QUESTIONS FOR SHORT ANSWER

1. Suppose you have three resistors each of value 30 Ω. List all the different resistances you can obtain using them.
2. A proton beam is going from east to west. Is there an electric current? If yes, in what direction?
3. In an electrolyte, the positive ions move from left to right and the negative ions from right to left. Is there a net current? If yes, in what direction?
4. In a TV tube, the electrons are accelerated from the rear to the front. What is the direction of the current?
5. The drift speed is defined as $v_d = \Delta l/\Delta t$ where Δl is the distance drifted in a long time Δt. Why don't we define the drift speed as the limit of $\Delta l/\Delta t$ as $\Delta t \to 0$?
6. One of your friends argues that he has read in previous chapters that there can be no electric field inside a conductor. And hence there can be no current through it. What is the fallacy in this argument?
7. When a current is established in a wire, the free electrons drift in the direction opposite to the current. Does the number of free electrons in the wire continuously decrease?
8. A fan with copper winding in its motor consumes less power as compared to an otherwise similar fan having aluminium winding. Explain.
9. The thermal energy developed in a current-carrying resistor is given by $U = i^2Rt$ and also by $U = Vit$. Should we say that U is proportional to i^2 or to i?
10. Consider a circuit containing an ideal battery connected to a resistor. Do "work done by the battery" and "the thermal energy developed" represent two names of the same physical quantity?
11. Is work done by a battery always equal to the thermal energy developed in electrical circuits? What happens if a capacitor is connected in the circuit?
12. A nonideal battery is connected to a resistor. Is work done by the battery equal to the thermal energy developed in the resistor? Does your answer change if the battery is ideal?
13. Sometimes it is said that "heat is developed" in a resistance when there is an electric current in it. Recall that heat is defined as the energy being transferred due to the temperature difference. Is the statement under quotes technically correct?
14. We often say "a current is going through the wire". What goes through the wire, the charge or the current?
15. Would you prefer a voltmeter or a potentiometer to measure the emf of a battery?
16. Does a conductor become charged when a current is passed through it?
17. Can the potential difference across a battery be greater than its emf?

OBJECTIVE I

1. A metallic resistor is connected across a battery. If the number of collisions of the free electrons with the lattice is somehow decreased in the resistor (for example, by cooling it), the current will
   (a) increase (b) decrease
   (c) remain constant (d) become zero.
2. Two resistors A and B have resistances R_A and R_B respectively with $R_A < R_B$. The resistivities of their materials are ρ_A and ρ_B.
   (a) $\rho_A > \rho_B$. (b) $\rho_A = \rho_B$. (c) $\rho_A < \rho_B$.
   (d) The information is not sufficient to find the relation between ρ_A and ρ_B.
3. The product of resistivity and conductivity of a cylindrical conductor depends on
   (a) temperature (b) material
   (c) area of cross-section (d) none of these.
4. As the temperature of a metallic resistor is increased, the product of its resistivity and conductivity
   (a) increases (b) decreases
   (c) remains constant (d) may increase or decrease.
5. In an electric circuit containing a battery, the charge (assumed positive) inside the battery
   (a) always goes from the positive terminal to the negative terminal
   (b) may go from the positive terminal to the negative terminal
   (c) always goes from the negative terminal to the positive terminal
   (d) does not move.
6. A resistor of resistance R is connected to an ideal battery. If the value of R is decreased, the power dissipated in the resistor will
   (a) increase (b) decrease (c) remain unchanged.
7. A current passes through a resistor. Let K_1 and K_2 represent the average kinetic energy of the conduction electrons and the metal ions respectively.
   (a) $K_1 < K_2$. (b) $K_1 = K_2$.
   (c) $K_1 > K_2$. (d) Any of these three may occur.
8. Two resistors R and $2R$ are connected in series in an electric circuit. The thermal energy developed in R and $2R$ are in the ratio
   (a) 1 : 2 (b) 2 : 1 (c) 1 : 4 (d) 4 : 1.
9. Two resistances R and $2R$ are connected in parallel in an electric circuit. The thermal energy developed in R and $2R$ are in the ratio
   (a) 1 : 2 (b) 2 : 1 (c) 1 : 4 (d) 4 : 1.
10. A uniform wire of resistance 50 Ω is cut into 5 equal parts. These parts are now connected in parallel. The

equivalent resistance of the combination is
(a) 2 Ω (b) 10 Ω (c) 250 Ω (d) 6250 Ω.

11. Consider the following two statements:
(A) Kirchhoff's junction law follows from conservation of charge.
(B) Kirchhoff's loop law follows from conservative nature of electric field.
(a) Both A and B are correct.
(b) A is correct but B is wrong.
(c) B is correct but A is wrong.
(d) Both A and B are wrong.

12. Two nonideal batteries are connected in series. Consider the following statements:
(A) The equivalent emf is larger than either of the two emfs.
(B) The equivalent internal resistance is smaller than either of the two internal resistances.
(a) Each of A and B is correct.
(b) A is correct but B is wrong.
(c) B is correct but A is wrong.
(d) Each of A and B is wrong.

13. Two nonideal batteries are connected in parallel. Consider the following statements:
(A) The equivalent emf is smaller than either of the two emfs.
(B) The equivalent internal resistance is smaller than either of the two internal resistances.
(a) Both A and B are correct.
(b) A is correct but B is wrong.
(c) B is correct but A is wrong.
(d) Both A and B are wrong.

14. The net resistance of an ammeter should be small to ensure that
(a) it does not get overheated
(b) it does not draw excessive current
(c) it can measure large currents
(d) it does not appreciably change the current to be measured.

15. The net resistance of a voltmeter should be large to ensure that
(a) it does not get overheated
(b) it does not draw excessive current
(c) it can measure large potential differences
(d) it does not appreciably change the potential difference to be measured.

16. Consider a capacitor-charging circuit. Let Q_1 be the charge given to the capacitor in a time interval of 10 ms and Q_2 be the charge given in the next time interval of 10 ms. Let 10 μC charge be deposited in a time interval t_1 and the next 10 μC charge is deposited in the next time interval t_2.
(a) $Q_1 > Q_2$, $t_1 > t_2$. (b) $Q_1 > Q_2$, $t_1 < t_2$.
(c) $Q_1 < Q_2$, $t_1 > t_2$. (d) $Q_1 < Q_2$, $t_1 < t_2$.

OBJECTIVE II

1. Electrons are emitted by a hot filament and are accelerated by an electric field as shown in figure (32-Q1). The two stops at the left ensure that the electron beam has a uniform cross-section.
(a) The speed of the electron is more at B than at A.
(b) The electric current is from left to right.
(c) The magnitude of the current is larger at B than at A.
(d) The current density is more at B than at A.

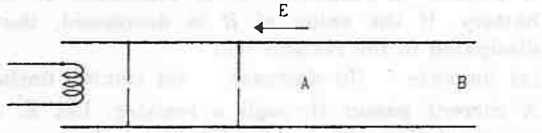


Figure 32-Q1

2. A capacitor with no dielectric is connected to a battery at $t = 0$. Consider a point A in the connecting wires and a point B in between the plates.
(a) There is no current through A.
(b) There is no current through B.
(c) There is a current through A as long as the charging is not complete.
(d) There is a current through B as long as the charging is not complete.

3. When no current is passed through a conductor,
(a) the free electrons do not move
(b) the average speed of a free electron over a large period of time is zero
(c) the average velocity of a free electron over a large period of time is zero
(d) the average of the velocities of all the free electrons at an instant is zero.

4. Which of the following quantities do not change when a resistor connected to a battery is heated due to the current?
(a) drift speed (b) resistivity
(c) resistance (d) number of free electrons.

5. As the temperature of a conductor increases, its resistivity and conductivity change. The ratio of resistivity to conductivity
(a) increases (b) decreases (c) remains constant
(d) may increase or decrease depending on the actual temperature.

6. A current passes through a wire of nonuniform cross-section. Which of the following quantities are independent of the cross-section?
(a) the charge crossing in a given time interval
(b) drift speed
(c) current density
(d) free-electron density.

7. Mark out the correct options.
(a) An ammeter should have small resistance.
(b) An ammeter should have large resistance.

(c) A voltmeter should have small resistance.
(d) A voltmeter should have large resistance.

8. A capacitor of capacitance 500 μF is connected to a battery through a 10 kΩ resistor. The charge stored on the capacitor in the first 5 s is larger than the charge stored in the next
(a) 5 s (b) 50 s (c) 500 s (d) 500.

9. A capacitor C_1 of capacitance 1 μF and a capacitor C_2 of capacitance 2 μF are separately charged by a common battery for a long time. The two capacitors are then separately discharged through equal resistors. Both the discharge circuits are connected at $t = 0$.
(a) The current in each of the two discharging circuits is zero at $t = 0$.
(b) The currents in the two discharging circuits at $t = 0$ are equal but not zero.
(c) The currents in the two discharging circuits at $t = 0$ are unequal.
(d) C_1 loses 50% of its initial charge sooner than C_2 loses 50% of its initial charge.

EXERCISES

1. The amount of charge passed in time t through a cross-section of a wire is
$$Q(t) = At^2 + Bt + C.$$
(a) Write the dimensional formulae for A, B and C.
(b) If the numerical values of A, B and C are 5, 3 and 1 respectively in SI units, find the value of the current at $t = 5$ s.

2. An electron gun emits $2·0 \times 10^{16}$ electrons per second. What electric current does this correspond to?

3. The electric current existing in a discharge tube is 2·0 μA. How much charge is transferred across a cross-section of the tube in 5 minutes?

4. The current through a wire depends on time as
$$i = i_0 + \alpha t,$$
where $i_0 = 10$ A and $\alpha = 4$ A/s. Find the charge crossed through a section of the wire in 10 seconds.

5. A current of 1·0 A exists in a copper wire of cross-section 1·0 mm^2. Assuming one free electron per atom calculate the drift speed of the free electrons in the wire. The density of copper is 9000 kg/m^3.

6. A wire of length 1 m and radius 0·1 mm has a resistance of 100 Ω. Find the resistivity of the material.

7. A uniform wire of resistance 100 Ω is melted and recast in a wire of length double that of the original. What would be the resistance of the wire?

8. Consider a wire of length 4 m and cross-sectional area 1 mm^2 carrying a current of 2 A. If each cubic metre of the material contains 10^{29} free electrons, find the average time taken by an electron to cross the length of the wire.

9. What length of a copper wire of cross-sectional area 0·01 mm^2 will be needed to prepare a resistance of 1 kΩ? Resistivity of copper = $1·7 \times 10^{-8}$ Ω–m.

10. Figure (32-E1) shows a conductor of length l having a circular cross-section. The radius of cross-section varies linearly from a to b. The resistivity of the material is ρ. Assuming that $b - a << l$, find the resistance of the conductor.

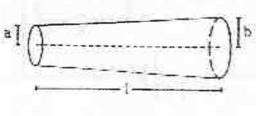


Figure 32-E1

11. A copper wire of radius 0·1 mm and resistance 1 kΩ is connected across a power supply of 20 V. (a) How many electrons are transferred per second between the supply and the wire at one end? (b) Write down the current density in the wire.

12. Calculate the electric field in a copper wire of cross-sectional area 2·0 mm^2 carrying a current of 1 A. The resistivity of copper = $1·7 \times 10^{-8}$ Ω–m.

13. A wire has a length of 2·0 m and a resistance of 5·0 Ω. Find the elecric field existing inside the wire if it carries a current of 10 A.

14. The resistances of an iron wire and a copper wire at 20°C are 3·9 Ω and 4·1 Ω respectively. At what temperature will the resistances be equal? Temperature coefficient of resistivity for iron is $5·0 \times 10^{-3}$ K^{-1} and for copper it is $4·0 \times 10^{-3}$ K^{-1}. Neglect any thermal expansion.

15. The current in a conductor and the potential difference across its ends are measured by an ammeter and a voltmeter. The meters draw negligible currents. The ammeter is accurate but the voltmeter has a zero error (that is, it does not read zero when no potential difference is applied). Calculate the zero error if the readings for two different conditions are 1·75 A, 14·4 V and 2·75 A, 22·4 V.

16. Figure (32-E2) shows an arrangement to measure the emf $\mathcal{E}$ and internal resistance r of a battery. The voltmeter has a very high resistance and the ammeter also has some resistance. The voltmeter reads 1·52 V when the switch S is open. When the switch is closed the voltmeter reading drops to 1·45 V and the ammeter reads 1·0 A. Find the emf and the internal resistance of the battery.

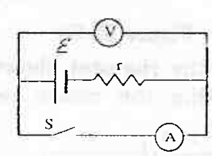


Figure 32-E2

17. The potential difference between the terminals of a battery of emf 6·0 V and internal resistance 1 Ω drops to 5·8 V when connected across an external resistor. Find the resistance of the external resistor.

18. The potential difference between the terminals of a 6·0 V battery is 7·2 V when it is being charged by a current of 2·0 A. What is the internal resistance of the battery ?

19. The internal resistance of an accumulator battery of emf 6 V is 10 Ω when it is fully discharged. As the battery gets charged up, its internal resistance decreases to 1 Ω. The battery in its completely discharged state is connected to a charger which maintains a constant potential difference of 9 V. Find the current through the battery (a) just after the connections are made and (b) after a long time when it is completely charged.

20. Find the value of i_1/i_2 in figure (32-E3) if (a) $R = 0{\cdot}1\ \Omega$, (b) $R = 1\ \Omega$ (c) $R = 10\ \Omega$. Note from your answers that in order to get more current from a combination of two batteries they should be joined in parallel if the external resistance is small and in series if the external resistance is large as compared to the internal resistances.

