Model Answers

Winter – 2018 Examinations

Subject & Code: Electrical Circuits & Networks (17323)

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Model Answers
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1 Attempt any TEN of the following: 20

1 a) Identify the circuit of Figure No. 1

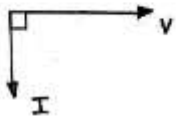


Fig. No. 1

Ans:
Given circuit is purely inductive type. 2 mark

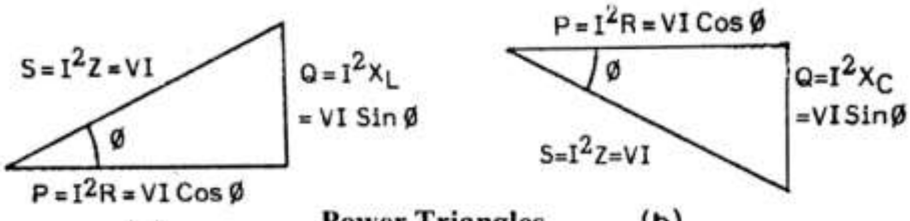
1 b) Define - Frequency. State its relation with time period.
Ans:
(i) **Frequency:** It is defined as number of cycles completed by an alternating quantity in one second**.** 1 mark
(ii) Frequency is inversely proportional to time period

$$f = \frac{1}{T}$$ 1 mark

1 c) If maximum value of a sine wave is 25A. Calculate its average value.
Ans:
Data Given: $I_{max} = 25$ A,
We have ,

$I_{avg} = 0.637 \times I_{max}$ 1 mark
$= 0.637 \times 25$
$I_{avg} =$ **15.92 A** 1 mark

1 d) Draw a power triangle and state the relation between its sides.
Ans -



Power Triangles

1 mark for any one Power triangle

Relation Between the sides of Power triangle –

$$S = \sqrt{P^2 + Q^2}$$ 1 mark for relation

Where, S = Apparent Power
P = Active Power
Q = Reactive Power

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1 e) State the range of phase angle and hence p.f. for a series RC circuit.

Ans:

- The range of phase angle: 0 to 90° — 1 mark
- The range of Power factor (cosϕ) for a series RC circuit: $0 \le \cos\phi < 1$ (leading) — 1 mark

1 f) In a series RL circuit V_R = 100V and V_L = 150V. Find the equivalent voltage across the circuit.

Ans:

The equivalent voltage across the circuit is given by,

$$V = \sqrt{(V_R^2 + V_L^2)}$$ 1 mark

$$= \sqrt{100^2 + 150^2} = \sqrt{32500} = 180.27\ volt$$ 1 mark

1 g) Write equation of resonant frequency and quality factor in terms of circuit components for a parallel circuit.

Ans:

Equation for resonance frequency in terms of circuit components for parallel circuit.

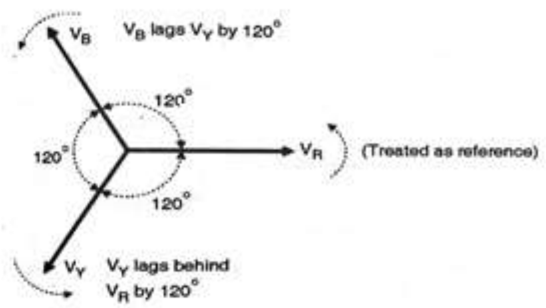
$f_r = \frac{1}{2\pi\sqrt{LC}}$ 1 mark

Equation for quality factor in terms of circuit components for parallel circuit.

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$ 1 mark

1 h) Draw phasor diagram for 3 ϕ generated voltages.

Ans –



2 marks for labeled diagram

1 mark for partially labeled diagram

1 i) List any two advantages of 3 ϕ circuits over single-phase circuits.

Ans -

Advantages of 3 ϕ circuits over 1 ϕ circuits.

i) The power generated by 3-phase machine is higher than that of 1-phase machine of the same size.

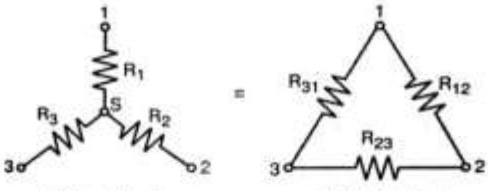
ii) The size of 3-phase machine is smaller than that of 1-phase machine of the same power rating.

iii) Three-phase transmission is more economical than single-phase transmission. It requires less copper material.

2 mark for any two advantages

iv) Three-phase induction motors are self-starting.
v) Three phase machines have high efficiency, better power factor and uniform torque.
vi) Parallel operation of 3-phase alternators is easier than that of single-phase alternators.

1 j) State only the formula for star to delta transformation.
Ans:



(a) Star Circuit (b) Delta Circuit

$$R_{12} = \frac{R_1R_2+R_2R_3+R_1R_3}{R_3}$$
$$R_{23} = \frac{R_1R_2+R_2R_3+R_1R_3}{R_1}$$
$$R_{31} = \frac{R_1R_2+R_2R_3+R_1R_3}{R_2}$$

2 marks for formula

1 k) **State 'Norton's' Theorem.**
Ans:
Norton's Theorem:
It states that any linear, active, resistive network containing one or more voltage and/or current source can be replaced by an equivalent circuit containing a single current source and equivalent conductance (resistance across the current source).

2 marks for statement

The equivalent current source (Norton's source) I_N is the current through the short circuited terminals of the load. The equivalent conductance G_N (or R_N) is the conductance (or resistance) seen between the load terminals while looking back into the network with the load removed and internal sources replaced by their internal resistances.
If R_L is load resistance then current through it is $I_L = I_N R_N/(R_N + R_L)$.

