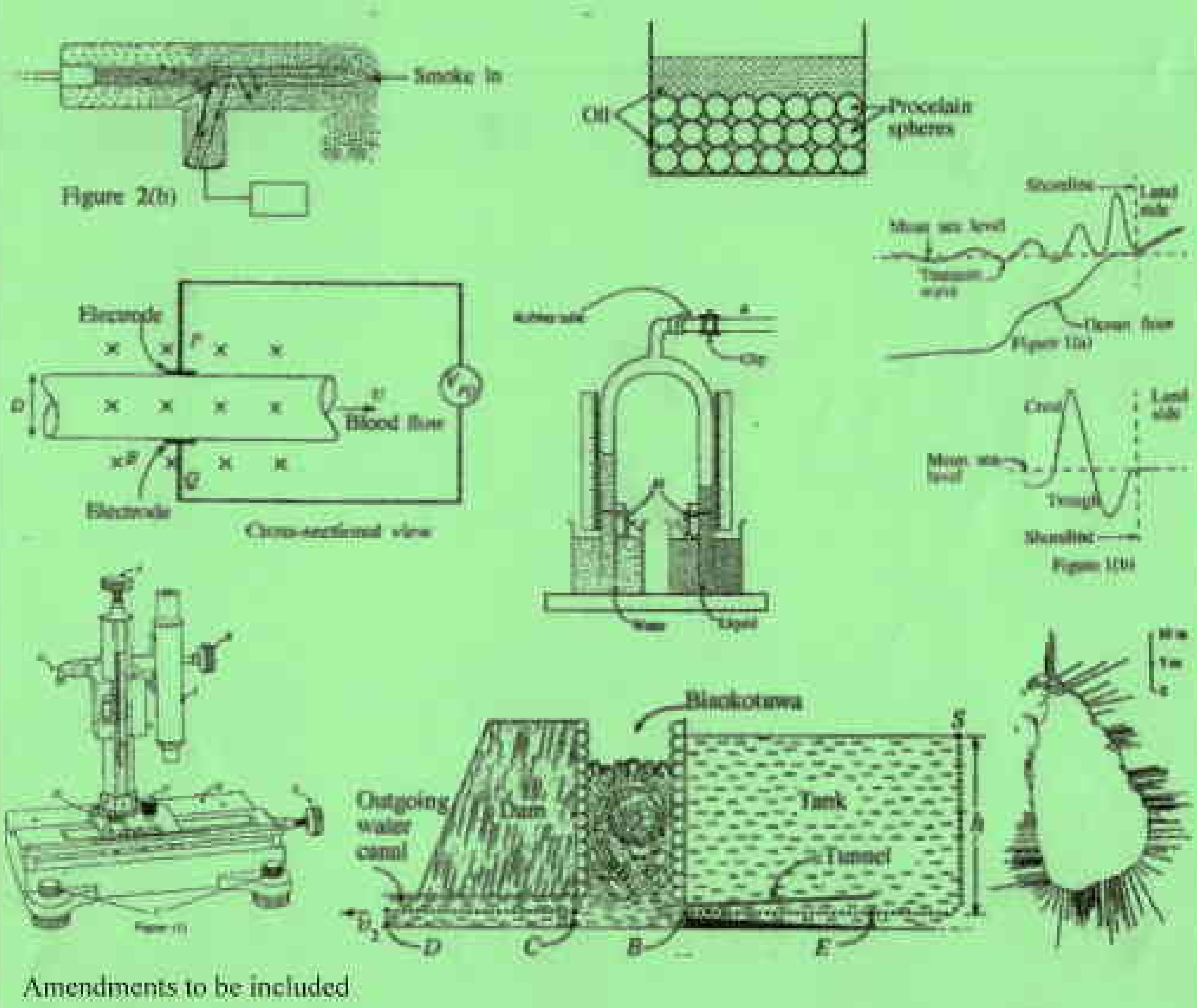
Confidential Document

Department of Examination – Sri Lanka

G. C. E. (A/L) Examination – 2018

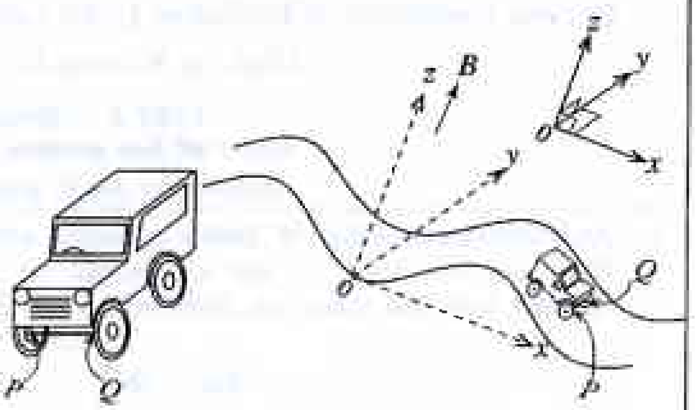
01- Physics

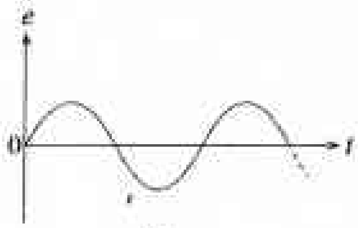
Marking Scheme

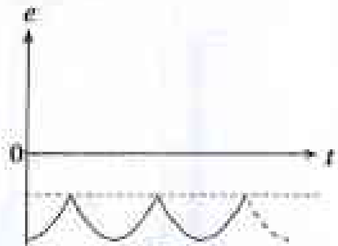


Amendments to be included

49. A toy car shown in figure (a) having an isolated metal axle PQ, travels with a constant speed v along a sinusoidal path whose vertical cross-section is in zx plane as shown in figure (b). At time $t = 0$, the axle PQ coincides with the y axis. If a uniform magnetic field of flux density B exists throughout the region in the $+z$ direction and normal to the xy plane, the variation of the induced e.m.f.(e) at end P of the axle with respect to end Q, with time (t) is best represented by, (Neglect the effect of the Earth magnetic field.)




(1)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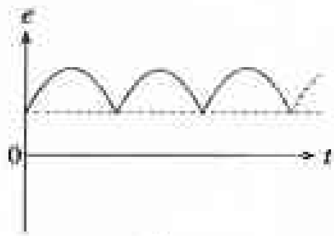
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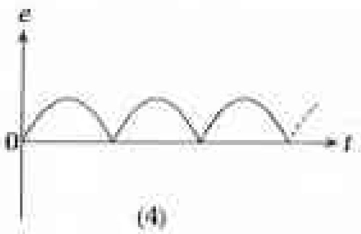
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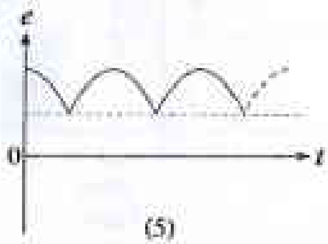

(5)

50. A, B, C and D represent vertical cross sections of four identical parallel rectangular metal plates placed normal to the plane of the paper. Each of the plates B, C, and D has a small hole at its centre. The three plates are arranged so that their holes are coaxially placed as shown in figure (a). Plate A is grounded and the entire system is in a vacuum. A stationary electron is created at time $t = 0$, at the position O on the axis through the holes as shown. Which of the voltages V_B, V_C and V_D should be applied to the plates to obtain the velocity (v) – time (t) curve shown in figure (b) for the electron? (Assume that the given voltages are suitable for practical use and that the edge effects and gravitational effects can be neglected.)

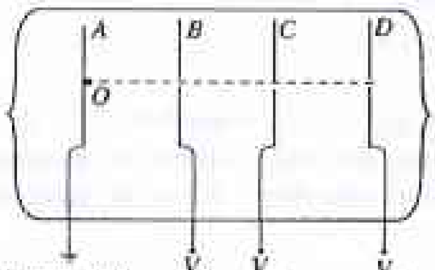


Figure (a)

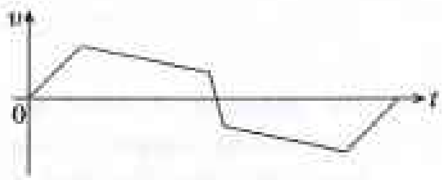


Figure (b)

	V_B	V_C	V_D
(1)	− 3 kV	+ 2.6 kV	0 V
(2)	+ 2.5 kV	− 2.6 kV	+ 3 kV
(3)	+ 2.5 kV	+ 2.4 kV	+ 200 V
(4)	+ 3 kV	+ 2.6 kV	− 2.8 kV
(5)	+ 3 kV	+ 3.2 kV	− 2.2 kV

General Certificate of Education (Adv. Level) Examination – August 2018

Marking Scheme for Physics II

PART A – Structured Essay

Answer all four questions on this paper itself.