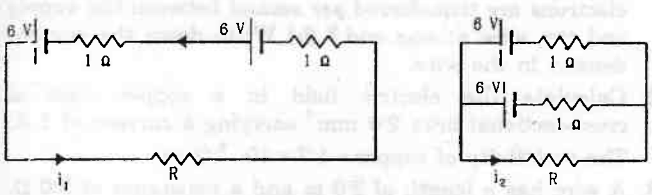


Figure 32-E3

21. Consider $N = n_1 n_2$ identical cells, each of emf $\mathcal{E}$ and internal resistance r. Suppose n_1 cells are joined in series to form a line and n_2 such lines are connected in parallel. The combination drives a current in an external resistance R. (a) Find the current in the external resistance. (b) Assuming that n_1 and n_2 can be continuously varied, find the relation between n_1, n_2, R and r for which the current in R is maximum.

22. A battery of emf 100 V and a resistor of resistance 10 kΩ are joined in series. This system is used as a source to supply current to an external resistance R. If R is not greater than 100 Ω, the current through it is constant upto two significant digits. Find its value. This is the basic principle of a *constant-current source.*

23. If the reading of ammeter A_1 in figure (32-E4) is 2·4 A, what will the ammeters A_2 and A_3 read ? Neglect the resistances of the ammeters.

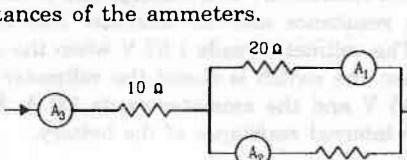


Figure 32-E4

24. The resistance of the rheostat shown in figure (32-E5) is 30 Ω. Neglecting the meter resistance, find the minimum and maximum currents through the ammeter as the rheostat is varied.

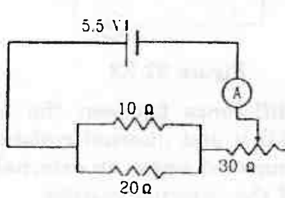


Figure 32-E5

25. Three bulbs, each having a resistance of 180 Ω, are connected in parallel to an ideal battery of emf 60 V. Find the current delivered by the battery when (a) all the bulbs are switched on, (b) two of the bulbs are switched on and (c) only one bulb is switched on.

26. Suppose you have three resistors of 20 Ω, 50 Ω and 100 Ω. What minimum and maximum resistances can you obtain from these resistors ?

27. A bulb is made using two filaments. A switch selects whether the filaments are used individually or in parallel. When used with a 15 V battery, the bulb can be operated at 5 W, 10 W or 15 W. What should be the resistances of the filaments ?

28. Figure (32-E6) shows a part of a circuit. If a current of 12 mA exists in the 5 kΩ resistor, find the currents in the other three resistors. What is the potential difference between the points A and B ?

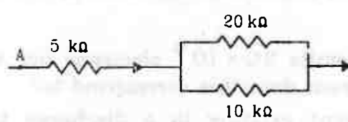


Figure 32-E6

29. An ideal battery sends a current of 5 A in a resistor. When another resistor of value 10 Ω is connected in parallel, the current through the battery is increased to 6 A. Find the resistance of the first resistor.

30. Find the equivalent resistance of the network shown in figure (32-E7) between the points a and b.

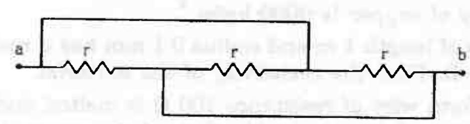


Figure 32-E7

31. A wire of resistance 15·0 Ω is bent to form a regular hexagon $ABCDEFA$. Find the equivalent resistance of the loop between the points (a) A and B, (b) A and C and (c) A and D.

32. Consider the circuit shown in figure (32-E8). Find the current through the 10 Ω resistor when the switch S is (a) open (b) closed.

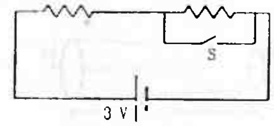


Figure 32-E8

33. Find the currents through the three resistors shown in figure (32-E9).

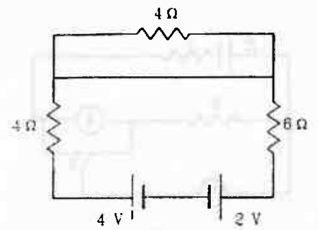


Figure 32-E9

34. Figure (32-E10) shows a part of an electric circuit. The potentials at the points a, b and c are 30 V, 12 V and 2 V respectively. Find the currents through the three resistors.

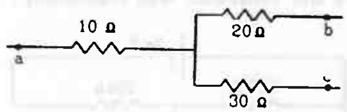


Figure 32-E10

35. Each of the resistors shown in figure (32-E11) has a resistance of 10 Ω and each of the batteries has an emf of 10 V. Find the currents through the resistors a and b in the two circuits.

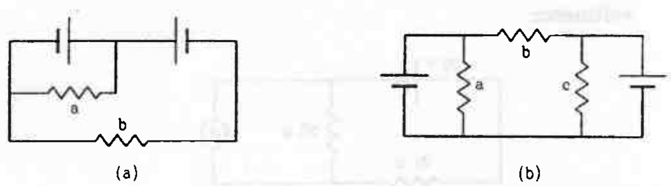


Figure 32-E11

36. Find the potential difference $V_a - V_b$ in the circuits shown in figure (32-E12).

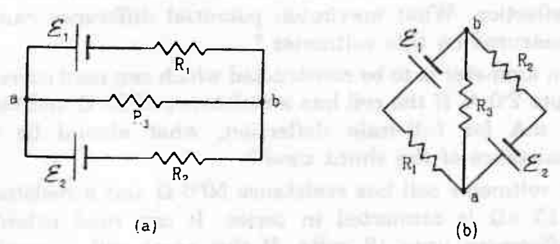


Figure 32-E12

37. In the circuit shown in figure (32-E13), $\mathcal{E}_1 = 3$ V, $\mathcal{E}_2 = 2$ V, $\mathcal{E}_3 = 1$ V and $r_1 = r_2 = r_3 = 1$ Ω. Find the potential difference between the points A and B and the current through each branch.

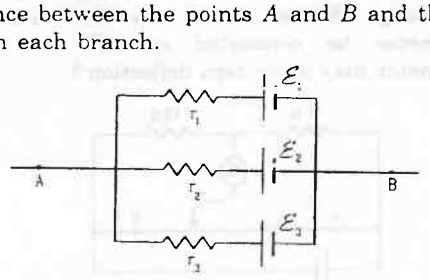


Figure 32-E13

38. Find the current through the 10 Ω resistor shown in figure (32-E14).

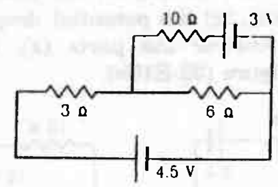


Figure 32-E14

39. Find the current in the three resistors shown in figure (32-E15).

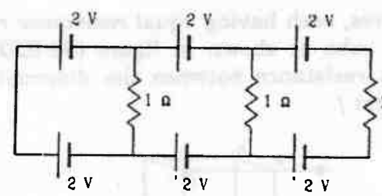


Figure 32-E15

40. What should be the value of R in figure (32-E16) for which the current in it is zero ?

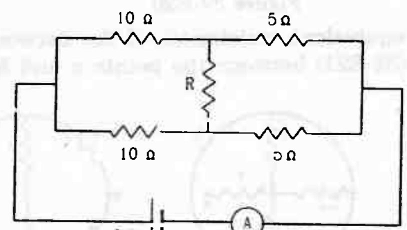


Figure 32-E16

41. Find the equivalent resistance of the circuits shown in figure (32-E17) between the points a and b. Each resistor has a resistance r.

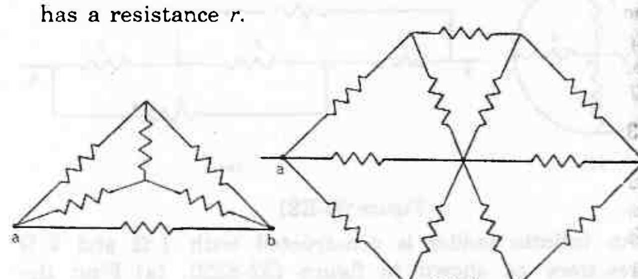


Figure 32-E17

42. Find the current measured by the ammeter in the circuit shown in figure (32-E18).

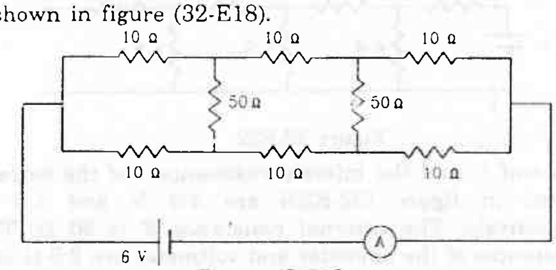


Figure 32-E18

43. Consider the circuit shown in figure (32-E19a). Find (a) the current in the circuit, (b) the potential drop across the 5 Ω resistor, (c) the potential drop across the 10 Ω resistor. (d) Answer the parts (a), (b) and (c) with reference to figure (32-E19b).

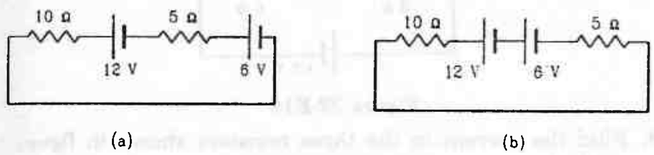


Figure 32-E19

44. Twelve wires, each having equal resistance r, are joined to form a cube as shown in figure (32-E20). Find the equivalent resistance between the diagonally opposite points a and f.

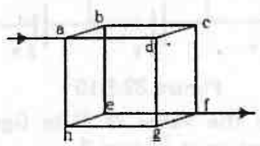


Figure 32-E20

45. Find the equivalent resistances of the networks shown in figure (32-E21) between the points a and b.

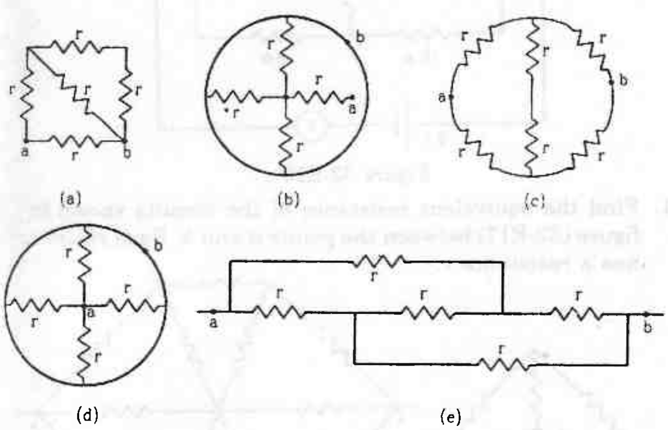


Figure 32-E21

46. An infinite ladder is constructed with 1 Ω and 2 Ω resistors as shown in figure (32-E22). (a) Find the effective resistance between the points A and B. (b) Find the current that passes through the 2 Ω resistor nearest to the battery.

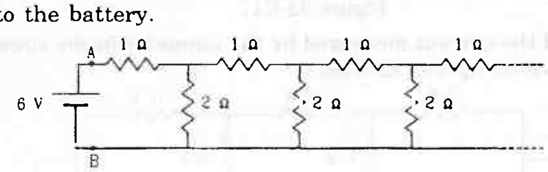


Figure 32-E22

47. The emf $\mathcal{E}$ and the internal resistance r of the battery shown in figure (32-E23) are 4·3 V and 1·0 Ω respectively. The external resistance R is 50 Ω. The resistances of the ammeter and voltmeter are 2·0 Ω and 200 Ω respectively. (a) Find the readings of the two meters. (b) The switch is thrown to the other side. What will be the readings of the two meters now ?

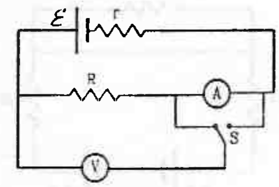


Figure 32-E23

48. A voltmeter of resistance 400 Ω is used to measure the potential difference across the 100 Ω resistor in the circuit shown in figure (32-E24). (a) What will be the reading of the voltmeter ? (b) What was the potential difference across 100 Ω before the voltmeter was connected ?

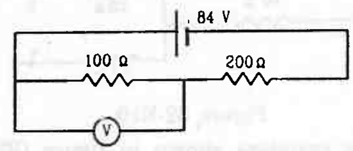


Figure 32-E24

49. The voltmeter shown in figure (32-E25) reads 18 V across the 50 Ω resistor. Find the resistance of the voltmeter.

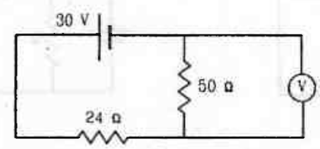


Figure 32-E25

50. A voltmeter consists of a 25 Ω coil connected in series with a 575 Ω resistor. The coil takes 10 mA for full scale deflection. What maximum potential difference can be measured on this voltmeter ?

51. An ammeter is to be constructed which can read currents upto 2·0 A. If the coil has a resistance of 25 Ω and takes 1 mA for full-scale deflection, what should be the resistance of the shunt used ?

52. A voltmeter coil has resistance 50·0 Ω and a resistor of 1·15 kΩ is connected in series. It can read potential differences upto 12 volts. If this same coil is used to construct an ammeter which can measure currents upto 2·0 A, what should be the resistance of the shunt used ?

53. The potentiometer wire AB shown in figure (32-E26) is 40 cm long. Where should the free end of the galvanometer be connected on AB so that the galvanometer may show zero deflection ?

