RRB - JE

ELECTRONICS

Railway Recruitment Board

Volume - 7

Network Theory

BASICS OF CIRCUITS & CIRCUITAL LAWS

1.1. INTRODUCTION

The phenomenon of transferring charge from one point to another is termed as electric current. An electric current may be defined as the time rate of electric charge q across-sectional boundary. Random motion of electrons in a metal does not constitute a current unless there is a net transfer of charge.

Conductivity is the ability of the path to transfer electrons. The resistivity is the resistance offered to passage of electron. Resistance is the inverse of conductance.

Charge : Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field. The smallest charge that exist is the charge carried by e^- is equal to -1.6×10^{-19} The MKS unit of charge is Coulomb (C). When an electron is removed from a substance, that substance becomes positively charged. A substance with excess of electrons is negatively charged.

Current : The time rate of flow of electric charge across a cross-sectional boundary is termed as current. Mathematically, current is given by

$$i = \frac{dq}{dt}$$

If the charge q is given in coulombs, and the time t in seconds, the current is measured in amperes and denoted by the letter 'A'. or columb/second. The charge transfer between t_0 and t is obtain by $q(t) = \int_{t_0}^{t} i(t)dt$

Voltage : Voltage is defined as work done in moving a unit positive charge once around the closed path. Mathematically, voltage is given by

$$V = \frac{dW}{dq}$$

The unit of potential is Volt (V).

Power : The instantaneous power delivered to a circuit element is the product of the instantaneous value of voltage and current of the element. Mathematically power is given by the relation.

$$p(t) = v(t)\, i(t)$$

The unit of power is Watt (W).

In terms of energy power is defined as, "The time rate of change of energy is called power". Mathematically, power is given by

$$P = \frac{dW}{dt}$$

Energy : The energy delivered to a circuit element over the time interval (t_0, t) is given by

$$E = \int_{t_0}^{t} p(t)dt = \int_{t_0}^{t} v(t)i(t)dt$$

The unit of energy is Watt-sec. or Joules.

1.2. *CIRCUIT COMPONENTS*

(i) Resistance : It is a linear, two terminal component which opposes the flow of current through it. Resistance dissipates energy as heat or some other way. It is measured in Ohms (Ω).

Most materials used to carry current in the form of wires. The resistance R of a conductor varies directly with the length *l* and is inversely proportional to the cross sectional area A.

i.e. $R = \rho \dfrac{\ell}{A}$

where ρ is the constant and is called resistivity. The unit of ρ is ohm-meter.

The ambient temperature of a body is the temperature surrounding it. When the ambient temperature of a resistor is varied, a change in resistance is noted which is related by the following relation

$$R_t = R_0 \left[1 + \alpha \left(T_t - T_0 \right) \right]$$

where, R_0 is the resistance at temperature $T_0 = 0°C$ and R_t is the resistance at temperature $T_t°C$.

Resistances can be connected either in series or in parallel.

Series connection of resistors : If n resistors are connected in series then these can be replaced by a single resistance R_{eq} such that

$$R_{eq} = R_1 + R_2 + \dots\dots + R_n$$

In series combination of resistance, current remains same.

Parallel combination of resistors : In n resistances are connected in parallel then these can be replaced by a single resistance R_{eq} such that.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots\dots + \frac{1}{R_n}$$

In parallel combination of resistances, voltage across parallel branches remains constant.

Ohm's Law : Ohm's law states that the current (I) flowing through a conductor is directly proportional to the voltage (V) across the ends of a conductor, provided physical conditions of a conductor such as pressure, mechanical strain, temperature etc. are kept constant.

$$I \propto V$$
$$I = G \times V$$
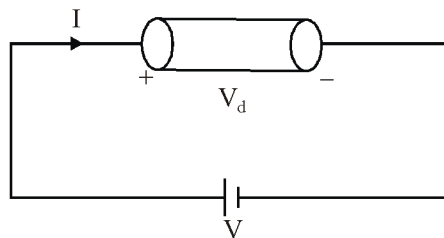
Ohm's law also state that at constant temperature potential difference across an element is directly proportional to current flowing through the element.

i.e. $\qquad V_d \propto I$

or $\qquad V_d = IR$

(ii) Inductance : It is a property of two terminal circuit element by virtue of which it is capable of storing energy in an electromagnetic field with the help of current passing through it. The device is known as inductor.

Inductance can be two types :

(a) Self Inductance : The property of coil due to which it opposes any increase or decrease of current or flux through it is called Self-inductance.

Self-inductance of a coil is given by the relation

$$L = \frac{N\phi}{I} = \frac{N^2\mu A}{\ell}$$

where, N = number of turns in coil

A = area of cross-section

l = length of coil

I = Current in ampere

ϕ = flux in Weber

L = Coefficient of self-inductance in Henry.

As per lenz's law, this self induced e.m.f. opposes the cause (i.e. current in the coil). This property which opposes any change in the current is called self inductance. Current through inductor is given by

$$i_L(t) = \frac{1}{L} \int_{-\infty}^{t} V_L(t)dt$$

Energy stored by an inductor

$$W_L = \frac{1}{2}Li^2$$

(b) Mutual Inductance (M) : Mutual inductance is the property of two coil because of which each opposes any change in the current flowing through the other by developing an induced emf.

Coefficient of Coupling : Coefficient of coupling (K) between two coils is the measure of coupling of two coils.

$$M = 1$$

Mathematically, $\qquad K = \dfrac{M}{\sqrt{L_1 L_2}}$, value of K < 1.

Coefficient of coupling $\qquad K = \dfrac{\phi_{12}}{\phi_1} = \dfrac{\phi_{21}}{\phi_2}$

Dot Convention for Coupled Circuits
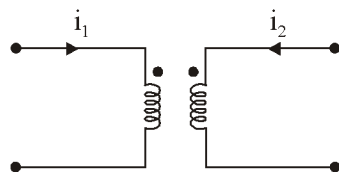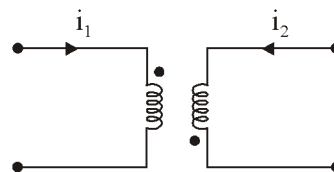

Figure (a)   **Figure (b)**

A dot placed at any end of the two coils indicates that, these coils are mutually coupled.

Now the mutual inductance M between two coils

(i)   Will be positive if the current enters through both the dots or leaves both the dots, (as shown in the above figure (a).

(ii)   Will be negative when current enters through a dot in one coil and leaves the dot in another coil as shown in figure (b) above.
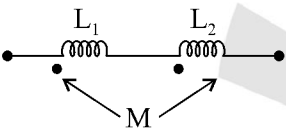
Series combination of inductors : If a number of inductors are connected in series, then they can be replaced by a single inductor of inductance L_{eq} such that
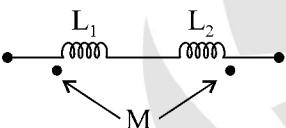
$$L_{eq} = L_1 + L_2 + L_3 + ... + L_n$$

Parallel combination of inductors : If a number of inductors are arranged in a parallel to one another then the equivalent inductance is given by:

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + ...+ \frac{1}{L_n}$$

Combination of Inductors with Mutual Inductance

(i) $L_{eq} = L_1 + L_2 + 2M$

(ii) $L_{eq} = L_1 + L_2 - 2M$

(iii) $L_{eq} = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$

(iv) $L_{eq} = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 + 2M}$

(iii) Capacitance : An electrical element which stores energy due to voltage across it and is independent of the current through it is called capacitor. The unit of capacitance is Farad and denoted by 'C'.