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

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.

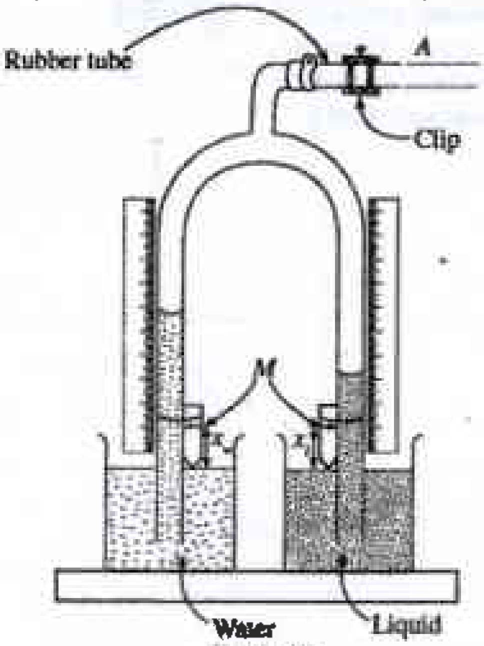


Figure (1)

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

To maintain liquid columns in the arms of the Hare's apparatus ***OR***

To maintain liquid heights at a constant value ***OR***

To maintain pressure inside the tubes at a constant value ***OR***

To block the air going **into** the tubes from outside.

(For **any** correct answer)....................**(01)**

(**No marks** for the answers just explaining properties of the clip)

(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.

$$P + (h_w + x_w)d_w g = P + (h_l + x_l)d_l g \quad .... \textbf{(01)}$$

(For correct expression. When awarding this mark, disregard the P or the symbol used for pressure. However, P or the symbol on both side should be the same)

$$h_l = \frac{d_w}{d_l}h_w + \left(\frac{d_w}{d_l}x_w - x_l\right) \quad .... \textbf{(01)}$$

(***OR*** any other correct form of h_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.

Answer: Larger height

Explanation: It will reach the maximum height of the tube first ***OR***

To obtain best possible/largest spread data points for the graph.

(For correct answer <u>and</u> explanation)..................**(01)**

(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.

<u>Indicators</u> have to be <u>readjusted</u> until they touch the surfaces of the water and liquid levels in the beaker. ....**(01)**

(Measuring scale should be readjusted to coincide one of its marks with *M*)

(*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.

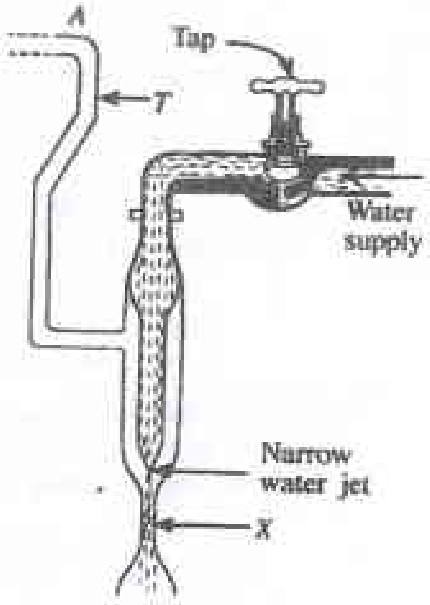


Figure (2)

(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 :

Sucking with mouth ....(01)

Improved version of the Hare's apparatus :

Adjusting the speed of the water jet ***OR***

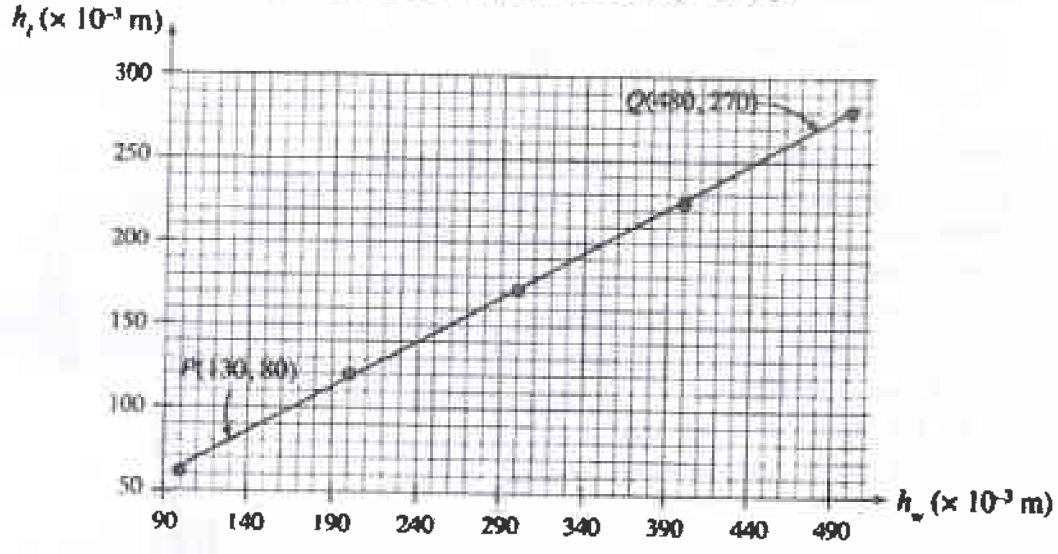
By adjusting the tap. (For **any** correct answer).............(01)

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

Sucking is not necessary ***OR***
Relative density of a poisonous liquid can be determined ***OR***
Inhaling vapors of liquid (poisonous) can be avoided ***OR***
Independent variable (h_w) can be set to a desired value easily ***OR***
A set of equally distributed data points can be obtained easily to plot the relevant graph.

(For **any** correct answer)..................(01)

(*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?

$$\frac{\Delta l}{l} = \frac{1}{100} = 0.01 \; OR \; 1\%$$ (**No marks** for other answers).......(01)

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

Relative density of sulfuric acid, $\frac{d_l}{d_w}$

$$= \frac{(480-130)}{(270-80)} = \frac{35}{19} = 1.84$$ ....(01)

(For identifying gradient as 1/relative density)

Total: 10 marks

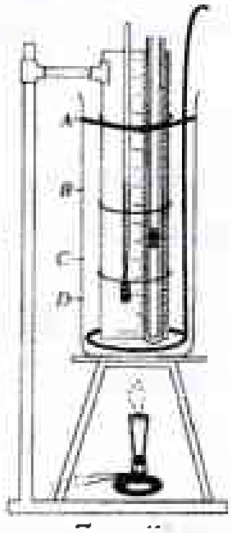
2. Figure (1) shows an incomplete diagram of an experimental setup that can be used to verify Charles's law.

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

Up to level $\underline{A}$ ....(01)

(***OR*** water level marked at the point A in the figure below)

(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.



Stirrer properly drawn as shown ....(01)

(To award this mark, the handle of the stirrer should be above the water level A, **and** the size of the ring of the stirrer should be large enough to do the stirring properly.)

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

Relatively high pressure can be obtained from a small mercury thread ***OR***

Measurements can be obtained for relatively a large range of temperatures ***OR***

Saturated vapor pressure of mercury is small ***OR***

Mercury does not wet glass ***OR***

Boiling point of mercury is high ***OR***

Edge of the mercury thread (silver color) can be seen easily.

(For any **two** correct answers)..**(01)**

(Correct **relevant** negative arguments are acceptable)

(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.

Mass/weight of mercury thread will remain constant ***OR***

Density of mercury thread will decrease (as length × density × g constant).

(For **any** correct answers) ....**01)**

(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) Stirring the water in the cylinder ***and***,
moving the Bunsen burner in and out of the system.

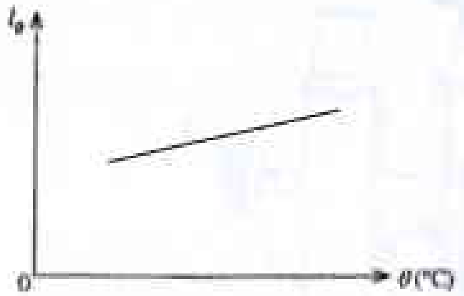
(If **both** procedures are correct)........................**(01)**

(ii) Ensuring a steady/stationary mercury thread in the tube (while maintaining a constant temperature in the water/thermometer) ....**(01)**

(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.

$$l_\theta = l_0(1 + \gamma_p \theta)$$ ....**(01)**

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



(For straight line with positive intercept (C). **No marks** if the value of C very close to 0 or straight lines with unacceptably high slopes) ....**(01)**

(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.

