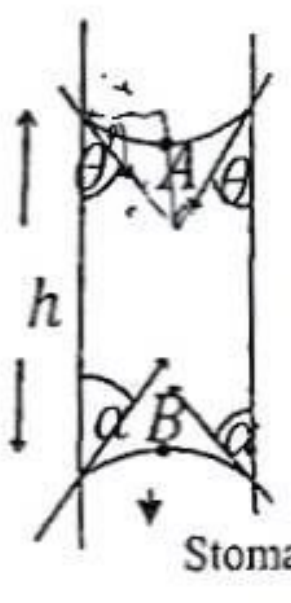
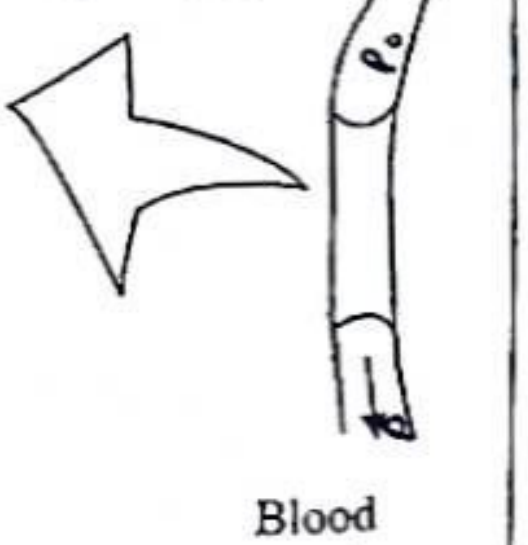


Figure (2)



I. Meniscus A
II. Meniscus B

(iv) If the pressure inside the heart is P_o and the pressure of the side which opens to the stomach is P, obtain an expression for the height of the fluid (h) using the above (iii) I, II and P, P_o.

(v) If the pressure inside the stomach is 10078 Pa, the pressure inside the heart is the value calculated in above (i), T=0.06 Nm^{-1}, θ=30°, α=60°, $r = 1mm$ and the density of the fluid is 1200 kgm^{-3}; calculate the height h. ($\sqrt{3} \simeq 1.7$)

(vi) Explain the reason for blocking of fluid inside the artery using the answer in part (i) and the pressure inside the stomach.

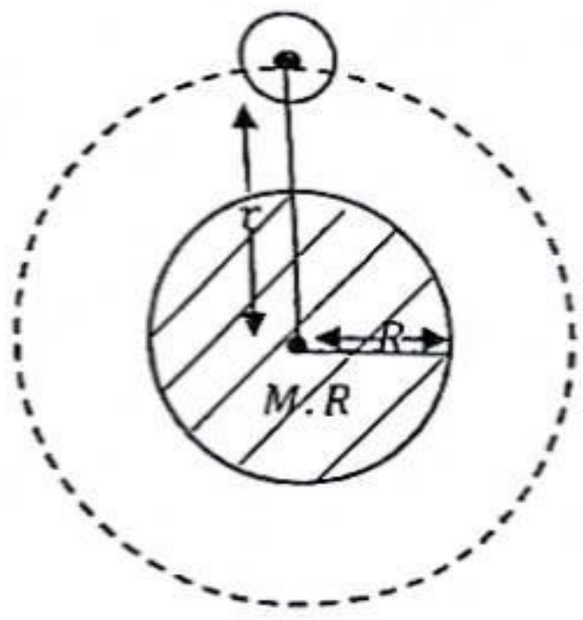
(vii) If this fluid layer needs to be removed from the patient, the fluid should be horizontal at the meniscus B (meniscus horizontal). What is the new pressure (P_o) should be supplied by the heart, while maintaining the height h same?

(viii) If the pressure is maintained at P_o as it is mentioned in above part (vi), how much extra fluid height should be added to keep the meniscus B horizontal?

(ix) If the pressure changes as mentioned in above part (vi) up to P_o', what is the volume of the heart that should be increased from 600cm^3, for doing the same work done mentioned in above (i)?

(x) Mention one good habit that we should maintain to avoid this type of blocks in heart.

(08) Consider an instance of two masses as m_1 and m_2 and their charges as q_1 and q_2. They are placed with a distance of r between their centre of gravity points. Universal gravitational constant is G and the permittivity of the medium is ε_0. Take $\frac{1}{4\pi\,\varepsilon_0} = k$



(a) (i) Write down the Coulomb's Law regarding charges and write an expression for the force F acting between the two charges using given symbols.

(ii) Write down the Newton's law of gravitation and write an expression for the force F acting between the two masses using given symbols.

(iii) By using the above two laws, write down one similarity and two differences between the gravitational force and the electrostatic force.

(b) A mass m having the charge q is rotated in a circular path of radius r around a charge $+Q$, mass M and radius R.

(I) $q = +Q$

(II) $q = -Q$

Obtain expressions for the period of time of mass m for both above instances (I and II).

(c) Consider that $q = -Q$.

(i) Obtain an expression for the total energy of m.

(ii) When this mass is rotating like this, another mass m collides with this and stick together. Consider the charge of new mass is $-Q$ and there isn't any energy loss due to this collision.

(I) Now, what is the charge of new mass 2m?

(II) If the new mass is rotated in the previous path with radius r, the velocity of this is,

(a) To equal to the velocity of previous mass m.

(b) To greater than the velocity of previous mass m.

(c) To less than the velocity of previous mass m

Show with a calculation, the requirement that should have for the value of Q.

(iii) Obtain an expression for the new total energy of the object.