The voltage across the capacitance is given by

$$V = \frac{Q}{C} = \frac{1}{C} \int_{-\infty}^{t} i\, dt \quad (\therefore \text{ where Q is the charge on capacitance in coulombs.})$$

The current through the capacitor is given by

$$i = C \frac{dV}{dt}$$

For a parallel plate capacitor whose plates are having an area of A (in square meter) each the separation between the plates is d (in meters). Then capacitance is given by

$$C = \frac{\varepsilon A}{d} \text{ Farad}$$

Various types of capacitors are as follows

(a) Ceramic capacitor : They are manufactured by depositing directly on each side of ceramic dielectric, coating of silver that serves as capacitor plates. These capacitors have very high capacitance per unit volume.

(b) Paper capacitor : They are manufactured by winding long narrow sheets of alternate layers of aluminium foil and was impregnated paper, into impact rolls.

(c) Electrolytic capacitors : They can only be used in circuits that maintains the polarity of the voltage in one direction. If the voltage polarity is reversed, the capacitor acts as a short circuit. These capacitors have a very high values of capacitance ranging from 1 to $2\mu F$ to the order to several thousand microfarads.

1.3 CIRCUIT TERMINOLOGY

(i) **Circuit element :** Any individual circuit component like inductor, resistor, capacitor etc. with two terminals.

(ii) **Branch :** A branch is a group of circuit elements with two terminals. Thus a branch consists of number of elements.

(iii) **Node :** A node is the meeting point of three or more branches at a common point. It is also referred as junction.

(iv) **Mesh and Loop :** A set of branches forming a closed path, with the omission of any branch makes the path open. Mesh must not have any other circuit inside it. Loop may have other loops or meshes inside it.

(v) **Active Network :** A network containing energy sources together with other circuit elements.

(vi) **Passive Network :** A network containing circuit elements without any energy sources.

(vii) **Lumped Network :** Network whose elements are physically separable are called as lumped elements, such as resistors, inductors, capacitors etc.

(viii) **Distributed Network :** A network in which resistors, capacitors, inductors etc. are not electrically separable and isolated as individual elements. A transmission line has distributed resistor, inductor, and capacitor which are not isolated from the network.

(ix) **Bilateral Network :** A bilateral network is defined as those whose elements can transmit well in either direction. For example, elements made of high conductivity material like iron core conductors are bilateral elements.

(x) **Unilateral Network :** A unilateral network is one whose elements follow different laws relating to voltage and current for different direction of current and voltage polarities. For example, vacuum tubes, crystal and metal rectifiers are unilateral elements.

(xi) **Linear and Non Linear Networks :** A linear network is one for which the principle of superposition holds. A circuit element is linear if the relation between current and voltage involves a constant coefficient.

e.g.
$$V = Ri, V = L\frac{di}{dt}, \ V = \frac{1}{C}\int i \ dt$$

Therefore, it is concluded that a linear network must be bilateral, but a bilateral network is not necessarily linear. For example, an iron-core conductor is bilateral but it is non-linear.

(xii)   **Current Source :** A generator which maintain its output current independent of the voltage across its terminals. It is indicated by a circle enclosing an arrow for reference current direction. An ideal current source has infinite internal resistance.

(xiii)   **Voltage Source :** A generator which maintain its value of potential independent of the output current. An AC source is indicated by a circle enclosing a wave line. An ideal voltage source has zero internal resistance.

1.4   *SOURCE TRANSFORMATION*

A voltage source is transformed into its equivalent current source as
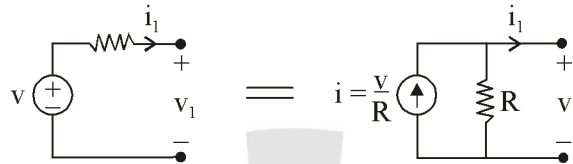
A current source is transformed into its equivalent voltage source as
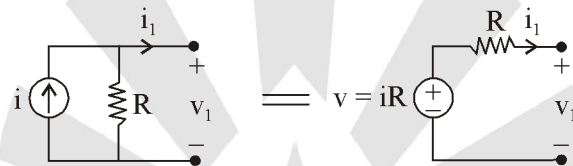
✎ *Key points :*

- An ideal voltage source has zero internal resistance.

- Ideally the internal resistance of a voltmeter should be infinite.

- An ideal current source has infinite internal resistance.

- Ideally the internal resistance of an ammeter should be zero.

- If two voltage sources are connected in series, they are summed up.
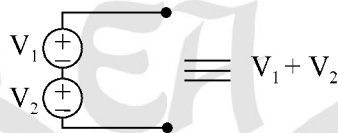
- If two voltage sources are connected in parallel, they are treated as equal.
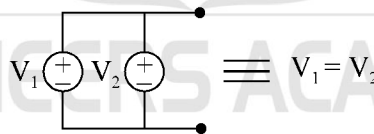
- If two current sources are connected in series, they are treated as equal.
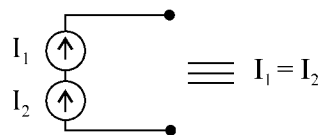
- If two current sources are connected in parallel, they are summed up.
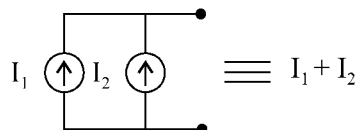
- **Circuit Response of single elements**

Element	Voltage across element	Current in element
Resistance, R	$v(t) = R\, i(t)$	$i(t) = \dfrac{v(t)}{R}$
Inductance, L	$v(t) = L\dfrac{di}{dt}$	$i(t) = \dfrac{1}{L}\displaystyle\int_0^t v\,dt$
Capacitance, C	$v(t) = \dfrac{1}{C}\displaystyle\int_0^t i\,dt$	$i(t) = C\dfrac{dv}{dt}$

1.5 KIRCHOFF'S LAWS

Kirchoff's basic circuit laws provides two methods for the solution of networks. They are as follows

(i) Kirchoff's Current Law (KCL) : It is based on conservation of charge. It states that, "The algebraic sum of currents at any node of a circuit is zero".

The direction of current coming towards node is taken as positive and outgoing current as negative. The reverse sense of directions can also be taken.

> Minimum number of nodal equations to calculate the voltage and current of every port of network is = n – 1   (where, n = number of nodes)

Sign Convention : *Take positive sign for current entering a node and negative sign for leaving a node.*

(ii) Kirchoff's Voltage Law (KVL) : It is based on conservation of energy. It states that, "The algebraic sum of voltages in any closed path of network that is transverse in any single direction is zero".

Sign Convention : *Current i causes a positive drop of voltage when flowing from positive to negative potential and a negative drop when flowing from negative to positive potential.*

Minimum number of loop equations = b – n + 1

where   b = number of branches.

                                                 n = number of loops.

Solved Examples

Example : For the circuit shown in figure below

(a)   Calculate the equivalent capacitance across the terminals a-b.