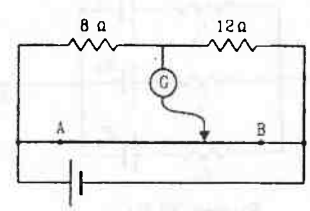


Figure 32-E26

54. The potentiometer wire AB shown in figure (32-E27) is 50 cm long. When $AD = 30$ cm, no deflection occurs in the galvanometer. Find R.

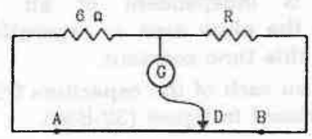


Figure 32-E27

55. A 6 volt battery of negligible internal resistance is connected across a uniform wire AB of length 100 cm. The positive terminal of another battery of emf 4 V and internal resistance 1 Ω is joined to the point A as shown in figure (32-E28). Take the potential at B to be zero. (a) What are the potentials at the points A and C ? (b) At which point D of the wire AB, the potential is equal to the potenial at C ? (c) If the points C and D are connected by a wire, what will be the current through it ? (d) If the 4 V battery is replaced by 7·5 V battery, what would be the answers of parts (a) and (b) ?

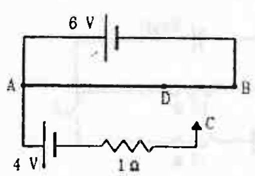


Figure 32-E28

56. Consider the potentiometer circuit arranged as in figure (32-E29). The potentiometer wire is 600 cm long. (a) At what distance from the point A should the jockey touch the wire to get zero deflection in the galvanometer ? (b) If the jockey touches the wire at a distance of 560 cm from A, what will be the current in the galvanometer ?

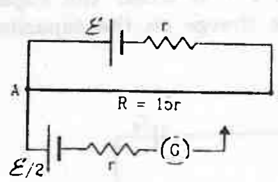


Figure 32-E29

57. Find the charge on the capacitor shown in figure (32-E30).

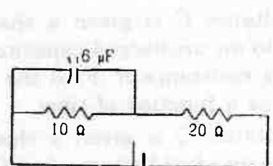


Figure 32-E30

58. (a) Find the current in the 20 Ω resistor shown in figure (32-E31). (b) If a capacitor of capacitance 4 μF is joined between the points A and B, what would be the electrostatic energy stored in it in steady state ?

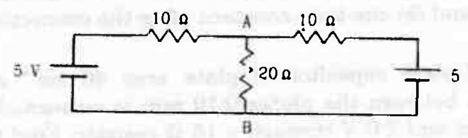


Figure 32-E31

59. Find the charges on the four capacitors of capacitances 1 μF, 2 μF, 3 μF and 4 μF shown in figure (32-E32).

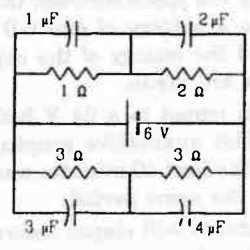


Figure 32-E32

60. Find the potential difference between the points A and B and between the points B and C of figure (32-E33) in steady state.

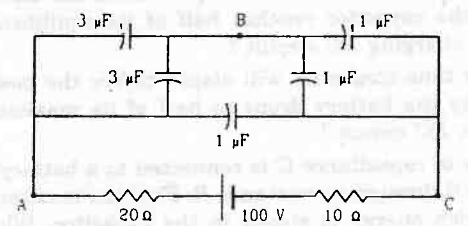


Figure 32-E33

61. A capacitance C, a resistance R and an emf $\mathcal{E}$ are connected in series at $t = 0$. What is the maximum value of (a) the potential difference across the resistor, (b) the current in the circuit, (c) the potential difference across the capacitor, (d) the energy stored in the capacitor, (e) the power delivered by the battery and (f) the power converted into heat.

62. A parallel-plate capacitor with plate area 20 cm^2 and plate separation 1·0 mm is connected to a battery. The resistance of the circuit is 10 kΩ. Find the time constant of the circuit.

63. A capacitor of capacitance 10 μF is connected to a battery of emf 2 V. It is found that it takes 50 ms for the charge on the capacitor to become 12·6 μC. Find the resistance of the circuit.

64. A 20 μF capacitor is joined to a battery of emf 6·0 V through a resistance of 100 Ω. Find the charge on the capacitor 2·0 ms after the connections are made.

65. The plates of a capacitor of capacitance 10 μF, charged to 60 μC, are joined together by a wire of resistance 10 Ω at $t = 0$. Find the charge on the capacitor in the circuit at (a) $t = 0$, (b) $t = 30$ μs, (c) $t = 120$ μs and (d) $t = 1·0$ ms.

66. A capacitor of capacitance 8·0 μF is connected to a battery of emf 6·0 V through a resistance of 24 Ω. Find

the current in the circuit (a) just after the connections are made and (b) one time constant after the connections are made.

67. A parallel-plate capacitor of plate area 40 cm^2 and separation between the plates 0·10 mm is connected to a battery of emf 2·0 V through a 16 Ω resistor. Find the electric field in the capacitor 10 ns after the connections are made.

68. A parallel-plate capacitor has plate area 20 cm^2, plate separation 1·0 mm and a dielectric slab of dielectric constant 5·0 filling up the space between the plates. This capacitor is joined to a battery of emf 6·0 V through a 100 kΩ resistor. Find the energy of the capacitor 8·9 μs after the connections are made.

69. A 100 μF capacitor is joined to a 24 V battery through a 1·0 MΩ resistor. Plot qualitative graphs (a) between current and time for the first 10 minutes and (b) between charge and time for the same period.

70. How many time constants will elapse before the current in a charging RC circuit drops to half of its initial value? Answer the same question for a discharging RC circuit.

71. How many time constants will elapse before the charge on a capacitor falls to 0·1% of its maximum value in a discharging RC circuit?

72. How many time constants will elapse before the energy stored in the capacitor reaches half of its equilibrium value in a charging RC circuit?

73. How many time constants will elapse before the power delivered by the battery drops to half of its maximum value in an RC circuit?

74. A capacitor of capacitance C is connected to a battery of emf $\mathcal{E}$ at $t = 0$ through a resistance R. Find the maximum rate at which energy is stored in the capacitor. When does the rate has this maximum value?

75. A capacitor of capacitance 12·0 μF is connected to a battery of emf 6·00 V and internal resistance 1·00 Ω through resistanceless leads. 12·0 μs after the connections are made, what will be (a) the current in the circuit, (b) the power delivered by the battery, (c) the power dissipated in heat and (d) the rate at which the energy stored in the capacitor is increasing.

76. A capacitance C charged to a potential difference V is discharged by connecting its plates through a resistance R. Find the heat dissipated in one time constant after the connections are made. Do this by calculating $\int i^2 R\, dt$ and also by finding the decrease in the energy stored in the capacitor.

77. By evaluating $\int i^2 R dt$, show that when a capacitor is charged by connecting it to a battery through a resistor, the energy dissipated as heat equals the energy stored in the capacitor.

78. A parallel-plate capacitor is filled with a dielectric material having resistivity ρ and dielectric constant K. The capacitor is charged and disconnected from the charging source. The capacitor is slowly discharged through the dielectric. Show that the time constant of the discharge is independent of all geometrical parameters like the plate area or separation between the plates. Find this time constant.

79. Find the charge on each of the capacitors 0·20 ms after the switch S is closed in figure (32-E34).

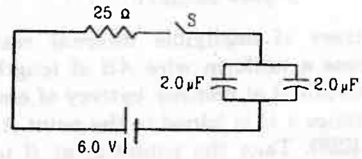


Figure 32-E34

80. The switch S shown in figure (32-E35) is kept closed for a long time and is then opened at $t = 0$. Find the current in the middle 10 Ω resistor at $t = 1·0$ ms.

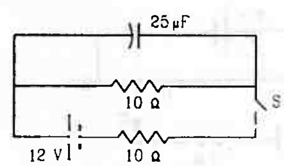


Figure 32-E35

81. A capacitor of capacitance 100 μF is connected across a battery of emf 6·0 V through a resistance of 20 kΩ for 4·0 s. The battery is then replaced by a thick wire. What will be the charge on the capacitor 4·0 s after the battery is disconnected?

82. Consider the situation shown in figure (32-E36). The switch is closed at $t = 0$ when the capacitors are uncharged. Find the charge on the capacitor C_1 as a function of time t.

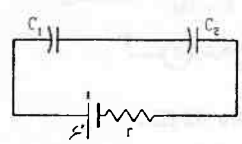


Figure 32-E36

83. A capacitor of capacitance C is given a charge Q. At $t = 0$, it is connected to an uncharged capacitor of equal capacitance through a resistance R. Find the charge on the second capacitor as a function of time.

84. A capacitor of capacitance C is given a charge Q. At $t = 0$, it is connected to an ideal battery of emf $\mathcal{E}$ through a resistance R. Find the charge on the capacitor at time t.

□

ANSWERS

OBJECTIVE I

1. (a)	2. (d)	3. (d)	4. (c)	5. (b)	6. (a)
7. (c)	8. (a)	9. (b)	10. (a)	11. (a)	12. (b)
13. (c)	14. (d)	15. (d)	16. (b)		

OBJECTIVE II

1. (a)	2. (b), (c)	3. (c), (d)
4. (d)	5. (a)	6. (a), (d)
7. (a), (d)	8. all	9. (b), (d)

EXERCISES

1. (a) IT^{-1}, I, IT (b) 53 A
2. $3·2 \times 10^{-3}$ A
3. $6·0 \times 10^{-4}$ C
4. 300 C
5. 0·074 mm/s
6. $\pi \times 10^{-6}$ Ω–m
7. 400 Ω
8. $3·2 \times 10^{4}$ s ≈ 8·9 hours
9. 0·6 km
10. $\frac{\rho l}{\pi ab}$
11. (a) $1·25 \times 10^{17}$ (b) $6·37 \times 10^{5}$ A/m^2
12. 8·5 mV/m
13. 25 V/m
14. 84·5°C
15. 0·4 V
16. 1·52 V, 0·07 Ω
17. 29 Ω
18. 0·6 Ω
19. (a) 0·3 A (b) 3 A
20. (a) 0·57 (b) 1 (c) 1·75
21. (a) $\frac{n\mathcal{E}}{R + \frac{n_1 r}{n_2}}$ (b) $rn_1 = Rn_2$
22. 10 mA
23. 1·6 A, 4·0 A
24. 0·15 A, 0·83 A
25. (a) 1·0 A (b) 0·67 A (c) 0·33 A
26. 12·5 Ω, 170 Ω
27. 45 Ω, 22·5 Ω
28. 4 mA in 20 kΩ resistor, 8 mA in 10 kΩ resistor and 12 mA in 100 kΩ resistor, 1340 V
29. 2 Ω
30. $r/3$
31. (a) 2·08 Ω (b) 3·33 Ω (c) 3·75 Ω
32. (a) 0·1 A (b) 0·3 A
33. zero in the upper 4 Ω resistor and 0·2 A in the rest two
34. 1 A through 10 Ω, 0·4 Ω through 20 Ω and 0·6 A through 30 Ω
35. 1 A in a and zero in b in both the circuits
36. (a) $\frac{\frac{\mathcal{E}_1}{R_1} - \frac{\mathcal{E}_2}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$ (b) same as (a)
37. 2 V, $i_1 = 1$ A, $i_2 = 0$, $i_3 = -1$ A
38. zero
39. zero
40. any value of R will do
41. (a) $r/2$ (b) $4r/5$
42. 0·4 A
43. (a) 1·2 A (b) 6 V (c) 12 V (d) same as the parts (a), (b) and (c)
44. $\frac{5}{6}r$
45. (a) $\frac{5}{8}r$ (b) $\frac{4}{3}r$ (c) r (d) $\frac{r}{4}$ (e) r
46. (a) 2 Ω (b) 1·5 A
47. (a) 0·1 A 4·0 V (b) 0·08 A, 4·2 V
48. (a) 24 V (b) 28 V
49. 130 Ω
50. 6 V
51. $1·25 \times 10^{-2}$ Ω
52. 0·251 Ω
53. 16 cm from A
54. 4 Ω
55. (a) 6 V, 2 V (b) AD = 66·7 cm (c) zero (d) 6 V, – 1·5 V, no such point D exists.
56. (a) 320 cm (b) $\frac{3\mathcal{E}}{22r}$
57. 4 μC
58. (a) 0·2 A (b) 32 μJ
59. 2 μC, 8 μC, 9 μC and 12 μC
60. 25 V, 75 V
61. (a) $\mathcal{E}$ (b) $\frac{\mathcal{E}}{R}$ (c) $\mathcal{E}$ (d) $\frac{1}{2}C\mathcal{E}^2$ (e) $\frac{\mathcal{E}^2}{R}$ (f) $\frac{\mathcal{E}^2}{R}$
62. 0·18 μs
63. 5 kΩ
64. 76 μC
65. (a) 60 μC (b) 44 μC (c) 18 μC (d) 0·003 μC
66. (a) 0·25 A (b) 0·09 A
67. $1·7 \times 10^{-4}$ V/m
68. $6·3 \times 10^{-10}$ J
70. 0·69 in both cases
71. 6·9
72. 1·23

73. 0·69

74. $\frac{\mathcal{E}^2}{4R}$, $CR \ln 2$

75. (a) 2·21 A (b) 13·2 W (c) 4·87 W (d) 8·37 W

76. $\frac{1}{2}(1 - 1/e^2)CV^2$

78. $\varepsilon_0 \rho K$

79. 9·2 μC

80. 11 mA

81. 70 μC

82. $q = \mathcal{E}C(1 - e^{-t/rc})$, where $C = \frac{C_1 C_2}{C_1 + C_2}$.