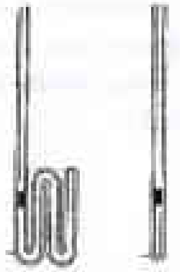


Figure 2(a) Figure 2(b)

Answer: Advantages

Explanation: Fractional error associated with length measurements can be reduced ***OR*** For a given temperature range, change in length will be large.

OR

Answer: Disadvantages

Explanation: Taking several readings for the temperature measurements to plot a graph will be difficult ***OR*** Mercury thread will be pushed out from the tube even for a relatively small increase in temperature.

(For the correct explanation/s **with** appropriate answer/s.) ....**(01)**

(Award this mark even if a student has provided **both answers**)

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

Answer: No

Explanation:

Controlling the temperature of the water will be difficult ***OR***
Keeping the temperature of the water at a constant value will be difficult ***OR***
Heat flow to water cannot be stopped suddenly by switching off the hot plate ***OR***
Removing the hot plate from the set up to keep temperature constant is impractical

(For **any** correct explanation) ....**(01)**

Total: **10** marks

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).

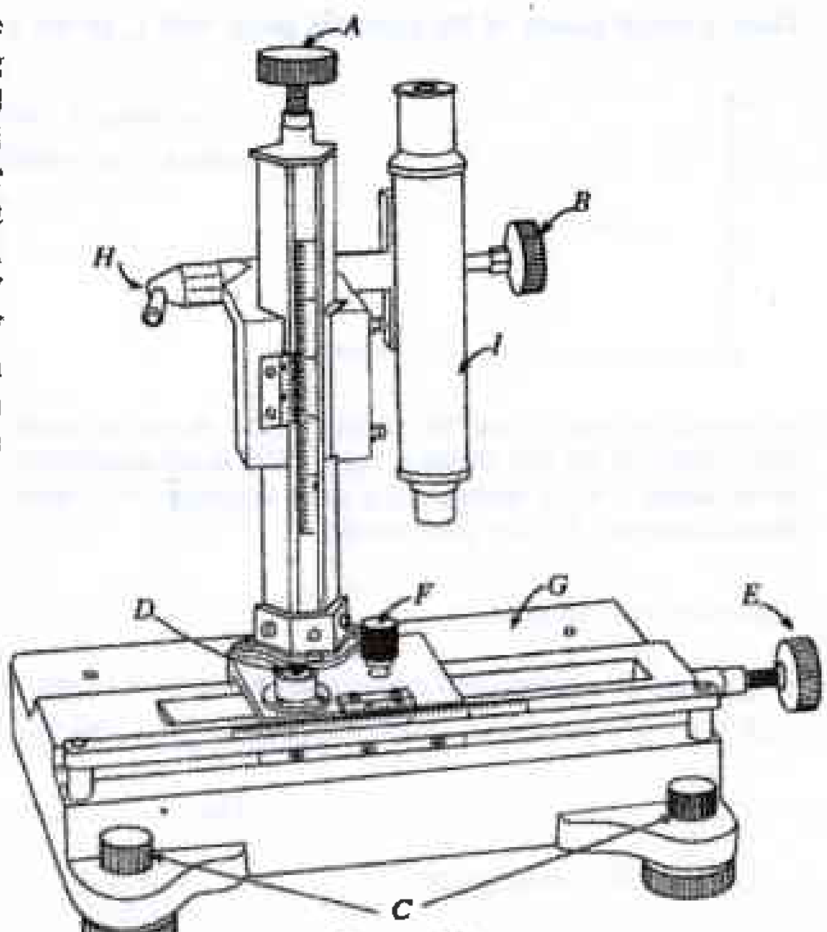


Figure (1)

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

	Identification	Function
A	Fine adjustment knob	To perform the fine adjustment in vertical direction ***OR*** For fine focusing of the image
B	Focusing knob/ Adjustment knob of the microscope	To focus the image of the object ***OR*** To get a clear image of the object
C	Levelling screws	To level the travelling microscope setup
D	Spirit level	To verify the leveling

(If the 'identification' is provided under 'function', accept it as correct)

[If any **three** (identification and the relevant function) correct]........................**(02)**

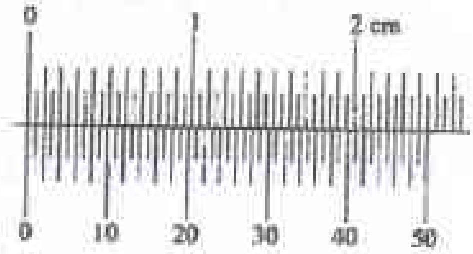
[If any **two** (identification and the relevant function) correct].........................**(01)**

(b) Before starting the experiment, while familiarizing with a travelling microscope a student observed that when the fine adjustment knob relevant to the horizontal movement was turned, the corresponding vernier scale did not move. Give the reason for this.

F/Locking knob is not locked...........................**(01)**

(**No marks** for other answers)

(c) An enlarged figure of the main scale and the vernier scale of a travelling microscope are shown. Calculate the least count of this travelling microscope in centimetres.



$$\text{Minimum reading} = \left(0.5 - \frac{24.5}{50}\right) = \frac{0.5}{50}$$

$$= .001 \text{ cm}$$

.................................**(01)**

(**No marks** if the correct derivation of the least count is not shown)

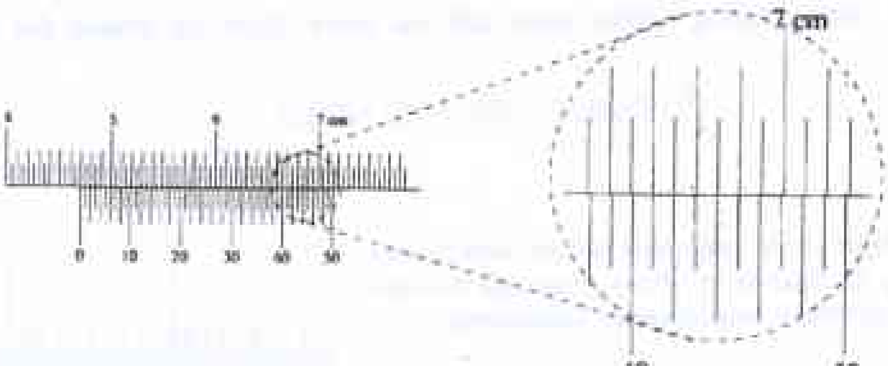
(d) What is the adjustment that you perform on the eyepiece before starting the experiment?

Focusing the cross wire of the microscope..................................**(01)**

(e) Now you are asked to place the given piece of paper on stage *G* of the travelling microscope and obtain the first measurement with the microscope using the mark 'X' before placing the glass block. Write down the main steps in the experimental procedure you would follow to achieve this.

(Unlock) the microscope and adjust the microscope assembly until an image of X is seen. (Lock it) use the knob *A*/*B* for fine focusing of the image. ....**(01)**

(When awarding this mark look for underline terms in the answers **in this part** or/and **in part (*g*)** below) (*f*) **Relevant positions of the main scale and vernier scale corresponding to the measurement mentioned in (*e*) above are shown below. Write down the reading corresponding to the measurement in centimetres.**



Reading $= (4.65 + 42 \times 0.001)$ cm

$= 4.692$ cm...**(01)**

(**No marks** for other answers)

(*g*) **After taking the first measurement mentioned in (*e*) above, write down the important steps in the experimental procedures pertaining to the other two measurements that you need to perform.**

(i) Place the glass block on the mark X and take the relevant reading of the focused image of X (as mentioned above use *A* without adjusting the *B*). ....**(01)**

(ii) Sprinkle a small amount of lycopodium powder on the glass block and take the relevant reading of the focused image of lycopodium power particle.........**(01)**

(*h*) **Readings of the relevant three measurements obtained by another student when performing this experiment are given below.**

4.606 cm 5.496 cm, 7.206 cm

Using these measurements, calculate the refractive index of glass.

$$\text{Refractive index} = \left(\frac{7.206-4.606}{7.206-5.496}\right) = \frac{2.600}{1.710} \text{ ....} \textbf{(01)}$$

$$= 1.52$$

Total: **10** marks

4. Figure (A) shows how a dc motor is run by a pack of four 1.5 V dry cells. A disc Y perforated with set of equidistant holes as shown in figure (B) is fixed perpendicular to the axle of the dc motor. When the disc rotates, light produced by LED passes through the holes and falls on a photodiode P. See figure (C). The photodiode circuit shown in figure (D) generates a voltage V.