1 l) Find R_{TH} from Figure No. 2

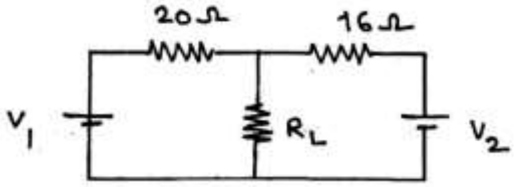
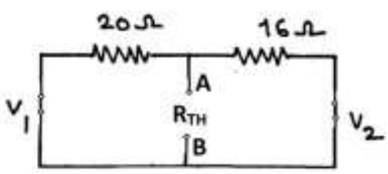


Fig. No. 2

Ans:
$R_{TH} = R_{AB} = 20 \parallel 16 = 320/36 = 8.89\ \Omega$



1 mark for circuit diagram
1 mark for stepwise solution

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1 m) State Maximum Power Transfer theorem for AC circuits.

Ans:

Maximum Power transfer theorem for AC circuits:

"It states that the maximum amount of power is delivered to the load impedance when the load impedance is equal to the complex conjugate of the internal impedance of the source or Thevenin's equivalent impedance of the network supplying the power to load." — 2 marks for correct statement

According to this theorem, condition for maximum power to be transferred to load is when $\mathbf{Z_L = Z_{TH}^* = Z_S^*}$

where Z_L = Load impedance
Z_S = Internal impedance of the source
Z_{TH} = Thevenin's Equivalent impedance of the network supplying power to the load.

1 n) State meaning of t = 0– and t = 0+.

Ans –

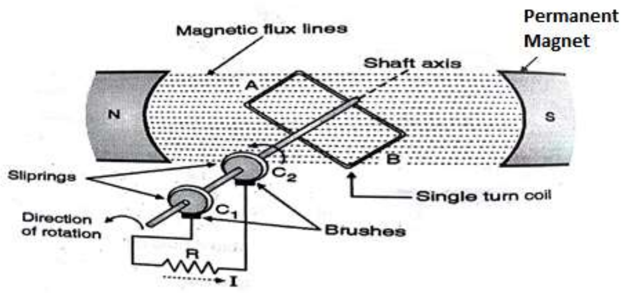
1) t = 0– is the instant just before the switching instant t = 0 — 1 mark each
2) t = 0+ is the instant just after the switching instant t = 0

2 Attempt any FOUR of the following: 16

2 a) For a single loop AC generator-
(i) Draw a neat sketch.
(ii) Identify components used.
(iii) Write equation of generated emf.
(iv) Draw waveform of output voltage.

Ans:

(i) Neat sketch of single loop AC generator — 1 mark



OR any other equivalent sketch

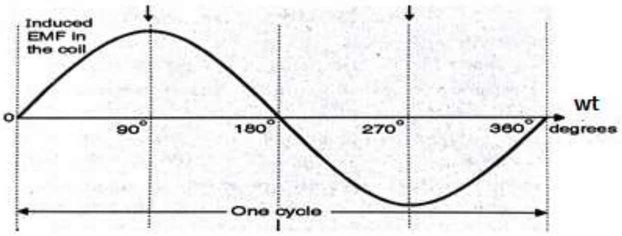
(ii) Components used: — 1 mark
a) Permanent magnets.
b) Single turn coil.
c) Slip rings
d) Brushes
e) Shaft.

(iii) Equation of generated emf: — 1 mark

$e = B.\ell.v.\sin(\omega t)$ volt $= E_m \sin(\omega t)$ volt

where, e = Instantaneous value of the emf
B = Flux-density in Wb/m^2
ℓ = Active length of conductor in m
v = Linear velocity of conductor in m/s.
ω = Angular velocity of conductor in rad/sec
t = time in sec.

(iii) Waveform of output voltage.



1 mark

2 b) An alternating current is given by i = 20 sin (314t).
Find –
(i) Current at t = 0.0025 sec at first instant.
(ii) Time period to reach at 12A for first time.

Ans:-

i) Current at t = 0.0025 sec at first instant:

Instantaneous value $i = 20\sin(314 \times 0.0025) = 20\sin(0.785)$

$$\therefore \mathbf{i = 14.1365\ A}$$

Thus the current at t = 0.0025 sec at first instant is 14.1365 A.

2 marks for stepwise solution

ii) Time period to reach at 12A for first time:

Instantaneous value $i = 12 = 20\sin(314t)$

$$\therefore \sin(314t) = \frac{12}{20} = 0.6$$

$$\therefore 314t = \sin^{-1}(0.6)$$

$$\therefore t = \frac{0.6435}{314} = 0.00205 \text{ sec}$$

Thus the current takes t = 0.00205 sec to reach at 12A for first time.

2 marks for stepwise solution

2 c) In RLC series circuit R = 8Ω, L= 0.42 H with an unknown capacitor. If the circuit is connected across 230V, 50Hz, 1ϕ AC. Calculate value of capacitor so that circuit resonates at supply frequency. Also calculate current and p.f. at this instant.

Ans:

Data given:
Resistance R = 8Ω
Inductance L = 0.42 H
Supply voltage V = 230V
Supply frequency f = 50 Hz
Resonant frequency is given by,

$$f = \frac{1}{2\pi\sqrt{LC}}$$

1 mark

$$\therefore 50 = \frac{1}{2\pi\sqrt{0.42 \times C}}$$

$$\therefore \sqrt{C} = \frac{1}{50(2\pi\sqrt{0.42})} = 4.911 \times 10^{-3}$$

$$\therefore C = 24.12 \times 10^{-6} F = \mathbf{24.12\ \mu F} \text{.............................}\textbf{(Ans)}$$ 1 mark

At resonance, the current is given by,

$$\text{I} = \frac{\text{V}}{\text{R}} = \frac{230}{8} = \mathbf{28.75\ A}$$ 1 mark

P.F. of the circuit:

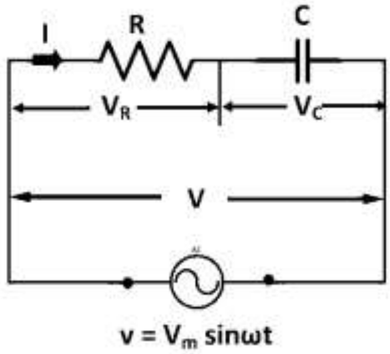
The power factor of the circuit at resonance is UNITY,

i.e $\mathbf{\cos\theta = 1}$ 1 mark

2 d) A series circuit has a leading pf. Express it with circuit, waveform and phasor diagram.

