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கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2018 ஓகஸ்ற்
General Certificate of Education (Adv. Level) Examination, August 2018

භෞතික විද්‍යාව II பௌதிகவியல் II **Physics II**	**01 E II**	**13. 08. 2018 / 0830 - 1140**

පැය තුනයි
மூன்று மணித்தியாலம்
Three hours

අමතර කියවීම් කාලය - මිනිත්තු 10 යි
மேலதிக வாசிப்பு நேரம் - 10 நிமிடங்கள்
Additional Reading Time - 10 minutes

Use **additional reading time** to go through the question paper, select the questions and decide on the questions that you give priority in answering.

Index No. : .....

Important :

- *This question paper consists of* **16** *pages.*
- *This question paper comprises of* ***two*** *parts, Part* **A** *and Part* **B.** *The time allotted for* ***both parts*** *is* ***three hours.***
- *Use of calculators is* ***not*** *allowed.*

PART A — Structured Essay :
(pages 2 - 8)

Answer ***all*** *the questions on this paper itself. Write your answers in the space provided for each question. Note that the space provided is sufficient for your answers and that extensive answers are not expected.*

PART B — Essay :
(pages 9 - 16)

This part contains ***six*** *questions, of which,* ***four*** *are to be answered. Use the papers supplied for this purpose.*

- *At the end of the time allotted for this paper, tie the* ***two parts together*** *so that* ***Part A*** *is* ***on top*** *of* ***Part B*** *before handing them over to the Supervisor.*
- *You are permitted to remove* ***only Part B*** *of the question paper from the Examination Hall.*

For Examiners' Use Only

For the second paper		
Part	**Question Nos.**	**Marks Awarded**
A	1	
	2	
	3	
	4	
B	5	
	6	
	7	
	8	
	9 (A)	
	9 (B)	
	10 (A)	
	10 (B)	
Total		

Final Marks

In numbers	
In words	

Code Numbers

Marking Examiner 1	
Marking Examiner 2	
Marks checked by	
Supervised by	

[see page two

PART A – Structured Essay

*Answer **all four** questions on this **paper itself**.*

(Acceleration due to gravity, $g = 10\,N\,kg^{-1}$)

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1. An experimental setup of Hare's apparatus used in a school laboratory is shown in figure (1). As shown, x_w and x_l represent the heights to the mark M of the relevant indicator from the water and liquid surfaces in the beakers respectively.

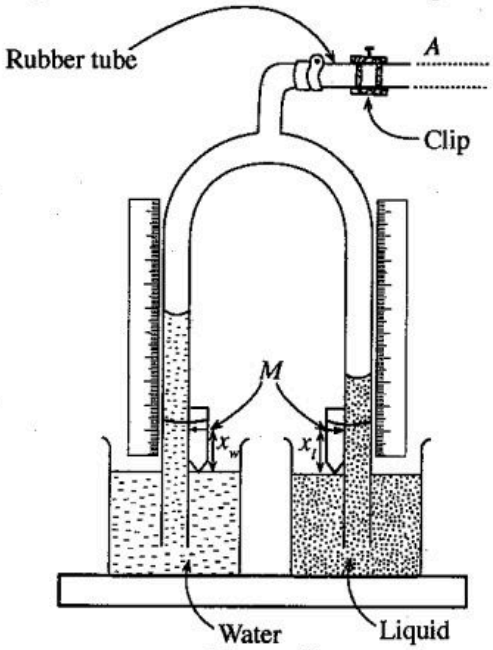

Figure (1)

(*a*) (i) What is the purpose of using a clip in Hare's apparatus?

.....

(ii) The densities of water and the liquid are d_w and d_l respectively. If h_w and h_l represent the heights of the water column and the liquid column in glass tubes as measured from the mark M of the respective indicators, derive an expression for h_l in terms of h_w, d_w, x_w, d_l, and x_l.

.....

.....

.....

.....

(iii) If the expected heights of the liquid column and the water column are significantly different to each other, more attention has to be paid on one height than the other when planning out the experiment to take a set of readings and plot a graph. What is the height you pay more attention (one with a smaller height or larger height)? Explain your answer giving reasons.

.....

.....

(iv) Every time after changing the heights of liquid and water columns in tubes and closing the clip you need to make another adjustment before taking the measurements with regard to new heights. Write down the experimental procedure which you should follow to make this adjustment.

.....

.....

[*see page three*

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(*b*) The apparatus shown in figure (2) can be used to vary the air pressure inside the tubes of the Hare's apparatus. This system works on Bernoulli's principle. The air pressure inside the tube *T* can be changed by adjusting the speed of the narrow water jet passing through the section *X* of the apparatus with the help of the tap. The position *A* of the apparatus shown in figure (2) can be connected to the position *A* of the rubber tube shown in figure (1), to make an improved version of Hare's apparatus.

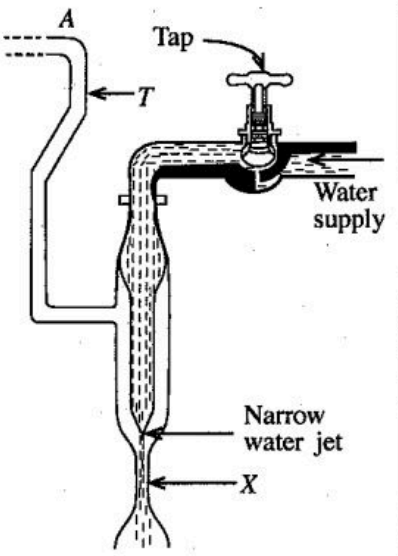


Figure (2)

(i) Write down the procedures used in Hare's apparatus available in the school laboratory, and improved version of Hare's apparatus mentioned in (*b*), when **establishing** the liquid columns in the tubes.

Hare's apparatus available in the school :

.....

