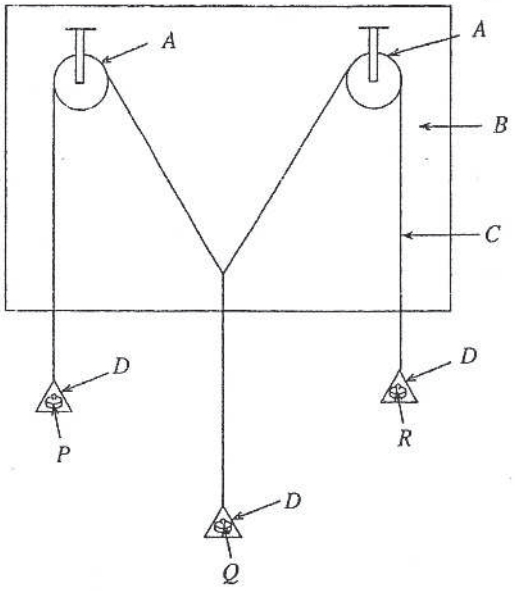
PART A — Structured Essay

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

(g = 10 N kg^{-1})

1. Figure shows a set-up used in a school laboratory to verify the principle of parallelogram of forces.



A - smooth small pulleys
B - vertical drawing board with a white paper pinned on
C - light string
D - light scale pans
P, *Q*, and *R* - weights

(*a*) Give a list of other items needed to carry out this experiment accurately.

.....

.....

(*b*) How do you test whether the friction of the pulleys is negligible?

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(*c*) If the above arrangement is set-up for you, briefly state the steps that you would adopt to verify the principle of parallelogram of forces.

1. .....

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2. .....

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3. .....

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4. .....

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5. .....

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(*d*) In order to carry out this experiment light strings should be used. What is the reason for this?

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(*e*) After completing the parallelogram correctly, a student noticed that the direction of the relevant diagonal was not exactly vertical. Give a reason for this.

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(*f*) If the scale pans are not light what should you do in order to carry out the experiment correctly?

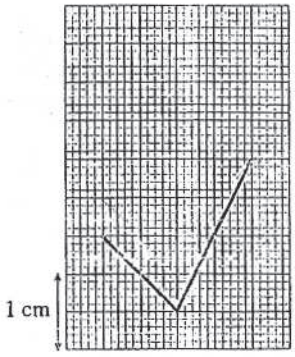
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(*g*) This set-up is used by a student to find the weight of a stone. The relevant sides of the force parallelogram are shown in the figure. Evaluate the weight of the stone (1 cm = 2 N).

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2. A student wants to determine the specific latent heat of fusion of ice using the method of mixtures in the school laboratory. A calorimeter containing water, ice and all other necessary items for the experiment have been provided.

(*a*) Should the initial temperature of water inside the calorimeter be below, above or at the room temperature?

.....

(*b*) Give the reason for your answer in (*a*) above.

.....

.....

(*c*) Give **three** precautionary steps that the student should follow when ice is added into the calorimeter.

.....

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.....

(*d*) When stirring the ice and water mixture, ice pieces should not float on water. What is the reason for this?

.....

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(*e*) What experimental procedure the student should follow when obtaining the final temperature?

.....

.....

(*f*) The student obtained the following data and information from this experiment.

Heat capacity of calorimeter and stirrer	=	40 J K^{-1}
Initial mass of water inside calorimeter	=	100 g
Initial temperature of water	=	35° C
Final temperature of water	=	25° C
Mass of ice melted	=	11 g

Calculate the specific latent heat of fusion of ice.
(Specific heat capacity of water = 4×10^3 J kg^{-1} K^{-1})

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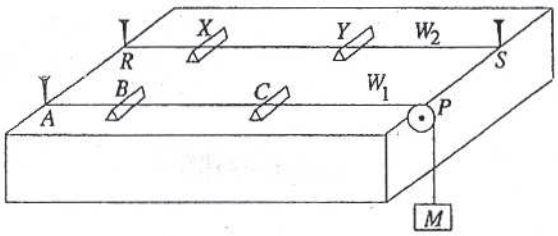
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(*g*) On another day when the room temperature was the same, the student repeated the experiment with the same apparatus and with the same amount of water. But he observed that dew was formed on the surface of the calorimeter when obtaining the final temperature 25° C. The mass of the ice melted is 18 g and the mass of dew formed on the calorimeter is 0·86 g. Assuming that the dew point is 25 °C and heat released by condensing water vapour is completely absorbed by the calorimeter, calculate the specific latent heat of vaporization of water at this temperature.

