S. Weperuma

AL/3/S/A/15

CONFIDENTIAL

SRI LANKA EXAMINATIONS DEPARTMENT

G.C.E.(A/L) EXAMINATION - 1994

SUBJECT

PHYSICS

SUBJECT NO:

03

PAPER - II

MARKING SCHEME

94ALMS/21/rs.

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SCHEME OF ASSESMENT

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අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 1994 අගෝස්තු
General Certificate of Education (Adv. Level) Examination, August 1994

03	භෞතික විද්‍යාව II PHYSICS II	B / 10		පැය තුනයි Three hours

Important : This question paper consists of **three** sheets. Put the sheets together in the correct **order of pages before** answering.

Use of calculators is **not** allowed.

This paper consists of **two** *parts* **A** *and* **B.** *The time allowed for both parts is* **three** *hours.*

PART A *contains* **four** *questions, all of which are to be answered. Answers to these questions must be written in the space provided in the question paper.*

PART B *contains* **eight** *questions of which* **four** *are to be answered. Answers to these are to be written on the writing paper provided.*

At the end of the time allowed for this paper, tie the **PARTS A** *and* **B** *together as one paper with* **PART A** *on top and hand them over to the Supervisor.*

PART A — Structured Essay

Answer all four questions.

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

Do not write anything in this column

1. (a) What is the basic cause for surface tension phenomenon observed in liquids ?

Attraction between molecules or cohesive forces between molecules — 01

(b) (i) If you are given a suitable capillary tube, what is the essential equipment needed to determine the surface tension of water using the capillary rise method ?

Travelling microscope Cathitometer — 01

(ii) Write down an expression for the surface tension of water, T, in terms of the capillary rise, h, radius of the capillary, r, density of water, ρ, and the acceleration due to gravity, g. (Assume the angle of contact to be zero.)

$T = rh\rho g/2$ (or any correct form) cos θ can be included. — 01

(iii) When this experiment was performed by students in a class using capillary tubes with same radius and identical set of apparatus, the heights h obtained by some students seemed to be very different. What is the main cause for this ?

The tubes are not cleaned properly or the tubes are dirty — 01

(iv) To overcome this discrepancies certain experimental procedure should have been adopted correctly. Give the steps of this procedure.

Wash the tube with caustic soda (NaoH), then with an acid and lastly with (distilled) water. the order — 01

Do not write anything in this column

(c) In such an experiment when the capillary tube is withdrawn from water and held vertically, a small column of water is found to remain at the bottom of the tube, Will the radius of the lower meniscus of this water column be same as that of the upper meniscus ? Explain your answer.

or pressure exerted by the liquid column

No. Because of the weight of the water column, ... 01

the pressure difference across the two meniscusi are not the same. 01

[award full marks if the student has shown that the two radii are different by writing down correct expressions]

(d) When the capillary tube is held horizontally and water from a constant pressure head is connected to one end of the tube, water is found to flow out of the other end very slowly.

(i) What property of the water determines the rate of flow ?

Viscosity or Coefficient of viscosity 01

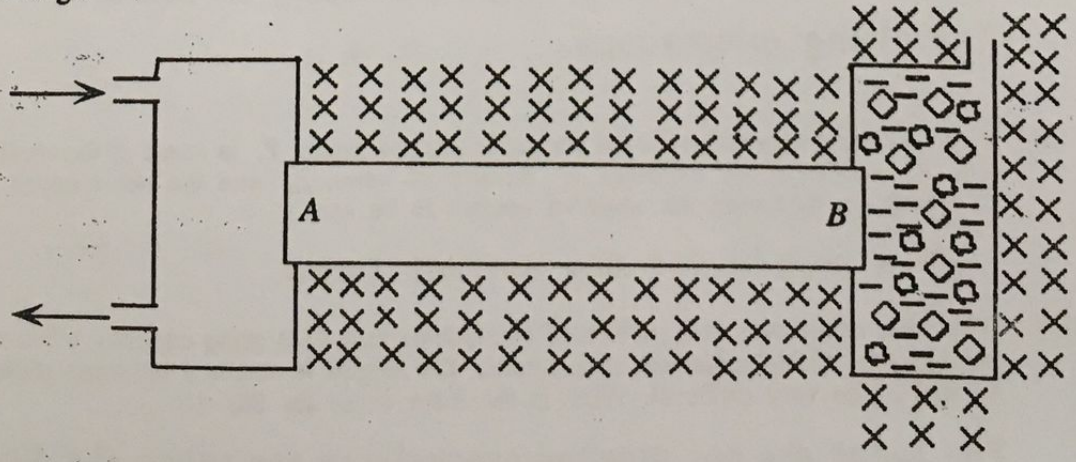
(ii) To determine the above property of water, the radius of the tube has to be measured very accurately. What is the other reason for this, apart from radius being small ?

Viscosity is determined by the rate of flow which is proportional to (radius)^4 01

(iii) For the same reason as in d(ii) above the tube must be of uniform bore. How would you check whether the given tube is of uniform bore ?

By measuring the length of a mercury thread at different places in the tube. 01

2. Figure shows a uniform metal rod *AB* of length 50 cm whose one end, *A*, is maintained at 100 °C and the other end, *B*, is in contact with a water-ice mixture at 0 °C. The cross-sectional area of the rod is 0.5 cm^2 and it is well lagged. You can assume that there is no heat transfer with the surroundings.



(a) (i) What is the most important physical property of the material used for the lagging ?

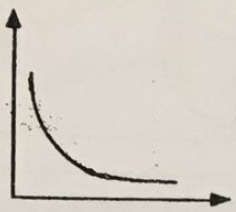
(Low) thermal conductivity or thermal insulation 01

ii) Liquids are generally not used for lagging. What is the main reason for this?

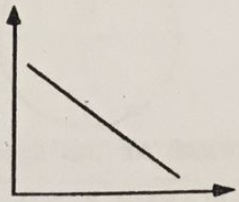
Heat is lost by convection currents 01

Do not write anything in this column

(b) Draw rough sketches of the temperature variations along the rod,
(i) at any instant before reaching the steady state.
(ii) in the steady state.



(i)



(ii)

(Look for the shape only) 02
(01 mark each)

(c) What is the temperature gradient along the rod, in the steady state ?

$(100-0)/(50\times10^{-2}) = 200\ ^{o}C(K)\ m^{-1}$ or $2\ ^{o}C(K)\ cm^{-1}$ 01 +01 unit

(d) If the rate of melting of ice in the steady state is 0.01 kg s^{-1}, find the rate of heat flow through the rod.
(specific latent heat of fusion of ice = 3×10^5 J kg^{-1})

$.01 \times 3 \times 10^5 = 3 \times 10^3\ Js^{-1}$ 01

(e) Calculate the thermal conductivity of the material of the rod.

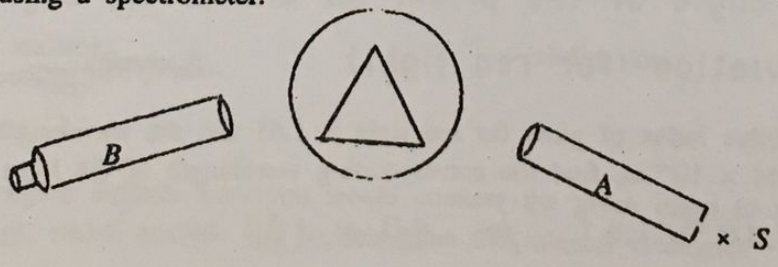
$= (3 \times 10^3)/(0.5\times 10^{-4}) \times 200$ [for correct substitution] 01

$= 3 \times 10^5\ W^{o}C^{-1}(K^{-1})m^{-1}$ [with the correct unit] $Js^{-1}{}^{o}C^{-1}m^{-1}$ 01

(f) After sometime the ice gets completely melted. If you wait long enough will the water boil ? Explain your answer.