83. $\frac{Q}{2}(1 - e^{-2t/RC})$

84. $C\mathcal{E}(1 - e^{-t/CR}) + Q e^{-t/CR}$

□

ELECTRIC CURRENT IN CONDUCTORS
CHAPTER - 32

1. $Q(t) = At^2 + Bt + c$

a) $At^2 = Q$

$\Rightarrow A = \frac{Q}{t^2} = \frac{A'T'}{T^{-2}} = A^1T^{-1}$

b) $Bt = Q$

$\Rightarrow B = \frac{Q}{t} = \frac{A'T'}{T} = A$

c) $C = [Q]$

$\Rightarrow C = A'T'$

d) Current t = $\frac{dQ}{dt} = \frac{d}{dt}\left(At^2 + Bt + C\right)$

$= 2At + B = 2 \times 5 \times 5 + 3 = 53$ A.

2. No. of electrons per second = 2×10^{16} electrons / sec.

Charge passing per second = $2 \times 10^{16} \times 1.6 \times 10^{-9}$ $\frac{\text{coulomb}}{\text{sec}}$

$= 3.2 \times 10^{-9}$ Coulomb/sec

Current = 3.2×10^{-3} A.

3. $i' = 2\ \mu A$, t = 5 min = 5×60 sec.

$q = i\,t = 2 \times 10^{-6} \times 5 \times 60$

$= 10 \times 60 \times 10^{-6}\ c = 6 \times 10^{-4}\ c$

4. $i = i_0 + \alpha t$, t = 10 sec, $i_0 = 10$ A, $\alpha = 4$ A/sec.

$q = \int_0^t idt = \int_0^t (i_0 + \alpha t)dt = \int_0^t i_0 dt + \int_0^t \alpha t dt$

$= i_0 t + \alpha\frac{t^2}{2} = 10 \times 10 + 4 \times \frac{10 \times 10}{2}$

$= 100 + 200 = 300$ C.

5. $i = 1$ A, A = 1 mm^2 = 1×10^{-6} m^2

f' cu = 9000 kg/m^3

Molecular mass has N_0 atoms

= m Kg has (N_0/M $\times$ m) atoms = $\frac{N_0 Al9000}{63.5 \times 10^{-3}}$

No.of atoms = No.of electrons

$n = \frac{\text{No.of electrons}}{\text{Unit volume}} = \frac{N_0 Af}{mAl} = \frac{N_0 f}{M}$

$= \frac{6 \times 10^{23} \times 9000}{63.5 \times 10^{-3}}$

$i = V_d\, n\, A\, e.$

$\Rightarrow V_d = \frac{i}{nAe} = \frac{1}{\frac{6 \times 10^{23} \times 9000}{63.5 \times 10^{-3}} \times 10^{-6} \times 1.6 \times 10^{-19}}$

$= \frac{63.5 \times 10^{-3}}{6 \times 10^{23} \times 9000 \times 10^{-6} \times 1.6 \times 10^{-19}} = \frac{63.5 \times 10^{-3}}{6 \times 9 \times 1.6 \times 10^{26} \times 10^{-19} \times 10^{-6}}$

$= \frac{63.5 \times 10^{-3}}{6 \times 9 \times 1.6 \times 10} = \frac{63.5 \times 10^{-3}}{6 \times 9 \times 16}$

$= 0.074 \times 10^{-3}$ m/s = 0.074 mm/s.

6. ℓ = 1 m, r = 0.1 mm = 0.1×10^{-3} m

R = 100 Ω, f = ?

$\Rightarrow$ R = f ℓ / a

$\Rightarrow f = \frac{Ra}{\ell} = \frac{100 \times 3.14 \times 0.1 \times 0.1 \times 10^{-6}}{1}$

$= 3.14 \times 10^{-6} = \pi \times 10^{-6}\ \Omega$-m.

7. $\ell' = 2\ell$

volume of the wire remains constant.

$A\ell = A'\ \ell'$

$\Rightarrow A\ell = A' \times 2\ell$

$\Rightarrow A' = A/2$

f = Specific resistance

$R = \frac{f\ell}{A}$; $R' = \frac{f\ell'}{A'}$

$100\ \Omega = \frac{f2\ell}{A/2} = \frac{4f\ell}{A} = 4R$

$\Rightarrow 4 \times 100\ \Omega = 400\ \Omega$

8. ℓ = 4 m, A = 1 mm^2 = 1×10^{-6} m^2

I = 2 A, n/V = 10^{29}, t = ?

i = n A V_d e

$\Rightarrow e = 10^{29} \times 1 \times 10^{-6} \times V_d \times 1.6 \times 10^{-19}$

$\Rightarrow V_d = \frac{2}{10^{29} \times 10^{-6} \times 1.6 \times 10^{-19}}$

$= \frac{1}{0.8 \times 10^4} = \frac{1}{8000}$

$t = \frac{\ell}{V_d} = \frac{4}{1/8000} = 4 \times 8000$

$= 32000 = 3.2 \times 10^4$ sec.

9. $f_{cu} = 1.7 \times 10^{-8}\ \Omega$-m

A = 0.01 mm^2 = 0.01×10^{-6} m^2

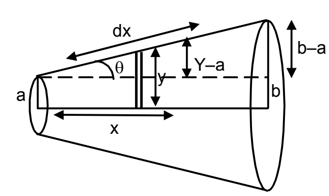
R = 1 KΩ = $10^3\ \Omega$

$R = \frac{f\ell}{a}$

$\Rightarrow 10^3 = \frac{1.7 \times 10^{-8} \times \ell}{10^{-6}}$

$\Rightarrow \ell = \frac{10^3}{1.7}$ = 0.58×10^3 m = 0.6 km.

10. dR, due to the small strip dx at a distanc x d = R = $\frac{fdx}{\pi y^2}$ …(1)



$\tan\theta = \frac{y-a}{x} = \frac{b-a}{L}$

$\Rightarrow \frac{y-a}{x} = \frac{b-a}{L}$

$\Rightarrow L(y - a) = x(b - a)$

$\Rightarrow$ Ly – La = xb – xa

$\Rightarrow L\dfrac{dy}{dx} - 0 = b - a$ (diff. w.r.t. x)

$\Rightarrow L\dfrac{dy}{dx} = b - a$

$\Rightarrow dx = \dfrac{Ldy}{b-a}$ …(2)

Putting the value of dx in equation (1)

$dR = \dfrac{fLdy}{\pi y^2(b-a)}$

$\Rightarrow dR = \dfrac{fl}{\pi(b-a)}\dfrac{dy}{y^2}$

$\Rightarrow \int_0^R dR = \dfrac{fl}{\pi(b-a)}\int_a^b \dfrac{dy}{y^2}$

$\Rightarrow R = \dfrac{fl}{\pi(b-a)}\dfrac{(b-a)}{ab} = \dfrac{fl}{\pi ab}$.

11. r = 0.1 mm = 10^{-4} m

R = 1 KΩ = 10^3 Ω, V = 20 V

a) No.of electrons transferred

$i = \dfrac{V}{R} = \dfrac{20}{10^3} = 20 \times 10^{-3} = 2 \times 10^{-2}$ A

$q = i\,t = 2 \times 10^{-2} \times 1 = 2 \times 10^{-2}$ C.

No. of electrons transferred = $\dfrac{2\times10^{-2}}{1.6\times10^{-19}} = \dfrac{2\times10^{-17}}{1.6} = 1.25 \times 10^{17}$.

b) Current density of wire

$= \dfrac{i}{A} = \dfrac{2\times10^{-2}}{\pi\times10^{-8}} = \dfrac{2}{3.14}\times10^{+6}$

$= 0.6369 \times 10^{+6} = 6.37 \times 10^5$ A/m^2.

12. A = 2×10^{-6} m^2, I = 1 A

f = 1.7×10^{-8} Ω-m

E = ?

$R = \dfrac{f\ell}{A} = \dfrac{1.7\times10^{-8}\times\ell}{2\times10^{-6}}$

$V = IR = \dfrac{1\times1.7\times10^{-8}\times\ell}{2\times10^{-6}}$

$E = \dfrac{dV}{dL} = \dfrac{V}{l} = \dfrac{1.7\times10^{-8}\times\ell}{2\times10^{-6}\ell} = \dfrac{1.7}{2}\times10^{-2}\,V/m$

= 8.5 mV/m.

13. l = 2 m, R = 5 Ω, i = 10 A, E = ?

V = iR = 10 × 5 = 50 V

$E = \dfrac{V}{l} = \dfrac{50}{2}$ = 25 V/m.

14. $R'_{Fe} = R_{Fe}(1 + \alpha_{Fe}\,\Delta\theta)$, $R'_{Cu} = R_{Cu}(1 + \alpha_{Cu}\,\Delta\theta)$

$R'_{Fe} = R'_{Cu}$

$\Rightarrow R_{Fe}(1 + \alpha_{Fe}\,\Delta\theta)$, $= R_{Cu}(1 + \alpha_{Cu}\,\Delta\theta)$

$\Rightarrow$ 3.9 [1 + 5 × 10^{-3} (20 – θ)] = 4.1 [1 + 4 x 10^{-3} (20 – θ)]

$\Rightarrow$ 3.9 + 3.9 × 5 × 10^{-3} (20 – θ) = 4.1 + 4.1 × 4 × 10^{-3} (20 – θ)

$\Rightarrow$ 4.1 × 4 × 10^{-3} (20 – θ) – 3.9 × 5 × 10^{-3} (20 – θ) = 3.9 – 4.1

$\Rightarrow$ 16.4(20 – θ) – 19.5(20 – θ) = 0.2 × 10^3

$\Rightarrow$ (20 – θ) (–3.1) = 0.2 × 10^3

$\Rightarrow$ θ – 20 = 200

$\Rightarrow$ θ = 220°C.

15. Let the voltmeter reading when, the voltage is 0 be X.

$$\frac{I_1R}{I_2R} = \frac{V_1}{V_2}$$

$$\Rightarrow \frac{1.75}{2.75} = \frac{14.4 - V}{22.4 - V} \Rightarrow \frac{0.35}{0.55} = \frac{14.4 - V}{22.4 - V}$$

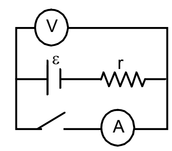
$$\Rightarrow \frac{0.07}{0.11} = \frac{14.4 - V}{22.4 - V} \Rightarrow \frac{7}{11} = \frac{14.4 - V}{22.4 - V}$$

$\Rightarrow$ 7(22.4 – V) = 11(14.4 – V) $\Rightarrow$ 156.8 – 7V = 158.4 – 11V

$\Rightarrow$ (7 – 11)V = 156.8 – 158.4 $\Rightarrow$ –4V = –1.6

$\Rightarrow$ V = 0.4 V.

16. a) When switch is open, no current passes through the ammeter. In the upper part of the circuit the Voltmenter has ∞ resistance. Thus current in it is 0.



∴ Voltmeter read the emf. (There is not Pot. Drop across the resistor).

b) When switch is closed current passes through the circuit and if its value of i.

The voltmeter reads

ε – ir = 1.45

$\Rightarrow$ 1.52 – ir = 1.45

$\Rightarrow$ ir = 0.07

$\Rightarrow$ 1 r = 0.07 $\Rightarrow$ r = 0.07 Ω.

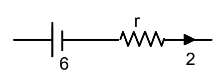
17. E = 6 V, r = 1 Ω, V = 5.8 V, R = ?

$$I = \frac{E}{R + r} = \frac{6}{R + 1}, \ V = E - Ir$$

$$\Rightarrow 5.8 = 6 - \frac{6}{R+1} \times 1 \Rightarrow \frac{6}{R+1} = 0.2$$

$\Rightarrow$ R + 1 = 30 $\Rightarrow$ R = 29 Ω.

18. V = ε + ir



$\Rightarrow$ 7.2 = 6 + 2 × r

$\Rightarrow$ 1.2 = 2r $\Rightarrow$ r = 0.6 Ω.

19. a) net emf while charging

9 – 6 = 3V

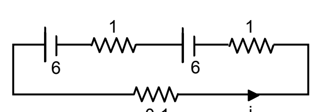
Current = 3/10 = 0.3 A

b) When completely charged.