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3. The sonometer shown in the diagram consists of two stretched thin metal wires W_1 and W_2. One end of W_1 is attached to the nail A and the other end carries a mass M as shown. The pulley P is smooth. W_2 is kept under tension by fixing to the nails R and S.



(*a*) (i) When W_1 is plucked in the middle of BC, the wave vibrates at the fundamental frequency. Draw the wave pattern of the wire produced between B and C in the figure shown below.



(ii) How is a stationary wave of this nature formed?

.....

(iii) If l_0 is the distance between B and C, write down the relationship between the wavelength λ_0 of the transverse wave and l_0.

.....

(iv) If T is the tension and m is the mass per unit length of W_1, write down an expression for the fundamental frequency f_0 in terms of T, m and l_0.

.....

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(*b*) The length XY corresponding to the fundamental frequency of vibration of W_2 in resonance with the fundamental frequency of W_1 is L_0.

(i) Suggest an experimental procedure to be followed in order to obtain L_0.

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(ii) If $M = 4$ kg, $m = 4 \times 10^{-3}$ kg m^{-1} and $l_0 = 12.5$ cm, what is the fundamental frequency of vibration of W_2.

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(iii) The value obtained for L_0 in (*b*)(i) is 20·2 cm. If the length between X and Y is changed to 20·0 cm, find the new fundamental frequency of W_2.

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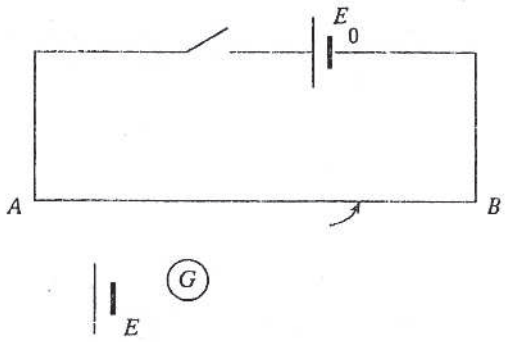
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(iv) Now if both wires are vibrated simultaneously with each of their fundamental frequency, what is the beat frequency obtained.

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4. A partially drawn incomplete arrangement of a potentiometer circuit used to measure e.m.f. E of a cell is shown in the figure.



(*a*) (i) What are the items that you need to use to protect the galvanometer from high currents and to perform this experiment accurately?

(1) .....

(2) .....

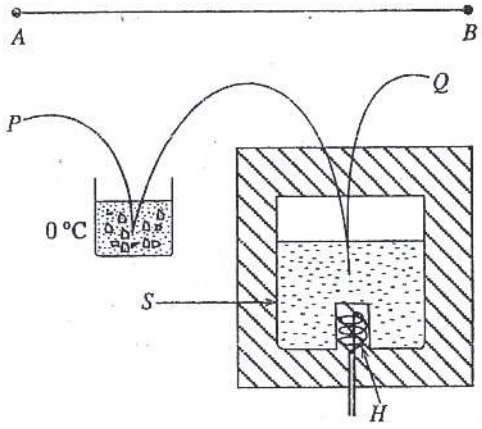
(ii) Complete the given circuit diagram adding the two items mentioned in (i) above and showing all the connections.

(*b*) In the potentiometer circuit shown the length and the resistance of the potentiometer wire are 600 cm and 8 Ω respectively and E_0 = 2·0 V. (Internal resistance of the accumulator is negligible). This potentiometer is needed to be modified in order to measure small voltages of the order of mV, instead of *E*.

If you are provided with a variable resistor *R*, show on a circuit diagram how you would connect this resistor to modify the potentiometer circuit to measure small voltages.

