G.C.E. (Advanced Level) Examination - August 2009
PHYSICS - II
Three hours

Answer all four questions. **PART A - Structured Essay** $[g = 10\ N\ kg^{-1}]$

01. Figure (I) shows an experimental setup of Hare's apparatus used in a school laboratory to measure the relative density of a liquid. In the figure, water and liquid are labelled as A and B respectively.

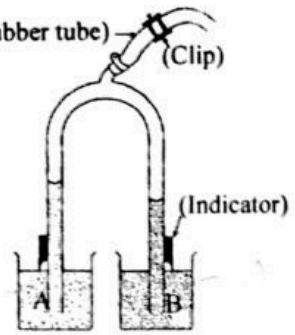

Figure (I)

(a) (i) Give an approximate value for the diameter in cm, of the tube in both arms in a Hare 's apparatus normally used in a school laboratory.

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(ii) Name the measuring instrument that is **not** shown in the figure given but needed for the experiment.

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(iii) State clearly how you would **establish** and **maintain** water and liquid columns in the arms of the Hare's apparatus.

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(iv) What is the special advantage of this method over the U tube method?

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(b)

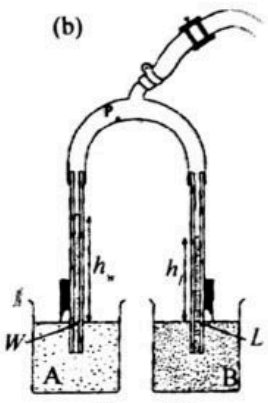

Figure (2)

In order to determine the surface tension as well as the density of a liquid a student has modified the Hare's apparatus by replacing its both arms with identical capillary tubes of internal radius r, as shown in figure (2).

(i) Let P_0 be the pressure of air above the water and liquid meniscus, (h_w, h_l) be the heights of the columns, (d_w, d_l) be the densities and (T_w, T_l) be the surface tensions of water and liquid respectively. If P_w, P_L are the pressures at points W and L respectively, write down expressions for P_w and P_L in terms of relevant parameters. Assume that the contact angles of water and liquid with glass are zero.

P_w : .....

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P_L : .....

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(ii) Hence derive an expression for h_w in terms of h_l, d_w, T_w, T_l, r and g in the form of $y = mx + c$.

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(iii) If you draw graph of h_w versus h_l, and if you know the values of d_w, T_w, r and g what quantities you should extract from the graph to determine T_l and d_l?

To determine T_l .....

To determine dl .....

(iv) Why is it always suitable to have the heights of the water and liquid columns as large as possible?

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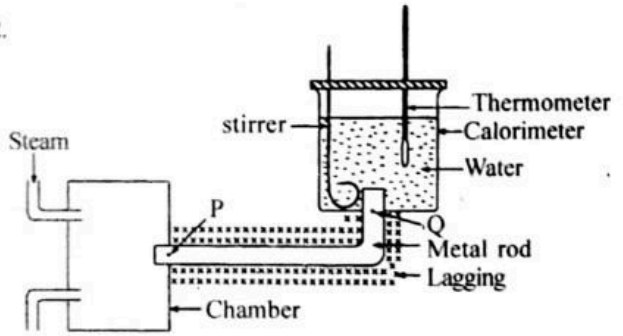
02.



The apparatus shown in the diagram can be used to determine the thermal conductivity of a metal in the form of a rod of uniform cross-section. In this experiment steam at 100 °C is passed through the chamber and the **temperature**, θ, of the water in the calorimeter is measured with **time** t.

(a) Give reasons as to why steam is always used in this type of experiments.

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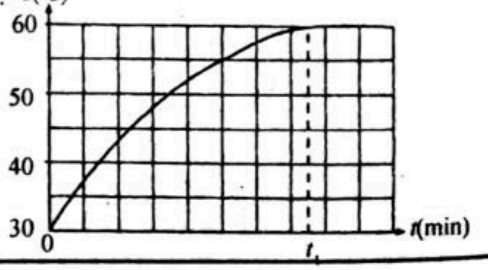
(b) The variation of the above mentioned θ, with t is given below.



