Current Electricity

1991 A/L

1) a) Define the term 'resistivity' of a conducting material.

A d c generator a voltage of 240 V to a resistive load of 120 Ω situated 1 km away from the generator.

(i) If the resistive load is connected to the generator by means of copper wires having diameter of 0.5 mm calculate the voltage of the d c generator.
(Resistivity of copper = 1.7×10^{-8} Ωm)

(ii) What is the power dissipated in the wires?

(iii) If the d c generator can provide only 241 V how would you supply the above mentioned voltage (i.e. 240 V) to the resistive load using the wires of same material?

(iv) In long distance power transmission why it is advantageous to use an alternating high voltage?

b) Draw a clear labelled diagram showing the essential features of a moving coil galvanometer. Explain how a steady deflection is produced when a steady current is passed through such a galvanometer.

A galvanometer with a resistance of 39.8 Ω is fitted with a shunt resistance of 0.2 Ω to function as an airmeter with a full scale deflection of 10A. What is the actual current through the galvanometer when it shows a full scale deflection?

This galvanometer is now to be used as a voltmeter with two different ranges having full scale deflections of 3V and 15 V respectively. What resistances should be used and how should they be fitted to achieve this?

1993 A/L

2) (a) There electrical appliances A, B and C reading 6 W, 6 V ; 2 W, 0.5 A and 27 W, 9 V respectively are to be connected in parallel with a cell of e.m.f. 10 V and internal resistance 0.5 Ω

(i) What is the total current that should be supplied by the cell for proper operation of the above appliances connected in a circuit as stated above.

(ii) Show that a single cell of the given type is unable to supply the necessary current to satisfactorily operate all the appliances as stated above.

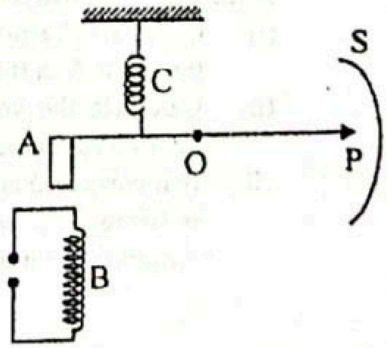
(iii) What is the minimum number of such cells that should be connected in parallel to overcome the difficulty encountered in (ii) above.

(iv) If you are supplied with a sufficient number of suitable resistors show in a diagram how you would connect all the appliances to the pack of cells as stated above.

(v) Calculate the values of resistors needed for the circuit.

(b) The diagram shows a sketch of a device that can be used to measure current with the following components.

A - soft iron B - fixed coil C - compensating spring
S - scale P - Pointer pivoted at O



Explain why the needle deflects when a steady current flows through the coil. Do you expect the pointer to deflect in the opposite direction if the current is reversed? Explain your answer. Why is that a piece of steel cannot be used in place of the soft iron A?

If the coil has a resistance of 0.5 Ω and the instrument gives a full scale deflection for a cuuent of 500 mA. Explain how this instrument cab be modified.

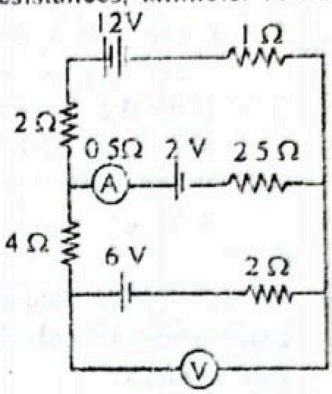
(i) to read currents up to 5 A

(ii) to read voltages up to 5 V

Explain with a diagram how this instrument can be used as a simple ohm meter. (assume that the deflection of the pointer is proportional to the current in the coil)

1994 A/L

13)(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.

1995 A/L

14)(a) A resistor network consisting of three series connected resistors R_1, R_2 and R_3 is placed across a 300 V supply with R_1 adjacent to the positive end A and R_3 adjacent to the negative end D. The junctions between R_1 and R_2 and that between R_2 and R_3 are denoted by B and C respectively. Two electrical appliances S_1 and S_2 connected between B and D, and C and D draw currents of 10 mA and 20 mA respectively.

(i) If the 300 V supply delivers 50 mA to the network and the voltages across BD and CD are 200 V and 150 V respectively, find the values of the resistors R_1, R_2 and R_3

(ii) Calculate the internal resistances of S_1, S_2

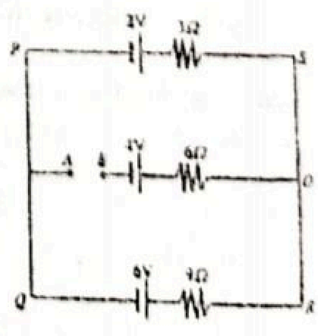
(iii) If S_1 is disconnected what will be the voltage appearing across S_2 and the current drawn by S_2?

(iv) For S_2 to operate properly, the input power given to it must lie between ±5% of the rated 3W value. When S_1 is removed, verify whether S_2 will continue to work properly or not.

1996) A/L

15)(a) State Kirchhoff's Laws

In the circuit shown all the cells have negligible internal resistance



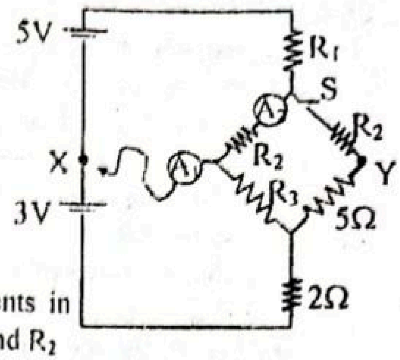
(i) Calculate the potential at the point B with respect to the point A in the circuit.

(ii) Calculate the voltmeter reading if a voltmeter having an internal resistance of 100 Ω is connected across AB.

(iii) Is it correct to connect a voltmeter across AB as mentioned in (ii) to measure the potential difference between A and B ? Explain your answer.

1997 A/L

16) (a) In the circuit shown, cells and both ammeters A_1 and A_2 have negligible internal resistance. S is a switch. Once the switch S is closed, the ammeter A_1 indicates a zero reading, when its free terminal is connected either to point X or Y. It is also found that when S is opened and A_1 is connected to X, the ammeter A_2 reads $\frac{5}{12}$ A.