Internal resistance ‘r’ = 1 Ω

Current = 3/1 = 3 A

20. a) $0.1i_1 + 1\,i_1 - 6 + 1i_1 - 6 = 0$



$\Rightarrow 0.1\,i_1 + 1i_1 + 1i_1 = 12$

$$\Rightarrow i_1 = \frac{12}{2.1}$$

ABCDA

$\Rightarrow 0.1i_2 + 1i - 6 = 0$

$\Rightarrow 0.1i_2 + 1i$

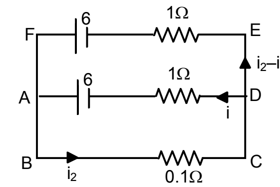
ADEFA,

$\Rightarrow i - 6 + 6 - (i_2 - i)1 = 0$

$\Rightarrow i - i_2 + i = 0$

$\Rightarrow 2i - i_2 = 0 \Rightarrow -2i \pm 0.2i = 0$

$\Rightarrow i_2 = 0.$



b) $1i_1 + 1\,i_1 - 6 + 1i_1 = 0$

$\Rightarrow 3i_1 = 12 \Rightarrow i_1 = 4$

DCFED

$\Rightarrow i_2 + i - 6 = 0 \Rightarrow i_2 + i = 6$

ABCDA,

$i_2 + (i_2 - i) - 6 = 0$

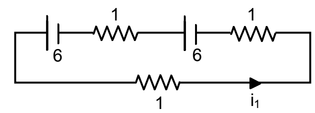
$\Rightarrow i_2 + i_2 - i = 6 \Rightarrow 2i_2 - i = 6$

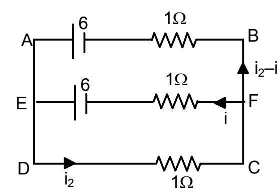
$\Rightarrow -2i_2 \pm 2i = 6 \Rightarrow i = -2$

$i_2 + i = 6$

$\Rightarrow i_2 - 2 = 6 \Rightarrow i_2 = 8$

$\frac{i_1}{i_2} = \frac{4}{8} = \frac{1}{2}.$





c) $10i_1 + 1i_1 - 6 + 1i_1 - 6 = 0$

$\Rightarrow 12i_1 = 12 \Rightarrow i_1 = 1$

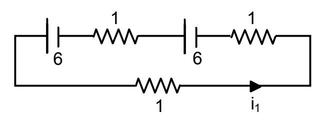
$10i_2 - i_1 - 6 = 0$

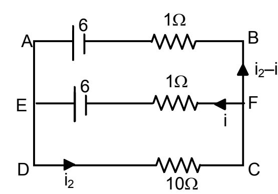
$\Rightarrow 10i_2 - i_1 = 6$

$\Rightarrow 10i_2 + (i_2 - i)1 - 6 = 0$

$\Rightarrow 11i_2 = 6$

$\Rightarrow -i_2 = 0$





21. a) Total emf = n_1E

in 1 row

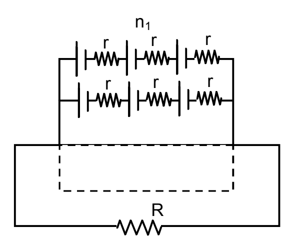
Total emf in all news = n_1E

Total resistance in one row = n_1r

Total resistance in all rows = $\frac{n_1r}{n_2}$

Net resistance = $\frac{n_1r}{n_2}$ + R

Current = $\frac{n_1E}{n_1/n_2r + R} = \frac{n_1n_2E}{n_1r + n_2R}$



b) I = $\frac{n_1n_2E}{n_1r + n_2R}$

for I = max,

$n_1r + n_2R$ = min

$\Rightarrow \left(\sqrt{n_1r} - \sqrt{n_2R}\right)^2 + 2\sqrt{n_1rn_2R}$ = min

it is min, when

$\sqrt{n_1r} = \sqrt{n_2R}$

$\Rightarrow n_1r = n_2R$

I is max when $n_1r = n_2R$.

22. E = 100 V, R′ = 100 kΩ = 100000 Ω

R = 1 – 100

When no other resister is added or R = 0.

$i = \frac{E}{R'} = \frac{100}{100000} = 0.001 Amp$

When R = 1

$i = \frac{100}{100000+1} = \frac{100}{100001} = 0.0009A$

When R = 100

$i = \frac{100}{100000+100} = \frac{100}{100100} = 0.000999$ A .

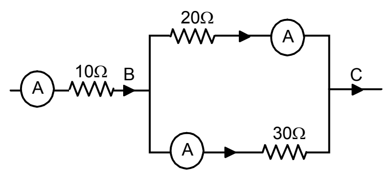
Upto R = 100 the current does not upto 2 significant digits. Thus it proved.

23. A_1 = 2.4 A

Since A_1 and A_2 are in parallel,

$\Rightarrow$ 20 × 2.4 = 30 × X

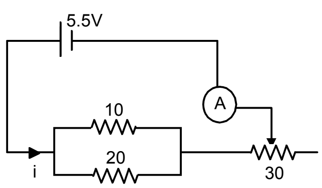
$\Rightarrow X = \frac{20 \times 2.4}{30}$ = 1.6 A.

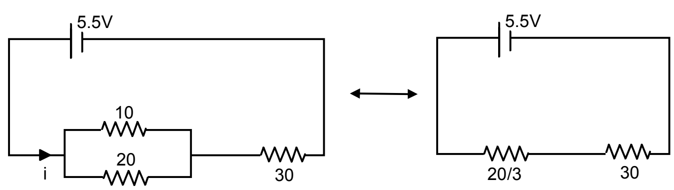


Reading in Ammeter A_2 is 1.6 A.

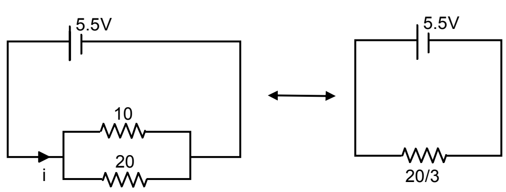
$A_3 = A_1 + A_2$ = 2.4 + 1.6 = 4.0 A.

24.





$i_{min} = \frac{5.5 \times 3}{110}$ = 0.15



$i_{max} = \frac{5.5 \times 3}{20} = \frac{16.5}{20}$ = 0.825.

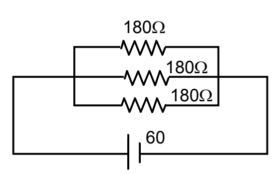
25. a) $R_{eff} = \frac{180}{3}$ = 60 Ω

i = 60 / 60 = 1 A

b) $R_{eff} = \frac{180}{2}$ = 90 Ω

i = 60 / 90 = 0.67 A

c) R_{eff} = 180 Ω $\Rightarrow$ i = 60 / 180 = 0.33 A



26. Max. R = (20 + 50 + 100) Ω = 170 Ω

Min R = $\dfrac{1}{\left(\dfrac{1}{20}+\dfrac{1}{50}+\dfrac{1}{100}\right)}$ = $\dfrac{100}{8}$ = 12.5 Ω.

27. The various resistances of the bulbs = $\dfrac{V^2}{P}$

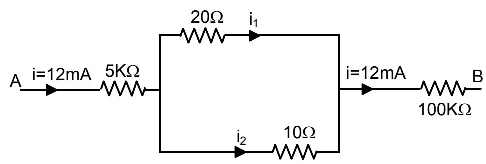
Resistances are $\dfrac{(15)^2}{10},\dfrac{(15)^2}{10},\dfrac{(15)^2}{15}$ = 45, 22.5, 15.

Since two resistances when used in parallel have resistances less than both.
The resistances are 45 and 22.5.

28. $i_1 \times 20 = i_2 \times 10$

$\Rightarrow \dfrac{i_1}{i_2}=\dfrac{10}{20}=\dfrac{1}{2}$

i_1 = 4 mA, i_2 = 8 mA



Current in 20 KΩ resistor = 4 mA
Current in 10 KΩ resistor = 8 mA
Current in 100 KΩ resistor = 12 mA

$V = V_1 + V_2 + V_3$
= 5 KΩ × 12 mA + 10 KΩ × 8 mA + 100 KΩ × 12 mA
= 60 + 80 + 1200 = 1340 volts.

29. $R_1 = R$, i_1 = 5 A

$R_2 = \dfrac{10R}{10+R}$, i_2 = 6A

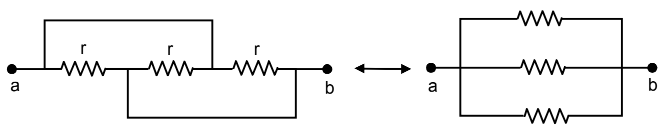
Since potential constant,
$i_1R_1 = i_2R_2$

$\Rightarrow 5 \times R = \dfrac{6\times 10R}{10+R}$

$\Rightarrow$ (10 + R)5 = 60

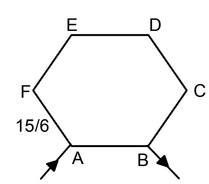
$\Rightarrow$ 5R = 10 $\Rightarrow$ R = 2 Ω.

30.



Eq. Resistance = r/3.

31. a) $R_{eff} = \dfrac{\dfrac{15\times 5}{6}\times\dfrac{15}{6}}{\dfrac{15\times 5}{6}+\dfrac{15}{6}}=\dfrac{\dfrac{15\times 5\times 15}{6\times 6}}{\dfrac{75+15}{6}}$



$= \dfrac{15\times 5\times 15}{6\times 90}=\dfrac{25}{12}$ = 2.08 Ω.

b) Across AC,

$R_{eff} = \dfrac{\dfrac{15\times 4}{6}\times\dfrac{15\times 2}{6}}{\dfrac{15\times 4}{6}+\dfrac{15\times 2}{6}}=\dfrac{\dfrac{15\times 4\times 15\times 2}{6\times 6}}{\dfrac{60+30}{6}}$

$= \dfrac{15\times 4\times 15\times 2}{6\times 90}=\dfrac{10}{3}$ = 3.33 Ω.

c) Across AD,

$$R_{eff} = \frac{\frac{15\times3}{6}\times\frac{15\times3}{6}}{\frac{15\times3}{6}+\frac{15\times3}{6}} = \frac{\frac{15\times3\times15\times3}{6\times6}}{\frac{60+30}{6}}$$

$$= \frac{15\times3\times15\times3}{6\times90} = \frac{15}{4} = 3.75\ \Omega.$$

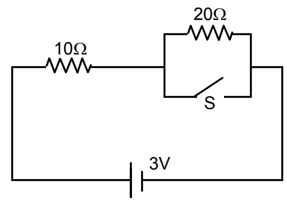
32. a) When S is open

R_{eq} = (10 + 20) Ω = 30 Ω.

i = When S is closed,

R_{eq} = 10 Ω

i = (3/10) Ω = 0.3 Ω.



33. a) Current through (1) 4 Ω resistor = 0

b) Current through (2) and (3)

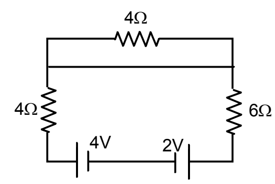
net E = 4V – 2V = 2V

(2) and (3) are in series,

R_{eff} = 4 + 6 = 10 Ω

i = 2/10 = 0.2 A

Current through (2) and (3) are 0.2 A.



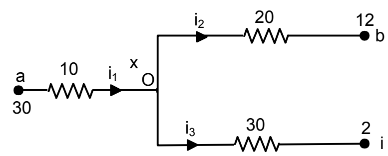
34. Let potential at the point be xV.

(30 – x) = 10 i_1

(x – 12) = 20 i_2

(x – 2) = 30 i_3

$i_1 = i_2 + i_3$



$$\Rightarrow\ \frac{30-x}{10} = \frac{x-12}{20} + \frac{x-2}{30}$$

$$\Rightarrow\ 30 - x = \frac{x-12}{2} + \frac{x-2}{3}$$

$$\Rightarrow\ 30 - x = \frac{3x-36+2x-4}{6}$$

⇒ 180 – 6x = 5x – 40

⇒ 11x = 220 ⇒ x = 220 / 11 = 20 V.

$$i_1 = \frac{30-20}{10} = 1\ A$$

$$i_2 = \frac{20-12}{20} = 0.4\ A$$

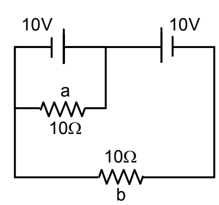
$$i_3 = \frac{20-2}{30} = \frac{6}{10} = 0.6\ A.$$

35. a) Potential difference between terminals of 'a' is 10 V.

i through a = 10 / 10 = 1A

Potential different between terminals of b is 10 – 10 = 0 V

i through b = 0/10 = 0 A

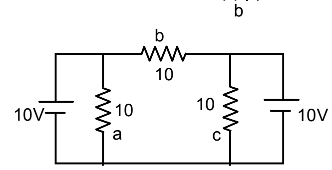


b) Potential difference across 'a' is 10 V

i through a = 10 / 10 = 1A

Potential different between terminals of b is 10 – 10 = 0 V

i through b = 0/10 = 0 A

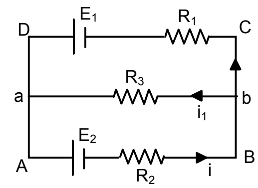


36. a) In circuit, AB ba A

$E_2 + iR_2 + i_1R_3 = 0$

In circuit, $i_1R_3 + E_1 - (i - i_1)R_1 = 0$

$\Rightarrow i_1R_3 + E_1 - iR_1 + i_1R_1 = 0$



$[iR_2 + i_1R_3 \qquad = -E_2]R_1$

$[iR_2 - i_1(R_1 + R_3) = E_1]\ R_2$

$iR_2R_1 + i_1R_3R_1 \qquad = -E_2R_1$

$iR_2R_1 - i_1R_2(R_1 + R_3) \qquad = E_1R_2$

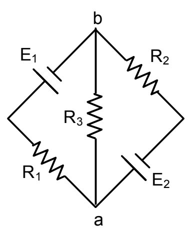
$iR_3R_1 + i_1R_2R_1 + i_1R_2R_3 = E_1R_2 - E_2R_1$

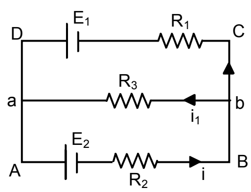
$\Rightarrow i_1(R_3R_1 + R_2R_1 + R_2R_3) = E_1R_2 - E_2R_1$

$$\Rightarrow i_1 = \frac{E_1R_2 - E_2R_1}{R_3R_1 + R_2R_1 + R_2R_3}$$

$$\Rightarrow \frac{E_1R_2R_3 - E_2R_1R_3}{R_3R_1 + R_2R_1 + R_2R_3} = \left(\frac{\frac{E_1}{R_1} - \frac{E_2}{R_2}}{\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_3}}\right)$$

b) $\therefore$ Same as a





37. In circuit ABDCA,

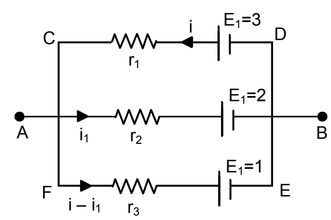
$i_1 + 2 - 3 + i = 0$

$\Rightarrow\ i + i_1 - 1 = 0 \qquad \ldots(1)$

In circuit CFEDC,

$(i - i_1) + 1 - 3 + i = 0$

$\Rightarrow\ 2i - i_1 - 2 = 0 \qquad \ldots(2)$



From (1) and (2)

$3i = 3 \Rightarrow i = 1$ A

$i_1 = 1 - i = 0$ A

$i - i_1 = 1 - 0 = 1$ A

Potential difference between A and B

$= E - ir = 3 - 1.1 = 2$ V.

