SYED AMMAL ENGINEERING COLLEGE
(Affiliated to ANNA UNIVERSITY, CHENNAI)
Dr.E.M.Abdullah Campus RAMANATHAPURAM-623 502.
Website: www.syedengg.ac.in Phone: (04567) 304 001
Department of Electrical and Electronics Engineering
(NBA Accredited)

Technical Aptitude

ELECTRIC CIRCUIT THEORY

Electrical Components and Circuits

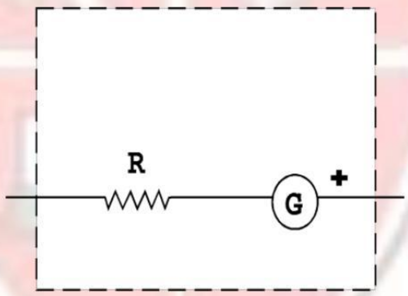
The purpose of this chapter is to discuss basic direct current (dc) circuit components in preparation for the two following chapters that deal with integrated circuits and microcomputers in instruments for chemical analysis.

DIRECT CURRENT CIRCUITS AND MEASUREMENTS

Some basic direct current circuits and how they are used in making current, voltage, and resistance measurements will be considered.

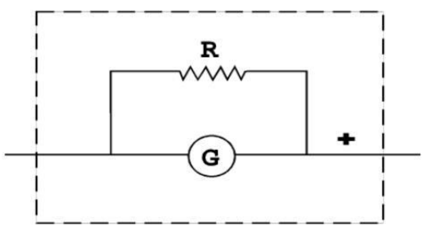
The general definition of a circuit is a closed path that may be followed by an electric current.

A galvanometer is a device with a rotating indicator that will rotate from its equilibrium position when a current passes through it. A galvanometer has negligible resistance.



Ampermeter

An ampermeter (ammeter) is a galvanometer with a calibrated current scale for its indicator and a bypass resistor (called a shunt) for a fixed fraction of the current, shown in Figure 1. Many ammeters have several selectable shunts which provide their corresponding current meter ranges. Typically, ammeters can be found with calibrated ranges of 1 micro-A for full scale deflection up to 1000 A for full scale deflection, and in multiples of 10 between these extremes.



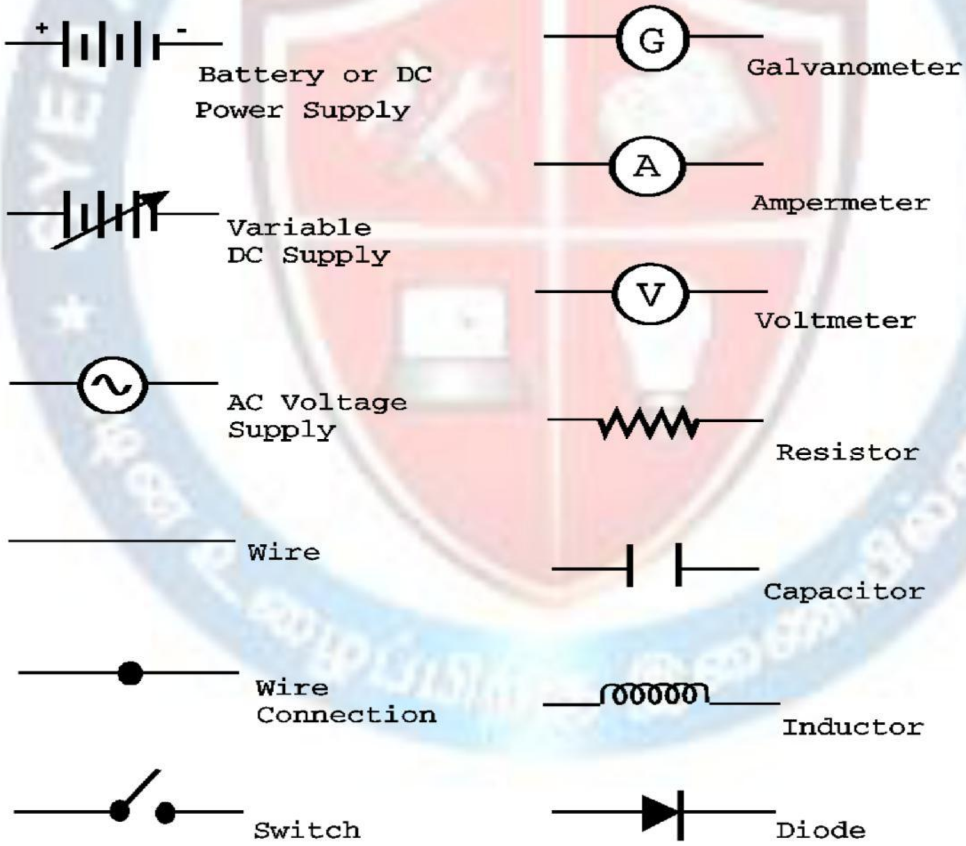
Voltmeter

A voltmeter, shown in Figure 2, is just a calibrated galvanometer with a series resistor so that the total resistance of the path is increased. The galvanometer range is calibrated for the current Ig passing through it. This scale is adjusted to display the potential difference between points A and B, (voltage) by substituting Vg values for Ig on the scale where Vg = Ig Rg and Rg is the total resistance of the voltmeter. Voltmeters may have more than one calibrated scale which can be selected by changing the resistance Rg.

Current in a circuit is the flow of the positive charge from a high potential (+) to a low potential (-). Meters are labeled to indicate the proper direction of current flow through them. A reverse flow of DC current may destroy a meter.

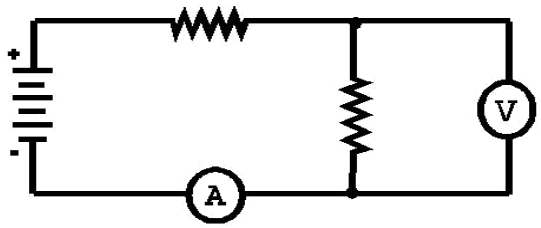
Electrical charge will not move through a conducting path unless there is a potential difference between the ends of the conductors. All materials resist the flow of current through them, requiring work to be done to move the charge through the material. The source of energy in a circuit which provides the energy to move the charge through the circuit can be a battery, photocell, or some other power supply.

An electrical circuit is a circuitous path of wire and devices. A schematic drawing of a real circuit utilizes the symbols shown in Figure 3.



Circuit Symbols

An example, Figure 4, shows a circuit with a DC. power supply in a series with a resistor, a parallel branch with a resistor and voltmeter, and an ammeter.



Example of an Electric Circuit.

BASIC ELECTRIC CIRCUIT

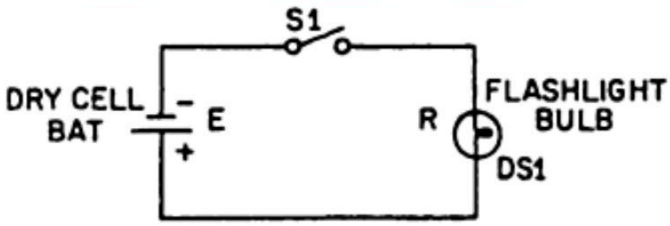
The flashlight is an example of a basic electric circuit. It contains a source of electrical energy (the dry cells in the flashlight), a load (the bulb) that changes the electrical energy into a more useful form of energy (light), and a switch to control the energy delivered to the load.

A load is any device through which an electrical current flows and which changes this electrical energy into a more useful form. The following are common examples of loads: A light bulb (changes electrical energy to light energy).

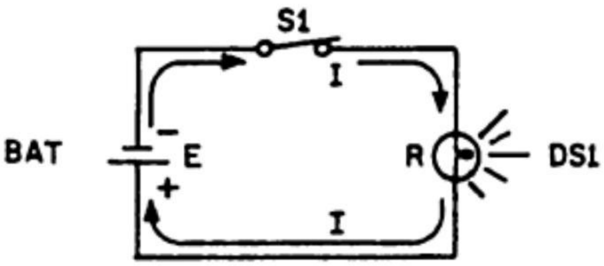
An electric motor (changes electrical energy into mechanical energy).

A speaker in a radio (changes electrical energy into sound).

A source is the device that furnishes the electrical energy used by the load. It may be a simple dry cell (as in a flashlight), a storage battery (as in an automobile), or a power supply (such as a battery charger). A switch permits control of the electrical device by interrupting the current delivered to the load.



(A) DEENERGIZED



(B) ENERGIZED

Schematic of a Basic Circuit, the Flashlight

Laws of Electricity

Ohm‟ s law describes the relationship among potential, resistance and current in a resistive series circuit. In a series circuit, all circuit elements are connected in sequence along a unique path, head to tail, as are the battery and three resistors shown in Figure 2-1. Ohm‟ s Law may be written as:

$$V = IR$$

Where V is the potential difference in volts between two points in a circuit, R is the resistance between the two points in ohms, and I is the resulting current in amperes.

diagrams for determining resistance and voltage in a basic circuit, respectively.

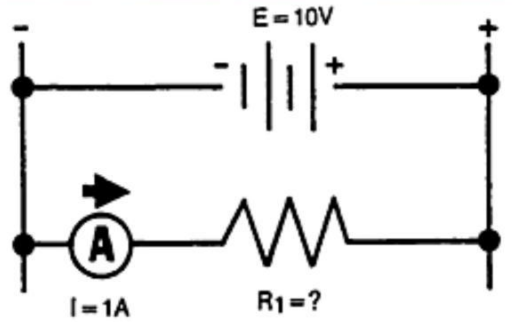


FIGURE 3-2. Determining Resistance in a Basic Circuit.

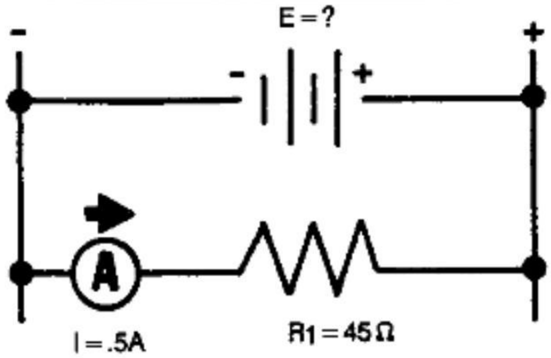


FIGURE 3-3. Determining Voltage in a Basic Circuit.

Using Ohms's Law, the resistance of a circuit can be determined knowing only the voltage and the current in the circuit. In any equation, if all the variables (parameters) are known except one, that unknown can be found. For example, using Ohm's Law, if current (I) and voltage (E) are known, you can determine resistance (R), the only parameter not known:

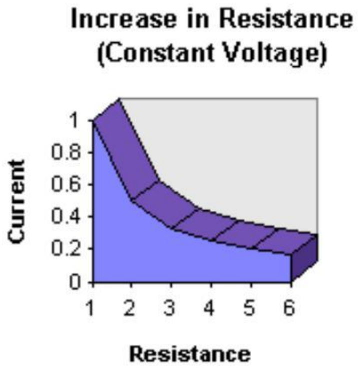
Basic formula: $I = \frac{E}{R}$

The formula may also be expressed as -

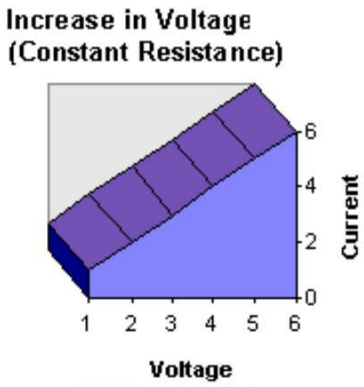
$E = I \times R$ or $R = \frac{E}{I}$

.

Q. A steady increase in resistance, in a circuit with constant voltage, produces a progressively (not a straight-line if graphed) weaker current.



In simpler terms, Ohm‟ s Law means:
R. A steady increase in voltage, in a circuit with constant resistance, produces a constant linear rise in current.



TECHNICAL DEFINITION ALERT!

Ohm's Law is a formulation of the relationship of voltage, current, and resistance, expressed as:

$$V = I \times R$$

$$I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$

Where:

V is the Voltage measured in volts

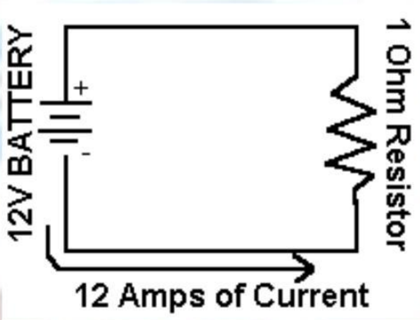
I is the Current measured in amperes

R is the resistance measured in Ohms

Therefore:

Volts = Amps times Resistance

Ohms Law is used to calculate a missing value in a circuit.



In this simple circuit there is a current of 12 amps (12A) and a resistive load of 1 Ohm (1W).

Using the first formula from above we determine the Voltage:

V = 12 x 1 : V = 12 Volts (12V)

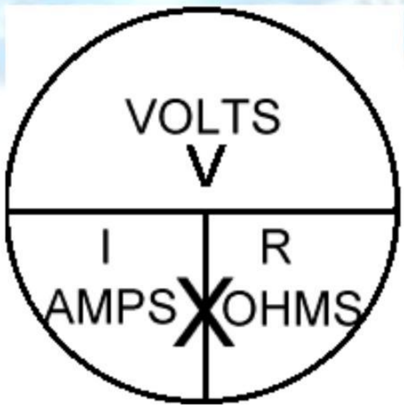
If we knew the battery was suppling 12 volt of pressure (voltage), and there was a resistive load of 1 Ohm placed in series, the current would be:

I = 12 / 1 : I = 12 Amps (12A)

If we knew the battery was suppling 12V and the current being generated was 12A, then the Resistance would be:

R = 12/12 : R = 1W

An easy way to remember the formulas is by using this diagram.



To determine a missing value, cover it with your finger. The horizontal line in the middle means to divide the two remaining values. The "X" in the bottom section of the circle means to multiply the remaining values.

S. If you are calculating voltage, cover it and you have I X R left (V= I times R).

T. If you are calculating amperage, cover it, and you have V divided by R left (I=V/R).

U. If you are calculating resistance, cover it, and you have V divide by I left (R=V/I).

Note: The letter **E** is sometimes used instead of **V** for voltage.

Kirchhoff‟ s Law

Kirchhoff‟ s current law states that the algebraic sum of currents around any point in a circuit is zero. Kirchhoff‟ s voltage law states that the algebraic sum of the voltages around a closed electrical loop is zero.

Kirchhoff's Voltage Law

Kirchhoff's Voltage Law (or Kirchhoff's Loop Rule) is a result of the electrostatic field being conservative. It states that the total voltage around a closed loop must be zero. If this were not the case, then when we travel around a closed loop, the voltages would be indefinite. So

$$\sum V=0$$

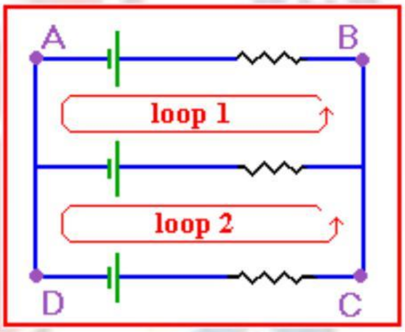


Figure 1 *Around a closed loop, the total voltage should be zero*

In Figure 1 the total voltage around loop 1 should sum to zero, as does the total voltage in loop2. Furthermore, the loop which consists of the outer part of the circuit (the path ABCD) should also sum to zero.

We can adopt the convention that *potential gains* (i.e. going from lower to higher potential, such as with an emf source) is taken to be positive. *Potential losses* (such as across a resistor) will then be negative. However, as long as you are consistent in doing your problems, you should be able to choose whichever convention you like. It is a good idea to adopt the convention used in your class.

Power Law

The power law states that the power in watts dissipated in a resistive element is given by the product of the current in amperes and the potential difference across the resistance in volts:

$$P = IV$$

And substituting Ohm‟ s law gives:

$$P = I^2R = V^2/R$$

Basic Direct Current Circuits

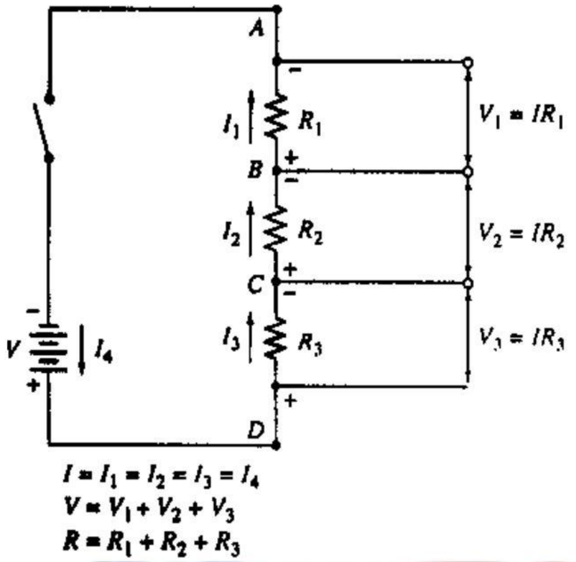
The Schematic Diagram

The schematic diagram consists of *idealized* circuit elements each of which represents some property of the *actual* circuit. The Figure shows some common circuit elements encountered in DC circuits. A two-terminal network is a circuit that has only two points of interest, say *A* and *B*.

Figure: Common circuit elements encountered in DC circuits: a) ideal voltage source, b) ideal current source and c) resistor.

Two types of basic dc circuits will be described; series resistive circuits and parallel resistive circuits.

Series Circuits Figure 2-1 shows a basic series circuit, which consists of a battery, a switch,



and three resistors in series.

Figure 2-1 (Principles of Instrumental Analysis)

The current is the same at all points in a series circuit, that is:

$I = I_1 = I_2 = I_3 = I_4$

Application of Kirchhoff‟ s voltage law to the circuit in Figure 2-1 yields:

$V = V_1 + V_2 + V_3$

The total resistance, R_s, of a series circuit is equal to the sum of the resistances of the individual components.

$R_s = R_1 + R_2 + R_3$

Parallel Circuits

Figure 2-2 shows a parallel dc circuit.

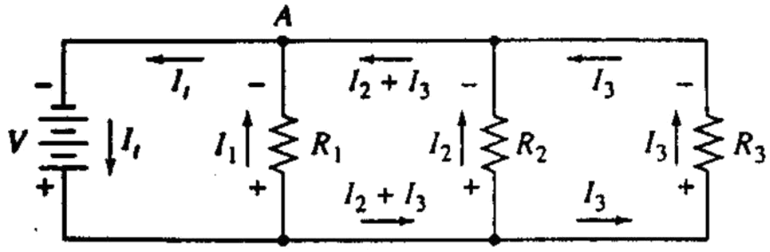


Figure 2-2 (Principles of Instrumental Analysis)

Applying Kirchhoff‟ s current law, we obtain:

$I_t = I_1 + I_2 + I_3$

Applying Kirchhoff‟ s voltage law to this circuit gives three independent equations.

$V. = I_1R_1$

$V = I_2R_2$

$V = I_3R_3$

Substitution and division by V gives:

$1/ R_p = 1/R_1 + 1/R_2 + 1/R_3$

Since the conductance, G, of a resistor, R, is given by G = 1/R:

$G_p = G_1 + G_2 + G_3$

Conductances are additive in a parallel circuit rather than the resistance.

In conclusion, the most important things to remember about the differences between resistors in series and parallel are as follows:

Resistors in series have the same current and

Resistors in parallel have the same voltage.

SEMICONDUCTOR DIODES

Learning objectives are stated at the beginning of each chapter. These learning objectives serve as a preview of the information you are expected to learn in the chapter. The comprehensive check questions are based on the objectives. The learning objectives are listed below.

Upon completion of this chapter, you should be able to do the following:

Ω. State, in terms of energy bands, the differences between a conductor, an insulator, and a semiconductor.

Ξ. Explain the electron and the hole flow theory in semiconductors and how the semiconductor is affected by doping.

Ψ. Define the term "diode" and give a brief description of its construction and operation.

Z. Explain how the diode can be used as a half-wave rectifier and as a switch.

AA. Identify the diode by its symbology, alphanumerical designation, and color code.

BB. List the precautions that must be taken when working with diodes and describe the different ways to test them.

A diode is a nonlinear device that has greater conductance in one direction than in another. Useful diodes are manufactured by forming adjacent n-type and p-type regions within a single germanium or silicon crystal: the interface between these regions is termed a pn junction.