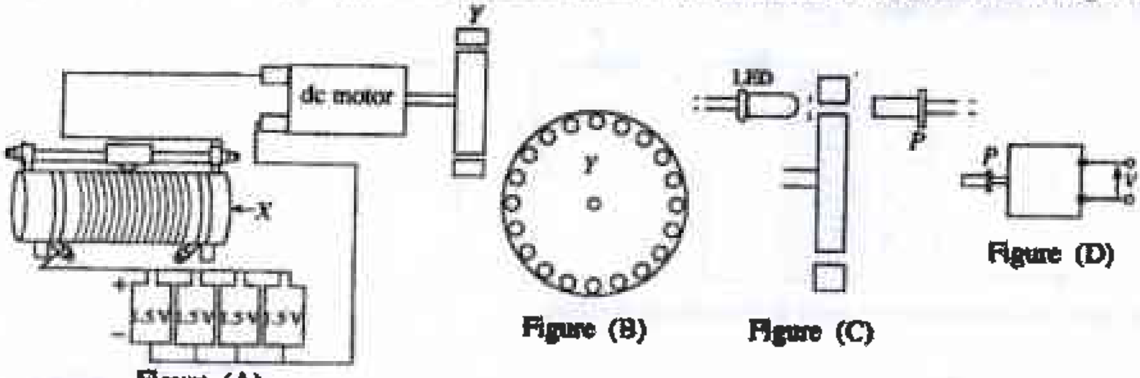


Figure (A) Figure (B) Figure (C) Figure (D)

(*a*) **Identify the component X.**

Rheostat ....(01)

(**Do not** accept any other answer as correct)

(*b*) **How would you change the rotational speed of the disc Y?**

By X/Rheostat/changing the current ....(01)

(*c*) **What is the advantage of having four 1.5 V cells in parallel?**

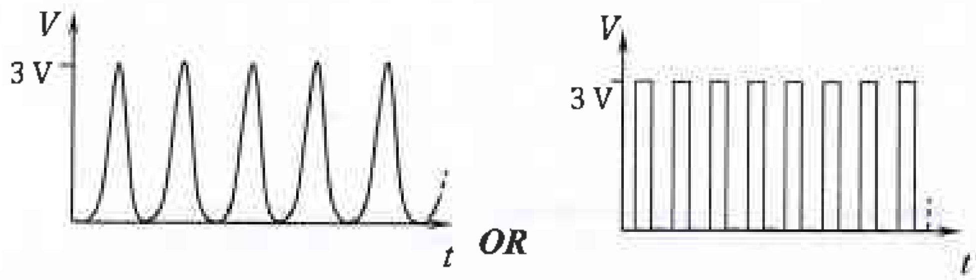
Current can be drawn for a longer time *OR*

Constant voltage can be maintained for a longer time ....(01)

(*d*) **The disc has 20 holes, and if it produces 5 rotations per second, what is the frequency with which the light beam hits P shown in figure (C)?**

Frequency = 20 × 5 = 100 Hz...............................(01)

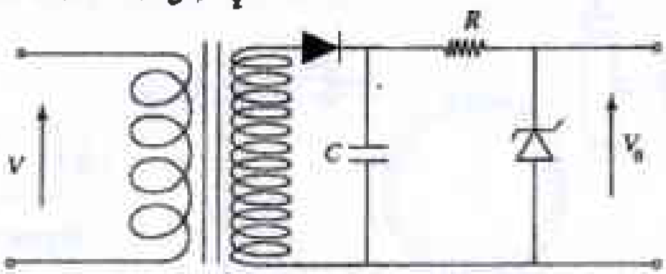
(*e*) **Draw a rough sketch to show how the voltage (V) produced by the photodiode circuit shown in figure (D) varies with time (t). Assume that the maximum value of V is 3 V.**



(For identification of V as a periodic function of t)..........................(01)

(For the shape of the curve **as shown above**) ....(01)

(*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?

Step-up transformer ....(01)

Note: The diode shown in the above circuit is not there in the corresponding circuit diagram given in the question paper under part (f). As such it has been decided to award the total of three (03) marks assigned for the following parts, to all candidates irrespective of whether they have attempted the question or not.

..................................(03)

Total: **10** marks

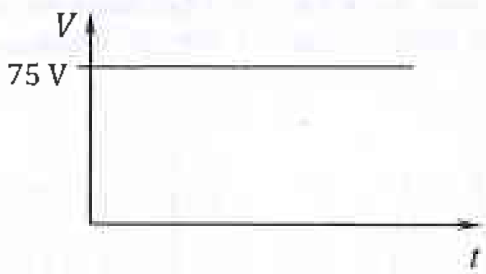
Additional information for future references

Under this situation, take the Zener diode voltage (V_Z) as 75 V.

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

$$V_0 = 75 \text{ V}$$

(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.

Yes, both input voltage (1.5 V) and output voltage (75 V) of the circuit are dc voltages.

5. (*a*) Bernoulli's equation for a fluid flow can be written as $P + \frac{1}{2}dv^2 + hdg =$ 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.

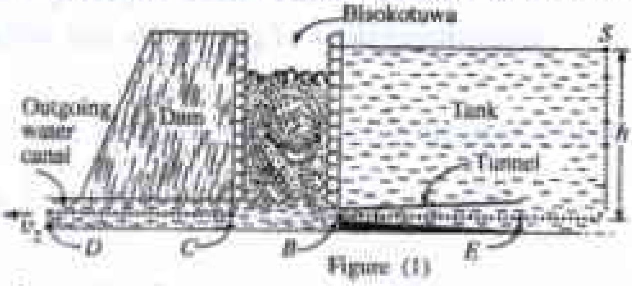


Figure (1)

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 $1000\,\text{kg m}^{-3}$.

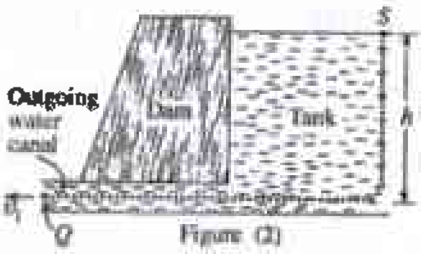


Figure (2)

(*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 $12\,\text{m s}^{-1}$.

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

(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.

(a) $\frac{1}{2}dv^2 \rightarrow (\text{kg m}^{-3})\ (\text{m s}^{-1})^2 \rightarrow (\text{kg m s}^{-2}\text{ m})(\text{m}^{-3})$ ....**(01)**

$\rightarrow \text{J m}^{-3}$

(Reasonable steps, **using base units or dimensions**, should be clearly shown in order to earn this mark. Equating the base units/dimensions of dv^2 to base units/dimensions of energy per unit volume is also acceptable)

(b)(i) Applying Bernoulli's equation to the points S and Q,

$$P_0 + hdg = P_0 + \frac{1}{2}dv_1^2$$ ....**(01)**

(**No marks**, if additional terms appear in the equation. Any symbol for atmospheric pressure is acceptable)

$$v_1 = \sqrt{2gh}$$ ....**(01)**

(ii) $v_1 = \sqrt{2 \times 10 \times 12.8}$

$v_1 = 16\text{ m s}^{-1}$ ....**(01)**

(iii) Energy per unit volume $= \frac{1}{2} \times 1000 \times 16^2 = 1.28 \times 10^5\text{ J m}^{-3}$ ..**(01)**

(For substitution ***OR*** final answer)

(*c*) (i) Applying continuity equation to the tunnel,

$A_E v_E = A_B v_B$ ***OR*** $A \times 12 = 0.6A \times v_B$ ....**(01)**

(For correct expression ***OR*** substitution)

$v_B = 20\text{ m s}^{-1}$.....................................**(01)**

(ii) Applying Bernoulli's equation to the points S and B,

$$P_0 + hdg = P_B + \frac{1}{2}dv_B^2 \quad \textit{OR}$$

$$10^5 + 12.8 \times 1000 \times 10 = P_B + \frac{1}{2} \times 1000 \times 20^2$$ ....**(01)**

(For correct expression ***OR*** substitution)

$P_B = 2.8 \times 10^4\text{N m}^{-2}$......................................**(01)**

(iii) (1) $P_c = 0.75 \times 2.8 \times 10^4 = 2.1 \times 10^4$ N m^{-2}. ....**(01)**

(For correct substitution)

(2) $v_c = 0.65 \times 20$ m s^{-1} = 13 m s^{-1} ....**(01)**

(For correct substitution)

(iv) Applying Bernoulli's equation to the points *C* and *D*,

$$P_0 + \frac{1}{2}dv_2^2 = P_c + \frac{1}{2}dv_c^2 \quad \textbf{\textit{OR}}$$

$$10^5 + \frac{1}{2} \times 1000 \times v_2^2 = 2.1 \times 10^4 + \frac{1}{2} \times 1000 \times 13^2$$ ....**(01)**

(For correct expression ***OR*** substitution)

$$v_2^2 = 42 + 169 - 200 = 11$$

$$v_2 = 3.32 \text{ m s}^{-1} \quad \textbf{[3.30-3.32]} \text{ m s}^{-1}$$ ....**(01)**

(v) Kinetic energy loss $\frac{\Delta KE}{KE} = \frac{\frac{1}{2}d(v_1^2 - v_2^2)}{\frac{1}{2}dv_1^2} \times 100\%$

$$= \frac{(16^2 - 3.32^2)}{16^2} \times 100\% = 96\%$$ ....**(01)**

(For correct substitution ***OR*** final answer)

(vi) <u>By destroying a significant amount of energy</u> of the water flow within the Bisokotuwa. ....**(01)**

Total: **15** marks

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 4km.