(iv) $G = 6.67 \times 10^{-11}\, Nkg^{-2}\, m^2$

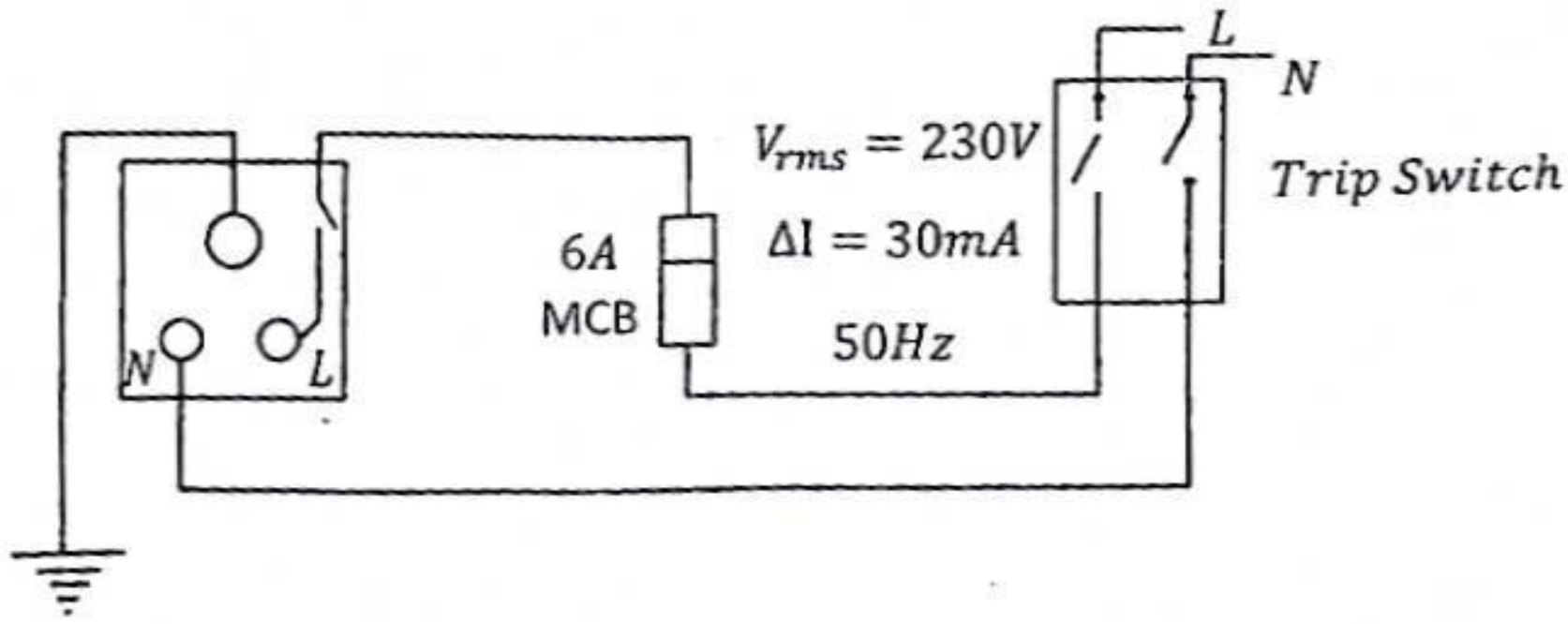
$k = 9 \times 10^9 Nm^2C^{-2}$

$M = 2kg\,, m = 500g,\ r = 10cm$

If $Q = 6\mu C$, calculate the new total energy.

(09) (A) A student constructs a part of a circuit as shown below.

(a) He prepares a safe electrical circuit and part of it is shown below. Instead of fuses he uses a MCB. ΔI is sensitive current deference



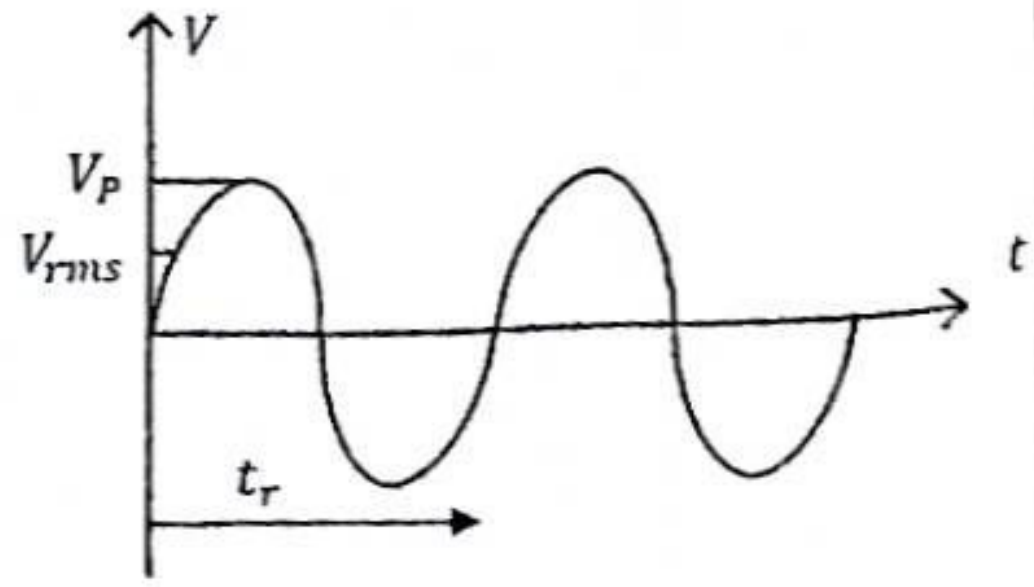
Below graph shows how the alternative voltage varies with time. $V_P = 1.4V_{rms}$

(i) What is the valuc of V_P?

(ii) What is the value of t_r?

