RPSC AEn-2024 Main Test Series

ELECTRICAL ENGINEERING

Test 1

Test Mode : • Offline • Online

Subjects : Electrical Circuits

DETAILED EXPLANATIONS

PART-A

1. Solution:

Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

$$\sum_{m=1}^{M} V_m = 0$$

Where M is the number of voltages in the loop (or the number of branches in the loop) and V_m is the m^{th} voltage.

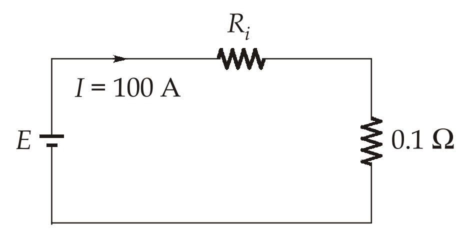
2. Solution:

A supernode is formed by enclosing a (dependent or independent) voltage source connected between two non-reference nodes and any elements connected in parallel with it.

3. Solution:

The superposition principle states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone.

4. Solution:



Given open-circuit voltage, E = 12 V

Also,
$$I = \frac{12}{R+0.1} = 100$$
$$R = 0.02\ \Omega$$

5. Solution:

For resonance,

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

6. Solution:

Condition for symmetricity

$$Z_{11} = Z_{22}$$
$$Y_{11} = Y_{22}$$
$$A = D$$
$$h_{11}h_{22} - h_{12}h_{21} = 1$$

7. Solution:

For maximum power,

$$R_{in} = R_{load} = 1\ \Omega$$
$$R_{in} = R \,||\, 3 \,||\, 3 = 1$$
$$R = 3\ \Omega$$
$$I = \frac{4}{1+1} = 2\text{ A}$$
$$P_{max} = I^2R_{load} = (2)^2 \times 1$$
$$= 4\text{ W}$$

8. Solution:

$$M = K\sqrt{L_1 L_2}$$

$$M = 0.4 \text{ H}, L_1 = 1 \text{ H}, L_2 = 0.25 \text{ H}$$

$$0.4 = K\sqrt{1 \times 0.25}$$

$$K = \frac{4}{5} = 0.8$$

9. Solution:

It is defined as the ratio of an output Laplace transform to an input Laplace transform with zero initial condition and with no internal energy sources except the controlled sources.

10. Solution:

1. Poles and zeros lie on the negative real axis and they alternate.
2. The residues of the poles must be real and positive.
3. The critical frequency nearest to the origin or at the origin must be a zero; whereas, the critical frequency nearest to infinity or at infinity must be a pole.

PART-B

11. Solution:

The voltage-current relationship of a capacitor is

$$V_c = \frac{1}{C}\int_{-\infty}^{t} i(t)dt$$

If an impulse current is applied to a capacitor then the resulting voltage across the capacitor is given by

$$V_c = \frac{1}{C}\int_{-\infty}^{t} \delta(t-T)dt = \frac{1}{C}u(t-T)$$

Thus, an impulse current applied to a capacitor C results in an instantaneous voltage of $\frac{1}{C}$.

12. Solution:

The Thevenin's theorem is very useful for replacement of a large portion of a network with a small equivalent circuit. This theorem is used to find the current in a particular passive element in a linear bilateral network. This theorem is also useful for calculating the load resistance in impedance-matching problems.

13. Solution:

The ABCD parameters represent the relation between the input quantities and the output quantities in a two-port network. They are thus voltage-current pairs.

These parameters are known as transmission parameters as in a transmission line, the currents enter at one end and leave at the other end, and we need to know a relation between the sending-end quantities and the receiving-end quantities.

14. Solution:

Apparent power: it is the product of the rms (effective) values of voltage and current (in VA). For a sinusoidal voltage, $V(t) = V_m \cos(\omega t + \theta_v)$ applied to a network resulting in current, $i(t) = I_m \cos(\omega t + \theta_p)$. The apparent power is given as

$$S = V_{rms} I_{rms}$$

Real power (Active power): It is the average of the instantaneous power over a time interval. It is the power consumed by the resistive loads in an electrical circuit.

In sinusoidally steady state, the active power is given as

$$P = \frac{1}{2} V_m I_m \cos(\theta_v - \theta_i)$$

$$= V_{rms} I_{rms} \cos(\theta_v - \theta_i)$$

$$= S \cos(\theta_v - \theta_i) \text{ W}$$

15. Solution:

In circuit analysis, the dot convention is a convention used to denote the voltage polarity of the mutual inductance of two components. The two conventions are as follows:

1. If a current enters the dotted terminal of one coil then the polarity of the emf induced in the second coil will be positive at the dotted terminal of the second coil.
2. If a current leaves the dotted terminals of one coil then the polarity of the emf induced in the second coil will be negative at the dotted terminal of the second coil.

16. Solution:

For 3-phase, 3-wire star-connected system without a neutral wire, unbalanced loading may cause different voltage drops in three lines. Consequently, the three-phase voltages will be different both in magnitude as well as in phase. In such cases, the voltage of one phase may even exceed the line voltage. This may damage the equipments connected to the line due to over-voltage.

For this reason, an unbalanced load is not normally used on a 3-phase, 3-wire system.

17. Solution:

In a series circuit, at resonance the inductive and capacitive reactances cancel each other and the impedance is minimum and equal to the resistance of the circuit. Hence in a series resonant circuit, the current will be the maximum.