No, when the temperature of water (reaches 100 °C,) ~~01~~
the heat flow stops due to zero temperature gradient across the rod. 01

3. Figure shows an experimental arrangement to produce a pure spectrum of the light from a source of white light *S* using a spectrometer.



(a) (i) What kind of lamp is suitable for the white light source *S* ?

Incandescent lamp or filament lamp, electric bulb 01
Candle - no marks

(ii) Name the components *A* and *B*.

A = Collimator
B = Telescope } 01

Do not write anything in this column.

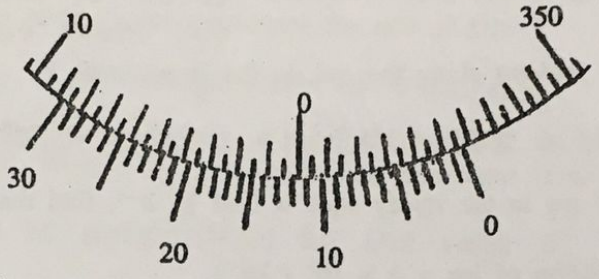
(b) When a student attempted to observe the images of the slit reflected from the two faces of the prism he observed the two images as shown below.



What was the reason for this appearence ?

The prism table is not levelled (or not horizontal) 01

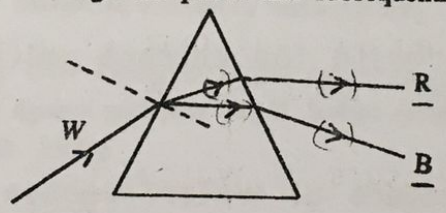
(c) The following figure shows the spectrometer scales for a certain setting.



What is the spectrometer reading indicated ?

354°15′(no mark for 5° 45′) no marks for 354.15° 01

(d) (i) If *W* is a ray of white light incident on the prism as shown, draw the paths of the blue and red rays through the prism and subsequently through air.



01

(ii) Which colour (blue or red) of light travels faster in glass ?

Red 01

(e) To determine the refractive index of glass for red light, the white light source is replaced by a red light source. What measurements would you require ?

Refracting angle of the prism (or the prism angle) 01

Minimum deviation (for red light) 01

(f) (i) If the refractive index of glass for red light is 1.61 and the wavelength of red light in air is 6.44×10^{-7} m, find the corresponding wavelength of the light in glass.

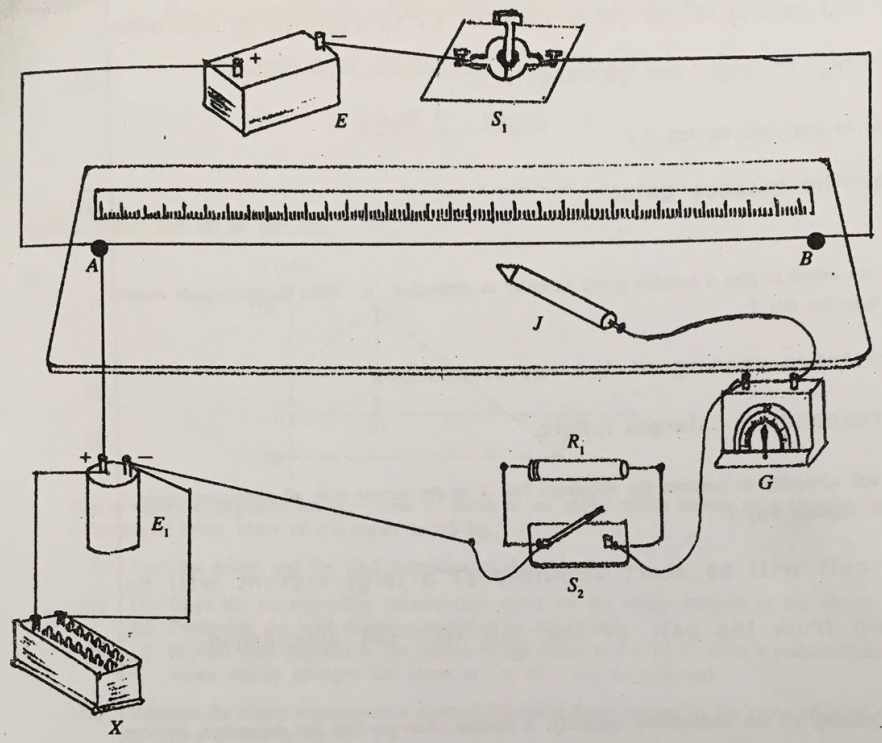
$=(6.44 \times 10^{-7})/1.61$ $= 4.0 \times 10^{-7}$ m 01

(ii) Will there be a change in colour of the light in glass due to the above change of wavelength ? Justify your answer.

No, there is no change in frequency 01

Do not write anything in this column.

4. Diagram below shows the apparatus which can be used in an experiment to determine the value of the internal resistance r of a cell E_1.



AB –	Potentiometer wire	S_1 –	plug key
G –	centre zero galvanometer	S_2 –	tap key
E –	accumulator	X –	resistance box
R_1 –	1 kΩ resistor	J –	sliding key

(a) In the above figure indicate how you would connect the given items to form a suitable electrical circuit, which enables you to determine the internal resistance r of the cell E_1

Correct circuit diagram
[One mark for the connection of E and S_1 with AB] 02

(b) Why is it advisable to use an accumulator for E ? 2 mf.

To obtain a steady (or constant) voltage (or current) across the potentiometer wire during the experiment. 01

Do not write anything in this column.

(c) What is the purpose of the resistor R_1 ?

For the safety of the galvanometer, or to avoid large currents flowing through the galvanometer 01

(d) When do you close the key S_2 ?

Near the balance point 01

(e) You are asked to plot a suitable graph in order to determine r. What measurements would you take for this ?

Resistance reading of the resistance box 01

Corresponding balance length 01

(f) It is not advisable to connect the resistance box X to the circuit with all resistance plugs closed. Explain why ?

The cell will be short circuited or a large current will be drawn from the cell or the cell will get discharged 01

(g) After making all the connections correctly, a student observes that the dependent variable mentioned in (e) above stays at the same value when the resistance plugs are being removed one by one. What is the most probable reason for the above observation ?

The infinity resistance plug has been pulled out 01

(h) A student says that in order to perform this experiment the e.m.f. of the cell E_1 has to be always less than that of E. Is the above statement true ? Give reasons for your answer.