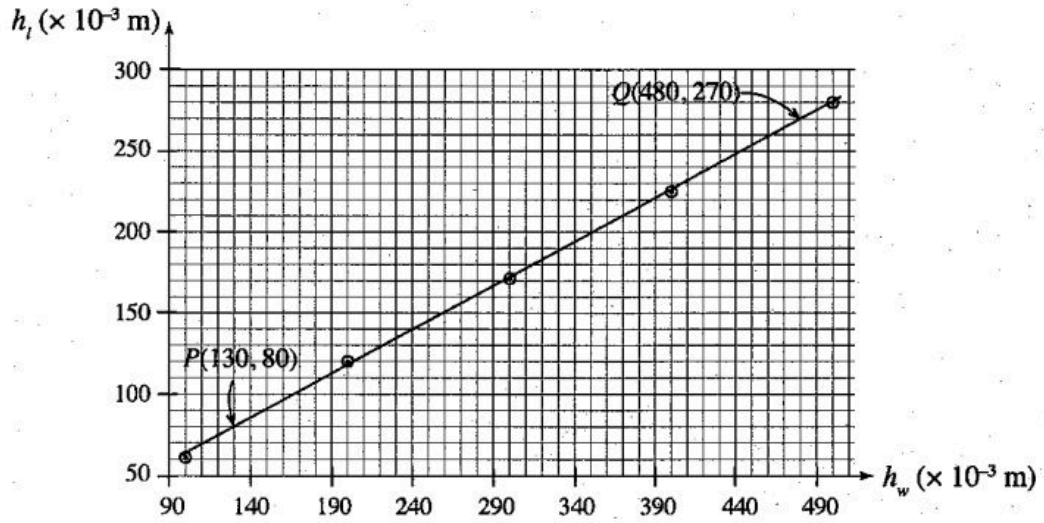
Improved version of the Hare's apparatus :

.....

(ii) Give **one** main advantage of using the improved setup mentioned in (*b*) over the apparatus generally available in the school laboratory.

.....

(*c*) A graph plotted using a set of readings obtained from the improved apparatus, mentioned in (*b*) above, is shown below. The graph shows the variation of the heights h_w and h_l of the liquid columns for water and sulphuric acid respectively.



(i) In this experiment you are provided with a scale which can measure the length with an accuracy of 1 mm. What is the maximum **fractional** error associated with h_w measurements taken in this experiment?

.....

.....

(ii) Using the two points *P* and *Q* on the graph, calculate the relative density of sulphuric acid.

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[see page four

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2. Figure (1) shows an **incomplete** diagram of an experimental setup that can be used to verify Charles's law.

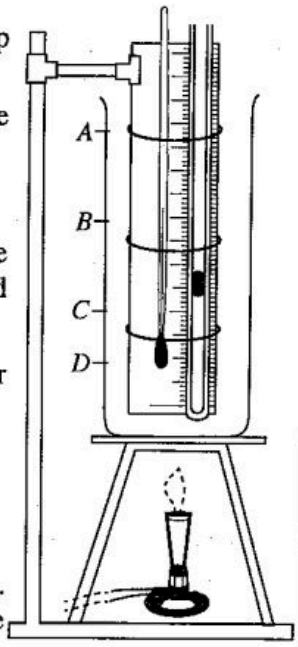

Figure (1)

(*a*) Upto what level *A*, *B*, *C* or *D* should water be filled in the cylinder in order to perform the experiment accurately?

.....

(*b*) Draw in figure (1), the important missing item, in the incomplete diagram (with appropriate size) other than water that you would require in this experiment.

(*c*) Give **two** advantages of using a mercury thread over a water thread in this experiment.

(i) .....

(ii) .....

(*d*) As the temperature is increased, mercury thread will also expand. Explain why this expansion does **not** affect the pressure of the trapped air column.

.....

(*e*) In this experiment, you are asked to measure the length (l_θ) of the trapped air column and its temperature (θ °C). Write down the main steps in the experimental procedures which you should follow to ensure that (i) the thermometer reading itself provides the temperature of the trapped air column, and (ii) length l_θ itself is the exact length corresponding to θ °C.

(i) Experimental procedure:

.....

.....

(ii) Experimental procedure:

.....

.....

(*f*) If the lengths of the dry air column trapped inside the capillary tube of uniform bore diameter at 0 °C and θ °C are l_0 and l_θ respectively, write down an expression for l_θ in terms of γ_p, l_0 and θ, where γ_p is the volume expansivity at constant pressure for dry air.

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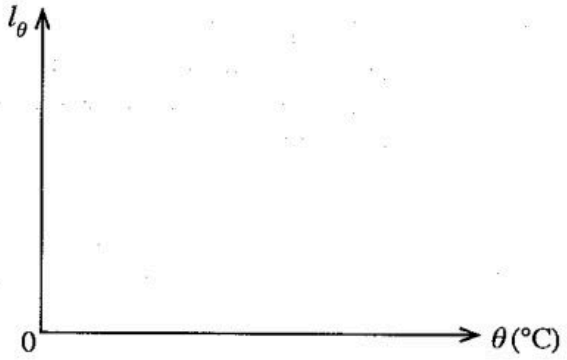
(*g*) Draw a rough sketch of the expected graph with l_θ on the *y*-axis and θ in °C on the *x*-axis.



[see page five

(*h*) A student decided to use the capillary tube shown in figure (2)(a) instead of the tube shown in figure (2)(b) in this experiment. When taking a set of readings, is it more advantageous or more disadvantageous? Explain your answer.

.....

.....

.....

.....

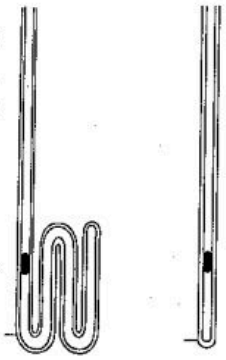


Figure 2(a) Figure 2(b)

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(*i*) Can you perform this experiment properly using an electric hot plate instead of a Bunsen burner? Explain your answer.

.....

.....

3. You are asked to find the refractive index of glass using a rectangular block of glass and a travelling microscope. A small amount of lycopodium powder and a piece of white paper cut to the size of the glass block are also provided. A letter 'X' is marked in the middle of the white paper. Diagram of a travelling microscope that can be used in this experiment is shown in figure (1).