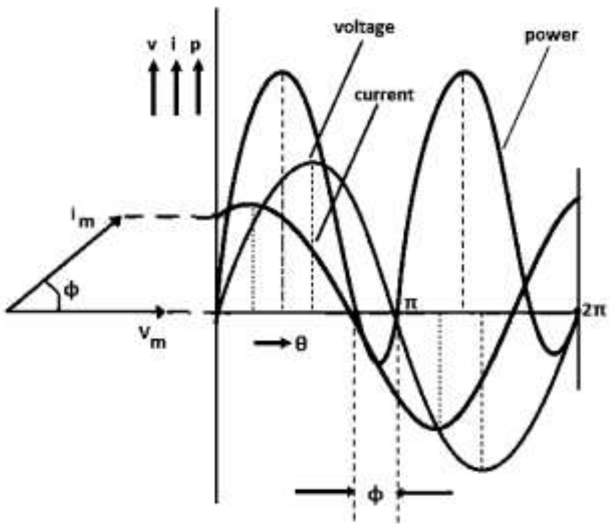
Ans:-

i) The series circuit having leading pf is capacitive circuit (i.e RC series circuit).



1 mark for circuit diagram

ii) The waveform and phasor diagram of voltage, current are as follows:



1 mark for phasor diagram

1 mark for waveform of current

1 mark for waveform of voltage

2 e) Find current I in the circuit shown in Figure No. 3 using admittance method.

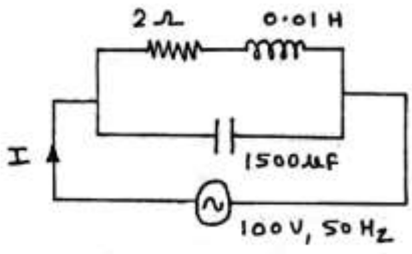


Fig. No. 3

Ans:

V= 100∠0° volts, f = 50Hz

$X_L = 2\pi fL = 2\pi(50)(0.01) = 3.142\Omega$ ½ mark

$Z_1 = R_1 + jX_L = (2 + j3.142)\Omega = 3.724\angle 57.52^\circ$ ½ mark

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(50)(1500\times 10^{-6})} = 2.12\ \Omega$ ½ mark

$Z_2 = R_2 - jX_C = (0 - j2.12)\Omega = 2.12\angle 90^\circ$

$Y_1 = \frac{1}{Z_1} = \frac{1}{3.724\angle 57.52^\circ} = 0.268\angle{-57.52^\circ} = 0.144 - j0.226$ ½ mark

$Y_2 = \frac{1}{Z_2} = \frac{1}{2.12\angle 90^\circ} = 0.472\angle 90^\circ = 0 + j0.472$

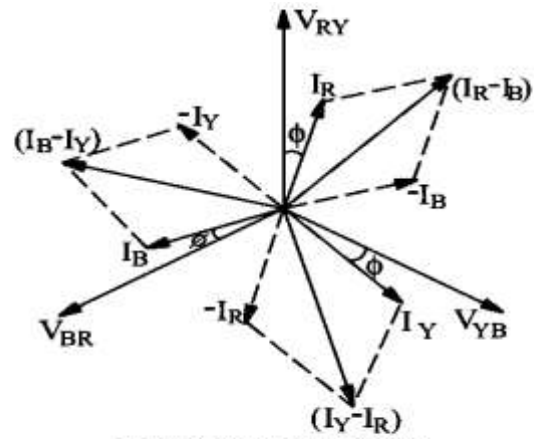
$Y = Y_1 + Y_2 = G + jB = 0.144 - j0.226 + 0 + j0.472 = 0.144 + j0.246 = \mathbf{0.285\angle 59.66^\circ}$ 1 mark

Total Current I = V×Y= (100∠0°) × (0.285∠59.66°) = **28.5∠59.66° amp** 1 mark

(Truncation errors may please be ignored)

2 f) List any four observations from the phasor diagram of a 3ϕ delta connection.

Ans:



Line & Phase Current and Line & Phase Voltage in Delta (Δ) Connection

1 mark for each of any four observations = 4 marks

For balanced delta connection, the observations from phasor diagram are:

- Line voltage = Phase voltage.
- Line current = √3 Phase current
- Phase currents are I_R, I_Y and I_B whereas the line currents are $(I_R\text{-}I_B)$, $(I_Y\text{-}I_R)$ and $(I_B\text{-}I_Y)$.
- The phase currents I_R , I_Y and I_B lag behind the corresponding phase voltages V_{RY} , V_{YB} and V_{BR} respectively by an angle ϕ.
- For balanced supply, the phase voltages (also line voltages) are balanced i.e

their RMS magnitudes are equal but displaced from each other by 120°.

- For balanced supply, the phase currents (also line currentss) are balanced i.e their RMS magnitudes are equal but displaced from each other by 120°.
- All the three impedances are identical.

3 Attempt any FOUR of the following: 16

3 a) Define peak factor and form factor. State value of each for a pure sine wave.