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.

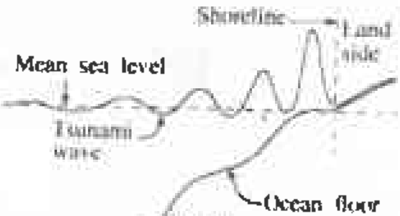


Figure 1(a)

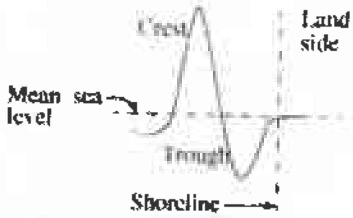


Figure 1(b)

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.

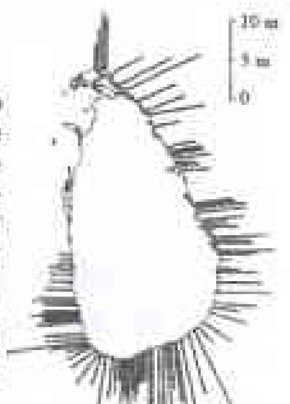


Figure (2)

(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.

(*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 $v = 10$ m s^{-1} and $\lambda = 18$ km.

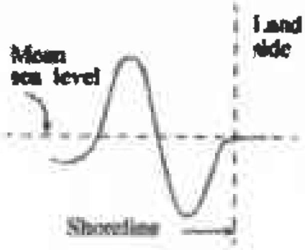


Figure (3)

(*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).

(*a*) When wind blows across the surface of the ocean, water surface is continuously disturbed by the wind. The force of gravity tries to restore the equilibrium at the interface between water and air. This creates the ocean waves. ....**(01)**

(*b*) **Deep-water wave:**

When the depth (h) of the ocean > half the wavelength (λ) of the wave ***OR***
Waves present in the ocean with wavelength (λ) ranging from 1 m – 1 km.

Shallow-water wave:

When the depth (h) of the ocean < half the wavelength (λ) of the wave ***OR***
Waves present in the ocean with wavelength (λ) ranging from 10 km – 500 km.

(**One answer from each type** must be correct to earn this mark)...........**(01)**

(*c*) Underwater earth quakes, volcanic eruptions occurring on/below the ocean floor, impact of a large meteorite with ocean. ....**(01)**

(*d*) Shallow-water waves ....**(01)**

$$v = \sqrt{10 \times 4 \times 10^3} = 200 \text{ m s}^{-1}$$ ....**(01)**

(For substitution ***OR*** final answer)

(*e*) Total energy depends on wave speed (v) and wave height (H) and it is a constant. As wave approaches towards shallow water, v decreases. Therefore, H will increase.

....**(01)**

(*f*) $$H_s = H_d \left(\frac{h_d}{h_s}\right)^{\frac{1}{4}}$$

$$5 = H_d \left(\frac{6250}{10}\right)^{\frac{1}{4}}$$ ....(01)

$$H_d = 1.0 \text{ m}$$ ....(01)

Even though the height of the tsunami wave in deep ocean is significantly large, it spreads through a distance of $\lambda/2$ (few hundred kilometers) which makes it difficult to detect. ....(01)

(*g*) First part of the wave shown in figure 1(a) is a trough, and it appears as a rapidly receding of the shoreline. ....(01)

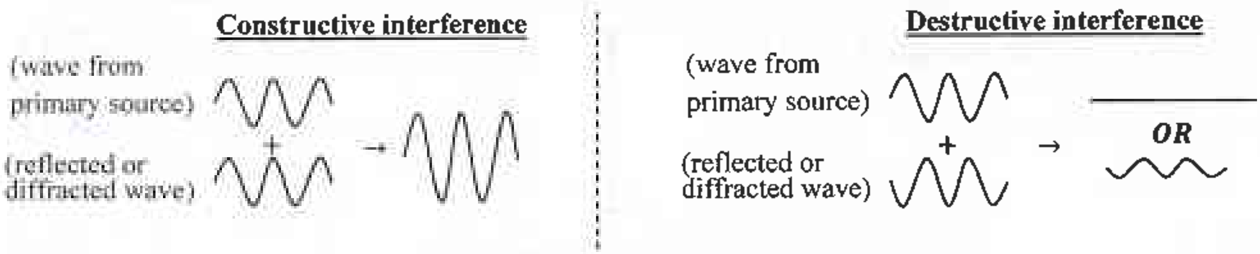
(*h*) $T = \frac{\lambda}{v} = \frac{18\times10^3}{10} = 1.8\times10^3\text{s} = 30 \text{ minutes}$ ....(01)

Time duration $= \frac{T}{2} = 15$ minutes......................................(01)

(If the **correct** time duration calculated using the equation $\frac{\lambda/2}{v}$ award the **both marks**)

(*i*) Interference. ....(01)

Superposition of waves from primary source with reflected and diffracted waves creates constructive and destructive interference ***OR***



(For **both** diagrams).............................(01)

(*j*) This is due to refraction.

Segments of the wave moving at different speeds as the water depth along the wave crests varies. As a result, ocean wave crests can undergo refraction. ....(01)

Total: **15** marks

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.**

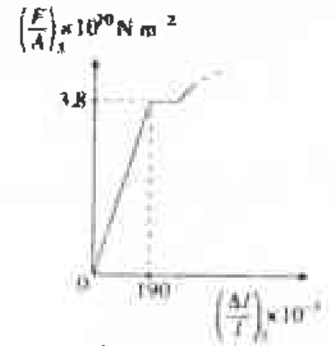


Figure 2(a)

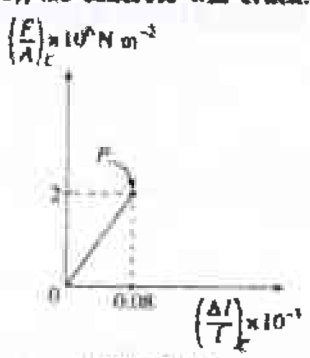


Figure 2(b)

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.

(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.

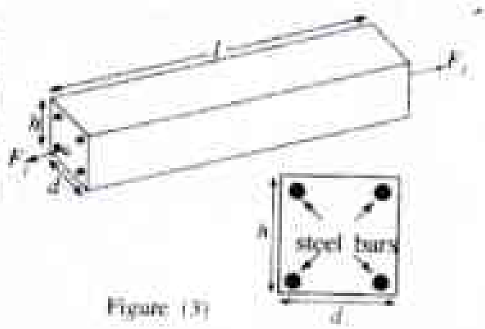


Figure (3) cross-sectional view

(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, Δl = 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.