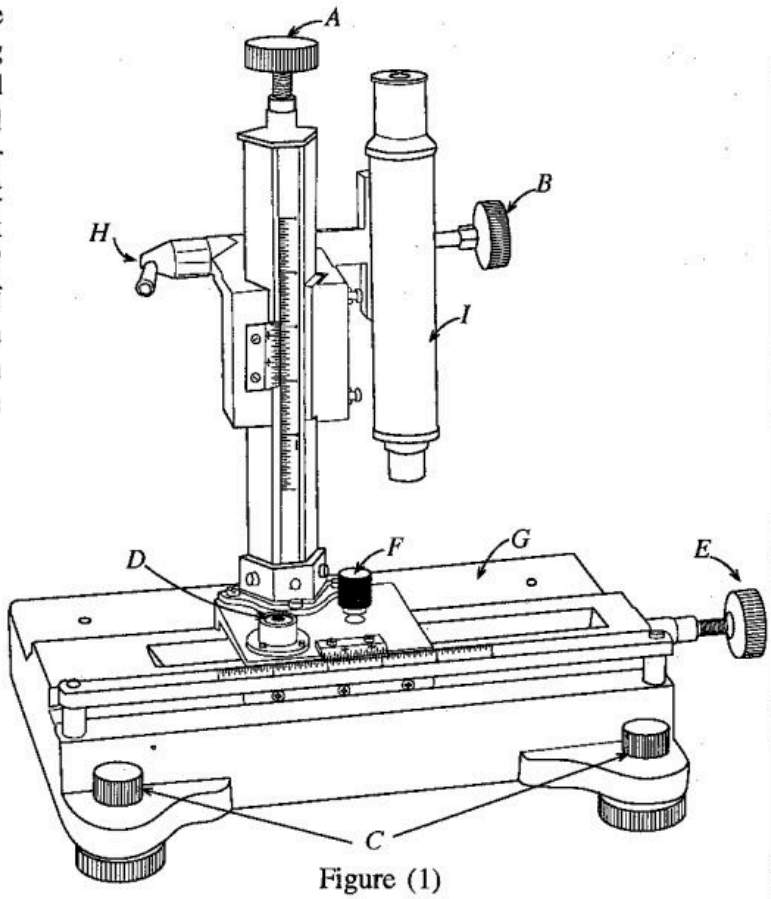

Figure (1)

(*a*) Identify the parts marked with *A*, *B*, *C* and *D*, and briefly state their functions.

Part	Identification	Function
A	.....	.....
B	.....	.....
C	.....	.....
D	.....	.....

[see page six

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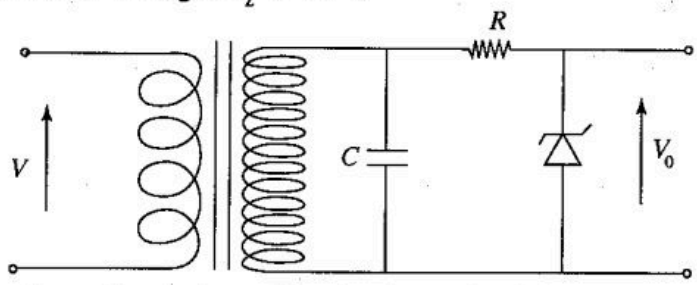
(*f*) The output of the photodiode circuit in figure (D) is now connected to the input of the circuit shown below. Number of turns in the primary and the secondary coils in the transformer are 25 and 750 respectively. Assume that the value of capacitance C is very large. Take Zener voltage, V_z = 75 V.



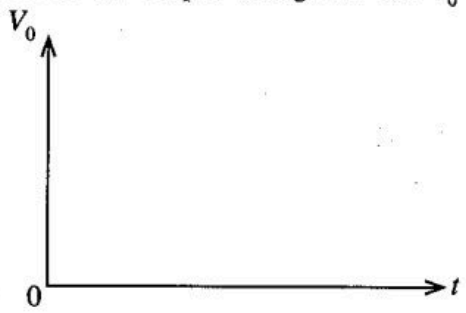
(i) What type of transformer is used in the above circuit?

.....

(ii) What is the value of the voltage that can be expected across the Zener diode?

.....

(iii) Draw a rough sketch to show how the output voltage V_0 varies with time t. Indicate the magnitude of the output voltage on the V_0 axis.



(*g*) A student argues that the experiment described above has provided a method to construct a dc to dc voltage converter. Would you agree with this argument? Explain your answer.

.....

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* *

[see page nine

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இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka
Department of Examinations, Sri Lanka
අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2018 අගෝස්තු
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2018 ஓகஸ்ட்
General Certificate of Education (Adv. Level) Examination, August 2018

භෞතික විද්‍යාව II பௌதிகவியல் II **Physics II**	**PART B – Essay**	**01 E II**

*Answer **four** questions only.*
(Acceleration due to gravity $g = 10\,N\,kg^{-1}$)

5. (*a*) Bernoulli's equation for a fluid flow can be written as $P + \frac{1}{2}dv^2 + hdg = \text{constant}$, where all symbols have their usual meaning. Show that the term $\frac{1}{2}dv^2$ has the **unit** of energy per unit volume.

(*b*) Sri Lanka has one of the most advanced ancient irrigation systems in the world. Such an irrigation system which supplies water for farmers and villagers consists of three major features as shown in figure (1).

Feature 1 : The tank or reservoir and the dam.

Feature 2 : The outgoing water canal from the tank which is exposed to **atmosphere**.

Feature 3 : The Bisokotuwa (also known as cistern sluice) is a rectangular shaped vertical tower chamber with walls made of stones or bricks (see figure (1)). When it is required to release water from the tank, the water is first allowed to enter the Bisokotuwa in which the speed of the water flow is drastically reduced. One reason for this reduction is the sudden increase in the cross-sectional area of the water flow within the Bisokotuwa. In addition, a substantial amount of energy of the water flow is also lost, within the Bisokotuwa, due to the collision of water with the stone walls of the Bisokotuwa.

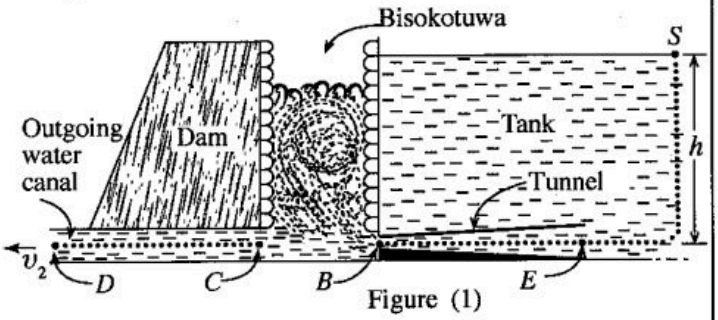

Figure (1)

For your calculations, assume that the steady and streamline flow conditions can be applied along the dotted line paths shown in figures and the height of the water level in the tank remains unchanged.

Consider an irrigation system which consists of **only** the features **1** and **2** as shown in figure (2).

(i) If the height of the water level in the tank is h, derive an expression for the speed v_1 of the outgoing water at point Q in terms of h and g.

(ii) If $h = 12.8\,m$, calculate the value of v_1.

(iii) Calculate the kinetic energy per unit volume carried by the water at point Q. The density of water is $1000\,kg\,m^{-3}$.