38. In the circuit ADCBA,

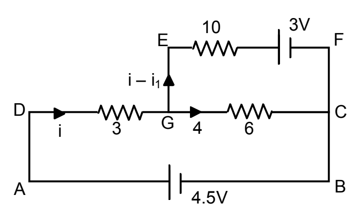
$3i + 6i_1 - 4.5 = 0$

In the circuit GEFCG,

$3i + 6i_1 = 4.5 \quad = \quad 10i - 10i_1 - 6i_1 = -3$

$\Rightarrow\ [10i - 16i_1 = -3]3 \qquad \ldots(1)$

$[3i + 6i_1 = 4.5]\ 10 \qquad \ldots(2)$



From (1) and (2)

$-108\ i_1 = -54$

$$\Rightarrow\ i_1 = \frac{54}{108} = \frac{1}{2} = 0.5$$

$3i + 6 \times ½ - 4.5 = 0$

$3i - 1.5 = 0 \Rightarrow i = 0.5.$

Current through 10 Ω resistor = 0 A.

39. In AHGBA,

$2 + (i - i_1) - 2 = 0$

$\Rightarrow\ i - i_1 = 0$

In circuit CFEDC,

$-(i_1 - i_2) + 2 + i_2 - 2 = 0$

$\Rightarrow\ i_2 - i_1 + i_2 = 0 \Rightarrow 2i_2 - i_1 = 0.$

In circuit BGFCB,

$-(i_1 - i_2) + 2 + (i_1 - i_2) - 2 = 0$

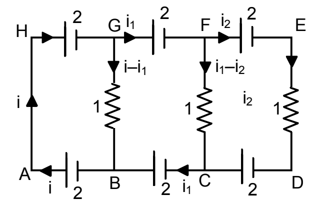
$\Rightarrow\ i_1 - i + i_1 - i_2 = 0 \qquad \Rightarrow\ 2i_1 - i - i_2 = 0 \qquad \ldots(1)$

$\Rightarrow\ i_1 - (i - i_1) - i_2 = 0 \qquad \Rightarrow\ i_1 - i_2 = 0 \qquad \ldots(2)$

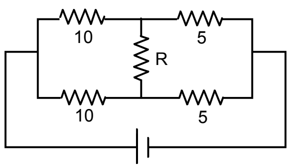
$\therefore\ i_1 - i_2 = 0$

From (1) and (2)

Current in the three resistors is 0.



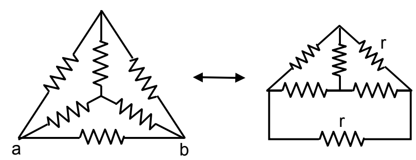
40.



For an value of R, the current in the branch is 0.

41. a) $R_{eff} = \dfrac{(2r/2)\times r}{(2r/2)+r}$

$= \dfrac{r^2}{2r} = \dfrac{r}{2}$

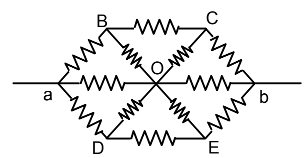


b) At 0 current coming to the junction is current going from BO = Current going along OE.

Current on CO = Current on OD

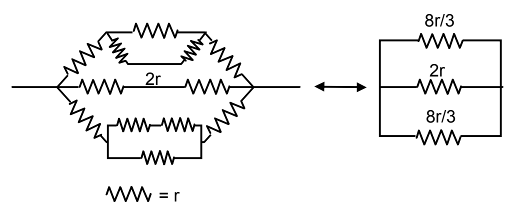
Thus it can be assumed that current coming in OC goes in OB.

Thus the figure becomes

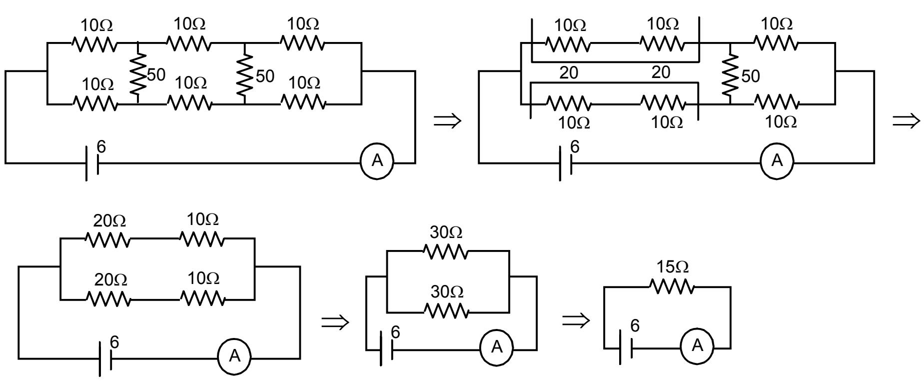


$\left[r + \left(\dfrac{2r.r}{3r}\right) + r\right] = 2r + \dfrac{2r}{3} = \dfrac{8r}{3}$

$R_{eff} = \dfrac{(8r/6)\times 2r}{(8r/6)+2r} = \dfrac{8r^2/3}{20r/6} = \dfrac{8r^2}{3}\times\dfrac{6}{20} = \dfrac{8r}{10} = 4r.$



42.



$I = \dfrac{6}{15} = \dfrac{2}{5} = 0.4\ A\ .$

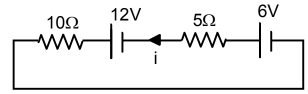
43. a) Applying Kirchoff's law,

$10i - 6 + 5i - 12 = 0$

$\Rightarrow 10i + 5i = 18$

$\Rightarrow 15i = 18$

$\Rightarrow i = \frac{18}{15} = \frac{6}{5} = 1.2$ A.



b) Potential drop across 5 Ω resistor,

$i\,5 = 1.2 \times 5$ V = 6 V

c) Potential drop across 10 Ω resistor

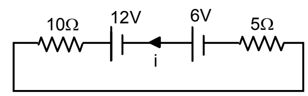
$i\,10 = 1.2 \times 10$ V = 12 V

d) $10i - 6 + 5i - 12 = 0$

$\Rightarrow 10i + 5i = 18$

$\Rightarrow 15i = 18$

$\Rightarrow i = \frac{18}{15} = \frac{6}{5} = 1.2$ A.



Potential drop across 5 Ω resistor = 6 V

Potential drop across 10 Ω resistor = 12 V

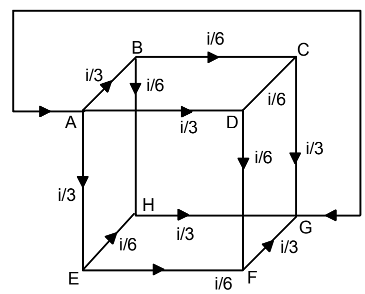
44. Taking circuit ABHGA,

$$\frac{i}{3r} + \frac{i}{6r} + \frac{i}{3r} = V$$

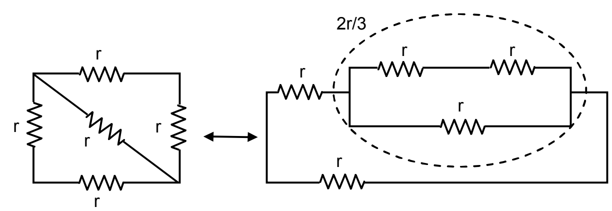
$$\Rightarrow \left(\frac{2i}{3} + \frac{i}{6}\right) r = V$$

$$\Rightarrow V = \frac{5i}{6} r$$

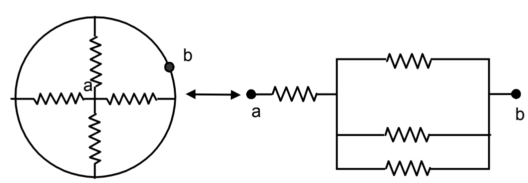
$$\Rightarrow R_{eff} = \frac{V}{i} = \frac{5}{6r}$$



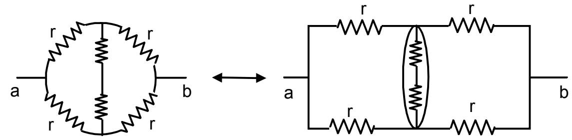
45. $$R_{eff} = \frac{\left(\frac{2r}{3} + r\right) r}{\left(\frac{2r}{3} + r + r\right)} = \frac{5r}{8}$$



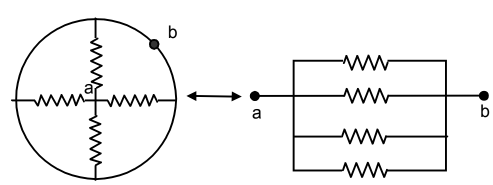
$$R_{eff} = \frac{r}{3} + r = \frac{4r}{3}$$



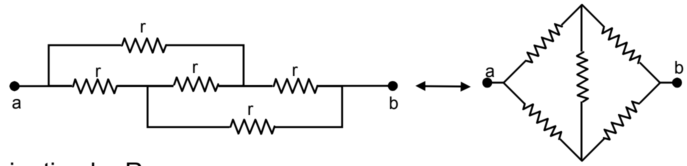
$$R_{eff} = \frac{2r}{2} = r$$



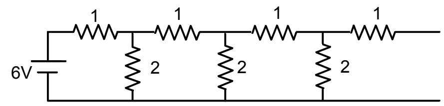
$$R_{eff} = \frac{r}{4}$$



$R_{eff} = r$

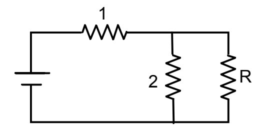


46. a) Let the equation resistance of the combination be R.



$$\left(\frac{2R}{R+2}\right) + 1 = R$$

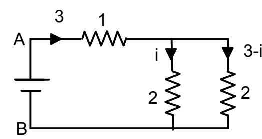
$$\Rightarrow \frac{2R + R + 2}{R+2} = R \Rightarrow 3R + 2 = R^2 + 2R$$



$$\Rightarrow R^2 - R - 2 = 0$$

$$\Rightarrow R = \frac{+1 \pm \sqrt{1 + 4.1.2}}{2.1} = \frac{1 \pm \sqrt{9}}{2} = \frac{1 \pm 3}{2} = 2\ \Omega.$$

b) Total current sent by battery = $\frac{6}{R_{eff}} = \frac{6}{2} = 3$



Potential between A and B

3.1 + 2.i = 6

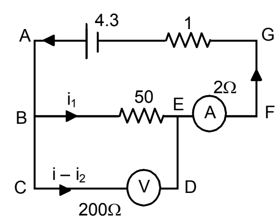
$\Rightarrow$ 3 + 2i = 6 $\Rightarrow$ 2i = 3

$\Rightarrow$ i = 1.5 a

47. a) In circuit ABFGA,

i_1 50 + 2i + i – 4.3 = 0

$\Rightarrow 50i_1 + 3i = 4.3$ …(1)



In circuit BEDCB,

$50i_1 - (i - i_1)200 = 0$

$\Rightarrow 50i_1 - 200i + 200i_1 = 0$

$\Rightarrow 250\ i_1 - 200i = 0$

$\Rightarrow 50i_1 - 40i = 0$ …(2)

From (1) and (2)

43i = 4.3 $\Rightarrow$ i = 0.1

$5i_1 = 4 \times i = 4 \times 0.1 \Rightarrow i_1 = \frac{4 \times 0.1}{5} = 0.08$ A.

Ammeter reads a current = i = 0.1 A.

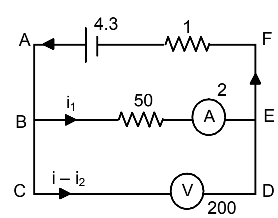
Voltmeter reads a potential difference equal to $i_1 \times 50 = 0.08 \times 50 = 4$ V.

b) In circuit ABEFA,

$50i_1 + 2i_1 + 1i - 4.3 = 0$

$\Rightarrow 52i_1 + i = 4.3$

$\Rightarrow 200 \times 52i_1 + 200\ i = 4.3 \times 200$ …(1)



In circuit BCDEB,

$(i - i_1)200 - i_1 2 - i_1 50 = 0$

$\Rightarrow 200i - 200i_1 - 2i_1 - 50i_1 = 0$

$\Rightarrow 200i - 252i_1 = 0$ …(2)

From (1) and (2)

$i_1(10652) = 4.3 \times 2 \times 100$

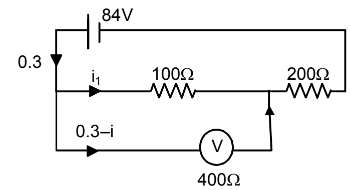
$$\Rightarrow i_1 = \frac{4.3 \times 2 \times 100}{10652} = 0.08$$

i = 4.3 – 52 × 0.08 = 0.14

Reading of the ammeter = 0.08 a

Reading of the voltmeter = $(i - i_1)200 = (0.14 - 0.08) \times 200 = 12$ V.

48. a) $R_{eff} = \dfrac{100 \times 400}{500} + 200 = 280$



$i = \dfrac{84}{280} = 0.3$

$100i = (0.3 - i)\ 400$

$\Rightarrow$ $i = 1.2 - 4i$

$\Rightarrow$ $5i = 1.2 \Rightarrow i = 0.24.$

Voltage measured by the voltmeter = $\dfrac{0.24 \times 100}{24V}$

b) If voltmeter is not connected

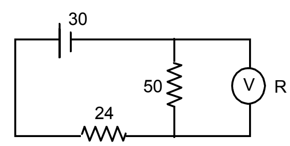
$R_{eff} = (200 + 100) = 300\ \Omega$

$i = \dfrac{84}{300} = 0.28$ A

Voltage across 100 Ω = (0.28 × 100) = 28 V.