Ans:

i) Peak Factor:

It is defined as the ratio of the peak or crest value to the RMS value of an alternating quantity. — 1 mark for definition

Peak factor $= \frac{Peak\ Value}{RMS\ Value}$ = **1.141** for a pure sine wave — 1 mark for value

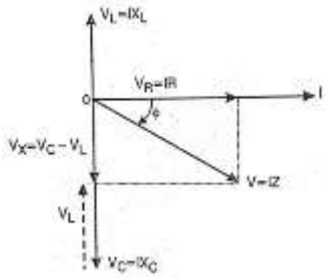
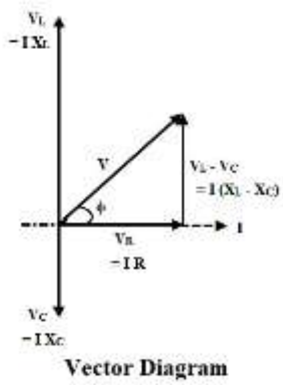
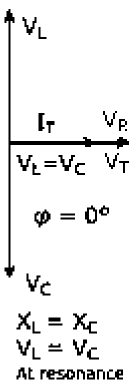
ii) Form Factor:

It is defined as the ratio of RMS value to average value of an alternating quantity. — 1 mark for definition

Form factor $= \frac{\text{RMS Value}}{\text{Average Value}}$ = **1.11** for a pure sine wave — 1 mark for value

3 b) State nature of pf for any two conditions in RLC series circuit. Draw phasor diagram for each.

Ans:

$X_C > X_L$	$X_L > X_C$	$X_L = X_C$
Power factor is leading	**Power factor is lagging**	**Power factor is Unity**
		

(Any two conditions)

2 marks for nature of pfs

2 marks for phasor diagrams

3 c) A series RLC circuit consists of R = 20 Ω, L = 1 H and C = 2500 μF. If it is connected across 230V, 1ϕ AC, calculate Q factor and resonant frequency.

Ans:

Given:

Supply voltage V_s =230V,

R = 20 Ω , L = 1 H, C = 2500 μF

Q-factor is given by,

2 marks

Q-factor $= \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{20}\sqrt{\frac{1}{2500\times10^{-6}}} = 1$ 2 marks

Resonant frequency $f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{1(2500\times10^{-6})}} = 3.183$ Hz

3 d) Two admittances $Y_1 = 0.012\angle60°$ mho and $Y_2 = 0.015\angle45°$ mho are connected in parallel across 250V, 50Hz AC. Calculate power consumed by the circuit.

Ans:

Given:

$Y_1 = 0.012\angle60° = 6\times10^{-3} + j0.0104$ 1 mark

$Y_2 = 0.015\angle45° = 0.0106 + j0.0106$

Total equivalent admittance is given by,

$Y = Y_1 + Y_2 = 6\times10^{-3} + j0.0104 + 0.0106 + j0.0106$ 1 mark

$= \mathbf{0.0166 + j\,0.021 = 0.0268\angle51.67°}$

Circuit current is given by,

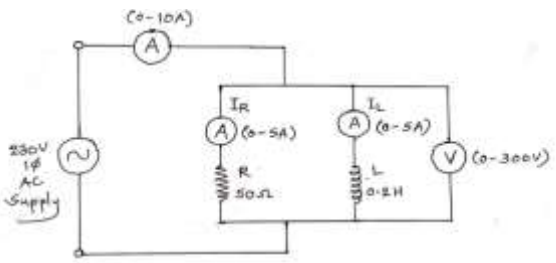
$I = VY = (250\angle0°)(0.0268\angle51.67°) = \mathbf{6.7\angle51.67°}$ **amp**. 1 mark

Power consumed by the circuit is given by,

$P = VI\cos\phi = (250)(6.7)\cos(51.67°) =$ **1038.82 watt** 1 mark

3 e) Draw an experimental set up to find current and power for parallel circuit of R = 50 Ω and L = 0.2 H, V = 230 V, 50 Hz, 1ϕ AC.

Ans:



4 marks for labeled diagram

Power = $V\times I_R = I_R^2 \times R$

OR Any other equivalent diagram

3 f) Three resistors each of 23 Ω are connected in delta across a 230V, 3ϕ, 50 Hz, AC. Calculate the power consumed by the load.

Ans:

For delta connection, Phase voltage is equal to line voltage, $\therefore V_{ph} = V_L = 230V$ 1 mark

Load is purely resistive, hence load pf = cosϕ = 1 1 mark

Phase current $I_{ph} = V_{ph}/R = 230/23 = 10$ A. 1 mark

Total 3ϕ power consumed by load $P_{3\phi} = 3\,V_{ph}I_{ph}\cos\phi = 3\,(230)(10)(1) =$ **6900 W** 1 mark

4 Attempt any FOUR of the following. 16 Marks

4 a) A choke coil when connected across a 200V, 50Hz, 1ϕ AC will take current at 0.8 pf lagging. The circuit consumes 2kW. Find circuit components.

Ans:

Circuit is **inductive** in nature.

Power factor cosϕ = 0.8 lagging ∴ Phase angle ϕ = 36.87° ½ mark

Active power P = 2kW = 2000 W.

Apparent power S = P/cosϕ = 2000/0.8 = 2500 VA ½ mark

∴ Current I = S/V = 2500/200 = 12.5A ½ mark

Impedance Z = V/I = 200/12.5 = 16Ω ½ mark

Resistance R = Zcosϕ = 16(0.8) = **12.8Ω** 1 mark

Inductive reactance X_L = Zsinϕ = 16(0.6) = 9.6Ω

Inductance L = X_L/(2πf) = 9.6/(2π×50) = **0.03056H** 1 mark

4 b) Derive the condition for resonance in an RLC series circuit. Also derive the equation for Q factor.

Ans:

Resonant Frequency of Series RLC Circuit:

For series R-L-C circuit, the complex impedance is given by,

$$\mathrm{Z = R + jX_L - jX_C = R + jX}$$

where, inductive reactance is given by $\mathrm{X_L = 2\pi fL}$

capacitive reactance is given by $\mathrm{X_C = \frac{1}{2\pi fC}}$

When the inductive reactance becomes equal to the capacitive reactance, the circuit impedance becomes purely resistive and equal to R. This condition is called the series resonance.

2 marks for stepwise derivation of resonant frequency

Hence, at resonance, $\mathrm{X_L = X_C}$

$$\mathrm{2\pi f_r L = \frac{1}{2\pi f_r C}}$$

$$\mathrm{f_r^2 = \frac{1}{(2\pi)^2 LC}}$$

∴ Series Resonant frequency $\mathrm{f_r = \frac{1}{2\pi\sqrt{LC}}}$ Hz

Resonant Angular frequency $\mathrm{\omega_r = \frac{1}{\sqrt{LC}}}$ rad/sec

Thus when supply frequency becomes equal to f_r the resonance is observed.