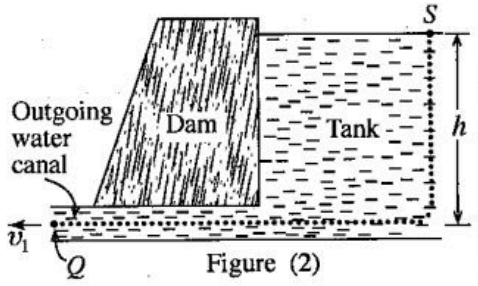

Figure (2)

(*c*) To control the destructive power of the outgoing water, ancient engineers incorporated the feature **3**, the Bisokotuwa to the tank as shown in figure (1).

(i) The water enters from the tank to the Bisokotuwa through a tunnel as shown in figure (1). Assume that the tunnel is tapered, and areas of cross-sections of the tunnel at the inlet and outlet are A and $0.6A$ respectively. Calculate the speed v_B of the water flow at the point B in the tunnel. Take the speed of the water flow at the inlet E of the tunnel as $12\,m\,s^{-1}$.

(ii) Calculate the pressure P_B of the water flow at the point B in the tunnel. The atmospheric pressure is $1 \times 10^5\,N\,m^{-2}$.

(iii) Consider a point C in the outgoing water canal where the pressure and the speed of the water flow are at the values of 75% of P_B and 65% of v_B respectively.

(1) **Write down** the value of the pressure of water flow P_C at the point C.

(2) **Write down** the value of the speed of water flow v_C at the point C.

(iv) Calculate the speed v_2 of the outgoing water at point D shown in figure (1).

(v) Calculate the **percentage loss**, in kinetic energy per unit volume carried by the water at point D shown in figure (1) with respect to the value calculated in (*b*)(iii) above.

(vi) Explain briefly, how ancient engineers managed to control the destructive power of the outgoing water flow by adding the Bisokotuwa to the irrigation system.

[see page ten

6. Read the following passage and answer the questions.

Ocean waves are generally caused by wind and gravity. Wind-driven waves in the ocean as well as tsunami waves and tidal waves are some examples of gravity waves. When wind blows across the surface of the ocean, water surface of the ocean is continuously disturbed by the wind. Under this situation the force of gravity tries to restore the equilibrium at the interface between water and air. As a result, ocean waves are created. Ocean waves can be categorized into two main types, namely deep-water waves and shallow-water waves. The **terms**, shallow-water waves and deep-water waves have nothing to do with the true depth of the ocean. The waves present in the ocean where the depth (h) of the ocean is greater than half the wavelength (λ), of the wave are called deep-water waves. When the depth (h) in the ocean is less than half the wavelength (λ), of the wave they are called shallow-water waves. The wavelengths of deep-water waves are in the range of 1 m–1 km whereas the wavelengths of shallow-water waves are in the range of 10 km-500 km in the ocean. The value of the speed of propagation v of shallow-water waves in the ocean of depth h is given by $v = \sqrt{gh}$. The average depth of the ocean is about 4 km.

Major tsunamis are caused by large-scale disturbances in the ocean, such as underwater earthquakes, volcanic eruptions occurring on or below the ocean floor, and impact of a large meteorite with ocean. A tsunami is a series of ocean waves with very long wavelengths, ranging from 10 km–500 km in the deep ocean. Even though the shape of a tsunami wave can be approximated to a sinusoidal wave in the deep ocean far away from the shore, it gradually takes a complex form as it reaches the shallow water near the coast as shown in figure 1(a). Depending on whether the first part of the tsunami wave which reaches the shore is a crest or a trough, it may appear as a rapidly rising or falling tide. In some situations, the front of the waveform can take a very complex shape near the shoreline as shown in figure 1(b), and it may appear as a rapidly receding of the shoreline followed by an incoming huge wave height grown up to several metres. The rate of transfer of tsunami wave energy through the ocean surface, which depends on both its wave speed and wave height, remains nearly constant. In general, the value of the height H_s of the tsunami wave as it enters shallow water is given by $H_s = H_d\left(\frac{h_d}{h_s}\right)^{\frac{1}{4}}$, where H_d is wave height in deep water, and h_s and h_d are depths of the shallow and deep water respectively.

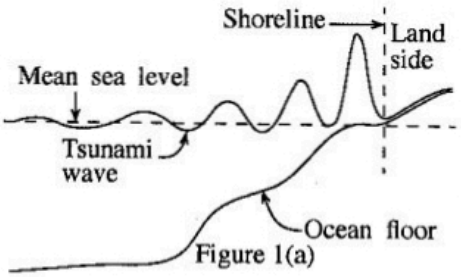

Figure 1(a)

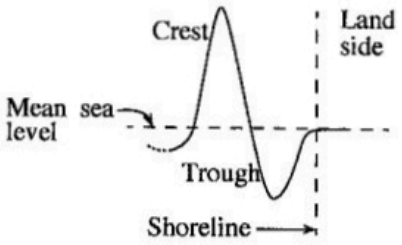

Figure 1(b)

When tsunami waves propagate across the ocean the wave crests can undergo refraction. It is caused by segments of the wave moving at different speeds as the water depth along the wave crest varies. In addition, due to uneven variation of the ocean floor near the coast and obstacles such as small islands, reefs, etc., on the tsunami path, these waves undergo interference and diffraction. The distribution of tsunami wave heights was estimated by a group of scientists along the coastline of Sri Lanka after the devastating tsunami that had occurred in December 26, 2004. The length of the lines in figure (2) shows the heights of the tsunami wave crests along the coastline. Superposition of waves from the primary source and reflected and diffracted waves from obstacles was responsible for the erratic pattern of the wave heights and the varying damage along the coastline.

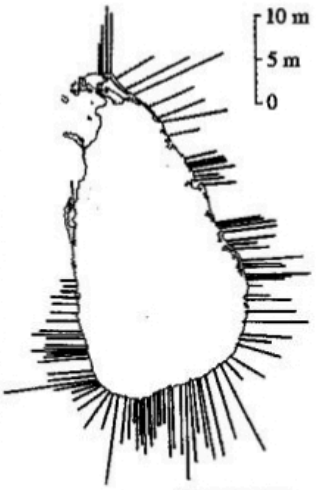

Figure (2)

(*a*) Explain briefly how the ocean waves are created by wind and gravity.

(*b*) What is the difference between deep-water waves and shallow-water waves exist in the ocean?

(*c*) What are the **three** causes of tsunami wave formation mentioned in the passage?

(*d*) Identify the type of the tsunami waves possible in ocean (deep-water waves or shallow-water waves), and estimate the speed of tsunami waves in $m\,s^{-1}$ in the ocean having an average depth of 4 km.

(*e*) The height of tsunami wave rapidly increases as it approaches shallow water near the coast. Explain qualitatively why this happens.