Figure 2-3a is a cross section of one type of pn junction, which is formed by diffusing an excess of a p-type impurity, such as indium, into a minute silicon chip that has been doped with an n-type impurity, such as antimony. A junction of this kind permits movement of holes from the p region into the n region and movement of electrons in the in the reverse direction. As holes and electrons diffuse in the opposite direction, a region is created that is depleted of mobile charge carriers and thus has very high resistance. This region is referred to as the depletion region. Because there is a separation of charge across the depletion region, a potential difference develops across the region that causes a migration of holes and electrons in the opposite direction. The current that results from the diffusion of holes and electrons is balanced by the current produced by migration of the carriers in the electric field, thus there is no net current. The magnitude of potential difference across the depleted region depends upon the composition of the materials used in the pn junction. For silicon diodes, the potential difference is about 0.6V, and for germanium, it is about 0.3V. When a positive potential is applied across a pn junction, there is little resistance to current in the direction of the p-type to the n-type material. On the other hand, the pn junction offers a high resistance to the flow of holes in the opposite direction and is called a current rectifier.

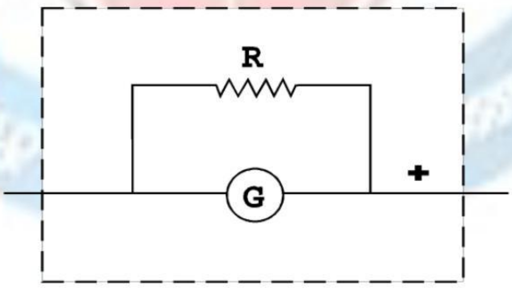
Figure 2-3b illustrates the symbol for a diode. The arrow points in the direction of low resistance to positive current. The triangular portion of the diode symbol may be imagined to point in the direction of current in a conducting diode.

Figure 2-3c shows the mechanism of conduction of charge when the p region is made positive with respect to the n region by application of a potential; this process is called forward biasing. The holes in the p region and the excess electrons in the n region move under the influence of the electric field toward the junction, where they combine and annihilate each other. The negative terminal of the battery injects new electrons into the n region, which can then continue the conduction process; the positive terminal extracts electrons from the p region, creating new holes that are free to migrate towards the pn junction.

Figure 2-3d shows when the diode is reverse-biased and the majority carriers in each region drift away from the junction to form the depletion layer, which contains few charges. Only the small concentration of minority carriers present in each region drifts toward the junction and creates a current.

Ampermeter

An ampermeter (ammeter) is a galvanometer with a calibrated current scale for its indicator and a bypass resistor (called a shunt) for a fixed fraction of the current, shown in Figure 1. Many ammeters have several selectable shunts which provide their corresponding current meter ranges. Typically, ammeters can be found with calibrated ranges of 1 micro-A for full scale deflection up to 1000 A for full scale deflection, and in multiples of 10 between these extremes.



Voltmeter

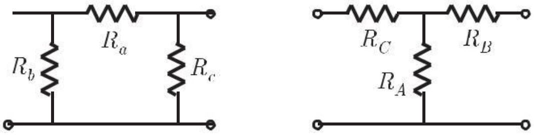
A voltmeter, shown in Figure 2, is just a calibrated galvanometer with a series resistor so that the total resistance of the path is increased. The galvanometer range is calibrated for the current Ig passing through it. This scale is adjusted to display the potential difference between points A and B, (voltage) by substituting Vg values for Ig on the scale where Vg = Ig Rg and Rg is the total resistance of the voltmeter. Voltmeters may have more than one calibrated scale which can be selected by changing the resistance Rg.

Current in a circuit is the flow of the positive charge from a high potential (+) to a low potential (-). Meters are labeled to indicate the proper direction of current flow through them. A reverse flow of DC current may destroy a meter.

Electrical charge will not move through a conducting path unless there is a potential difference between the ends of the conductors. All materials resist the flow of current through them, requiring work to be done to move the charge through the material. The source of energy in a circuit which provides the energy to move the charge through the circuit can be a battery, photocell, or some other power supply.

ELECTRIC CIRCUIT THEORY

Q. 1 Consider a delta connection of resistors and its equivalent star connection as shown below. If all elements of the delta connection are scaled by a factor k, $k > 0$, the elements of the corresponding star equivalent will be scaled by a factor of



(A) k^2 (B) k

(C) $1/k$ (D) $\sqrt{k}$

Q. 2 The flux density at a point in space is given by $\vec{B} = 4x\vec{a}_x + 2ky\vec{a}_y + 8\vec{a}_z$ Wb/m^2. The value of constant k must be equal to

(A) -2 (B) -0.5

(C) +0.5 (D) +2

Q. 3 A single-phase load is supplied by a single-phase voltage source. If the current flowing from the load to the source is $10\angle-150°$ A and if the voltage at the load terminal is $100\angle60°$ V, then the

(A) load absorbs real power and delivers reactive power

(B) load absorbs real power and absorbs reactive power

(C) load delivers real power and delivers reactive power

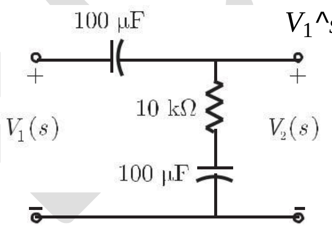
(D) load delivers real power and absorbs reactive power

Q. 4 A source $v_s(t) = V\cos 100\pi t$ has an internal impedance of $(4 + j3)\,\Omega$. If a purely resistive load connected to this source has to extract the maximum power out of the source, its value in Ω should be

(A) 3 (B) 4

(C) 5 (D) 7

Q. 5 The transfer function $\dfrac{V_2(s)}{V_1(s)}$ of the circuit shown below is



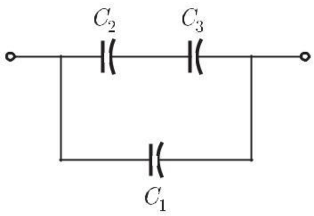
(A) $\dfrac{0.5s + 1}{s + 1}$ (B) $\dfrac{3s + 6}{s + 2}$

(C) $\dfrac{s + 2}{s + 1}$ (D) $\dfrac{s + 1}{s + 2}$

Q. 6 A dielectric slab with 500 mm # 500 mm cross-section is 0.4 m long. The slab is subjected to a uniform electric field of $E = 6a_x + 8a_y$ kV/mm. The relative permittivity of the dielectric material is equal to 2. The value of constant e_0 is 8.85 # 10^{-12} F/m. The energy stored in the dielectric in Joules is

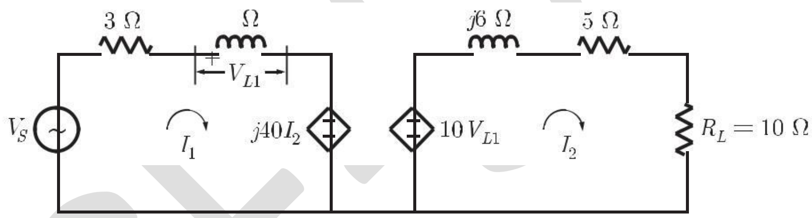
(A) 8.85 # 10^{-11} (B) 8.85 # 10^{-5}
(C) 88.5 (D) 885

Q. 7 Three capacitors C_1, C_2 and C_3 whose values are 10 mF, 5 mF, and 2 mF respectively, have breakdown voltages of 10 V, 5 V and 2 V respectively. For the interconnection shown below, the maximum safe voltage in Volts that can be applied across the combination, and the corresponding total charge in mC stored in the effective capacitance across the terminals are respectively,



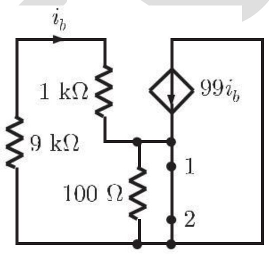
(A) 2.8 and 36 (B) 7 and 119
(C) 2.8 and 32 (D) 7 and 80

Q. 8 In the circuit shown below, if the source voltage V_S = 100+53.13cV then the Thevenin's equivalent voltage in Volts as seen by the load resistance R_L is



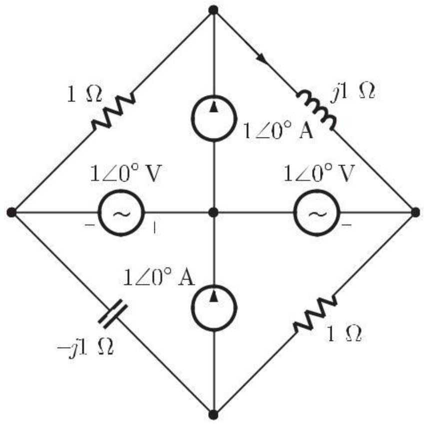
(A) 100+90c (B) 800+0c
(C) 800+90c (D) 100+60c

Q. 9 The impedance looking into nodes 1 and 2 in the given circuit is



(A) 50 W (B) 100 W
(C) 5 kW (D) 10.1 kW

Q. 10 In the circuit shown below, the current through the inductor is



(A) $\frac{2}{1+j}$ A (B) $\frac{-1}{1+j}$ A

(C) $\frac{1}{1+j}$ A (D) 0 A

CC. 11 A system with transfer function $G(s) = \frac{(s^2+9)(s+2)}{(s+1)(s+3)(s+4)}$ is excited by sin(wt). The steady-state output of the system is zero at

(A) w = 1 rad/s (B) w = 2 rad/s

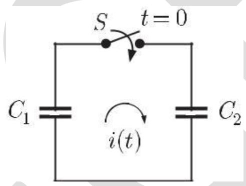
(C) w = 3 rad/s (D) w = 4 rad/s

Q. 12 The average power delivered to an impedance (4 - j3) W by a current 5 cos(100pt + 100) A is

(A) 44.2 W (B) 50 W

(C) 62.5 W (D) 125 W

Q. 13 In the following figure, C_1 and C_2 are ideal capacitors. C_1 has been charged to 12 V before the ideal switch S is closed at $t = 0$. The current $i(t)$ for all t is



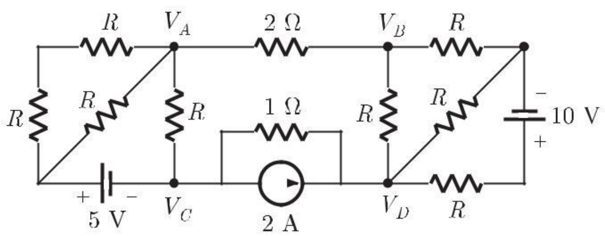
(A) zero

(B) a step function

(C) an exponentially decaying function

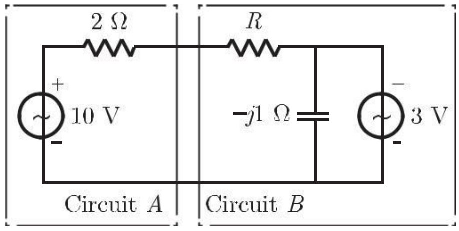
(D) an impulse function

Q. 14 If $V_A - V_B = 6$ V then $V_C - V_D$ is



(A) -5 V (B) 2 V
(C) 3 V (D) 6 V

Q. 15 Assuming both the voltage sources are in phase, the value of R for which maximum power is transferred from circuit A to circuit B is



(A) 0.8 W (B) 1.4 W
(C) 2 W (D) 2.8 W

Common Data for Questions 16 and 17 :

With 10 V dc connected at port A in the linear nonreciprocal two-port network shown below, the following were observed :

(i) 1 W connected at port B draws a current of 3 A

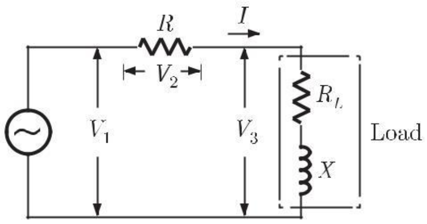
(ii) 2.5 W connected at port B draws a current of 2 A

Q. 16 With 10 V dc connected at port A, the current drawn by 7 W connected at port B is
(A) 3/7 A (B) 5/7 A
(C) 1 A (D) 9/7 A

Q. 17 For the same network, with 6 V dc connected at port A, 1 W connected at port B draws 7/3 A. If 8 V dc is connected to port A, the open circuit voltage at port B is
(A) 6 V (B) 7 V
(C) 8 V (D) 9 V

Statement for Linked Answer Questions 18 and 19 :

In the circuit shown, the three voltmeter readings are V_1 = 220 V, V_2 = 122 V, V_3 = 136 V.



Q. 18 The power factor of the load is

(A) 0.45 (B) 0.50

(C) 0.55 (D) 0.60

Q. 19 If R_L = 5 W, the approximate power consumption in the load is

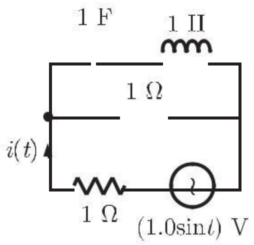
(A) 700 W (B) 750 W

(C) 800 W (D) 850 W

Q. 20 The r.m.s value of the current *i* (*t*) in the circuit shown below is

(A) $\frac{1}{2}$ A (B) $\frac{1}{\sqrt{2}}$ A

(C) 1 A (D) $\sqrt{2}$ A



Q. 21 The voltage applied to a circuit is $100\sqrt{2}$ cos(100p*t*) volts and the circuit draws a current of $10\sqrt{2}$ sin(100p*t* + p/4) amperes. Taking the voltage as the reference phasor, the phasor representation of the current in amperes is

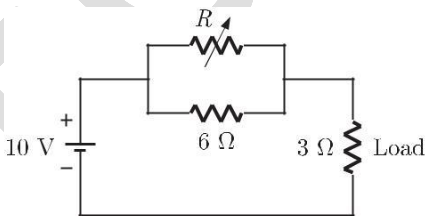
(A) $10\sqrt{2}$ ∠-p/4

(B) 10 -p/4

(C) 10 ∠+p/4

(D) $10\sqrt{2}$ ∠+p/4

Q. 22 In the circuit given below, the value of *R* required for the transfer of maximum power to the load having a resistance of 3 W is



(A) zero

(B) 3 W

(C) 6 W

(D) infinity

Q. 23 A lossy capacitor C_x, rated for operation at 5 kV, 50 Hz is represented by an equivalent circuit with an ideal capacitor C_p in parallel with a resistor R_p. The value C_p is found to be 0.102 μF and value of R_p = 1.25 MΩ. Then the power loss and $\tan\delta$ of the lossy capacitor operating at the rated voltage, respectively, are

(A) 10 W and 0.0002
(B) 10 W and 0.0025
(C) 20 W and 0.025
(D) 20 W and 0.04

Q. 24 A capacitor is made with a polymeric dielectric having an ε_r of 2.26 and a dielectric breakdown strength of 50 kV/cm. The permittivity of free space is 8.85 pF/m. If the rectangular plates of the capacitor have a width of 20 cm and a length of 40 cm, then the maximum electric charge in the capacitor is

(A) 2 μC
(B) 4 μC
(C) 8 μC
(D) 10 μC

Common Data For Q. 25 and 26

The input voltage given to a converter is $v_i = 100\sqrt{2}\sin(100\pi t)$ V

The current drawn by the converter is

$i_i = 10\sqrt{2}\sin(100\pi t - \pi/3) + 5\sqrt{2}\sin(300\pi t + \pi/4) + 2\sqrt{2}\sin(500\pi t - \pi/6)$ A

Q. 25 The input power factor of the converter is

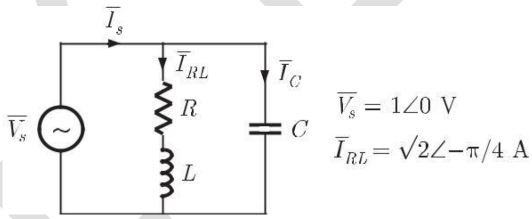
(A) 0.31
(B) 0.44
(C) 0.5
(D) 0.71

Q. 26 The active power drawn by the converter is

(A) 181 W
(B) 500 W
(C) 707 W
(D) 887 W

Common Data For Q. 27 and 28

An RLC circuit with relevant data is given below.



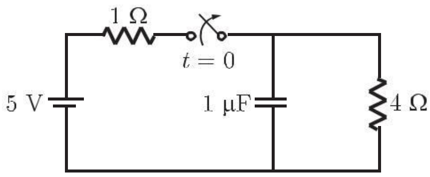
Q. 27 The power dissipated in the resistor R is

(A) 0.5 W
(B) 1 W
(C) $\sqrt{2}$ W
(D) 2 W

Q. 28 The current $\overline{I}_C$ in the figure above is

(A) $-j2$ A
(B) $-j\frac{1}{\sqrt{2}}$ A
(C) $+j\frac{1}{\sqrt{2}}$ A
(D) $+j2$A

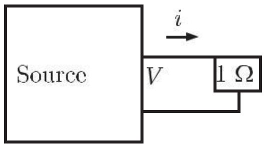
Q. 29 The switch in the circuit has been closed for a long time. It is opened at $t = 0$. At $t = 0^+$, the current through the 1 mF capacitor is



(A) 0 A (B) 1 A

(C) 1.25 A (D) 5 A

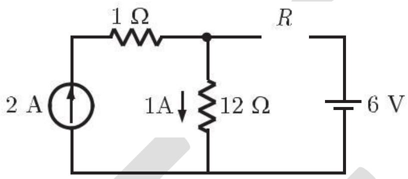
Q. 30 As shown in the figure, a 1 W resistance is connected across a source that has a load line $v + i = 100$. The current through the resistance is



(A) 25 A (B) 50 A

(C) 100 A (C) 200 A

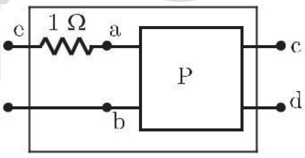
Q. 31 If the 12 W resistor draws a current of 1 A as shown in the figure, the value of resistance R is



(A) 4 W (B) 6 W

(C) 8 W (D) 18 W

Q. 32 The two-port network P shown in the figure has ports 1 and 2, denoted by terminals (a,b) and (c,d) respectively. It has an impedance matrix Z with parameters denoted by Z_{ij}. A 1 W resistor is connected in series with the network at port 1 as shown in the figure. The impedance matrix of the modified two-port network (shown as a dashed box) is



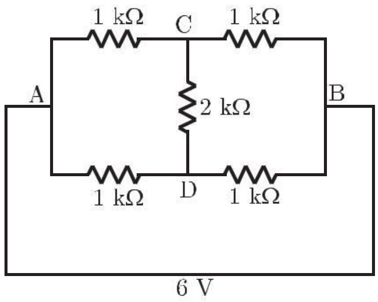
(A) $Z_{11} + 1$ $Z_{12} + 1$ e Z_{21} $Z_{22} + 1$ o $Z_{11} + 1$ Z_{12}

(B) $Z_{11} + 1$ Z_{12} e Z_{21} $Z_{22} + 1$ o $Z_{11} + 1$ Z_{12}

(C) e Z_{21} Z_{22} o

(D) e $Z_{21} + 1$ Z_{22} o

Q. 33 The current through the 2 kW resistance in the circuit shown is

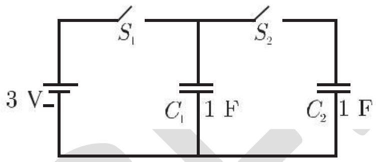


(A) 0 mA (B) 1 mA
(C) 2 mA (D) 6 mA

Q. 34 How many 200 W/220 V incandescent lamps connected in series would consume the same total power as a single 100 W/220 V incandescent lamp ?

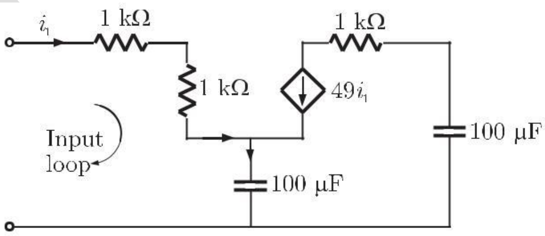
(A) not possible (B) 4
(C) 3 (D) 2

Q. 35 In the figure shown, all elements used are ideal. For time $t < 0$, S_1 remained closed and S_2 open. At $t = 0$, S_1 is opened and S_2 is closed. If the voltage V_{c2} across the capacitor C_2 at $t = 0$ is zero, the voltage across the capacitor combination at $t = 0^+$ will be



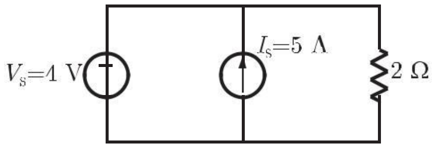
(A) 1 V
(B) 2 V
(C) 1.5 V
(D) 3 V

Q. 36 The equivalent capacitance of the input loop of the circuit shown is



(A) 2 mF (B) 100 mF
(C) 200 mF (D) 4 mF

Q. 37 For the circuit shown, find out the current flowing through the 2 W resistance. Also identify the changes to be made to double the current through the 2 W resistance.



