G.C.E.(A.L.) Examination - 2012

Evaluation Report

01 - Physics

Research & Development Branch
National Evaluation & Testing Service
Department of Examinations

2.1.3. Expected answers and the scheme of marking

Scheme of Marking for paper I

Question No.	Answer	Question No.	Answer
01.	2	26.	3
02.	2	27.	2
03.	3	28.	1
04.	1	29.	3
05.	3	30.	2, 3, 4, 5
06.	5	31.	1
07.	2	32.	5
08.	4	33.	3
09.	4	34.	1
10.	3, 4	35.	4
11.	1	36.	2
12.	4	37.	4
13.	5	38.	5
14.	1	39.	5
15.	4	40.	1
16.	3	41.	2
17.	2	42.	5
18.	3	43.	4
19.	3	44.	1
20.	4	45.	5
21.	1	46.	1
22.	1	47.	4
23.	4	48.	1
24.	5	49.	2
25.	4	50.	2

Each correct answer carries 02 marks, amounting the total to 100.

2.2.2 Expected answers, scheme of marking, observations on the responses, conclusions and suggestions related to question paper II :

★ **Observations for answers to paper II are based on graphs 2, 3, 4.1, 4.2 and 4.3.**

Part A - Structured Essay

1. A student has decided to measure the density of a stone with a smooth surface but having an irregular shape, at home using the following items.

   A rectangular container

   A 30 cm ruler (foot ruler) with mm scale

   Assume that he has access to the following items too.

   A household glass measuring cylinder capable of measuring liquid volumes upto nearest 5 ml.

   Electronic balance at a nearby retail shop.

(*a*) He started the experiment by determining the volume of the container using the 30 cm ruler.

(i) What are the measurements he has to take?

(1) Length [Say (x_1)]

(2) Breadth/Width [Say (x_2)]

(3) Depth OR Height [Say (x_3)] .... (01 mark)

(Measurements can be stated in any order) (All three are correct)

(ii) When an ordinary 30 cm ruler (foot ruler) is used to take the above three measurements one measurement may be less accurate,

What is that measurement?

Depth OR Height OR x_3 or any other appropriate variable

What is the reason for that?

The zero mark of the foot ruler does not coincide with its edge OR there is a gap between the zero mark and the edge of the foot ruler OR fractional error/ error of the height measurement is large .... (01 mark)

(Identification of the measurement correctly)

(*b*) He washed the stone thoroughly, dried it, and kept it inside the container as shown in figure (1). Then he filled the remaining volume of the container upto the brim with a measured amount of water using the measuring cylinder. Let the volume of water measured and added to the cylinder be *V*.

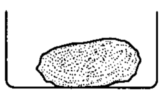


Figure (1)

(i) Write down an expression for the volume of the stone (V_0) in terms of V, x_1, x_2 and x_3.

$V_0 = x_1 x_2 x_3 - V$ .... (01 mark)

(ii) If he has the option to choose a container with the same volume but having a narrow brim as shown in figure (2), explain as to why it is advantageous to select such a container?

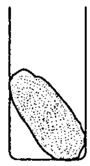


Figure (2)

Volume of water occupied above the brim level is less,

OR Error or Fractional error (or uncertainty) in V measurement,

OR in V_0, is low

.... (01 mark)

(*c*) (i) What is the other measurement that he should take in order to determine the density of the stone?

Mass of the stone OR weight (say p) .... (01 mark)

(ii) Hence write down an expression for the density (d_0) of the stone in terms of the symbols defined above.

$$d_0 = \frac{p}{x_1 x_2 x_3 - V} \quad \text{OR} \quad d_0 = \frac{p}{V_0}$$ .... (01 mark)

(No marks if weight is given as the answer under (*c*) (i), however the mark will be awarded if p is divided by 10 or g)

(*d*) Suppose you want to estimate the mass of a huge rock that is situated on a flat land as shown in figure (3), using the knowledge that you have gained from the above experiment. Assume that you have ability and provisions to construct wooden boxes of any known volume, or wooden structures of known size, and access to sufficient quantity of fine sand instead of water.

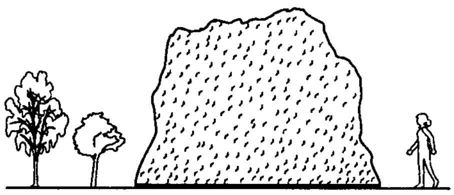


Figure (3)

(i) Write down the major steps of a method that you would suggest in order to measure the volume of the rock.

(1) Construct a rectangular structure (OR frame OR a box) enclosing the rock (a structure drawn on the above figure can be accepted)

(2) Measure its dimensions (OR volume)

(3) Fill in the remaining volume with (a measured amount of) sand

[(4) Volume of the rock = Volume enclosed by the structure - Volume of sand]

[For steps (1), (2), and (3)] .... (01 mark)

(ii) What kind of measuring device can be constructed to measure the volume of sand using the materials given under (*d*) above?

Construct a (small wooden) box with a known volume .... (01 mark)

(iii) What is the other physical quantity that is needed to estimate the mass of the rock?

Density of the rock (material) .... (01 mark)

(iv) Suggest a method to measure the quantity mentioned in (*d*) (iii) above.

Take a small sample/piece or part of the rock material and do the experiment described above (or any other acceptable method) to find the density of the rock material

.... (01 mark)

2. You are asked to perform an experiment to verify that the value of the specific latent heat of fusion of ice is 3.3×10^5 J kg^{-1} using the method of mixtures.
Some of the items given to you are listed below.
   (1) A copper calorimeter
   (2) A beaker containing water heated to 45 °C
   (3) A block of ice

(*a*) Prepare a list of other items needed to perform this experiment.

Thermometer
Chemical balance OR Electronic balance OR Three-beam balance OR Four beam balance
(Both correct) ....(01 mark)

(Blotting papers, Stirrer with a mesh)
(No marks for 'Balance' OR 'Spring balance')

(*b*) When performing this experiment, what steps would you take to minimize the heat absorbed from the surroundings?

Start the experiment with water having a temperature higher than the room temperature by a few degrees, (OR 5 degrees) and add ice until the temperature drops below the room temperature by the same number of degrees ....(01 mark)
(Lag the Calorimeter)

(*c*) If the room temperature is 30 °C and the dew point of the atmosphere is 25 °C what values would you suggest for

(i) initial temperature of water	: 34.5 °C	OR	34 °C	............(01 mark)
(ii) minimum temperature of water	: 25.5 °C		26°C	(Both correct)

OR any initial temperature ≥ 34 °C and < 35 °C
any minimum temperature > 25 °C and ≤ 26 °C

Give reasons,

Under this condition heat absorbed form surroundings (or room)
is equal to (or compensated with)
the heat given out to surroundings OR
no net absorption of heat from the surroundings OR
to avoid the formation of dew
...........(01 mark)
(Any one reason)

(*d*) List all the experimental measurements that you would take before adding ice.

Mass of the empty calorimeter plus stirrer
Mass of the calorimeter with stirrer plus water
Initial temperature of water
(Any order ; All correct) ....(01 mark)

(*e*) What procedures would you follow when preparing ice, adding it, and mixing with water?