49. Let resistance of the voltmeter be R Ω.

$R_1 = \dfrac{50R}{50 + R}$, $R_2 = 24$



Both are in series.

$30 = V_1 + V_2$

$\Rightarrow 30 = iR_1 + iR_2$

$\Rightarrow 30 - iR_2 = iR_1$

$\Rightarrow iR_1 = 30 - \dfrac{30}{R_1 + R_2} R_2$

$\Rightarrow V_1 = 30\left(1 - \dfrac{R_2}{R_1 + R_2}\right)$

$\Rightarrow V_1 = 30\left(\dfrac{R_1}{R_1 + R_2}\right)$

$\Rightarrow 18 = 30\left(\dfrac{50R}{50 + R\left(\dfrac{50R}{50 + R} + 24\right)}\right)$

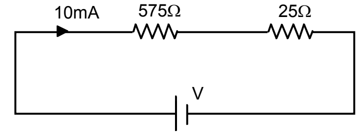
$\Rightarrow 18 = 30\left(\dfrac{50R \times (50 + R)}{(50 + R) + (50R + 24)(50 + R)}\right) = \dfrac{30(50R)}{50R + 1200 + 24R}$

$\Rightarrow 18 = \dfrac{30 \times 50 \times R}{74R + 1200}$ = 18(74R + 1200) = 1500 R

$\Rightarrow$ 1332R + 21600 = 1500 R $\Rightarrow$ 21600 = 1.68 R

$\Rightarrow$ R = 21600 / 168 = 128.57.

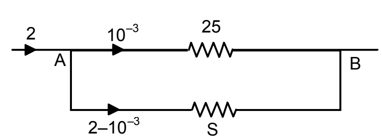
50. Full deflection current = 10 mA = (10×10^{-3})A



$R_{eff} = (575 + 25)\Omega = 600\ \Omega$

$V = R_{eff} \times i = 600 \times 10 \times 10^{-3} = 6$ V.

51. G = 25 Ω, Ig = 1 ma, I = 2A, S = ?



Potential across A B is same

$25 \times 10^{-3} = (2 - 10^{-3})S$

$\Rightarrow S = \dfrac{25 \times 10^{-3}}{2 - 10^{-3}} = \dfrac{25 \times 10^{-3}}{1.999}$

$= 12.5 \times 10^{-3} = 1.25 \times 10^{-2}$.

52. $R_{eff} = (1150 + 50)\Omega = 1200\ \Omega$

$i = (12 / 1200)A = 0.01$ A.

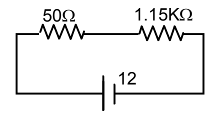
(The resistor of 50 Ω can tolerate)

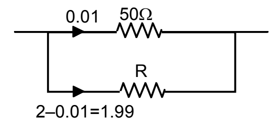
Let R be the resistance of sheet used.

The potential across both the resistors is same.

$0.01 \times 50 = 1.99 \times R$

$\Rightarrow R = \frac{0.01 \times 50}{1.99} = \frac{50}{199} = 0.251\ \Omega$.





53. If the wire is connected to the potentiometer wire so that $\frac{R_{AD}}{R_{DB}} = \frac{8}{12}$, then according to wheat stone's bridge no current will flow through galvanometer.

$\frac{R_{AB}}{R_{DB}} = \frac{L_{AB}}{L_B} = \frac{8}{12} = \frac{2}{3}$ (Acc. To principle of potentiometer).

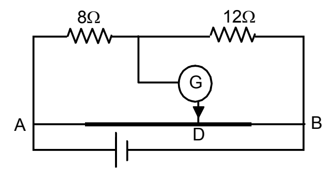
$I_{AB} + I_{DB} = 40$ cm

$\Rightarrow I_{DB}\ 2/3 + I_{DB} = 40$ cm

$\Rightarrow (2/3 + 1)I_{DB} = 40$ cm

$\Rightarrow 5/3\ I_{DB} = 40 \Rightarrow L_{DB} = \frac{40 \times 3}{5} = 24$ cm.

$I_{AB} = (40 – 24)$ cm = 16 cm.



54. The deflections does not occur in galvanometer if the condition is a balanced wheatstone bridge.

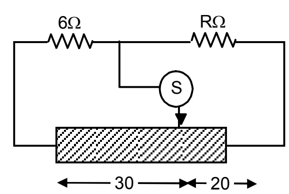
Let Resistance / unit length = r.

Resistance of 30 m length = 30 r.

Resistance of 20 m length = 20 r.

For balanced wheatstones bridge = $\frac{6}{R} = \frac{30r}{20r}$

$\Rightarrow 30\ R = 20 \times 6 \Rightarrow R = \frac{20 \times 6}{30} = 4\ \Omega$.



55. a) Potential difference between A and B is 6 V.

B is at 0 potential.

Thus potential of A point is 6 V.

The potential difference between Ac is 4 V.

$V_A – V_C = 0.4$

$V_C = V_A – 4 = 6 – 4 = 2$ V.

b) The potential at D = 2V, $V_{AD} = 4$ V ; V_{BD} = OV

Current through the resisters R_1 and R_2 are equal.

Thus, $\frac{4}{R_1} = \frac{2}{R_2}$

$\Rightarrow \frac{R_1}{R_2} = 2$

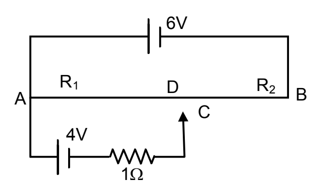
$\Rightarrow \frac{l_1}{l_2} = 2$ (Acc. to the law of potentiometer)

$l_1 + l_2 = 100$ cm

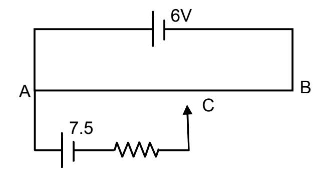
$\Rightarrow l_1 + \frac{l_1}{2} = 100 \text{ cm} \Rightarrow \frac{3l_1}{2} = 100$ cm

$\Rightarrow l_1 = \frac{200}{3}$ cm = 66.67 cm.

AD = 66.67 cm



c) When the points C and D are connected by a wire current flowing through it is 0 since the points are equipotential.



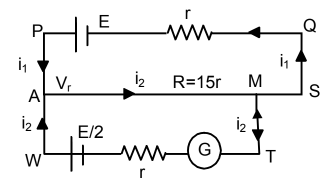
d) Potential at A = 6 v

Potential at C = 6 – 7.5 = –1.5 V

The potential at B = 0 and towards A potential increases.

Thus –ve potential point does not come within the wire.

56. Resistance per unit length = $\frac{15r}{6}$



For length x, Rx = $\frac{15r}{6} \times x$

a) For the loop PASQ $(i_1 + i_2)\frac{15}{6}rx + \frac{15}{6}(6 - x)i_1 + i_1R = E$ …(1)

For the loop AWTM, $-i_2.R - \frac{15}{6}rx\,(i_1 + i_2) = E/2$

$\Rightarrow i_2R + \frac{15}{6}r \times (i_1 + i_2) = E/2$ …(2)

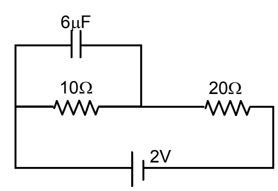
For zero deflection galvanometer $i_2 = 0 \Rightarrow \frac{15}{6}rx \,.\, i_1 = E/2 = i_1 = \frac{E}{5x \cdot r}$

Putting $i_1 = \frac{E}{5x \cdot r}$ and $i_2 = 0$ in equation (1), we get x = 320 cm.

b) Putting x = 5.6 and solving equation (1) and (2) we get $i_2 = \frac{3E}{22r}$.

57. In steady stage condition no current flows through the capacitor.

$R_{eff} = 10 + 20 = 30\ \Omega$



$i = \frac{2}{30} = \frac{1}{15}A$

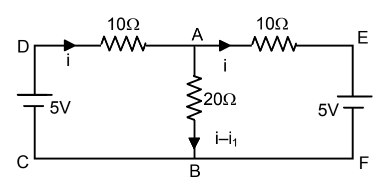
Voltage drop across 10 Ω resistor = i × R

$= \frac{1}{15} \times 10 = \frac{10}{15} = \frac{2}{3}V$

Charge stored on the capacitor (Q) = CV

$= 6 \times 10^{-6} \times 2/3 = 4 \times 10^{-6}$ C = 4 μC.

58. Taking circuit, ABCDA,



$10i + 20(i - i_1) - 5 = 0$

$\Rightarrow 10i + 20i - 20i_1 - 5 = 0$

$\Rightarrow 30i - 20i_1 - 5 = 0$ …(1)

Taking circuit ABFEA,

$20(i - i_1) - 5 - 10i_1 = 0$

$\Rightarrow 10i - 20i_1 - 10i_1 - 5 = 0$

$\Rightarrow 20i - 30i_1 - 5 = 0$ …(2)

From (1) and (2)

$(90 - 40)i_1 = 0$

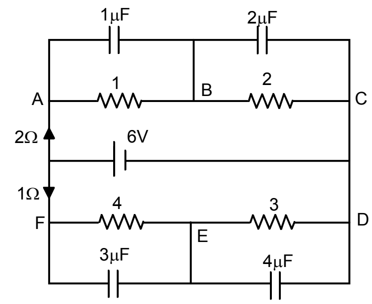
$\Rightarrow i_1 = 0$

$30i - 5 = 0$

$\Rightarrow i = 5/30 = 0.16$ A

Current through 20 Ω is 0.16 A.

59. At steady state no current flows through the capacitor.



$R_{eq} = \frac{3 \times 6}{3+6} = 2\ \Omega.$

$i = \frac{6}{2} = 3.$

Since current is divided in the inverse ratio of the resistance in each branch, thus 2Ω will pass through 1, 2 Ω branch and 1 through 3, 3Ω branch

$V_{AB} = 2 \times 1 = 2V.$

Q on 1 μF capacitor = 2 × 1 μc = 2 μC

$V_{BC} = 2 \times 2 = 4V.$

Q on 2 μF capacitor = 4 × 2 μc = 8 μC

$V_{DE} = 1 \times 3 = 2V.$

Q on 4 μF capacitor = 3 × 4 μc = 12 μC

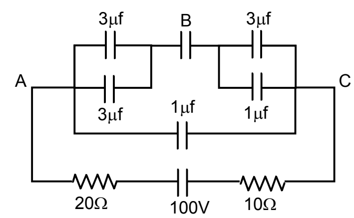
$V_{FE} = 3 \times 1 = V.$

Q across 3 μF capacitor = 3 × 3 μc = 9 μC.

60. C_{eq} = [(3 μf p 3 μf) s (1 μf p 1 μf)] p (1 μf)

= [(3 + 3)μf s (2μf)] p 1 μf

= 3/2 + 1 = 5/2 μf



V = 100 V

Q = CV = 5/2 × 100 = 250 μc

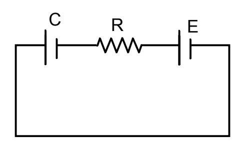
Charge stored across 1 μf capacitor = 100 μc

C_{eq} between A and B is 6 μf = C

Potential drop across AB = V = Q/C = 25 V

Potential drop across BC = 75 V.

61. a) Potential difference = E across resistor



b) Current in the circuit = E/R

c) Pd. Across capacitor = E/R

d) Energy stored in capacitor = $\frac{1}{2}CE^2$

e) Power delivered by battery = E × I = $E \times \frac{E}{R} = \frac{E^2}{R}$

f) Power converted to heat = $\frac{E^2}{R}$

62. A = 20 cm^2 = 20 × 10^{-4} m^2

d = 1 mm = 1 × 10^{-3} m ; R = 10 KΩ

$C = \frac{E_0 A}{d} = \frac{8.85 \times 10^{-12} \times 20 \times 10^{-4}}{1 \times 10^{-3}}$

$= \frac{8.85 \times 10^{-12} \times 2 \times 10^{-3}}{10^{-3}}$ = 17.7 × 10^{-2} Farad.

Time constant = CR = 17.7 × 10^{-2} × 10 × 10^3

= 17.7 × 10^{-8} = 0.177 × 10^{-6} s = 0.18 μs.

63. C = 10 μF = 10^{-5} F, emf = 2 V

t = 50 ms = 5 × 10^{-2} s, q = Q(1 – $e^{-t/RC}$)

Q = CV = 10^{-5} × 2

q = 12.6 × 10^{-6} F

⇒ 12.6 × 10^{-6} = 2 × 10^{-5} $(1 - e^{-5\times10^{-2}/R\times10^{-5}})$

$\Rightarrow \frac{12.6\times10^{-6}}{2\times10^{-5}} = 1 - e^{-5\times10^{-2}/R\times10^{-5}}$

$\Rightarrow$ 1 – 0.63 = $e^{-5\times10^{3}/R}$

$\Rightarrow \frac{-5000}{R} = \ln 0.37$

$\Rightarrow$ R = $\frac{5000}{0.9942}$ = 5028 Ω = 5.028 × 10^3Ω = 5 KΩ.

64. C = 20 × 10^{-6} F, E = 6 V, R = 100 Ω
t = 2 × 10^{-3} sec
q = EC (1 – $e^{-t/RC}$)
= $6\times20\times10^{-6}\left(1-e^{\frac{-2\times10^{-3}}{100\times20\times10^{-6}}}\right)$
= 12 x 10^{-5} (1 – e^{-1}) = 7.12 × 0.63 × 10^{-5} = 7.56 × 10^{-5}
= 75.6 × 10^{-6} = 76 μc.