(i) According to the graph, after $t = t_1$, θ attains a steady value. What is the reason for this?

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(ii) From 0 to t_1, the variation of θ with t is non linear, and there are two main reasons for this. What are they?

(1) .....

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(2) .....

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(iii) What is the temperature achieved by water at the steady state?

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(c) It has been found from a separate cooling experiment that the rate, R (in watts) of heat dissipation from the calorimeter and its contents at temperature, θ, is given by $R = 0.16 (\theta - \theta_R)$, where θ_R is the room temperature.

(i) Calculate R at the steady state temperature. ($\theta_R = 30\ ^0C$)

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(ii) Hence, determine the thermal conductivity of the metal. The cross-sectional area of the rod = $1.2 \times 10^{-4}\ m^2$, and the length of the rod from P to Q = 0.4m.

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(d) If the calorimeter is also lagged well, could you perform this experiment successfully? Explain your answer.

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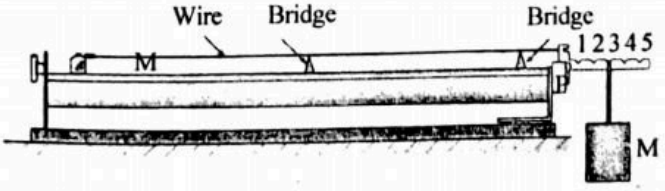
03. In order to determine the unknown frequency (f) of a given tuning fork, you are provided with a sonometer and a single mass M as shown in figure. In the given sonometer, it is possible to change the tension of the wire by hanging the given mass at different slots of an arm of a lever wihich is pivoted at P. Slots are numbered from 1 to 5 as shown in the figure, and distances to the slots 1, 2, 3, 4 and 5 from P are 1.0, 2.0, 3.0, 4.0 and 5.0 cm, respectively. **Perpendicular distance from P to the wire is also 1.0cm.** Assume that the elogatiob of the wire due to the mass is kept negligibly small.



(a) How do you experimentally find the fundamental resonance length (l) of the sonometer wire that resonates with the given tuning fork?

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(b) Write down an expression for l in terms of f, tension of the wire (T), and mass per unit length of the wire (m).

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(c) The mass M is hung from each slot and corresponding value of l is measured. When the mass is hung from the n^{th} slot (n = 1, 2,3, 4, 5.), the tension of the wire is given by $T = Mgn$. How do you obtain this relationship?

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(d) Obtain an expression for l^2 in terms of Mg, m, f and n.

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(e) The maximum tension that the sonometer wire can bear without producing a significant elongation is 54N. What is the maximum value of M (in kg) which enables you to use all five slots for taking measurements?

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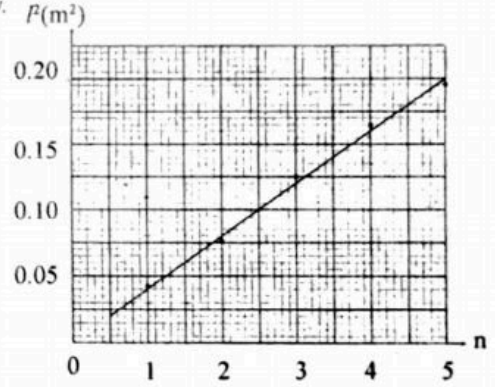
(f) You are provided with the density of the material of the sonometer wire. In order to determine the value of m, write down the measurement you have to make, together with the measuring instrument you use for that measurement.
(i) Measurement to be obtained : .....
(ii) Appropriate measuring instrument : .....

(g) A graph of l^2 versus n drawn in such an experiment is given below.



(i) Obtain the numerical value of the quantity required from the graph in order to determine the value of f.

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(ii) If $M = 0.5$kg and $m = 2 \times 10^{-3}$ kg m^{-1}, calculate the value of f.