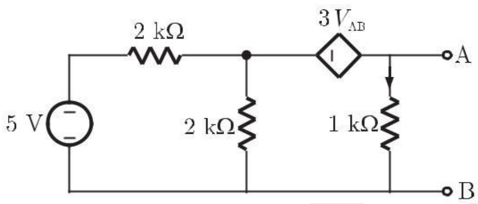
(A) (5 A;PutV_S = 30 V)

(B) (2 A; PutV_S = 8 V)

(C) (5 A; Put I_S = 10 A)

(D) (7 A; Put I_S = 12 A)

Statement for Linked Answer Question 38 and 39 :



Q. 38 For the circuit given above, the Thevenin's resistance across the terminals A and B is

(A) 0.5 kW

(B) 0.2 kW

(C) 1 kW

(D) 0.11 kW

Q. 39 For the circuit given above, the Thevenin's voltage across the terminals A and B is

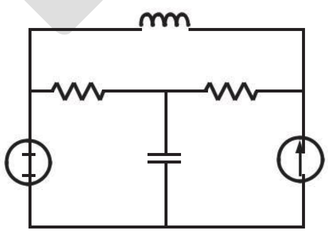
(A) 1.25 V

(B) 0.25 V

(C) 1 V

(D) 0.5 V

Q. 40 The number of chords in the graph of the given circuit will be



(A) 3

(B) 4

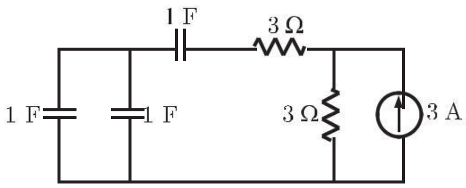
(C) 5

(D) 6

Q. 41 The Thevenin's equivalent of a circuit operation at w = 5 rads/s, has V_{oc} = 3.71+ -15.9% V and Z_0 = 2.38 - j0.667 W. At this frequency, the minimal realization of the Thevenin's impedance will have a

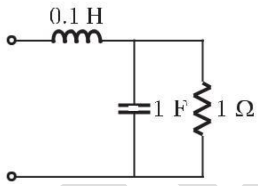
(A) resistor and a capacitor and an inductor
(B) resistor and a capacitor
(C) resistor and an inductor
(D) capacitor and an inductor

Q. 42 The time constant for the given circuit will be



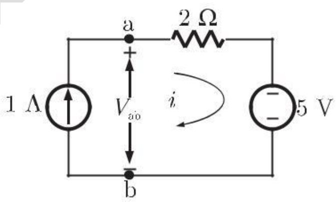
(A) 1/9 s
(B) 1/4 s
(C) 4 s
(D) 9 s

Q. 43 The resonant frequency for the given circuit will be



(A) 1 rad/s
(B) 2 rad/s
(C) 3 rad/s
(D) 4 rad/s

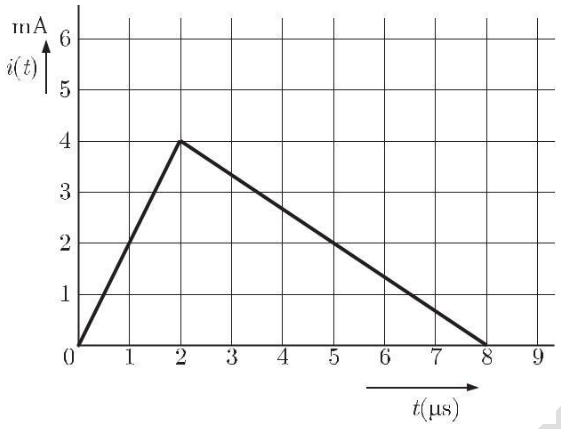
Q. 44 Assuming ideal elements in the circuit shown below, the voltage V_{ab} will be



(A) -3 V
(B) 0 V
(C) 3 V
(D) 5 V

Statement for Linked Answer Question 45 and 46

The current *i* (*t*) sketched in the figure flows through a initially uncharged 0.3 nF capacitor.



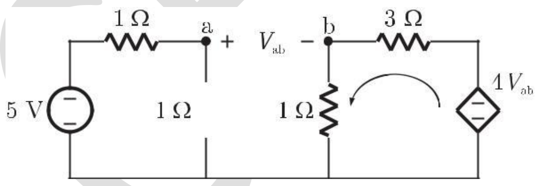
Q. 45 The charge stored in the capacitor at $t = 5$ *m*s, will be

(A) 8 nC
(B) 10 nC
(C) 13 nC
(D) 16 nC

Q. 46 The capacitor charged upto 5 ms, as per the current profile given in the figure, is connected across an inductor of 0.6 mH. Then the value of voltage across the capacitor after 1 *m*s will approximately be

(A) 18.8 V
(B) 23.5 V
(C) -23.5 V
(D) -30.6 V

Q. 47 In the circuit shown in the figure, the value of the current *i* will be given by



(A) 0.31 A
(B) 1.25 A
(C) 1.75 A
(D) 2.5 A

Q. 48 Two point charges $Q_1 = 10$ *m*C and $Q_2 = 20$ mC are placed at coordinates (1,1,0) and (- 1, - 1,0) respectively. The total electric flux passing through a plane $z = 20$ will be

(A) 7.5 *mC*
(B) 13.5 *mC*
(C) 15.0 *mC*
(D) 22.5 *mC*

Q. 49 A capacitor consists of two metal plates each 500 # 500 mm^2 and spaced 6 mm apart. The space between the metal plates is filled with a glass plate of 4 mm thickness and a layer of paper of 2 mm thickness. The relative primitivities of the glass and paper are 8 and 2 respectively. Neglecting the fringing effect, the capacitance will be (Given that $e_0 = 8.85 \# 10^{-12}$ F/m)

(A) 983.3 pF (B) 1475 pF

(C) 637.7 pF (D) 9956.25 pF

Q. 50 A coil of 300 turns is wound on a non-magnetic core having a mean circumference of 300 mm and a cross-sectional area of 300 mm^2. The inductance of the coil corresponding to a magnetizing current of 3 A will be

(Given that $\mu_0 = 4\pi \times 10^{-7}$ H/m)

(A) 37.68 μH (B) 113.04 μH

(C) 3.768 μH (D) 1.1304 μH

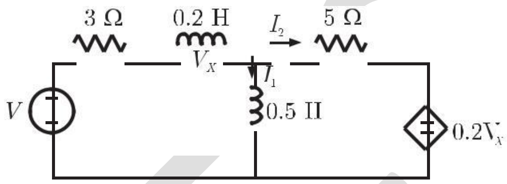
Q. 51 Divergence of the vector field

$V(x, y, z) = -(x\cos xy + y)\hat{i} + (y\cos xy)\hat{j} + (\sin z^2 + x^2 + y^2)\hat{k}$ is

(A) $2z\cos z^2$ (B) $\sin xy + 2z\cos z^2$

(C) $x\sin xy - \cos z$ (D) None of these

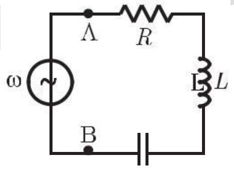
Q. 52 The state equation for the current I_1 in the network shown below in terms of the voltage V_X and the independent source V, is given by



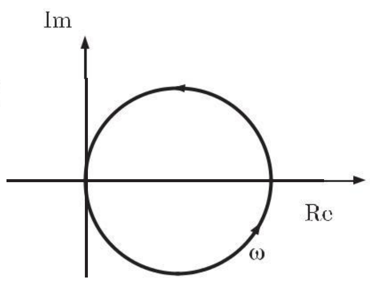
(A) $\frac{dI_1}{dt} = -1.4V_X - 3.75I_1 + \frac{5}{4}V$ (B) $\frac{dI_1}{dt} = 1.4V_X - 3.75I_1 - \frac{5}{4}V$

(C) $\frac{dI_1}{dt} = -1.4V_X + 3.75I_1 + \frac{5}{4}V$ (D) $\frac{dI_1}{dt} = -1.4V_X + 3.75I_1 - \frac{5}{4}V$

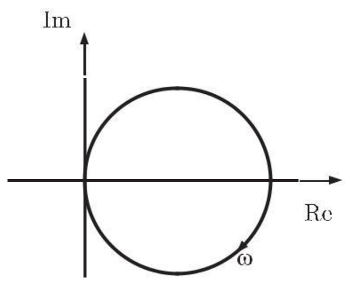
Q. 53 The R-L-C series circuit shown in figure is supplied from a variable frequency voltage source. The admittance - locus of the R-L-C network at terminals AB for increasing frequency ω is



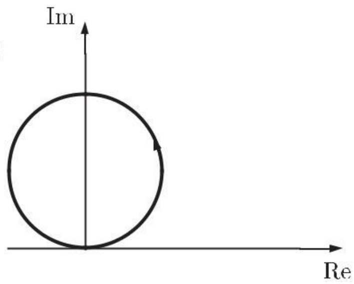
(A)



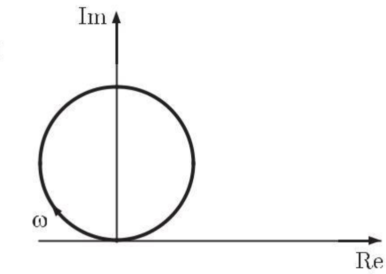
(B)



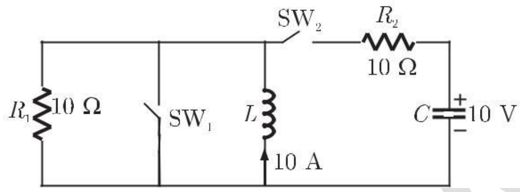
(C)



(D)



Q. 54 In the circuit shown in figure. Switch SW_1 is initially closed and SW_2 is open. The inductor L carries a current of 10 A and the capacitor charged to 10 V with polarities as indicated. SW_2 is closed at $t = 0$ and SW_1 is opened at $t = 0$. The current through C and the voltage across L at $(t = 0^+)$ is



(A) 55 A, 4.5 V

(B) 5.5 A, 45 V

(C) 45 A, 5.5 A

(D) 4.5 A, 55 V

Q. 55 A 3 V DC supply with an internal resistance of 2 W supplies a passive non-linear resistance characterized by the relation $V_{NL} = I_{NL}^2$. The power dissipated in the non linear resistance is

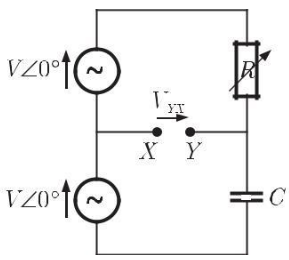
(A) 1.0 W

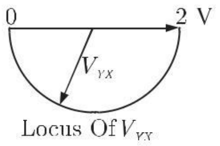
(B) 1.5 W

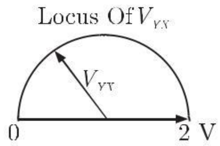
(C) 2.5 W

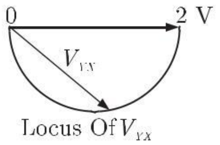
(D) 3.0 W

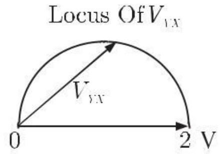
Q. 56 In the figure given below all phasors are with reference to the potential at point "O". The locus of voltage phasor V_{YX} as R is varied from zero to infinity is shown by



(A) 

(B) 

(C) 

(D) 

Q. 57 The matrix A given below in the node incidence matrix of a network. The columns correspond to branches of the network while the rows correspond to nodes. Let $V = [V_1\ V_2\ .....V_6]^T$ denote the vector of branch voltages while $I = [i_1\ i_2\ .....i_6]^T$ that of branch currents. The vector $E = [e_1\ e_2\ e_3\ e_4]^T$ denotes the vector of node voltages relative to a common ground.

$$\begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 1 & 0 \\ -1 & 0 & 0 & 0 & -1 & -1 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{bmatrix}$$

Which of the following statement is true ?

(A) The equations $V_1 - V_2 + V_3 = 0, V_3 + V_4 - V_5 = 0$ are KVL equations for the network for some loops

(B) The equations $V_1 - V_3 - V_6 = 0, V_4 + V_5 - V_6 = 0$ are KVL equations for the network for some loops

(C) $E = AV$

(D) $AV = 0$ are KVI equations for the network

Q. 58 A solid sphere made of insulating material has a radius R and has a total charge Q distributed uniformly in its volume. What is the magnitude of the electric field intensity, E, at a distance r $(0 < r < R)$ inside the sphere ?

(A) $\frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3}$

(B) $\frac{3}{4\pi\varepsilon_0}\frac{Qr}{R^3}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

(D) $\frac{1}{4\pi\varepsilon_0}\frac{QR}{r^3}$

Statement for Linked Answer Question 59 and 60.

An inductor designed with 400 turns coil wound on an iron core of 16 cm^2 cross sectional area and with a cut of an air gap length of 1 mm. The coil is connected to a 230 V, 50 Hz ac supply. Neglect coil resistance, core loss, iron reluctance and leakage inductance, $(\mu_0 = 4\pi \times 10^{-7}$ H/M)

Q. 59 The current in the inductor is

(A) 18.08 A

(B) 9.04 A

(C) 4.56 A

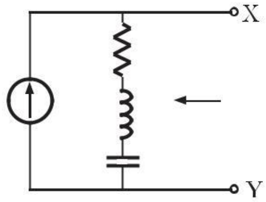
(D) 2.28 A

Q. 60 The average force on the core to reduce the air gap will be

(A) 832.29 N (B) 1666.22 N

(C) 3332.47 N (D) 6664.84 N

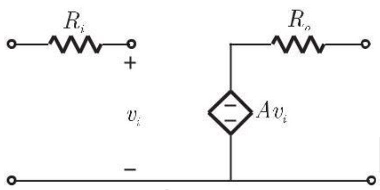
Q. 61 In the figure the current source is 1+0 A, R = 1 W, the impedances are Z_C =- j W and Z_L = 2j W. The Thevenin equivalent looking into the circuit across X-Y is



(A) $\sqrt{2}$ +0 V,(1 + 2j) W (B) 2+45% V,(1 - 2j) W

(C) 2+45% V,(1 + j) W (D) 2+45% V,(1 + j) W

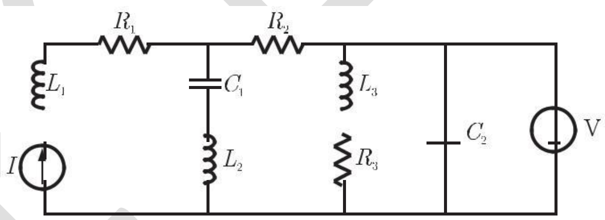
Q. 62 The parameters of the circuit shown in the figure are R_i = 1 MW R_0 = 10 W, A = 10^6 V/V If v_i = 1 mV, the output voltage, input impedance and output impedance respectively are



(A) 1 V,3,10 W (B) 1 V,0,10 W

(C) 1 V, 0, 3 (D) 10 V, 3, 10 W

Q. 63 In the circuit shown in the figure, the current source I = 1 A, the voltage source V = 5 V, $R_1 = R_2 = R_3$ = 1 W, $L_1 = L_2 = L_3$ = 1 H,$C_1 = C_2$ = 1 F

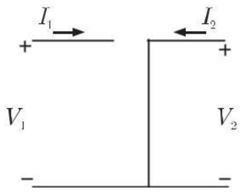


The currents (in A) through R_3 and through the voltage source V respectively will be

(A) 1, 4 (B) 5, 1

(C) 5, 2 (D) 5, 4

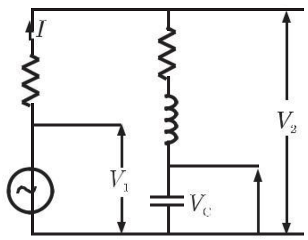
Q. 64 The parameter type and the matrix representation of the relevant two port parameters that describe the circuit shown are



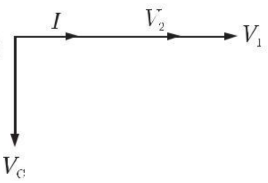
(A) z parameters, $= \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$ (B) h parameters, $= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

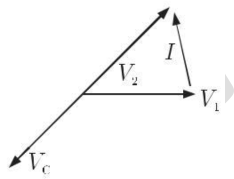
(C) h parameters, $= \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$ (D) z parameters, $= \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

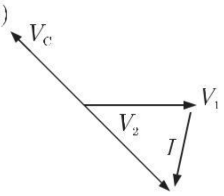
Q. 65 The circuit shown in the figure is energized by a sinusoidal voltage source V_1 at a frequency which causes resonance with a current of I .

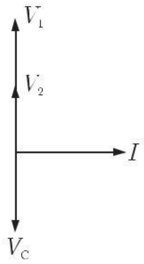


The phasor diagram which is applicable to this circuit is

(A)


(B)


(C)


(D)


Q. 66 An ideal capacitor is charged to a voltage V_0 and connected at $t = 0$ across an ideal inductor L. (The circuit now consists of a capacitor and inductor alone). If we let $w_0 = \frac{1}{\sqrt{LC}}$, the voltage across the capacitor at time $t > 0$ is given by

(A) V_0 (B) $V_0 \cos(w_0 t)$

(C) $V_0 \sin(w_0 t)$ (D) $V_0 e^{-w_0 t} \cos(w_0 t)$

Q. 67 An energy meter connected to an immersion heater (resistive) operating on an AC 230 V, 50 Hz, AC single phase source reads 2.3 units (kWh) in 1 hour. The heater is removed from the supply and now connected to a 400 V peak square wave source of 150 Hz. The power in kW dissipated by the heater will be

(A) 3.478 (B) 1.739

(C) 1.540 (D) 0.870

Q. 68 Which of the following statement holds for the divergence of electric and magnetic flux densities ?

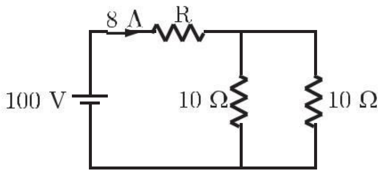
(A) Both are zero

(B) These are zero for static densities but non zero for time varying densities.

(C) It is zero for the electric flux density

(D) It is zero for the magnetic flux density

Q. 69 In the figure given below the value of R is



(A) 2.5 W (B) 5.0 W

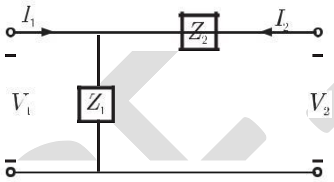
(C) 7.5 W (D) 10.0 W

Q. 70 The RMS value of the voltage $u(t) = 3 + 4\cos(3t)$ is

(A) $\sqrt{17}$ V (B) 5 V

(C) 7 V (D) $(3 + 2\sqrt{2})$ V

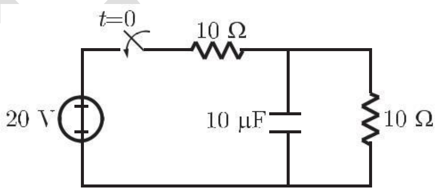
Q. 71 For the two port network shown in the figure the Z-matrix is given by



(A) $\begin{bmatrix} Z_1 & Z_1 + Z_2 \\ Z_1 + Z_2 & Z_2 \end{bmatrix}$ (B) $\begin{bmatrix} Z_1 & Z_1 \\ Z_1 + Z_2 & Z_2 \end{bmatrix}$

(C) $\begin{bmatrix} Z_1 & Z_2 \\ Z_2 & Z_1 + Z_2 \end{bmatrix}$ (D) $\begin{bmatrix} Z_1 & Z_1 \\ Z_1 & Z_1 + Z_2 \end{bmatrix}$

Q. 72 In the figure given, for the initial capacitor voltage is zero. The switch is closed at $t = 0$. The final steady-state voltage across the capacitor is



(A) 20 V (B) 10 V

(C) 5 V (D) 0 V

Q. 73 If $\vec{E}$ is the electric intensity, $\nabla \cdot (\nabla \times \vec{E})$ is equal to

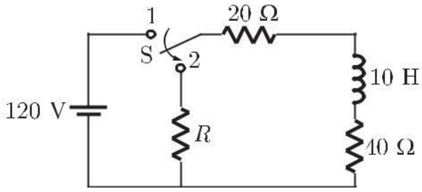
(A) $\vec{E}$ (B) $|\vec{E}|$

(C) null vector (D) Zero

Statement for Linked Answer Question 74 and 75.