(b)   Also calculate the charging time to charge these capacitances by a steady direct current of constant magnitude of 10A.
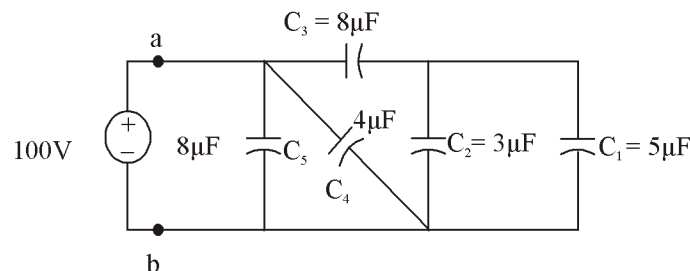
Solution : Equivalent capacitance between terminals a-b is given by-

$$C_{eq} = \left[\frac{(C_1 + C_2)C_3}{C_1 + C_2 + C_3} \| C_4 \right] \| C_5 = \left[\frac{(5\mu + 3\mu) \times 8\mu}{5\mu + 3\mu + 8\mu} \| 4\mu \right] \| 8\mu = 4\mu F$$
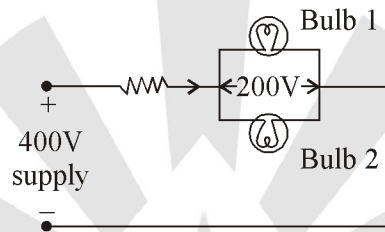
Then, net charge is given by

$$Q_{net} = C_{eq} \times V = 4 \times 10^{-6} \times 100 = 400 \mu F$$

Therefore, charging time is $t = \dfrac{Q_{net}}{I} = \dfrac{400 \times 10^{-6}}{10} = 40 \mu \sec$

Example : Two bulbs of rating 100 W and 220 V are required to be connected across a 400 Volts supply. Find the value of the resistance to be inserted in the line so that the voltage across the bulbs does not exceed 220 V

Solution : Total power drawn from the circuit is 2 × 100 = 200 W

Hence supply current I is given by $I = \dfrac{200W}{220V} = 0.91A$

Let R be the resistance connected in series such that the voltage across the bulbs is 220 V

Now   Supply voltage = drop in R + voltage across bulbs

$$400 = V_R + 220$$

or $V_R = IR = 180$

or $R = \dfrac{180}{0.91} = 197.8 \Omega$

Example : The two constant voltage sources V_a and V_b act in the same circuit as shown in figure below. Calculate the power delivered by each voltage source ?
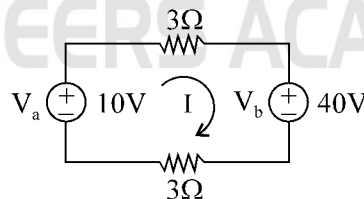
Solution : Applying KVL to the circuit

$$3 \times I + 3 \times I - 10 + 40 = 0$$

or $I = -5A$

Power delivered by $V_a = V_a \times I = 10(-5) = -50W$

Power delivered by $V_b = V_b \times I = 40(5) = 200 \, W$

○○○

PRACTICE SHEET

OBJECTIVE QUESTIONS

1. A network is said to be non-linear if it does not satisfy
   (a) superposition condition
   (b) homogeneity condition
   (c) both superposition and homogeneity condition
   (d) None of these

2. If there are b branches and n nodes, the number of KCL equations required will be
   (a) n
   (b) b
   (c) $b - n + 1$
   (d) $n - 1$

3. An inductor stored energy in
   (a) electrostatic field
   (b) electromagnetic field
   (c) magnetic field
   (d) electric field

4. The simplest series combination of a 5 V voltage source, a 5 A current source and a 5 ohm resistor is a
   (a) 5 A current source
   (b) 5 V voltage source
   (c) 5 ohm resistor
   (d) None of these

5. Which of the following is not a non-linear element:
   (a) electric arc with unlike electrode
   (b) diode
   (c) transistor
   (d) heater coil

6. The following constitutes a bilateral element:
   (a) a resistor
   (b) vacuum tube
   (c) metal rectifier
   (d) FET

7. In a linear network, when the a.c. input is doubled, the a.c. output becomes
   (a) doubled
   (b) halved
   (c) remains unchanged
   (d) becomes four times

8. The volt ampere equation for the circuit given below is

   (a) $e = 4.0 + 2i$
   (b) $e = 10 + 5i$
   (c) $e = -10 + 5i$
   (d) $e = -2 + 10i$

9. The current i_4 in the circuit given below is
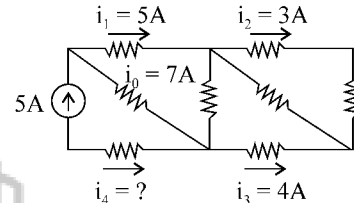
   (a) 12 A
   (b) -12 A
   (c) 4 A
   (d) None of these

10. A capacitor stores energy in
    (a) electric field
    (b) magnetic field
    (c) electromagnetic field
    (d) all of the above

11. In the circuit shown, the v(t) and i(t) will be
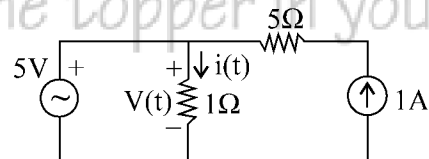
    (a) 1 V, 1 A
    (b) 1 V, 6 A
    (c) 5 V, 5 A
    (d) None of the above

12. In the figure shown, if we connect a source of 2V, with internal resistance of 1Ω at A'A, with positive terminal at A', then the current through R is
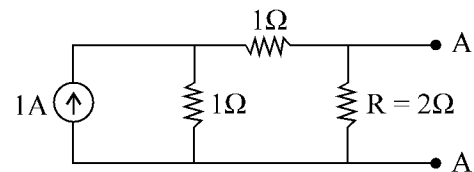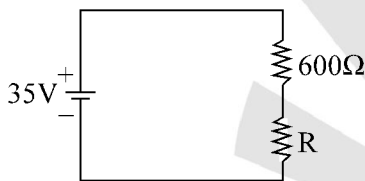

    (a) 2 A
   (b) 1.6 A
    (c) 1 A
    (d) 0.625 A

13. In the circuit shown the value of I is
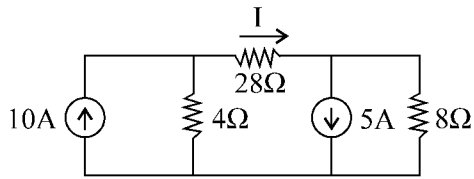
(a) 1 A (b) 2 A

(c) 4 A (d) 8 A

14. A 35 V source is connected to a series circuit of 600 ohm and R as shown. If a voltmeter of internal resistance 1.2 kilo ohms is connected across 600 ohm resistor, it reads 5 V. The value R is

(a) 1.2 kΩ (b) 2.4 kΩ

(c) 3.6 kΩ (d) 7.2 kΩ

15. When all resistances in the circuit are of one ohm each, the equivalent resistance across the points A and B will be
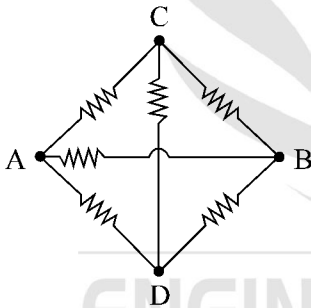
(a) 1Ω (b) $\frac{1}{2}$ Ω

(c) 2Ω (d) 4 Ω

16. A battery is connected to a resistance causing a current of 0.5 A in the circuit. The current drops to 0.4 A when an additional resistance of 5 Ω is connected in series. The current will drop to 0.2A when the resistance is further increased by

(a) 10 Ω (b) 15 Ω

(c) 25 Ω (d) 40 Ω

17. If the practical units of voltage and current were each made 20 times as large as they are at present, what would be the consequent alternation in the size of the unit of capacitance ?