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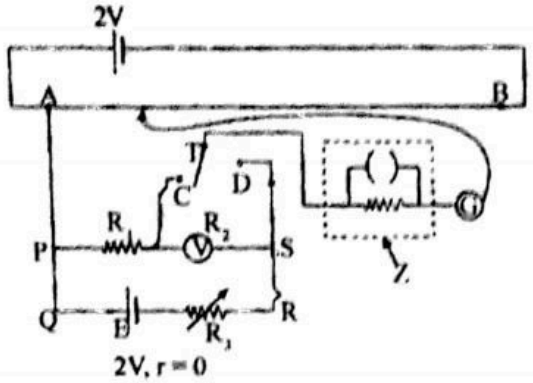
04. You are asked to use a potentiometer to measure the internal resistance (R_v) of a voltmeter (V). Its value is known to be of the order of 1000Ω. The full scale deflection of the voltmeter, V is 1.5V. The experimental arrangement that is made for this purpose is shown below.



R_1 is a suitable fixed resistance and R_3 represents the resistance of a resistance box.

(a) What is the importance of having the circuit inside the broken lines marked as *Z*?

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(b) Show how you would connect the voltmeter V to circuit *PQRS* properly, by labelling the polarities of the terminals of the voltmeter V with + and - in the circuit given above.

(c) When the circuit is connected, if you observe that the voltmeter reading tends to exceed its full scale deflection, how would you rectify this?

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(d) Write down the test that you would perform to check if all components of the experimental arrangement are properly connected.

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(e) If the balanced length of the potentiometer wire when the swtich *T* is connected to *C* and *D* are l_1 and l_2 respectively derive an expression relating l_1, l_2, R_1 and R_2.

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(f) Rearrange the expression in (*e*) to plot a graph of l_2 versus l_1 with l_2 as the dependent variable.

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(g) How would you obtain a set of measurements for l_1 and l_2 in order to plot the graph?

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(h) A student has suggested another method to find the internal resistance of the voltmeter *V*. According to his method, the *PQRS* section of the circuit shown above is to be isolated, and the value of R_3 is to be adjusted until the reading of the voltmeter, V becomes 1V.

(i) If you adopt this method, write down the expression that will give the internal resistance of the voltmeter.

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(ii) Give reasons as to why this method is **not** as accurate as the potentiometer method.

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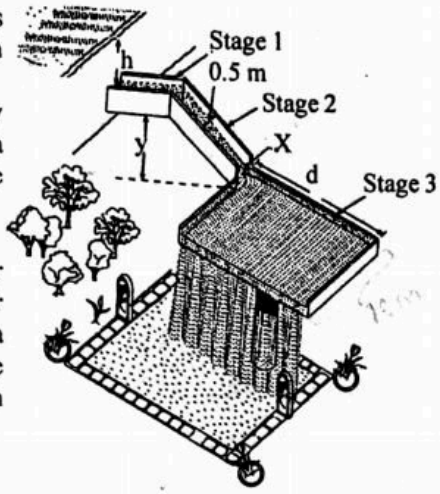
PART B - Essay

Answer four questions only

$[g = 10\ N\ kg^{-1}]$

01. Write down Bernoulli's equation and identify each term.

An ancient waterway which supplies water to a pond consists of three stages as shown in figure;



Stage 1: A rectangular horizontal open water channel originating from a rectangular outlet of large reservoir at a depth h from the water level.

Stage 2: Another rectangular open water channel having same floor width as in stage 1 but runs with a slope as shown in figure. Width of the channel floor in stages 1 and 2 is 0.5 m.

Stage 3: The stage 3 linked to the stage 2 is an open **horizontal shallow channel** of rectangular cross-section with much broader floor width, *d*, of 10m. Water coming from stage 2 enters this channel and starts to flow in orthogonal direction as shown in figure creating a waterfall which provides water to the pond below.

(a) At the steady state waterfall carries 1.5 m^3 of water per second. If the speed of water flow at the exit X of the stage 2 is $10 ms^{-1}$, calculate the height of the water level of the channel of stage 2 at X.

(b) Assuming that the height of the water level of the shallow channel of stage 3 is equal to the height of the water level of the stage 2 at X, calculate the speed with which water flows through the shallow channel.

(c) If the speed of the water flow at the horizontal channel of stage 1 is $5 ms^{-1}$, calculate the height of the water level of the open channel of stage 1.