On the other hand, in a parallel circuit, at resonance the resultant susceptance is zero and the admittance is minimum and equal to the conductance of the circuit.

Hence, in parallel resonant circuit, the current will be minimum.

18. Solution:

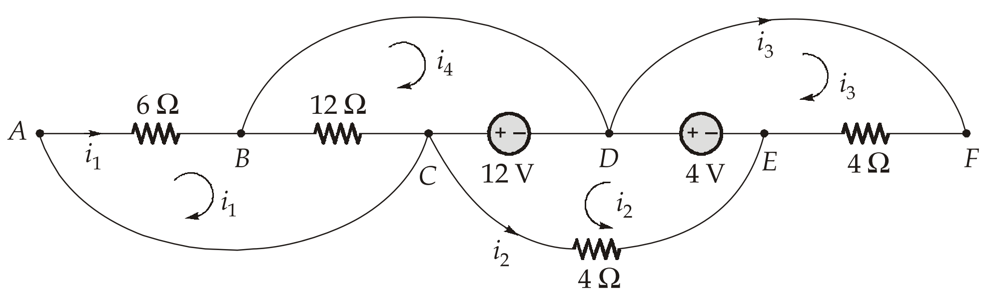
A loop or mesh denotes a closed path obtained by starting at a node and returning back to the same node through a set of connected circuit elements without passing through any intermediate node more than once.

However, the difference between mesh and loop is that a mesh does not contain any other loop within it, i.e., a mesh is the smallest loop.

PART-C

19. Solution:

We consider the four meshes and mesh currents.



By KVL for the meshes, we get

$$18i_1 - 12i_4 = 0$$

$$3i_1 = 2i_4$$

$$i_4 = \frac{3}{2}i_1$$

$$-12i_1 + 12i_4 = 12$$

$$12i_1 = 12i_4 - 12 = 12\left(\frac{3}{2}i_1\right) - 12 = 18i_1 - 12$$

$$i_1 = 2\text{ A}$$

$\therefore$ $$i_4 = 3\text{ A}$$

$$4i_2 = 16$$
$$i_2 = 4\text{ A}$$
$$4i_3 = 4$$
$$i_3 = 1\text{ A}$$

Therefore, the required currents are

$i_1 = 2$ A; $i_2 = 4$ A; $i_3 = 1$ A, $\quad i_4 = 3$ A

Power delivered by the 12 V source = $12 \times (i_4 + i_2)$

$$= 84\text{ W}$$

Power delivered by the 4 V source = $4 \times (i_2 + i_3)$

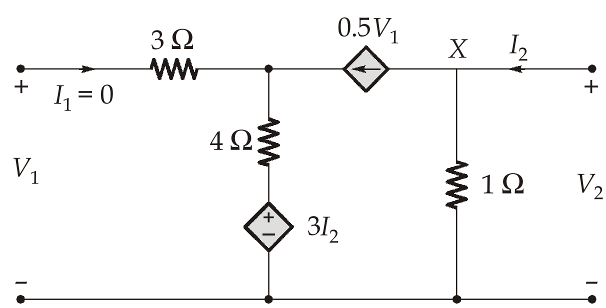
$$= 20\text{ W}$$

20. Solution:

To find h parameters, we consider two cases:

When $I_1 = 0$

Here, no current will flow through the 3 Ω resistance



By KVL at the left mesh, we get

$$V_1 = 4 \times 0.5V_1 + 3I_2 = 2V_1 + 3I_2$$
$$V_1 = -3I_2$$

Also, by KCL at the node (X), we get

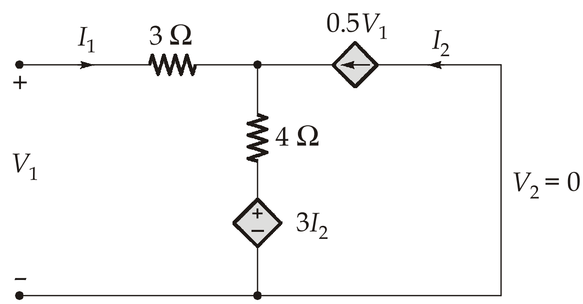
$$I_2 = \frac{V_2}{1} + 0.5V_1 = V_2 + 0.5V_1$$
$$= V_2 + 0.5 \times (-3I_2)$$
$$2.5I_2 = V_2$$

$$\therefore \qquad h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1 = 0} = \frac{1}{2.5} = 0.4\ \mho$$

$\therefore \qquad V_1 = -3I_2 = -3 \times \frac{V_2}{2.5} = -1.2V_2$

$\therefore \qquad h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0} = -1.2$

When $\qquad V_2 = 0$



Here, Port 2 is short-circuited.

The 1 Ω resistance becomes redundant.

$\therefore \qquad I_2 = 0.5V_1 = 0.5 \times [3I_1 + 4I_1 + 4I_2 + 3I_2]$

$= 3.5I_1 + 3.5I_2$

$2.5I_2 = -3.5I_1$

$\therefore \qquad h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0} = \frac{-3.5}{2.5} = -1.4$

Also,

$V_1 = 3I_1 + 4I_1 + 4I_2 + 3I_2$

$= 7I_1 + 7I_2$

$= 7I_1 + 7 \times (-1.4I_1) = -2.8I_1$

$\therefore \qquad h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0} = -2.8\ \Omega$

Therefore, the h parameters of the network are given as

$$[h] = \begin{bmatrix} -2.8 & -1.2 \\ -1.4 & 0.4 \end{bmatrix}$$

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