(a) 20 times (b) 60 times

(c) 20 times (d) None of the above

18. The number of 2μF, 400 V capacitors needed to obtain a capacitance value of 1.5μF rated for 1600V is

(a) 12 (b) 8

(c) 6 (d) 4

19. The value of the current I following in the 1 ohm resistor in the circuit shown in the given will be
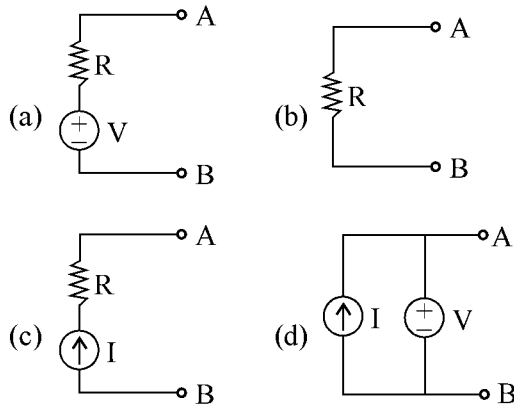

(a) 10 A (b) 6 A

(c) 5 A (d) zero

20. In the circuit shown in the given figure the current I through resistance R_L is
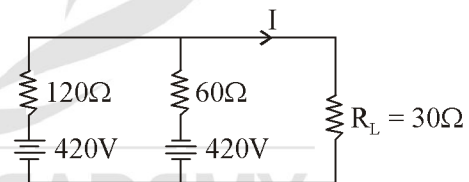
(a) 2A (b) zero

(c) –2 A (d) –6 A

21. A simple equivalent circuit of the 2-terminal network shown in figure, is
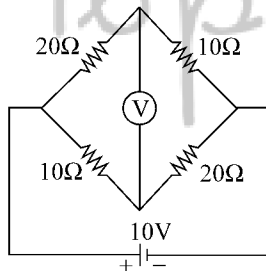
(a)

(b)

(c)

(d)
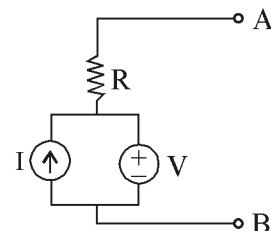
22. Two coupled coils connected in series have an equivalent inductance of 16 mH or 8 mH depending on the interconnection. Then the mutual inductance is

(a) 12 mH   (b) $8\sqrt{2}$ mH

(c) 4 mH   (d) 2 mH

23. Two coupled coils with $L_1 = L_2 = 0.6$ H have a coupling coefficient of K = 0.8. The turns ratio $\dfrac{N_1}{N_2}$ is
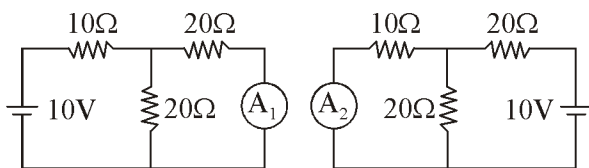
(a) 4   (b) 2

(c) 1   (d) 0.5

24. In the bridge given in figure, the reading of the high impedance voltmeter is

(a) zero   (b) 66.6 V

(c) 4.20 V   (d) 3.33 V

25. Consider the two circuits I and II shown in the following figures

Which one of the following statements regarding the current flowing through the ammeters A_1 and A_2 is correct ?

(a) The currents in A_1 and A_2 are of the same value and equal 0.25 A

(b) The currents in A_1 and A_2 are respectively 0.25 A and 2.5 A

(c) The current in both the ammeters is of the same value and equal 2.5 A

(d) None of these

26. Two inductive coils with self-inductances L_1 and L_2 are magnetically coupled in series opposing and in parallel aiding respectively. The mutual inductance between the coils is M. The equivalent inductances in the two cases are respectively

(a) $L_1 + L_2 + 2M, \dfrac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$

(b) $L_1 + L_2 - 2M, \dfrac{L_1 L_2 - M^2}{L_1 + L_2 + 2M}$

(c) $L_1 + L_2 - 2M, \dfrac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$

(d) $L_1 + L_2 + 2M, \dfrac{L_1 L_2 - M^2}{L_1 + L_2 + 2M}$

27. A network contains linear resistors and ideal voltage sources. If values of all the resistor are doubled, then the voltage across is resistor is

(a) halved

(b) doubled

(c) increased by four times

(d) not changed

28. Which of the following is/are the equivalent circuits of an iron-cored coil, valid at one frequency? Select the correct answer using the codes given below
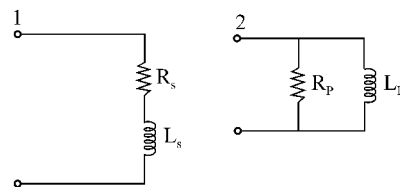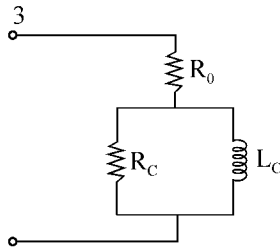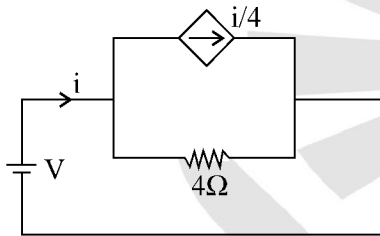
(a) 1 alone   (b) 2 alone

(c) 2 and 3   (d) 1, 2 and 3

29. A 10 V battery with an internal resistance of 1 Ω is connected across a non-linear load whose VI-characteristic is given by $7i = v^2 + 2v$. The current delivered by the battery is

(a) 2.5 A   (b) 5 A

(c) 6 A   (d) 7 A

30. In the network shown in the figure, the effective resistance faced by the voltage source is

(a) 4 Ω (b) 3 Ω

(c) 2 Ω (d) 1Ω

31. Two identical coils of negligible resistance, when connected in series across a 50 Hz fixed voltage source, draws a current of 10 A. When the terminals of one of the coils are reversed, the current drawn is 8 A. The coefficient of coupling between the two coils is

(a) 1/100   (b) 1/9

(c) 4/10   (d) 8/10

32. Five cells are connected in series in a row and then four such rows are connected in parallel to feed the current to a resistive load of 1.25 W. Each cell has emf of 1.5 V with internal resistance of 200 W The current through the load will be

(a) 3.33 A   (b) 23.33 A

(c) 5 A   (d) 1 A

33. The mutual inductance between two coupled coils is 16 mH If the turns in one coil are doubled and that in the other are halved, then the mutual inductance will be

(a) 5 mH   (b) 10 mH

(c) 14 mH   (d) 20 mH

34. Four resistances 80 W, 50 Ω, 25 Ω and R are connected in parallel. Current through 25 Ω resistance is 4 A. Total current of the supply is 10 A. The value of R will be
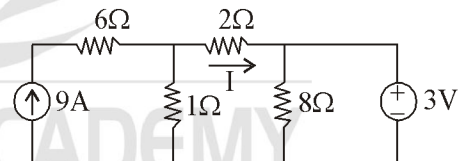
(a) 66.66 Ω