Preparing : Break the ice cube into small pieces and mop (OR wipe/dry) them with a blotting (filter) paper ....(01 mark)

Adding : Add and dissolve one piece at a time
(Without splashing water) ....(01 mark)

Mixing : Mix with a stirrer having a mesh OR keep the piece of ice under water all the time ....(01 mark)

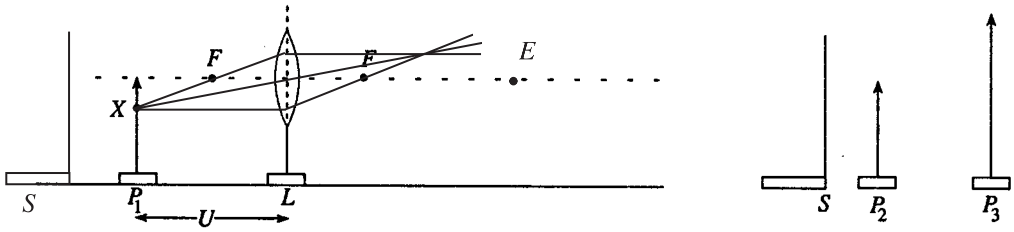
(f) Write down the rest of the experimental measurements that you would take after adding ice.

Minimum temperature of water / mixture / system
Mass of the calorimeter and its contents
(Both correct) .... (01 mark)

(g) In this experiment the measurements that are used to determine the mass of ice have to be taken more carefully and accurately. Explain why.

Since the latent heat of ice is large, the amount of ice needed will be small (i.e mass of ice, $M = M_2 - M_1$ is small), and therefore error (fractional error) associated with the mass measurement of ice is large .... (01 mark)

3. You are asked to verify the lens formula by plotting a suitable graph, and to determine the focal length of a convex lens. A partly assembled set-up that can be used for this purpose is shown in the following diagram. U is the object distance. You are provided with an object pin P_1, lens L, locating pins (P_2 and P_3; one short and other tall) and a white screen S.



(*a*) Considering two light rays coming from point X marked on P_1, draw a suitable ray diagram to locate the image of the object pin P_1.

At least any two of the rays as drawn above
(No need to draw the image, but the two rays should be extended until they meet each other; An arrow should be marked at least on one of the rays) .... (01 mark)

(*b*) (i) Draw the screen S at an appropriate place in the above diagram.

Screen placed to the left of P_1 as shown .... (01 mark)

(ii) What is the purpose of keeping S at the place where you have drawn it?

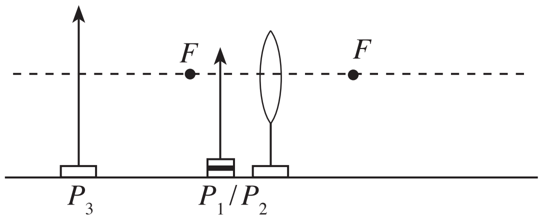
To obtain a clear view OR To avoid obstructions from other objects (for a clear view) OR To view the image of P_1 clearly OR To view only P_2 and the image of P_1
[This mark is awarded even if part (*b*) (i) is incorrect or not answered] .... (01 mark)

(*c*) (i) To determine the image distance (V) of the object pin P_1, the locating pin P_2 has to be used and you have to place your eye at a suitable position. Label this position as E in the above diagram.

Position of the eye marked (E) / the symbol of eye drawn on the principal axis and to the right of the image of P_1 OR to right of the position where the two rays intersect .... (01 mark)

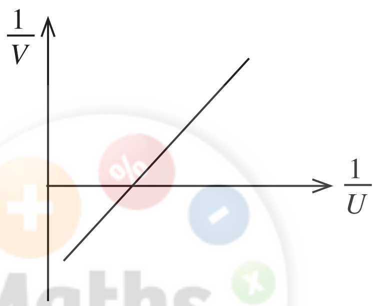
(ii) How do you make sure that the image of P_1 coincides with P_2 ?

(When the eye is moved) there should not be any relative movement between (tips of) P_2 and the image of P_1 OR P_2 and the image of P_1 move together .... (01 mark) (*d*) Suppose you want to take a few readings with virtual images too. Draw the object pin and the locating pin at appropriate places for taking such a reading, and label them as P_1, P_2 or P_3 in the following diagram (positioning them at exact locations is **not** necessary).



Placing P_1 (*or* P_2) and P_3 (taller pin) as shown
(P_1 or P_2 should be placed between F and the optical center; P_3 should be placed to the left of P_1 or P_2; the exact location of P_3 is not needed; Disregard the actual position of the tip of P_1 / P_2) .... (01 mark)

(*e*) (i) Draw a graph that you would expect to obtain on the following grid. Your graph must contain data points for real images as well as virtual images. Label the axes.



The straight line graph as shown; labeling the axes correctly.
(For both parts of the answer) .... (01 mark)

(ii) What is the expected gradient of the graph?

1 .... (01 mark)

(iii) How do you determine the focal length of the lens from the graph?

$\frac{1}{\text{intercept}}$ .... (01 mark)

(No mark for writing the intercept)

(*f*) A student says that in the case of real images when one pair of U and V values are obtained, two data points could be plotted, on the graph. Would you agree with this? Give reasons for your answer.

Yes

(For real images) U and V values can be interchanged with each other OR When a certain V value becomes U, the corresponding U value will become V OR Due to the principle of reversibility of light .... (01 mark)

4. Figure (1) shows an incomplete diagram of a potentiometer arrangement used for measuring the internal resistance of a cell.

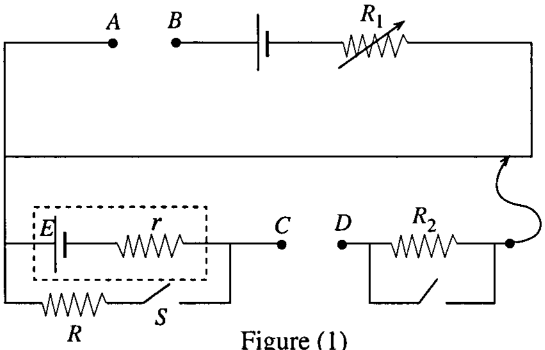


Figure (1)

(*a*) In addition to the items corresponding to the symbols shown in figure (1), if you are provided with the items shown in figure (2) to perform this experiment,

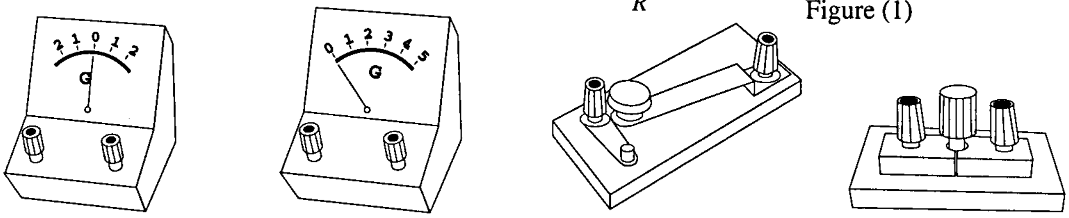


Figure (2)

Item (1) Item (2) Item (3) Item (4)

(i) which item would you connect between *AB*?

Item 4 ....(01 mark)

(ii) which item would you connect between *CD*?

Item 1 ....(01 mark)

(If the connections of the appropriate items to the circuit have been drawn, they are considered as correct.)

(*b*) In this experiment, after the apparatus is setup properly, two balance lengths must be taken. What are they?