Not true. Here the quantity that will be balanced is the potential difference across E_1 (or the potential difference across the resistance box) which can be less than the e.m.f. of E. 01

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G.C.E. Advanced Level Examination - August 1994

Scheme of Assesment for Physics II

PART B - Essay

1. Answer **either** part (a) or part (b).

(a)

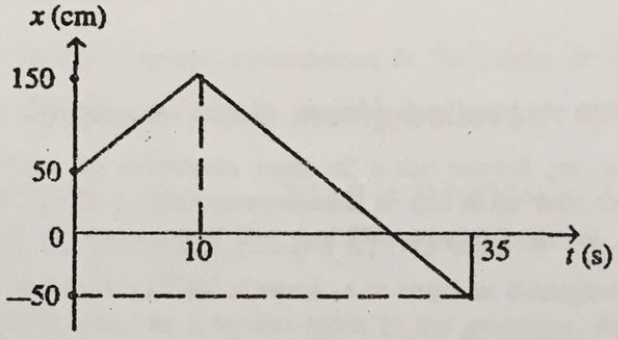


Figure shows a displacement (x) - time (t) curve of an object which moves in a straight line on a horizontal table. Mass of the object is 0.5 kg.

(i) Find the initial and the final velocities of the object.

(ii) (a) Draw the corresponding velocity-time curve for the whole journey of the object.
(b) Determine the total distance travelled by the object.
(c) Explain what happens to the motion of the object at t = 10 s. Give a practical example where similar changes that occur at t = 10 s can be observed.

(iii) Suppose the object experiences a constant frictional force exerted by the table after 35 s, and it comes to rest in further 2 s .
(a) What is the magnitude of the frictional force acting on the object ?
(b) Calculate the coefficient of kinetic friction between the object and the table.

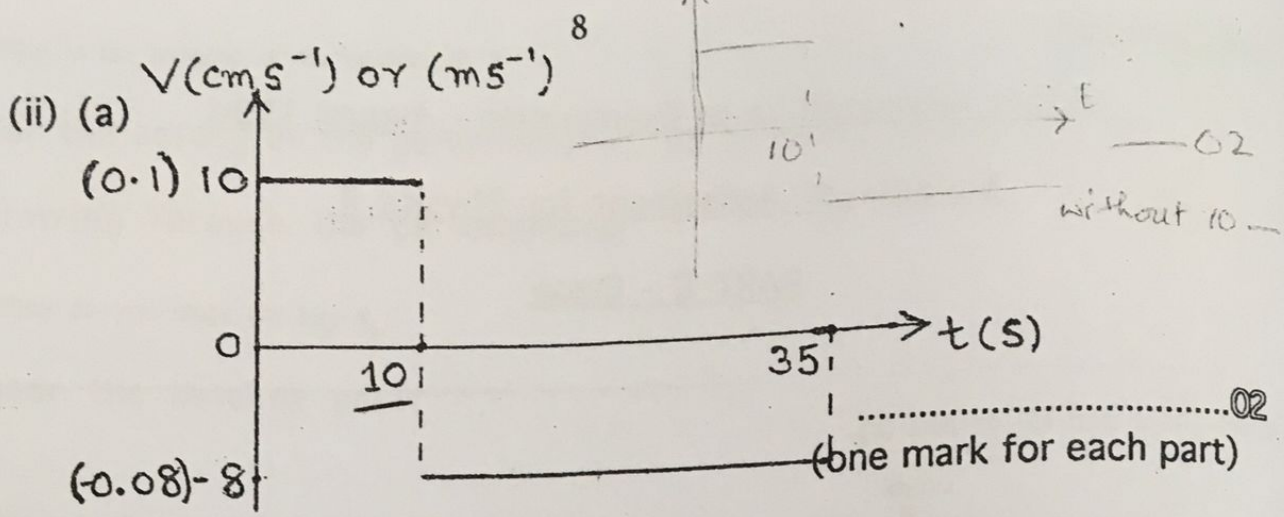
(i) Initial velocity = (150 - 50)/10 01

= 10 cm s^{-1} (1.0x10^{-1} m s^{-1}).....01 +01 (unit

Final velocity = - (150+50)/(35-10) 01

=(-)8 cm s^{-1} (-8x10^{-2} m s^{-1}) 01

(ii) (a)



.....02

(one mark for each part)

(b) Total distance travelled (from the v-t curve)

=10x10 + 8x25

= 300 cm (3 m).....02

[OR from the x-t curve the total distance travelled

= (150-50)+150+50

= 300 cm (3 m).....02]

(c) At t = 10 s the velocity is reversed OR the object turns back....01

Bouncing back of a ball when it hits the ground or a wall
(accept any type of similar example as above) 01

(iii) (a) Retardation of the object(applying v = u+at) = 8/2 01

= 4 cm s^{-2} ($4x10^{-2}$ m s^{-2})

∴ the frictional force = $0.5x4x10^{-2}$

= $2x10^{-2}$ N 01

[OR Applying $(1/2)mv^2 = Fs$

where $s = \frac{(0.08+0)2}{2}$ 01

= 0.08m

Then, $(1/2)x0.5x(.08)^2 = Fx.08$

∴ F = $2x10^{-2}$ N .....01]

(b) using $F = \mu R$ 01

the coefficient of kinetic friction $\mu = \frac{2x10^{-2}}{0.5x10}$ 01

$= 4x10^{-3}$ 01

(b) The present electrical energy consumption in Sri Lanka is 3.0×10^9 kWh per year.

(i) Calculate the above energy consumption per year in Joules.

(ii) Calculate the **minimum** mass of water needed per year to generate the above amount of electricity in a hydro-power plant, if the water falls from a vertical height of 200 m. State clearly the assumption that you have made to arrive at the answer.

(iii) Taking the rate of flow of water to be constant throughout the year, determine the force exerted by falling water on a turbine blade in the generator. Assume that the water strikes the blade perpendicular to its surface and then flows along the surface without any recoil.

(iv) The Ceylon Electricity Board estimates that the energy demand for electrical power will increase to 7.5×10^9 kWh per year in the year 2000. The Board plans to meet this increase in energy demand by operating coal powered thermal power stations. Calculate the mass of coal needed per year to generate the extra amount of electrical energy. Assume that a coal power station operates with an overall efficiency of 40%.
(1 kg of coal on burning gives 4.5×10^5 kJ of energy.)

(i) Energy consumption per year = $3.0x10^9x10^3x3600$.....01

$= 1.08x10^{16}$ J 01

(ii) Let M be the minimum mass of water needed

Then, $Mgh = 1.08x10^{16}$ (Mgh - 01 mark;equating 01 mark).....02

$M = 5.4x10^{12}$ kg 01

Assumption: The grvitational potential energy (or the kinetic energy) of falling water is totally transformed into electrical energy. OR the energy transfer is 100% 01

(iii) Let v be the speed at which water strikes the blade

Then, $Mgh = (1/2)Mv^2$ (for equating P.E. and K.E OR using $v^2=2gh$)..01

$v^2 = 2x10x200$

$v = 20\sqrt{10}\ ms^{-1}$

mass of water incident per second = $\frac{5.4x10^{12}}{365x24x3600}$ 01

Since the water does not recoil, the rate of change of momentum of water(or the force exerted on the blade) → Idea

$= Mv$ 01

$= \frac{5.4x10^{12}}{365x24x3600} \times 20\sqrt{10}$

$= 1.08x10^7$ N ....or $1.1x10^7$.....02

(deduct 01 mark if the unit is wrong)

(iv) Extra amount of electrical energy to be generated

$=(7.5 - 3.0)10^9$ kWh 01

(for the subtraction)

$= 4.5x10^9$ kWh

Let M' be the mass of coal needed

Then, $M'x4.5x10^5 x \frac{40}{100} = 4.5x10^9x3600$ 02

(for the L.H.S. term - 01 mark;
for equatin - 01 mark)

$M' = 9.0x10^7$ kg 01

2. Distinguish between the elastic limit and the proportional limit of a given material.

Two uniform steel wires of equal lengths of 0.5 m and cross-sectional area of 0.5 cm^2 and 0.2 cm^2, respectively, are connected together to form a compound wire of length 1m.