A coil of inductance 10 H and resistance 40 W is connected as shown in the figure. After the switch S has been in contact with point 1 for a very long time, it is moved to point 2 at, $t = 0$.

Q. 74 If, at $t = 0^+$, the voltage across the coil is 120 V, the value of resistance R is



(A) 0 W (B) 20 W

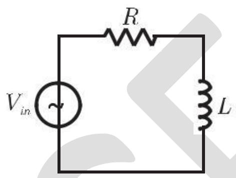
(C) 40 W (D) 60 W

Q. 75 For the value as obtained in (a), the time taken for 95% of the stored energy to be dissipated is close to

(A) 0.10 sec (B) 0.15 sec

(C) 0.50 sec (D) 1.0 sec

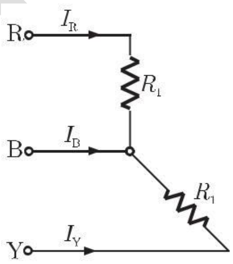
Q. 76 The RL circuit of the figure is fed from a constant magnitude, variable frequency sinusoidal voltage source V_{in} . At 100 Hz, the $R$and L elements each have a voltage drop m_{RMS} .If the frequency of the source is changed to 50 Hz, then new voltage drop across R is



(A) $\sqrt{\frac{5}{8}}u_{RMS}$ (B) $\sqrt{\frac{2}{3}}u_{RMS}$

(C) $\sqrt{\frac{8}{5}}u_{RMS}$ (D) $\sqrt{\frac{3}{2}}u_{RMS}$

Q. 77 For the three-phase circuit shown in the figure the ratio of the currents I_R: I_Y : I_B is given by

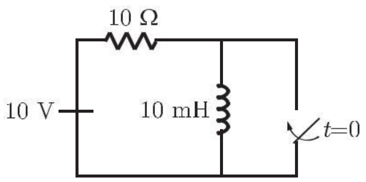


(A) $1 :1 : \sqrt{3}$ (B) $1 :1 : 2$

(C) $1 :1 : 0$ (D) $1 :1 : \sqrt{3/2}$

Q. 78

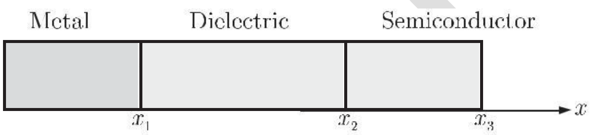
The circuit shown in the figure is in steady state, when the switch is closed at $t = 0$.Assuming that the inductance is ideal, the current through the inductor at $t = 0^{+}$ equals

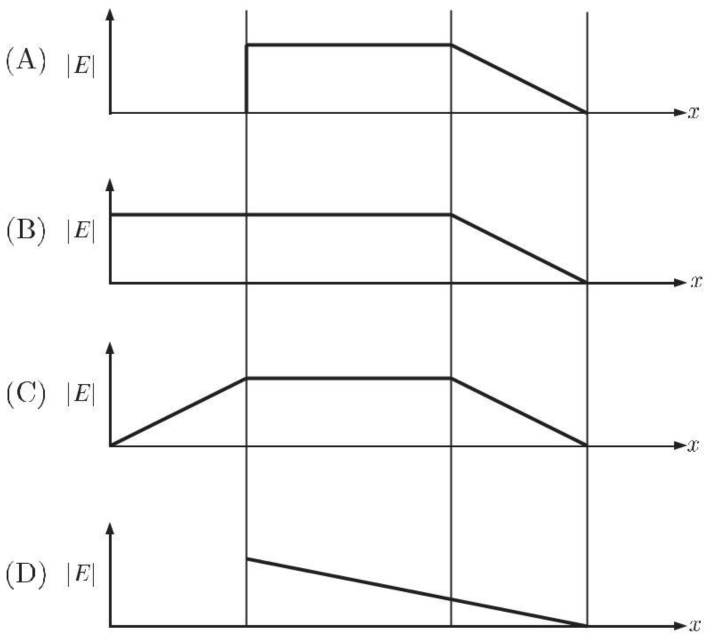


(A) 0 A
(B) 0.5 A
(C) 1 A
(D) 2 A

Q. 79

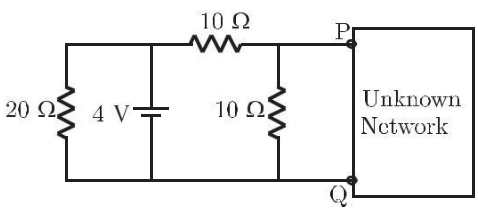
The charge distribution in a metal-dielectric-semiconductor specimen is shown in the figure. The negative charge density decreases linearly in the semiconductor as shown. The electric field distribution is as shown in





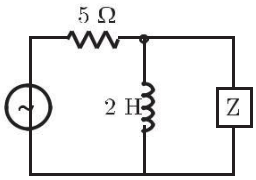
Q. 80

In the given figure, the Thevenin's equivalent pair (voltage, impedance), as seen at the terminals P-Q, is given by



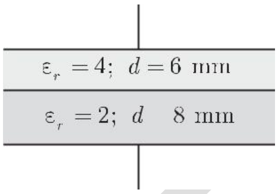
(A) (2 V, 5 W) (B) (2 V, 7.5 W)
(C) (4 V, 5 W) (D) (4 V, 7.5 W)

Q. 81 The value of Z in figure which is most appropriate to cause parallel resonance at 500 Hz is



(A) 125.00 mH (B) 304.20 *m*F
(C) 2.0 *m*F (D) 0.05 *m*F

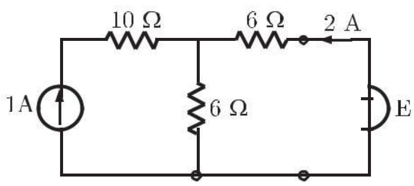
Q. 82 A parallel plate capacitor is shown in figure. It is made two square metal plates of 400 mm side. The 14 mm space between the plates is filled with two layers of dielectrics of e_r = 4, 6 mm thick and e_r = 2, 8 mm thick. Neglecting fringing of fields at the edge the capacitance is



(A) 1298 pF (B) 944 pF
(C) 354 pF (D) 257 pF

Q. 83 The inductance of a long solenoid of length 1000 mm wound uniformly with 3000 turns on a cylindrical paper tube of 60 mm diameter is
(A) 3.2 *m*H (B) 3.2 mH
(C) 32.0 mH (D) 3.2 H

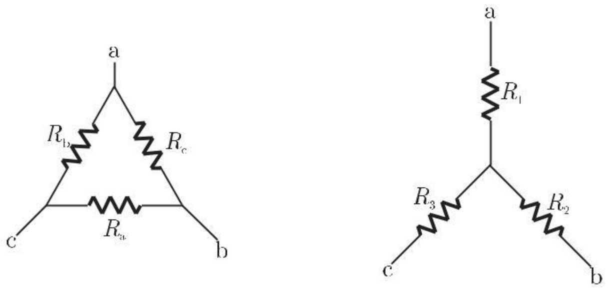
Q. 84 In figure, the value of the source voltage is



(A) 12 V (B) 24 V
(C) 30 V (D) 44 V

Q. 85

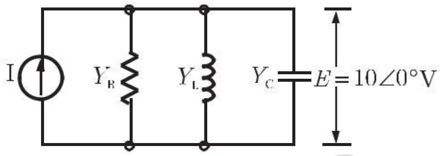
In figure, R_a , R_b and R_c are 20 W, 20 W and 10 W respectively. The resistances R_1 , R_2 and R_3 in W of an equivalent star-connection are



(A) 2.5, 5, 5
(B) 5, 2.5, 5
(C) 5, 5, 2.5
(D) 2.5, 5, 2.5

Q. 86

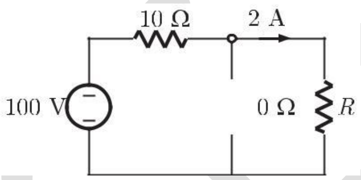
In figure, the admittance values of the elements in Siemens are $Y_R = 0.5 + j0, Y_L = 0 - j1.5, Y_C = 0 + j0.3$ respectively. The value of I as a phasor when the voltage E across the elements is 10+0% V



(A) $1.5 + j0.5$
(B) $5 - j18$
(C) $0.5 + j1.8$
(D) $5 - j12$

Q. 87

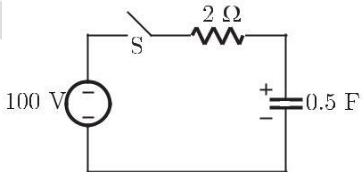
In figure, the value of resistance R in W is



(A) 10
(B) 20
(C) 30
(D) 40

Q. 88

In figure, the capacitor initially has a charge of 10 Coulomb. The current in the circuit one second after the switch S is closed will be



(A) 14.7 A
(B) 18.5 A
(C) 40.0 A
(D) 50.0 A

Q. 89

The rms value of the current in a wire which carries a d.c. current of 10 A and a sinusoidal alternating current of peak value 20 A is

(A) 10 A
(B) 14.14 A
(C) 15 A
(D) 17.32 A

0.9 0.2

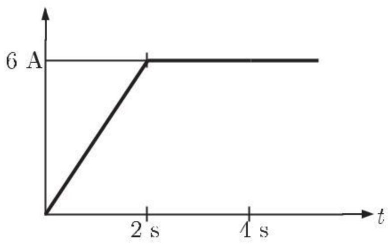
Q. 90 The Z-matrix of a 2-port network as given by =0.2 0.6G

The element Y_{22} of the corresponding Y-matrix of the same network is given by

(A) 1.2 (B) 0.4

(C) -0.4 (D) 1.8

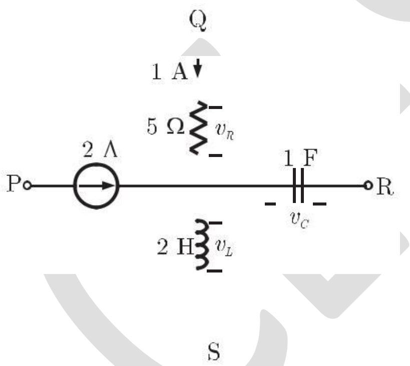
Q. 91 Figure Shows the waveform of the current passing through an inductor of resistance 1 W and inductance 2 H. The energy absorbed by the inductor in the first four seconds is



(A) 144 J (B) 98 J

(C) 132 J (D) 168 J

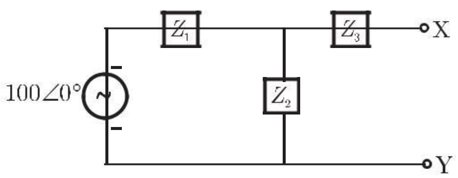
Q. 92 A segment of a circuit is shown in figure $v_R = 5V$, $v_c = 4 \sin 2t$ .The voltage v_L is given by



(A) 3 - 8 cos $2t$ (B) 32 sin $2t$

(C) 16 sin $2t$ (D) 16 cos $2t$

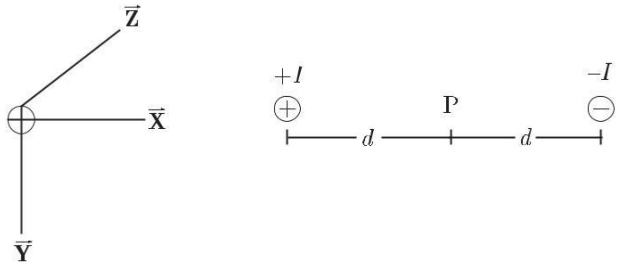
Q. 93 In the figure, Z_1 = 10+ - 60%, Z_2 = 10+ 60%, Z_3 = 50+53.13%.
Thevenin impedance seen form X-Y is



(A) 56.66+45% (B) 60+30%

(C) 70+30% (D) 34.4+65%

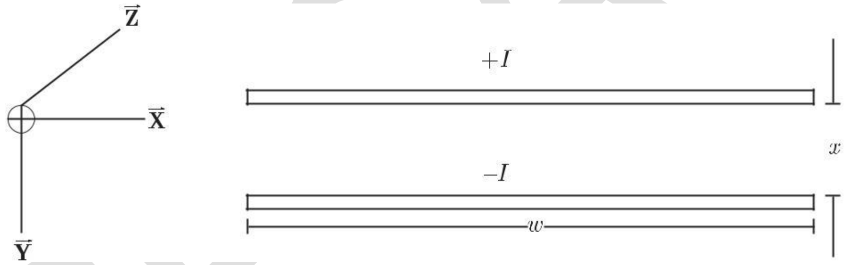
Q. 94 Two conductors are carrying forward and return current of +I and -I as shown in figure. The magnetic field intensity $\vec{\mathbf{H}}$ at point P is



(A) $\frac{I}{pd}$ Y (B) $\frac{I}{pd}$ X

(C) $\frac{I}{2pd}$ Y (D) $\frac{I}{2pd}$ X

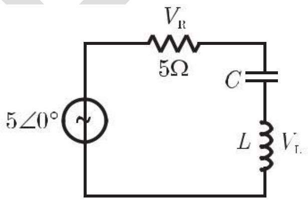
Q. 95 Two infinite strips of width w m in x -direction as shown in figure, are carrying forward and return currents of +I and -I in the z - direction. The strips are separated by distance of x m. The inductance per unit length of the configuration is measured to be L H/m. If the distance of separation between the strips in snow reduced to x/2 m, the inductance per unit length of the configuration is



(A) 2L H/m (B) L/4 H/m

(C) L /2 H/m (D) 4L H/m

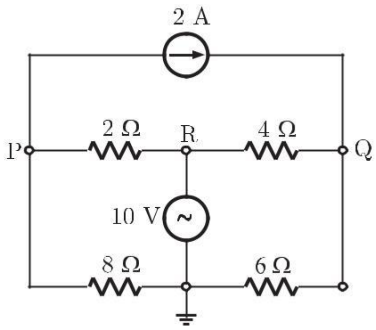
Q. 96 In the circuit of figure, the magnitudes of V_L and V_C are twice that of V_R . Given that f = 50 Hz, the inductance of the coil is



(A) 2.14 mH (B) 5.30 H

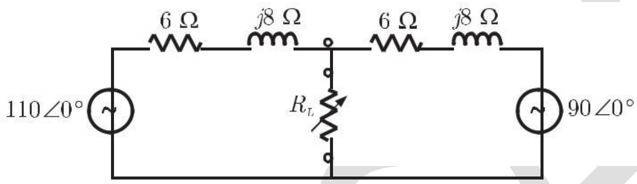
(C) 31.8 mH (D) 1.32 H

Q. 97 In figure, the potential difference between points P and Q is



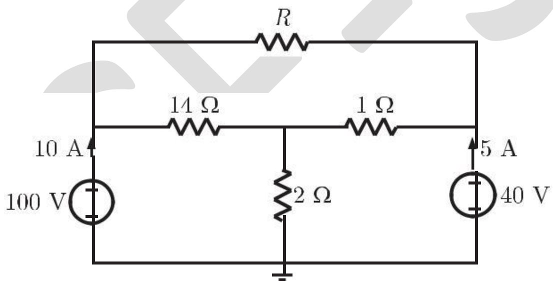
(A) 12 V
(B) 10 V
(C) -6 V
(D) 8 V

Q. 98 Two ac sources feed a common variable resistive load as shown in figure. Under the maximum power transfer condition, the power absorbed by the load resistance R_L is



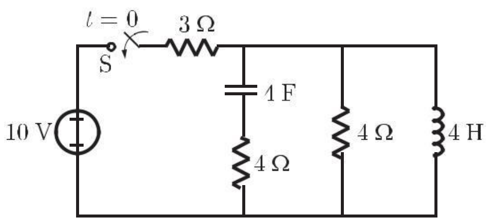
(A) 2200 W
(B) 1250 W
(C) 1000 W
(D) 625 W

Q. 99 In figure, the value of *R* is



(A) 10 W
(B) 18 W
(C) 24 W
(D) 12 W

Q. 100 In the circuit shown in figure, the switch S is closed at time (t = 0). The voltage across the inductance at $t = 0^+$, is

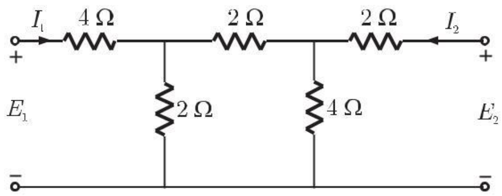


(A) 2 V
(B) 4 V
(C) -6 V
(D) 8 V

Q. 101 The h-parameters for a two-port network are defined by

$$\begin{bmatrix} E_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ E_2 \end{bmatrix}$$

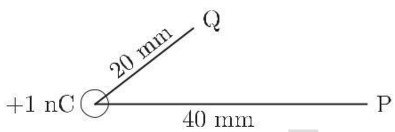
For the two-port network shown in figure, the value of h_{12} is given by



(A) 0.125 (B) 0.167

(C) 0.625 (D) 0.25

Q. 102 A point charge of +I nC is placed in a space with permittivity of 8.85 # 10^{-12} F/m as shown in figure. The potential difference V_{PQ} between two points P and Q at distance of 40 mm and 20 mm respectively fr0m the point charge is



(A) 0.22 kV (B) -225 V

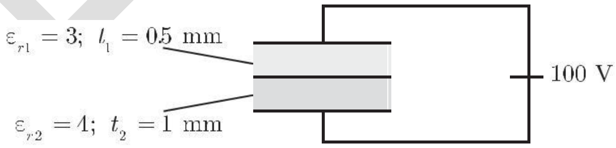
(C) -2.24 kV (D) 15 V

Q. 103 A parallel plate capacitor has an electrode area of 100 mm^2, with spacing of 0.1 mm between the electrodes. The dielectric between the plates is air with a permittivity of 8.85 # 10^{-12} F/m. The charge on the capacitor is 100 V. The stored energy in the capacitor is

(A) 8.85 pJ (B) 440 pJ

(C) 22.1 nJ (D) 44.3 nJ

Q. 104 A composite parallel plate capacitor is made up of two different dielectric material with different thickness (t_1 and t_2) as shown in figure. The two different dielectric materials are separated by a conducting foil F. The voltage of the conducting foil is



(A) 52 V (B) 60 V

(C) 67 V (D) 33 V

SOLUTION

Sol. 1 Option (B) is correct.

In the equivalent star connection, the resistance can be given as

$$R_C = \frac{R_b R_a}{R_a + R_b + R_c}\,;\; R_B = \frac{R_a R_c}{R_a + R_b + R_c} \text{ and } R_A = \frac{R_b R_c}{R_a + R_b + R_c}$$

So, if the delta connection components R_a, R_b and R_c are scaled by a factor k then

$$R_A' = \frac{(k R_b)(k R_c)}{kR_a + kR_b + kR_c} = \frac{k^2}{k}\frac{R_b R_c}{R_a + R_b + R_c} = k R_A$$

Hence, it is also scaled by a factor k

Sol. 2 Option (A) is correct.

Given, flux density

$$\vec{B} = 4x\,\hat{a}_x + 2ky\,\hat{a}_y + 8\,\hat{a}_z$$

Since, magnetic flux density is always divergence less.

i.e., $\nabla \cdot \vec{B} = 0$

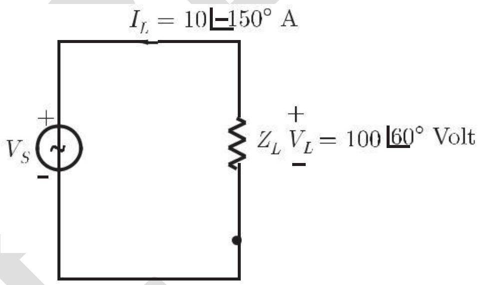
So, for given vector flux density, we have

$$\nabla \cdot \vec{B} = 4 + 2k + 0 = 0$$

or, $k = -2$

Sol. 3 Option (B) is correct.

Consider the voltage source and load shown in figure



We obtain the power delivered by load as

$$P_{delivered} = I_L^* V_L = (10\angle +150^\circ)(10\angle 60^\circ) = 100\angle 210^\circ$$
$$= 1000\cos 210^\circ + j1000\sin 210^\circ$$
$$= -866.025 - j500$$

As both the reactive and average power (real power) are negative so, power is absorbed by load. i.e., load absorbs real as well as reactive power.

Sol. 4 Option (C) is correct.

For the purely resistive load, maximum average power is transferred when

$$R_L = \sqrt{R_{Th}^2 + X_{Th}^2}$$

where $R_{Th} + jX_{Th}$ is the equivalent thevinin (input) impedance of the circuit.

i.e., $R_L = \sqrt{4^2 + 3^2} = 5\ \Omega$

Sol. 5 Option (D) is correct.