(*a*) (i) Bottom ....**(01)**

(ii) Steel bars experience extension at the bottom of the beam where the cracks are most likely to be created ***OR***

For a given load steel bars have smaller extension ***OR***
Steel has larger Young's modulus. ....**(01)**

(For **any** correct answer)

(*b*) (i) $E_S = \frac{3.8\times10^{10}}{190\times10^{-3}} = 2.0 \times 10^{11}$ N m^{-2} ....**(01)**

(ii) $E_C = \frac{2.0\times10^{6}}{0.08\times10^{-3}} = 2.5 \times 10^{10}$ N m^{-2} ....**(01)**

(*c*) (i) Force on concrete $F_C = \frac{E_C A_C \Delta l}{l}$ ....**(01)**

(ii) Force on mild steel bars $F_S = \frac{E_S A_S \Delta l}{l}$ ....**(01)**

(iii) Total force on the beam $F_t = F_C + F_S$ ***OR*** $F_t = \frac{\Delta l}{l}(E_C A_C + E_S A_S)$

..........................**(01)**

(For **addition**)

(iv) (1) Concrete must be within the linear/proportional region of the curve ***OR***

Concrete must be below the cracking stress / $\left(\frac{F}{A}\right)_C < 2 \times 10^6$ N m^{-2} ***OR***

Concrete must be below the cracking strain / $\left(\frac{\Delta l}{l}\right)_C < 0.08 \times 10^{-3}$

(For **one** correct condition)............**(01)**

For the concrete $\left(\frac{\Delta l}{l}\right)_C = \frac{0.1}{2000} = 0.05 \times 10^{-3}$

$\therefore \left(\frac{\Delta l}{l}\right)_C = 0.05 \times 10^{-3} < 0.08 \times 10^{-3}$ ....**(01)**

Alternative method
For the concrete $\left(\frac{F}{A}\right)_C = 2.5 \times 10^{10} \times \frac{0.1}{2000} = 1.25 \times 10^6$ N m^{-2}
$\therefore \left(\frac{F}{A}\right)_C = 1.25 \times 10^6 < 2 \times 10^6$ ....**(01)**

(2) $\frac{A_S}{A} = \frac{4\pi r^2}{dh} = \frac{4\times3\times(6\times10^{-3})^2}{(15\times10^{-2})\ \times(25\times10^{-2})} = 1.15 \times 10^{-2} = 1.15\%$ ....**(01)**

$$\therefore \frac{A_S}{A} = 1.15\% < 3\%$$

$$F_t = \frac{\Delta l}{l}(E_C A_C + E_S A_S)$$

$$F_t = \frac{0.1}{2000}[2.5 \times 10^{10} \times (15 \times 10^{-2} \times 25 \times 10^{-2})] +$$

$\frac{0.1}{2000}[2 \times 10^{11} \times 4 \times 3 \times (6 \times 10^{-3})^2]$..................**(02)**

(**One mark** for **each** correct term)

$$F_t = 5 \times 10^{-5}[9.375 \times 10^8 + 0.864 \times 10^8]$$

$F_t = 5.11 \times 10^4$N **[5.10 -5.12]** $\times 10^4$N ....**(01)**

(v)

$$(F_t)_{min} = (0.08 \times 10^{-3})[2.5 \times 10^{10} \times (15 \times 10^{-2} \times 25 \times 10^{-2})] +$$

$$(0.08 \times 10^{-3})[2 \times 10^{11} \times 4 \times 3 \times (6 \times 10^{-3})^2] \text{........} \mathbf{(01)}$$

(For **identification** of $\frac{\Delta l}{l} = 0.08 \times 10^{-3}$)

$$F_t = 0.08 \times 10^{-3}[9.375 \times 10^8 + 0.864 \times 10^8]$$

$F_t = 8.19 \times 10^4 \text{N}$ **[8.18 -8.20]** $\times 10^4$N ....**(01)**

Total: **15** marks

If a student has obtained the answers for (iv) (2) and (v) disregarding the conditions stated above, use the following marking guide.

(iv) (2) $A_C = dh - A_s$

$A_C = (15 \times 10^{-2} \times 25 \times 10^{-2}) - 4 \times 3 \times (6 \times 10^{-3})^2 = 3.71 \times 10^{-2}$....**(01)**

[3.70 -3.72] $\times 10^{-2}$N

$$F_t = \frac{\Delta l}{l}(E_C A_C + E_S A_S)$$

$$F_t = \frac{0.1}{2000}[2.5 \times 10^{10} \times 3.71 \times 10^{-2}] + \frac{0.1}{2000}[2 \times 10^{11} \times 4 \times 3 \times (6 \times 10^{-3})^2]$$

(**One mark** for **each** correct term) ....**(02)**

$$F_t = 5 \times 10^{-5}[9.267 \times 10^8 + 0.864 \times 10^8]$$

$F_t = 5.07 \times 10^4 \text{N}$ **[5.06 -5.08]** $\times 10^4$N ....**(01)**

(v)

$$(F_t)_{min} = (0.08 \times 10^{-3})[2.5 \times 10^{10} \times 3.71 \times 10^{-2}] +$$

$$(0.08 \times 10^{-3})[2 \times 10^{11} \times 4 \times 3 \times (6 \times 10^{-3})^2] \text{........} \mathbf{(01)}$$

(For **identification** of $\frac{\Delta l}{l} = 0.08 \times 10^{-3}$)

$$F_t = 0.08 \times 10^{-3}[9.267 \times 10^8 + 0.864 \times 10^8]$$

$F_t = 8.10 \times 10^4 \text{N}$ **[8.00 -8.20]** $\times 10^4$N ....**(01)**

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.

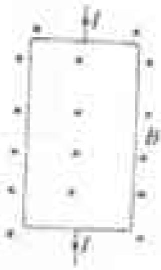


Figure (2)

(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.

(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).

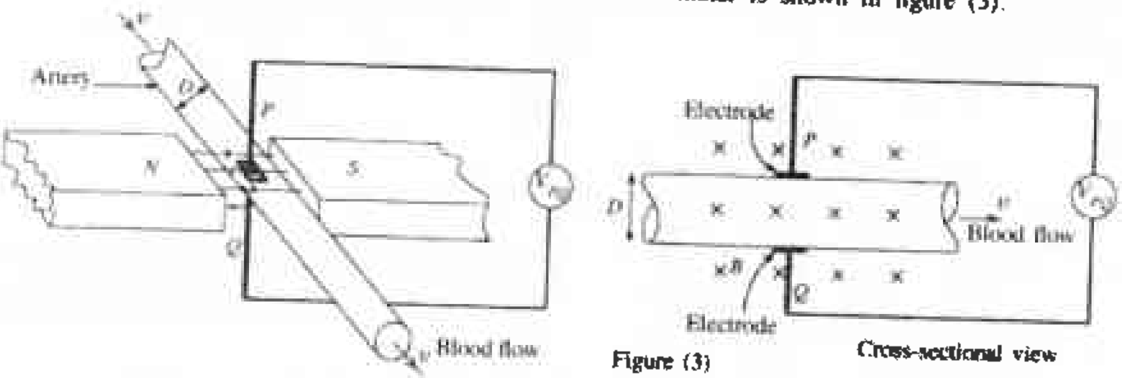


Figure (3)

Cross-sectional view

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.

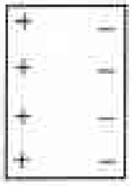
(*a*) (i)  ***OR***  ***OR*** e→

..................(01)

(ii) Same direction as in (a)(i) ***OR*** Same direction as on the electron................(01)

(***OR*** a figure as (*a*) (i))

(*b*) (i)

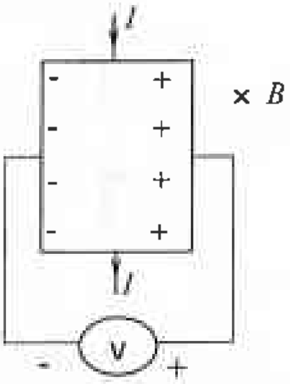


....(01)

(For at **least one** "+" and **one** "-")

(ii) Electrons will move to one side of the strip due to the magnetic force acting on them and it creates an electric field. Further movement of electrons towards the side is prevented by the electric field. ....(01)

(iii) By checking the polarity of the sides of the strip using the situation described in (a)(ii) [relative to the situation described in (a)(i) for electrons], if the right side of the strip is positive (+) relative to the left side, the charge carries are positively charged holes.



OR

(If the diagram is given, the directions of ***I*** **and** ***B*** should be indicated.)

..................................(01)

(*c*) (i) If the electric field produced by the charge separation is *E*,

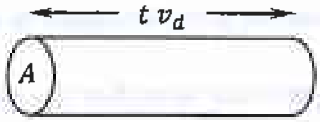
Electric force on charge *q* = magnetic force on charge *q*

$qE = qv_dB$ and $E = \frac{V_H}{d}$ (For **any** correct expression)..........(01)

$V_H = dv_dB$ ....(01)

(If the equation is **not derived**, v_d should be there to award the mark for V_H)

(ii) (1) Consider a small time interval t (or Δt),



Current $I = \frac{Q}{t}$ ....(01)

$I = \frac{ne(t\,A\,v_d)}{t}$ ....(01)

$I = nev_dA$

(2) Hall voltage $V_H = \frac{BId}{nedt} = \frac{BI}{net}$ ....(01)

(Correct expression ***OR*** For identification of $A = dt$)

(3) Concentration of charge carriers $n = \frac{BI}{V_Het}$

$= \frac{0.5 \times 48}{1.6 \times 10^{-19} \times 10^{-3} \times 1.5 \times 10^{-6}} = 10^{29}\ m^{-3}$......(01)

(For substitution ***OR*** final answer)

(d) (i) Positive (+)

Magnetic force acting on Na^+ irons directs them towards the P.....................(01)

(For the correct answer <u>**and**</u> the reason)

(ii) Using the expression obtained in (c)(i)

$V_{PQ} = vDB$..................................(01)

(iii) $v = \frac{V_{PQ}}{DB}$

$v = \frac{160 \times 10^{-6}}{5 \times 10^{-3} \times 2 \times 10^{3} \times 10^{-4}}$..(01)

(For correct substitution)

$v = 1.6 \times 10^{-1}\ m\ s^{-1}$...(01)

Total: **15** marks

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.