(*c*) The figure shows a part of an experimental set-up with the above potentiometer circuit and a thermocouple arrangement used to measure the specific heat capacity of molten tin.

H - Heating coil
S - Well-lagged container with molten tin



(i) If it is desired to have a potential drop of 40 mV across the full wire length of the potentiometer, what is the value of the resistor *R* that you should use?

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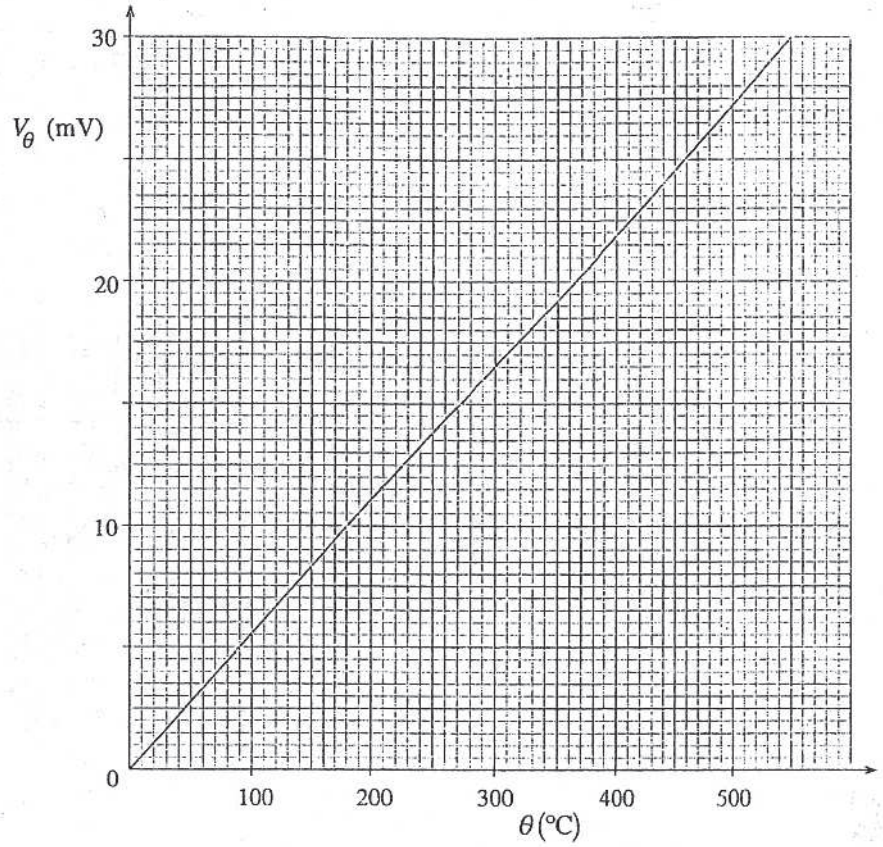
(ii) The balance length at a certain instant, sometime after the heating coil was turned on, was observed to be 240 cm. Find the thermocouple voltage in mV at that instant.

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(iii) Using the graph shown of the thermocouple voltage V_θ (mV) versus temperature θ (°C) find the temperature of molten tin at the instant mentioned in (c)(ii) above.



.....

(iv) The balance length was obtained again two minutes later and its value was 360 cm. If the mass of tin used is 375 g and the power of the heating coil is 100 W, calculate a value for the specific heat capacity of molten tin. Neglect the heat capacity of the container.

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இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka

01 E II

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2005 අප්‍රේල්
கல்விப் பொதுத் தராதரப் பத்திர(உயர் தர)ப் பரீட்சை, 2005 ஏப்பிரல்
General Certificate of Education (Adv. Level) Examination, April 2005

භෞතික විද්‍යාව II
பௌதிகவியல் II
Physics II

PART B — Essay

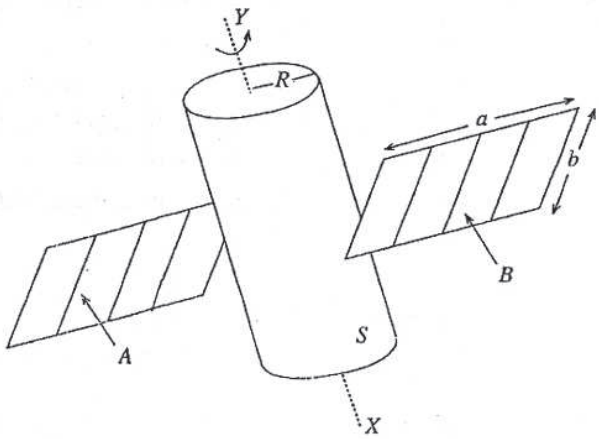
Answer four questions only.