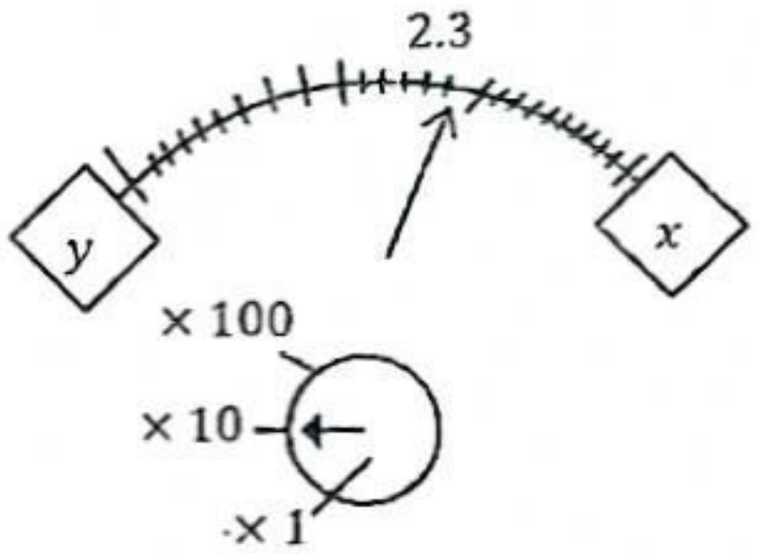
(iii) Write down the root mean square potentials of E, L, N connected to the plug respectively.

1. V_E
2. V_L
3. V_N



(iv) When a filament bulb rated as 5.29W, 230V is connected to L and E terminals. the trip switch is disconnected. Calculate the current that flowed through the bulb in mA and mention whether the trip switch is in a good condition or not (Take $23^2=529$)

(b) When an electric iron which is brought for repairs is connected to a plug, a MCB mentioned as 6A is disconnected. When this iron is removed from the plug and resistance between terminals is measured using an Ohm meter, the Ohm meter is as shown in the figure.



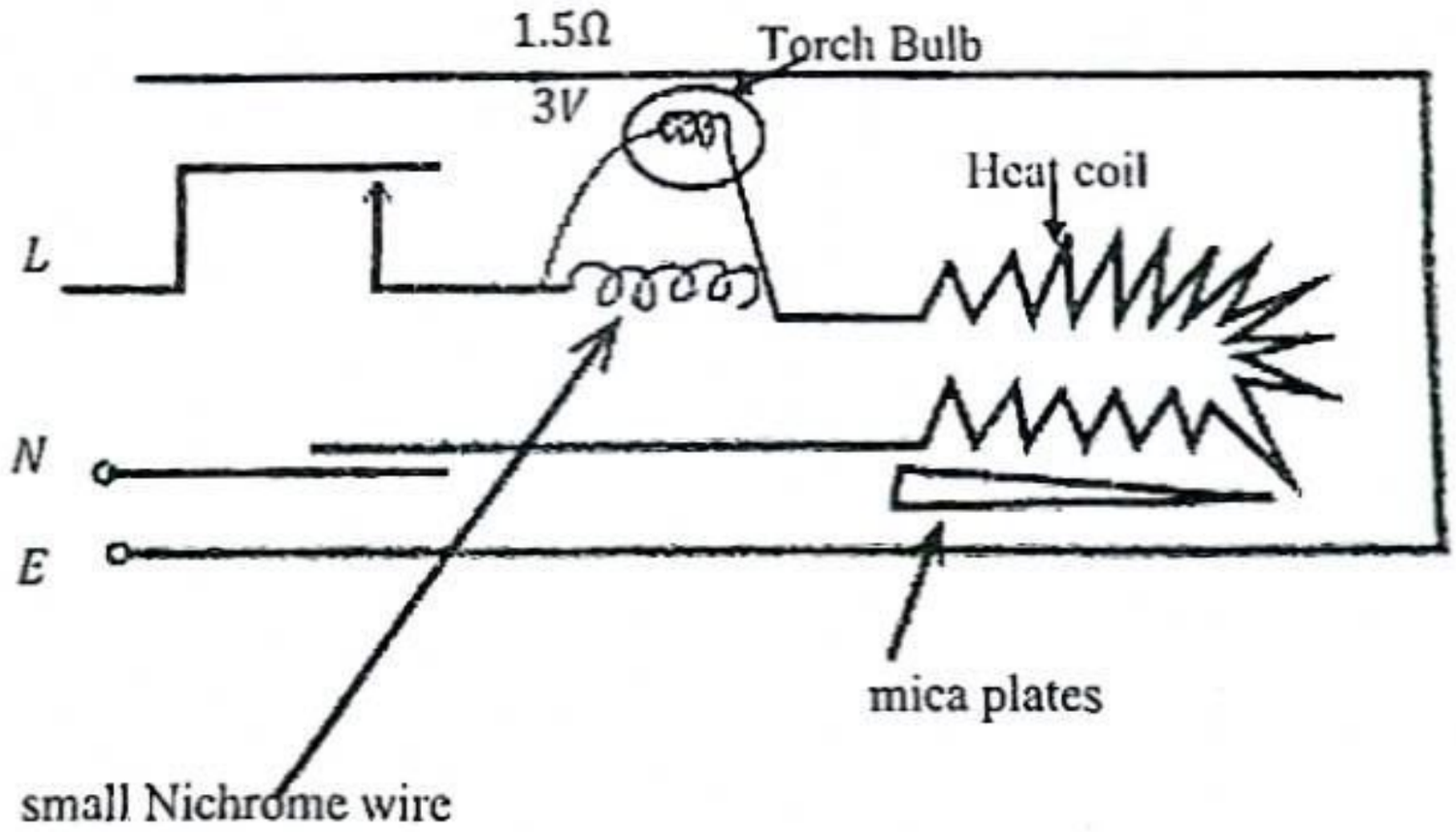
(i) If the range selector of the Ohm meter is at × 10 and the pointer is at 2.3, what is the internal resistor of the iron?

(ii) Find the current that flowed through the iron and write down whether MCB is in a good condition or not.

(iii) What is the X value in the Ohm meter face?

(iv) What is the Y value in the Ohm meter face?