The Young's modulus and the proportional limit of steel are 2.0×10^{11} N m^{-2} and 2.5×10^{8} N m^{-2} respectively.

(i) What is the maximum mass that can be hunged by the compound wire so that the proportional limit is not exceeded ? Calculate the total elongation of the compound wire in this situation.

(ii) If the two wires are joined at the ends so that they are parallel to each other and forms a compound wire of length 0.5 m, what is the maximum mass that can be hunged by the compound wire so that the proportional limit is not exceeded ?

Elastic limit : Up to this limit the strain becomes zero when the stress is removed. OR the material comes to its original shape when the stress is removed. 01

Proportional limit: Up to this limit the strain (or the extension) is linearly proportional to the stress. (or to the load) 01

(i) The force acting in each wire is the same 01

∴ The proportional limit reaches first in the thinner wire. 01

Then, the maximum weight that can be hunged

$= 2.5 \times 10^{8} \times 0.2 \times 10^{-4}$ 01

$= 5 \times 10^{3}$ N

∴ the maximum mass that can be hunged

$= 5 \times 10^{2}$ kg .....01 +01 unit

[OR the maximum weight that can be hunged by the thinner wire

$= 2.5 \times 10^{8} \times 0.2 \times 10^{-4}$ 01

$= 5 \times 10^{3}$ N

the maximum weight that can be hunged by the thicker wire

$= 2.5\times10^{8}\times0.5\times10^{-4}$ 01

$= 1.25\times10^{4}$ N

∴ the maximum weight that can be hunged by the compound wire

$= 5\times10^{3}$ N 01

∴ the maximum mass that can be hunged by the compound wire

$= 5\times10^{2}$ kg .....01 +]01 unit

Using e = (F/A)(L/Y)

Elongation of the thinner wire, $e_1 = \frac{2.5\times10^{8}\times0.5}{2.0\times10^{11}}$ 01

$= 6.25\times10^{-4}$ m

Elongation of the thicker wire, $e_2 = \frac{5\times10^{3}}{0.5\times10^{-4}} \times \frac{0.5}{2.0\times10^{11}}$ 01

$= 2.5\times10^{-4}$ m

∴ The total elongation = e_1+e_2 01

$= (6.25+2.50)\times10^{-4}$

$= 8.75\times10^{-4}$ m .....(8.8 01

(ii) The elongation in each wire is the same. ∴ the stress in each wire is the same since the lengths are equal. 01

∴ the maximum weight that can be hunged by the compound wire

$= 2.5\times10^{8}\times0.2\times10^{-4} + 2.5\times10^{8}\times0.5\times10^{-4}$ 02

(01 mark for ~~each~~ each term; ~~01 mark for the addition~~ 01 mark for the addition)

$= 1.75\times10^{4}$ N .....1.8 .....~~01~~

then the maximum mass = 1.75×10^{3} kg 01

AMENDMENTS

PART A

1. (b) Award this mark even if the answer to (a) is incorrect.

   (c) Alternative answers:
   (i) Lower Jaws OR Larger Jaws
   (ii)Upper Jaws OR Smaller Jaws
   OR shown in a diagram correctly.

   (g) No mark for stating that the volume of sheet is small. OR the volume of water cannot be measured accurately.

3. (a) Disregard the screen S.

   (c) Alternative answer :
   The focal length of the concave lens is less than that of the convex lens.

4. (a) (iii) Award the mark for any correct statement of the law given in terms of the direction of e.m.f.

   (c) (ii) Alternative answer:
   This is done by making the core with thin metal sheets insulated from one another.

   (d) (ii) Award this mark for the correct reason even if the answer to (d) (i) is incorrect.

AMENDMENTS

PART A

1. (b) Award this mark even if the answer to (a) is incorrect.

   (c) Alternative answers:
   (i) Lower Jaws OR Larger Jaws
   (ii)Upper Jaws OR Smaller Jaws
   OR shown in a diagram correctly.

   (g) No mark for stating that the volume of sheet is small. OR the volume of water cannot be measured accurately.

3. (a) Disregard the screen S.

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   The focal length of the concave lens is less than that of the convex lens.

4. (a) (iii) Award the mark for any correct statement of the law given in terms of the direction of e.m.f.

   (c) (ii) Alternative answer:
   This is done by making the core with thin metal sheets insulated from one another.

   (d) (ii) Award this mark for the correct reason even if the answer to (d) (i) is incorrect.

2. Compare the advantages and disadvantages of the following three methods used in determining the specific heat capacity of water :

(A) Joule's electrical calorimeter method
(B) The method of mixtures
(C) The continuous flow method

An ice cube of mass 100 g kept at a temperature of — 40 °C is dropped into a large amount of water in a container which is at 0 °C. Assume that no heat is transferred with the surroundings.

(i) Calculate the mass of water that will freeze to form ice. Where will this ice settle ?

(ii) What would you expect to happen if the container initially contained only 20 g of water ? Determine the final temperature attained by the ice cube in this situation. Neglect the heat capacity of the container. (specific heat capacity of ice = 2.1×10^3 J kg^{-1} K^{-1} ; specific latent heat of fusion of ice = 3.36×10^5 J kg^{-1})

	ADVANTAGES	DISADVANTAGES
Joule's Calorimeter	(1) No heat loss during transfer of material. (3) No possible spill overs.	(2) Not a straight forward method.
Method of Mixtures	Simple and straight forward method.	Heat losses during transfer. Possible spill overs.
Continuous flow Method	(4) Heat capacity of the container does not come into calculations. (5) Heat losses can be eliminated. (6) Temperature measurements can be taken accurately.	Not simple and straight forward. (7) complex arrangement. (8) Requires a large quantity of water.

.....04

(one mark for each comparison - maximum of 04 marks)

(i) Heat gained by the ice cube = $100x10^{-3}x2.1x10^{3}x40$ 01

If M is the mass of water that will freeze to form ice,

then, the heat loss by the water = $Mx3.36x10^{5}$ 01

$Mx3.36x10^{5} = 100x10^{-3}x2.1x10^{3}x40$ 01

$M = 2.5x10^{-2}$ kg (25 g).....01

This frozen water will settle on the ice cube. 01

(ii) All the water will freeze. 01

Let the final temperature be θ,then

* Heat gained by the ice cube = $100x10^{-3}x2.1x10^{3}x[\theta - (-40)]$ 01

Latent heat lost by the freezing water = $20x10^{-3}x3.36x10^{5}$ 01

Heat lost by the ice formed = $20x10^{-3}x2.1x10^{3}x(0 - \theta)$ 01

$100x10^{-3}x2.1x10^{3}x[\theta + 40] = 20x10^{-3}x3.36x10^{5}$

$+ 20x10^{-3}x2.1x10^{3}x(0 - \theta)$ 01
(for equating)

$\theta = -6.7\ ^{0}C$ ..... 6.66 6.6 – 6.8 01

* If a student get the an answer less than 20g for 1st and then argue correctly.