(i) Determine the value of R_3. Clearly state your arguments in arriving at the answer. Also calculate the values of R_1 and R_2

(ii) When S is open and A_1 is connected to X, will a part of the current that is flowing through R_2 pass through R_3 as well? Explain your answer.

(iii) What will be the reading of the ammeter A_1 in (ii).

1998 A/L

17) (a) (i) You are provided with a DC supply of voltage V and a variable resistor with a sliding contact. Using these apparatus, the voltage across a load is to be increased steadily from zero to the maximum value, V

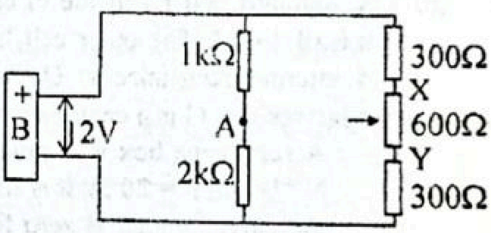
Draw a suitable circuit diagram to obtain such a voltage, clearly indicating the terminals to which the load is to be connected.

Sketch a graph of load current against the voltage applied when the load is

(a) a constant resistance (b) a tungsten filament lamp.

Explain why the two graphs are different.

(ii) In the circuit shown, B is a battery with negligible internal resistance, A variable resistor of 600Ω with a sliding contact is connected across the points X and Y. An ideal voltmeter is connected between the terminals A and the sliding terminal of the variable resistor,



(a) Find the current through XY

(b) Find the readings of the voltmeter when the sliding terminal is at X, and Y respectively.

(c) If the above voltmeter is a 0 – 12V moving coil type voltmeter, can it be used to measure both values calculated in (b) above? Explain your answer.

2000 A/L

18) (a) A 60 W light bulb is connected to a 12 V voltage source using a copper wire. The bulb lights with its full brightness.

(i) Calculate the current through the wire

(ii) Considering that each copper atom contributes one electron to the conduction process. Calculate the number of conduction electrons in $1 m^3$ of copper.

[Relative atomic mass of copper = 63 ; Density of copper = 9.0×10^3 kgm^{-3},

Take Avogrado's number as 6.0×10^{23} atoms per gram mole]

(iii) If the radius of the copper wire is 0.7 mm, calculate the drift velocity (v_d) of conduction electrons in copper [Electronic charge = 1.6×10^{-19} C]

(iv) Assuming that the conduction electrons act like molecules in a perfect gas determine the root mean square velocity (v_{rms}) of electrons at 27°C

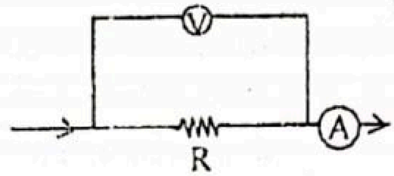
(Boltzmann's constant = 1.4×10^{-23} JK^{-1}; mass of the electron = 9.1×10^{-31} kg)

Explain why there is a vast difference of magnitudes between V_d and $V_{r.m.s}$?

(v) If the length of wire is 1 m. what is the time taken by an electron to travel from one end of the wire to the other ? In reality , however, the bulb will light as soon as the switch is closed Explain this

2001 A/L

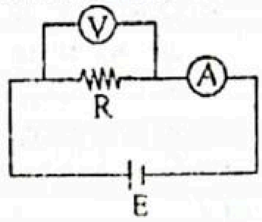
19) (a) The diagram shows how a voltmeter and an ammeter are connected to determine the resistance R of a resistor which is a part of an electrical circuit. Let V_m and I_m be the voltmeter and ammeter readings respectively



(i) If the voltmeter and ammeter were perfect instruments, write down an expression for the resistance R.

(ii) If the resistance of the voltmeter is R_V, obtain an expression for the resistance R in terms of V_m, I_m and R_V.

To measure, the resistance of a nichrome wire a voltmeter of resistance 1000 Ω and an ammeter of resistance R_1 are connected as shown in the diagram, the internal resistance of the cell E is negligible.



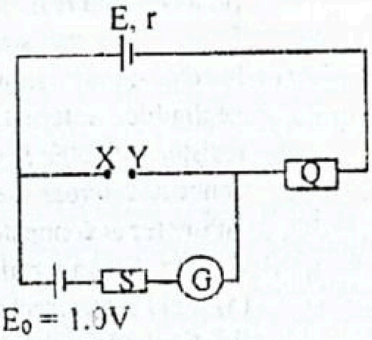
At room temperature of 30^0C the voltmeter and ammeter readings are 4.00V and 0.020 A respectively. When the nichrome wire is immersed in an oil bath at temperature 430^0C the voltmeter and ammeter readings are 4.05 V and 0.018 A respectively.

(iii) Find the temperature coefficient of resistance of nichrome

(iv) Find also the resistance R_1 of the ammeter and the e.m.f. of the cell.

2002 A/L

20) (a) The standard cell E_0 in the circuit shown below has an e.m.f. of 1.0 V. The other cell has an unknown e.m.f. E and internal resistance r. Q is a resistance box. S is another resistor G is a centre zero galvanometer.



(i) A resistance box P is now connected across X and Y. When P = 20 Ω it is found that the deflection of the galvanometer is zero for Q = 17 Ω. When P = 40 Ω, again it was found that the deflection is zero for Q = 35 Ω. Find the e.m.f. E and the internal resistance r of the cell.

(ii) Instead of the resistance box P, a Nichrome wire of cross – sectional area 3×10^{-7} m^2 and length 10 m is now connected across X and Y. It is found that the galvanometer deflection becomes zero when Q = 53 Ω. Find the resistivity of Nichrome. Find also the current through the Nichrome wire.

(iii) What is the necessity of having a resistance S?
What apparatus is used for S?
How do you use S in order to find the balance condition (zero deflection) accurately?

2003 A/L

21) (a) How does a real voltmeter differ from ideal voltmeter concept?

