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இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Departmen

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2012 අගෝස්තු
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2012 ஓகஸ்ற்
General Certificate of Education (Adv. Level) Examination, August 2012

නව නිර්දේශය
புதிய பாடத்திட்டம்
New Syllabus

# භෞතික විද්‍යාව II
# பௌதிகவியல் II
# Physics II

01 E II

පැය තුනයි
மூன்று மணித்தியாலம்
Three hours

Index No. : ..........................................

**Important :**

- This question paper consists of 12 pages.
- This question paper comprises of two parts, Part A and Part B. The time allotted for both parts is three hours.
- Use of calculators is not allowed.

**PART A — Structured Essay :**
(pages 02 - 06)

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

**PART B — Essay :**
(pages 07 - 12)

*This part contains six questions, of which, four are to be answered. Use the papers supplied for this purpose. At the end of the time allotted for this paper, tie the two parts together so that Part A is on top of Part B before handing them over to the Supervisor.*

*You are permitted to remove only Part B of the question paper from the Examination Hall.*

**For Examiner's Use Only**

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

**Final Marks**

| | |
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| In numbers | |
| In words | |

**Code Numbers**

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|---|---|
| Marking Examiner 1 | |
| Marking Examiner 2 | |
| Marks checked by | |
| Supervised by | |

[see page two

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## PART A — Structured Essay

*Answer all four questions on this paper itself.*

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

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) ................................................... (say $x_1$)

(2) ................................................... (say $x_2$)

(3) ................................................... (say $x_3$)

(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? ..................................................

What is the reason for that? ..................................................

..................................................................................

(*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 $V$.

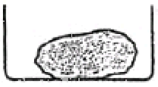

Figure (1)

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

$V_0$ = ..................................................................................

(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?

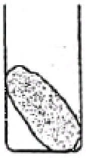

Figure (2)

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

.................................................................................. (say $P$)

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

$d_0$ = ..................................................................................

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(*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.

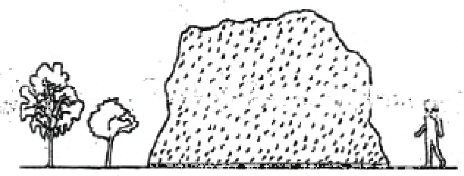

Figure (3)

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

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

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

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

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2. You are asked to perform an experiment to verify that the value of the specific latent heat of fusion of ice is $3.3 \times 10^5$ 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.

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

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(*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 : ........................................................................

(ii) minimum temperature of water : ........................................................................

Give reasons.

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

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

Preparing : ..................................................................................................................

Adding : ..................................................... ......................................................

Mixing : ......................................................................................................................

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

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(*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.

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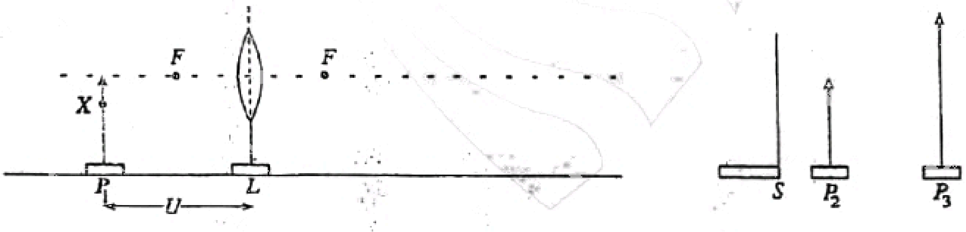
3. You are asked to verify the lens formula by plotting a suitable graph, and to determine the focal length of a convex lens. A partly assembled set-up that can be used for this purpose is shown in the following diagram. *U* is the object distance. You are provided with an object pin $P_1$, lens *L*, 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 $P_1$.

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

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

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(*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.

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

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[see page five

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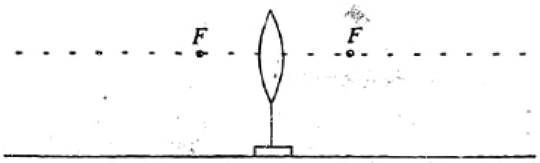
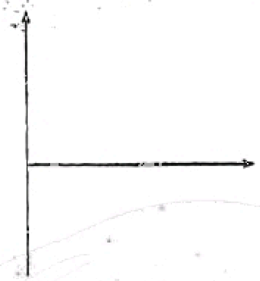
(*d*) Suppose you want to take a few readings with virtual images too. Draw the object pin and the locating pin at appropriate places for taking such a reading, and label them as $P_1$, $P_2$ or $P_3$ in the following diagram (positioning them at exact locations is not necessary).



(*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.



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

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

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(*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.