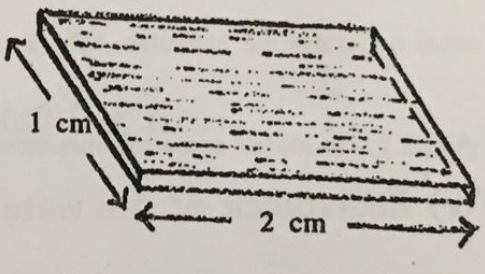
4. On a day when the relative humidity of the atmosphere is 85%, a certain room of capacity 50 m^3 was completly closed and isolated from the rest of the atmosphere. The room temperature was found to be 30 °C at the time of closure. Use the above data and the table given below to calculate,

(i) the dew point of the room.

(ii) the mass of water vapour condensed inside the room when the temperature drops to 24 °C during the night.

Temperature (°C)	Mass (g) of water vapour required to saturate 1 m^3 of air
30	30.01
29	28.45
28	26.93
27	25.51
26	24.11
25	22.80
24	21.51
23	20.35

(iii) Assume that 0.01% of the mass calculated in (ii) above is deposited over the upper surface of a rectangular plate made of carbon, forming a uniform film of water on it. This plate is shown in the figure and it's width and length are 1 cm and 2 cm respectively. Calculate the thickness of the water film formed on the plate. (density of water = 10^3 kg m^{-3})



(iv) The plate has an electrical resistance of 30 Ω along its length. Due to the formation of the water film, the effective resistance of the plate along its length will change. Calculate this change in the resistance as a percentage (resistivity of water = 10^{-3} Ω m)

(v) For better performance some electronic equipment are usually kept in air - conditioned rooms. What is the major reason for this ?

(i) The mass of water vapour present in 1 m^3 of air at 30^0C

$= \frac{30.01 \times 85}{100}$ 01

$= 25.51$ g

$\therefore$ the dew point of the room = 27^0C 01

(ii) The mass of water vapour condensed in 1 m^3 of air when the temp. drops

$= 25.51-21.51$ 01

$= 4\ g$

$\therefore$ The mass of water vapour condensed in the room

$= 4x50 = 200\ g$ 01

(iii) volume of water condensed $= \frac{200x10^{-3}}{10^3}$ 01

$= 200x10^{-6}\ m^3$

Let h be the thickness of the water film formed, then

$1x10^{-2}x2x10^{-2}xh = 200x10^{-6}x\frac{0.01}{100}$ 02

(L.H.S. - 01 mark ; equation - 01 mark)

$h = 1.0x10^{-4}\ m\ (0.1\ mm)$ .....01 with units

(iv) Resistance of the water film (using $R = \rho L/A$)

$= \frac{10^{-3}x2x10^{-2}}{1x10^{-2}x10^{-4}}$ 01

$= 20(\Omega)$ 01

Let R be the effective resistance of the plate, then

$\frac{1}{R} = \frac{1}{30} + \frac{1}{20}$ (or the parallel idea) 01

$R = 12(\Omega)$ .....

the change in the resistance $= 30 - 12$ 01

$= 18\ \Omega$ 01

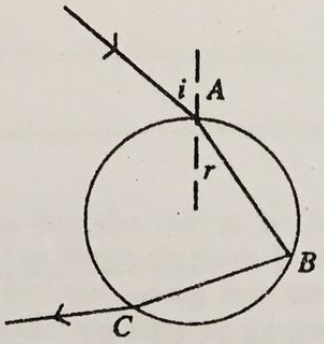
$\therefore$ the percentage change $= \frac{18x100}{30}$

$= 60\%$ .....

(v) To acheive low humidity conditions OR to prevent condensation of water 01

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

(a) Why does the refractive index vary from medium to medium ?



As shown in the figure a monochromatic ray of light in air is incident on the surface of a spherical water drop at *A*, with an angle of incidence *i*. The ray is refracted into the water with a refractive angle *r*. Reaching the opposite side of the drop at *B*, the ray is partly reflected back and emerges into air at *C*.

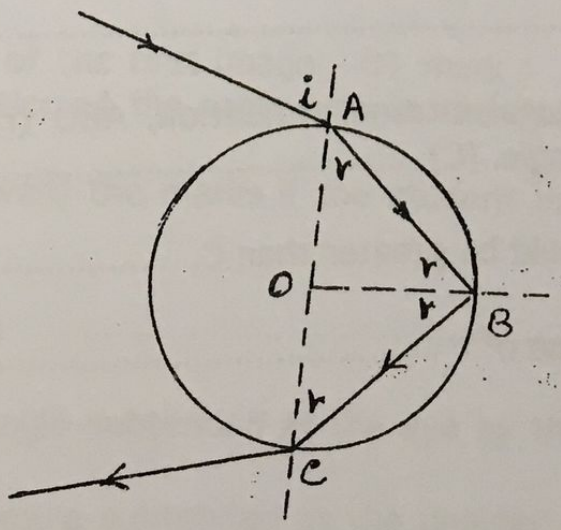
(i) What is the value of the angle of emergence ?

(ii) Derive an expression for the **total** deviation of the ray in terms of *i* and *r*.

(iii) if $i = 30°$, and the ray is **fully** deviated by an angle of 156°, calculate the refractive index of water for the given colour.

(iv) Can the ray suffer total internal reflection at the opposite side for some values of *i* ? Justify your answer.

speed of light vary from medium to medium 01



(i) Identifying ABO as r 01

Identifying OBC as r 01

then OCB = r

∴ angle of emergence = i 01

(ii) deviation suffers at A = i - r 01

deviation suffers at B = 180 - 2r 01

deviation suffers at C = i - r

∴ the total deviation = i-r+180-2r+i-r 01
(addition of individual deviations)

= 2i - 4r + 180 01

(iii) 2i - 4r +180 = 156

2x30 - 4r + 180 = 156 01

$r = 21^0$ 01

$n = \frac{\sin 30^0}{\sin 21^0}$ [for n = (sin i)/(sin r)] 01

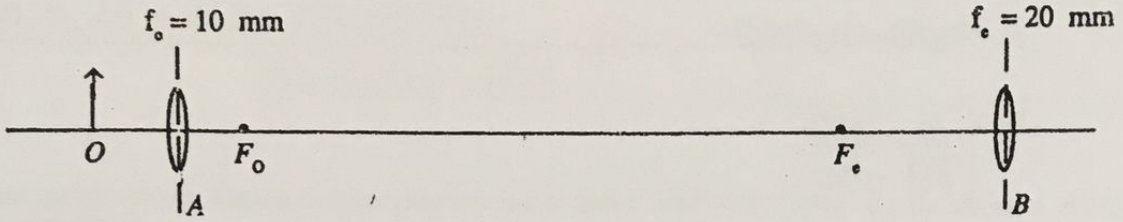
= 1.4 01

(iv) No,if the ray suffers total internal reflection, ABO (r) should be greater than the critical angle. (C) 01