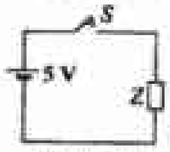


Figure (1)

(*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 $2\times10^8\ \mathrm{m\,s^{-1}}$. Assume that the rectangular shape of the pulse remains unchanged when it passes through the circuit.

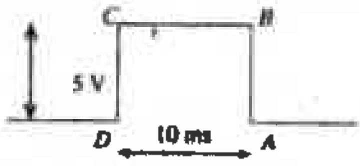


Figure (2)

(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.

(*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).

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.

Figure (4)

(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.

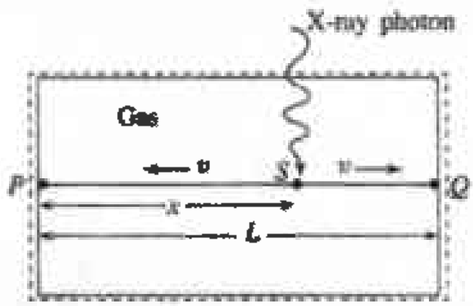


Figure (5)

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.

In this question use of I^2R and VI for calculating power, whenever relevant, is acceptable

(*a*) Power dissipation $= \frac{V^2}{R} = \frac{25}{10^3}$ ....(01)

$= 2.5 \times 10^{-2}$ W..(01)

(*b*) (i) Time taken to travel 2cm $= \frac{2\times10^{-2}}{2\times10^{6}} = 10^{-8}$ s..(01)

(ii) 10 ms ....(01)

(iii) Energy dissipation $= \frac{25}{10^3} \times 10 \times 10^{-3} = 25 \times 10^{-3} \times 10 \times 10^{-3}$

$= 2.5 \times 10^{-4}$ J..(01)

(*c*) Power dissipation$= \frac{V^2}{R} \times 1$ ms $\times$ frequency

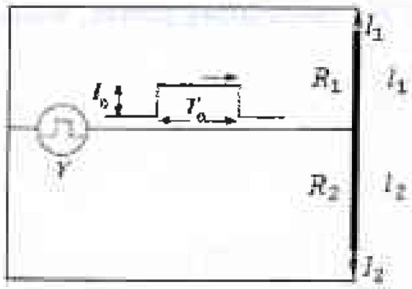
$= \frac{V^2}{R} \times 1\text{ ms} \times \frac{1}{\text{Period}}$

$= \frac{25\times10^{-3}}{10^3\times5\times10^{-3}}$ ....(01)

$= 5 \times 10^{-3}$ W ....(01)

(*d*) (i) $R_1 = \rho\frac{l_1}{A}$ and $R_2 = \rho\frac{l_2}{A}$ (For any expression)................(01)

(ii)



Potential differences across the wires of length l_1 and l_2 are equal (say V).

$I_1 = \frac{V}{R_1} \ldots\ldots(X)$ and $I_2 = \frac{V}{R_2} \ldots\ldots(Y)$ (For **any** expression)......**(01)**

$$\text{Using } (X) \text{ and } (Y) \Rightarrow \frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{l_2}{l_1}$$

$\frac{I_1}{I_2} = \frac{l_2}{l_1}$ ***OR*** $\frac{I_1}{I_2} = \frac{R_2}{R_1}$ ....**(01)**

$I_0 = I_1 + I_2$..**(01)**

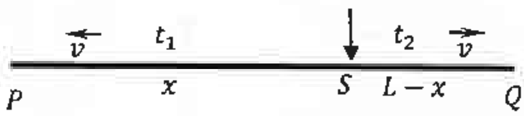
Eliminating I_2 from the above equations, $\frac{I_1}{I_0 - I_1} = \frac{l_2}{l_1}$ or $\frac{I_1}{I_0 - I_1} = \frac{R_2}{R_1}$

$I_1 = I_0 \frac{l_2}{l_1 + l_2}$ ....**(01)**

Eliminating I_1 from the above equations, $\frac{I_0 - I_2}{I_2} = \frac{l_2}{l_1}$ or $\frac{I_0 - I_2}{I_2} = \frac{R_2}{R_1}$

$I_2 = I_0 \frac{l_1}{l_1 + l_2}$ ....**(01)**

(*e*)



$t_1 = \frac{x}{v}$ and $t_2 = \frac{L - x}{v}$ (For **any** expression).......................**(01)**

$$\Delta t = t_1 - t_2 = \frac{x}{v} - \left(\frac{L - x}{v}\right)$$

$x = \frac{v}{2}\left(\Delta t + \frac{L}{v}\right)$ ....**(01)**

Total: **15** marks

(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.

(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?

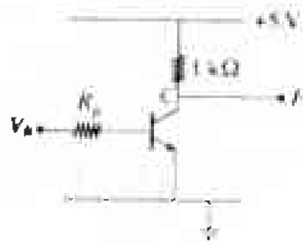


Figure (1)

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

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 $F_3 = 0$

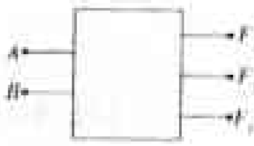


Figure (2)

(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.

(a) (i) $(I_C)_{max} = \frac{5}{1000}$ ....(01)

$= 5 \times 10^{-3}$ A. [5 mA] ....(01)

(ii) $(I_B)_{max} = \frac{I_C}{\beta}$ ....(01)

$= \frac{5\times10^{-3}}{100} = 5 \times 10^{-5}$ A ....(01)

$V_B - V_{BE} = I_B R_B$ ***OR***

$5 - 0.7 = 5 \times 10^{-5} R_B$ ....(01)

(For correct expression ***OR*** substitution)

$R_B = 86$ kΩ ....(01)

(iii) $(5 - 0.7 = I_B \times 86 \times 10^3)$

$I_B = 5 \times 10^{-5}$A ....**(01)**

(1) $I_C = \beta I_B = 50 \times 5 \times 10^{-5}$

$= 2.5 \times 10^{-3}$A ....**(01)**

$5 - V_F = 2.5 \times 10^{-3} \times 10^3$

$V_F = 2.5$ V ....**(01)**

(2) Active mode ....**(01)**

(*b*) (i)

A	B	F_1	F_2	F_3
0	0	0	1	0
0	1	1	0	0
1	0	0	0	1
1	1	0	1	0

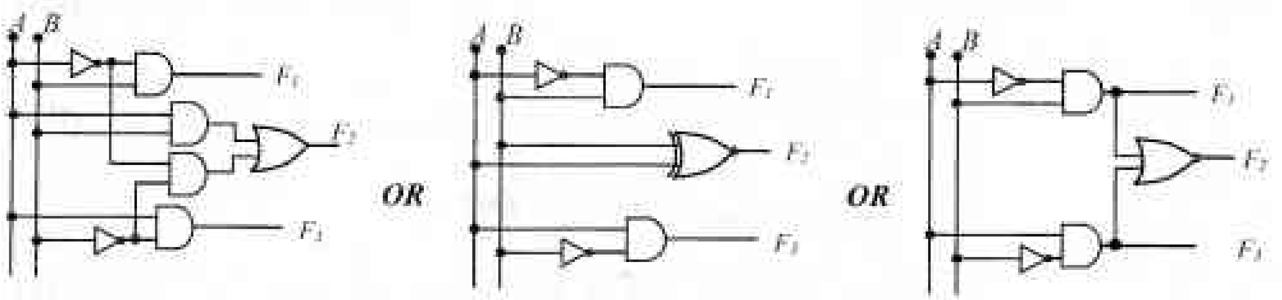
....**(01)**

(For correct truth table)

(ii) $F_1 = \bar{A}B$ and $F_3 = A\bar{B}$ (For **any** expression)....................**(01)**

$F_2 = \bar{A}\bar{B} + AB$ ....**(01)**

(iii)



(***OR*** any other correct circuit)

(If **all** outputs are correct)...**(02)**

(If only **two** outputs are correct)...**(01)**

Total: **15** marks

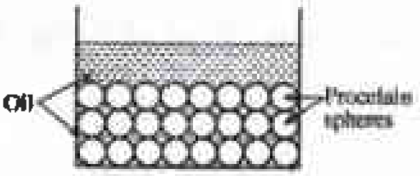
10. Answer either part (A) or part (B) only.