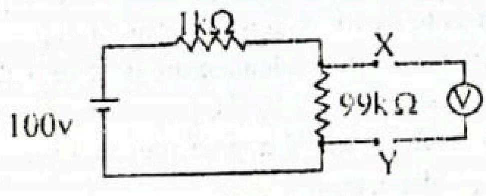


Figure (1)

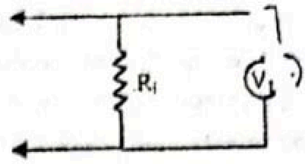
(i) Voltage across the terminals XY of the above circuit is measured

(a) With a voltmeter (V) having an internal resistance very much greater than 99kΩ

(b) With a voltmeter (V) having an internal resistance of the order of 1kΩ

Estimate the approximate values of voltmeter readings in (a) and (b). Neglect the in ternal resistance of the cell.

(ii) If the voltmeter (V) in figure (1) above has an internal resistance R_i give reasons to justify that the voltmeter V is equivalent to the following combination, where V_1 represents an ideal voltmeter.



(iii) Figure (2) shows a potentiometer arrangement.

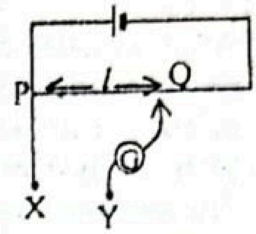
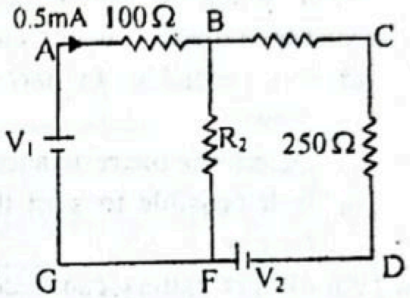


Figure (2)

Terminals XY can be connected to a suitable electrical circuit. 'Under the balanced condition, the terminals XY of the above arrangement act as the terminals of an ideal voltmeter. Would you agree with this statement? Give reasons to justify your answer.

(iv) In the circuit shown, current through the 100 Ω resistor is 0.5 mA. When the terminals XY of the above potentiometer arrangement are connected across AB, CD and BF, the balanced lengths obtained are 40 cm, 20 cm and 64 cm respectively. Find the resistance of R_2

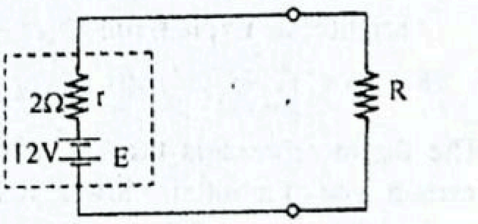


2004 A/L

22) (a) The battery in the circuit shown has an e.m.f. (E) of 12V and an internal resistance (r) of 2Ω.

(i) Find the power (P) transferred by the battery to the resistance R in each of the following cases.

(a) R = 1Ω
(b) R = 2Ω
(c) R = 3Ω
(d) R = 0 and
(e) R is infinite



(ii) Hence draw a rough sketch to show how power P varies with resistance R

(iii) Write down the relationship between r and R when the power transfer from the battery to R is maximum

(iii) The above mentioned battery is used to light a set of 6V, 0.36 V, 0.36 W bulbs at the recommended rating.

a. Find the maximum number of bulbs that can be connected to the battery for this purpose

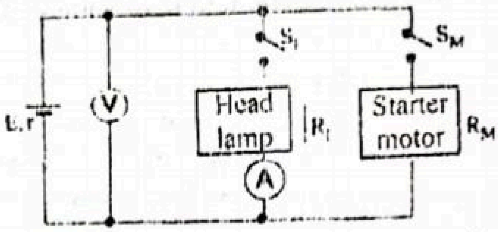
b. Draw a circuit diagram to show how you would connect the bulbs to the battery.

(iv) a) The battery is rated as 90 ampere – hours. This indicates that when it is fully charged, it cab deliver a current of 1 A for 90 hours, or 2A for 45 hours, and so forth. For how long the above mentioned battery can provide power to the maximum number of bulbs calculated in part (iv) (a) ?

b) If the mass of the battery is 15 kg and its average specific heat capacity is 900 $Jkg^{-1}\,^{0}C^{-1}$, find the maximum possible increase in temperature of the battery after lighting the set of bulbs for 30 minutes.

2005 A/L

23) 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 S_L is closed ammeter reading is 10 A and voltmeter reading 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.

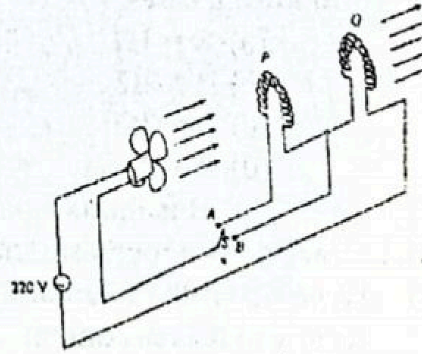
iii) An old car battery can become "sulphated". When this happens, chemical structure of the battery plates changes. As a result the internal resistance of the battery increases without changing the e. m. f.

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 12V, 6 W bulb with almost full brightness. Explain this.

2006 A/L

24) a) The figure represents the essential parts of a certain type of a hot air blower. It shows a way in which stream of hot air is produced by flowing air through two identical heating elements P and Q, using a fan.



(i) If each heating element is made of nichrome wires with area of cross section 10^{-8} m^2 and length 0.45 m, calculate the resistance of one heating element at room temperature of 25^0 C. (Resistively of nichrome at 25^0 C is 10^{-6} Ω m.)

(ii) Assuming that the effective resistance of the fan motor is 10 Ω and that the heating elements are still at room temperature, calculate the following.

(a) The total power consumption of the heating elements when the switch S is at position A.

(b) The power consumption of the fan motor when the switch S is at position A.

(c) The total power consumption of heating elements when the switch S is at position B.

(d) The power consumption of the fan motor when the switch S is at position B.

(iii)(a) What are the forms to which the electrical energy consumed by the fan motor is converted?

(b) Considering your calculations in part (ii) above, make a qualitative comparison on the speeds and the temperatures of the air flow at switch positions *A* and *B*. (Assume that the fan speed is proportional to the current through it.)

(iv) When the hot air blower is operating at switch position *B*, the temperature of the heating element *Q* rises to a steady value of 200^0 C.