Then the angle OAB also should be greater than C. 01

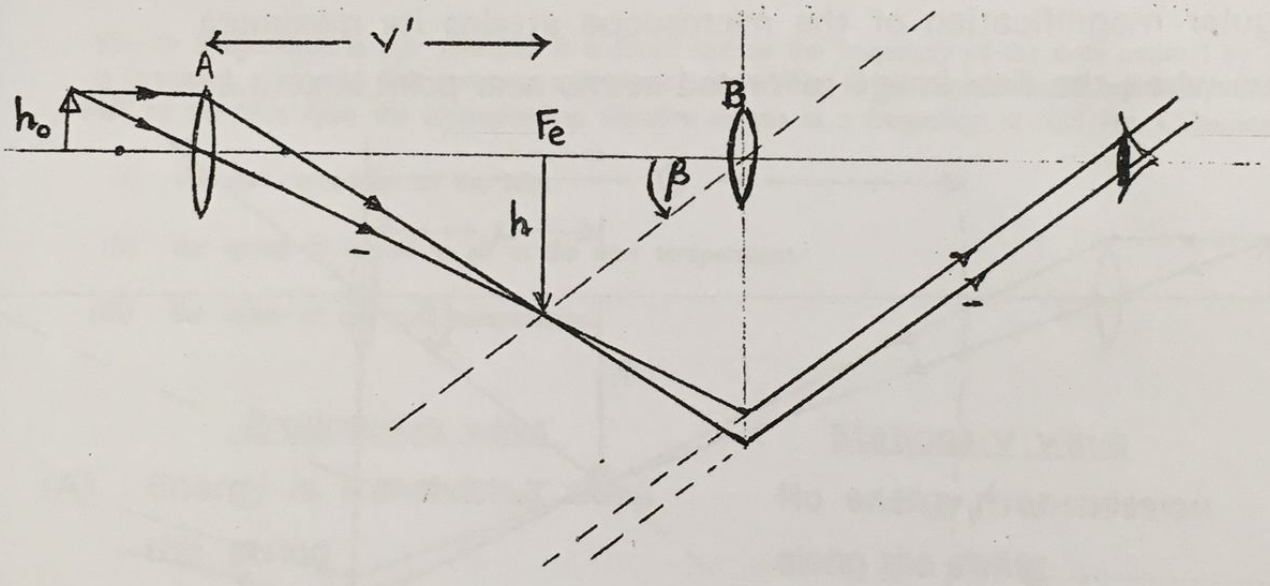
This is impossible for any value of i 01

(b) The diagram shows two converging lenses arranged as a compound microscope.



The focal length of the objective lens, *A*, is 10 mm and that of the eye piece lens, *B*, is 20 mm. If the final image of an object placed at *O*, 12 mm from the objective lens is formed at infinity, trace the paths of two rays coming from the head of the object through the microscope to the eye. Calculate the angular magnification (magnifying power) of the microscope.

The separation of the lenses is changed keeping the object distance fixed until the angular magnification of the microscope attains its maximum value. What is the position of the final image in this situation ? Calculate the new lens separation and the angular magnification of the microscope. (The least distance of distinct vision is 25 cm).



.....02

(Location of the first image - 01 mark ;
continuation of the same rays to the eye - 01 mark)

(do not award the marks if the student has drawn only a single ray)

$M = \beta/\alpha$ 01

where, β = angle subtended at the eye by the image

α = angle subtended at the unaided eye by the object when it is at the near point.

$\beta = h/20$ 01

$\alpha = h_o/D = h_o/250$ 01

$M = \frac{h}{20} \cdot \frac{250}{h_o}$

Applying $1/v - 1/u = 1/f$ to the objective lens 01

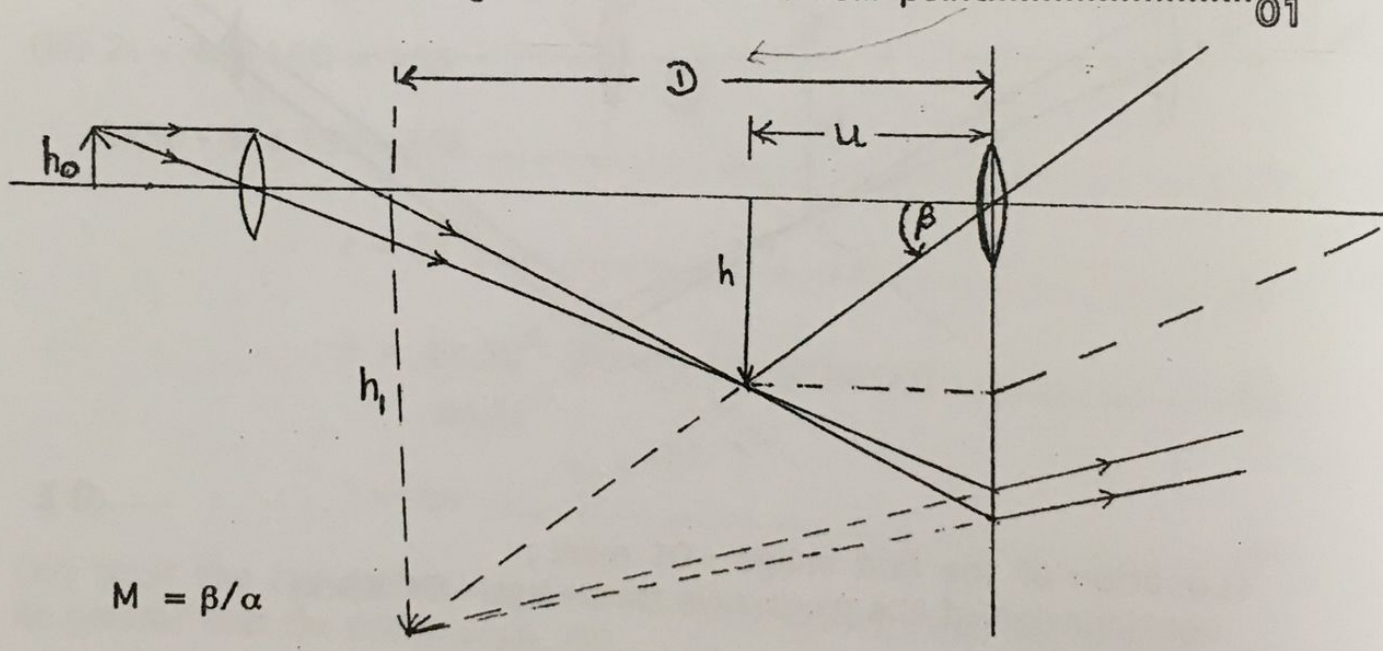
$1/v' - 1/12 = -1/10$ 01

$v' = -60$ mm (60 mm) 01

Now, $h/h_o = 60/12 = 5$ 01

$\therefore$ the angular magnification = 62.5 01

Angular magnification of the microscope attains its maximum value when the final image is formed at the near point..... 01



$M = \beta/\alpha$

$\beta = h_1/D$; $\alpha = h_o/D$

$M = h_1/h_o = \frac{h_1}{h} \cdot \frac{h}{h_o} = \frac{h_1 \cdot 5}{h}$ 01

Again applying $1/v - 1/u = 1/f$ for the eyepiece

$1/250 - 1/u = -1/20$ .....

$\therefore \quad u = 250/13.5$ mm (18.5 mm) 01

New lens separation = 60 + 18.5

= 78.5 mm 01

Then, h_1/h = 250x (13.5/250)

M = 13.5x5 = 67.5 01

6. Distinguish clearly between a progressive wave and a stationary wave set up along a string considering the following:

(A) the energy transmitted along the string
(B) the amplitude of the points on the string
(C) the frequency of the points on the string

Give the essential steps of a laboratory method in determining the speed of sound in air.

A variable frequency source emitting a pure note is placed just above the open end of a uniform vertical tube 0.5 m long. The lower end of the tube is closed. If the frequency of the note emitted by the source is gradually raised from 150 Hz to 900 Hz, at what frequencies will resonance occur ? The speed of sound in air is 330 m s^{-1}, at the room temperature, 27 °C. (You can neglect the end correction of the tube.)