(b) 40.25 Ω

(c) 36.36 Ω

(d) 76.56 Ω

35. The current in the given circuit with a dependent voltage source is
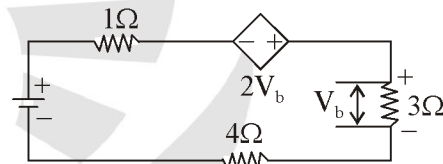
(a) 10 A   (b) 12 A

(c) 14 A   (d) 16 A

36. The current I in the figure is

(a) 3   (b) 2

(c) 1   (d) 0

37. Cells are connected in series to

(a) increase the current rating

(b) increase the voltage rating

(c) decrease the internal resistance

(d) none of these

38. The hot resistance of a bulb's filament is higher than its cold resistance because the temperature coefficient of the filament is

(a) zero

(b) negative

(c) positive

(d) about 2 Ω per deg C

39. There are three 100 bulbs in parallel across 220 V, 50 Hz line. If one bulb burns out

(a) remaining two will not operate

(b) all the three will produce light

(c) there will be heavy current in the mains line

(d) remaining two bulbs will produce light

40. In electrical appliance, the power rating is calculated by

(a) current   (b) voltage

(c) copper loss   (d) iron loss

41. Two resistance are connected in parallel and each dissipates 20 watts. The total power supplied by the voltage source equals

(a) 20 watts   (b) 40 watts

(c) 10 watts   (d) 80 watts

42. The circuit whose properties are not the same in either direction is known as

(a) unilateral circuit   (b) bilateral circuit

(c) reversible circuit   (d) irreversible circuit

43. In the circuit shown, the ammeter reads 1 ampere and voltmeter 10 volts. The internal resistance of the ammeter is 1 ohm and that of voltmeter is 100 ohms. The value of R is
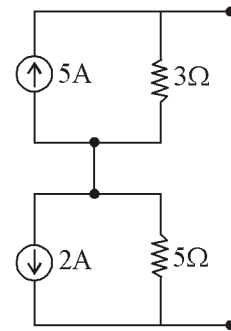

(a) 111.2 Ω   (b) 120 Ω

(c) 100/9 Ω   (d) 112.5 Ω
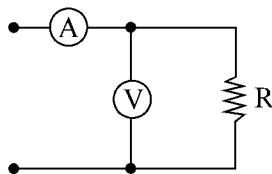
44. An active network has

(a) current source   (b) e.m.f. source

(c) resistance   (d) all of the above
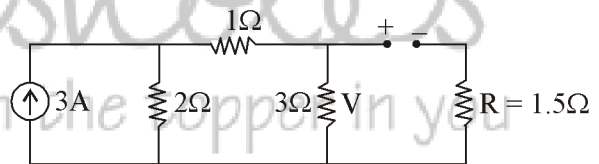
45. In the circuit shown the current is given by
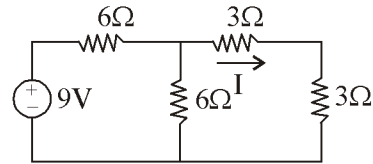
(a) 1/2   (b) 1/5

(c) 1   (d) 5/3

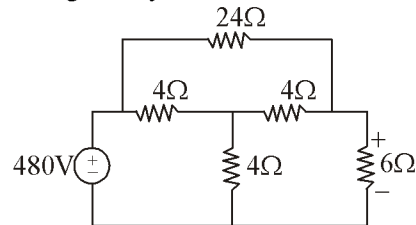**46.** If we convert the circuit below in a single source and a single resistance the values will be

(a) 1 A, 7 Ω   (b) 3 A, 7 Ω

(c) 5/8 A, 8 Ω   (d) 3 A, 1 Ω

47. In the figure V is the voltage when R = 1.5 is not connected. When R = 1.5 is connected, the current through it is I. The values of V and I respectively are

(a) 3 and 2   (b) 3 and 1

(c) 1 and 1   (d) 9 and 3

**48.** The current in the 24 Ω resistor in the following circuit is given by

(a) 10 amp from left to right

(b) 10 amp from right to left

(c) 5 amp from left to right

(d) 4/3 amp from left to right

49. A passive network has

(a) no voltage source but current sources

(b) no current source but voltage sources

(c) both (a) and (b)

(d) none of these

50. Open circuit voltage is the potential difference between two points when the impedance between these point is

(a) infinity   (b) reactive

(c) zero   (d) none of these

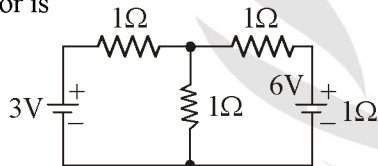**51.** The voltage marked V_x is given by
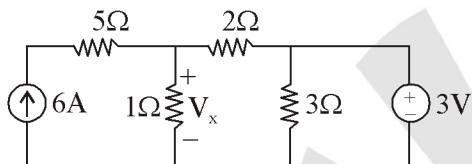
(a) 30   (b) 5

(c) 3   (d) 1

52. Kirchoff's current is valid for

(a) DC circuits only

(b) AC circuits only

(c) Both DC and AC circuits

(d) sinusoidal sources only

53. In the given circuit the current flowing in the 1Ω resistor is

(a) 3 Amp   (b) 1.5 Amp

(c) 0.8 Amp   (d) 2 Amp

54. With the two resistor in parallel one of which is a 100 ohm resistor and the other one is not known, the only likely value for the net resistance is
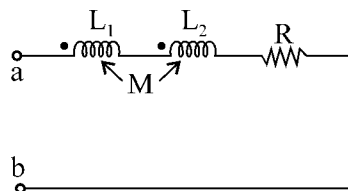
(a) 101 ohms   (b) 1000 ohms

(c) 90 ohms   (d) 110 ohms

55. Convert the following to single current source in parallel with single resistor
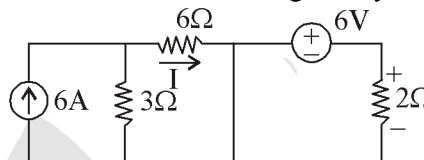

(a) 3.7 amp, 2.77 Ω (b) 5 amp, 8 Ω

(c) 1 amp, 7 Ω (d) 7 amp, 1 Ω
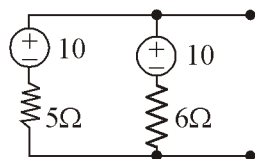
56. The equivalent inductance of the given circuit between terminals a-b is equal to
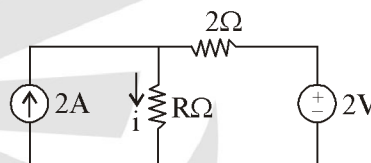

(a) $L_1 + L_2$ (b) $L_1 + L_2 - 2M$

(c) $L_1 + L_2 + 2M$ (d) $L_1 + L_2 - M$

57. The current in the circuit is given by in (amp.)

(a) 5   (b) 4

(c) 2   (d) 1

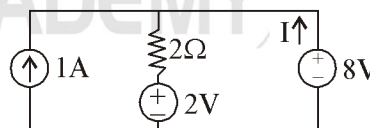**58.** Given the current through R is $i = 2$. The value of R is