(i) Balance length with S open
OR balance length when current is not flowing from cell E ....(01 mark)

(ii) Balance length with S closed
OR balance length when current is flowing from cell E ....(01 mark)

(*c*) If the balance lengths taken by a student were 90 cm and 80 cm, calculate *r*. (The value of *R* was 5 Ω during these measurements).

$E = kl_1$ OR $E \propto l_1$ or 90 ....(01 mark)

$\frac{ER}{R+r} = kl_2$ OR $\frac{ER}{R+r} \propto l_2$ or 80 ....(01 mark)

[OR $\frac{E}{ER/(R+r)} = \frac{90}{80}$ ....02 mark]

$$r = R\frac{(l_1 - l_2)}{l_2}$$

$$= 5\frac{(90-80)}{80}$$

$= 0.625\ \Omega$ ....(01 mark) (*d*) For maximum accuracy, the potentiometer must be adjusted so as to give largest possible values for the balance lengths.

(i) Which of the **two** balance lengths mentioned in (*b*) above must be used for this adjustment? Give reasons for your answer.

The balance length with S open
This is the larger balance length
(For both correct) .... (01 mark)

(ii) With what item do you perform this adjustment?

R_1 .... (01 mark)

(*e*) If an R value much larger than 5 Ω, is used in the circuit when taking measurements under (*b*) above, would you expect a more accurate or less accurate value for r? Give reasons for your answer.

A less accurate value,
Because the error (or fractional error) in the $(l_1 - l_2)$ measurement is large
OR the measurements of l_1 and l_2 will be almost the same
OR the measurement of l_1 will be approximately equal to that of l_2
OR the difference between the measurements of l_1 and l_2 will be small.
(For any reason) .... (01 mark)

PART B – Eassy

5. In this question, you will investigate a few basic movements of a robotic arm shown in figure (1).

The arm segments A and B of the robot have the ability to rotate in either direction around joints 1 and 2 in horizontal planes. Joint 3 allows segment C to move up and down. All three joints are operated by electric motors. Assume that only one movement around or across a joint is allowed at a given time and that there is no friction in any of the joints.

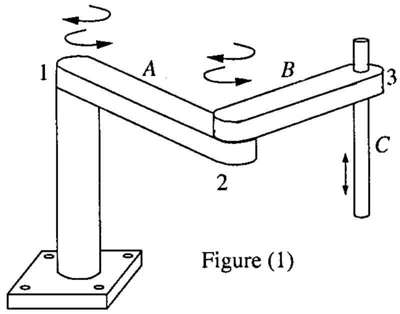


Figure (1)

(*a*) First consider an upward motion of segment C. This motion is described by the velocity (υ) - time (t) graph in figure (2). Mass of segment C is 0.1 kg.

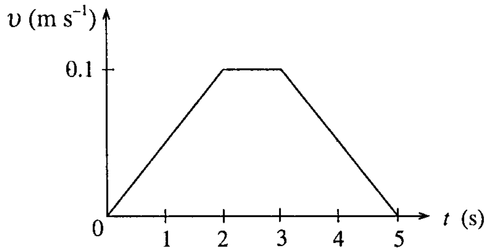


Figure (2)

(i) Calculate the acceleration of segment C during the first 2 seconds.

(ii) The forces acting on C are its weight, and the force applied by the motor for the motion of C. Calculate the force applied by the motor during the first 2 seconds.

(iii) What are the magnitude and direction of the force applied by the motor on C during the last 2 seconds of motion?

(iv) Suppose the magnitude of the maximum force the motor can exert on C is 1.2 N. If starting from rest, C moves up under this maximum force for 0.5 s, how far will it move?

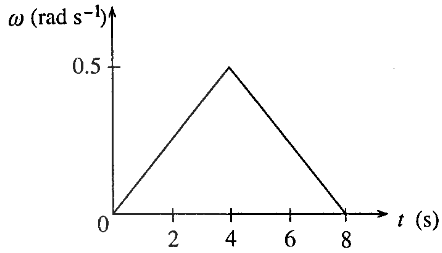


Figure (3)

(*b*) Next consider a rotation of segment B (together with segment C) occuring around joint 2. The angular velocity (ω) - time (t) graph in figure (3) shows this rotation. Assume that segment A is held fixed during this rotational motion.

The moment of inertia of the combined system of segments B and C around the axis of joint 2 is 0.01 kg m^2.

(i) Calculate the torque applied by the motor on B during the first 4 seconds of motion shown in figure (3).

(ii) Calculate the angular displacement of B during the 8 s period shown in figure (3).

(iii) If the magnitude of the maximum torque that can be applied by the motor is 0.002 N m, what is the **minimum** time that will take for B to start from rest and come to rest again after an angular displacement of 3.2 radians?

(*c*) Now if segment A is allowed to rotate freely around joint 1, what would be the direction of rotation of segment A, when segment B, starting from rest, rotates clockwise around joint 2? Give reasons for your answer.

5. (*a*) (i) Acceleration $= \dfrac{0.1}{2}$

$= 0.05 \text{ m s}^{-2}$ ....(01 mark)

(ii) Using $F = ma,$ ....(01 mark)

$F - 0.1 \times 10 = 0.1 \times 0.05$ ....(01 mark)

$F = 1.005 \text{ N}$ ....(01 mark)

(iii) Acceleration $= -0.05 \text{ m s}^{-2}$

$F - 0.1 \times 10 = -0.1 \times 0.05$

$F = 0.995 \text{ N}$ ....(01 mark)

Direction is upward. (OR an arrow pointing upwards) ....(01 mark)

(iv) Using $F = ma$,

$$1.2 - 0.1 \times 10 = 0.1\,a$$ ....(01 mark)

$$a = 2\,\mathrm{m\,s^{-2}}$$

Using $s = \frac{1}{2}at^2$,

$$s = \frac{1}{2} \times 2 \times (0.5)^2$$

$$= 0.25\,\mathrm{m}$$ ....(01 mark)

(*b*) (i) Angular acceleration $= \dfrac{0.5}{4}$ ....(01 mark)

$= 0.125\,\mathrm{rad\,s^{-2}}$

Torque $= 0.01 \times 0.125$

$= 0.00125\,\mathrm{N\,m}$ ....(01 mark)

(ii) Angle of rotation $= \dfrac{1}{2} \times 0.5 \times 8$ (OR $2 \times \dfrac{1}{2} \times 0.125 \times 4^2$)

$= 2$ rad ....(01 mark)

(iii) Angular acceleration under maximum torque $= \dfrac{0.002}{0.01}$

$= 0.2\,\mathrm{rad\,s^{-2}}$

To perform the required operation at a minimum time, arm B would have to be rotated at an angular acceleration of $0.2\,\mathrm{rad\,s^{-2}}$ during the first half of the time, and at a deceleration of $0.2\,\mathrm{rad\,s^{-2}}$ during the second half.