(d) Considering a stream line along the top surface of the water flow calculate the height (y) from channel floor of stage 2 at X to channel floor of stage 1 (see the figure.) You may assume that the water leaves to the atmosphere of atmospheric pressure P at the outlet of the reservoir, and water enters the shallow channel at X which is also at pressure P.

(e) Calculate the height h of the water level in the reservoir that has to be maintained for this purpose.

(f) If the water level of the reservoir exceeds the value calculated in (e), propose a method to regulate water flow so that the waterfall carries the same amount of water per second, mentioned in (a).

02. Figure (1) shows a monochromatic ray of light entering a spherical raindrop at A and emerging from C after a single reflection at P.

(a) If the refractive index of water is $\frac{4}{3}$, calculate the critical angle for water air interface (sin 48.6° = 0.750).

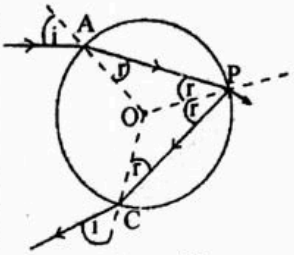


Figure (1)

(b) Giving reasons, show that the ray of light can **never** be totally internally reflected from the opposite surface of the raindrop for any angle of incidence i.

(c) (i) Write down an expression for the angle of deviation of the ray due to the refraction at A in terms of i and r.

(ii) Write down an expression for the angle of deviation of the ray AP due to the reflection at P in terms of r.

(iii) Write down an expression for the angle of deviation of the ray PC due to the refraction at C in terms of i and r.

(iv) Hence, write down an expression for the total angle of deviation (D) of the emergent ray relative to the incident ray in terms of i and r.

A rainbow can be seen due to the emergence of incident sunlight from raindrops.

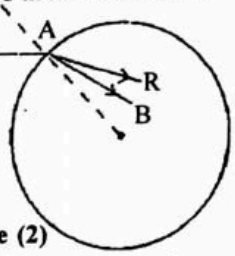


Figure (2)

Since sunlight consists of all visible colours, when white light refracts at A it separates into its colours. Figure (2) shows such a refracted red colour ray (R) and blue colour ray (B).

(d) Copy the figure (2) onto your answer sheet and complete the subsequent paths of the red and blue rays.

(e) The expression obtained in (c) (iv) above shows that D varies with i. It has been found that when $i = 52^0$, the blue rays emerge from the raindrop with the angle of minimum deviation.

(i) Determine the corresponding angle of minimum deviation D_{min} for blue rays.

(sin 52° = 0.788, sin 36.25° = 0.591, Take the refractive index of water for blue colour also to be $\frac{4}{3}$).

(ii) Assuming $i = 52^0$ in your ray diagram drawn in (d) above, mark D_{min}.

The light of any colour that emerges from the rain drop with the angle of minimum deviation corresponding to that colour is especially bright as rays bunch up at that angle. These bright colour bands which are deviated with minimum angles of deviation enter the eyes of an observer on the ground, and thereby a rainbow is seen.

(iii) Determine the angle made by the blue colour of the rainbow with the horizontal relative to the observer on the ground.

(iv) Which colour forms the outer edge of the rainbow?

03. (a) Young's modulus E of a material in the form of a wire is given by $E = \frac{F/A}{\Delta l / l}$. Here all the symbols have their usual meaning.

Identify the terms F/A and $\frac{\Delta l}{l}$ in the expression.

(b) Figure (1) is a characteristic curve showing the elastic behaviour of a material. Identify the points X and Y marked on the curve.

(c) Two uniform nylon strings of length l (=10cm) and $2l$(=20cm) of similar area of cross-section A are separately fastened to a rigid oval shaped frame as shown in figure 2 (a). Both strings are just stretched with negligible tension. The strings lay perpendicular to each other and run just touching each other.

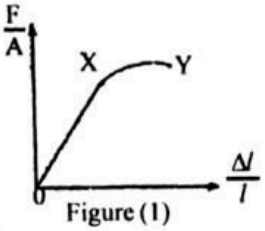
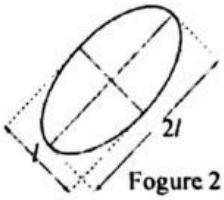
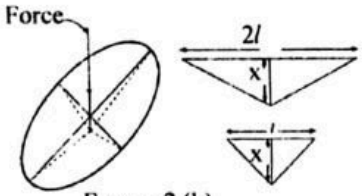


Figure (1)

Now a force is applied to the point of contact of the strings and perpendicular to the plane containing the strings as shown in fogure 2 (b).