For the given capacitance, $C = 100\mu F$ in the circuit, we have the reactance.

$$X_C = \frac{1}{sC} = \frac{1}{s \times 100 \times 10^{-6}} = \frac{10^4}{s}$$

So, $$\frac{V_2(s)}{V_1(s)} = \frac{\frac{10^4}{s} + 10^4}{\frac{10^4}{s} + 10^4 + \frac{10^4}{s}} = \frac{s+1}{s+2}$$

Sol. 6 Option (B) is correct.

Energy density stored in a dielectric medium is obtained as

$$w_E = \frac{1}{2}\varepsilon |E|^2 \quad \text{J/m}^2$$

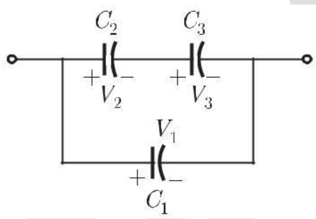
The electric field inside the dielectric will be same to given field in free space only if the field is tangential to the interface

So, $$w_E = \frac{1}{2} 2\varepsilon_0 \left(\sqrt{6^2 + 8^2}\right)^2 \times 10^6 \ /\text{mm}^2$$

Therefore, the total stored energy is

$$W_E = \int_v w_E\, dv = \varepsilon_0\, 100 \times 10^6\ /\text{mm}^2 \times (500 \times 500)\ \text{mm}^2 \times (0.4)$$
$$= \varepsilon_0 \times 100 \times 10^6 \times 0.4 \times 25 \times 10^4$$
$$= 8.85 \times 10^{-12} \times 10^{13} = 88.5\ \text{J}$$

Sol. 7 Option (C) is correct.



Consider that the voltage across the three capacitors C_1, C_2 V_3 and C_3 are V_1, V_2 and respectively. So, we can write

$$\frac{V_2}{V_3} = \frac{C_3}{C_2} \qquad ....(1)$$

Since, Voltage is inversely proportional to capacitance

Now, given that

$$C_1 = 10\ \mu F;\ (V_1)_{max} = 10\text{V}$$
$$C_2 = 5\ \mu F;\ (V_2)_{max} = 5\ \text{V}$$
$$C_3 = 2\ \mu F;\ (V_3)_{max} = 2\text{V}$$

So, from Eq (1) we have

$$\frac{V_2}{V_3} = \frac{2}{5}$$

for $(V_3)_{max} = 2$

We obtain,

$$V_2 = \frac{2 \times 2}{5} = 0.8 \text{ volt} < 5$$

i.e., $V_2 < (V_2)_{max}$

Hence, this is the voltage at C_2. Therefore,

$$V_3 = 2 \text{ volt}$$

$$V_2 = 0.8 \text{ volt}$$

and $$V_1 = V_2 + V_3 = 2.8 \text{ volt}$$

Now, equivalent capacitance across the terminal is

$$C_{eq} = \frac{C_2 C_3}{C_2 + C_3} + C_1 = \frac{5 \times 2}{5+2} + 10 = \frac{80}{7}\ \mu\text{F}$$

Equivalent voltage is (max. value)

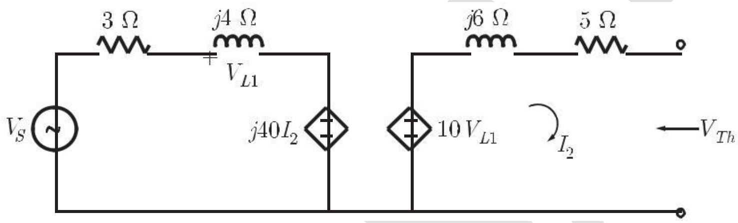
$$V_{\max} = V_1 = 2.8$$

So, charge stored in the effective capacitance is

$$Q = C_{eq} V_{\max} = \left(\frac{80}{7}\right)(2.8) = 32\ \mu\text{C}$$

Sol. 8 Option (C) is correct.

For evaluating the equivalent thevenin voltage seen by the load R_L, we open the circuit across it (also if it consist dependent source).
The equivalent circuit is shown below



As the circuit open across R_L so

$$I_2 = 0$$

or, $$j40I_2 = 0$$

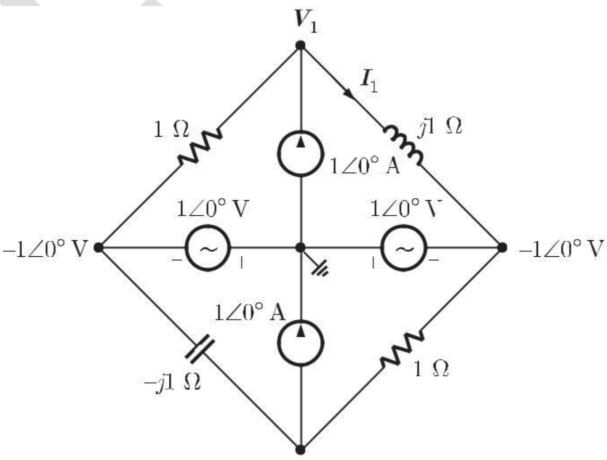
i.e., the dependent source in loop 1 is short circuited. Therefore,

$$V_{L1} = \frac{(j4)V_s}{j4+3}$$

$$V_{Th} = 10V_{L1} = \frac{j40}{j4+3}\, 100\angle 53.13^\circ = \frac{40\angle 90^\circ}{5\angle 53.13^\circ}\, 100\angle 53.13^\circ$$

$$= 800\angle 90^\circ$$

Sol. 9 Option (C) is correct.



Applying nodal analysis at top node.

$$\frac{\boldsymbol{V}_1 + 1\angle 0^\circ}{1} + \frac{\boldsymbol{V}_1 + 1\angle 0^\circ}{j1} = 1\angle 0^\circ$$

$$\boldsymbol{V}_1(j\,1 + 1) + j\,1 + 1\angle 0^\circ = j1$$

$$\boldsymbol{V}_1 = \frac{-1}{1 + j1}$$

Current $$\boldsymbol{I}_1 = \frac{\boldsymbol{V}_1 + 1\angle 0^\circ}{j\,1} = \frac{-\frac{1}{1+j} + 1}{j1} = \frac{j}{(1+j)j} = \frac{1}{1+j}\ \text{A}$$

Sol. 10 Option (C) is correct.

$$G(s) = \frac{(s^2 + 9)(s + 2)}{(s + 1)(s + 3)(s + 4)}$$

$$G(j\omega) = \frac{(-\omega^2 + 9)(j\omega + 2)}{(j\omega + 1)(j\omega + 3)(j\omega + 4)}$$

The steady state output will be zero if

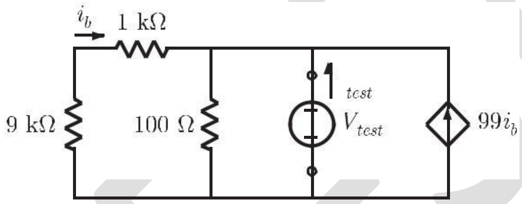
$$|G(j\omega)| = 0$$

$$-\omega^2 + 9 = 0$$

$$\omega = 3 \text{ rad/s}$$

Sol. 11 Option (A) is correct.

We put a test source between terminal 1, 2 to obtain equivalent impedance



$$Z_{Th} = \frac{V_{test}}{I_{test}}$$

Applying KCL at top right node

$$\frac{V_{test}}{9\text{k} + 1\text{k}} + \frac{V_{test}}{100} - 99I_b = I_{test}$$

$$\frac{V_{test}}{10\text{k}} + \frac{V_{test}}{100} - 99I_b = I_{test} \qquad \text{...(i)}$$

But $$I_b = -\frac{V_{test}}{9k + 1k} = -\frac{V_{test}}{10\text{k}}$$

Substituting I_b into equation (i), we have

$$\frac{V_{test}}{10\text{k}} + \frac{V_{test}}{100} + \frac{99V_{test}}{10\text{k}} = I_{test}$$

$$\frac{100V_{test}}{10 \times 10^3} + \frac{V_{test}}{100} = I_{test}$$

$$\frac{2V_{test}}{100} = I_{test}$$

$$Z_{Th} = \frac{V_{test}}{I_{test}} = 50\ \Omega$$

Sol. 12 Option (B) is correct.

In phasor form $$Z = 4 - j3$$

$$Z = 5\angle -36.86^\circ\ \Omega$$

$$\boldsymbol{I} = 5\angle 100^\circ \text{ A}$$

Average power delivered :

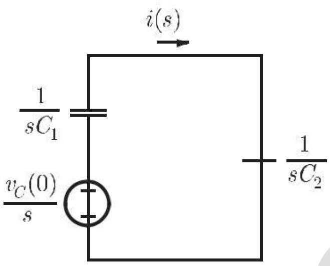
$$P_{avg.} = \frac{1}{2}|\boldsymbol{I}|^2 Z\cos\theta = \frac{1}{2}\times 25\times 5\cos 36.86^\circ = 50 \text{ W}$$

Alternate Method:

$$Z = (4 - j3)\ \Omega$$
$$I = 5\cos(100\pi t + 100)\text{ A}$$
$$P_{avg} = \frac{1}{2}\text{Re}\{|I|^2 Z\} = \frac{1}{2}\times\text{Re}[(5)^2\times(4 - j3)] = \frac{1}{2}\times 100 = 50 \text{ W}$$

Sol. 13 Option (D) is correct.

The s -domain equivalent circuit is shown as below.



$$I(s) = \frac{v_c(0)/s}{\frac{1}{C_1 s} + \frac{1}{C_2 s}} = \frac{v_c(0)}{\frac{1}{C_1} + \frac{1}{C_2}}$$
$$= \left(\frac{C_1 C_2}{C_1 + C_2}\right)(12 \text{ V}) \qquad v_C(0) = 12 \text{ V}$$
$$= 12 C_{eq}$$

Taking inverse Laplace transform for the current in time domain,

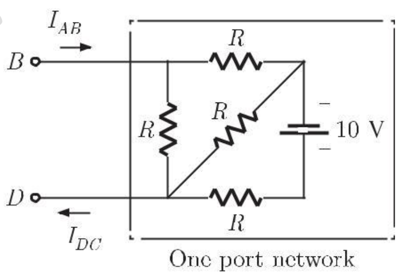
$$i(t) = 12 C_{eq}\,\delta(t) \qquad \text{(Impulse)}$$

Sol. 14 Option (A) is correct.

In the given circuit, $V_A - V_B = 6$ V

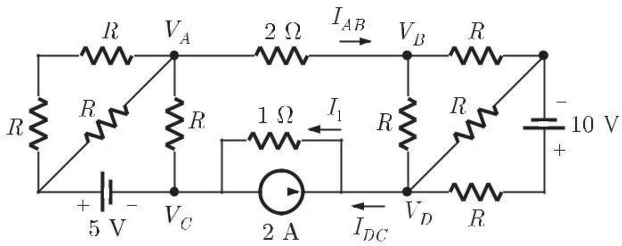
So current in the branch, $I_{AB} = \frac{6}{2} = 3$ A

We can see, that the circuit is a one port circuit looking from terminal BD as shown below



For a one port network current entering one terminal, equals the current leaving the second terminal. Thus the outgoing current from A to B will be equal to the incoming current from D to C as shown

i.e. $I_{DC} = I_{AB} = 3$ A



The total current in the resistor 1 W will be

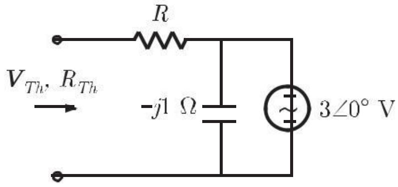
$$I_1 = 2 + I_{DC} \qquad \text{(Writing KCL at node } D\text{)}$$

$$= 2 + 3 = 5 \text{ A}$$

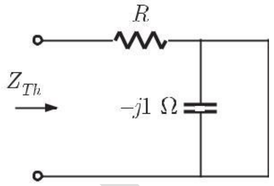
So, $\quad V_{CD} = 1 \times (-I_1) = -5 \text{ V}$

Sol. 15 Option (A) is correct.

We obtain Thevenin equivalent of circuit B.



Thevenin Impedance :

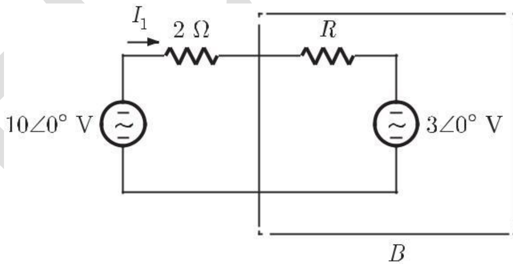


$$Z_{Th} = R$$

Thevenin Voltage :

$$\boldsymbol{V_{Th}} = 3\angle 0^\circ \text{ V}$$

Now, circuit becomes as



Current in the circuit, $\quad I_1 = \frac{10-3}{2+R}$

Power transfer from circuit A to B

$$P = (I_1^2)^2 R + 3I_1$$

$$= \left(\frac{10-3}{2+R}\right)^2 R + 3\left(\frac{10-3}{2+R}\right) = \frac{49R}{(2+R)^2} + \frac{21}{(2+R)}$$

$$= \frac{49R + 21(2+R)}{(2+R)^2} = \frac{42+70R}{(2+R)^2}$$

$$\frac{dP}{dR} = \frac{(2+R)^2\, 70 - (42+70R)2(2+R)}{(2+R)^4} = 0$$

$$(2+R)[(2+R)70 - (42+70R)2] = 0$$

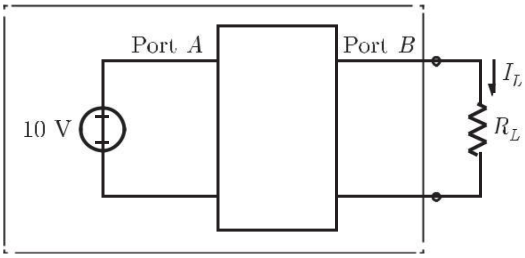
$$140 + 70R - 84 - 140R = 0$$

$$56 = 70R$$

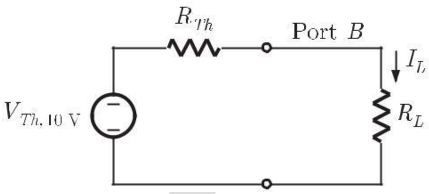
$$R = 0.8\ \text{W}$$

Sol. 16 Option (C) is correct.

When 10 V is connected at port A the network is



Now, we obtain Thevenin equivalent for the circuit seen at load terminal, let Thevenin voltage is $V_{Th,\,10\text{ V}}$ with 10 V applied at port A and Thevenin resistance is R_{Th} .



$$I_L = \frac{V_{Th,10\text{ V}}}{R_{Th} + R_L}$$

For $R_L = 1$ W, $I_L = 3$ A

$$3 = \frac{V_{Th,10\text{ V}}}{R_{Th} + 1} \qquad \text{...(i)}$$

For $R_L = 2.5$ W, $I_L = 2$ A

$$2 = \frac{V_{Th,10\text{ V}}}{R_{Th} + 2.5} \qquad \text{...(ii)}$$

Dividing above two

$$\frac{3}{2} = \frac{R_{Th} + 2.5}{R_{Th} + 1}$$

$$3R_{Th} + 3 = 2R_{Th} + 5$$

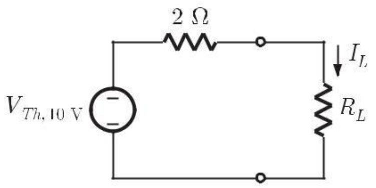
$$R_{Th} = 2\ \text{W}$$

Substituting R_{Th} into equation (i)

$$V_{Th,10\text{ V}} = 3(2+1) = 9\text{ V}$$

Note that it is a non reciprocal two port network. Thevenin voltage seen at port B depends on the voltage connected at port A. Therefore we took subscript $V_{Th,10\text{ V}}$. This is Thevenin voltage only when 10 V source is connected at input port A. If the voltage connected to port A is different, then Thevenin voltage will be different. However, Thevenin's resistance remains same.

Now, the circuit is

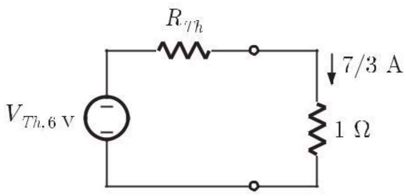


For $R_L = 7\ \Omega$, $\qquad I_L = \frac{V_{Th,10\ V}}{2 + R_L} = \frac{9}{2+7} = 1$ A

Sol. 17 Option (B) is correct.

Now, when 6 V connected at port A let Thevenin voltage seen at port B is $V_{Th,6\ V}$.

Here $R_L = 1\ \Omega$ and $I_L = \frac{7}{3}$ A



$$V_{Th,\,6\ V} = R_{Th} \times \frac{7}{3} + 1 \times \frac{7}{3} = 2 \times \frac{7}{3} + \frac{7}{3} = 7\ \text{V}$$

This is a linear network, so V_{Th} at port B can be written as

$$V_{Th} = V_1\alpha + \beta$$

where V_1 is the input applied at port A.

We have $V_1 = 10$ V, $V_{Th,10\ V} = 9$ V

$$9 = 10\alpha + \beta \qquad \text{...(i)}$$

When $V_1 = 6$ V, $V_{Th,\,6\ V} = 9$ V

$$7 = 6\alpha + \beta \qquad \text{...(ii)}$$

Solving (i) and (ii)

$$\alpha = 0.5,\ \beta = 4$$

Thus, with any voltage V_1 applied at port A, Thevenin voltage or open circuit voltage at port B will be

So, $\qquad V_{Th\,,\,V_1} = 0.5V_1 + 4$

For $\qquad V_1 = 8$ V

$$V_{Th,8\ V} = 0.5 \times 8 + 4 = 8 = V_{oc} \qquad \text{(open circuit voltage)}$$

Sol. 18 Option (A) is correct.

By taking $\boldsymbol{V}_1$, $\boldsymbol{V}_2$ and $\boldsymbol{V}_3$ all are phasor voltages.

$$\boldsymbol{V}_1 = \boldsymbol{V}_2 + \boldsymbol{V}_3$$

Magnitude of $\boldsymbol{V}_1$, $\boldsymbol{V}_2$ and $\boldsymbol{V}_3$ are given as

$$V_1 = 220\ \text{V},\ V_2 = 122\ \text{V},\ V_3 = 136\ \text{V}$$

Since voltage across R is in same phase with $\boldsymbol{V}_1$ and the voltage V_3 has a phase difference of θ with voltage $\boldsymbol{V}_1$, we write in polar form

$$\boldsymbol{V}_1 = V_2 \angle 0° + V_3 \angle \theta$$

$$\boldsymbol{V}_1 = V_2 + V_3 \cos\theta + jV_3 \sin\theta$$

$$\boldsymbol{V}_1 = (V_2 + V_3\cos\theta) + jV_3\sin\theta$$

$$|\boldsymbol{V}_1| = \sqrt{(V_2 + V_3\cos\theta)^2 + (V_2\sin\theta)^2}$$

$$220 = \sqrt{(122 + 136\cos\theta)^2 + (136\sin\theta)^2}$$

Solving, power factor

$$\cos\theta = 0.45$$

Sol. 19 Option (B) is correct.

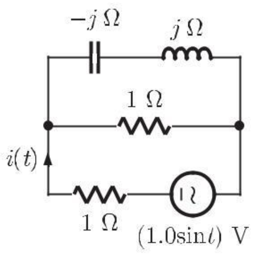
Voltage across load resistance

$$V_{RL} = V_3 \cos\theta = 136 \times 0.45 = 61.2 \text{ V}$$

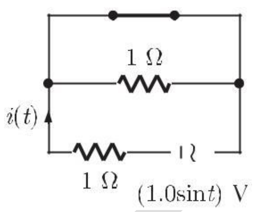
Power absorbed in R_L $\quad P_L = \frac{V_{RL}^2}{R_L} = \frac{(61.2)^2}{5} \approx 750 \text{ W}$

Sol. 20 Option (B) is correct.

The frequency domains equivalent circuit at $\omega = 1$ rad/sec.



Since the capacitor and inductive reactances are equal in magnitude, the net impedance of that branch will become zero. Equivalent circuit



Current $\quad i(t) = \frac{\sin t}{1\,\Omega} = (1 \sin t)$ A

rms value of current $\quad i_{rms} = \frac{1}{\sqrt{2}}$ A

Sol. 21 Option (D) is correct.