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

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1. Figure shows a satellite having a cylindrical body S and two identical solar panels A and B. This satellite is moving in the space where gravity is negligible and rotates about the axis of the cylinder XY with an angular velocity of 6 revolutions per minute. The plane of the solar panels is perpendicular to the XY axis of the cylinder. Radius of the cylinder $R = 0{\cdot}4$ m and moment of intertia of the cylinder about XY axis $I = 6\,\text{kg m}^2$. For each solar panel, mass $m = 2$ kg, length $a = 1{\cdot}2$ m and width $b = 0{\cdot}6$ m. The moment of inertia of each solar panel about XY is given by

$$m\frac{\left(a^2+b^2\right)}{12}+m\left(R+\frac{a}{2}\right)^2.$$



(i) Calculate the moment of intertia of the satellite about XY.

(ii) Calculate the rotational kinetic energy of the satellite.

(iii) If the two solar panels are folded so that the new moment of intertia of each panel about XY becomes $\frac{1}{4}$ of the previous value, calculate the new moment of intertia and the new angular velocity of the satellite about XY.

(iv) In order to control the rotation of the satellite a mechanism is available to apply a torque τ on the satellite along XY. This mechanism does not change the moment of intertia of the satellite.

(a) If the angular velocity of the satellite has to be brought back to its original value, from the value calculated in (iii) above, by maintaining a uniform angular deceleration for a period of 5 minutes, calculate the magnitude of the angular deceleration and the torque τ required.

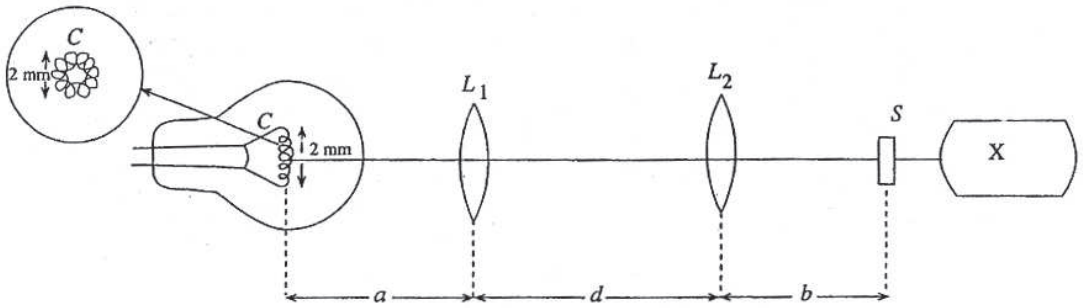
(b) Determine the energy required to bring the angular velocity of the satellite back to the original value.

2. (i) Drawing the usual ray diagram, show that the angular magnification M of a compound microscope is given by

$$M=\frac{l}{f_0}\frac{25}{f_E},$$

when the microscope is adjusted to form the final image at infinity. Here f_0 is the focal length of the objective, f_E is the focal length of the eyepiece and l is the distance between the focal points of the objective and the eyepiece lying between the two lenses. Here all distances are in cm.

(ii) When a microscope is used, care should be taken to illuminate the specimen to achieve better viewing. The following figure shows an arrangement consisting of a lens combination and a lamp, used to illuminate the specimen *S*. The microscope is indicated by *X*.



Each lens has focal length of 20 mm and diameter of 20 mm. The filament *C* has an effective diameter of 2 mm. The distances *a* and *d* are adjusted so that the image of the filament formed by L_1 is positioned on L_2 and fills all of L_2.

(*a*) In this situation,

(1) what linear magnification does L_1 produce?