Fogure 2 (a)



Fogure 2 (b)

If x is the depression of the point of contact of strings (see figure 2(b)) due to the application of force,

(i) write down expressions for the increase in length of the two strings in terms of x and l.

(ii) derive expressions for the tensions of the two strings in terme of E, A, l and x where E is the Young's modulus of the material of the nylon strings.

(iii) If $x = 0.5$ cm, substitute the values given for l and x, and **hence** show that the tension of the shorter string is higher than that of the longer string.

[When x = 0.5 cm and l = 10cm, take $\sqrt{x^2+l^2} = 10.0125$ cm and $\sqrt{x^2+\frac{l^2}{4}} = 5.025$ cm]

(d) (i) Explain qualitatively how the two tensions behave as the applied force to the point of contact of strings is increased.

(ii) Draw rough sketches of the tension (T) versus extension Δl curves for both strings on the same graph and label them.

(iii) Suggest a method which enables both strings to reach the condition depicted by point X shown in figure (1) simultaneously.

04. Letters, numbers, images etc. printed by certain computer printers consist of a large number of very small circular dots just touching one another. The number of such dots printed per unit length is normally used to express the quality of the printers.

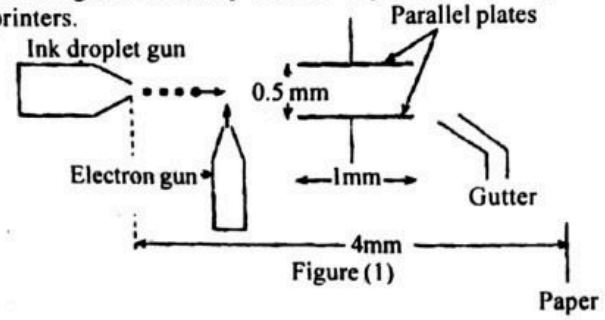


Figure (1)

A simplified diagram of a system, which illustrates only the relevant parts of the ink delivering process of such a printer, is given in figure (1). Use the dimensions shown in figure (1) in answering the questions, whenever necessary.

As shown in figure (1), the ink droplet gun sends a stream of neutral spherical ink droplets towards the paper on which the printing is to be done, and the appropriate movements of the system will give rise to printing. In order to print letters, numbers and images on the paper, only some of these droplets must be allowed to hit the paper and the rest of the droplets must be prevented from reaching the paper. This is done by charging only those droplets, that must be prevented from hitting the paper, using an electron gun and deflecting them into a gutter by means of an electric field produced by a pair of parallel plates.

(a) (i) Assume that each **spherical** droplet emitted from the ink droplet gun has a diameter D and each droplet produces a **circular dot** whose diameter is 25% larger than D when it strikes the paper. Find the value D must have for the printer to be able to print 200 dots per cm.

(ii) Ink droplet gun shoots droplets **horizontally** towards the paper with a velocity of $20 ms^{-1}$. Calculate the vertical displacement of a neutral droplet due to gravity when it hits the paper which is placed vertically 4mm away from the ink droplet gun. Show that this deflection is much smaller then the diameter of a dot printed on the paper.

(b) Each droplet, which has to be deflected into the gutter is given a charge of -1.6×10^{-10} C by allowing a very narrow beam of electrons from the electron gun to strike the droplets, under suitable conditions. A potential difference of 50V is applied between the parallel plates.

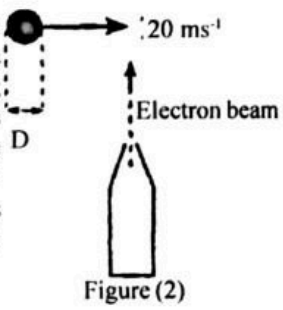


Figure (2)

(i) If the droplets move across the electron beam as shown in figure (2) find the time required for a droplet to pass the electron beam.