(a) 1   (b) 2

(c) 4   (d) 8

59. To neglect a current source the terminals across the source are

(a) open circuited

(b) replaced by a capacitance

(c) replaced by a resistance

(d) short circuited

60. Current marked I is given by

(a) 1   (b) 2

(c) 3   (d) 4

61. A 4Ω resistor carrying 2 Amp current will dissipate power equal to

(a) 4 W   (b) 16 W

(c) 8 W   (d) None of these

62. A battery is connected across the series combination of two resistors of values 5 ohms and 20 ohms respectively. The voltage across 5 Ω resistor is 20 V. The battery voltage will be

(a) 150 V   (b) 100 V

(c) 175 V   (d) 200 V

63. A circuit has 10V applied across a 10Ω resistance R_1. How much resistance R_2 must be added in series with R_1 reduce the current one half
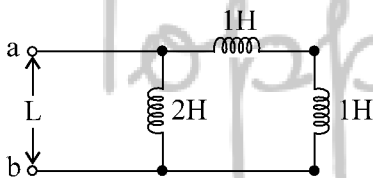
(a) 5 Ω (b) 10 Ω

(c) 20 Ω (d) 33 Ω

64. Equivalent resistance of the given network is
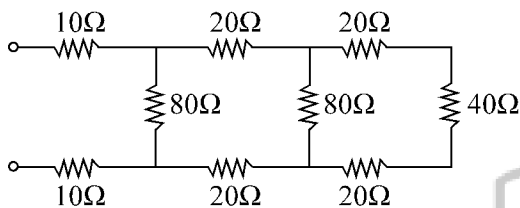
(a) 100 Ω (b) 120 Ω

(c) 60 Ω (d) 40 Ω

65. The equivalent inductance of the circuit is given by:

(a) 1   (b) 2

(c) 3   (d) 4

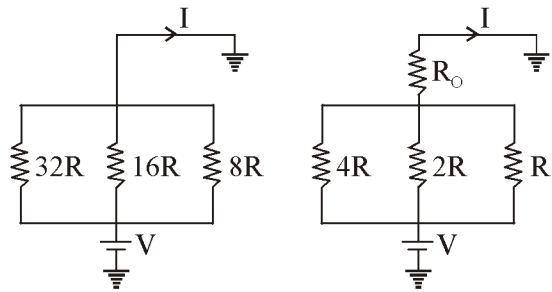**66.** The voltages V_a, V_b, V_c in the circuit are given by:
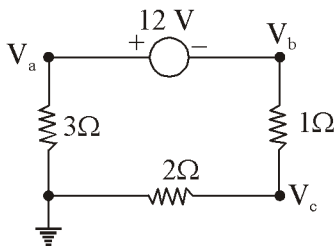
(a) $-6, -6, 4$ (b) $6, -6, -4$

(c) $6, -10, -4$ (d) $6, -10, 4$

67. Two coupled inductors $L_1 = 0.2$ H and $L_2 = 0.45$ H have coefficient of coupling k = 0.8. The mutual inductance M is
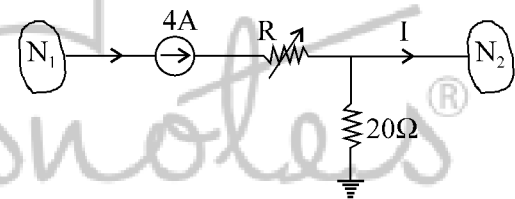
(a) 0.2 H   (b) 0.24 H

(c) 0.8 H   (d) 0.42 H

68. The circuit shown in figure-I is replaced by that in Figure-II. If current 'I' remains the same, then R_0 will be in (Ω)
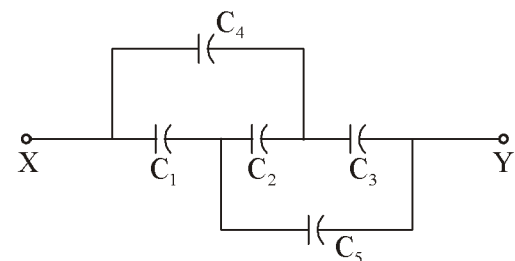

(a) zero   (b) R

(c) 2R   (d) 4R

69. In the circuit shown in the figure, for R = 20 Ω the current 'I' is 2 A. When R is 10 Ω, the current 'I' would be:

(a) 1 A   (b) 2 A

(c) 2.5 A   (d) 3 A

70. In the given figure, the capacitors C_1, C_3, C_4 and C_5 have a capacitance of 4 microfarads each and the capacitor C_2 has a capacitance of 10 microfarads. The effective capacitance (in microfarads) between the points X and Y will be:

(a) 2   (b) 4

(c) 3   (d) 10

71. For a given voltage, four heating coils will produce maximum heat when connected

(a) All in parallel

(b) All in series

(c) With two parallel pairs in series

(d) One pair in parallel with the other two in series

72. When two coupled coils of equal self-inductance are connected in series in one way, the net inductance is 12 mH, and when they are connected in the other way, the net inductance is 4mH. The maximum value of net inductance when they are connected in parallel in a suitable way is

(a) 2 mH   (b) 3 mH

(c) 4 mH   (d) 6 mH

73. Two perfectly coupled coils each of one Henry self inductance are connected in parallel so as to aid each other. The overall inductance in Henrys is

(a) 2   (b) 1

(c) 1/2   (d) zero

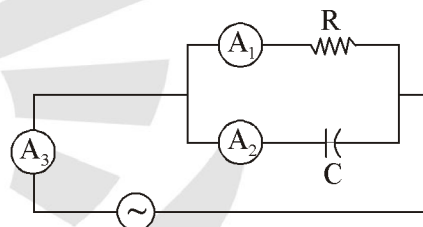**73.** The resistance R_{AB} in the circuit:
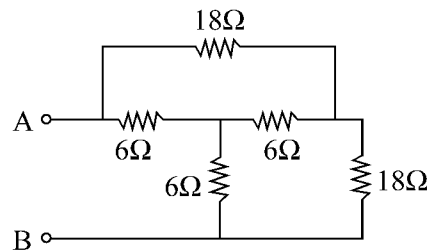
(a) 12 Ω   (b) 10.8 Ω

(c) 6.75 Ω   (d) 9 Ω

74. A loudspeaker transformer has a turns ratio of 20 : 1. The speaker impedance is 12 ohms. The primary impedance of transformer is

(a) 4800 Ω   (b) 0.03 Ω

(c) 240 Ω   (d) 0.004 Ω

75. In figure A_1, A_2 and A_3 are ideal ammeters. If A_1 reads 5A, A_2 reads 12A, then A_3 should read

(a) 7 A   (b) 12 A

(c) 13 A   (d) 17 A

○○○

PRACTICE SHEET

ANSWER & EXPLANATIONS

1. *Ans. (c)*

2. *Ans. (d)*

3. *Ans. (c)*

4. *Ans. (d)*

5. *Ans. (d)*

6. *Ans. (a)*

7. *Ans. (a)*

8. *Ans. (c)*

$$e = 40 + 5(i - 10)$$

$$e = 5i - 10$$

9. *Ans. (d)*

10. *Ans. (a)*

11. *Ans. (c)*

$$v(t) = 5V$$
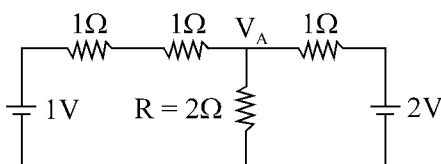
$$i(t) = \frac{5}{1} = 5A$$