(c) When this electric iron is dismantled and checked, it is observed that the coil that generates heat has a loose connection. It is repaired by replacing the coil with a new coil properly between the mica plates and after the repair when its internal resistance was measured, it measured as 57.5 Ω. The circuit of this iron is shown.



(i) Now, what is the current of the iron?

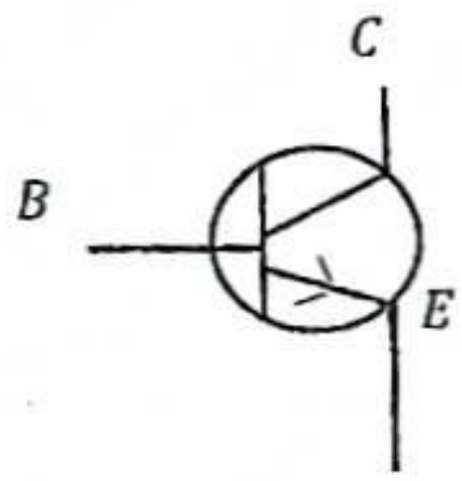
(ii) What is the power of the iron?

(iii) If the resistance of small Nichrome wire is R_1, the resistance of the heating coil is R_2 and $R_1 <<< R_2$, what should be the resistance of this small Nichrome coil to light the torch bulb with 3V? The resistor of the bulb is 1.5 Ω

(iv) Write down the special property the mica should have, to place these mica plates besides of the heating coil.

(v) Draw the rough sketch of the variation of the current with time, when ironing clothes for long time period.

(B) (a) Below figure (1) shows a circuit symbol of npn bipolar transistor.



Figure(1)

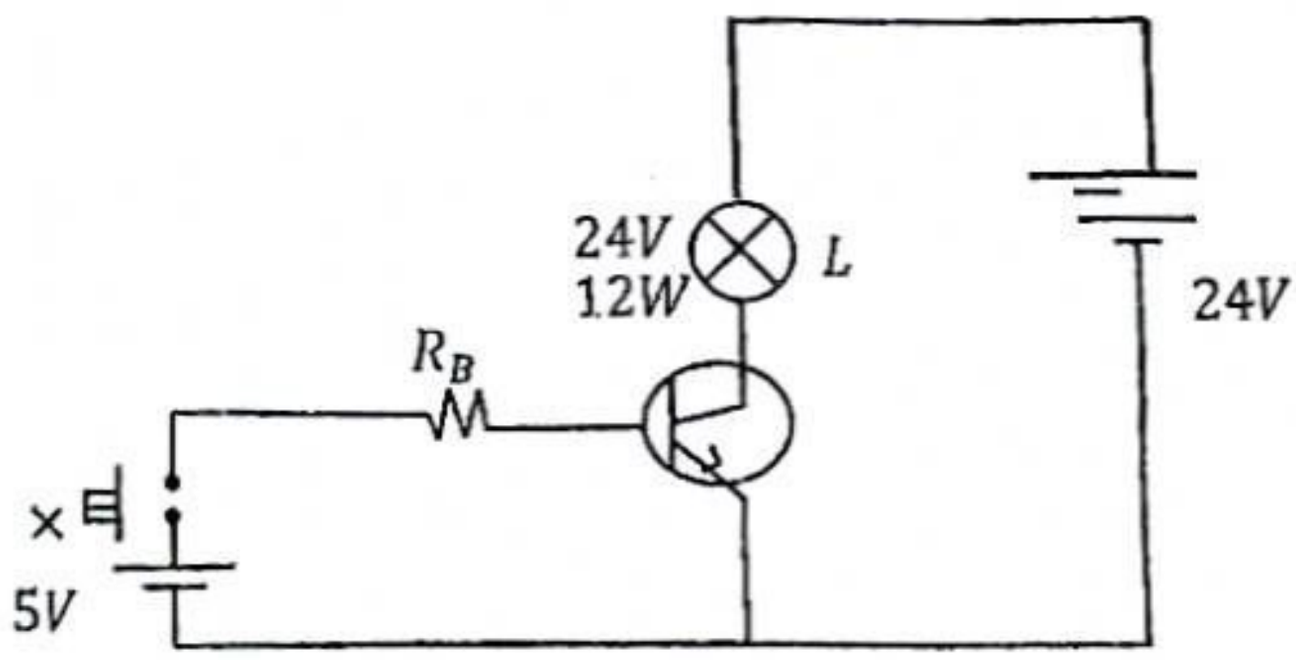
(i) Write down 3 instances a transistor can be used in an electronic circuit.

(ii) Draw the input, output current characteristics of a npn transistor in common emitter configuration and clearly mark the three regions:

(iii) Mention clearly the biasing of B-E junction and B-C junction with relation to the above each region. (Copy the below table onto your answer script and write on it.)

Region	Biasing of B-E junction	Biasing of B-C junction

(b) Below figure (2) shows a touch sensitive system created by using a transistor.



Figure(2)

(i) Explain the bulb L lights up or not when an instance of button switch (X) is opened.

(ii) When the button switch (x) is closed, calculate the value R_B should have to light up the bulb with maximum power. (Consider the current gain as 100)

(c) Below figure (3) shows a touch sensitive circuit which is prepared by using 741 operational amplifier.