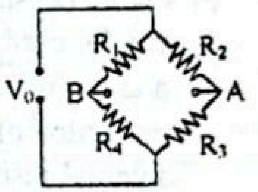
(a) Calculate the resistance of *Q* at the new temperature. (Temperature coefficient of resistance of nichrome is $0.002\ \Omega\ K^{-1}$)

(b) Will this change in temperature cause an increase or decrease of the rate of heat generated by *Q* ? If so, by how much? (Neglect any temperature changes of other parts of the circuit)

(v) While the hot air blower is operating at switch position *B*, if the heating element *Q* is moved away from the air flow without disconnecting it from the circuit, will the fan speed increase or decrease? Give reasons for your answer.

2008 A/L

25) Figure 1 shows a circuit diagram of a Wheatstone bridge. V_0 is the voltage supplied to the bridge and a galvanometer can be connected across *AB* if needed.



(a) Show that when the bridge is balanced $\frac{R_1}{R_4} = \frac{R_2}{R_3}$.

(b) Suppose $R_1 = R_2 = R_3 = R_4 = R$. The bridge is now made unbalanced by introducing a small resistance *r* into the R_3 arm so that $R_3 = R + r$. Show that under this condition a voltage of $\frac{Vr}{4R+2r}$ will appear across *AB* (Note that when R >> r the above expression reduces to $\frac{Vr}{4r}$).

(c) The resistance of the R_2 arm is now reduced to R-r while keeping R_3 arm at R + r. Show that by doing this change, the voltage across AB in (b) above can be doubled. (Assume R >> r)

(d) Such increases or decreases of resistance occur, for example, when metal strips are subjected to elongations or contractions by the applications of external forces. If the volume and the resistivity of a metal strip do not change when elongated, show that it resistance increases.

(e) An accelerometer is constructed to measure accelerations of objects by fastening vertically an insulating rectangular rod *XY* to the upper-inner surface of a box and attaching a mass *M* firmly to the other end as shown in figure 2.

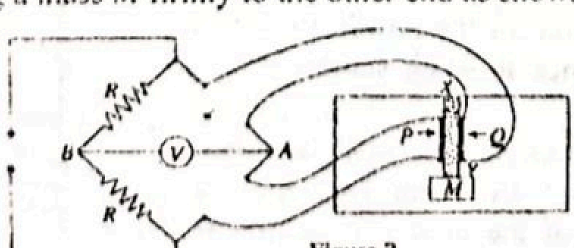


Figure 2

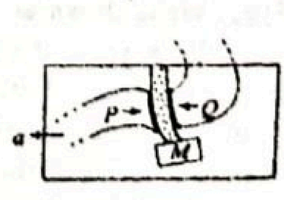


Figure 3

Two metal strips P and Q of resistance R are also fixed to either side of the rod. The ends of the strips are connected to two arms of a Wheatstone bridge as shown. When the box is placed on an accelerating object the rod and the strips bend as shown in figure 3.

(i) When the rod bends due to acceleration what would happen to lengths of the strips P and Q.

(ii) If $V_0 = 5$ V and the magnitude of the fractional changes in resistance of the strips are same, and is equal to $\frac{1}{100}$, find the voltage generated across a voltmeter connected between A and B.

(iii)How would you calibrate such an accelerometer?

2009 A/L

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

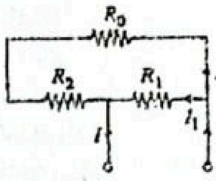


Figure (1)

b) Figure (2) shows a circuit of a multi – range ammeter which can be used to measure currents in the ranges, 0 – 0.01 A and 0 – 0.1 A using a microammeter (μA) with a full scale deflection of 100 μA, and internal resistance R_0 of 1000 Ω. 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.

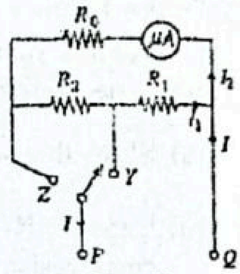


Figure (2)

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

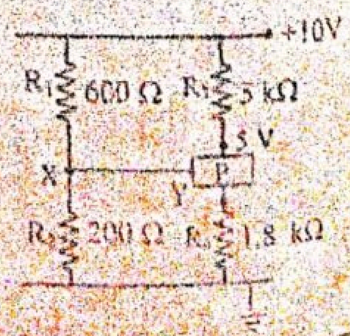
ii) Calculate suitable values for R_1 and R_2 which enable you to use the circuit as a multi – range ammeter for the current ranges given above. Give your answers to the nearest integer.

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 resistance.

2010 A/L

27) a) Write down an expression for the power dissipated by a resistor of resistance R when subjected to a potential difference of V.



b) The circuit shown is powered by a battery of e. m. f 10V, P is a three - terminal element. [Assume that the internal resistance of the battery is negligible when answering the part (i), (ii) and (iii)

i) Calculate the power dissipated by the resistors R_1, R_2, R_3 and R_4 separately. Give your answers to the nearest integer in mW. Assume that the current through the path XY is negligible.

ii) Resistors are available with different power ratings, and the price of resistors go up with the power rating value. Some of the standard ratings for resistors are 0.125 W, 0.25 W, 0.5 W, 1W, 2W etc. Considering the above information indicate suitable power ratings for R_1, R_2, R_3 and R_4.

iii) Find the total power consumed by the circuit. You may assume P also as a purely resistive element.

iv) If the entire circuit is constructed in IC form in a small piece of silicon of mass 0.9 mg and there is no heat dissipation to surroundings, find the temperature of the circuit 5 minutes after connecting the power supply. Take the room temperature as 30°C. Specific heat capacity of silicon is 600 J kg^{-1} K^{-1}.

v) When 5 such circuits are connected to a battery of e. m. f 10V it is found that the terminal voltage drops to 9.9 V. Calculate the internal resistance of the battery.

2011 A/L

28) The circuit shown in figure 1 has three inputs A, B and C and voltages V_A, V_B and V_C of either zero or 7V can be applied between the inputs and the common grounded line XY.