(*f*) Calculate the height of the tsunami wave in the ocean at a place where the water depth is 6250 m. Take the height of the wave at a water depth of 10 m as 5 m. Considering the wavelength of tsunami, explain why it is difficult to detect tsunami waves in the deep ocean.

[*see page eleven*

(*g*) Assuming that a tsunami wave takes the shape shown in figure (1)(*b*) at the shoreline, explain briefly why the shoreline recedes from the land just before the arrival of the huge mass of water.

(*h*) If the tsunami waveform mentioned in question (*g*) above can be approximated to part of a sinusoidal wave as shown in figure (3), calculate the time duration **in minutes** between the instant that the shoreline starts receding into the ocean and the arrival of the water mass at the former shoreline. For the part of sinusoidal wave, take $v = 10\ \text{m s}^{-1}$ and $\lambda = 18\ \text{km}$.

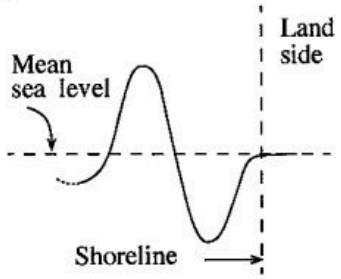

Figure (3)

(*i*) Figure (2) shows some locations where the wave height is very high compared to their adjoining regions having very low wave heights. What phenomenon could be responsible for this? Explain your answer.

(*j*) Briefly explain the reason why the tsunami waves in 2004 reached even the west coast of the island as shown in figure (2).

7. (*a*) Concrete is a hardened mixture of cement, sand, gravel and water. Reinforced concrete structures are structures composed of concrete and steel bars. All rigid bodies, such as steel and concrete are elastic to some extent. Concrete is strong under compression but **weak** under extension while steel is strong under both situations. As a combination, concrete mainly resists compression, and steel bars mainly sustain the tension.

Consider a plain concrete beam having rectangular cross-section, and **without** steel bars, kept on two supports, and subjected to a load W as shown in figure 1(a). Under this situation the bottom part of the beam will experience an extension while the top part will experience a compression as shown with dotted lines.

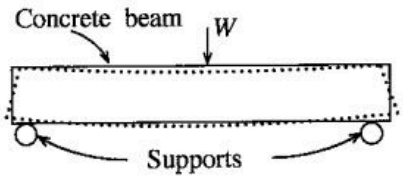

Figure 1(a)

(i) Which side of the plain concrete beam (top or bottom) is most vulnerable to crack under the load W?

(ii) To improve the situation shown in figure 1(a), steel bars are inserted closer to the bottom of the concrete beam at the production stage as shown in figure 1(b). Based on the information given at the beginning of the question, explain, how this improves the load bearing capacity and prevents cracking of the concrete beam.

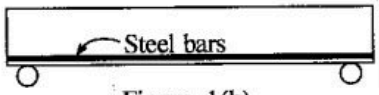

Figure 1(b)

(*b*) The tensile stress $\left(\frac{F}{A}\right)_S$ - strain $\left(\frac{\Delta l}{l}\right)_S$ relationship for mild steel (S) can be modelled, as shown in figure 2(a). Even though concrete is a brittle material, the tensile stress $\left(\frac{F}{A}\right)_C$ -strain $\left(\frac{\Delta l}{l}\right)_C$ relationship of the concrete (C) **under tensile force** can also be modelled as shown in figure 2(b). In reinforced concrete, steel bars are well bonded to concrete, thus they can jointly resist external loads together until concrete cracks.

When the curve reaches the point P shown in figure 2(b), the **concrete will crack.**

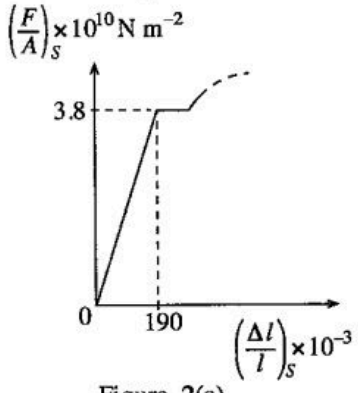

Figure 2(a)

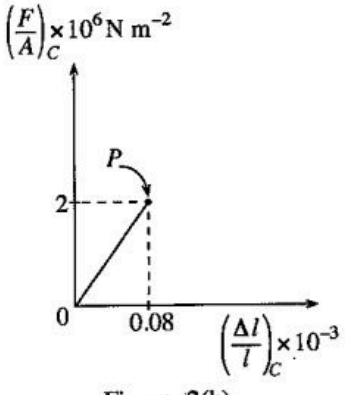

Figure 2(b)

Using the figures 2(a) and 2(b),

(i) calculate Young's modulus of mild steel E_S.

(ii) calculate Young's modulus of concrete E_C.

[see page twelve

(c) Figure (3) shows a reinforced uniform concrete beam of length l kept on a rigid horizontal surface. The beam is reinforced with concrete and identical four uniform cylindrical mild steel bars each of length l. The tensile stress-strain relationships corresponding to the concrete and the steel used are given in figures 2(a) and 2(b) respectively. Assume that the beam is subjected to total tensile force of F_t applied uniformly throughout the area of cross-section of the beam, and mild steel bars and concrete produce **same extension** Δl under the tensile force.

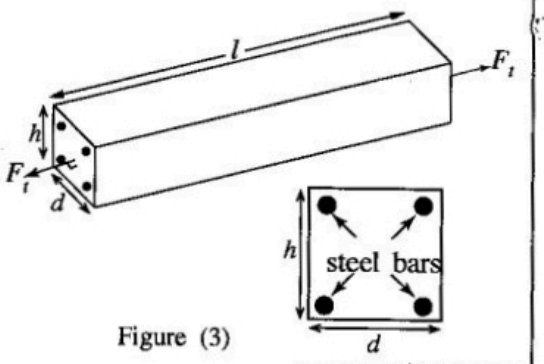

Figure (3)

cross-sectional view

(i) Write down an expression for the tensile force (F_C) on concrete in terms of E_C, area of cross-section of the concrete A_C, l and Δl.

(ii) Write down an expression for the tensile force (F_S) **on the four** mild steel bars in terms of E_S, **total** area of cross-section of the four mild steel bars A_S, l and Δl.

(iii) Prior to concrete cracking, if the total tensile force (F_t) is carried by both concrete and the steel, obtain an expression for the **total** tensile force F_t on the reinforced concrete beam.

(iv) The area of cross-section A of the reinforced concrete beam is dh. See figure (3). For the beam, take $l = 2000$ mm, radius of a cylindrical mild steel bar $r = 6$ mm, $\Delta l = 0.1$ mm, $d = 150$ mm and $h = 250$ mm.