(ii) Assuming that all electrons, which strike the droplet are uniformly distributed over the surface of the droplet, calculate the electric current due to the emitted electrons from the electron gun during the charging process.

(c) (i) Find the electric field intensity between parallel plates.

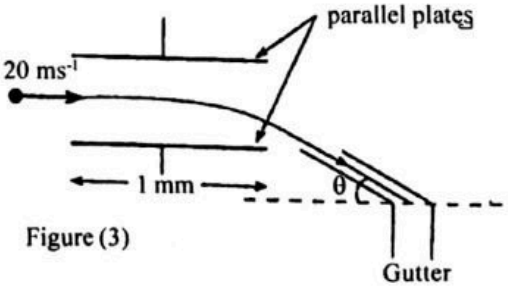


Figure (3)

(ii) What must be the direction of the electric field?

(d) The mass of a charged droplet is given as 4.0×10^{-11} kg. Find the angle (θ) that the gutter must make with the horizontal direction so that the charged droplets travel straight into the gutter as shown in figure (3). (Neglect the effect of gravity.)

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

(A) (a) Show that the ratio of currents, $\frac{I_2}{I}$, in the circuit shown is figure (1) can be given as $\frac{I_2}{I} = \frac{R_1}{R_0 + R_1 + R_2}$

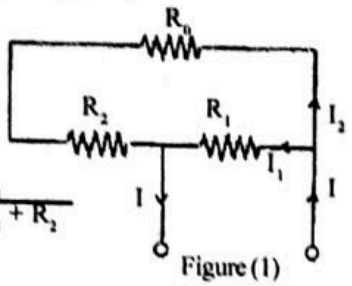


Figure (1)

(b)

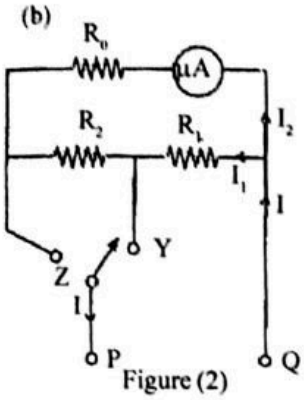


Figure (2)

Figure (2) shows a circuit of a multi-range ammeter which can be used to measure currents in the ranges, 0 - 0.01A and 0 - 0.1 A using a microammeter (μA) with a full scale deflection of 100 μA, and internal resistance R_0 of 1000Ω. Internal resistance R_0 is shown separately in the circuit for convenience. *P* and *Q* represent the terminals of the multi-range ammeter, and the microammeter is calibrated to read currents in both ranges. The necessary range can be selected by connecting the terminal *P* either to *Y* or *Z*.

(i) If you want to measure currents in the 0-0.01A range (smaller range) which terminal (*Y* or *Z*) do you use with *P*? explain your answer.

(ii) Calculate suitable values for R_1 and R_2 which enable you to use the circuit as a multi-range ammeter for the current ranges given above. Give your answers to the nearest integer.

(iii) Write down separate expressions, for the internal resistance of the multi-range ammeter in terms of R_0, R_1 and R_2 when it is set to measure currents in 0 - 0.01 A and 0 - 0.1 A ranges respectively.

(iv) Show by drawing a circuit diagram how you would extend the circuit shown in figure (2) to include another range, 0 - 1 A. Clearly identify the terminals to be used for each range. It is not necessary to calculate the values of the relevant resistors.

(B) (a) Write down an expression relating the voltages V_0, V_1, V_2 and the open loop gain *A* of the operational amplifier shown in figure (1).

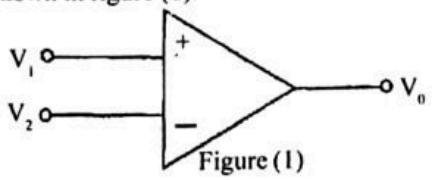


Figure (1)

(b) Input resistance of a 741 operational amplifier is approximately 2MΩ. Give a rough estimate of the expected input current when a voltage of 5V is applied between the inputs.

(c) Water level of a water tank is to be monitored and displayed remotely by a linear vertical array of LED^S as shown in figure (2).