The air temperature is now changed. It is found that as the frequency of the note emitted by the source is increased, resonance first occurs at a frequency of 168 Hz. If the experiment is repeated with the lower end of the tube open the corresponding situation occurs at a frequency of 335 Hz. Calculate,

(i) the end correction of the tube.

(ii) the speed of sound in air at the new temperature.

(iii) the value of the new temperature.

Progressive wave	Stationary wave
(A) Energy is transmitted along the string	No energy transmission along the string. 01
(B) Amplitude is same for all the points.	Amplitude vary from point to point. 01
(C) Frequency is same for all the points.	Frequency is same for all the points. 01

Experiment:

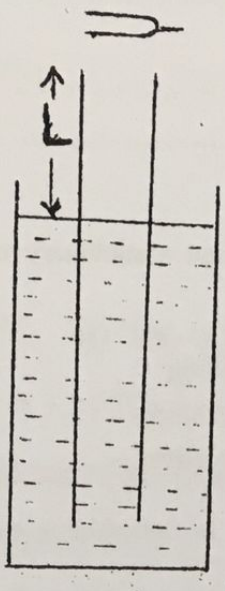


Diagram 01

Starting with a very short length of the air column, move the tube up (or increase the length of the air column) until resonance (or a loud sound) occurs for the first time (or with the shortest length of the air column) with a tuning fork of known frequency. 01

Repeat the experiment with several tuning forks and measure the corresponding length of the air columns (L) 01

Then $v = 4f(L+e)$ OR $L = (v/4)(1/f) - e$

Plot a graph of L vs 1/f. v can be determined from the gradient. 01

The corresponding wavelength of the resonating air columns are given by 2 m ($\lambda = 4 \times 0.5$), 2/3 m, 2/5 m, (2/7 m etc.). 01

$f = v/\lambda = 330/\lambda$

∴ The frquencies at which resonance occur are

165 Hz, 495 Hz, and 825 Hz. 01

Let v' be the speed of sound at the new temperature, then

$v' = 168x4(0.5+e)$ 01

$v' = 335x2(0.5+2e)$.....01

By solving,

$e = 1.5$(mm.).....01

$v' = \cancel{336}\ ms^{-1}$ $337\ ms^{-1}$ 01

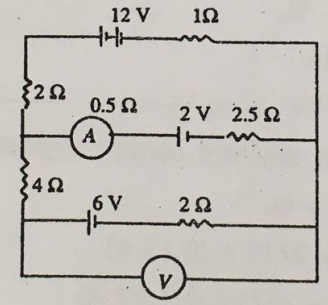
$v/\sqrt{T} = const$ (OR $v \propto \sqrt{T}$) 01

$330/\sqrt{300} = 33\cancel{6}/\sqrt{T}$

$T = 311$ K ($38^{\circ}C$) $313\ K\ (40^{\circ}c)$ 01

7. **Answer either part (a) or part (b)**

(a)

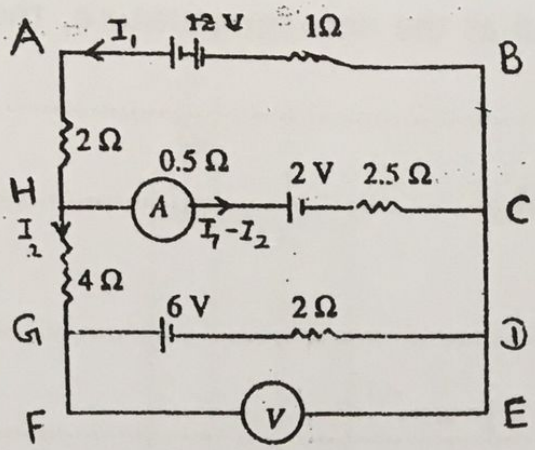


In the circuit shown, all the batteries have negligible internal resistances, ammeter *A* has a resistance of 0.5 Ω and *V* is a voltmeter with infinite resistance.

(i) Find (a) the readings in the ammeter *A* and voltmeter *V*.
(b) the energy supplied by the 12 V battery in 2 s.
(c) the total heat dissipated in the circuit in the 2 s duration.

(ii) What is the reason for the difference in your answers to parts (i)(b) and (i)(c) ?

(iii) When *A* and *V* are interchanged in the above circuit, find the new readings of *A* and *V*.



(i) (a) No current flows through the voltmeter

If I_1, I_2 are the currents in the branches AH and HG, then current through HC is I_1-I_2 (application of Kirchhoff's first law) 01

For the circuit AHCBA

$12 - 2 = I_1 2 + (I_1-I_2)(0.5+2.5) + I_1 1$ 01

$10 = 6I_1 - 3I_2$

For the circuit AGDBA

$12 - 6 = 3I_1 + 6I_2$ 01

(award marks for any two correct expressions)

$6 = 3I_1 + 6I_2$

On solving $I_2 = 2/15$ A (0.13 A)

$I_1 = 26/15$ A (1.73 A)

∴ current through the ammeter = $I_1 - I_2 = 26/15 - 2/15$

$= 8/5$ A = 1.6 A 01

Reading of the voltmeter = $6 + 2xI_2$ 01

(for the correct expression)

$= 6 + (4/15)$

$= 6.27$ V 01

(b) Energy supplied by the 12 V battery in 2 s

$= 12 \times I_1 \times 2$ 01

(for the correct expression)

$= 12 \times (26/15) \times 2$

$= 41.6$ J 01

(c) Total heat dissipated in the circuit in 2 s

$= I_1^2(2+1)x2 + I_2^2(4+2)x2 + (I_1 - I_2)^2(2.5+0.5)x2$ 01

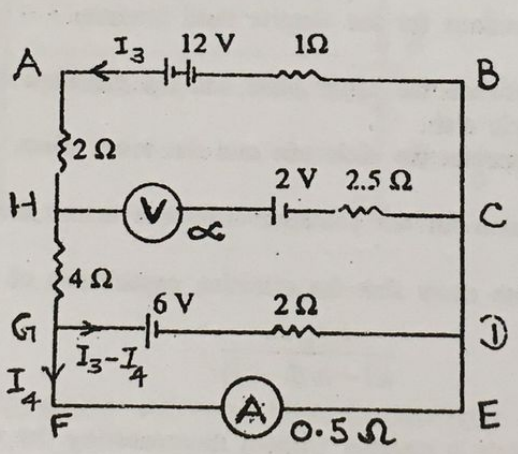
(for the correct expression)

$= 33.5$ J 01

(ii) The difference is used to do work against the opposing e.m.f. s of the other batteries OR it is used to charge the other batteries.

.....01

(iii)



No current flows in the arm HC OR no current flows through the voltmeter. (OR indicating on the diagram) 01

For the circuit AGDBA

$12 - 6 = I_3(2+4) + (I_3-I_4)2 + I_3 1$

For the circuit GFED 01

$6 = I_4 0.5 - (I_3-I_4)2$ (for both 01 mark)

On solving $I_4 = 66/18.5$ A

$\therefore$ the current through the ammeter = 3.57 A.....01

$I_3 = 27/18.5 = 1.46$ A

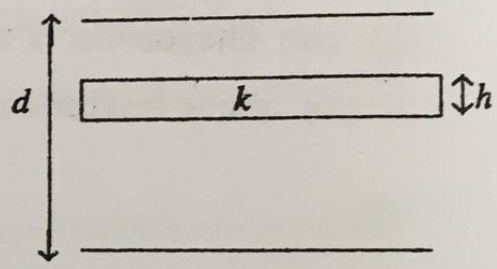
Reading of the voltmeter = 12 - 3 x 1.46 - 2 01

(for the correct expression)

= 5.62 V

(b) A parallel plate capacitor having plate area A carries a charge Q. If the capacitor is placed in air derive an expression for the electric field intensity E across the plates.