(1) Physically under what condition the expression obtained in (c)(iii) above is valid? Use the data provided above for the reinforced concrete beam and show that the expression obtained in c(iii) is physically valid for the beam.

(2) Calculate the value of F_t. (For your calculation, if $\frac{A_S}{A} \leq 3\%$ then take $A_C = dh$, otherwise take $A_C = dh - A_s$. Take π as 3.)

(v) Calculate the minimum tensile force which cracks the reinforced concrete beam.

8. A copper strip of width d and thickness t carries a current I from top to bottom as shown in figure 1(a). The strip is kept in a uniform magnetic field of flux density B directed perpendicular and into the plane of the strip. Cross-sectional view of the same arrangement is also shown in figure 1(b). The charge carriers are electrons and they drift with drift speed v_d.

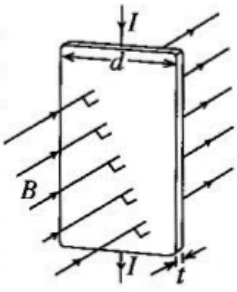

Figure 1(a)

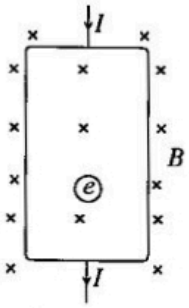

Figure 1(b)

(a) (i) What is the direction of the magnetic force acting on the electron ⓔ shown in figure 1(b)? Copy the figure 1(b) to your answer script and clearly draw an arrow on the electron to indicate the direction of this force.

(ii) Now if you replace the copper strip shown in figure 1(b) with another strip having positively charged carriers, what is the direction of the magnetic force acting on a positively charged carrier?

(b) (i) As time goes on, in the coper strip described in (a)(i) above, there would be a new equilibrium situation with regard to the **charges residing**. Copy figure (2) to you answer script and illustrate this new equilibrium situation using '+' to represent positive charges and '–' to represent negative charges.

(ii) Explain the reason to have the equilibrium condition as mentioned in (b)(i).

(iii) Briefly describe how you would use this effect to verify that holes in a p-type semiconductor are positively charged carriers.

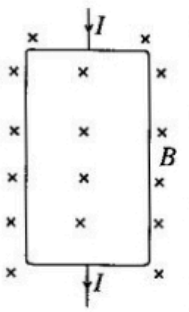

Figure (2)

(c) (i) Derive an expression for the Hall voltage V_H in terms of v_d, B and d.

(ii) The current I flowing through a conductor, such as copper, can be written as $I = neAv_d$, where all symbols have their usual meaning.

(1) Derive the equation $I = neAv_d$.

(2) Obtain an expression for V_H for the copper strip in terms of n, e, t, I and B.

(3) Consider a copper strip of thickness 1×10^{-3} m in a uniform magnetic field of 0.5 T. If $I = 48$ A and $V_H = 1.5 \times 10^{-6}$ V, calculate the number of charge carriers per unit volume in copper. Take $e = 1.6 \times 10^{-19}$ C.

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(*d*) Cardiologists monitor the flow speed of blood through an artery using an electromagnetic flow meters. A schematic diagram of the relevant parts of such a flow meter is shown in figure (3).

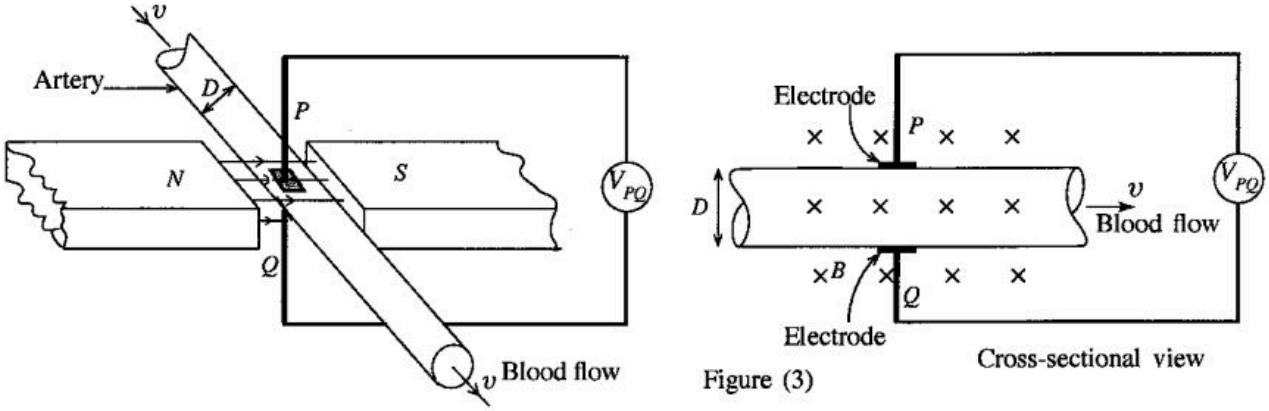

Figure (3)

Blood plasma has a high concentration of Na^+ and Cl^- ions moving through the artery with the blood at the same speed v and same direction as the blood flow. Assume that the ions in the blood behave as charge carriers.

(i) When the blood flows through the artery shown in figure (3), what is the polarity of the electrode *P*? Give the reason for your answer.

(ii) If the flux density of the uniform magnetic field applied to the system is B and the diameter of the artery is D, write down an expression for the magnitude of the voltage V_{PQ} across the two electrodes P and Q in terms of v, B and D.

(iii) If V_{PQ} = 160 μV, D = 5 mm and $B = 2 \times 10^3$ gauss (1 gauss = 10^{-4} T), calculate the value of speed v of the blood through the artery.

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

(A) In the circuit shown in figure (1), 5 V cell has a negligible internal resistance. *Z* is a resistor.

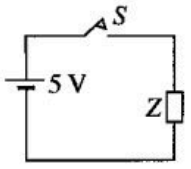

Figure (1)

(*a*) Once the switch *S* is closed calculate the power dissipation in the resistor *Z* when its value is 1 kΩ.

(*b*) The switch is now closed and opened once to produce the rectangular voltage pulse *ABCD* shown in figure (2).

Amplitude and the width of the voltage pulse are 5 V and 10 ms respectively. Once the pulse is produced it travels through the circuit with a speed of 2×10^6 m s^{-1}. Assume that the rectangular shape of the pulse remains unchanged when it passes through the circuit.

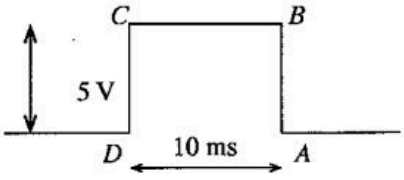

Figure (2)

(i) How long does the edge *AB* of the voltage pulse take to travel across the length of the resistor *Z* of 2 cm long?