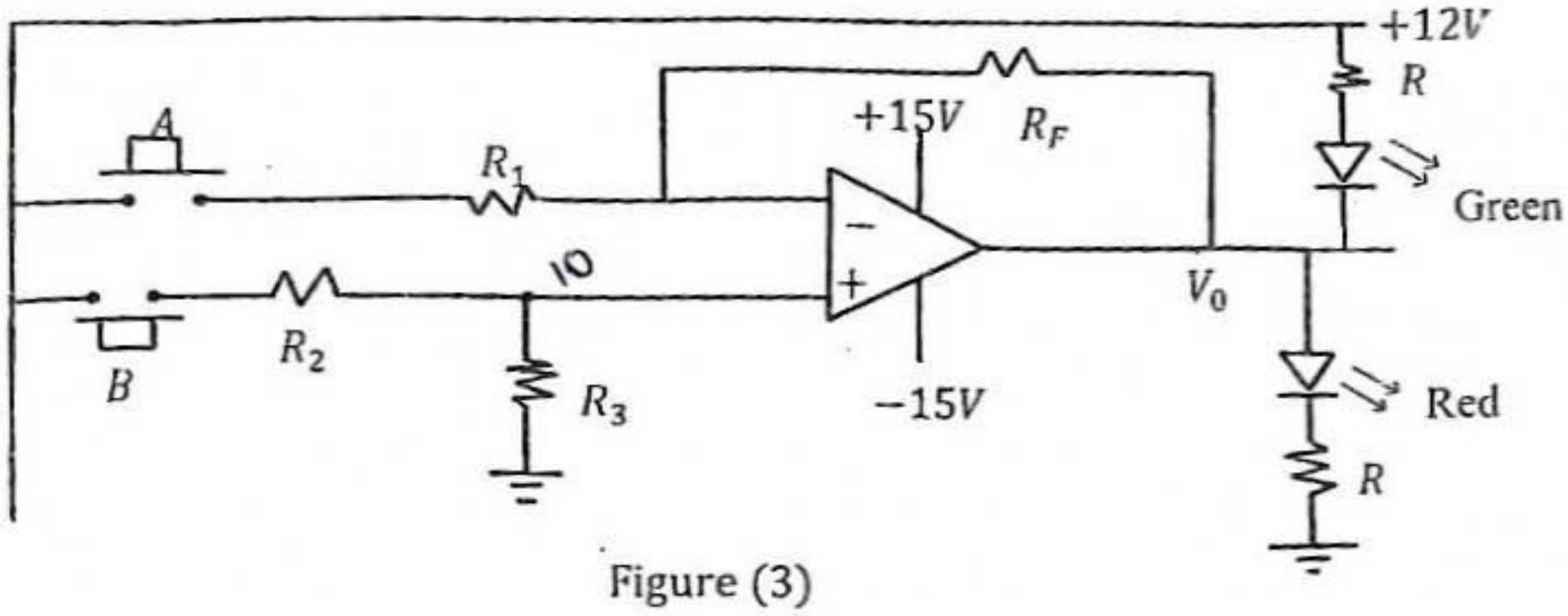


Figure (3)

The relevant resistances values of figure (3) are given below.

R_f = R_3 = $10k\Omega$, $R_1, R_2 = 2k\Omega$

(i) Write down two golden rules relevant to the operational amplifier.

(ii) When only the switch A is closed, derive an expression for the voltage gain.

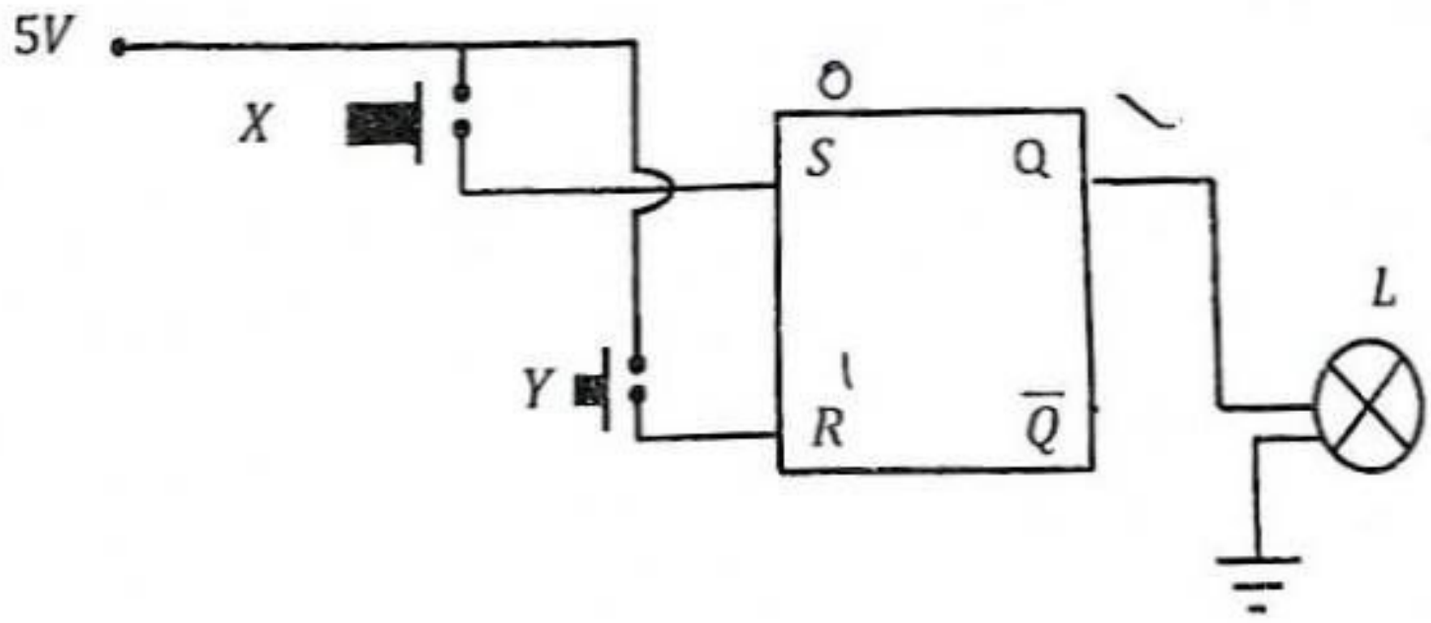
(iii) Calculate the voltage gain and the output voltage using (c) (ii).