Derivation of equation of Q-factor:

A quality factor (Q-factor) basically represents a figure of merit of the component or circuit. It is defined as,

$$Q = 2\pi\left[\frac{Maximum\ energy\ stored}{Energy\ dissipated\ per\ cycle}\right]$$

Under resonance condition, the maximum energy stored in inductor is equal to that stored in capacitor.

$$\therefore E_{max} = \frac{1}{2}LI_m^2 = \frac{1}{2}CV_{Cm}^2 = \frac{1}{2}C(I_m X_C)^2 = \frac{1}{2}\frac{I_m^2}{\omega_r^2 C}$$

The energy dissipated per cycle is given by,

E_d = (Average power dissipated) × (Time of one cycle)

$$= I^2RT = \left[\frac{I_m}{\sqrt{2}}\right]^2 R\,\frac{1}{f_r} = \frac{1}{2}I_m^2 R\left(\frac{2\pi}{\omega_r}\right)$$

Therefore, the Q-factor of series RLC circuit at resonance is given by,

$$Q_r = 2\pi\left[\frac{\frac{1}{2}LI_m^2}{\frac{1}{2}I_m^2 R\left(\frac{2\pi}{\omega_r}\right)}\right] \quad or \quad 2\pi\left[\frac{\frac{1}{2}\frac{I_m^2}{\omega_r^2 C}}{\frac{1}{2}I_m^2 R\left(\frac{2\pi}{\omega_r}\right)}\right]$$

2 marks for stepwise derivation of Q-factor

$$\therefore Q_r = \frac{\omega_r L}{R} = \frac{1}{\omega_r RC}$$

Since series resonant $\omega_r = \frac{1}{\sqrt{LC}}$

$$\therefore Q_r = \frac{1}{\sqrt{LC}}\frac{L}{R} \quad or \quad \frac{1}{\frac{1}{\sqrt{LC}}RC}$$

$$\therefore Q_r = \frac{1}{R}\sqrt{\frac{L}{C}}$$

4 c) Three impedances each of Z = (15+j18)Ω are connected in star across a 400V, 3ϕ, AC. Calculate: i) V_{ph} ii) I_{ph} iii) I_L iv) pf

Ans:

i) Phase voltage V_{ph}:

Line voltage V_L = 400V

For star connection, Phase voltage $V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94V$ — 1 mark

ii) Phase current I_{ph}:

Impedance per phase Z = 15+j18 = 23.43∠50.19°Ω

Phase current $I_{ph} = \frac{V_{ph}}{Z} = \frac{230.94}{23.43} = 9.86A$ — 1 mark

iii) Line current I_L:

For star connection, Line current = Phase current = 9.86A — 1 mark

iv) Power factor:

Power factor = cos(50.19°) = 0.64 lagging — 1 mark

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4 d) Find the value of V of Figure No. 4 if the voltage at node A is 12V.

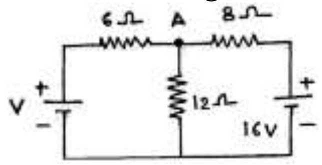


Fig. No. 4

Ans:
Given: V_A = 12V
By applying KCL at node A, the equation can be written as,

$$\frac{V_A - V}{6} + \frac{V_A}{12} + \frac{V_A - 16}{8} = 0$$ 1 mark

$$V_A\left[\frac{1}{6} + \frac{1}{12} + \frac{1}{8}\right] - \frac{V}{6} - 2 = 0$$ 1 mark

$$(0.375)V_A - (0.167)V = 2$$
$$(0.375)(12) - (0.167)V = 2$$ 1 mark

4.5 – 2 = 0.167V
∴ **V = 14.97 volt** 1 mark

4 e) Find the value of maximum power transferred to R_L = 6Ω from the source of Figure No. 5

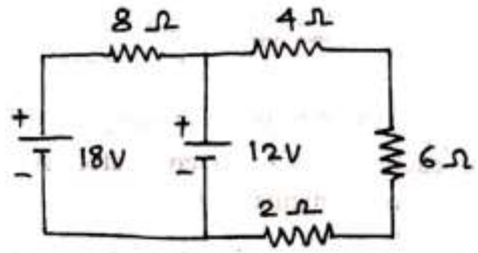
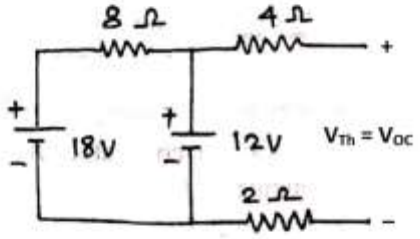


Fig. No. 5

Ans:
This problem can be solved by using Thevenin's theorem.

A) Determination of Thevenin's equivalent Voltage V_{Th}:

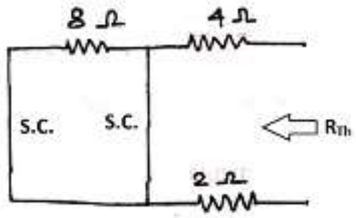


1 mark

Referring to above figure, it is clear that when load is removed and terminals are kept open, the current through 4Ω and 2Ω becomes zero. Therefore, no voltage drops across them and the open-circuit voltage is given by,

$V_{Th} = V_{OC}$ = 12 volt

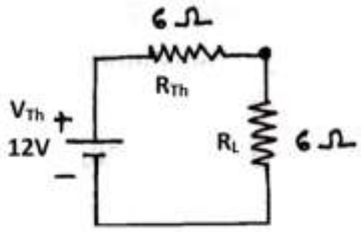
B) Determination of Thevenin's equivalent Resistance R_{Th}:



1 mark

Referring to above figure, since 8Ω is short-circuited, the $\mathbf{R_{Th} = 4+2 = 6\Omega}$

C) Thevenin's Equivalent Circuit:



1 mark

Circuit current $I = V_{Th} / (R_{Th}+R_L)$
$= 12/(6+6) = 1$ amp
Maximum power transferred to load of 6Ω,
$P_{Max} = I^2 R_L = (1)^2 (6) =$ **6 watt**

1mark

4 f) Write a step by step procedure to find current through R_L of a circuit using Norton's theorem.