Voltage in time domain

$$v(t) = 100\sqrt{2}\cos(100\pi t)$$

Current in time domain

$$i(t) = 10\sqrt{2}\sin(100\pi t + \pi/4)$$

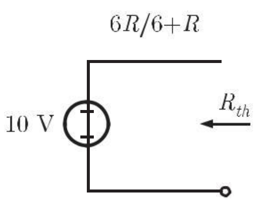
Applying the following trigonometric identity

$$\sin(\phi) = \cos(\phi - 90^\circ)$$

So, $\quad i(t) = 10\sqrt{2}\cos(100\pi t + \pi/4 - \pi/2) = 10\sqrt{2}\cos(100\pi t - \pi/4)$

In phasor form, $\quad \boldsymbol{I} = \frac{10\sqrt{2}}{\sqrt{2}}\angle -\pi/4$

Sol. 22 Option (A) is correct.



Power transferred to the load

$$P = I^2 R_L = \left(\frac{10}{R_{th} + R_L}\right)^2 R_L$$

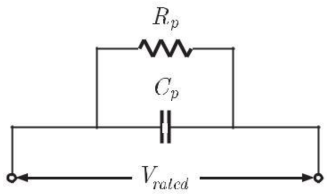
For maximum power transfer R_{th} , should be minimum.

$$R_{th} = \frac{6R}{6+R} = 0$$

$$R = 0$$

Note: Since load resistance is constant so we choose a minimum value of R_{th}

Sol. 23 Option (C) is correct.



$$\text{Power loss} = \frac{V_{rated}^2}{R_p} = \frac{(5 \times 10^3)^2}{1.25 \times 10^6} = 20\ \text{W}$$

For an parallel combination of resistance and capacitor

$$\tan \delta = \frac{1}{\omega C_p R_p} = \frac{1}{2\pi \times 50 \times 1.25 \times 0.102} = \frac{1}{40} = 0.025$$

Sol. 24 Option (C) is correct.

Charge $\quad Q = CV = \frac{\epsilon_0 \epsilon_r A}{d} V = (\epsilon_0 \epsilon_r A) \frac{V}{d} \qquad C = \frac{\epsilon_0 \epsilon_r A}{d}$

$$Q = Q_{\max}$$

We have $\epsilon_0 = 8.85 \times 10^{-14}$ F/cm, $\epsilon_r = 2.26$, $A = 20 \times 40$ cm^2

$$\frac{V}{d} = 50 \times 10^3\ \text{kV/cm}$$

Maximum electrical charge on the capacitor

when $\quad \frac{V}{d} = \left(\frac{V}{d}\right)_{\max} = 50$ kV/cm

Thus, $\quad Q = 8.85 \times 10^{-14} \times 2.26 \times 20 \times 40 \times 50 \times 10^3 = 8\ \mu\text{C}$

Sol. 25 Option (C) is correct.

$$v_i = 100\sqrt{2} \sin(100\pi t)\ \text{V}$$

Fundamental component of current

$$i_{i1} = 10\sqrt{2} \sin(100\pi t - \pi/3)\ \text{A}$$

Input power factor

$$pf = \frac{I_{1(rms)}}{I_{rms}} \cos \phi_1$$

$I_{1(rms)}$ is rms values of fundamental component of current and I_{rms} is the rms value of converter current.

$$pf = \frac{10}{\sqrt{10^2 + 5^2 + 2^2}} \cos \pi/3 = 0.44$$

Sol. 26 Option (B) is correct.

Only the fundamental component of current contributes to the mean ac input power. The power due to the harmonic components of current is zero.

So, $\quad P_{in} = V_{rms} I_{1rms} \cos \phi_1 = 100 \times 10 \cos \pi/3 = 500$ W

Sol. 27 Option (B) is correct.

Power delivered by the source will be equal to power dissipated by the resistor.

$$P = V_s I_s \cos \pi/4 = 1 \times \sqrt{2} \cos \pi/4 = 1 \text{ W}$$

Sol. 28 Option (D) is correct.

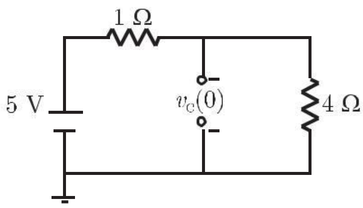
$$\overline{I_C} = \overline{I_s} - \overline{I_{RL}} = \sqrt{2}\angle\pi/4 - \sqrt{2}\angle-\pi/4$$

$$= \sqrt{2}\left[(\cos \pi/4 + j \sin \pi/4) - (\cos \pi/4 - j \sin \pi/4)\right]$$

$$= 2\sqrt{2}\, j \sin \pi/4 = 2j$$

Sol. 29 Option (B) is correct.

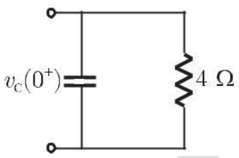
For $t < 0$, the switch was closed for a long time so equivalent circuit is



Voltage across capacitor at $t = 0$

$$v_c(0) = \frac{5}{4+1} \times 4 = 4 \text{ V}$$

Now switch is opened, so equivalent circuit is



For capacitor at $t = 0^+$

$$v_c(0^+) = v_c(0) = 4 \text{ V}$$

current in 4 Ω resistor at $t = 0^+$, $i_1 = \frac{v_c(0^+)}{4} = 1$ A

so current in capacitor at $t = 0^+$, $i_c(0^+) = i_1 = 1$ A

Sol. 30 Option (B) is correct.

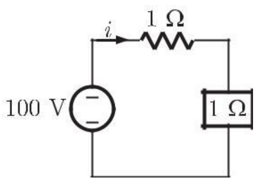
Thevenin equivalent across 1 Ω resistor can be obtain as following

Open circuit voltage $\quad v_{th} = 100 \text{ V} \quad (i = 0)$

Short circuit current $\quad i_{sc} = 100 \text{ A} \quad (v_{th} = 0)$

So, $\quad R_{th} = \frac{v_{th}}{i_{sc}} = \frac{100}{100} = 1\ \Omega$

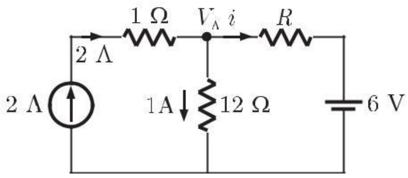
Equivalent circuit is



$$i = \frac{100}{1+1} = 50 \text{ A}$$

Sol. 31 Option (B) is correct.

The circuit is



Current in R Ω resistor is

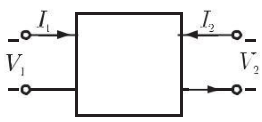
$$i = 2 - 1 = 1\text{ A}$$

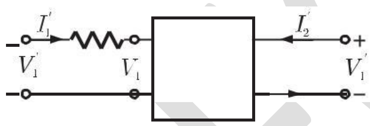
Voltage across 12 Ω resistor is

$$V_A = 1 \times 12 = 12\text{ V}$$

So, $$i = \frac{V_A - 6}{R} = \frac{12 - 6}{1} = 6\ \Omega$$

Sol. 32 Option (C) is correct.





$V_1 = Z_{11} I_1 + Z_{12} I_2$ $\qquad$ $V'_1 = Z'_{11} I'_1 + Z'_{12} I'_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$ $\qquad$ $V'_2 = Z'_{21} I'_1 + Z'_{22} I'_2$

Here, $I_1 = I'_1$, $I_2 = I'_2$

When $R = 1\ \Omega$ is connected

$$V'_1 = V_1 + I'_1 \times 1 = V_1 + I_1$$

$$V'_1 = Z_{11} I_1 + Z_{12} I_2 + I_1$$

$$V'_1 = (Z_{11} + 1) I_1 + Z_{12} I_2$$

So, $$Z'_{11} = Z_{11} + 1$$

$$Z'_{12} = Z_{12}$$

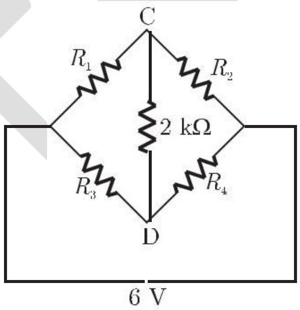
Similarly for output port

$$V'_2 = Z'_{21} I'_1 + Z'_{22} I'_2 = Z'_{21} I_1 + Z'_{22} I_2$$

So, $Z'_{21} = Z_{21}$, $Z'_{22} = Z_{22}$

Z-matrix is $$Z = \begin{bmatrix} Z_{11} + 1 & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

Sol. 33 Option (A) is correct.



In the bridge

$$R_1 R_4 = R_2 R_3 = 1$$

So it is a balanced bridge

$$I = 0\text{ mA}$$

Sol. 34 Option (D) is correct.

Resistance of the bulb rated 200 W/220 V is

$$R_1 = \frac{V^2}{P_1} = \frac{(220)^2}{200} = 242\ \text{W}$$

Resistance of 100 W/220 V lamp is

$$R_T = \frac{V^2}{P_2} = \frac{(220)^2}{100} = 484\ \text{W}$$

To connect in series

$$R_T = n \# R_1$$
$$484 = n \# 242$$
$$n = 2$$

Sol. 35 Option (D) is correct.

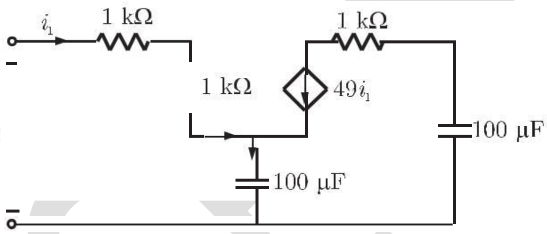
For $t < 0$, S_1 is closed and S_2 is opened so the capacitor C_1 will charged upto 3 volt.

$$V_{C1}(0) = 3\ \text{Volt}$$

Now when switch positions are changed, by applying charge conservation

$$C_{eq} V_{C_1}(0^+) = C_1 V_{C_1}(0^+) + C_2 V_{C_2}(0^+)$$
$$(2+1) \# 3 = 1 \# 3 + 2 \# V_{C_2}(0^+)$$
$$9 = 3 + 2V_{C_2}(0^+)$$
$$V_{C_2}(0^+) = 3\ \text{Volt}$$

Sol. 36 Option (A) is correct.



Applying KVL in the input loop

$$v_1 - i_1(1+1) \# 10^3 - \frac{1}{j\text{W}C}(i_1 + 49i_1) = 0$$

$$v_1 = 2 \# 10^3\, i_1 + \frac{1}{j\text{W}C} 50 i_1$$

Input impedance, $Z_1 = \frac{v_1}{i_1} = 2 \# 10^3 + \frac{1}{j\text{W}(C/50)}$

Equivalent capacitance, $C_{eq} = \frac{C}{50} = \frac{100\ nF}{50} = 2\ nF$

Sol. 37 Option (B) is correct.

Voltage across 2 X resistor, $V_S = 2$ V

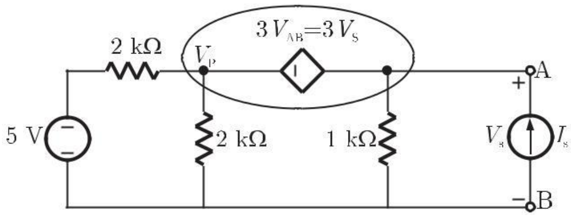
Current, $I_{2\text{W}} = \frac{V_S}{2} = \frac{4}{2} = 2$ A

To make the current double we have to take

$$V_S = 8\ \text{V}$$

Sol. 38 Option (B) is correct.

To obtain equivalent Thevenin circuit, put a test source between terminals AB



Applying KCL at super node

$$\frac{V_P - 5}{2} + \frac{V_P}{2} + \frac{V_S}{1} = I_S$$

$$V_P - 5 + V_P + 2V_S = 2I_S$$

$$2V_P + 2V_S = 2I_s + 5$$

$$V_P + V_S = I_S + 2.5 \qquad ...(1)$$

$$V_P - V_S = 3V_S$$

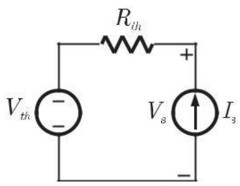
& $$V_P = 4V_S$$

So, $$4V_S + V_S = I_S + 2.5$$

$$5V_S = I_S + 2.5$$

$$V_S = 0.2I_S + 0.5 \qquad ...(2)$$

For Thevenin equivalent circuit



$$V_S = I_S R_{th} + V_{th} \qquad ...(3)$$

By comparing (2) and (3),

Thevenin resistance $R_{th} = 0.2\ \text{k}\Omega$

Sol. 39 Option (D) is correct.

From above $V_{th} = 0.5$ V

Sol. 40 Option (A) is correct.

No. of chords is given as

$$l = b - n + 1$$

$b \rightarrow$ no. of branches

$n \rightarrow$ no. of nodes

$l \rightarrow$ no. of chords

$b = 6$, $n = 4$

$$l = 6 - 4 + 1 = 3$$

Sol. 41 Option (A) is correct.

Impedance $Z_o = 2.38 - j0.667\ \Omega$

Constant term in impedance indicates that there is a resistance in the circuit.

Assume that only a resistance and capacitor are in the circuit, phase difference in Thevenin voltage is given as

$$\theta = -\tan^{-1}(\omega CR) \qquad \text{(Due to capacitor)}$$

$$Z_o = R - \frac{j}{\omega C}$$

So, $\frac{1}{\omega C} = 0.667$

and $R = 2.38\ \Omega$

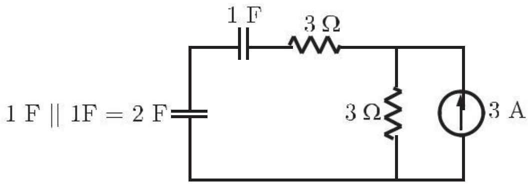
$$\theta = -\tan^{-1}\left(\frac{1\times 2.38}{0.667}\right) = -74.34^\circ \neq -15.9^\circ$$

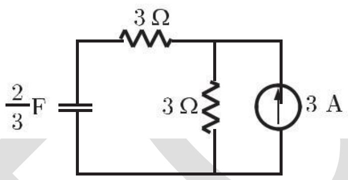
given $V_{oc} = 3.71\angle -15.9^\circ$

So, there is an inductor also connected in the circuit

Sol. 42 Option (C) is correct.

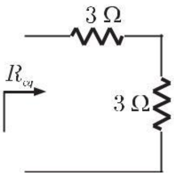
Time constant of the circuit can be calculated by simplifying the circuit as follows





$$C_{eq} = \frac{2}{3}\text{ F}$$

Equivalent Resistance



$$R_{eq} = 3 + 3 = 6\ \Omega$$

Time constant $\tau = R_{eq} C_{eq} = 6 \times \frac{2}{3} = 4$ sec

Sol. 43 Option (C) is correct.

Impedance of the circuit is

$$Z = j\omega L + \frac{\frac{1}{j\omega C}R}{\frac{1}{j\omega C} + R} = j\omega L + \frac{R}{1 + j\omega CR} \times \frac{1 - j\omega CR}{1 - j\omega CR}$$

$$= j\omega L + \frac{R(1 - j\omega CR)}{1 + \omega^2 C^2 R^2} = \frac{j\omega L(1 + \omega^2 C^2 R^2) + R - j\omega CR^2}{1 + \omega^2 C^2 R^2}$$

$$= \frac{R}{1 + \omega^2 C^2 R^2} + \frac{j[\omega L(1 + \omega^2 C^2 R^2) - \omega CR^2]}{1 + \omega^2 C^2 R^2}$$

For resonance $\text{Im}(Z) = 0$

So, $\omega L(1 + \omega^2 C^2 R^2) = \omega CR^2$

$L = 0.1$ H, $C = 1$ F, $R = 1\ \Omega$

So, $\omega \times 0.1[1 + \omega^2 (1)(1)] = \omega(1)(1)^2$

$$1 + \omega^2 = 10$$

& $\omega = \sqrt{9} = 3$ rad/sec

Sol. 44 Option (A) is correct.

Applying KVL in the circuit

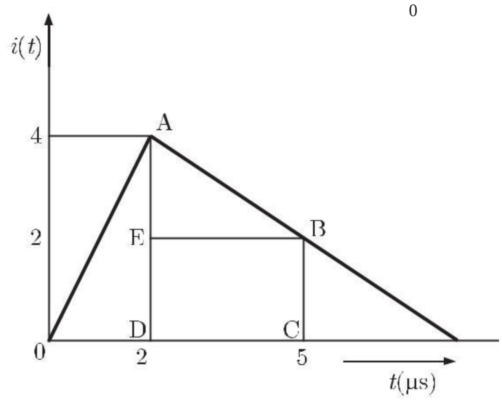
$$V_{ab} - 2i + 5 = 0$$

$i = 1$ A, $V_{ab} = 2 \times 1 - 5 = -3$ Volt

Sol. 45 Option (C) is correct.

Charge stored at $t = 5\ \mu$ sec

$$Q = \int_0^5 i(t)dt = \text{area under the curve}$$



$$\begin{aligned} Q &= \text{Area OABCDO} \\ &= \text{Area (OAD)+Area(AEB)+Area(EBCD)} \\ &= \frac{1}{2} \times 2 \times 4 + \frac{1}{2} \times 2 \times 3 + 3 \times 2 \\ &= 4 + 3 + 6 = 13 \text{ nC} \end{aligned}$$

Sol. 46 Option (D) is correct.

Initial voltage across capacitor

$$V_0 = \frac{Q_o}{C} = \frac{13 \text{ nC}}{0.3 \text{ nF}} = 43.33 \text{ Volt}$$

When capacitor is connected across an inductor it will give sinusoidal esponse as $v_c(t) = V_o \cos \omega_o t$

where $$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.3 \times 10^{-9} \times 0.6 \times 10^{-3}}}$$

$$= 2.35 \times 10^6 \text{ rad/sec}$$

At $t = 1\ \mu$ sec, $$v_c(t) = 43.33 \cos(2.35 \times 10^6 \times 1 \times 10^{-6})$$

$$= 43.33 \times (-0.70) = -30.44 \text{ V}$$

Sol. 47 Option (B) is correct.

Writing node equations at node A and B

$$\frac{V_a - 5}{1} + \frac{V_a - 0}{1} = 0$$

$$2V_a - 5 = 0$$

$$V_a = 2.5 \text{ V}$$

Similarly

$$\frac{V_b - 4V_{ab}}{3} + \frac{V_b - 0}{1} = 0$$

$$\frac{V_b - 4(V_a - V_b)}{3} + V_b = 0$$

$$V_b - 4(2.5 - V_b) + 3V_b = 0$$

$$8V_b - 10 = 0$$

$$V_b = 1.25 \text{ V}$$

Current $$i = \frac{V_b}{1} = 1.25 \text{ A}$$

Sol. 48 Option ( ) is correct.

Sol. 49 Option (B) is correct.

Here two capacitance C_1 and C_2 are connected in series, so equivalent capacitance is

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

$$C_1 = \frac{\varepsilon_0 \varepsilon_{r1} A}{d_1} = \frac{8.85 \times 10^{-12} \times 8 \times 500 \times 500 \times 10^{-6}}{4 \times 10^{-3}}$$

$$= 442.5 \times 10^{-11} \text{ F}$$

$$C_2 = \frac{\varepsilon_0 \varepsilon_{r2} A}{d_2} = \frac{8.85 \times 10^{-12} \times 2 \times 500 \times 500 \times 10^{-6}}{2 \times 10^{-3}}$$

$$= 221.25 \times 10^{-11} \text{ F}$$

$$C_{eq} = \frac{442.5 \times 10^{-11} \times 221.25 \times 10^{-11}}{442.5 \times 10^{-11} + 221.25 \times 10^{-11}} = 147.6 \times 10^{-11}$$

$$\approx 1476 \text{ pF}$$

Sol. 50 Option (B) is correct.

Circumference $l = 300$ mm

no. of turns $n = 300$

Cross sectional area $A = 300 \text{ mm}^2$

Inductance of coil $L = \frac{\mu_0 n^2 A}{l} = \frac{4\pi \times 10^{-7} \times (300)^2 \times 300 \times 10^{-6}}{(300 \times 10^{-3})}$

$= 113.04$ mH

Sol. 51 Option (A) is correct.

Divergence of a vector field is given as

Divergence $= \nabla \cdot V$

In cartesian coordinates

$$\nabla = \frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}$$

So $$\nabla \cdot V = \frac{\partial}{\partial x}\left[-(x\cos xy + y)\right] + \frac{\partial}{\partial y}\left[(y \cos xy)\right] + \frac{\partial}{\partial z}\left[(\sin z^2 + x^2 + y^2)\right]$$

$$= -x(-\sin xy)y + y(-\sin xy)x + 2z\cos z^2 = 2z \cos z^2$$

Sol. 52 Option (A) is correct.