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

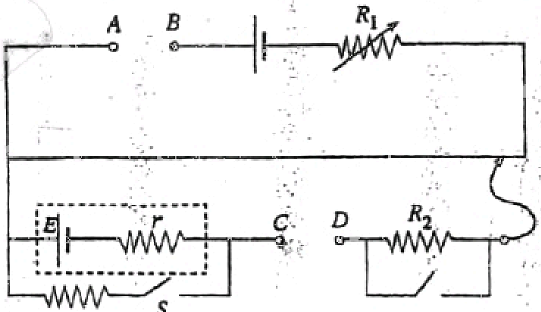

Figure (1)

(*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,

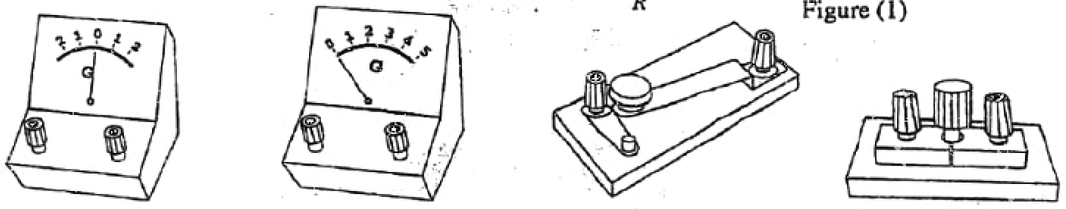

Figure (2)

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

(i) which item would you connect between $AB$? ..........................................................

(ii) which item would you connect between $CD$? ..........................................................

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

(i) ..............................................................................................

(ii) ..............................................................................................

(*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).

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(*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.

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

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(*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.

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கல்விப் பொதுத் தராதரப் பத்திர(உயர் தர)ப் பரீட்சை, 2012 ஓகஸ்ற்
General Certificate of Education (Adv. Level) Examination, August 2012

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புதிய பாடத்திட்டம்
New Syllabus

භෞතික විද්‍යාව II
பௌதிகவியல் II
Physics II

01 E II

## PART B — Essay

*Answer four questions only.*

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

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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.

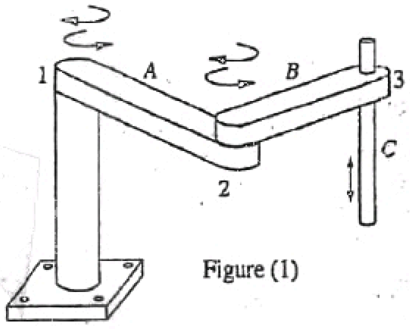

Figure (1)

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

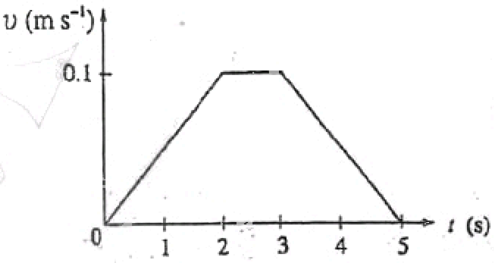

Figure (2)

(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.

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?

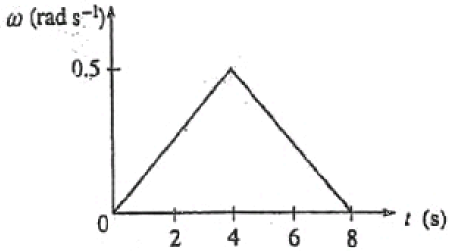

Figure (3)

(*b*) Next consider a rotation of segment *B* (together with segment *C*) occuring around joint 2. The angular velocity ($\omega$) - 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.

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 ($\upsilon$) 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 $\upsilon$ ($\upsilon << c$), 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.

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

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.

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

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

If the light source is moving away from us, $\lambda$ is longer than $\lambda_0$, $\Delta\lambda$ is positive, and the Doppler shift is called a red shift. If the light source is moving toward us, then $\lambda$ is shorter than $\lambda_0$, $\Delta\lambda$ is negative, and the Doppler shift is called a blue shift.

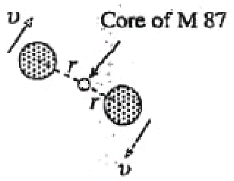

Figure (1)

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.

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 $\upsilon$ and and the other region is moving away from us with the same speed. Figure (2) shows the variation of intensity ($I$) with wavelength ($\lambda$) 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.

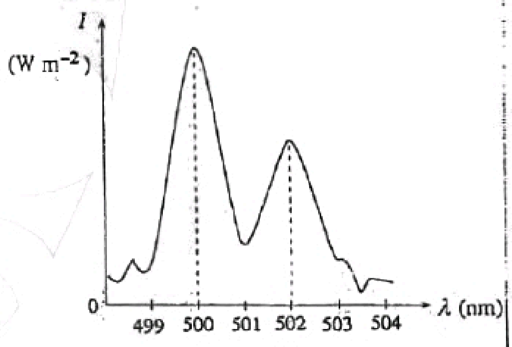

Figure (2)

(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 $\upsilon = \frac{\Delta\lambda}{\lambda_0}c$. [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 $\lambda_0$ (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 $\upsilon$ of the gas. Round off your answer to the nearest integer ($c = 3.0 \times 10^8$ m s$^{-1}$).