(Identification of this as the minimum time) ....(01 mark)

$$\Delta\theta = 2 \times \frac{1}{2}\alpha\left(\frac{t}{2}\right)^2$$

$$t = \sqrt{\frac{4\Delta\theta}{\alpha}}$$

$t = \sqrt{\dfrac{4 \times 3.2}{0.2}}$ OR $t_1 = \sqrt{\dfrac{2 \times 1.6}{0.2}}$ (where $t_1 = t/2$)

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

$t = 8\,\mathrm{s}$ ....(01 mark)

(*c*) The arm will rotate anti-clock wise. This is due to conservation of angular momentum.
(For direction and reason both) ....(01 mark)

6. Read the following passage and answer the questions given below.

The Doppler effect for sound waves depends on three velocities, namely the velocities of sound, the source, and the observer with respect to the air. Normally air is considered to be stationary relative to the ground and therefore these velocities can be measured relative to the ground.

However, this is not the situation with regard to light waves. Light as well as other electromagnetic waves require no medium, and they are capable of travelling even through a vacuum. The Doppler effect for light waves depends on two velocities, namely the velocity of light (c) and the relative velocity (v) between the source and the observer, as measured from the reference frame of either source or the observer.

If a certain light source is at rest relative to us, we would detect light from it with the same frequency (f_0) as that of the source, and it is known as the proper frequency. If it is moving away from us with a speed v ($v << c$), then the light we detect has a frequency f that is shifted from f_0 due to the Doppler effect and f is given by the following formula.

$$f = f_0(1-\beta) \quad \text{where} \quad \beta = \frac{v}{c}$$

However, measurements involving light are usually made in wavelengths rather than frequencies, and the above formula can be rewritten in terms of wavelengths in the following form.

$$v = \frac{\Delta\lambda}{\lambda_0}c \quad \text{where} \quad \Delta\lambda = \lambda - \lambda_0$$

The quantity $\Delta\lambda$ is called the Doppler shift.

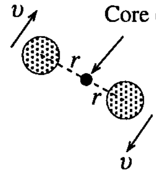


Figure (1)

If the light source is moving away from us, λ is longer than λ_0, $\Delta\lambda$ is positive, and the Doppler shift is called a red shift. If the light source is moving toward us, then λ is shorter than λ_0, $\Delta\lambda$ is negative, and the Doppler shift is called a blue shift.

Using astronomical observations of stars, galaxies and other sources of light, scientists can determine how fast the sources are moving, either directly away from us or directly towards us by measuring the Doppler shift of the light that reaches us.

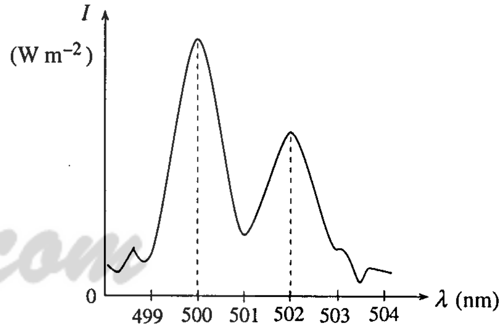


Figure (2)

Two regions of interstellar gas orbiting the core of a galaxy known as M87 at a radius r = 100 light years is shown in figure (1). One region is moving towards us with a speed v and and the other region is moving away from us with the same speed. Figure (2) shows the variation of intensity (I) with wavelength (λ) of light reaching us from those two regions.
The gas is under the influence of the gravitational force due to the mass M of the core of the galaxy. This mass of the core is about two billion times the mass of our sun, strongly suggesting that a super massive black hole occupies the core.

(*a*) (i) Doppler effect for sound waves depends on three velocities. Name them.

(ii) These velocities are normally measured relative to the ground. What is the reason for this?

(*b*) Why does the Doppler effect for light depends only on two velocities?

(*c*) Starting from $f = f_0(1-\beta)$, derive the relationship $v = \frac{\Delta\lambda}{\lambda_0}c$. [**Hint**: When $\beta << 1$, $\frac{1}{1-\beta} = 1+\beta$].

(*d*) (i) From figure (2), determine the values of two wavelengths at which the intensities are peaked.

(ii) Which peak corresponds to the gas moving towards us?

(iii) If the gas were not moving relative to the core, what is the wavelength λ_0 (proper wavelength) of the light that would be detected by us?

(iv) What is the Doppler shift ($\Delta\lambda$) of the light from the gas moving away from us?

(v) Hence determine the speed v of the gas. Round off your answer to the nearest integer ($c = 3.0 \times 10^8$ m s^{-1}).

(vi) Is β << 1? Justify your answer.

(*e*) (i) Determine the mass M of the core of the galaxy. (G = 6.0×10^{-11} N m^2 kg^{-2}).

(ii) What is believed to be occupying the core of the galaxy?

6. (*a*) (i) Velocity of sound (relative to air)
Velocity of the source (relative to air)
Velocity of the observer (relative to air) .... (01 mark)
(All correct)

(ii) Air is (considered to be) stationary relative to ground .... (01 mark)

(*b*) Light does not need a medium to travel OR Light travels even in vacuum
.... (01 mark)

(*c*) $f = f_0(1-\beta)$

$\frac{c}{\lambda} = \frac{c}{\lambda_0}(1-\beta)$ [For applying $c = f\lambda$] .... (01 mark)

$\lambda = \frac{\lambda_0}{1-\beta} = \lambda_0(1+\beta) = \lambda_0\left(1+\frac{v}{c}\right)$

$\lambda - \lambda_0 = \lambda_0 \frac{v}{c}$ .... (01 mark)

$v = \frac{\Delta\lambda}{\lambda_0} c$

(*d*) (i) $500\,\text{nm}$ and $502\,\text{nm}$ (for both) .... (01 mark)

(ii) Peak with $\lambda = 500\,\text{nm}$ OR Left peak OR peak with smaller wavelength
.... (01 mark)

(iii) $\lambda_0 = 501\,\text{nm}$ .... (01 mark)

(iv) $\Delta\lambda = 1\,\text{nm}$ .... (01 mark)

(v) $v = \frac{1}{501} \times 3 \times 10^8 = 5.988 \times 10^5$

$v = 6 \times 10^5\,\text{m s}^{-1}$ $(5.988 - 6.0) \times 10^5\,\text{m s}^{-1}$ .... (01 mark)
$(598800 - 600000)\,\text{m s}^{-1}$

[501 (not 500) should be substituted for λ_0]

(vi) $\beta = \frac{6 \times 10^5}{3 \times 10^8}$

$\beta = 2 \times 10^{-3}$ $(0.001996 - 0.002)$ .... (01 mark)

$\beta << 1$ is justified.

(*e*) (i) Let m be the mass of gas.

$\frac{mv^2}{r} = \frac{GmM}{r^2}$ .... (01 mark)

(No mark if the mass of the gas is omitted in the above equation.)

$M = \frac{v^2 r}{G}$

$r = 100 \times 3 \times 10^8 \times 365 \times 24 \times 3600$ .... (01 mark)
(For converting light years to m)

$M = \frac{(6 \times 10^5)^2 \times 100 \times 3 \times 10^8 \times 365 \times 24 \times 3600}{6.0 \times 10^{-11}}$

$M = 5.68 \times 10^{39}\,\text{kg}$ .... (01 mark)
$(5.65 - 5.70) \times 10^{39}\,\text{kg}$

(ii) Super massive black hole .... (01 mark)

7. Figure (1) shows the stress-strain curve for a uniform steel rod. Identify the points A, B and C.

An underground storage (S) of length 150 m, and width 6 m is to be constructed at a depth of 20 m from the ground level. Figure (2) shows the side view and figure (3) shows the front view of the storage. The weight of the soil existing above the roof of the storage is to be supported entirely by 30 cm × 30 cm square steel columns (C). The soil has a uniform density of 3.0×10^3 kg m^{-3}.