(2) what are the values of *a* and *d*?

(*b*) For better viewing, the specimen *S* should be placed at the point where the image of L_1 is formed by L_2.

In this situation,

(1) what is the value of *b*?

(2) what is the illuminated area of the specimen?

3. **Read the following passage carefully and answer the questions given below.**

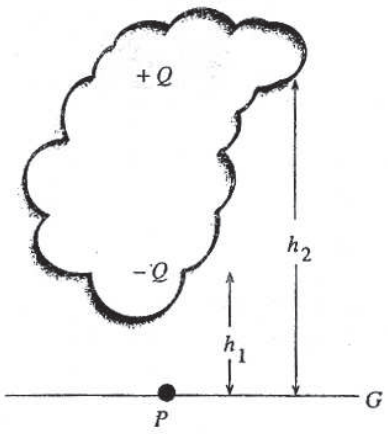


Figure 1

A thundercloud is formed by a strong updraft of warm and humid air. The humid air expands as it rises and its temperature decreases.

Usually thunderclouds have, two main centres of charge, with the lower charge being negative as shown in the figure 1 (Note that the figure is not drawn to a scale).

In this figure the negative charge centre and the positive charge centre are situated at heights h_1 and h_2 above the ground (*G*), respectively. The magnitude of the electric field intensity under a thundercloud is one of the factors which determines the possibility of a lightning flash to the ground. Because the earth is a good conductor compared to air, an approximate value for this electric field can be calculated using a technique called 'method of images'.

A charge $-Q$ will induce a positive charge on the surface of the earth as shown in fig. 2(a). It can be seen that the same pattern of lines of force in fig. 2(a) will be obtained if the earth did not exist and a positive charge $+Q$ was placed, as in fig. 2(b). Therefore the actual electric field intensity at the point *P* on the ground will be the same as the field intensity halfway between these two charges $-Q$ and its mirror image $+Q$.

Lightning could cause human deaths and property damage. To save buildings from lightning, lightning conductors are fixed at the highest points of the buildings. A conductor like this has a pointed end on one side and the other side is connected to a thick copper strip which runs down the building. The lower end of the copper strip has to be grounded properly.

What should one not do during lightning? A discharge can be carried into a house through power lines, telephone wires or even through the water in pipe lines. Therefore we should avoid using electrical equipment such as televisions and telephones during lightning. If you are in outdoor, avoid taking shelter under isolated trees or shacks that are obvious targets. When a lightning stroke hits a tree, a large current flows along the wet channels in the trunk and it may enter a person who is either standing near or leaning on the tree. This current that enters a tree subsequently flows along the surface of the ground. The potential difference produced between two points on the ground about 1 m apart can result in a fatal current flow through animals or people. One can minimize the effect of such a potential difference by keeping one's feet together.

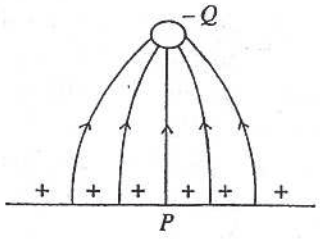


Figure 2 (a)

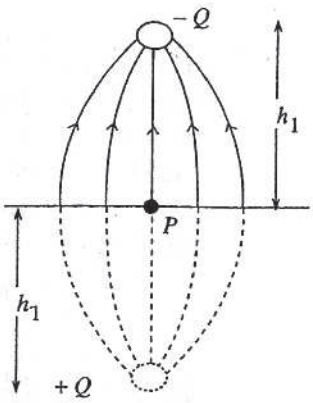


Figure 2 (b)

(i) If you are inside a house during lightning list **two** things that you should avoid doing.

(ii) If you are at outdoor why is it dangerous to stand near or lean on a tall tree during lightning?

(iii) To protect buildings from lightning, lightning conductors are used. Give reasons for the following.

(*a*) Open end of a lightning conductor should be pointed.

(*b*) Lightning conductor should be properly earthed.

(*c*) The connecting copper strip has to be thick.

(iv) Why do the air masses

(*a*) expand

(*b*) cool

as they ascend?