(ii) Approximately how long does the full voltage of 5 V appear across the entire length of the resistor *Z*?

(iii) Assuming that the resistor has a value of 1 kΩ, calculate the energy dissipated in the resistor *Z* by the voltage pulse.

(*c*) The switch *S* is now closed and opened regularly to produce the rectangular voltage waveform shown in figure (3).

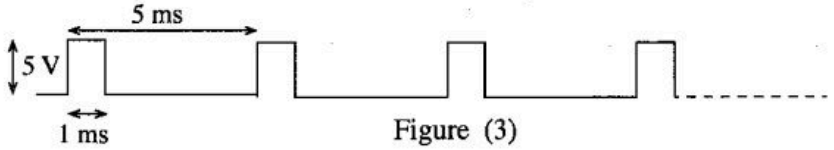

Figure (3)

As shown in figure (3), width of a pulse is 1 ms and the period of the voltage waveform is 5 ms. Under this situation, calculate the power dissipated in the resistor *Z* when its value is 1 kΩ.

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(*d*) A rectangular current pulse of amplitude I_0 and width T_0 generated by a pulsating current source Y enters two resistive wires of lengths l_1 and l_2 as shown in figure (4).

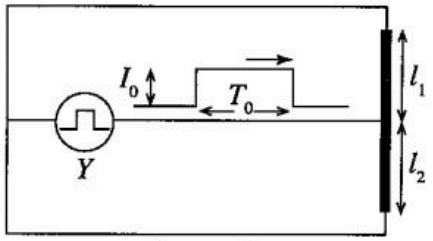

Figure (4)

Assume that all the other connecting wires in the circuit have negligible resistance. The two resistive wires of lengths l_1 and l_2, each having area of cross-section A, are made of a material of resistivity ρ.

(i) If R_1 and R_2 are the resistances of the wires of lengths l_1 and l_2, respectively, write down expressions for R_1 and R_2.

(ii) Derive expressions for the amplitudes I_1 and I_2 of current pulses through the wires of length l_1 and l_2 respectively in terms of I_0, l_1 and l_2.

(*e*) A gaseous X-ray detector consists of a resistive anode wire PQ of length L surrounded by a suitable gas as shown in figure (5). Suppose an X-ray photon is absorbed by the gas producing a narrow electron pulse **in the gas** close to the point S of the anode wire as shown in figure (5). The anode wire has the capability of extracting this electron pulse from the gas and forming an electron current pulse at the point S of the anode wire PQ. Subsequently, the electron current pulse gets divided into two and move through the wire in either direction with speed v.

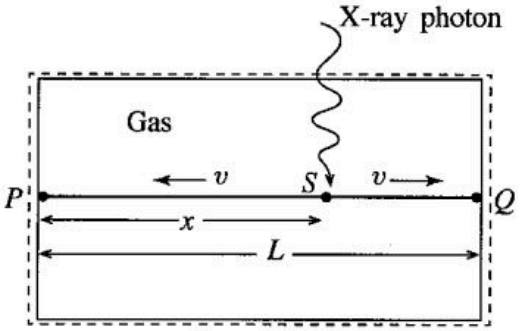

Figure (5)

If Δt is the **difference** in the arrival times of the two electron current pulses to reach the ends P and Q of the anode wire, derive an expression for the distance x from the point P to the point S where the X-ray photon is absorbed, in terms of Δt, v and L.

(B)(*a*) The circuit shown in figure (1) is constructed using a silicon transistor of current gain 100. Assume that 0.7 V is needed to forward bias the base-emitter junction of the transistor.

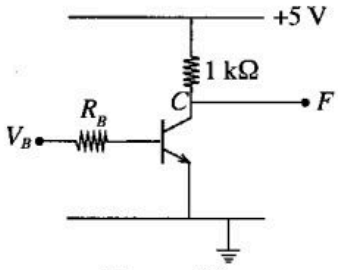

Figure (1)

(i) Calculate the maximum current possible through the collector resistor.

(ii) Calculate the maximum value for R_B which ensures the condition stated in (i) above, for V_B = 5 V.

(iii) If the transistor in the above circuit has been replaced later by a similar transistor but having a current gain of 50, keeping R_B at the value calculated in (ii) above.

(1) Calculate the voltage at the output F for V_B = 5 V.

(2) What is the new mode of operation of the transistor?

(*b*) The digital circuit whose block diagram is shown in figure (2) operates as follows.

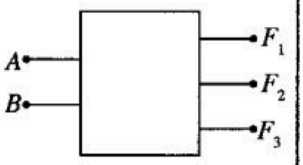

Figure (2)

Each of the inputs A and B accepts binary 1 or 0. F_1, F_2 and F_3 are outputs, where

F_1 = 1 only when $A < B$, otherwise F_1 = 0
F_2 = 1 only when $A = B$, otherwise F_2 = 0
F_3 = 1 only when $A > B$, otherwise F_3 = 0

(i) Prepare a truth table with A and B as inputs and F_1, F_2 and F_3 as outputs.

(ii) Write down Boolean expressions for F_1, F_2 and F_3.

(iii) Draw a logic circuit which operates according to the conditions given above, using logic gates.

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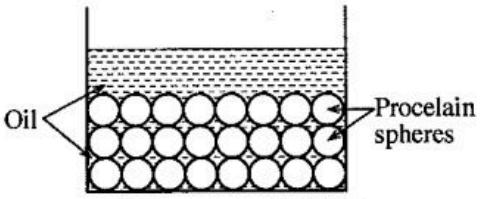
10. Answer either part (A) or part (B) only.

(A) Frying is a food processing technique which involves the use of hot oil as heating medium to prepare food. If the frying is done using a large quantity of oil with respect to the quantity of food material to be fried, then it is called deep frying. If it is done with a relatively smaller quantity of oil it is called stir frying. Generally deep frying takes place in the temperature range of 190 °C – 140 °C and the stir frying in the temperature range of 115 °C – 100 °C. Deep frying is expensive, as a large quantity of oil has to be replaced regularly, however, in most of the cases deep frying yields tastier food.

Results of an investigation conducted by a student in an attempt to achieve higher temperatures by using a small quantity of oil is given below. To increase the heat capacity of the system and there by to achieve higher temperatures, he has used small reusable solid porcelain spheres mixed with a relatively small quantity of oil.