Writing KVL for both the loops

$$V - 3(I_1 + I_2) - V_x - 0.5\frac{dI_1}{dt} = 0$$

$$V - 3I_1 - 3I_2 - V_x - 0.5\frac{dI_1}{dt} = 0 \qquad ...(1)$$

In second loop

$$-5I_2 + 0.2V_x + 0.5\frac{dI_1}{dt} = 0$$

$$I_2 = 0.04V_x + 0.1\frac{dI_1}{dt} \qquad ...(2)$$

Put I_2 from eq(2) into eq(2)

$$V - 3I_1 - 3\left(0.04V_x + 0.1\frac{dI_1}{dt}\right) - V_x - 0.5\frac{dI_1}{dt} = 0$$

$$\frac{dI_1}{dt} = -1.4V_x - 3.75I_1 + \frac{5}{4}V$$

Sol. 53 Option (A) is correct.

Impedance of the given network is

$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

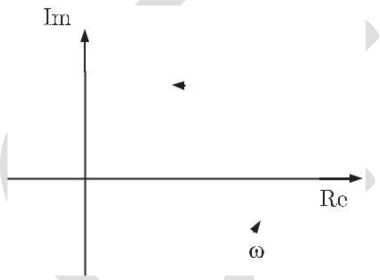
$$\text{Admittance } Y = \frac{1}{Z} = \frac{1}{R + j\left(\omega L - \frac{1}{\omega C}\right)}$$

$$= \frac{1}{R + j\left(\omega L - \frac{1}{\omega C}\right)} \times \frac{R - j\left(\omega L - \frac{1}{\omega C}\right)}{R - j\left(\omega L - \frac{1}{\omega C}\right)} = \frac{R - j\left(\omega L - \frac{1}{\omega C}\right)}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$= \frac{R}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} - \frac{j\left(\omega L - \frac{1}{\omega C}\right)}{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$= \mathrm{Re}(Y) + \mathrm{Im}(Y)$$

Varying frequency for Re(Y) and Im(Y) we can obtain the admittance-locus.



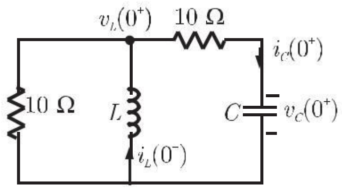
Sol. 54 Option (D) is correct.

At $t = 0^+$, when switch positions are changed inductor current and capacitor voltage does not change simultaneously

So at $t = 0^+$ $\qquad v_c(0^+) = v_c(0^-) = 10$ V

$\qquad i_L(0^+) = i_L(0^-) = 10$ A

The equivalent circuit is



Applying KCL

$$\frac{v_L(0^+)}{10} + \frac{v_L(0^+) - v_c(0^+)}{10} = i_L(0^+) = 10$$

$$2v_L(0^+) - 10 = 100$$

Voltage across inductor at $t = 0^+$

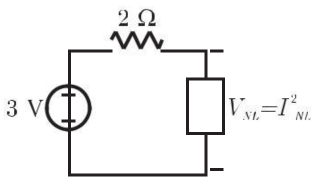
$$v_L(0^+) = \frac{100 + 10}{2} = 55 \text{ V}$$

So, current in capacitor at $t = 0^+$

$$i_C(0^+) = \frac{v_L(0^+) - v_c(0^+)}{10} = \frac{55 - 10}{10} = 4.5 \text{ A}$$

Sol. 55 Option (A) is correct.

The circuit is

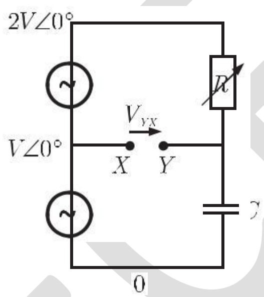


Applying KVL

$$3 - 2 \times I_{NL}^2 = V_{NL}$$
$$3 - 2I_{NL}^2 = I_{NL}^2$$
$$3I_{NL}^2 = 3 \Rightarrow I_{NL} = 1 \text{ A}$$
$$V_{NL} = (1)^2 = 1 \text{ V}$$

Sol. 56 Option (B) is correct.

In the circuit



$$V_X = V\angle 0°$$

$$\frac{V_y - 2V\angle 0°}{R} + (V_y)j\omega C = 0$$

$$V_y(1 + j\omega CR) = 2V\angle 0°$$

$$V_y = \frac{2V\angle 0°}{1 + j\omega CR}$$

$$V_{YX} = V_X - V_Y = V - \frac{2V}{1 + j\omega CR}$$

$R \to 0$, $\quad V_{YX} = V - 2V = -V$

$R \to \infty$, $\quad V_{YX} = V - 0 = V$

So power dissipated in the non-linear resistance

$$P = V_{NL} I_{NL} = 1 \times 1 = 1 \text{ W}$$

Sol. 57 Option (C) is correct.

In node incidence matrix

$$\begin{array}{c} \\ n_1 \\ n_2 \\ n_3 \\ n_4 \end{array}\begin{array}{c} \begin{array}{cccccc} b_1 & b_2 & b_3 & b_4 & b_5 & b_6 \end{array} \\ \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 1 & 0 \\ -1 & 0 & 0 & 0 & -1 & -1 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

In option (C)

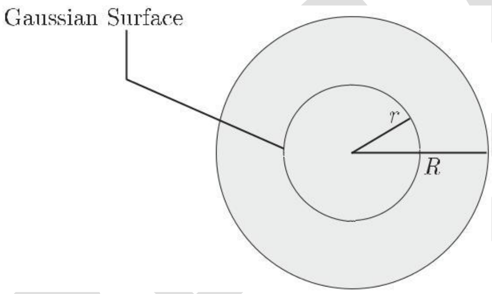
$$E = AV$$

$$\begin{bmatrix} e_1 & e_2 & e_3 & e_4 \end{bmatrix}^T = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 1 & 0 & 1 \end{bmatrix}\begin{bmatrix} V_1 & V_2 & \cdots & V_6 \end{bmatrix}^T$$

$$\begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix} = \begin{bmatrix} V_1 + V_2 + V_3 \\ -V_2 - V_4 + V_5 \\ -V_1 - V_5 - V_6 \\ -V_3 + V_4 + V_6 \end{bmatrix}$$ which is true.

Sol. 58 Option (A) is correct.

Assume a Gaussian surface inside the sphere ($x < R$)



From gauss law

$$\psi = Q_{enclosed}$$

$$= \oint D \cdot ds = Q_{enclosed}$$

$$Q_{enclosed} = \frac{Q}{\frac{4}{3}\pi R^3} \times \frac{4}{3}\pi r^3 = \frac{Qr^3}{R^3}$$

So, $$\oint D \cdot ds = \frac{Qr^3}{R^3}$$

or $$D \times 4\pi r^2 = \frac{Qr^3}{R^3} = \frac{Q}{4\pi\varepsilon_0}\frac{r}{R^3} \qquad \because D = \varepsilon_0 E$$

Sol. 59 Option (D) is correct.

Inductance is given as

$$L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi \times 10^{-7} \times (400)^2 \times (16 \times 10^{-4})}{(1 \times 10^{-3})} = 321.6 \text{ mH}$$

$$V = IX_L = \frac{230}{2\pi f L} \qquad \therefore X_L = 2\pi f L$$

$$= \frac{230}{2 \times 3.14 \times 50 \times 321.6 \times 10^{-3}} = 2.28 \text{ A}$$

Sol. 60 Option (A) is correct.

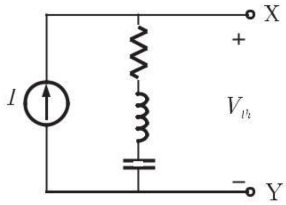
Energy stored is inductor

$$E = \frac{1}{2}LI^2 = \frac{1}{2} \times 321.6 \times 10^{-3} \times (2.28)^2$$

$$F = \frac{E}{l} = \frac{0.835}{1 \times 10^{-3}} = 835 \text{ N}$$

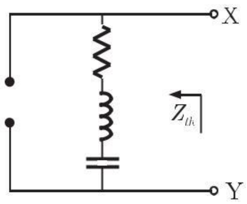
Sol. 61 Option (D) is correct.

Thevenin voltage:



$$V_{th} = I(R + Z_L + Z_C) = 1\angle 0^\circ[1 + 2j - j]$$
$$= 1(1 + j) = \sqrt{2}\angle 45^\circ \text{ V}$$

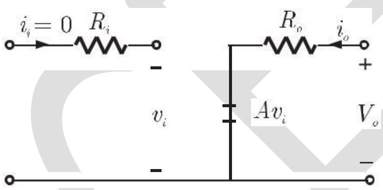
Thevenin impedance:



$$Z_{th} = R + Z_L + Z_C = 1 + 2j - j = (1 + j)\ \Omega$$

Sol. 62 Option (A) is correct.

In the given circuit



Output voltage

$$v_o = Av_i = 10^6 \times 1 \text{ mV} = 1 \text{ V}$$

Input impedance

$$Z_i = \frac{v_i}{i_i} = \frac{v_i}{0} = \infty$$

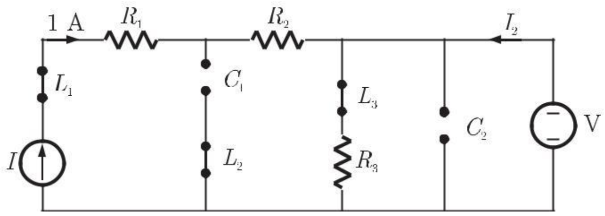
Output impedance

$$Z_o = \frac{v_o}{i_o} = \frac{Av_i}{i_o} = R_o = 10\ \Omega$$

Sol. 63 Option (D) is correct.

All sources present in the circuit are DC sources, so all inductors behaves as short circuit and all capacitors as open circuit

Equivalent circuit is



Voltage across R_3 is

$$5 = I_1 R_3$$
$$5 = I_1(1)$$
$$I_1 = 5 \text{ A} \qquad \text{(current through } R_3\text{)}$$

By applying KCL, current through voltage source

$$1 + I_2 = I_1$$
$$I_2 = 5 - 1 = 4 \text{ A}$$

Sol. 64 Option () is correct.

Given Two port network can be described in terms of h-parametrs only.

Sol. 65 Option (A) is correct.

At resonance reactance of the circuit would be zero and voltage across inductor and capacitor would be equal

$$V_L = V_C$$

At resonance impedance of the circuit

$$Z_R = R_1 + R_2$$

Current $$I_R = \frac{V_1 + 0c}{R_1 + R_2}$$

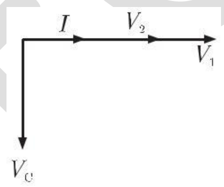
Voltage $$V_2 = I_R R_2 + j(V_L - V_C)$$

$$V_2 = \frac{V_1 + 0c}{R_1 + R_2} R_2$$

Voltage across capacitor

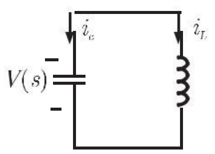
$$V_C = \frac{1}{jwC} \# I_R = \frac{1}{j\,wC} \# \frac{V_R + 0c}{R_1 + R_2} = \frac{V_R + -90c}{wC(R_1 + R_2)}$$

So phasor diagram is



Sol. 66 Option (B) is correct.

This is a second order LC circuit shown below



Capacitor current is given as

$$i_C(t) = C\frac{dv_c(t)}{dt}$$

Taking Laplace transform

$$I_C(s) = CsV(s) - V(0), \quad V(0) \rightarrow \text{initial voltage}$$

Current in inductor

$$i_L(t) = \frac{1}{L}\int v_c(t)dt$$

$$I_L(s) = \frac{1}{L}\frac{V(s)}{s}$$

For $t > 0$, applying KCL(in s-domain)

$$I_C(s) + I_L(s) = 0$$

$$CsV(s) - V(0) + \frac{1}{L}\frac{V(s)}{s} = 0$$

$$\left[s^2 + \frac{1}{LCs}\right]V(s) = V_o$$

$$V(s) = V_o\frac{s}{s^2 + \omega_0^2}, \qquad \because \omega_0^2 = \frac{1}{LC}$$

Taking inverse Laplace transformation

$$v(t) = V_o\cos\omega_o t, \qquad t > 0$$

Sol. 67 Option (B) is correct.

Power dissipated in heater when AC source is connected

$$P = 2.3\text{ kW} = \frac{V_{rms}^2}{R}$$

$$2.3 \times 10^3 = \frac{(230)^2}{R}$$

$$R = 23\,\Omega \text{ (Resistance of heater)}$$

Now it is connected with a square wave source of 400 V peak to peak

Power dissipated is

$$P = \frac{V_{rms}^2}{R}, \qquad V_{p-p} = 400\text{ V} \;\&\; V_p = 200\text{ V}$$

$$= \frac{(200)^2}{23} = 1.739\text{ kW} \qquad V_{rms} = V_p = 200 \text{ (for square wave)}$$

Sol. 68 Option (D) is correct.

From maxwell's first equation

$$\nabla\cdot D = \rho_v$$

$$\nabla\cdot E = \frac{\rho_v}{\varepsilon} \qquad \text{(Divergence of electric field intensity is non-Zero)}$$

Maxwell's fourth equation

$$\nabla\cdot B = 0 \qquad \text{(Divergence of magnetic field intensity is zero)}$$

Sol. 69 Option (C) is correct.

Current in the circuit

$$I = \frac{100}{R + (10 \parallel 10)} = 8\text{ A} \qquad \text{(given)}$$

$$\frac{100}{R + 5} = 8$$

Or $$R = \frac{60}{8} = 7.5\,\Omega$$

Sol. 70 Option (A) is correct.

Rms value is given as

$$m_{rms} = \sqrt{3^2 + \frac{(4)^2}{2}} = \sqrt{9 + 8} = \sqrt{17}\ \text{V}$$

Sol. 71 Option (D) is correct.

Writing KVL in input and output loops

$$V_1 - (i_1 + i_2)Z_1 = 0$$

$$V_1 = Z_1 i_1 + Z_1 i_2 \quad ...(1)$$

Similarly

$$V_2 - i_2 Z_2 - (i_1 + i_2)Z_1 = 0$$

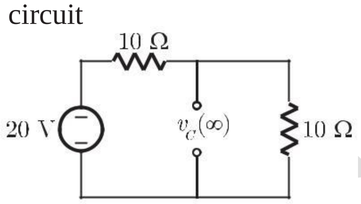
$$V_2 = Z_1 i_1 + (Z_1 + Z_2)i_2 \quad ...(2)$$

From equation (1) and (2) Z -matrix is given as

$$Z = \begin{bmatrix} Z_1 & Z_1 \\ Z_1 & Z_1 + Z_2 \end{bmatrix} \Omega$$

Sol. 72 Option (B) is correct.

In final steady state the capacitor will be completely charged and behaves as an open circuit



Steady state voltage across capacitor

$$v_c(\infty) = \frac{20}{10 + 10}(10) = 10\ \text{V}$$

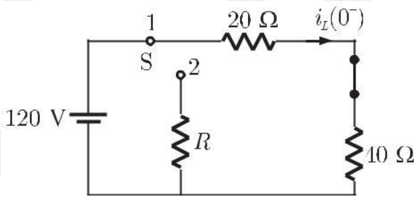
Sol. 73 Option (D) is correct.

We know that divergence of the curl of any vector field is zero

$$\nabla \cdot (\nabla \times \vec{\mathbf{E}}) = 0$$

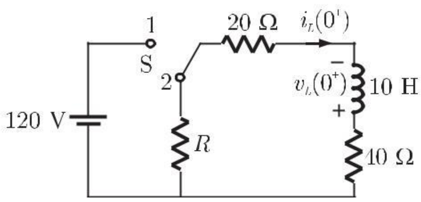
Sol. 74 Option (A) is correct.

When the switch is at position 1, current in inductor is given as



$$i_L(0^-) = \frac{120}{20 + 40} = 2\ \text{A}$$

At $t = 0$, when switch is moved to position 1,inductor current does not change simultaneously so



$$i_L(0^+) = i_L(0^-) = 2\ \text{A}$$

Voltage across inductor at $t = 0^+$

$$v_L(0^+) = 120 \text{ V}$$

By applying KVL in loop

$$120 = 2(40 + R + 20)$$
$$120 = 120 + R$$
$$R = 0\ \Omega$$

Sol. 75 Option (C) is correct.

Let stored energy and dissipated energy are E_1 and E_2 respectively. Then Current

$$\frac{i_2^2}{i_1^2} = \frac{E_2}{E_1} = 0.95$$
$$i_2 = \sqrt{0.95}\, i_1 = 0.97 i_1$$

Current at any time t, when the switch is in position (2) is given by

$$i(t) = i_1 e^{-\frac{R}{L}t} = 2e^{-\frac{60}{10}t} = 2e^{-6t}$$

After 95% of energy dissipated current remaining in the circuit is

$$i = 2 - 2 \times 0.97 = 0.05 \text{ A}$$

So,
$$0.05 = 2e^{-6t}$$
$$t \approx 0.50 \text{ sec}$$

Sol. 76 Option (C) is correct.

At $f_1 = 100$ Hz, voltage drop across R and L is μ_{RMS}

$$\mu_{RMS} = \left|\frac{V_{in} \cdot R}{R + j\omega_1 L}\right| = \left|\frac{V_{in}(j\omega_1 L)}{R + j\omega_1 L}\right|$$

So, $R = \omega_1 L$

At $f_2 = 50$ Hz, voltage drop across R

$$\mu'_{RMS} = \left|\frac{V_{in} \cdot R}{R + j\omega_2 L}\right|$$
$$\frac{\mu_{RMS}}{\mu'_{RMS}} = \left|\frac{R + j\omega_2 L}{R + j\omega_1 L}\right| = \sqrt{\frac{R^2 + \omega_2^2 L^2}{R^2 + \omega_1^2 L^2}}$$
$$= \sqrt{\frac{\omega_1^2 L^2 + \omega_2^2 L^2}{\omega_1^2 L^2 + \omega_1^2 L^2}}, \quad R = \omega_1 L$$
$$= \sqrt{\frac{\omega_1^2 + \omega_2^2}{2\omega_1^2}} = \sqrt{\frac{f_1^2 + f_2^2}{2f_1^2}} = \sqrt{\frac{(100)^2 + (50)^2}{2(100)^2}} = \sqrt{\frac{5}{8}}$$
$$\mu'_{RMS} = \sqrt{\frac{8}{5}}\, \mu_{RMS}$$

Sol. 77 Option (A) is correct.

In the circuit

$$\bar{I}_B = I_R \angle 0^\circ + I_Y \angle 120^\circ$$
$$I_B^2 = I_R^2 + I_Y^2 + 2I_R I_Y \cos\left(\frac{120^\circ}{2}\right) = I_R^2 + I_Y^2 + I_R I_Y$$

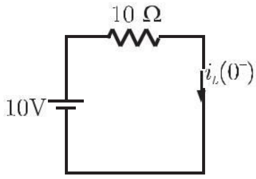
Since $I_R = I_Y$

so, $I_B^2 = I_R^2 + I_R^2 + I_R^2 = 3I_R^2$

$$I_B = \sqrt{3}\, I_R = \sqrt{3}\, I_Y$$
$$I_R : I_Y : I_B = 1 : 1 : \sqrt{3}$$

Sol. 78 Option (C) is correct.

Switch was opened before $t = 0$, so current in inductor for $t < 0$



$$i_L(0^-) = \frac{10}{10} = 1\text{ A}$$

Inductor current does not change simultaneously so at $t = 0$ when switch is closed current remains same

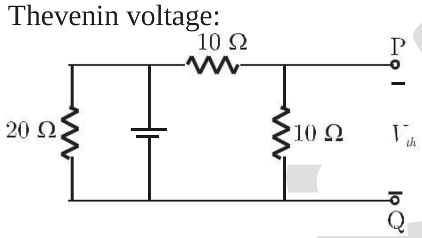
$$i_L(0^+) = i_L(0^-) = 1\text{ A}$$

Sol. 79 Option (A) is correct.

Electric field inside a conductor (metal) is zero. In dielectric charge distribution os constant so electric field remains constant from x_1 to x_2. In semiconductor electric field varies linearly with charge density.

Sol. 80 Option (A) is correct.

Thevenin voltage:

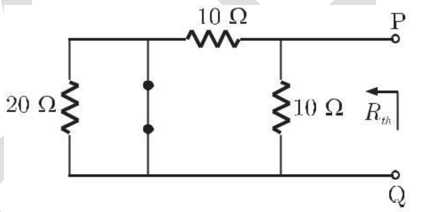


Nodal analysis at P

$$\frac{V_{th} - 4}{10} + \frac{V_{th}}{10} = 0$$

$$V_{th} = 2\text{ V}$$

Thevenin resistance:



$$R_{th} = 10\,\Omega \parallel 10\,\Omega = 5\,\Omega$$

Sol. 81 Option (D) is correct.