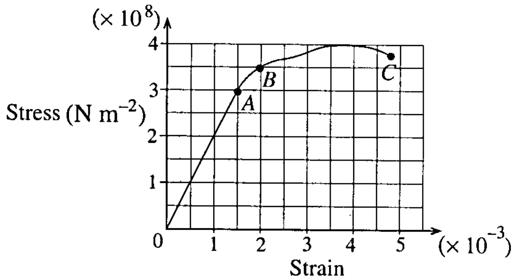


Figure (1)

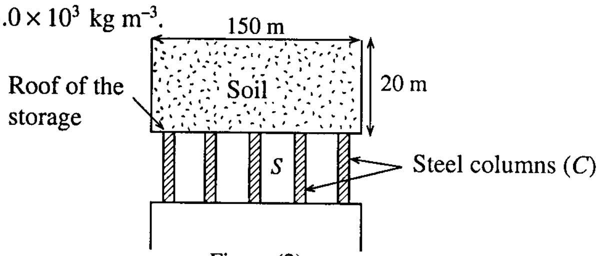


Figure (2)

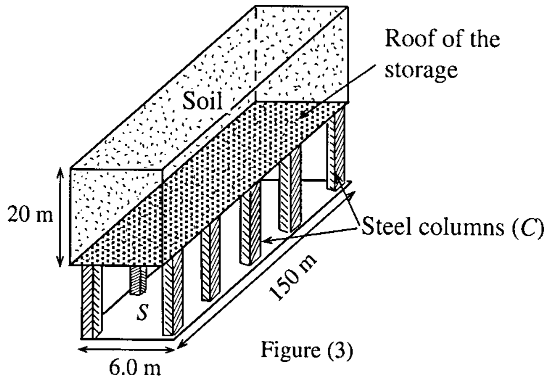


Figure (3)

(a) (i) Calculate the total weight of the soil that the columns must support.

(ii) What is the number of columns needed to keep the compressive stress on each column at 2×10^8 N m^{-2} ? Assume that the weight of the soil is equally distributed among the columns. Neglect the mass of the roofing material.

(b) (i) Determine the Young's modulus of steel from the curve given in figure (1) above.

(ii) If the height of a steel column is 4.995 m what was its original uncompressed height?

(c) If the columns have a circular cross-section of radius 15 cm instead of the square cross-section of 30 cm×30 cm mentioned above, does the number of columns calculated in (a)(ii) above would be less, same or more? Give reasons for your answer.

7. (a) A - Proportional limit ....(01 mark)

B - Elastic limit ....(01 mark)

C - Breaking point ....(01 mark)

(i) Volume of the soil = $6 \times 150 \times 20$ ....(01 mark)

Mass of the soil = $6 \times 150 \times 20 \times 3 \times 10^3$ ....(01 mark)

(For multiplying the volume by 3×10^3)

Weight of the soil = 5.4×10^8 N ....(01 mark)

(ii) Let n be the number of columns needed, then

the stress on a single column $= \dfrac{5.4 \times 10^8}{n \times 30 \times 30 \times 10^{-4}}$ ....(01 mark)

(For dividing the weight by $n \times 30 \times 30 \times 10^{-4}$)

$$\frac{5.4 \times 10^8}{n \times 30 \times 30 \times 10^{-4}} = 2 \times 10^8$$ ....(01 mark)

(For equating the L.H.S. to 2×10^8)

$$n = \frac{5.4 \times 10^8}{9 \times 10^{-2} \times 2 \times 10^8}$$

$n = 30$ ....(01 mark)

(*b*) (i) Young's modulus = gradient of the stress vs. strain curve .... (01 mark)
(For the idea)

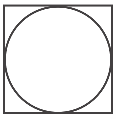
$= 2 \times 10^{11}\,\mathrm{N\,m^{-2}}$ .... (01 mark)

(ii) The corresponding strain for a stress of $2 \times 10^{8}\,\mathrm{N\,m^{-2}}$ is 0.001 (from the graph)
Let L be the uncompressed height of the column, then

$$\frac{L - 4.995}{L} = 0.001 \quad \text{OR} \quad \left[\frac{2 \times 10^{8}}{(L - 4.995)} \times L = 2 \times 10^{11}\right]$$ .... (01 mark)

$$0.999\,L = 4.995$$
$$L = 5\,\mathrm{m}$$ .... (01 mark)

(*c*) Area of cross section of the circular column $= \pi(15)^2 \approx 707\,\mathrm{cm}^2$
This area is less than $900\ \mathrm{cm}^2$
OR
Area of cross section of a circular column is less than that of a square column OR Area of cross section of a square column is more than that of a circular column.
OR
For a diagram drawn as shown



.... (01 mark)

$\therefore$ Need more columns. .... (01 mark)

8. Two metal plates A and B kept parallel to each other in a vacuum are connected to a voltage source as shown in figure (1). A molecular ion of mass m and charge $+q$, starting from rest from the plate A accelerates towards the metal plate B under the influence of the voltage V maintained between the plates.

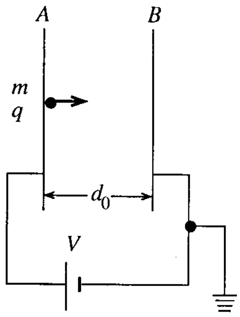


Figure (1)

(*a*) (i) Write down an expression for the kinetic energy gained by the ion when it reaches the plate B.

(ii) Derive an expression for the velocity υ acquired by the ion when it reaches the plate B.

(iii) If d_0 is the distance between the plates derive an expression for the time (t) taken by the molecular ion to reach the plate B.

(*b*) Suppose the metal plate B is now replaced with a metal wire mesh so that the ions moving through the region AB could enter a field free region and move towards an ion detector D placed at a distance S from the wire mesh B as shown in figure (2).

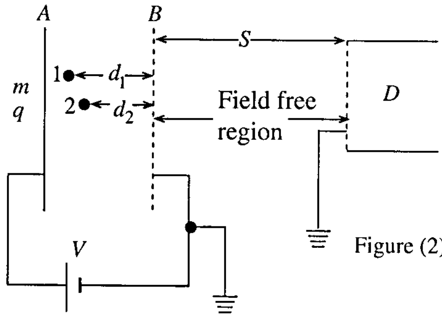


Figure (2)

Consider two molecular ions 1 and 2 of mass m and charge $+q$ suddenly being formed at time $t = 0$ at distances d_1 and d_2 from the wire mesh B as shown in figure (2). If they start from rest and move towards B under the electric field

(i) derive expressions for times t_1 and t_2 taken by the ions 1 and 2 to reach the mesh B, and indicate which ion reaches the mesh first.

(ii) derive expressions for velocities υ_1 and υ_2 of ions 1 and 2 when they reach the mesh B. Indicate which ion has the higher velocity when they reach B.

(iii) Derive an expression in terms of t_1, t_2, υ_1 and υ_2 for the suitable value for the distance S at which the detector D has to be placed so that it detects both ions 1 and 2 at the **same time** as shown in figure (3).