(v) (*a*) Using the method of images, show that the magnitude of the resultant electric field intensity E at point P in figure 1 is given by

$$E = \frac{Q}{2\pi \epsilon_0}\left[\frac{1}{h_1^2} - \frac{1}{h_2^2}\right]$$

(*b*) Taking $Q = 20$ C, $h_1 = 3$ km and $h_2 = 6$ km, calculate E. $\left(\frac{1}{2\pi \epsilon_0} = 1{\cdot}80 \times 10^{10}\ \text{N m}^2\ \text{C}^{-2}\right)$.

What is the direction of this field?

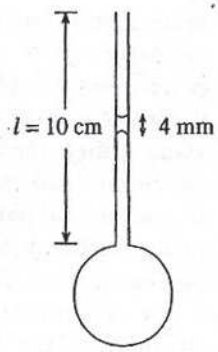
Hence determine the induced surface charge density on the ground at point P.

($\varepsilon_0 = 8{\cdot}85 \times 10^{-12}\ \text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}$).

(vi) Suppose a single lightning stroke transfers a charge of –5 C through a potential difference of 10^8 V. Calculate the energy released by this lightning discharge assuming the potential difference remains constant. State **two** modes of dissipation of this energy.

(vii) During lightning, cattle standing on the ground have high risk of getting killed even in the absence of a direct lightning strike. Suggest a reason for this.

4. A soap bubble of radius R = 2·5 mm is formed at the lower end of a narrow vertical glass tube of length l = 10 cm and internal radius r = 0·8 mm. The soap bubble is kept at equilibrium by having a small column of the same soap solution of length 4·0 mm as shown in the diagram.



(i) Calculate the surface tension T of the soap solution. Assume that the density of the soap solution is 1050 kg m^{-3} and the angle of contact between glass and the soap solution is zero.

(ii) (*a*) If now the bubble is broken and the height of the liquid column is gradually increased by adding soap solution, calculate the height at which the lower meniscus becomes flat.

(*b*) What is the maximum height of the liquid column that can be kept inside the tube?

(iii) When a soap bubble of radius R is formed at the lower end of the narrow tube described above without trapping the air by a column of the soap solution, air will escape through the upper end of the tube and the radius R of the bubble will decrease with time t according to the equation,

$$R^4 = \frac{-Tr^4}{2\eta l} t + A$$

where A is a constant and η is the viscosity of air.

A student decides to find the viscosity of air by finding the radius of the bubble at different times. Since it was difficult to measure the diameter of the bubble directly, the student obtains a real image of the bubble on a screen using a convex lens. His observations are as follows.

Distance between the soap bubble and the lens = 15·0 cm
Distance between the lens and the screen = 27·0 cm

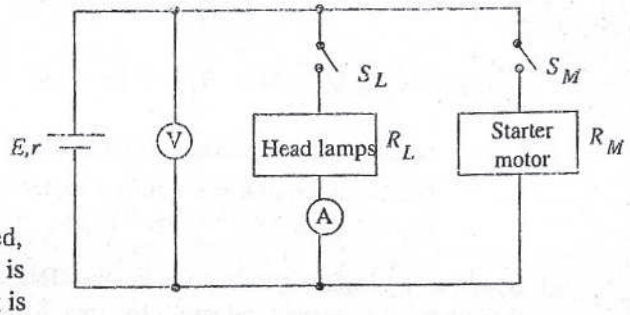
Time (s)	Diameter of image
0	51·0 mm
30	36·5 mm

(*a*) Find the radii of the soap bubble at t = 0 and t = 30 s, to the nearest mm.

(*b*) Using the value of T obtained in (i) find a value for the viscosity of air.

5. **Answer either part (a) or part (b) only.**

(a) Figure shows a part of the electrical circuit of a motor car. E and r are the e.m.f. and the internal resistance respectively of the car battery. The ammeter and the voltmeter connected to the circuit can be considered as ideal.



(i) When the switches S_L and S_M are opened, voltmeter reading is 12 V. When S_M is opened and S_L is closed ammeter reading is 10 A and voltmeter reading is 11·5 V.

(*a*) Determine E and r.