(vi) Is $\beta << 1$? Justify your answer.

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

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

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 $3.0 \times 10^3$ kg m$^{-3}$.

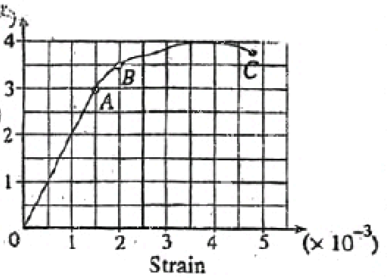

Figure (1)

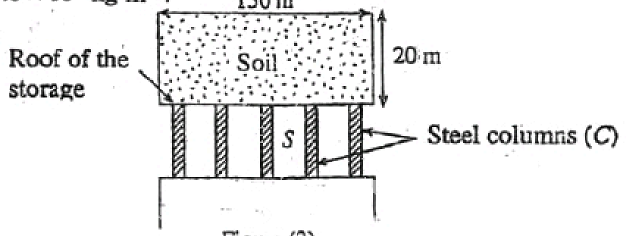

Figure (2)

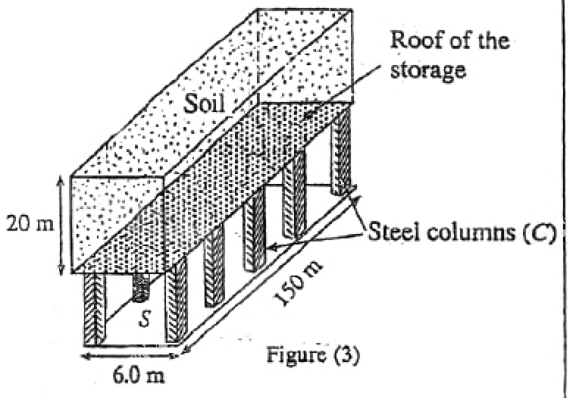

Figure (3)

(*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 $2 \times 10^8$ 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.

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.

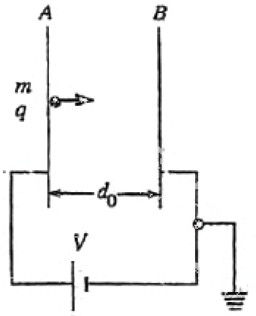

Figure (1)

(*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 $\upsilon$ 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).

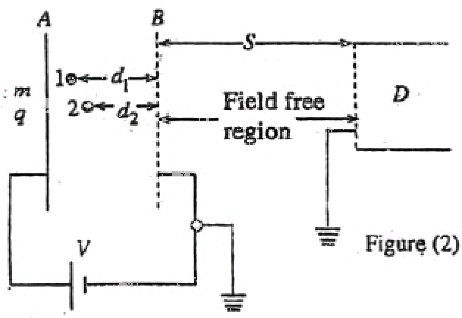

Figure (2)

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 $\upsilon_1$ and $\upsilon_2$ 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 $t_1$, $t_2$, $\upsilon_1$ and $\upsilon_2$ 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).

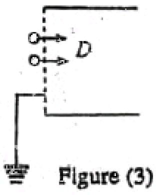

Figure (3)

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

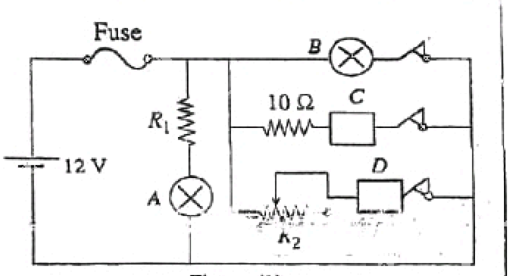

Figure (1)

(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.

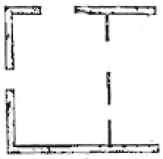

Figure (2)

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.

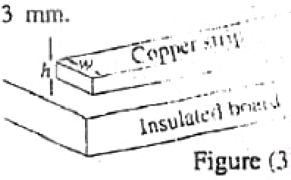

Figure (3)

(i) Calculate the resistance of a 10 mm long copper strip of width $w = 1$ mm. (Resistivity of copper is $1.8 \times 10^{-8}$ 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 temperatu heat capacity and density of copper are 400 J $\text{kg}^{-1}$ $\text{K}^{-1}$ and $9 \times 10^3$ kg $\text{m}^{-3}$ resp

(iv) Copper strips carrying large currents are normally made wider than those carrying sr Give two reasons for this.