Ans:

Steps for finding load current by Norton's Theorem:

i) Identify the load branch whose current is to be found.
ii) Redraw the circuit with load branch separated from the rest of the circuit such that the the load branch appears between terminals, say A and B, which are connected to rest of the circuit by two wires.
iii) Remove the load branch from terminals A and B, so that the rest of the circuit appears between these terminals A and B.
iv) Short the terminals A and B and then find the short-circuit current flowing through the shorted terminals A and B due to internal independent sources, using any circuit analysis technique. Let this short-circuit current be I_N.
v) Determine the equivalent impedance of the circuit seen between the open terminals A and B, while looking back into the circuit, with all internal independent volatge sources replaced by short-circuit and all internal independent current soutrces replaced by open-circuit. Let this equivalent impedance be Z_N.
vi) The circuit appearing between open circuited terminals A and B (due to removal of load branch) is now represented by simple circuit consisting of a current source, having magnitude I_N in parallel with an impedance Z_N.
vii) If the load impedance is Z_L, then connecting it between terminals A and B gives rise to load current $I_L = I_N \left[\frac{Z_N}{Z_N+Z_L}\right]$

4 marks for correct stepwise answer

5 Attempt any FOUR of the following: 16

5 a) A balanced load connected in delta across a 415V, 3ϕ, 50Hz supply takes a phase

current of 15A at 0.8 pf lag. Find components of the load.

Ans:

For delta connection, Phase voltage = Line voltage = 415V ½ mark

Phase current = 15A

Power factor pf = 0.8 lagging

$\therefore$ Phase angle $\phi = \cos^{-1}(0.8) = 36.87°$ lagging ½ mark

$\therefore$ Load impedance per phase = $Z_{ph} = V_{ph} / I_{ph} = 415\angle 0°/15\angle -36.87°$

$= 27.67\angle 36.87°$

$= (22.14+j16.6)\Omega$ 1 mark

$\therefore$ Load Components are: Resistance **R = 22.14Ω** 1 mark

Inductive reactance $X_L = 16.6\Omega$

Inductance **L** = $X_L/(2\pi f) = 16.6/(2\pi\times 50)$ = **0.053H** 1 mark

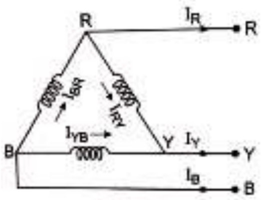
5 b) Derive relation between I_L and I_{Ph} from the phasor diagram of a 3ϕ delta connected balanced load.

Ans:

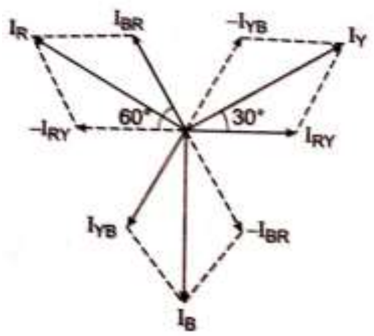
From the diagram, the current in each line is vector difference of the two phase currents.

For example:

Current in line R is $I_R = I_{BR} - I_{RY}$
Current in line Y is $I_Y = I_{RY} - I_{YB}$
Current in line B is $I_B = I_{YB} - I_{BR}$



Delta connection



1 mark for phasor diagram

3 marks for stepwise derivation

Current in line R is found by compounding I_{BR} and I_{RY} and value given by parallelogram in phasor diagram.

Angle between I_{BR} and $-I_{RY}$ is 60° ,

where $|I_{BR}| = |I_{RY}|$ = Phase current I_{ph}

$$I_R = I_{BR} - I_{RY} = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$

$$I_Y = I_{RY} - I_{YB} = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$

$$I_B = I_{YB} - I_{BR} = 2I_{ph}\cos\left(\frac{60}{2}\right) = 2I_{ph}\frac{\sqrt{3}}{2} = \sqrt{3}I_{ph}$$

As $I_R = I_Y = I_B = I_L$

$I_L = \sqrt{3}I_{ph}$

5 c) Find current through 8Ω resistor of Figure No. 6 using Nodal Analysis.

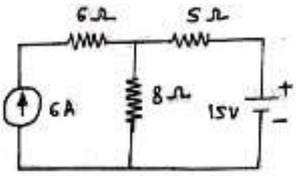
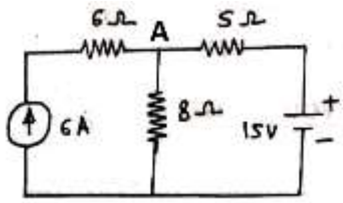


Fig. No. 6

Ans:



1 mark

Referring to figure, the nodal equation at node A can be written as:

$$6 = \frac{V_A}{8} + \frac{V_A - 15}{5}$$ 1 mark

$$\therefore V_A\left[\frac{1}{8} + \frac{1}{5}\right] = 9$$

$\therefore V_A = 27.69V$ 1 mark

Current flowing through 8Ω resistor is then given by, 1 mark

$I = V_A / 8 = 27.69/8 =$ **3.46A**

5 d) Write a step by step procedure to find current through a load resistor using Mesh analysis.

Ans:

Steps to Solve Circuit using Mesh Analysis:

i) For a given planar circuit, convert each current source, if any, into voltage source.
ii) Assign a mesh current to each mesh. The direction for each mesh current can be marked arbitrarily, however if same direction is considered for all mesh currents, then the resulting equations will have certain symmetry properties.
iii) Write KVL equation for each mesh. The equations will have terms with currents on one side and constant on the other side.
iv) Solve the resulting set of simultaneous algebraic equations and find the mesh currents.
v) Using mesh currents then find the branch currents and branch voltages.