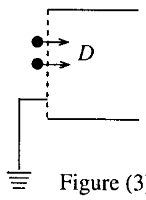


Figure (3)

8. (*a*) (i) Kinetic energy gained $= qV$ ....(01 mark)

(No mark for $\frac{1}{2}mv^2$)

(ii) $qV = \frac{1}{2}mv^2$ ....(01 mark)

$\therefore v^2 = \sqrt{\frac{2qV}{m}}$ ....(01 mark)

(iii) Applying $S = \frac{1}{2}at^2$

Where $a = \frac{qV}{md_0}$ ....(01 mark)

$$d_0 = \frac{1}{2}\left(\frac{qV}{md_0}\right)t^2$$

$t = d_0\sqrt{\frac{2m}{qV}}$ ....(01 mark) (*b*) (i) $d_1 = \frac{1}{2}\left(\frac{qV}{md_0}\right)t_1^2$ ....(01 mark)

$\therefore\ t_1 = \sqrt{\frac{2\,m\,d_1 d_0}{qV}}$ ....(01 mark)

Similarly $t_2 = \sqrt{\frac{2\,m\,d_2 d_0}{qV}}$ ....(01 mark)

(Since $d_1 > d_2$, from the above expressions), $t_2 < t_1$ ....(01 mark)
Ion 2 reaches the mesh first.

(ii) Applying $qV' = \frac{1}{2}mv^2$

$qV\frac{d_1}{d_0} = \frac{1}{2}mv_1^{\,2}$ (For LHS) ....(01 mark)

{Alternative Method : Applying $v^2 = u^2 + 2as$; $v_1^{\,2} = 2\frac{qV}{md_0}d_1$ ....(01)}

$\therefore\ v_1 = \sqrt{\frac{2qVd_1}{d_0 m}}$ ....(01 mark)

Similarly

$v_2 = \sqrt{\frac{2qVd_2}{d_0 m}}$ ....(01 mark)

(Since $d_1 > d_2$, from the above expressions,) $v_1 > v_2$ ....(01 mark)
Ion 1 has the higher velocity.

(iii) The detector will detect both ions simultaneously if,

$t_1 + \frac{s}{v_1} = t_2 + \frac{s}{v_2}$ ....(01 mark)

$S\left(\frac{1}{v_2} - \frac{1}{v_1}\right) = t_1 - t_2$

$\therefore\ S = (t_1 - t_2)\frac{v_1 v_2}{v_1 - v_2}$ ....(01 mark)

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

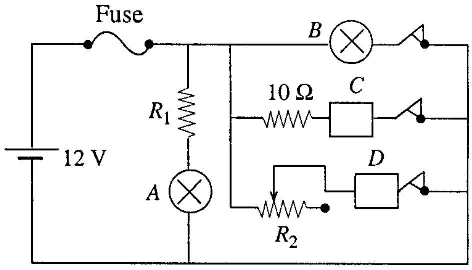


Figure (1)

(A) (*a*) Figure (1) shows a circuit powered by a 12 V battery with negligible internal resistance. The two bulbs *A* and *B* are rated at 3 V, 0.1 A and 12 V, 2 A respectively. *C* and *D* are two devices having internal resistance 6 Ω each.

(i) Calculate the value of resistor R_1 that would provide the rated voltage to bulb *A*.

(ii) Calculate the voltage across *C* and the power dissipated in the 10 Ω resistor.

(iii) In order to be able to limit the current through *D* between 0.5 A and 2 A, what should be the value of the variable resistor R_2?

(iv) Suppose three fuses with current ratings 4 A, 5 A and 10 A are given. In order to make it possible to operate all devices simultaneously, under the above conditions, which fuse would be most suitable to be connected to this circuit?

(*b*) Electrical circuits such as the one above are constructed by mounting electrical components on insulated boards, and joining the terminals of the components by copper wires. In modern circuits, however, such connections are made by thin copper strips printed on insulated boards.

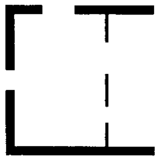


Figure (2)

A part of a printed circuit board is shown in figure (2), and an enlarged diagram of one copper strip is shown in figure (3).

For all calculations below, take the thickness of copper strip, *h*, as 0.3 mm.

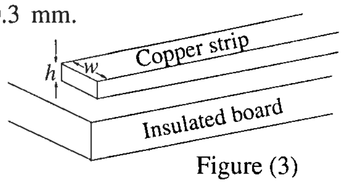


Figure (3)

(i) Calculate the resistance of a 10 mm long copper strip of width w = 1 mm. (Resistivity of copper is 1.8×10^{-8} Ω m.)

(ii) Calculate the voltage across this strip and its power dissipation, when a current of 0.1 A passes through it.

(iii) If all the heat dissipated in one second is accumulated in the strip without being lost to the environment, what will be its increase in temperature? (Specific heat capacity and density of copper are 400 J kg^{-1} K^{-1} and 9×10^3 kg m^{-3} respectively.)

(iv) Copper strips carrying large currents are normally made wider than those carrying small currents.

9. (A) (*a*) (i) $12 - 3 = 0.1 \times R_1$ ....(01 mark)

$R_1 = 90\ \Omega$ ....(01 mark)

(ii) $12 = i \times (10 + 6)$

$i = 0.75$ A ....(01 mark)

Power dissipation $= (0.75)^2 \times 10$

$= 5.625$ W ....(01 mark)

Voltage across *C* $= 0.75 \times 6$

$= 4.5$ V ....(01 mark)

(iii) $12 = 0.5 \times (R_2 + 6)$

$R_2 = 18\ \Omega$ ....(01 mark)

(iv) Maximum total current = 4.85 A. Therefore, the 5 A fuse is suitable

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

(For determining the total current <u>and</u> the selection of the fuse) (*b*) (i) Using $R = \dfrac{\rho l}{A}$, ... (01 mark)

(For the use of this equation)

Resistance $= \dfrac{1.8 \times 10^{-8} \times 10 \times 10^{-3}}{0.3 \times 10^{-3} \times 1 \times 10^{-3}}$ .... (01 mark)

$= 6 \times 10^{-4}\ \Omega$ .... (01 mark)

(ii) Voltage across the strip $= 6 \times 10^{-4} \times 0.1$

$= 6 \times 10^{-5}$ V .... (01 mark)

Power dissipation $= 6 \times 10^{-6}$ W .... (01 mark)

(iii) Dissipated power $= m s \Delta\theta$

$6 \times 10^{-6} = 10 \times 10^{-3} \times 0.3 \times 10^{-3} \times 1 \times 10^{-3} \times 9 \times 10^{3} \times 400 \times \Delta\theta$

(For correct substitution)................ (01 mark)

$\Delta\theta = 5.5 \times 10^{-4}$ °C (OR K) .... (01 mark)

(iv) (1) Larger width reduces resistance (and therefore reduces power dissipation)

(2) Larger width increases heat transfer to the environment OR Larger width increases area exposed to air .... (01 mark)

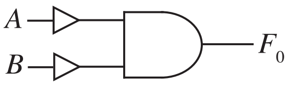
(both correct)

9. (B) (*a*)

A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

.... (01 mark)

(*b*) (i)

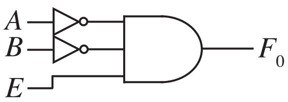


A	B	F_0
0	0	1
0	1	0
1	0	0
1	1	1

.... (01 mark)
(For the truth table)