Resonance will occur only when Z is capacitive, in parallel resonance condition, suseptance of circuit should be zero.

$$\frac{1}{j\omega L} + j\omega C = 0$$

$$1 - \omega^2 LC = 0$$

$$\omega = \frac{1}{\sqrt{LC}} \quad \text{(resonant frequency)}$$

$$C = \frac{1}{\omega^2 L} = \frac{1}{4 \times \pi^2 \times (500)^2 \times 2} = 0.05\ \mu\text{F}$$

Sol. 82 Option (D) is correct.

Here two capacitor C_1 and C_2 are connected in series so equivalent Capacitance is

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

$$C_1 = \frac{\varepsilon_0 \varepsilon_{r1} A}{d_1} = \frac{8.85 \times 10^{-12} \times 4\,(400 \times 10^{-3})^2}{6 \times 10^{-3}}$$

$$= \frac{8.85 \times 10^{-12} \times 4 \times 16 \times 10^{-2}}{6 \times 10^{-3}} = 94.4 \times 10^{-11}\ \text{F}$$

Similarly

$$C_2 = \frac{\varepsilon_0 \varepsilon_{r2} A}{d_2} = \frac{8.85 \times 10^{-12} \times 2 \times (400 \times 10^{-3})^2}{8 \times 10^{-3}}$$

$$= \frac{8.85 \times 10^{-12} \times 2 \times 16 \times 10^{-12}}{8 \times 10^{-3}} = 35.4 \times 10^{-11}\ \text{F}$$

$$C_{eq} = \frac{94.4 \times 10^{-11} \times 35.4 \times 10^{-11}}{(94.4 + 35.4) \times 10^{-11}} = 25.74 \times 10^{-11} \approx 257\ \text{pF}$$

Sol. 83 Option (C) is correct.

Inductance of the Solenoid is given as

$$L = \frac{\mu_0 N^2 A}{l}$$

Where $A \rightarrow$ are of Solenoid

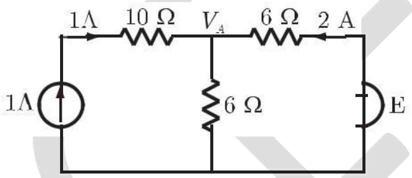
$l \rightarrow$ length

$$L = \frac{4\pi \times 10^{-7} \times (3000)^2 \times \pi_3 (30 \times 10^{-3})^2}{(1000 \times 10\ )} = 31.94 \times 10^{-3}\ \text{H}$$

$\approx$ 32 mH

Sol. 84 Option (C) is correct.

In the circuit



Voltage $V_A = (2 + 1) \times 6 = 18$ Volt

So,

$$2 = \frac{E - V_A}{6}$$

$$2 = \frac{E - 18}{6}$$

$$E = 12 + 18 = 30\ \text{V}$$

Sol. 85 Option (A) is correct.

Delta to star ($\Delta - Y$) conversions is given as

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} = \frac{10 \times 10}{20 + 10 + 10} = 2.5\ \Omega$$

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c} = \frac{20 \times 10}{20 + 10 + 10} = 5\ \Omega$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} = \frac{20 \times 10}{20 + 10 + 10} = 5\ \Omega$$

Sol. 86 Option (D) is correct.

For parallel circuit

$$I = \frac{E}{Z_{eq}} = EY_{eq}$$

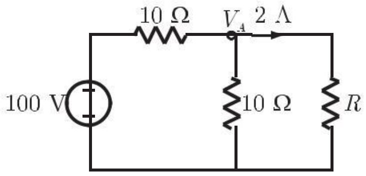
Y_{eq} " Equivalent admittance of the circuit

$$Y_{eq} = Y_R + Y_L + Y_C = (0.5 + j\,0) + (0 - j\,1.5) + (0 + j0.3)$$
$$= 0.5 - j1.2$$

So, current $\quad I = 10(0.5 - j1.2) = (5 - j12)$ A

Sol. 87 Option (B) is correct.

In the circuit



Voltage $\quad V_A = \dfrac{100}{10 + (10 \parallel R)} \times (10 \parallel R) = \dfrac{100}{\left(10 + \dfrac{10R}{10+R}\right)}\left(\dfrac{10R}{10+R}\right)$

$$= \frac{1000R}{100 + 20R} = \frac{50R}{5+R}$$

Current in $R\,\Omega$ resistor

$$2 = \frac{V_A}{R}$$
$$2 = \frac{50R}{R(5+R)}$$

or $\quad R = 20\,\Omega$

Sol. 88 Option (A) is correct.

Since capacitor initially has a charge of 10 coulomb, therefore

$$Q_0 = Cv_c(0) \qquad v_c(0) \text{ " initial voltage across capacitor}$$
$$10 = 0.5v_c(0)$$
$$v_c(0) = \frac{10}{0.5} = 20 \text{ V}$$

When switch S is closed, in steady state capacitor will be charged completely and capacitor voltage is

$$v_c(\infty) = 100 \text{ V}$$

At any time t transient response is

$$v_c(t) = v_c(\infty) + [v_c(0) - v_c(\infty)]e^{-\frac{t}{RC}}$$
$$v_c(t) = 100 + (20 - 100)e^{-\frac{t}{2 \times 0.5}} = 100 - 80e^{-t}$$

Current in the circuit

$$i(t) = C\frac{dv_c}{dt} = C\frac{d}{dt}[100 - 80e^{-t}]$$
$$= C \times 80e^{-t} = 0.5 \times 80e^{-t} = 40e^{-t}$$

At $t = 1$ sec,

$$i(t) = 40e^{-1} = 14.71 \text{ A}$$

Sol. 89 Option (D) is correct.

Total current in the wire

$$I = 10 + 20\sin \omega t$$

$$I_{rms} = \sqrt{10^2 + \frac{(20)^2}{2}} = \sqrt{100 + 200} = \sqrt{300} = 17.32 \text{ A}$$

Sol. 90 Option (D) is correct.

From Z to Y parameter conversion

$$\begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}^{-1}$$

So,
$$\begin{bmatrix} Y_{11} & Y_{12} \\ Y_{12} & Y_{22} \end{bmatrix} = \frac{1}{0.50} \begin{bmatrix} 0.6 & -0.2 \\ -0.2 & 0.9 \end{bmatrix}$$

$$Y_{22} = \frac{0.9}{0.50} = 1.8$$

Sol. 91 Option (C) is correct.

Energy absorbed by the inductor coil is given as

$$E_L = \int_0^t P\,dt$$

Where power
$$P = VI = I\left(L\frac{dI}{dt}\right)$$

So,
$$E_L = \int_0^t LI\left(\frac{dI}{dt}\right)dt$$

For $0 \le t \le 4$ sec

$$E_L = 2\int_0^4 I\left(\frac{dI}{dt}\right)dt$$

$$= 2\int_0^2 I\,(3)dt + 2\int_2^4 I\,(0)dt \qquad \ast\;\frac{dI}{dt} = 3, 0 \le t \le 2, \; = 0, 2 < t < 4$$

$$= 6\int_0^2 I.dt = 6(\text{area under the curve } i(t) - t)$$

$$= 6 \times \frac{1}{2} \times 2 \times 6 = 36 \text{ J}$$

Energy absorbed by 1 Ω resistor is

$$E_R = \int_0^t I^2 R\,dt = \int_0^2 (3t)^2 \times 1\,dt + \int_2^4 (6)^2\,dt \qquad I = 3t, \; 0 \le t \le 2; \; = 6 \text{ A}, \; 2 \le t \le 4$$

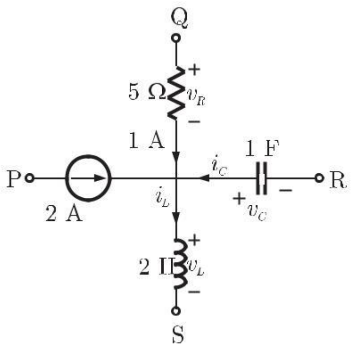
$$= 9 \times \left[\frac{t^3}{3}\right]_0^2 + 36[t]_2^4 = 24 + 72 = 96 \text{ J}$$

Total energy absorbed in 4 sec

$$E = E_L + E_R = 36 + 96 = 132 \text{ J}$$

Sol. 92 Option (B) is correct.

Applying KCL at center node



$$i_L = i_C + 1 + 2$$
$$i_L = i_C + 3$$
$$i_C = -C\frac{dv_c}{dt} = -1\frac{d}{dt}[4\sin 2t]$$
$$= -8\cos 2t$$

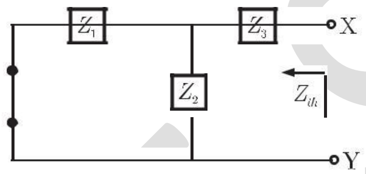
so $\quad i_L = -8\cos 2t + 3 \quad$ (current through inductor)

Voltage across inductor

$$v_L = L\frac{di_L}{dt} = 2\times\frac{d}{dt}[3 - 8\cos 2t] = 32\sin 2t$$

Sol. 93 Option (A) is correct.

Thevenin impedance can be obtain as following



$$Z_{th} = Z_3 + (Z_1 \| Z_2)$$

Given that $\quad Z_1 = 10\angle -60° = 10\left(\frac{1-\sqrt{3}j}{2}\right) = 5(1-\sqrt{3}j)$

$$Z_2 = 10\angle 60° = 10\left(\frac{1+\sqrt{3}j}{2}\right) = 5(1+\sqrt{3}j)$$

$$Z_3 = 50\angle 53.13° = 50\left(\frac{3+4j}{5}\right) = 10(3+4j)$$

So, $\quad Z_{th} = 10(3+4j) + \frac{5(1-\sqrt{3}j)\,5(1+\sqrt{3}j)}{5(1-\sqrt{3}j)+5(1+\sqrt{3}j)}$

$$= 10(3+4j) + \frac{25(1+3)}{10} = 30 + 40j + 10$$

$= 40 + 40j$

$$Z_{th} = 40\sqrt{2}\angle 45°\ \Omega$$

Sol. 94 Option (A) is correct.

Due to the first conductor carrying $+I$ current, magnetic field intensity at point P is

$$\vec{H}_1 = \frac{I}{2\pi d}\vec{Y} \quad \text{(Direction is determined using right hand rule)}$$

Similarly due to second conductor carrying $-I$ current, magnetic field intensity is $\vec{H}_2 =$

$$\frac{I}{2\pi d}(-\vec{Y}) = \frac{I}{2\pi d}\vec{Y}$$

Total magnetic field intensity at point P.

$$\mathbf{H} = \vec{H}_1 + \vec{H}_2 = \frac{I}{2\pi d}\,\mathrm{Y} + \frac{I}{2\pi d}\,\mathrm{Y} = \frac{I}{\pi d}\,\mathrm{Y}$$

Sol. 95 Option ( ) is correct.

Sol. 96 Option (C) is correct.

Given that magnitudes of V_L and V_C are twice of V_R

$$|V_L| = |V_C| = 2V_R \quad \text{(Circuit is at resonance)}$$

Voltage across inductor

$$V_L = i_R \times j\omega L$$

Current i_R at resonance

$$i_R = \frac{5\angle 0^\circ}{R} = \frac{5}{5} = 1\text{ A}$$

so, $$|V_L| = \omega L = 2V_R$$

$$\omega L = 2 \times 5 \qquad V_R = 5\text{ V, at resonance}$$

$$2 \times \pi \times 50 \times L = 10$$

$$L = \frac{10}{314} = 31.8\text{ mH}$$

Sol. 97 Option (C) is correct.

Applying nodal analysis in the circuit

At node P

$$2 + \frac{V_P - 10}{2} + \frac{V_P}{8} = 0$$

$$16 + 4V_P - 40 + V_P = 0$$

$$5V_P - 24 = 0$$

$$V_P = \frac{24}{5}\text{ Volt}$$

At node Q

$$2 = \frac{V_Q - 10}{4} + \frac{V_Q - 0}{6}$$

$$24 = 3V_Q - 30 + 2V_Q$$

$$5V_Q - 54 = 0$$

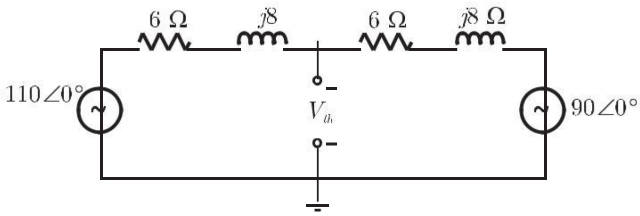
$$V_Q = \frac{54}{5}\text{ V}$$

Potential difference between P-Q

$$V_{PQ} = V_P - V_Q = \frac{24}{5} - \frac{54}{5} = -6\text{ V}$$

Sol. 98 Option (D) is correct.

First obtain equivalent Thevenin circuit across load R_L



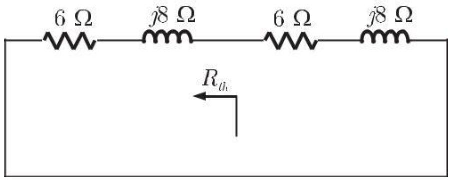
Thevenin voltage

$$\frac{V_{th} - 110\angle 0^\circ}{6 + 8j} + \frac{V_{th} - 90\angle 0^\circ}{6 + 8j} = 0$$

$$2V_{th} - 200\angle 0^\circ = 0$$

$$V_{th} = 100\angle 0^\circ \text{ V}$$

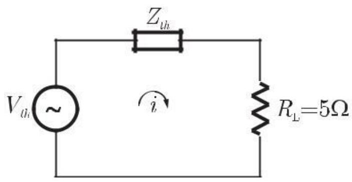
Thevenin impedance



$$Z_{th} = (6 + 8j)\Omega \parallel (6 + 8j)\,\Omega = (3 + 4j)\Omega$$

For maximum power transfer

$$R_L = |Z_{th}| = \sqrt{3^2 + 4^2} = 5\ \Omega$$



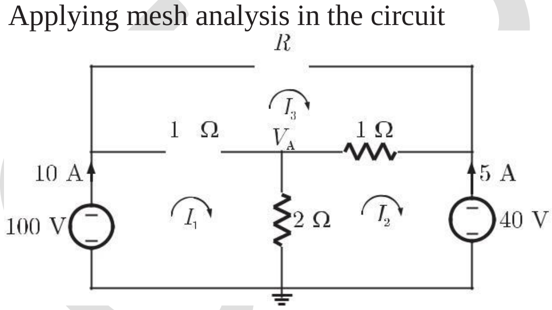
Power in load

$$P = i_{eff}^2 R_L$$

$$P = \left|\frac{100}{3 + 4j + 5}\right|^2 \times 5 = \frac{(100)^2}{80} \times 5 = 625 \text{ Watt}$$

Option (D) is correct.

Sol. 99 Applying mesh analysis in the circuit



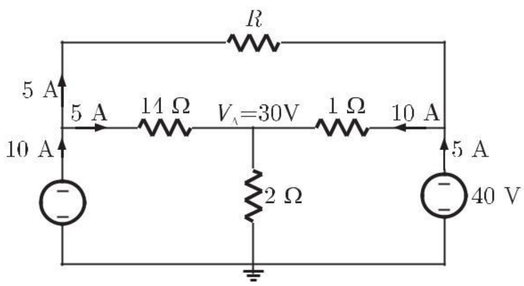
$I_1 = 10$ A, $I_2 = -5$ A

Current in 2 Ω resistor

$$I_{2\Omega} = I_1 - (-I_2) = 10 - (-5) = 15 \text{ A}$$

So, voltage $V_A = 15 \times 2 = 30$ Volt

Now we can easily find out current in all branches as following



Current in resistor R is 5 A

$$5 = \frac{100 - 40}{R}$$

$$R = \frac{60}{5} = 12\ \text{W}$$

Sol. 100 Option (B) is correct.

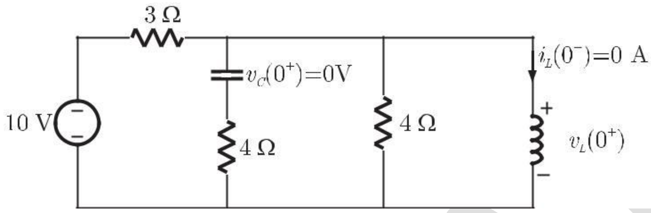
Before $t = 0$, the switch was opened so current in inductor and voltage across capacitor for $t < 0$ is zero

$v_c(0^-) = 0, \quad i_L(0^-) = 0$

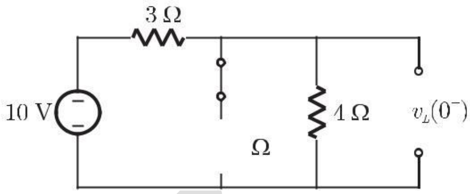
at $t = 0$, when the switch is closed, inductor current and capacitor voltage does not change simultaneously so

$v_c(0^+) = v_c(0^-) = 0, \quad i_L(0^+) = i_L(0^-) = 0$

At $t = 0^+$ the circuit is



Simplified circuit



Voltage across inductor (at $t = 0^+$)

$$v_L(0^+) = \frac{10}{3+2} \# 2 = 4 \text{ Volt}$$

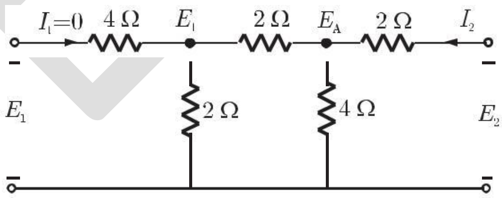
Sol. 101 Option (D) is correct.

Given that $\quad E_1 = h_{11} I_1 + h_{12} E_2$

and $\quad I_2 = h_{21} I_1 + h_{22} E_2$

Parameter h_{12} is given as

$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1 = 0 \text{(open circuit)}}$$



At node A

$$\frac{E_A - E_1}{2} + \frac{E_A - E_2}{2} + \frac{E_A}{4} = 0$$

$$5E_A = 2E_1 + 2E_2 \qquad \text{...(1)}$$

Similarly

$$\frac{E_1 - E_A}{2} + \frac{E_1}{2} = 0$$

$$2E_1 = E_A \qquad ...(2)$$

From (1) and (2)

$$5(2E_1) = 2E_1 + 2E_2 4$$

$$8E_1 = 2E_2$$

$$h_{12} = \frac{E_1}{E_2} = \frac{1}{4}$$

Sol. 102 Option (B) is correct.

$$V_{PQ} = V_P - V_Q = \frac{KQ}{OP} - \frac{KQ}{OQ}$$

$$= \frac{9 \# 10^9 \# 1 \# 10^{-9}}{40 \# 10^{-3}} - \frac{9 \# 10^9 \# 1 \# 10^{-9}}{20 \# 10^{-3}}$$

$$= 9 \# 10^3 : \frac{1}{40} - \frac{1}{20} D = -225 \text{ Volt}$$

Sol. 103 Option (D) is correct.

Energy stored in Capacitor is

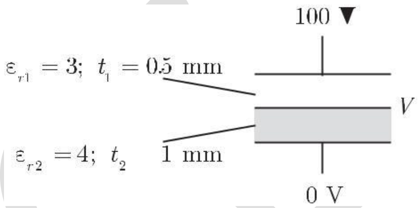
$$E = \frac{1}{2} CV^2$$

$$C = \frac{e_0 A}{d} = \frac{8.85 \# 10^{-12} \# 100 \# 10^{-6}}{0.1 \# 10^{-3}} = 8.85 \# 10^{-12} \text{ F}$$

$$E = \frac{1}{2} \# 8.85 \# 10^{-12} \# (100)^2 = 44.3 \text{ nJ}$$

Sol. 104 Option (B) is correct.

The figure is as shown below



The Capacitor shown in Figure is made up of two capacitor C_1 and C_2 connected in series.

$$C_1 = \frac{e_0 e_{r1} A}{t_1}, C_2 = \frac{e_0 e_{r2} A}{t_2}$$

Since C_1 and C_2 are in series charge on both capacitor is same.

$$Q_1 = Q_2$$

$C_1(100 - V) = C_2 V$ (Let V is the voltage of foil)

$$\frac{e_0 e_{r1} A}{t_1}(100 - V) = \frac{e_0 e_{r2} A}{t_2} V$$

$$\frac{3}{0.5}(100 - V) = \frac{4}{1} V$$

$$300 = 5V \;\&\; V = 60 \text{ Volt}$$