(iv) Derive an expression for the voltage gain when only the switch B is closed.

(v) Calculate the voltage gain and the output voltage using (c)(iv).

(vi) Write down separately the colour of the LED when the A and B switches are closed separately. Suitable values are given for R.

(d) Below figure (4) shows a touch sensation circuit which is prepared by using SR flip flop.

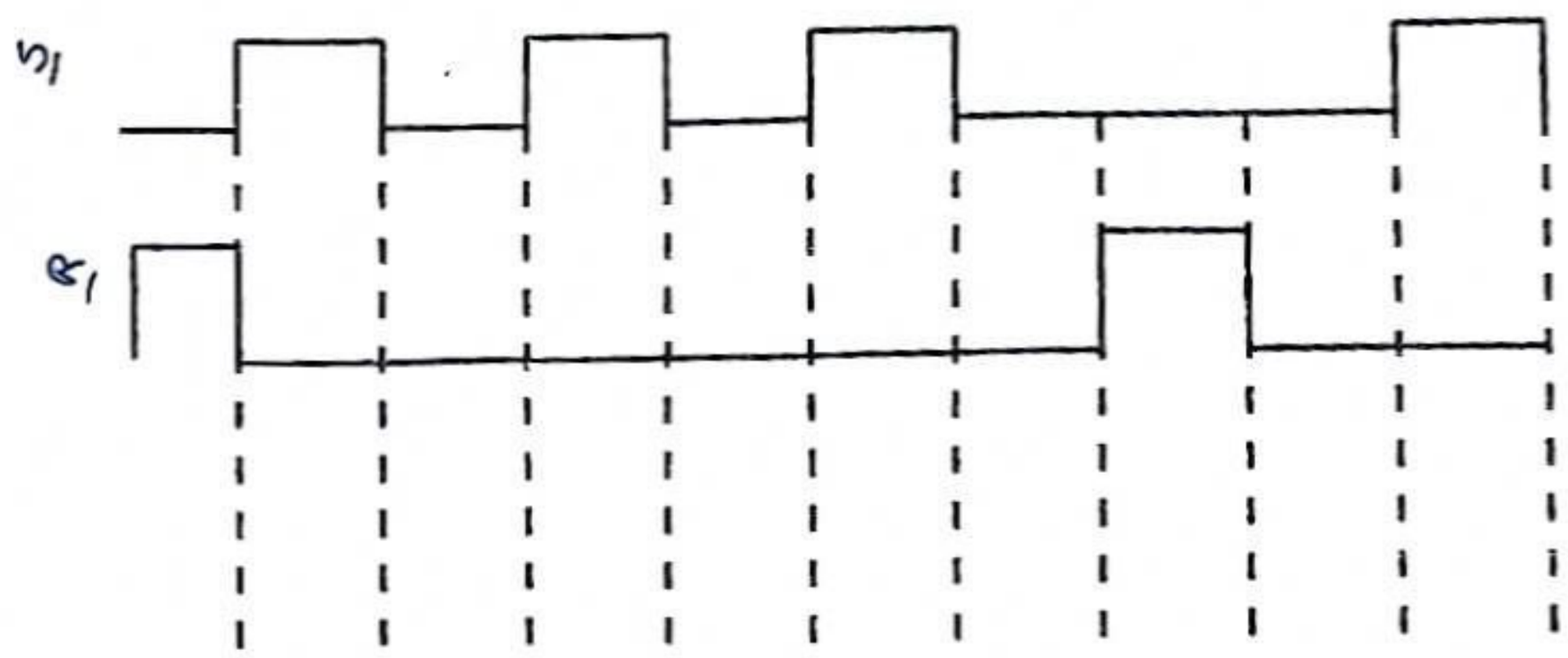


Figure(4)

(i) Complete the below given truth table according to the SR flip flop.