(*b*) If the two head lamps are identical and if they are connected in parallel, determine the power dissipation by a head lamp.

(ii) The current that should be supplied to the starter motor in order to start the car is 50 A. When the starter motor is turned on while the head lamps are on, the lights become dim and the ammeter reading drops to 8·0 A.

(*a*) Is it possible to start this car engine while head lamps are on? Explain your answer.

(*b*) Determine the resistance R_M of the starter motor.

(*c*) Is it possible to start this car engine when head lamps are off? Explain your answer.

(iii) An old car battery can become 'sulphated'. When this happens, chemical structure of the battery plates changes. As a result, the internal resistance of the battery increases without changing the e.m.f.

(*a*) How would this affect on starting a car? Give the reasons for your answer.

(*b*) However this battery can be used to light a 12 V, 6 W bulb with almost full brightness. Explain this.

(b) (i) It has become necessary to operate a certain electronic device that requires a precise 10 V supply voltage, by a 12 V battery. A circuit suitable for this purpose, which can reduce a 12 V supply to 10 V, is shown in figure 1.

In this circuit, the load resistance of the electronic device is represented by R_L. The breakdown voltage of the Zener diode is 10 V.

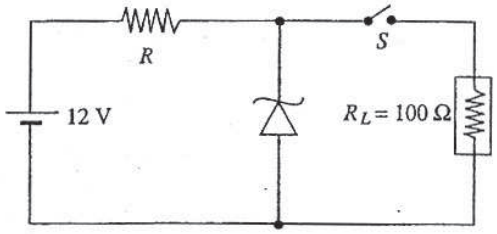


Figure 1

(*a*) Assuming that the battery has no internal resistance, calculate the value of R that will allow a 10 mA current through the Zener diode, when the switch S is closed.

(*b*) For the value of R obtained in (*a*) above, calculate the power dissipation of the Zener diode when

(1) the switch S is closed, and

(2) the switch S is opened.

Hence state the minimum power rating of the Zener diode required for the proper operation of the circuit.

(ii) A better circuit that can be used for the purpose of obtaining 10 V is shown in figure 2.

The breakdown voltage of the Zener diode used in this circuit is 10·6 V.

(*a*) If the transistor used in this circuit is a silicon transistor, show that the electronic device receives the correct supply voltage. (Assume that the potential difference across a forward biased silicon diode is 0·6 V.)

(*b*) If the current gain (β) of the transistor is 99, calculate the base current I_B when the switch S' is closed.

(*c*) Calculate the maximum power dissipation of the Zener diode and determine whether a Zener diode of $\frac{1}{4}$ W power rating will be sufficient for the proper operation of the circuit.

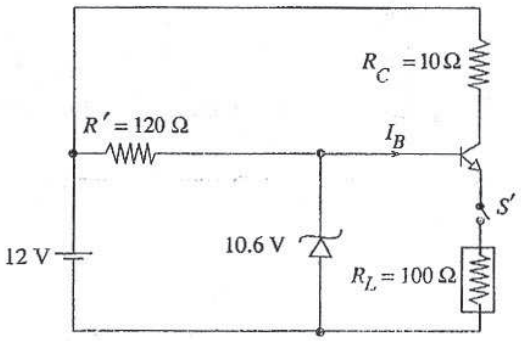


Figure 2

(*d*) What is the advantage of this circuit, compared to the circuit used in part (i) above?

6. Answer either part (a) or part (b) only.

(a) A small building having a wall area 100 m^2 exposed to the surrounding is made with brick walls of thickness 10 cm. This building has a wooden door of area 3 m^2 of thickness 2 cm and a glass window of area 4 m^2 made of a single glass sheet of thickness 0·5 cm. The temperature inside the building is maintained at 25°C using an air conditioner. The outside temperature remains at 30° C. Heat transfer through the ceiling and the floor of the building can be neglected.

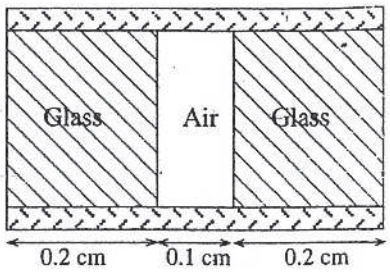
(i) What is the rate of heat transfer from the surroundings into the building?