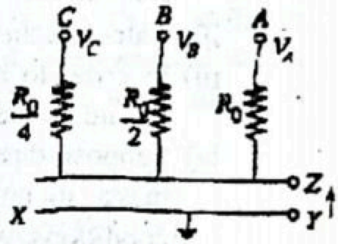


Figure 1

(a) If a zero voltage is applied (i. d $V_A = V_B = V_C = 0$) to all three inputs by grounding each input terminal as shown in figure 2, find

(i) the equivalent resistance across ZF.

(ii) Output voltage V_0.

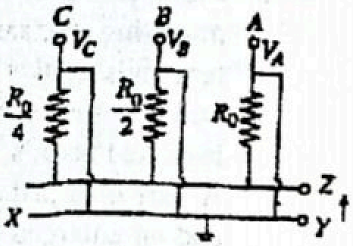


Figure 2

Now copy the table given below onto your answer script and complete the row 1. (i. e V_0 value) of the table

Important (All calculations and corresponding circuit diagrams must be shown clearly in order to earn marks for the parts (b), (c) and (d)

	V_C (Volt)	V_B (Volt)	V_A (Volt)	V_0 (Volt)
row 1	0	0	0	
row 2	0	0	7	
row 3	0	7	0	
row 4	0	7	7	
row 5	7	0	0	
row 6	7	0	7	
row 7	7	7	0	
row 8	7	7	7	

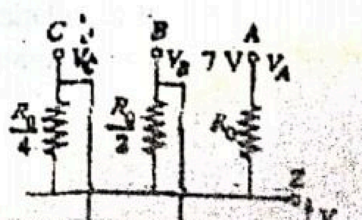


Figure 3

(b) Now the A input is connected to 7V and B and C inputs are grounded as shown in figure 3. Calculate the new value of V_0 and hence fill in the row 2 of the table.

(c) (i) Draw a circuit – diagram similar to figure 3 connecting the inputs A and C to ground and input B to 7V.

(ii) Find the value of V_0 and fill in the row 3.

(d) Draw the circuit diagrams corresponding to the situations depicted in rows 4 and 5 of the table. find the values of V_0 and fill in the corresponding rows.

(e) (i) Hence deduce V_0 values for the rest of the input voltage combinations of the table and complete the V_0 column of the table

(ii) If the voltage 7V and 0 are considered to represent binary 1 and 0 respectively. explain the function of the above circuit given in figure 1.

2012 A/L

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

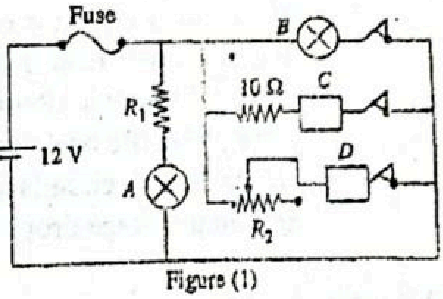


Figure (1)

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

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

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

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

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

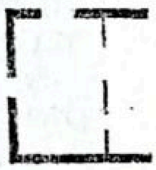


Figure (2)

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

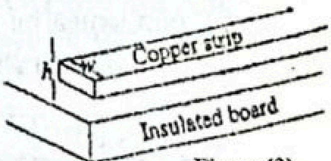


Figure (3)

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

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

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

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

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

2013 A/L

30) The box P shown in the figure (1) comprises a complex electrical circuit containing only cells and resistances. Assume that the entire circuit inside the box can be replaced with a series combination of a single cell with an e.m.f. E and a single resistance R_0 as shown in figure (2)

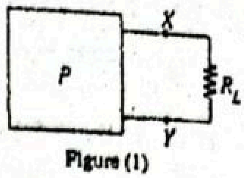


Figure (1)

a) Write down an expression for the current I drawn from the circuit in P when an external resistance R_L is connected across the terminals XY in figure (2) in terms of E, R_0, and R_L.

Values of E and R_0 mentioned above can be determined experimentally by using the two methods indicated under (b) and (c) below.

b) After removing the resistance R_L the voltage across the terminals XY is measured with a voltmeter having an internal resistance very much greater than R_0. Let the voltmeter reading be V_0. Then the terminals XY are short circuited for a short time and the current in the circuit is measured by an ammeter with negligible internal resistance. Let the ammeter reading be I_s.

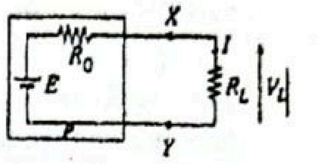


Figure (2)

Use the results obtained above to write down expressions for E and R_0

c) In order to find values of E and R_0 using the second method, two resistors having different values are used for R_L in figure (2), and the voltages V_L across R_L are measured with a voltmeter having an extremely high internal resistance compared to R_L values. Set of values obtained in such a measurement is given below.

When $R_L = 1\ k\Omega$, $V_L = 75\ mV$

When $R_L = 100\ k\Omega$, $V_L = 5\ V$

Use the above measurements and calculate E and R_0

d) i) In general if R_0 is extremely large compared to R_L, show that the current I in the circuit is almost independent of the value of R_L and it depends only on E and R_0. You may use the expression obtained for I under part (a) above for this. (Under this condition the circuit in P consisting of E and R_0 can be treated as a constant current source.)

ii) If the voltage appearing across R_L under the conditions mentioned in (d) (i) above is V_L, draw a rough sketch to show how the current I varies with V_L. (Use V_L for x-axis)

e) Part of the output I-V characteristic of an npn transistor [see figure (3)] connected in the common emitter mode is almost similar to the rough sketch that you have drawn in (d) (ii). From this what can you infer about the magnitude of the resistance between the collector and the emitter of the transistor? Briefly explain your answer.

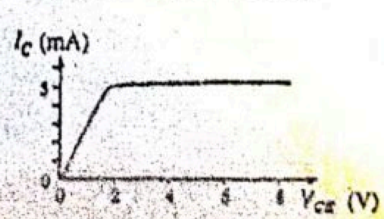


Figure (3)

2014 A/L

31) a) A potential divider AB of total resistance R_0 is used to provide a variable voltage to a load resistance R_L. The potential divider is connected to a power supply of voltage V as shown in figure (1).