12. *Ans. (d)*

The current source is converted into voltage source

Current through R is

$$I = \frac{V_A}{R}$$

Applying KCL at node A,

$$\frac{V_A - 1}{2} + \frac{V_A}{2} + \frac{V_A - 2}{1} = 0$$
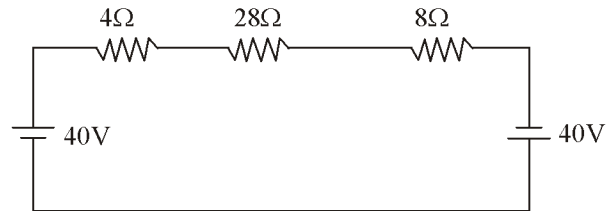

$$V_A = 1.25V$$

and

$$I = \frac{1.25}{2} = 0.625A$$

13. *Ans. (b)*

Rearranging circuit,

$$I = \frac{80}{40} = 2A$$

14. *Ans. (b)*

Voltage across 600 ohm resistor is 5V. Hence remaining 30V is across R. Total current through the circuit

$$I = \frac{V}{R_{eq}}$$

where

$$R_{eq} = \frac{600 \times 1200}{60 + 1200} = R' = 400 + R$$

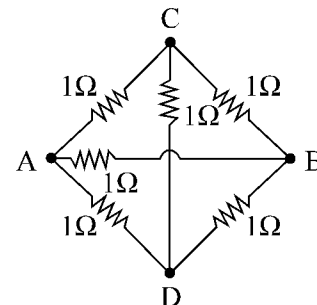Therefore $V = IR$

or

$$30 = \frac{35}{400 + R} \times R$$

$$12000 + 30R = 35R$$

or $R = 2.4k\Omega$

15. *Ans. (b)*

Circuit is a balance bridge

Hence resistor between C and D can be removed and $R_{AB} = 1/2\Omega$

16. *Ans. (c)*

$$I_1 R = I_2$$

$$0.5 \times R = 0.4(R + 5)$$

$$R = 20\Omega$$

Again $I_1 R = I_2 R$
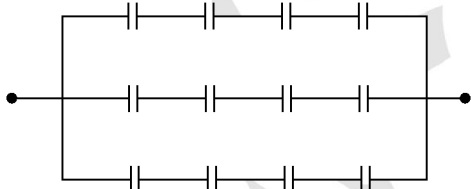
$$25 \times 0.4 = 0.2(25 + R)$$

$$R = 25\Omega$$

17. *Ans. (d)*

Since $C = \dfrac{Q}{V} = \dfrac{di}{dt \times V} = \dfrac{20}{20} = 1$
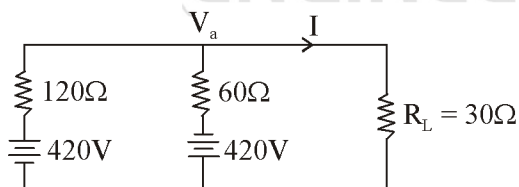
or $i = C\dfrac{dv}{dt}$

or $C = \dfrac{i}{dV/dt} = \dfrac{20}{20} = 1$

19. *Ans. (a)* The circuit shown below

18. *Ans. (c)*

$$I = \dfrac{V}{R} = \dfrac{5}{1} = 5A$$

19. *Ans. (c)*

The circuit becomes

Applying node equation at node V_a

$$2V_a + 840 + V_a - 420 + 4V_a = 0$$

$$7V_a = -420$$

or $V_a = -60$

Current I is given by

$$I = \dfrac{V_a}{R_L} = \dfrac{-60}{30} = -2A$$

20. *Ans. (a)*

21. *Ans. (d)*

$$L_{eq} = L_1 + L_2 \pm 2M$$

$$16 \times 10^{-3} = L_1 + L_2 + 2M \qquad ...(i)$$

$$8 \times 10^{-3} = L_1 + L_2 - 2M \qquad ...(ii)$$

Subtracting equation (ii) from equation (i),
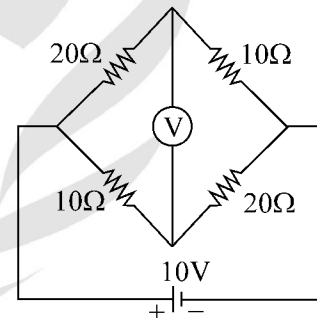
$$M = 2mH$$

22. *Ans. (c)*

$$L \propto N^2$$

or $\dfrac{L_1}{L_2} = \left(\dfrac{N_1}{N_2}\right)^2$ or, $\dfrac{N_1}{N_2} = \sqrt{\dfrac{0.6}{0.6}} = 1$

23. *Ans. (d)*

The circuit is

Voltage at node A using voltage divider is

$$V_A = \dfrac{20}{10 + 20} \times 10 = 6.66V$$

Voltage at node B

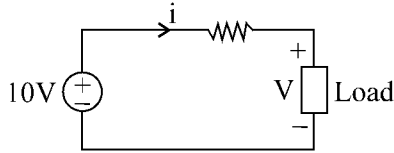$$V_B = \dfrac{10}{10 + 20} \times 10 = 3.33V$$

Now $V_{AB} = V_A - V_B = 6.66 - 3.33 = 3.33\ V$

24. *Ans. (a)*

25. *Ans. (c)*

26. *Ans. (d)*

27. Ans. (a)

28. Ans. (b)

The circuit is drawn as

Applying KVL, we get voltage V as

$$V = 10 - i$$

Put this value of V in equation given in question

i.e. $\qquad 7i = (10 - i)^2 + (210 - i)$

or $\quad i^2 - 29i + 120 = 0$

or $\qquad\qquad i = 5, 24$

29. Ans. (b)

Applying loop in the circuit,

$$-V + 4\left(i - \frac{i}{4}\right) = 0$$

$$V = 3i$$

or $\qquad\qquad \dfrac{V}{i} = 3\Omega$

30. Ans. (b)

$$\frac{V}{\omega\left(L_1 + L_2 - 2k\sqrt{L_1 L_2}\right)} = 10 \qquad \text{...(i)}$$

$$\frac{V}{\omega\left(L_1 + L_2 + 2k\sqrt{L_1 L_2}\right)} = 8 \qquad \text{...(ii)}$$

From equation (i) and (ii)

$$L_1 = L_2$$

$$\frac{1-k}{1+k} = \frac{8}{10} \quad \text{or} \quad k = \frac{1}{9}$$

31. Ans. (c)

Current is given by

$$I = \frac{V_{eq}}{R_{eq} + R_L}$$

Voltage in a row is $\qquad V_{eq} = 5 \times 1.5 = 7.5V$

Four rows of resistor are in parallel and each row has five 0.2 ohm resistors in series. hence

$R_{eq} = (4 \times 0.2) \parallel (5 \times 0.2) \parallel (5 \times 0.2) \parallel (5 \times 0.2)$

$R_{eq} = 0.25\Omega$

$$I = \frac{75}{1.25 + 0.25} = 5A$$

32. Ans. (b)
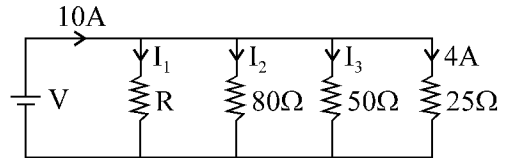
$$M = K\sqrt{L_1 L_2}$$

and $\qquad\qquad L \propto N^2$

$$M' = K\sqrt{\frac{L_1}{4} \times 4L_2} = M$$

33. Ans. (c)

Network is shown below

$$V = 4 \times 25 = 100 \text{ V}$$

$$I_3 = \frac{100}{50} = 2A$$

$$I_2 = \frac{100}{80} = 1.25A$$

$$I_3 = \frac{100}{R}$$

and $I_1 + I_2 + I_3 + 4 = 10$

$$\frac{100}{R} + 1.25 + 2 + 4 = 10$$

$$R = \frac{100}{2.75} = 36.36\Omega$$

34. Ans. (b)

Applying KVL $4i - 24 + i \times 1 - 2v_b + v_b = 0$ ...(i)

and $v_b = 3i$ ...(ii)

From equation (i) and (ii)

$$-24 + 5i - 3i = 0$$

or $\qquad\qquad i = 12A$

35. Ans. (b)

Applying superposition principle.