65. C = 10 μF, Q = 60 μC, R = 10 Ω
a) at t = 0, q = 60 μc
b) at t = 30 μs, q = $Qe^{-t/RC}$
= 60 × 10^{-6} × $e^{-0.3}$ = 44 μc
c) at t = 120 μs, q = 60 × 10^{-6} × $e^{-1.2}$ = 18 μc
d) at t = 1.0 ms, q = 60 × 10^{-6} × e^{-10} = 0.00272 = 0.003 μc.

66. C = 8 μF, E = 6V, R = 24 Ω
a) I = $\frac{V}{R} = \frac{6}{24} = 0.25A$
b) q = Q(1 – $e^{-t/RC}$)
= (8 × 10^{-6} × 6) [1 – c^{-1}] = 48 × 10^{-6} × 0.63 = 3.024 × 10^{-5}
V = $\frac{Q}{C} = \frac{3.024\times10^{-5}}{8\times10^{-6}} = 3.78$
E = V + iR
$\Rightarrow$ 6 = 3.78 + i24
$\Rightarrow$ i = 0.09 Å

67. A = 40 m^2 = 40 × 10^{-4}
d = 0.1 mm = 1 × 10^{-4} m
R = 16 Ω ; emf = 2 V
C = $\frac{E_0A}{d} = \frac{8.85\times10^{-12}\times40\times10^{-4}}{1\times10^{-4}}$ = 35.4 × 10^{-11} F
Now, E = $\frac{Q}{AE_0}(1-e^{-t/RC}) = \frac{CV}{AE_0}(1-e^{-t/RC})$
= $\frac{35.4\times10^{-11}\times2}{40\times10^{-4}\times8.85\times10^{-12}}(1-e^{-1.76})$
= 1.655 × 10^{-4} = 1.7 × 10^{-4} V/m.

68. A = 20 cm^2, d = 1 mm, K = 5, e = 6 V
R = 100 × 10^3 Ω, t = 8.9 × 10^{-5} s
C = $\frac{KE_0A}{d} = \frac{5\times8.85\times10^{-12}\times20\times10^{-4}}{1\times10^{-3}}$
= $\frac{10\times8.85\times10^{-3}\times10^{-12}}{10^{-3}}$ = 88.5 × 10^{-12}

$q = EC(1 - e^{-t/RC})$

$= 6 \times 88.5 \times 10^{-12} \left(1 - e^{\frac{-89\times10^{-6}}{88.5\times10^{-12}\times10^{4}}}\right) = 530.97$

Energy = $\frac{1}{2} \times \frac{500.97 \times 530}{88.5 \times 10^{-12}}$

$= \frac{530.97 \times 530.97}{88.5 \times 2} \times 10^{12}$

69. Time constant RC = $1 \times 10^6 \times 100 \times 10^6 = 100$ sec

a) $q = VC(1 - e^{-t/CR})$

I = Current = dq/dt = VC.(-) $e^{-t/RC}$, (–1)/RC

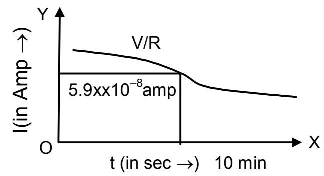
$= \frac{V}{R} e^{-t/RC} = \frac{V}{R \cdot e^{t/RC}} = \frac{24}{10^6} \cdot \frac{1}{e^{t/100}}$

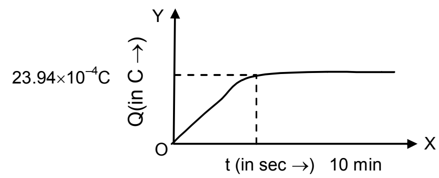
$= 24 \times 10^{-6}\ 1/e^{t/100}$

t = 10 min, 600 sec.

Q = 24 × 10+–4 × $(1 - e^{-6}) = 23.99 \times 10^{-4}$

I = $\frac{24}{10^6} \cdot \frac{1}{e^6} = 5.9 \times 10^{-8}$ Amp. .





b) $q = VC(1 - e^{-t/CR})$

70. $Q/2 = Q(1 - e^{-t/CR})$

$\Rightarrow \frac{1}{2} = (1 - e^{-t/CR})$

$\Rightarrow e^{-t/CR} = ½$

$\Rightarrow \frac{t}{RC} = \log 2 \Rightarrow n = 0.69.$

71. $q = Qe^{-t/RC}$

q = 0.1 % Q   RC ⇒ Time constant

$= 1 \times 10^{-3}$ Q

So, 1×10^{-3} Q = Q × $e^{-t/RC}$

$\Rightarrow e^{-t/RC} = \ln 10^{-3}$

⇒ t/RC = –(–6.9) = 6.9

72. $q = Q(1 - e^{-n})$

$\frac{1}{2}\frac{Q^2}{C} =$ Initial value ; $\frac{1}{2}\frac{q^2}{c} =$ Final value

$\frac{1}{2}\frac{q^2}{c} \times 2 = \frac{1}{2}\frac{Q^2}{C}$

$\Rightarrow q^2 = \frac{Q^2}{2} \Rightarrow q = \frac{Q}{\sqrt{2}}$

$\frac{Q}{\sqrt{2}} = Q(1 - e^{-n})$

$\Rightarrow \frac{1}{\sqrt{2}} = 1 - e^{-n} \Rightarrow e^{-n} = 1 - \frac{1}{\sqrt{2}}$

$\Rightarrow n = \log\left(\frac{\sqrt{2}}{\sqrt{2} - 1}\right) = 1.22$

73. Power = $CV^2 = Q \times V$

Now, $\frac{QV}{2} = QV \times e^{-t/RC}$

$\Rightarrow$ ½ = $e^{-t/RC}$

$\Rightarrow$ $\frac{t}{RC} = -\ln 0.5$

$\Rightarrow$ –(–0.69) = 0.69

74. Let at any time t, q = EC $(1 - e^{-t/CR})$

E = Energy stored = $\frac{q^2}{2c} = \frac{E^2C^2}{2c}(1-e^{-t/CR})^2 = \frac{E^2C}{2}(1-e^{-t/CR})^2$

R = rate of energy stored = $\frac{dE}{dt} = \frac{-E^2C}{2}\left(\frac{-1}{RC}\right)^2(1-e^{-t/RC})e^{-t/RC} = \frac{E^2}{CR}\cdot e^{-t/RC}\left(1-e^{-t/CR}\right)$

$\frac{dR}{dt} = \frac{E^2}{2R}\left[\frac{-1}{RC}e^{-t/CR}\cdot(1-e^{-t/CR}) + (-)\cdot e^{-t/CR(1-/RC)}\cdot e^{-t/CR}\right]$

$\frac{E^2}{2R} = \left(\frac{-e^{-t/CR}}{RC} + \frac{e^{-2t/CR}}{RC} + \frac{1}{RC}\cdot e^{-2t/CR}\right) = \frac{E^2}{2R}\left(\frac{2}{RC}\cdot e^{-2t/CR} - \frac{e^{-t/CR}}{RC}\right)$ …(1)

For R_{max} dR/dt = 0 $\Rightarrow$ $2.e^{-t/RC} - 1 = 0 \Rightarrow e^{-t/CR} = 1/2$

$\Rightarrow$ $-t/RC = -\ln^2 \Rightarrow t = RC \ln 2$

$\therefore$ Putting t = RC ln 2 in equation (1) We get $\frac{dR}{dt} = \frac{E^2}{4R}$.

75. C = 12.0 μF = 12 × 10^{-6}

emf = 6.00 V, R = 1 Ω

t = 12 μc, i = $i_0 e^{-t/RC}$

= $\frac{CV}{T}\times e^{-t/RC} = \frac{12\times10^{-6}\times 6}{12\times10^{-6}}\times e^{-1}$

= 2.207 = 2.1 A

b) Power delivered by battery

We known, V = $V_0 e^{-t/RC}$ (where V and V_0 are potential VI)

VI = $V_0 I e^{-t/RC}$

$\Rightarrow$ VI = $V_0 I \times e^{-1} = 6\times 6\times e^{-1}$ = 13.24 W

c) U = $\frac{CV^2}{T}(e^{-t/RC})^2$ [$\frac{CV^2}{T}$ = energy drawing per unit time]

= $\frac{12\times10^{-6}\times36}{12\times10^{-6}}\times\left(e^{-1}\right)^2$ = 4.872.

76. Energy stored at a part time in discharging = $\frac{1}{2}CV^2(e^{-t/RC})^2$

Heat dissipated at any time

= (Energy stored at t = 0) – (Energy stored at time t)

= $\frac{1}{2}CV^2 - \frac{1}{2}CV^2(-e^{-1})^2 = \frac{1}{2}CV^2(1-e^{-2})$

77. $\int i^2 R dt = \int i_0^2 R e^{-2t/RC} dt = i_0^2 R \int e^{-2t/RC} dt$

= $i_0^2 R(-RC/2)e^{-2t/RC} = \frac{1}{2}Ci_0^2R^2e^{-2t/RC} = \frac{1}{2}CV^2$ (Proved).

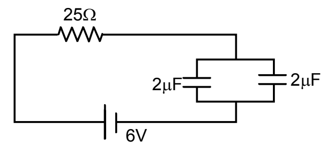
78. Equation of discharging capacitor

= $q_0 e^{-t/RC} = \frac{K\epsilon_0 AV}{d}e^{\frac{-1}{(\rho dK\epsilon_0 A)/Ad}} = \frac{K\epsilon_0 AV}{d}e^{-t/\rho K\epsilon_0}$

$\therefore$ $\tau = \rho K\epsilon_0$

$\therefore$ Time constant is $\rho K\epsilon_0$ is independent of plate area or separation between the plate.

79. $q = q_0(1 - e^{-t/RC})$

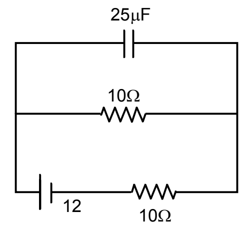


$= 25(2 + 2) \times 10^{-6} \left(1 - e^{\frac{-0.2\times10^{-3}}{25\times4\times10^{-6}}}\right)$

$= 24 \times 10^{-6} (1 - e^{-2}) = 20.75$

Charge on each capacitor = 20.75/2 = 10.3

80. In steady state condition, no current passes through the 25 μF capacitor,



$\therefore$ Net resistance = $\frac{10\Omega}{2} = 5\Omega$.

Net current = $\frac{12}{5}$

Potential difference across the capacitor = 5

Potential difference across the 10 Ω resistor

= 12/5 × 10 = 24 V

$q = Q(e^{-t/RC}) = V \times C(e^{-t/RC}) = 24 \times 25 \times 10^{-6} \left[e^{-1\times10^{-3}/10\times25\times10^{-4}}\right]$

$= 24 \times 25 \times 10^{-6}\, e^{-4} = 24 \times 25 \times 10^{-6} \times 0.0183 = 10.9 \times 10^{-6}$ C

Charge given by the capacitor after time t.

Current in the 10 Ω resistor = $\frac{10.9\times10^{-6}\,\text{C}}{1\times10^{-3}\,\text{sec}} = 11\text{mA}$.

81. C = 100 μF, emf = 6 V, R = 20 KΩ, t = 4 S.

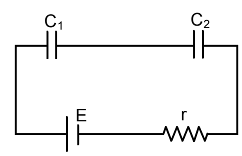
Charging : $Q = CV(1 - e^{-t/RC})$ $\left[\frac{-t}{RC} = \frac{4}{2\times10^{4}\times10^{-4}}\right]$

$= 6 \times 10^{-4}(1 - e^{-2}) = 5.187 \times 10^{-4}$ C = Q

Discharging : $q = Q(e^{-t/RC}) = 5.184 \times 10^{-4} \times e^{-2}$

$= 0.7 \times 10^{-4}$ C = 70 μc.

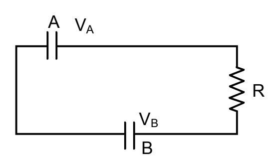
82. $C_{eff} = \frac{C_1C_2}{C_1 + C_2}$



$Q = C_{eff}\, E(1 - e^{-t/RC}) = \frac{C_1C_2}{C_1 + C_2}\, E(1 - e^{-t/RC})$

83. Let after time t charge on plate B is +Q.

Hence charge on plate A is Q – q.



$V_A = \frac{Q-q}{C}$, $V_B = \frac{q}{C}$

$V_A - V_B = \frac{Q-q}{C} - \frac{q}{C} = \frac{Q-2q}{C}$

Current = $\frac{V_A - V_B}{R} = \frac{Q-2q}{CR}$

Current = $\frac{dq}{dt} = \frac{Q-2q}{CR}$

$\Rightarrow \frac{dq}{Q-2q} = \frac{1}{RC}\cdot dt \quad \Rightarrow \int_0^q \frac{dq}{Q-2q} = \frac{1}{RC}\cdot\int_0^t dt$

$\Rightarrow -\frac{1}{2}[\ln(Q-2q) - \ln Q] = \frac{1}{RC}\cdot t \Rightarrow \ln\frac{Q-2q}{Q} = \frac{-2}{RC}\cdot t$

$\Rightarrow Q - 2q = Q\, e^{-2t/RC} \Rightarrow 2q = Q(1 - e^{-2t/RC})$

$\Rightarrow q = \frac{Q}{2}(1 - e^{-2t/RC})$

84. The capacitor is given a charge Q. It will discharge and the capacitor will be charged up when connected with battery.

Net charge at time t = $Qe^{-t/RC} + Q(1 - e^{-t/RC})$.