4 marks for stepwise answer

5 e) Find current through 8Ω resistor of Figure No. 7 using super position theorem.

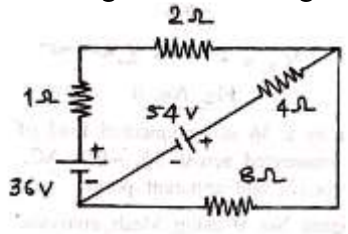
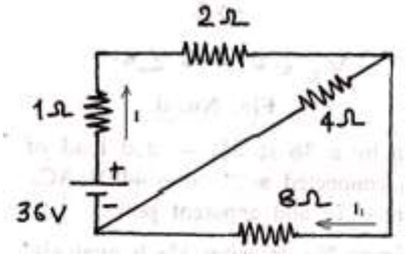


Fig. No. 7

Ans:

(A) Consider voltage source of 36V acting alone:



The total resistance appearing across 36V source is given by,

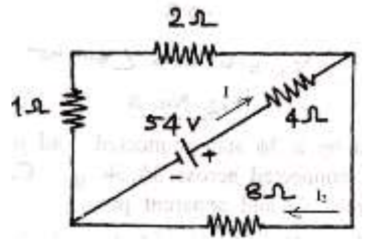
$R_T = 1+2+(4||8) = 1+2+(32/12) = 5.67$

The current I = 36/5.67 = 6.35A

The current through 8Ω due to 36V source alone is given by, — 1½ Marks for Steps

$I_1 = I\ (4/12) = 6.35(1/3) =$ **2.12 A**

(B) Consider voltage source of 54V acting alone:



The total resistance appearing across 54V source is given by, — ½ Marks for Steps

$R_T = 4+(2+1)||8 = 4+ (24/11) = 6.182\Omega$

The current I = 54/6.182 = 8.735A

The current through 8Ω due to 54V source alone is given by,

$I_2 = I\ (3/12) = 8.735(1/4) =$ **2.184 A**

By Superposition theorem, the current through 8Ω due to both sources is given by,

$I_L=I_1+I_2= (2.12+ 2.184) =$ **4.304A** — 1 mark

5 f) Find current through 8Ω resistor of Figure No. 7 using Thevenin's theorem.

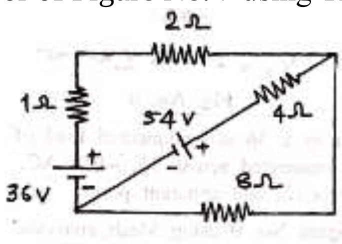
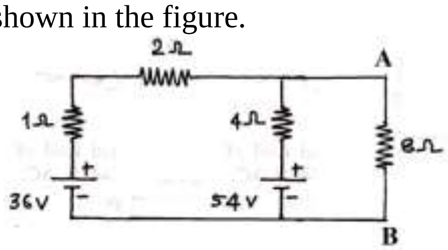


Fig. No. 7

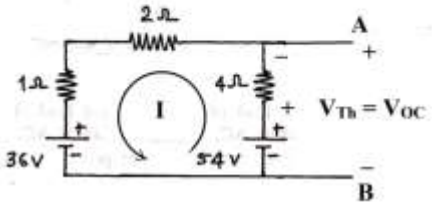
Ans:

The circuit is redrawn as shown in the figure.



A) Determination of Thevenin's Equivalent Voltage (V_{TH}):

The Thevenin's equivalent voltage V_{TH} is given by the open circuit voltage V_{OC} appearing across the load (8 Ω) terminals A-B when it is removed, as shown below.



1½ mark for V_{Th}

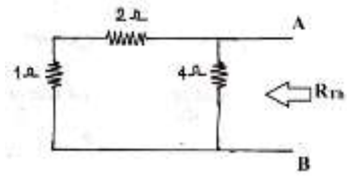
When the load branch (8 Ω) is removed, only one loop remains in the circuit making the loop or circuit current equal to that delivered by both the sources

$I = \frac{54-36}{(4+2+1)} = \frac{18}{7} = 2.57A$

The Thevenin's equivalent voltage is given by,

$V_{Th} = V_{OC} = V_{AB} = 54 - 4(I) = 54 - 4(2.57) =$ **43.72 V**

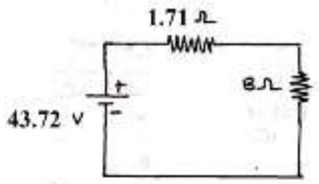
B) Determination of R_{TH}:



1½ mark for R_{Th}

$R_{Th} = 4||3 = 1.71\ \Omega$

C) Determination of I_L:



1 mark for I_L

$I_L = V_{Th}/(R_{Th}+R_L) = 43.72/(1.71+8) = 4.5\ A$

6 Attempt any FOUR of the following: 16

6 a) Find I_1, I_2, and I of the Figure No. 8

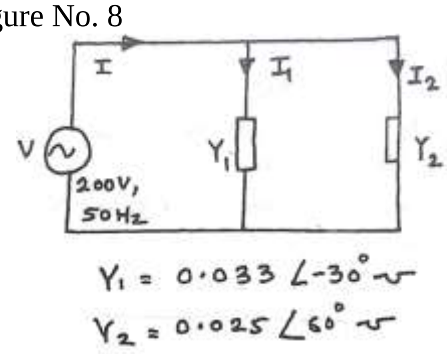


Fig. No. 8

Ans:

For parallel circuit shown in the figure,

$I_1 = V.Y_1 = 200\angle 0^\circ \times 0.033\angle -30^\circ =$ **$6.6\angle -30^\circ$ A = (5.716-j3.3) A** 1 mark

$I_2 = V.Y_2 = 200\angle 0° \times 0.025\angle 60°$ = **$5\angle 60°$ A = (2.5+j4.33) A** 1 mark
Total current $I = I_1 + I_2$ = (5.716-j3.3) + (2.5+j4.33) 1 mark
= **(8.216 +j 1.03) A = $8.28\angle 7.146°$ A** 1 mark

6 b) Current drawn by a 3ϕ star connected load of 12Amp. 0.8 p.f. lagging when connected across 3ϕ, 440V AC. Find active, reactive and apparent power.