(B) (*a*) Write down the truth table for a 2-input AND gate. Use symbols *A* and *B* for inputs and

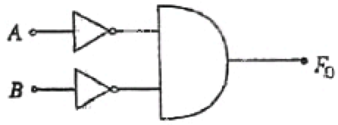

Figure (1)

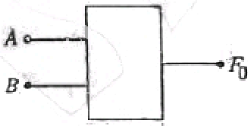

Figure (2)

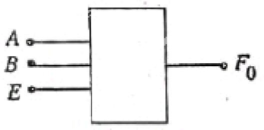

Figure (3)

(*b*) The block diagram of the circuit shown in figure (1) is given in figure (2).

(i) Write down the truth table for the circuit shown in figure (1).

(ii) Hence, show that the circuit shown in figure (1) operates as follows:

$$F_0 = 1 \text{ only when } A = 0 \text{ and } B = 0,$$
$$\text{and } F_0 = 0 \text{ otherwise.}$$

(*c*) Suppose now you use a 3-input AND gate in the circuit shown in figure (1) above instead of a 2-input AND gate. Let the third input be *E*. Then the block diagram will take the form shown in figure (3).

(i) Draw the circuit diagram corresponding to the block diagram in figure (3).

(ii) By filling the two truth tables shown, show that the circuit will operate similar to the circuit given in figure (1) when $E = 1$, and the output $F_0 = 0$ when $E = 0$ irrespective of the values of *A* and *B*.

| A | B | E | $F_0$ |
|---|---|---|---|
| 0 | 0 | 1 | |
| 0 | 1 | 1 | |
| 1 | 0 | 1 | |
| 1 | 1 | 1 | |

| A | B | E | $F_0$ |
|---|---|---|---|
| 0 | 0 | 0 | |
| 0 | 1 | 0 | |
| 1 | 0 | 0 | |
| 1 | 1 | 0 | |

(d) Now draw a circuit diagram using a 3-input AND gate and one NOT gate to operate as follows.

The output $F_1 = 1$ only when $A = 0$, $B = 1$ and $E = 1$

$F_1 = 0$ when $E = 0$

(e) Similarly draw two separate circuits using 3-input AND gates and NOT gates, to operate as follows

(i) Output $F_2 = 1$ only when $A = 1$ and $B = 0$ and $E = 1$

$F_2 = 0$ when $E = 0$

(ii) Output $F_3 = 1$ only when $A = 1$ and $B = 1$ and $E = 1$

$F_3 = 0$ when $E = 0$

(f) Now combine all four circuits drawn under (c)(ii), (d), (e)(i) and (e)(ii) and draw a single circuit so that it will have only 3 common inputs A, B and E, and four outputs $F_0$, $F_1$, $F_2$ and $F_3$.

The circuit that you have drawn should conform with the block diagram given in figure (4).

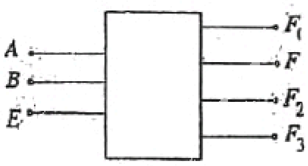

Figure (4)

(g) Suppose you are given four devices, an electric fan, an electric heater, an electric kettle and an electric motor which can be switched ON or OFF with logic signals 1 or 0 respectively.

(i) Draw a block diagram to show how you would connect the devices shown in figure (5) to the block diagram given in figure (4) so that any one of them can be selected and operated, one at a time.

Write down the combination of appropriate logic signals that you would apply to the inputs A and B to select each device.

(ii) How would you keep all the devices in non operative condition using logic signals?

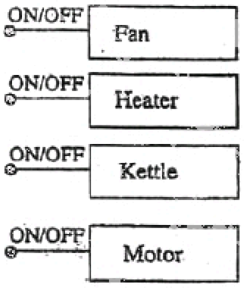

Figure (5)

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 $\theta$ °C be $\rho_0$ and $\rho_\theta$ respectively. Obtain an expression for $\rho_\theta$ in terms of $\rho_0$, $\theta$ and the volume expansivity of water $\gamma$.

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

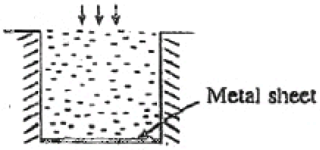

Figure (1)

(*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.

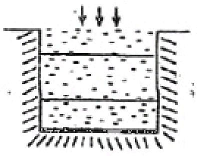

Figure (2)

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 $\rho_0 = 1554$ kg $m^{-3}$ for salt water, calculate the density of salt water at 90 °C. (Volume expansivity of salt water is $4 \times 10^{-4}$ $K^{-1}$)

(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 $m^{-1}$ $K^{-1}$.)

(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 ($\lambda$), 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 [illegible] 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 $\lambda$ of helium atoms in terms of $h$, $k$, $T$ and mass $m$ of a helium atom.

(iii) Calculate $\lambda$ 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 $K^{-1}$)

* * *