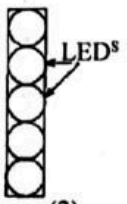


Figure (2)

Height of the water level in the tank is to be proportional to the number of LED^S that glows from the bottom. A water level detector mounted in the tank will provide a voltage, which is proportional to the height of the water level, and is used to light the LED array.

An **incomplete** diagram of a circuit designed for this purpose is shown in figure (3). Positive saturation voltage of 5V from operational amplifier outputs are used to light the LED array.

(i) Copy the figure (3) onto your answer sheet and complete the circuit by
(1) connecting the other input terminals of the operational amplifiers to the appropriate points in the circuit.
(2) clearly indicating the non-inverting and inverting inputs of the operational amplifiers with + and - signs according to the circuit requirements.

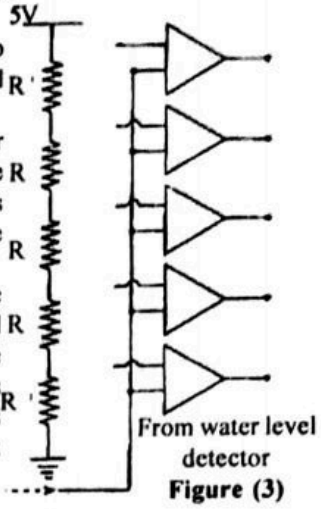
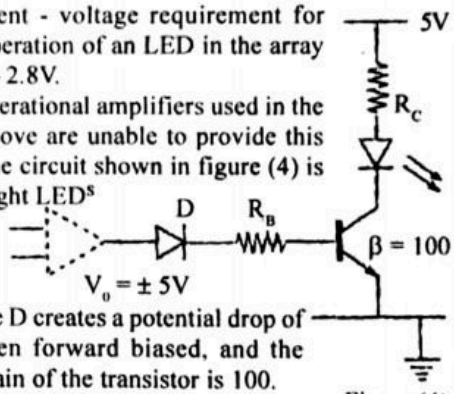


Figure (3)

(ii) Values of the resistors (*R*) should be determined so that they draw only 1 mA from the power supply. Calculate a suitable value for resistors *R*. Assume that the currents drawn by operational amplifier inputs are negligible.

(iii) The current - voltage requirement for proper operation of an LED in the array is 20mA - 2.8V.
As the operational amplifiers used in the circuit above are unable to provide this current the circuit shown in figure (4) is used to light LED^S



The diode D creates a potential drop of 0.7V when forward biased, and the current gain of the transistor is 100.
Figure (4)

Assume that the transistor operates just at the saturation level and the collector current I_C can still be given by $I_C = BI_B$.
(1) Calculate a suitable value for R_C.
(2) If $V_{BE} = 0.7V$ and $V_0 = 5V$ calculate a suitable value for R_B.

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

(A) An electric kettle as shown in the figure contains 0.8 kg of water at 20 °C. A person switched ON this kettle and left the water in it to boil.

He however, has forgotten to switched OFF the kettle in time and finally when he switcher it OFF only 50% of water was found to be left in the kettle at its boiling temperature of 100 °C. The heater H in the kettle is rated as 2025W. Assume during the heating process only 80% of the heat produced by the heater goes to heating of water.

(a) (i) Calculate the amount of heat that is produced by the heater H before the kettle is switched OFF.

(ii) How long the kettle would have been in the ON position? Give your answer to the nearest minute.

(iii) At what rate the boiling water would have evaporated? Give your answer in kg s^{-1}.

(iv) Assuming that the water vapour in the kettle behaves like an ideal gas, write down an expression for its density ρ in terms of pressure P of the vapour, gas constant R, temperature T of the vapour and molar mass of the water M.

(v) If the spout S of kettle has a cross-sectional area of 3.73×10^{-4} m^2, using the result of part (iii) above and the expression from part (iv) above, calculate the speed υ with the water vapour would have escaped from the spout of the kettle.
Assume that the water vapour could escape only through the spout of the kettle and the pressure of water vapour in the kettle is at the atmospheric pressure of $10^5 Nm^{-2}$.