S	R	Q	$\overline{Q}$
0	0		
0	1		
1	0		
1	1		

(ii) Draw the time figure of Q which is relevant to S and R



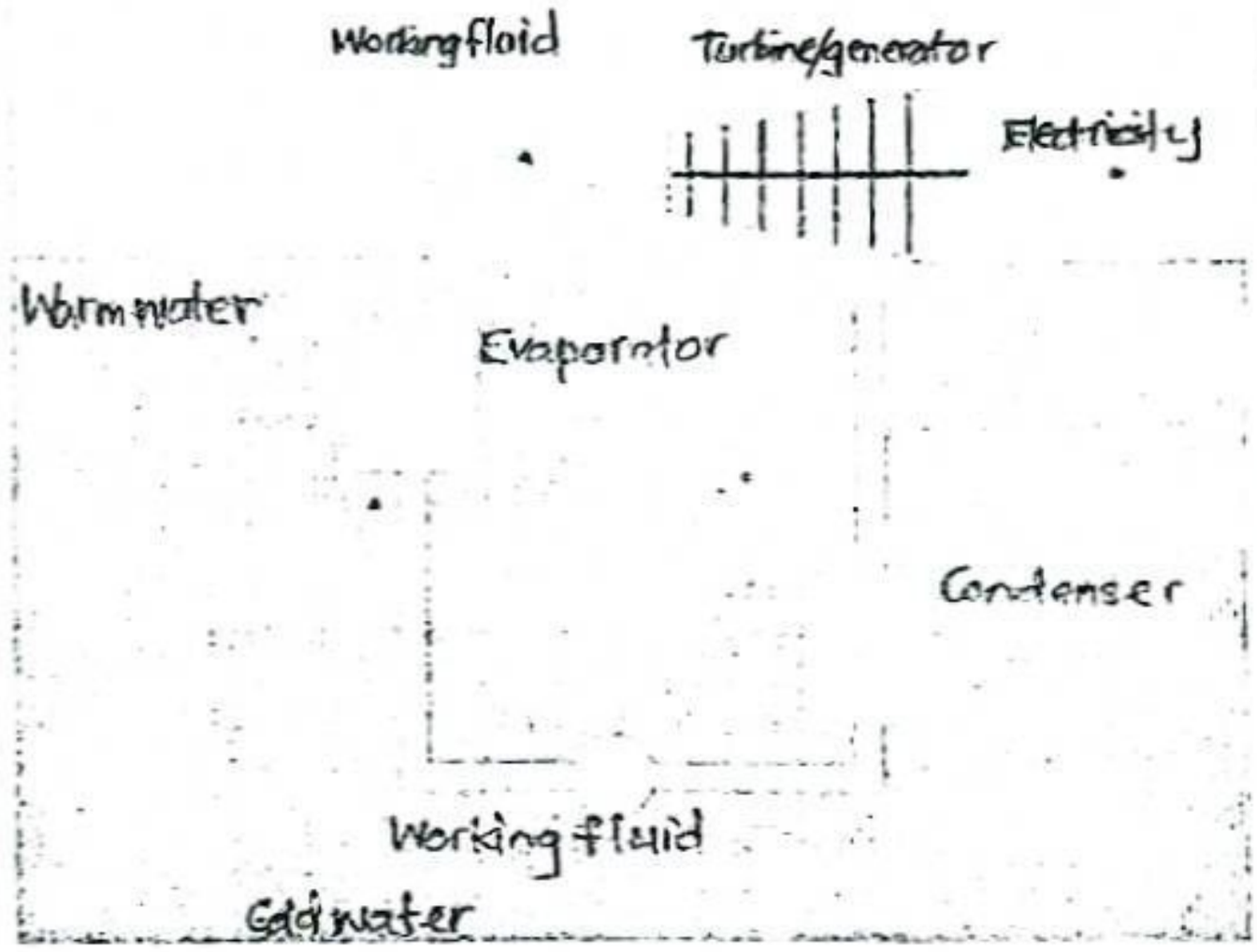
(iii) Write down the logic levels of S and R which is relevant to the below instances independent of each other according to figure (4).

Instance	S	R
Y closed and X opened instance		
Y opened and X closed instance		
Y and X opened instance		

(iv) Above circuit is fixed to the passenger seat of an air plane. Bulb L is positioned at the place where the air hostess is. Construct the signal relevant to S, R and Q according to the below process. Passenger close and release only X. Then Y Switch is opened. It takes some time for the air hostess to arrive. X switch is closed and the service needed by the passenger is supplied.

(10) (A) Ocean thermal energy conversion (OTEC) power plant generates electricity by using the temperature difference between warm surface ocean water and cold deep ocean water to drive an electrical generator. The temperature difference between these two layers is approximately 20°C.

Temperature of the warm surface ocean water is 30°C. Heat energy released by this warm water is used to evaporate liquid Amonia with low boiling point. Liquid Amonia is flowing to the evaporator through a cylindrical pipe as shown in the figure. Warm surface ocean water is flowing to the evaporator through horizontal cylindrical pipe.



Figure(1)

(a) (i) Write down an expression for the rate of heat flow (Q) at steady state through a material and identify all the symbols you used.

(ii) This cylindrical horizontal pipe which is used to flow warm ocean water to the evaporator is completely wrapped with an insulating material. Cylindrical pipe made of thermal conductivity $100Wm^{-1}K^{-1}$ whose inner and outer radii are $0.5m$ and $0.75m$ respectively is covered with thick insulating material of thermal conductivity $0.25Wm^{-1}K^{-1}$ and the thickness is $0.25m$ The outside temperature (θ_1) of the pipe is $30°C$. If the rate of heat loss at steady state is $60W$, calculate the temperature of water flowing inside the tube (θ_2). The length of the tube is 2.0m. Take $\pi = 3$. Round off your answer to a whole number. [Hint: $\frac{1}{1.75} = 0.6$]

(iii) Calculate the amount of heat released by water per second which is flowing in above mentioned (a) (ii) tube. Rate of water flowing through this tube is 3 metric tons. Mean specific heat capacity of water is $4100\ Jkg^{-1}K^{-1}$. Boiling point of liquid Ammonia is $-30°C$. [1 metric ton = $1000kg$]

(iv) Calculate the total mass of Ammonia vapour that can be produced using the energy released from warm water calculated in (a)(iii) above. Specific heat capacity of liquid Ammonia is 80 $kJkg^{-1}K^{-1}$ and the latent heat of liquid Ammonia is $1.4 \times 10^6\ Jkg^{-1}$. Round off your answer to the nearest whole number.

(b) $1kg$ of Ammonia vapour releases 9×10^{10}J energy. This power is used to operate electrical generators to generate electricity. From this power generation, 120 houses in Hawaii can be powered during a year and Hawaii's annual power consumption is $1 \times 10^{20}W$. Take 1 year = $3 \times 10^7 s$.

(i) Write down an equitation for the efficiency?