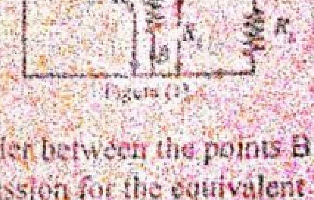


Figure (1)

(i) When the resistance of the section of the potential divider between the points B and the sliding contact (wiper) W is R_1, derive an expression for the equivalent resistance between A and B.

(ii) Through argumentation or otherwise, show that the minimum and the maximum resistances that can exist between A and B are $\frac{R_0 R_1}{R_0 + R_1}$ and R_0 respectively.

(iii) If $R_0 = 5\ k\Omega$, calculate the minimum value of R_1 which will permit only up to a 1% of variation in the current I of the circuit when slider W is moved from A to B.

(b) Terminals 1-9 of the potential divider shown in figure (2) are used to provide currents to 9 electrodes (not shown in the figure) of a certain device. Values of the resistors R_1, R_2 and R_3 are selected so that when electrodes are not connected to the potential divider, and a voltage (V_0) is applied to the potential divider, the voltage appearing across the resistor R_1 is 4 times that appearing across each and every R_2 resistor, and the voltage appearing across R_3 is 3 times that across R_2.

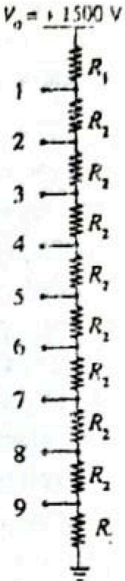


Figure (2)

(i) If $V_0 = 1500$ V and the current through the potential divider is 1 mA, calculate R_1, R_2 and R_3

(ii) Consider a situation where only terminal 9 has to provide a current of 5 μA for a period of 1 μs to the electrode to which it is connected. Calculate the voltage drop appearing across R_3 during this period due to the supply of the above current from the potential divider. Assume that the current through the potential divider from terminal 1 to terminal 9 remains unchanged at 1 mA.

(iii) In situations where currents are drawn for short periods of time as in (b)(ii), the drop created in terminal voltage can be minimized by providing this current from the charges stored in the capacitor connected across R_3, as shown in figure (3).

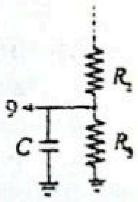


Figure (3)

(1) Calculate the amount of charge ΔQ carried by 5 μA current during the Period of 1 μs.

(2) If this amount of charge ΔQ is provided by the capacitor of capacitance C shown in figure (3), write down an expression for the drop in voltage ΔV across the capacitor in terms of ΔQ and C.

(3) If this drop in voltage is to be limited to 0.05 V, find the value of the capacitor that has to be connected across R_3.

2015 A/L

32) a) In the circuit shown in figure (1), X is an accumulator of e.m.f. E and internal resistance r. L is an electric lamp connected across AB, and the current through the lamp is I.

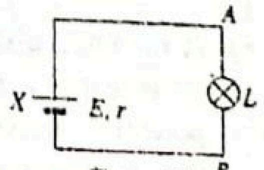


Figure (1)

i) Show that the power P consumed by the electric lamp can be given as $P = EI - I^2r$.

ii) Using the definitions for E and I, explain why the product EI is equal to the power generated by the accumulator.

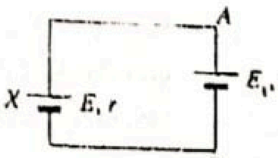


Figure (2)

iii) Electric lamp in the figure (1) is now replaced by another accumulator of e.m.f E_1 and internal resistance r_1 as shown in figure (2). $E > E_1$ and the current in the circuit is now I_1.

1) Show that $EI_1 - I_1^2 r = E_1 I_1 + I_1^2 r_1$

2) Physically what quantities do the products EI_1 and $E_1 I_1$ in the above expression represent? Explain your answer.

b) A circuit similar to the one given in figure (2) above can be used to re-charge a run –down rechargeable battery. In this context X is a source capable of delivering a constant power output, and is known as the battery charger. Y represents the run-down battery. Consider such a circuit shown in figure (3).

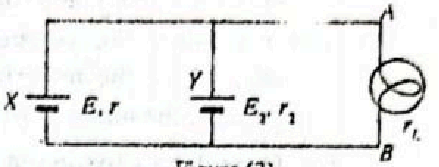


Figure (3)

X is a 12 V battery charger. For the purpose of calculations consider it as a constant power source with e.m.f 12V and an internal resistance $r = 2\Omega$. L is an indicator lamp of resistance $r_L = 2\Omega$ connected across the battery charger. E_2 and r_2 represent the e.m.f of the battery Y and its internal resistance at a particular instant in the charging process. If $r_2 = 1\Omega$ and the current through Y is 1A at that instant.

i) calculate the e.m.f. E_2 of the battery Y at that instant.

ii) calculate the power generated by the battery charger, and the power dissipated in r, r_2 and r_L at that instant.

iii) apply the principle of conservation of energy to the charging process at that instant. and explain what has happened to the excess power generated by the battery charger.

2016 A/L

33) a) Write down an expression for the expression for the energy (W) dissipated in a resistor of resistance R when a current of magnitude I is passed through it for a period of time t.

b) An electrical fuse is a small element consisting of a thin metal wire. Electrical fuses are connected in series with electrical / electronic circuits to avoid damages caused to them due to the passage of currents larger than the recommended current for the circuits (due to over – load currents and short circuits) when the current through the fuse in a certain becomes larger than the recommended current in the circuit, the fuse burns (melts) and disconnects the circuit from the power source. The electrical fuses are selected so that their ratings are equal to the recommended currents in the circuits.

i) Figure (1) shows how a fuse is connected to a circuit of load resistance R. Current in a contain fuse is rated as 5A. If the length of the fuse wire is 3 cm and its radius is 0.1 mm (area of cross - section - 3×10^{-8} m^2) and the resistively of the material of the wire at 25^{0}C is 1.7×10^{-8} m. Calculate the resistance of the fuse wire at room temperature of 25^{0}C.