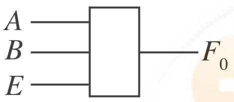
(ii) Truth table shows that $F_0 = 1$ only when $A = 0$ and $B = 0$, and it is zero under all other combinations .... (01 mark)

(*c*) (i)



.... (01 mark)

(ii)



A	B	E	F_0
0	0	1	1
0	1	1	0
1	0	1	0
1	1	1	0

Truth table 1

A	B	E	F_0
0	0	0	0
0	1	0	0
1	0	0	0
1	1	0	0

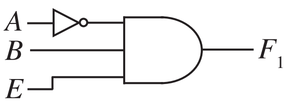
Truth table 2

For correctly drawing the truth table 1 .... (01 mark)

For correctly drawing the truth table 2 .... (01 mark)

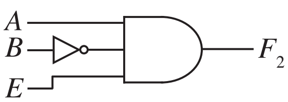
Above tables show that the truth table 1 is identical to the truth table given under *b* (i) when $E = 1$

(*d*)



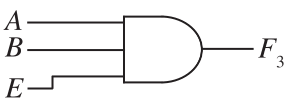
.... (01 mark)

(*e*) (i)



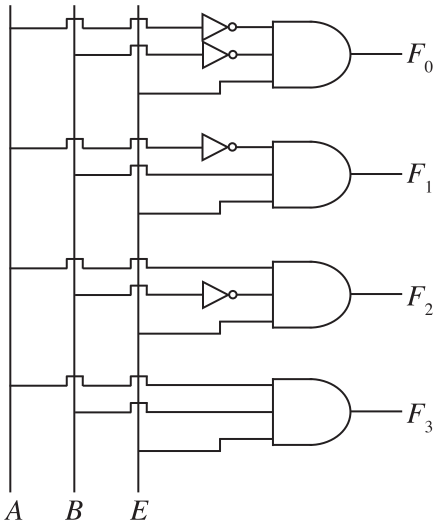
.... (01 mark)

(ii)



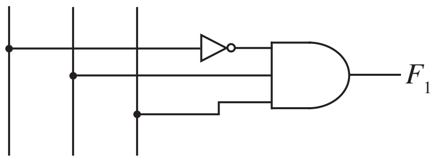
.... (01 mark)

(*f*)



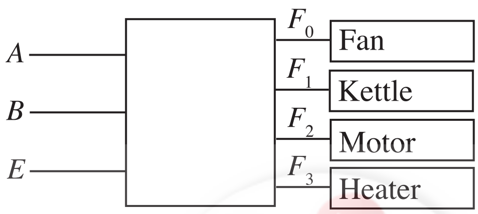
.... (02 mark)

(01 mark is awarded for correct interconnections even when the sub circuits are wrong)



The connections shown above are also accepted as correct.

(*g*) (i)



.... (01 mark)

Input conditions to operate the fan : $A = 0, B = 0, E = 1$

Input conditions to operate the Kettle : $A = 0, B = 1, E = 1$

Input conditions to operate the Motor : $A = 1, B = 0, E = 1$

Input conditions to operate the Heater : $A = 1, B = 1, E = 1$

.... (02 mark)

(All 4 correct - 02, any 3 correct - 01)

(Devices can be connected to block diagram in any order, but the appropriate input conditions should be given in order to earn the marks)

(ii) Keep $E = 0$ .... (01 mark)

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

(A) (*a*) Consider a pond of cross section 2 m × 2 m, and containing pure water constantly being exposed to direct sunlight. (see figure 1) The amount of solar heat radiation falling on the pond is 1000 W m^{-2} and assume that it is constant for the calculations below.

Furthermore assume that solar heat is incident normal to the water surface at all times, no heat transfer occurs between water and the walls of the pond and that **no heat is absorbed by water directly from sunlight**. All the heat is absorbed by a blackened metal sheet placed at the bottom of the pond and then transferred to water near the bottom by conduction.

(i) If the amount of heat absorbed by the metal sheet over a 7 minute period entirely contributed to raise the temperature of a thin layer of water of mass 40 kg just above the metal sheet, how much will be the temperature rise in water? (Take specific heat capacity of water as 4200 J kg^{-1} K^{-1})

(ii) Let densities of water at 0 °C and at θ °C be ρ_0 and ρ_θ respectively. Obtain an expression for ρ_θ in terms of ρ_0, θ and the volume expansivity of water γ.

(iii) Explain why convection currents will occur when water is heated as mentioned in (*a*) (i) above.

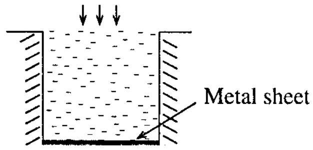


Figure (1)

(*b*) A solar pond is a pond used to collect and store solar energy as heat. Solar heat reaching the bottom of such a pond is trapped by suppressing convection currents. A very simple model of a solar pond with a 2 m × 2 m area is shown in figure (2). It has three distinct layers. The top layer has relatively pure water. The bottom layer has a very high salt concentration resulting a high density. The density is uniform throughout that layer. In the middle layer, the salt concentration and density decreases gradually with height.

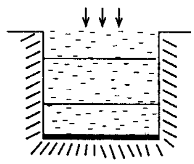


Figure (2)

For the following parts, assume that the initial temperature of water throughout the pond is 30 °C.

(i) In a practical solar pond, the temperature of the bottom layer can reach about 90 °C. If the mass of water in this layer is 6000 kg and if it receives heat radiation at the constant rate of 1000 W m^{-2}, how long will water take to reach 90 °C? Assume that this heat is entirely used to increase the temperature of water, and that salt water has the same specific heat capacity as pure water.

(ii) Taking ρ_0 = 1554 kg m^{-3} for salt water, calculate the density of salt water at 90 °C. (Volume expansivity of salt water is 4×10^{-4} K^{-1})

(iii) If the top layer remains at 30 °C, can there be convection currents from the bottom to the top layer under the above condition? Justify your answer. (Take density of pure water at 30 °C as 1000 kg m^{-3}.)

(iv) (1) When the temperature of the bottom layer increase from 30 °C to 90 °C, calculate the amount of heat stored in that layer.

(2) Suggest a method to use this energy for a practical purpose.

(v) In a practical solar pond, heat loss through the walls must be minimised. If a styrofoam layer of thickness 10 cm is used as an insulation between water and walls of the pond, and if the temperature of the walls stays at 40 °C while water is at 90 °C, what will be the rate of heat loss per m^2 through styrofoam? (Heat conductivity of styrofoam is 0.01 W m^{-1} K^{-1}.)