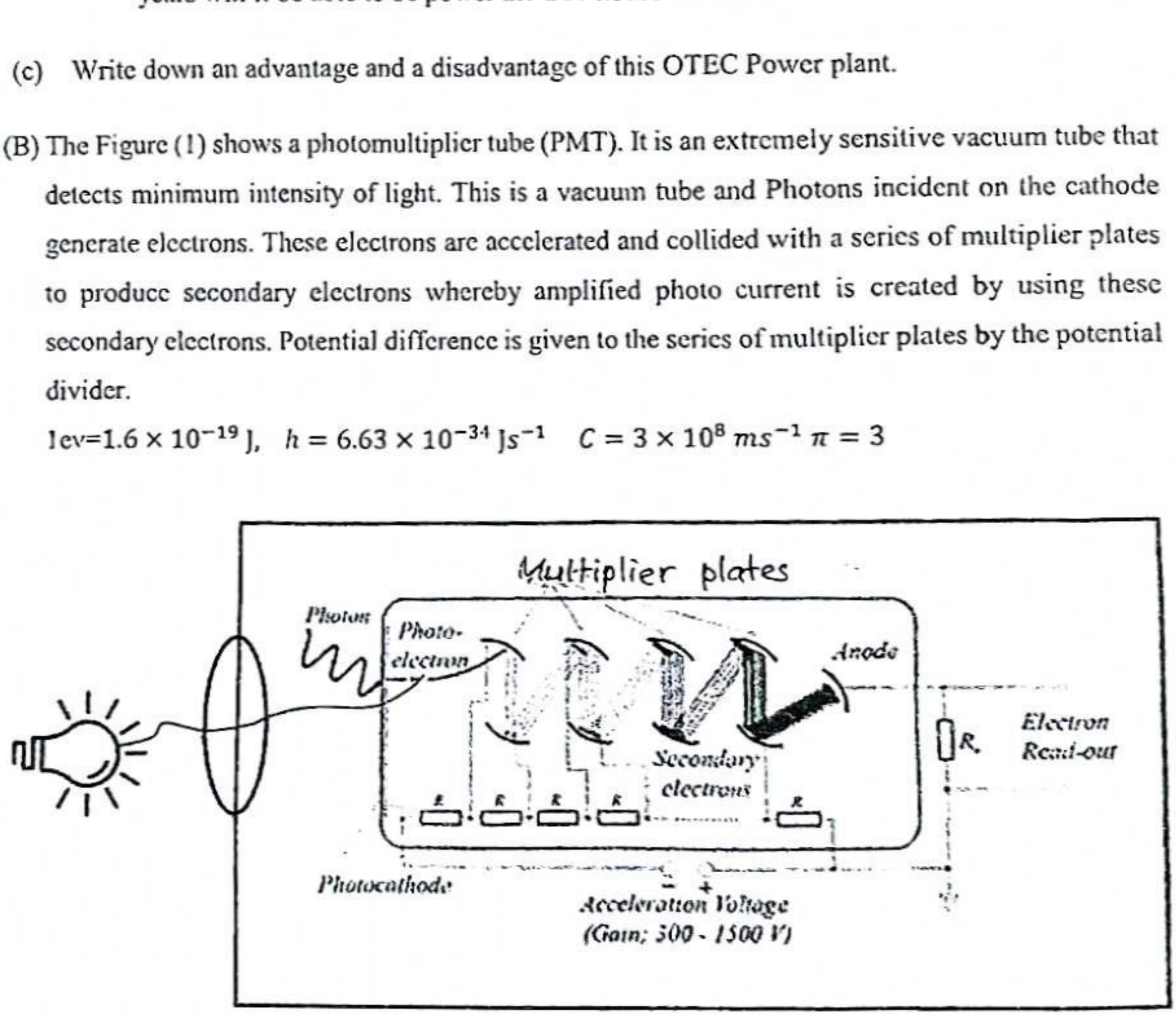
(ii) Find the efficiency of this OTEC power plant in Hawaii. [Hint: $\frac{1}{8154} = 1.23 \times 10^{-4}$]

(iii) If this OTEC power plant works with 100% efficiency without power loss, how many years will it be able to be power the 120 houses in Hawaii?

(c) Write down an advantage and a disadvantage of this OTEC Power plant.

(B) The Figure (1) shows a photomultiplier tube (PMT). It is an extremely sensitive vacuum tube that detects minimum intensity of light. This is a vacuum tube and Photons incident on the cathode generate electrons. These electrons are accelerated and collided with a series of multiplier plates to produce secondary electrons whereby amplified photo current is created by using these secondary electrons. Potential difference is given to the series of multiplier plates by the potential divider.

1ev=1.6×10^{-19} J, $h = 6.63 \times 10^{-34}\ Js^{-1}$ $C = 3 \times 10^8\ ms^{-1}$ $\pi = 3$



Figure(1)

(a) (i) What is the phenomenon used in the photomultiplier tube (PMT)?

(ii) Explain, why the photo multiplier (PMT) is sensitive to detect low intensity of light?

(iii) Explain why the electrons are accelerated through a series of multiplier plates?

(b) The photo cathode of this photomultiplier is made with Cs. The work function of this metal is 1.8 eV. Monochromatic light with the wavelength 442 nm incidents on this cathode.

(i) Explain what is the work function of a metal?

(ii) What is the maximum wavelength of light that can be detected by the above PMT instrument?

(iii) Explain why the above PMT instrument cannot detect IR rays?

(iv) Calculate the maximum energy of the photons which incidents on the cathode.

(v) Calculate the maximum kinetic energy of the emitted photo electrons by the photo cathode mentioned in above (b).

(vi) What is the stopping potential of a photo electron?

(vii) Find the value of the stopping potential.

(viii) Sketch a rough graph to show the variation of kinetic energy of emitted photo electrons with wave length of the photons.

(c) Quantum Efficiency (QE) shows how effectively a system convert incident photons into photo electrons as a percentage. It is 20% in the PMT instrument mentioned in above (b). It is having 8 multipliers. Wave length of the incident light rays is 442nm and when the accelerated electron collides with the anode the accelerated electron multiply 4 times.

(i) Sketch a rough graph to represent how the photo current varies with the frequency of light and the intensity of light.

(ii) PMT instrument is kept 1.0m away from the 300W of point light source. Light enters the instrument from an area of $2cm^2$ window. Calculate the number of photons entering the instrument in one second.

(Light source uniformly emits 442 nm wavelength of monochromatic light)

(iii) Some percentage of incident photons in above incidents on the cathode. The amount of incident photon is 2×10^{15}. Then, calculate the number of photo electrons generated by the cathode.

(iv) Calculate the flowing photo current from PMT instrument in μA.

(v) Calculate the power of the exposed light source when 2.09A current flows through the circuit.

(vi) What are the assumptions you have made?

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