(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 $\pi = 3$.)

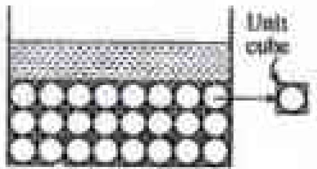


Figure (2)

(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?

(*a*) Let θ be the final temperature of the mixture.

Amount of heat lost by oil (200 °C), $Q_o = m_o\, C_o\, (200 - \theta)$..................**(01)**

Amount of heat gain by food material (30 °C), $Q_f = m_f\, C_f\, (\theta - 30)$.........**(01)**

$$Q_o = Q_f$$ **OR**

$$m_o\, C_o\, (200 - \theta) = m_f\, C_f\, (\theta - 30)$$ ....**(01)**

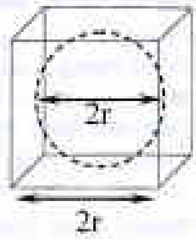
$$0.2 \times 1650\,(200 - \theta) = 0.2 \times 1600\,(\theta - 30)$$

(If **all the terms** in the above equation **are correct**, award all **03 marks.**)

$$(200 - \theta)1.65 = 1.6\,(\theta - 30)$$

$\theta = 116.3$ °C **[116.2 - 116.4]** °C ......**(01)**

(b)(i)



$$\frac{\text{Volume occupied by a sphere}}{\text{Volume of a unit cube}} = \frac{\frac{4}{3}\pi r^3}{(2r)^3} = \frac{4\times3\times r^3}{24r^3}$$ ....(01)

$$= \frac{1}{2}$$

∴ Total volume (V) of oil <u>within the voids</u> is = Total volume of the spheres ...**(01)**

(ii) Let d_o and d_p be the densities of oil and porcelain respectively. If the mass of the porcelain spheres is m_p,

$m_p = Vd_p$ and $m_o = 0.1 = Vd_o$ (For any expression)................**(01)**

$m_p = \frac{0.1}{\rho_o} d_p = \frac{0.1}{900} \times 2500$ ....**(01)**

$m_p = 0.28$ kg **[0.27-0.29]** kg..........................**(01)**

Alternative method

Since the total volume of oil within the voids and total volume of porcelain are equal,

$m \propto d \rightarrow \frac{m_p}{m_o} = \frac{d_p}{d_o}$ ....**(01)**

$\frac{m_p}{0.1} = \frac{2500}{900}$ ....**(01)**

$m_p = 0.28$ kg **[0.27-0.29]** kg ....**(01)**

(iii) Let θ' be the final temperature of the mixture.

Amount of heat lost by oil (200 ^{0}C), $Q_o = m_o\, C_o\, (200 - \theta')$ ***OR***

Amount of heat gain by food material (30 ^{0}C), $Q_f = m_f\, C_f\, (\theta' - 30)$

(For **any** expression)...............**(01)**

Amount of heat lost by porcelain (200 ^{0}C), $Q_p = m_p\, C_p\, (200 - \theta')$...........**(01)**

$$Q_o + Q_p = Q_f \;\; \textbf{\textit{OR}}$$

$$m_o\, C_o\, (200 - \theta') + m_p\, C_p\, (200 - \theta') = m_f\, C_f\, (\theta' - 30) \text{...........}\textbf{(01)}$$

$$0.2 \times 1650\, (200 - \theta') + 0.28 \times 1000\, (200 - \theta')$$
$$= 0.2 \times 1600\, (\theta' - 30)$$

(If **all the terms** in the above equation **are correct**, award all **03 marks**.)

$$1.65 \times (200 - \theta') + 1.4 \times (200 - \theta') = 1.6\, (\theta' - 30)$$

$\theta' = 141.5$ ^{0}C **[140.5 - 142.5]** ^{0}C ....**(02)**

(02 *OR* 0)

(*c*) Heat can be transferred to oil very quickly ....**(01)**

Total: **15** marks

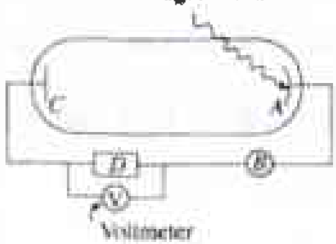


Figure (1)

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

(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.

(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).

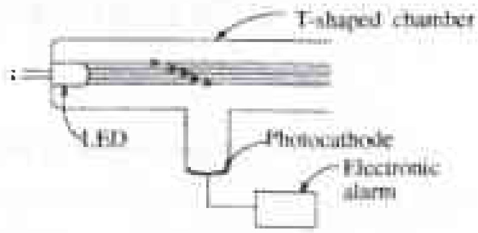


Figure 2(a)

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.

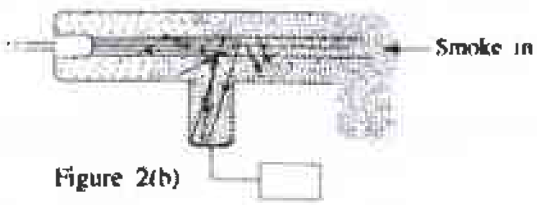


Figure 2(b)

(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 eV = 1.6×10^{-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.

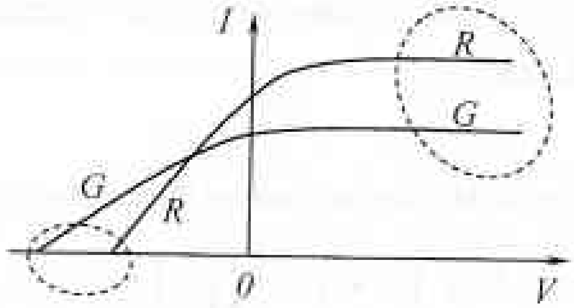
(iv) Photocathode should receive at least 20% of the emitted photons per second from the LED to activate the alarm. Calculate the minimum number of photons per second that should be incident on the photocathode to activate the alarm.

(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.

(B) *(a)* (i) dc, variable and reversible (Any **two** correct)................**(01)**

(ii) **A-** Photocathode/Cathode and **B-** Ammeter (**Both** correct)...........**(01)**

(iii)(1)



Photoelectric current (I), when V >0:

Curve for red (R) should be **above** the curve for green (G) .....**(01)**

*Stopping potential (V), when **V < 0 and at I = 0:***

Curve for red (R) should be **behind** the curve for green (G) .....**(01)**

(To earn these marks, at least **one curve and one axis** must be **labeled.** If both axis are not labeled **deduct** one mark.)

(2) Let V_R and V_G be the stopping potentials for red and green respectively, and f_R and f_G be the frequencies for red and green respectively. If work function of the cathode material is ϕ,

For red color, $eV_R = hf_R - \phi$ ... ... (X)

For green color, $eV_G = hf_G - \phi$ ... ... (Y)

[For **either** expression (X) ***OR*** (Y)]..**(01)**

(ϕ can be written as hf_0)

$(Y) - (X) \rightarrow e(\Delta V) = h(\Delta f)$

$$\frac{(\Delta f)}{(\Delta V)} = \frac{e}{h}$$ ....**(01)**

(*b*) (i) Energy of a photon $E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{825\times10^{-9}\times1.6\times10^{-19}}$ ....**(01)**

$= 1.5\ \text{eV}$....................................**(01)**

(ii) X, To produce photoelectrons,

work function (or ϕ) of the cathode material < energy of an incident photon (or 1.5 eV). ....**(01)**

(iii) Let n be the number of photons emitted by the LED per second.

$$nE = 10 \times 10^{-3}\left(\frac{3}{100}\right)$$ ....**(01)**

(For correct substitution)

If the energy of a photon $E = 1.5$ eV

$$n = \frac{10\times10^{-3}\times0.03}{1.5\times1.6\times10^{-19}} = 1.25\times10^{15}\ \text{s}^{-1}$$ ....**(01)**

(iv) Minimum number of photons $= \left(\frac{20}{100}\right)\times1.25\times10^{15} = 2.5\times10^{14}\ \text{s}^{-1}$

(For correct substitution)........... **(01)**

(v) Number of electrons generated by the photons $= \left(\frac{10}{100}\right)\times2.5\times10^{14}$

$= 2.5\times10^{13}\ \text{s}^{-1}$.....**(01)**

Photoelectric current = e × number of electrons emitted per second

$= 1.6\times10^{-19}\times2.5\times10^{13}$ ....**(01)**

(For correct substitution)

$= 4\times10^{-6}$ A ....**(01)**

Total: 15 marks