Specific heat capacity of water is 4200J kg^{-1} K^{-1};
Specific latent heat of vaporization of water is 2.25×10^6 J kg^{-1};
Gas constant R = 8.3 J mol^{-1} K^{-1}; Molar mass M of the water = 0.018kg mol^{-1}.

(b) Once the water in the kettle has reached the temperature of 95°C, 200 cm^3 of water is poured into a glass cup which is initially at 25 °C. The mass of the cop is 250 g. calculate the maximum temperature attained by the cup of water. Assume that there is on heat loss to the surroundings. Take the specific heat capacity of glass as 840 J kg^{-1} K^{-1} and density of water as 10^3 kg m^{-3}.

(B) Read the following passage and answer the questions given below.

The Sun which provides the energy necessary to sustain all forms of life on the earth, is a star in our Galaxy. At present, the Sun contains about 74% hydrogen and 24% helium by mass and remaining 2% makes up some of the heavier elements. All these elements are in a completely ionized gaseous state, also known as a plasma state. The photosphere is the lowest of the three layers comprising the Sun's atmosphere and has a blackbody spectrum. Most of the visible light from the Sun comes from this photosphere which has a relatively small thickness. Immediately above the photosphere is a dim layer of less dense gas called the chromosphere. The outermost region of the Sun's atmosphere, the corona, extends several million kilometres from the chromosphere. Because the corona is the farthest region in the Sun's atmosphere from the surface of the Sun, it is expected that the temperature in that region to be the lowest. But it has been found that the highest temperature of the Sun's atmosphere which is around 1.5×10^6 K, is in the coronal region. Astrophysicists have suggested that this unexpected rise in temperature of the corona is due to the release of energy carried from the interior of the sun by complex magnetic fields that exist in the Sun.

Region below the photosphere is considered to be the interior of the Sun and has a radius of $R_\odot = 7 \times 10^8$ m, which is also considered as the solar radius, and a mass $M_\odot = 2 \times 10^{30}$ kg. The region closer to the centre of the Sun where the temperature and pressure are very high is known as the core. Because of very high temperature and pressure fusion of hydrogen nuclei takes place at the core of the Sun. This hydrogen fusion reaction can be written as follows;

$$4H \rightarrow He + 2e^+ + \text{neutrinos} + \text{energy}$$

The generated energy travels to the surface of the Sun and is released from there. When answering the following questions take Wien's constant to be 3×10^{-3} mK.

(a) What is meant by the plasma state of matter?
(b) What are the **three** regions exist in the Sun's atmosphere?
(c) Which region of the Sun's atmosphere has the highest temperature? Give a reason for that regior to have the highest temperature?
(d) Calculate the wavelength associated with the maximum intensity of the radiation emitted from the corona. To which region of electromagnetic spectrum does this radiation belong?
(e) If the wavelength corresponding to the maximum intensity of the light emitted from the photosphere is 500nm, what is the temperature of the photosphere (i.e.the temperature of the surface of the Sun)
(f) Find the energy, $L_\odot$, released from the surface of the Sun per second which is also known as the solar luminosity. Take the Stefan constant as $0 = 6 \times 10^{-8}$ Wm^{-2} K^{-4}, and the emissivity of the solar surface as 1.
(g) (i) If the mass of a hydrogen nucleus is 1.67×10^{-27}kg and mass of a helium nucleus is 6.65×10^{-27} kg, calculate the mass difference (Δm) between four hydrogen nuclei and one helium nucleus. Hence calculate the energy released in a single fusion reaction using $\Delta E = (\Delta m)c^2$. Here $c = 3 \times 10^8$ ms^{-1}. Assume that the positrons and neutrinos have negligible masses.
(ii) Assuming that the energy released at the core of the Sun entirely contributes to the solar luminosity that you have obtained in (f) above, calculate the number of the hydrogen nuclei, which is converted into helium within its core each second.
(iii) If it is assumed that hydrogen is converted into helium at the present rate, how long will it take to convert entire mass of hydrogen inside the Sun into helium? [For this part of the question take the mass of a hydrogen nucleus as 2×10^{-27}kg.]