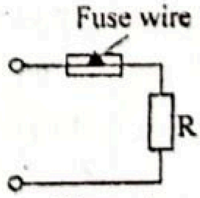


Figure 1

ii) When the fuse is operated at the rating mentioned in (i). at steady state, the entire heat generated by the fuse wire is dissipated to the surrounding without burning the fuse, Calculate the power dissipated by 5A fuse in that manner. Take the average value of the resistance of the fuse wire over the temperature range is equal to five times the resistance calculated under (b) (i).

iii) A test performed by manufacturers of electrical fuses is to determine the amplitude of a current pulse needed to melt (burn) the fuse wire approximately in one millisecond. Considering the rectangular current pulse of one millisecond duration shown in the figure (2). Calculate the peak current I_0 of the pulse needed to melt the fuse wire given in (*b*) (*i*). Assume that the heat dissipation to the surroundings under this condition is negligible. Take the mass of the fuse wire given in (*b*) (*i*) as 7.5×10^{-6} kg, and the average value of resistance of the fuse wire as five times the resistance calculated under (*b*) (*i*). Specific heat capacity of the material of the fuse wire is 390 J kg^{-1} $^0C^{-1}$. Melting point of the material of the fuse wire is 1075 ^0C.

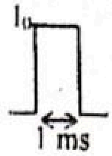


Figure 2

iv) Consider a situation in which a load circuit with an applied voltage of 230 V as shown in the figure (3) is short circuited at *XY*. Calculate the current through a 5A fuse under this situation. Using the results obtained in (b) (iii), show that the fuse will melt before 1 millisecond. (Assume that the current produce is a rectangular current pulse)

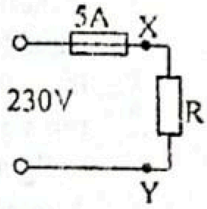


Figure 3

v) A rectangle narrow current pulse of 500 A occurring for a duration of 1 μs passes through a 5A fuse. In this situation, will the fuse get burnt? Justify your answer using an appropriate calculation.

2018 A/L

34) In the circuit shown in figure (1), 5V cell has a negligible internal resistance. Z is a resistor.

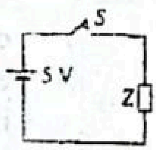


Figure (1)

a) Once the switch S is closed calculate the power dissipation in the resistor Z when its value is 1 kΩ.

b) The switch is now closed and opened once to produce the rectangular voltage pulse ABCD shown in figure (2). Amplitude and the width of the voltage pulse are 5V and 10 ms respectively. Once the pulse is produced it travels through the circuit with a speed of 2×10^6 ms^{-1}. Assume that the rectangular shape of the pulse remains unchanged when it passes through the circuit.

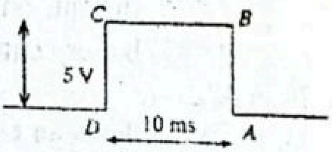


Figure (2)

i) How long does the edge AB of the voltage pulse take to travel across the length of the resistor Z of 2 cm long?

ii) Approximately how long does the full voltage of 5V appear across the entire length of the resistor Z?

iii) Assuming that the resistor has a value of 1 kΩ, calculate the energy dissipated in the resistor Z by the voltage pulse.

c) The switch S is now closed and opened regularly to produce the rectangular voltage waveform shown in figure (3).

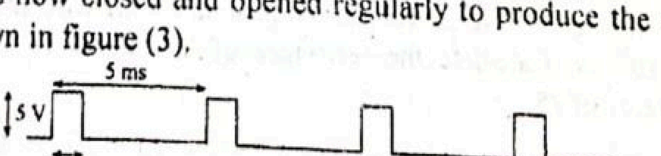


Figure (3)

As shown in figure (3), width of a pulse is 1 ms and the period of the voltage waveform is 5 ms. Under this situation, calculate the power dissipated in the resistor Z when its value is 1 kΩ.

d) A rectangular current pulse of amplitude I_0 and width T_0 generated by a pulsating current source Y centers two resistive wires of lengths l_1 and l_2 as shown in figure (4).

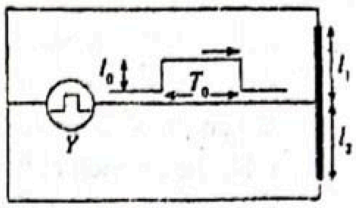


Figure (4)

Assume that all the other connecting wires in the circuit have negligible resistance. The two resistive wires of lengths l_1 and l_2, each having area of cross – section A, are made of a material of resistivity ρ.

i) If R_1 and R_2 are the resistances of the wires of lengths l_1 and l_2, respectively, write down expressions for R_1 and R_2.

ii) Derive expressions for the amplitudes I_1 and I_2 of current pulses through the wires of length l_1 and l_2 respectively in terms of I_0, l_1 and l_2.

e) A gaseous X – ray detector consists of a resistive anode wire PQ of length L surrounded by a suitable gas as shown in figure (5). Suppose an X – ray photon is absorbed by the gas producing a narrow electron pulse in the gas close to the point S of the anode wire as shown in figure (5).

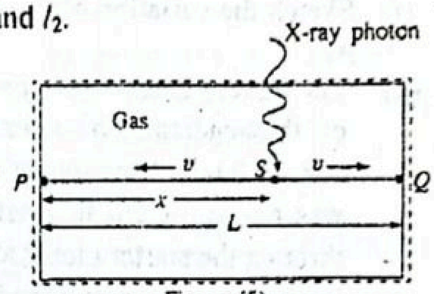


Figure (5)

The anode wire has the capability of extracting this electron pulse from the gas and forming an electron current pulse at the point S of the anode wire PQ. Subsequently, the electron current pulse gets divided into two and move through the wire in either direction with speed v.

If Δt is the difference in the arrival times of the two electron current pulses to reach the ends P and Q of the anode wire, derive an expression for the distance x from the point P to the point S where the X – ray photon is absorbed, in terms of Δt, v and L.

2019 A/L

35)(a) The electromotive force (emf) of an electric source is defined as the work done by the source on a unit charge. Using this definition:

(i) determine the units of emf.

(ii) obtain an expression for the power generated by a source in terms of its emf E and the current I flowing through it.

(b) A source of emf E and internal resistance r is connected to an external resistor with resistance R. Obtain an expression for the total energy dissipated in the circuit in time t, in terms of E, r, R, and t.