Thermal conductivity of brick = 0·6 $Wm^{-1}\ K^{-1}$

Thermal conductivity of wood = 0·1 $Wm^{-1}\ K^{-1}$

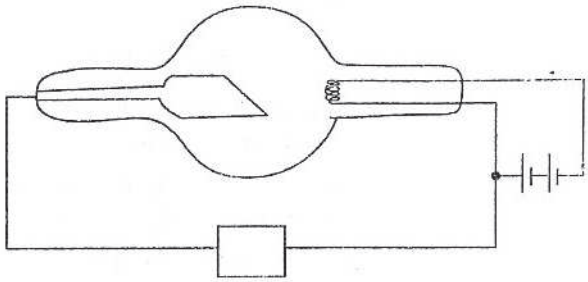
Thermal conductivity of glass = 0·8 $Wm^{-1}\ K^{-1}$

(ii) Suppose instead of the single glass sheet the window is made of two glass sheets of equal thickness of 0·2 cm with an air gap of thickness 0·1 cm, as shown in the figure. By what percentage the heat transfer rate through the window reduce due to this change?
(Thermal conductivity of air = 3×10^{-2} Wm^{-1} K^{-1})



(iii) The dew point inside the building is 20 °C and the dew point outside is 25° C. If the relative humidity outside is 80 %, calculate the relative humidity inside the building.
Saturated vapour pressures of air at 30 °C and 20 °C are 30 mm Hg and 16 mm Hg respectively.

(b) (i) A sketch of an X-ray tube is given in the diagram. Copy the diagram and label the target, the filament and the high voltage supply showing the correct polarity.



(ii) Briefly state how the electrons inside the tube are produced.

(iii) Why should the X-ray tube be evacuated?

(iv) What is the supply voltage required to produce X-rays of maximum energy 100 keV?

(v) Find the wavelength of 100 keV X-rays in Å.

(vi) When X-rays go through human tissue or bone, they are absorbed mainly through photoelectric effect. The effect of X-rays on living beings (effective dose) depends on the amount of X-ray energy absorbed by a unit mass of tissue or bone. It is measured by a unit called sievert (Sv). 1Sv = 1 J kg^{-1}. For persons who do not work with radiation an accumulated annual effective dose above 1 mSv is considered to be dangerous. (Effective dose due to the unavoidable background radiation is not included in this.)

(*a*) If the accumulated annual background effective dose is 2 mSv, calculate the background effective dose rate in units of $\mu Sv\,hr^{-1}$.

(*b*) The maximum permissible annual effective dose for a radiation worker in an X-ray laboratory is 20 mSv. If he works 40 hours per week and 40 weeks per year, determine the average maximum effective dose rate in $\mu Sv\,hr^{-1}$ allowed in the X-ray laboratory for him to be safe.

(*c*) The intensity I of an X-ray beam is normally considered as the number of photons travelling through a unit area per unit time. When exposed to an X-ray beam of intensity I, the effective dose rate H received by human tissue is given by $H = 0{\cdot}57\ IEa\ \mu Sv\,hr^{-1}$, where E is the energy of an X-ray photon in MeV, a is the mass absorption coefficient of tissue in $cm^2\ g^{-1}$ and I is the beam intensity in $cm^{-2}\ s^{-1}$.

(1) The time taken to get a chest X-ray photograph is 0·1 s. If $I = 9{\cdot}4 \times 10^5$ photons $cm^{-2}\ s^{-1}$, $a = 0{\cdot}027\ cm^2\ g^{-1}$ and $E = 100$ keV, determine the effective dose received by tissue when a chest X-ray is taken.

(2) Assuming that the above dose is received by a 5 kg of body tissue, calculate the number of X-ray photons absorbed by the tissue.

Planck's constant	=	$6{\cdot}6 \times 10^{-34}$ J s
Speed of light	=	$3{\cdot}0 \times 10^8$ m s^{-1}
1 eV	=	$1{\cdot}6 \times 10^{-19}$ J

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