10.(A) (*a*) (i) $\Delta Q = ms\Delta\theta$ OR $Q = ms\theta$ ....(01 mark)

$40 \times 4200 \times \Delta\theta = 1000 \times 7 \times 60 \times 4$

$\Delta\theta = \dfrac{1000 \times 7 \times 60 \times 4}{40 \times 4200}$ ....(01 mark)

$= 10\,°C$ ....(01 mark)

(ii) $V_\theta = V_0 (1 + \gamma\theta)$ ....(01 mark)

Using $\rho = \dfrac{m}{V}$ $\dfrac{m}{\rho_\theta} = \dfrac{m}{\rho_0}(1 + \gamma\theta)$

$\rho_\theta = \dfrac{\rho_0}{1 + \gamma\theta}$ ....(01 mark)

(iii) Since $\rho_\theta < \rho_0$, water will rise ....(01 mark)

(*b*) (i) $ms\theta = \dfrac{Q}{t} \times t$

$t = \dfrac{6000 \times 4200 \times (90 - 30)}{1000 \times 4}$ ....(01 mark)

$= 378000\,\text{s}$ OR 6300 min. OR 105 h ....(01 mark)

(ii) $\rho_\theta = \dfrac{1544}{1 + 4 \times 10^{-4} \times 90}$ ....(01 mark)

$= 1500\ \text{kg m}^{-3}$ ....(01 mark)

(iii) This density is greater than the density of pure water at $30\,°\text{C}$.
Therefore, water will not rise to the top layer ....(01 mark)
[If a wrong value is obtained for ρ_θ, no mark is awarded for part (*b*)(iii)]

(iv) 1. Amount of heat stored $= 6000 \times 4200 \times (90 - 30)$

$= 1.512 \times 10^9\,\text{J}$ ....(01 mark)

2. (i) To produce hot water by circulating (cold) water through (copper) tubes (which are laid in the bottom layer) OR

(ii) To generate electricity (by operating thermoelectric devices) using the temperature difference between bottom and the top layers

................(01 mark)
(Any one of the methods)

(v) Using $\dfrac{Q}{t} = \dfrac{kA\Delta\theta}{l}$ ....(01 mark)

Rate of heat loss per unit area

$= \dfrac{0.01 \times (90 - 40)}{0.1}$

$= 5\ \text{W m}^{-2}$ ....(01 mark)
(With the correct unit)

(B) In 1924 Louis de Broglie proposed that a particle having a linear momentum p can be described by a matter wave known as a de Broglie wave.

(*a*) (i) Write down an expression for the de Broglie wavelength (λ), in terms of the Planck constant h and p.

(ii) For a particle of mass m and kinetic energy E, rewrite the above expression in terms of h, m and E.

(*b*) A vessel is filled with helium gas at temperature T and atmospheric pressure of 10^5 Pa.

(i) Write down an expression for the mean kinetic energy E of helium atoms in terms of the Boltzmann constant k and T.

(ii) Using the expression derived in (*a*) (ii) above write down an expression for the mean de Broglie wavelength λ of helium atoms in terms of h, k, T and mass m of a helium atom.

(iii) Calculate λ at T = 27 °C. (The numerical values of the constants are given at the end of the question.) [Take $\sqrt{8.4} = 3$]

(iv) If a is the mean distance between helium atoms, by taking the total volume of helium gas to be Na^3, where N is the number of helium atoms present in the vessel, determine a. Consider helium to be an ideal gas. [Take $\sqrt[3]{60} = 4$].

(v) Can the helium atoms be treated as particles under these conditions? Give reasons for your answer.

(vi) If the volume of the gas could be decreased without changing its pressure by cooling it down, at a certain temperature T' the mean de Broglie wavelength of helium atoms can be made equal to the mean distance between helium atoms. Derive an expression for T', in terms of h, m and k.

(Planck constant $h = 6.6 \times 10^{-34}$ J s; Mass of a helium atom $m = 6.0 \times 10^{-27}$ kg;
Boltzman constant $k = 1.4 \times 10^{-23}$ J K^{-1})

10.(B) (*a*) (i) $\lambda = \dfrac{h}{p}$ ....(01 mark)

(ii) $E = \dfrac{p^2}{2m}$ ....(01 mark)

(or $E = \dfrac{1}{2}mv^2$ and $p = mv$)

$\lambda = \dfrac{h}{\sqrt{2mE}}$ ....(01 mark)

(*b*) (i) $E = \dfrac{3}{2}kT$ ....(01 mark)

(ii) $\lambda = \dfrac{h}{\sqrt{3mkT}}$ ....(01 mark)

(iii) $\lambda = \dfrac{6.6 \times 10^{-34}}{\sqrt{3 \times 6 \times 10^{-27} \times 1.4 \times 10^{-23} \times 300}}$ ....(01 mark)
(For correct substitution)

$\lambda = \dfrac{6.6 \times 10^{-34}}{\sqrt{9 \times 8.4 \times 10^{-48}}}$

$\lambda = \dfrac{6.6 \times 10^{-34} \times 10^{24}}{9} \left[\dfrac{6.6 \times 10^{-10}}{9}\right]$ ....(01 mark)

$\lambda = 7.3 \times 10^{-11}$ (7.3×10^{-11} to 7.6×10^{-11}) m ....(01 mark)

(iv) Applying

$PV = NkT$ ....(01 mark)

$10^5 Na^3 = NkT$ ....(01 mark)

$$a^3 = \frac{1.4 \times 10^{-23} \times 300}{10^5}$$

$a = \sqrt[3]{42} \times 10^{-9}$ ....(01 mark)

$a = 3.5 \times 10^{-9}\,\text{m}$

(v) Yes, (can be treated as particles) ....(01 mark)

$\lambda < a$ [(Mean) de Broglie wavelength is less than the (mean) distance between the atoms] ....(01 mark)

(vi) $\dfrac{h}{\sqrt{3mkT'}} = \left[\dfrac{kT'}{10^5}\right]^{\frac{1}{3}}$ ....(01 mark)

$$T'^{\frac{5}{6}} = \frac{h \times 10^{\frac{5}{3}}}{\sqrt{3m} \times k^{\frac{5}{6}}} \quad \text{OR} \quad T' = \left[\frac{h \times 10^{\frac{5}{3}}}{\sqrt{3m} \times k^{\frac{5}{6}}}\right]^{\frac{5}{6}} \quad \text{OR}$$

$T' = \left[\dfrac{h^6 \times 10^{10}}{27m^3 k^5}\right]^{\frac{1}{5}}$ ....(01 mark)

Part III

3. Facts to be considered when answering questions and suggestions :

3.1. Facts to be considered when answering :

General instructions :

* Basic Instructions given in the question paper must be carefully read and understood before starting to answer. The facts such as how many questions have to be answered, which questions are compulsory, the period of time allocated and the amount of marks allotted must be taken into account and before selecting the questions, these things should be clearly read and understood.
* For each of the questions in paper I, only one most appropriate answer must be selected and only one cross must be marked clearly on the answer sheet.
* The answers for each major question of paper II must be started at the top of a new page.
* Answers must be in clear hand writing.
* Index Number of the candidate must be written at the relevant place of each page.
* The Number of Question, its parts and the sub-part must be indicated accurately.
* Extensive answers must not be given where precise answers are expected and also short answers are not sufficient where descriptive answers are expected.
* The facts must be submitted logically and analytically according to the form of the question.
* In answering the paper II, all the parts and subparts of the major question must be well read and only the targeted answer for each sub-part must be written down.
* It is necessary to be accountable to manage the allotted time for each of the questions.
* Red colour pens or Green colour pens should not be used to write the answers. Only Black or Blue pens are allowed.

Special instructions :

* The numerical values given in the questions must be used to make the simplifications of the calculations easy.
* Diagrams must be very clearly drawn and labelled where ever necessary.
* The steps of calculations must be clearly given in the sequential order.
* The units where ever necessary must be used accurately.
* When ray-diagrams (in optics) are drawn, the directions must be indicated using arrow-heads.
* In graphs , the axes *x* and *y* must be labelled accurately and the units also must be given where ever necessary.