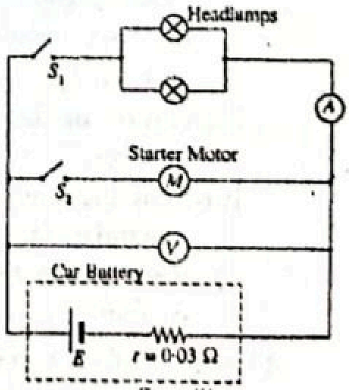


Figure (1)

(c) Consider an electrochemical battery of a car that powers the starter motor and the headlamps as shown in the circuit of figure (1). Rated power of each headlamp is 60 W. The internal resistance of the battery is 0.03 Ω. Consider that the ammeter behaves as an ideal ammeter. When only the headlamps are turned on (S_1 is closed) without starting the car (S_2 is open), the voltmeter shows a value of 12.0 V.

(i) What is the reading of the ammeter?

(ii) What is the resistance of a headlamp?

(iii) Calculate the emf of the battery.

(d) When the starter motor is just turned on (S_2 is just closed) while the headlamps are ON, the ammeter shows a value of 8.0 A. Calculate,

(i) the current through the starter motor, and

(ii) the resistance of the starter motor.

(e) When the armature of the starter motor is rotating while the headlamps are ON, the current through the starter motor is 34.2 A and the voltmeter reading is 11.0 V. Calculate,

(i) the back emf, and (ii) the efficiency of the starter motor, at this instant.

(f) Sketch the variation of the back emf E_b of the motor with the current flowing through it.

(g) The battery discharged considerably because the driver parked the car without turning off the headlamps on a certain night. As a result, emf of the battery dropped to 10.8 V and its internal resistance increased to 0.24 Ω. The current through the starter motor was not sufficient to rotate it due to the discharge of the battery. Find the current through the starter motor at this instance.

(h) In the situation mentioned in (g) above, the driver used an external battery with an emf 12.3 V and an internal resistance 0.02 Ω to jump start the car. For this, the external battery was connected to the discharged battery using two jumper cables, each having a resistance of 0.015 Ω and the car was then started.

i) Draw the circuit diagram showing the connections to the external battery with the discharged battery, when jump starting the car.

ii) Calculate the maximum current through the starter motor when starting the engine.

2020 A/L

36) a) i) Write down an expression for the energy dissipation in a resistor of resistance R, when a direct current (d.c.) I flows through it in time t.

ii) The variation of sinusoidal alternating voltage V with time t is shown in figure (1). Write down an expression for root mean square voltage V_{rms} in terms of peak voltage V_p.

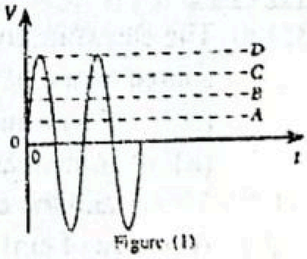


Figure (1)

iii) Out of the four lines A, B, C, D drawn in figure (1) which lines represent V_p and V_{rms} respectively?

iv) State the main advantage of using high tention a.c. voltage in long distance power transmission.

v) Rewrite the expression obtained for energy dissipation in (a) (i) above for a.c. currents.

b) A part of an electrical circuit connected to the a.c. main supply is shown in figure (2).
Following electrical appliances are connected to the main 230 V supply using a copper wire AB of cross sectional area 1 mm^2 and length 10 m. Assume that the voltage drop across AB is negligible.

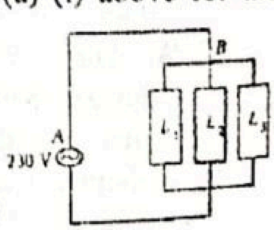


Figure (2)

L_1 - Rice cooker of 1200 W
L_2 - Refrigerator of 300 W,
L_3 - Electric kettle of 800 W,

i) Calculate the maximum current flow in the wire.

ii) Calculate the temperature rise when the maximum current flows through the wire for 10 s. Assume that the wire is completely insulated and no loss of heat to the outside. Mass of the wire is 100 g. Resistivity and the specific heat capacity of copper are 1.8×10^{8} m and 360 J kg^{-1} $^{0}C^{-1}$ respectively.

iii) Instead of a single copper wire a composite wire made of few such wires connected in parallel is used in high current flowing applications. Explain how this arrangement reduces hear dissipation.

c) An electricity meter measures the amount of electrical energy consumption in kWh. It uses eddy currents to rotate a thin circular aluminum disc. The number of revolutions of the aluminum disc is directly proportional to the electrical energy consumption.

i) A solenoid is placed other the horizontal aluminum disc. The number of revolutions of the aluminum disc, perpendicular to its plane as illustrated in figure (3). Suppose that the current through the solenoid is increasing in the direction as indicated in the figure. Copy the figure (3) in to your answer sheet and draw the magnetic flux lines due to current in the solenoid and eddy current loops on the disc, indicating their directions.

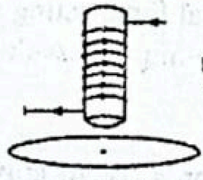


Figure (3)

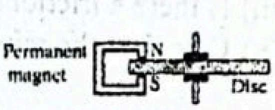


Figure (4)

ii) To decelerate the free revolutions of the disc when the power consumption is stopped, a permanent magnet is fixed as shown in the figure (4). Explain how the deceleration of the disc happen.

d) During the period from 6.00 p.m. to 10.00 p.m for a particular day at a house, the number of revolutions per minute (r.p.m) of the disc is measured. The graph in figure (5) shows its variation. The electricity meter is calibrated in such a way that 500 rotations is equivalent to 1 kWh.

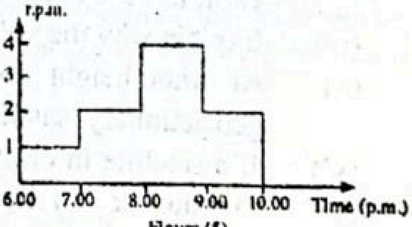


Figure (5)

i) Calculate the electrical power consumption at 8.30 p.m.

ii) If the electricity unit price between 7.00 p.m. to 9.00 p.m. is Rs. 40.00 per kWh and rest of the time is Rs. 10.00 per kWh, calculate the total cost for the period from 6.00 p.m. to 10.00 p.m.