A parallel plate capacitor placed in air has a plate area A and a plate separation d. It is charged to charge Q by connecting a constant voltage source across the plates. The voltage source is then disconnected and a slab of dielectric constant k and thickness h is inserted between the plates as shown in the figure.



(i) Write down expressions for the electric field intensity :

(a) in the gap between the upper plate and the dielectric slab.
(b) in the dielectric slab.
(c) in the gap between the dielectric and the lower plate.

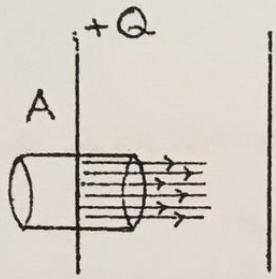
(ii) Derive an expression for the potential difference across the plates of the capacitor.

(iii) Hence or otherwise show that the effective capacitance of the capacitor is given by

$$\frac{k \varepsilon_0 A}{kd - h(k-1)}.$$

(iv) If the dielectric slab is inserted without disconnecting the voltage source what will be the final charge on the capacitor ?

(v) In which situation it is easier to insert the dielectric slab? Explain your answer without doing any calculations.



.....01

Consider a cylindrical volume with unit area of crossection and perpendicular to the plates of the capacitor as shown above.

Total outward flux through the surface of the cylinder

$= E + 0$ 01

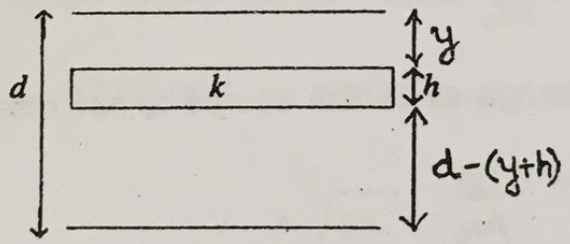
Total charge enclosed by the volume = Q/A 01

$\therefore$ according to Gauss's theorem $E = Q/(A\varepsilon_0)$.....01

(i) (a) $E_1 = Q/(A\varepsilon_0)$ 01

(b) $E_2 = Q/(kA\varepsilon_0)$ 01

(c) $E_3 = Q/(A\varepsilon_0)$ 01



(ii) potential difference across the capacitor

$$V = \frac{Q\,y}{A\varepsilon_0} + \frac{Q\,h}{kA\varepsilon_0} + \frac{Q\,[d-(y+h)]}{A\varepsilon_0}$$ 02

(01 mark for a correct term, with a maximum of 02 marks)

$$V = \frac{Q\,[kd - h(k-1)]}{kA\varepsilon_0}$$ 01

(award the mark for any equivalent form)

(iii) Applying $Q = CV$ 01

$$C = \frac{kA\varepsilon_0}{[kd - h(k - 1)]} \quad \text{.....01}$$

[Alternative Method:

By considering three series capacitors

$$\frac{1}{C} = \frac{y}{A\varepsilon_0} + \frac{h}{kA\varepsilon_0} + \frac{[d - (y+h)]}{A\varepsilon_0} \quad \text{.....01}$$

$$C = \frac{kA\varepsilon_0}{[kd - h(k - 1)]} \quad \text{.....01} \quad]$$

(iv) Voltage across the plates before inserting the slab

$$= \frac{Qd}{A\varepsilon_0} \quad \text{.....01}$$

this voltage does not change since the source is not disconnected

$\therefore$ the final charge $= C\frac{Qd}{A\varepsilon_0}$

$$= \frac{kQd}{[kd - h(k - 1)]}. \quad \text{.....01}$$

(v) The energy stored in the capacitor will be reduced when the slab is inserted without the voltage source. $\therefore$ the slab will be pulled into the plates (OR no work has to be done in inserting the slab). $\therefore$ it is easier to insert the slab when the source is disconnected. 01

(iii) Let h be the vertical rise of the liquid level,then

$$h\rho g = 240 \quad \text{.....01}$$

$$h = \frac{240}{1.2 \times 10^3 \times 10} \quad \text{.....01}$$

$$h = 20 \times 10^{-3} \text{ m (20 mm)} \quad \text{.....01}$$

(iv) Potential energy gained due to raising the liquid column

$$= mg(h/2) \quad \text{.....01}$$

where m is the mass of the raised liquid column

If the arm AB is removed this energy should be converted into kinetic energy .

∴ if V is the speed of the ejected liquid, then

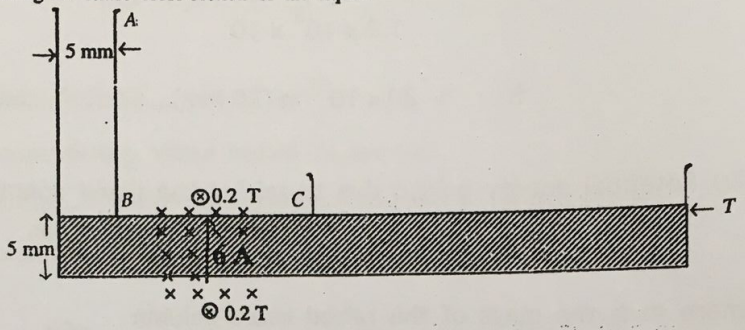
$$(1/2)mV^2 = mg(h/2) \quad \text{.....01}$$

$$V = \sqrt{gh}$$

$$= \sqrt{10 \times 20 \times 10^{-3}} \quad \text{.....01}$$

$$= \sqrt{0.2} \text{ m s}^{-1} \text{ (0.45 m s}^{-1}\text{)} \quad \text{.....01}$$

8. An *L* - shaped tube *ABC* of square cross - section of side 5 mm is connected to a large tank *T* containing a conducting liquid as shown in the diagram. A uniform magnetic field of flux denisity 0.2 T is acting in the direction indicated across the horizontial arm of the tube *BC*. A current of 6 A is passed vertically upwards along an entire cross-section of the liquid.



(i) Find the magnitude and direction of the force acting across the cross-section of the liquid.

(ii) Find the pressure developed across the cross-section of the liquid due to the above force.

(iii) If the denisity of the liquid is 1.2×10^3 kg m^{-3} how high will the liquid level rise in the vertical arm *AB* due to this pressure ? (Assume that the change in level of liquid in the tank is negligibly small.)

(iv) If the vertical arm *AB* of the tube is not there, what is the flow speed of the liquid ?

(i) Magnitude of the force = BiL 01

$= 0.2 \times 6 \times 5 \times 10^{-3}$ 01

$= 6 \times 10^{-3}$ N 02

(award 01 mark for the unit)

Direction of the force = along CB direction OR to the left....01

(ii) Pressure developed $= \frac{F}{A} = \frac{6 \times 10^{-3}}{5 \times 10^{-3} \times 5 \times 10^{-3}}$ 01

$= 240\ \text{N m}^{-2}$ 02

(award 01 mark for the unit)