(*a*) As the first step, the student poured 0.2 kg of oil into a suitable pot having outer walls covered with an insulating material, and heated upto 200 °C using a small immersion heater. The heater was then removed and 0.2 kg of dry food material was added instantly and mixed with the oil. If the specific heat capacities of the oil and the food material are 1650 J kg^{-1} °C^{-1} and 1600 J kg^{-1} °C^{-1} respectively, and the initial temperature of food material is 30 °C, calculate the final temperature of the mixture. Assume that the heat capacity of the empty pot is negligible compared with that of oil, and the heat loss to surrounding is also negligible.

(*b*) Student then emptied the pot and added the same amount (0.2 kg) of fresh oil as in (*a*) above and also a certain amount of small solid uniform porcelain spheres. Assume that the added spheres get packed, in the regular manner (regular packing) as shown in figure (1). The spheres were added to the pot in such a way that the space of the voids created by the spheres when get packed occupies half the volume of oil in the pot (see figure (1)).



Voids occupy half the volume of oil
Figure (1)

(i) As the spheres are packed in the regular manner, considering the unit **cubes** occupied by spheres as shown in figure (2), show that the **total volume of spheres** is equal to the volume of oil containing in the voids. **(Take $\pi = 3$.)**

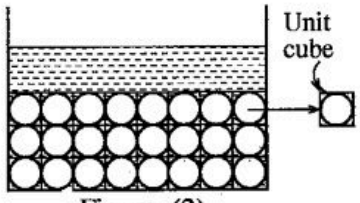


Figure (2)

(ii) If the densities of the oil and porcelain are 900 kg m^{-3} and 2500 kg m^{-3} respectively, calculate the mass of the porcelain spheres.

(iii) The student then heated the pot containing oil together with the porcelain spheres upto 200 °C, and again added and mixed the same amount (0.2 kg) of the same food material at 30 °C, as in (*a*) above. If the specific heat capacity of porcelain is 1000 J kg^{-1} °C^{-1}, calculate the final temperature of the mixture. Neglect the heat capacity of the empty pot and the heat loss to surrounding.

(*c*) What is the advantage if smaller porcelain spheres than those used in the above investigation are used?

(B)(*a*) The diagram given in figure (1) shows the essential parts of a setup necessary to carry out the photoelectric effect experiment.

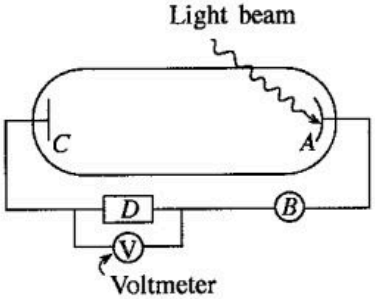


Figure (1)

(i) The part marked as *D* is a voltage supply. What are the **two** main features, *D* should have in order to obtain photoelectric current (*I*) – potential difference (*V*) characteristic?

(ii) Name the parts labelled as *A* and *B*.

(iii) Two monochromatic light beams, green [wavelength λ_g] and red [wavelength $\lambda_r (> \lambda_g)$] colours with **same** intensities measured in W m^{-2}, are allowed to incident on *A*, one beam at a time. The frequencies of the light beams are higher than the threshold frequency of the material made of *A*.

(1) Draw a rough sketch to indicate the variation of *I* with *V*, for both green and red colours in the **same** graph. The curves for green and red colours should be clearly labelled as *G* and *R* respectively. Assume that same percentage of incident green and red colour photons emit photoelectrons.

(2) If the difference between the stopping potentials is ΔV, and the difference between the frequencies is Δf for green and red colours, obtain an expression for the ratio $\frac{\Delta f}{\Delta V}$, in terms of Planck's constant *h* and magnitude of the electronic charge *e* using the Einstein's photoelectric effect equation.

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(*b*) A certain photoelectric smoke alarm system mainly consists of a T-shaped chamber fitted with a monochromatic light emitting diode (LED), a photocathode and an electronic alarm as shown in figure 2(a).

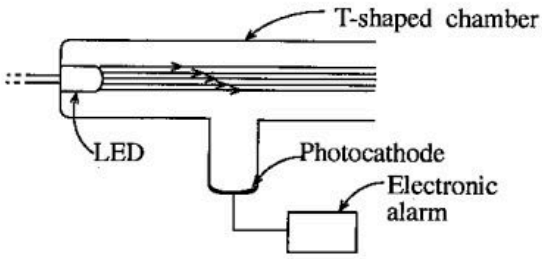

Figure 2(a)

Under the normal smoke-free condition, the photons of the LED light beam travel through the chamber and move away without striking the photocathode as shown in figure 2(a). When smoke enters the chamber, some of the photons collide with the smoke particles and move in different directions without change in their wavelength as shown in figure 2(b). The number of photons thus collides is proportional to the number of smoke particles present in the chamber. Out of the collided photons, a certain number is incident on the photocathode and generates a small photoelectric current. When a sufficient number of photons is incident on the photocathode it generates an adequate current to activate the electronic alarm.

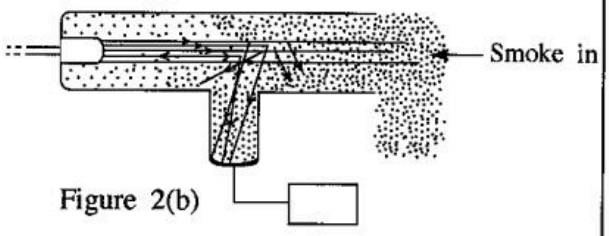

Figure 2(b)

(i) If the wavelength of the photons emitted by the LED is 825 nm, calculate the energy of a photon in eV.

Take $h = 6.6 \times 10^{-34}$ J s, speed of light in vacuum $c = 3 \times 10^{8}$ m s^{-1} and $1\,\text{eV} = 1.6 \times 10^{-19}$ J.

(ii) Two photocathodes *X* and *Y*, made of materials with work functions 1.4 eV and 1.6 eV respectively, are available to you. Which photocathode (*X* or *Y*) is suitable to construct a smoke alarm system with the LED mentioned in (*b*)(i) above? Justify your answer.

(iii) Power of the LED is 10 mW. If only 3% of energy goes into produce light of wavelength of 825 nm, calculate the number of photons emitted by the LED per second.

(iv) Photocathode should receive at least 20% of the emitted photons per second from the LED to activate the alarm. Calculate the minimum number of photons per second that should be incident on the photocathode to activate the alarm.

(v) When photons are incident on the photocathode, only a part of the incident photons contributes to the emission of photoelectrons. Assuming that only 10% of incident photons emits photoelectrons, calculate the minimum photoelectric current that should be generated by the photocathode to activate the alarm. Take $e = 1.6 \times 10^{-19}$ C.

* * *