Considering only 3V source.

$$I' = 1A$$

Considering only 9A source.

$$I'' = \frac{1}{3} \times 9 = 3A$$

Equivalent current I is given by

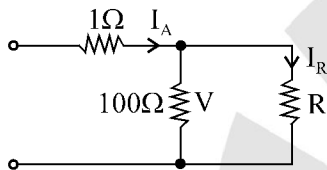$$I = I'' - I' = 3 - 1 = 2A$$

36. Ans. (b)

37. Ans. (c)

38. Ans. (d)

39. Ans. (c)

40. Ans. (b)

41. Ans. (a)

42. Ans. (c)

Current through voltmeter is

$$I_V = \frac{V}{100} = \frac{10}{100} = 0.1A$$

$$I_R = I_A - I_V = 1 - 0.1 = 0.9A$$

Therefore $$R = \frac{V}{I_R} = \frac{10}{0.9} = \frac{100}{9}\Omega$$
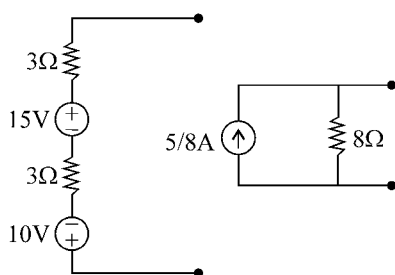
43. Ans. (d)

44. Ans. (a)

$$I_1 = \frac{V}{R_{eq}} = \frac{9}{9} = 1A$$

Using current divider

$$I = \frac{6}{6+6} \times 1 = \frac{1}{2}$$

45. Ans. (c)

Voltage equivalent of given circuit is

46. Ans. (b)

47. Ans. (d)

48. Ans. (d)

49. Ans. (a)

50. Ans. (b)

V_x due to 6A only

$$V_{x1} = 4 \times 1 = 4V$$

V_x due to 3V source only

$$V_{x2} = 1 \times 1 = 1V$$

$$V_x = V_{x1} + V_{x2} = 5V$$

51. Ans. (c)

52. Ans. (a)

Applying node equation, we get

$$\frac{V_a - 3}{1} + \frac{V_a}{1} + \frac{V_a - 6}{1} = 0$$

$$3V_a = 9 \quad \text{or} \quad V_a = 3$$

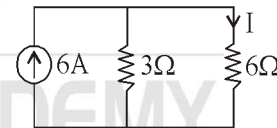and current is given by

$$I = \frac{3}{1} = 3A$$

53. Ans. (c)

54. Ans. (a)

55. Ans. (c)

56. Ans. (c)

Due to short branch in the circuit, the circuit changes to

Applying current divider

$$I = \frac{3}{9} \times 6 = 2 \, A$$

57. Ans. (a)

Applying node equation at R,

$$\frac{V - 2}{2} = 2 - 2$$

$$V = 2$$

$$R = \frac{V}{I} = 1$$

58. *Ans. (d)*

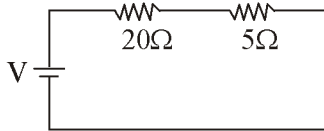**59.** *Ans. (b)*

Applying node equation

$$\frac{8-2}{2} = I + 1$$

or $\quad\quad I = 2A$

60. *Ans. (b)*

$$P = I^2R = 4 \times 2^2 = 16W$$

61. *Ans. (b)*

Voltage across 5 ohm resistor
By voltage divider rule,

$$20 = \frac{5}{5+20} \times V \implies V = 100V$$

62. *Ans. (b)*

Initially current is

$$I = \frac{10}{10} = 1A$$

$$\frac{1}{2} = \frac{10}{10+R}$$

or $\quad\quad R = 10 \text{ ohms.}$

63. *Ans. (c)*

64. *Ans. (a)*

$$L_{eq} = 2 \| (1+1) = 1H$$

65. *Ans. (b)* 16

66. *Ans. (b)*

$$M = K\sqrt{L_1 L_2} = 0.8\sqrt{0.2 \times 0.45}$$
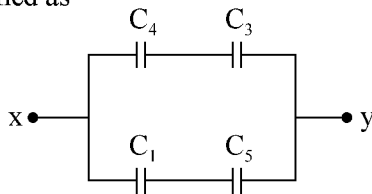$$M = 0.24$$

67. *Ans. (d)*

Impedance seen by V should be equal in both cases.

68. *Ans. (b)*

69. *Ans. (b)*

It is a balanced bridge therefore C_2 has no current, hence acts as an open circuit. The circuit now modified as

$$C_1 = C_4 = C_5 = C_3 = 4\mu F$$
$$C_{xy} = 4\mu F$$

70. *Ans. (a)*

71. *Ans. (b)*

Given

$$L_1 + L_2 + 2M = 12 \text{ mH} \quad\quad\quad ....(i)$$
$$L_1 + L_2 - 2M = 4mH \quad\quad\quad ...(ii)$$
$$2(L_1 + L_2) = 16 \quad \text{or} \quad L_1 + L_2 = 8$$
$$2L_1 = 8$$

$\because \quad\quad\quad L_1 = L_2$

or $\quad\quad\quad L_1 = 4$

From equation (i) and (ii) M = 2

L_{eq} for parallel combination

$$L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M} = \frac{16-4}{8-4} = 3mH$$
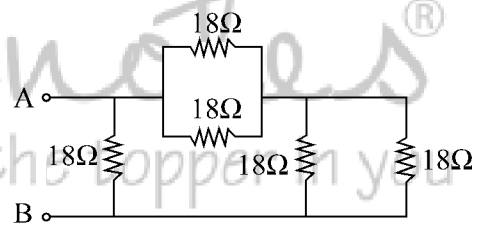
72. *Ans. (d)*

For perfectly aiding coils,

$$M = 1$$

i.e. $\quad\quad L_{eq} = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$

$$L_{eq} = \frac{1 - 1^2}{1 - 2} = 0$$

73. *Ans. (d)*

Using star to delta conversion. We get,

Z_{AB} = (18 || 18 + 18|| 18) || 18 = 9Ω

74. *Ans. (a)*

$$\frac{Z_{in}}{Z_L} = \left(\frac{20}{1}\right)^2$$

or $\quad\quad Z_{in} = 12 \times 20^2 = 4800\Omega$

75. *Ans.(c)*

$$A_3 = \sqrt{A_1^2 + A_2^2}$$

$$A_3 = \sqrt{12^2 + 5^2} = 13A$$