Ans:
Data given:
Line Voltage V_L = 440V
Line current I_L = Phase current I_{Ph} = 12 A
Power factor cosϕ = 0.8 lagging ∴ sinϕ = 0.6 1 mark

i) Active power P = $\sqrt{3}V_L I_L cos\emptyset = \sqrt{3}(440)(12)(0.8) = \mathbf{7316.18\ W}$ 1 mark
ii) Reactive power Q = $\sqrt{3}V_L I_L sin\emptyset = \sqrt{3}(440)(12)(0.6) = \mathbf{5487.14\ VAr}$ 1 mark
iii) Apparent power S = $\sqrt{3}V_L I_L = \sqrt{3}(440)(12) = \mathbf{9145.23\ VA}$ 1 mark

6 c) Find I_L of Figure No. 9 using Mesh analysis.

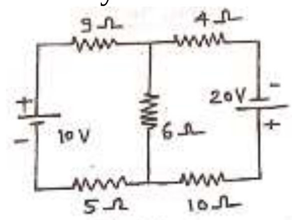
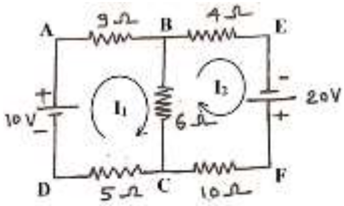


Fig. No. 9

Ans:



By applying KVL to loop ABCDA

$$10 - 9I_1 - 6(I_1 - I_2) - 5I_1 = 0$$

$$20I_1 - 6I_2 = 10 \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

1 mark

By applying KVL to Loop EFCBE

$$20 - 10I_2 - 6(I_2 - I_1) - 4I_2 = 0$$

$$6I_1 - 20I_2 = -20 \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

1 mark

Expressing eq.(1) and (2) in matrix form,

$$\begin{bmatrix} 20 & -6 \\ 6 & -20 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ -20 \end{bmatrix}$$

$$\therefore \Delta = \begin{vmatrix} 20 & -6 \\ 6 & -20 \end{vmatrix} = -400 + 36 = -364$$

By Cramer's rule,

$$I_1 = \frac{\begin{vmatrix} 10 & -6 \\ -20 & -20 \end{vmatrix}}{\Delta} = \frac{10(-20) - (-6)(-20)}{-364} = \frac{-200 - 120}{-364} = \mathbf{0.879\ A}$$

½ mark

$$I_2 = \frac{\begin{vmatrix} 20 & 10 \\ 6 & -20 \end{vmatrix}}{\Delta} = \frac{(20)(-20) - (6 \times 10)}{-364} = \frac{-400 - 60}{-364} = \mathbf{1.264\ A}$$ ½ mark

Current flowing through load resistance of 6Ω 1 mark
$I_L = I_2 - I_1 =$ 1.264 – 0.879 **= 0.385 A (Upward direction)**

6 d) Find current through 12Ω resistor using super position theorem.

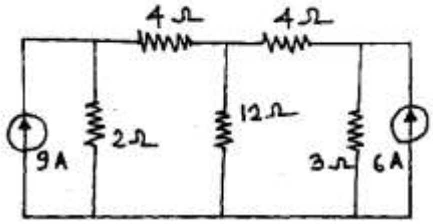
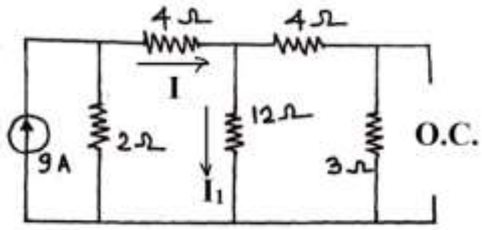


Fig. No. 10

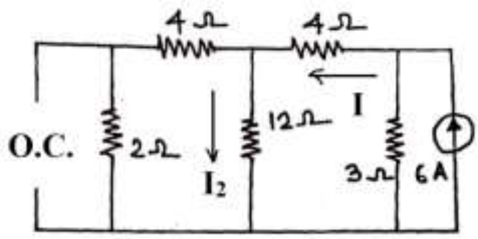
Ans:

(A) Consider current source of 9A acting alone:



The total resistance appearing across 2Ω is given by,
= 4+12||(4+3) = 4+ (84/19) = 8.42Ω
The current I = 9×2/(2+8.42) = 1.73A 1½ marks
The current through 12Ω due to 9A source alone is given by,
I_1 = I (4+3)/(12+4+3) = 1.73(7/19) = **0.6374 A**

(B) Consider current source of 6A acting alone:



The total resistance appearing across 3Ω is given by, 1½ marks
= 4+12||(4+2) = 4+ (72/18) = 8Ω
The current I = 6×3/(3+8) = 1.636A
The current through 12Ω due to 6A source alone is given by,
I_2 = I (4+2)/(12+4+2) = 1.636(6/18) = **0.5453 A**

By Superposition theorem, the current through 12Ω due to both sources is given by,
$I_L = I_1 + I_2$ = (0.6374+ 0.5453) = **1.1827A**

1 mark

6 e) Find R_{TH} for the circuit shown in Figure No. 11.

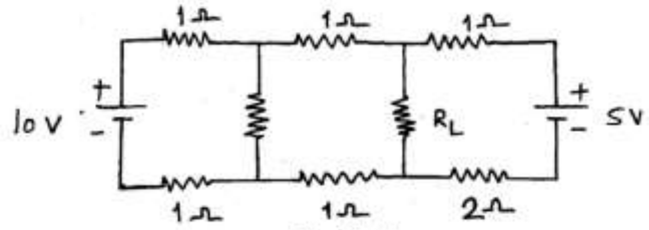
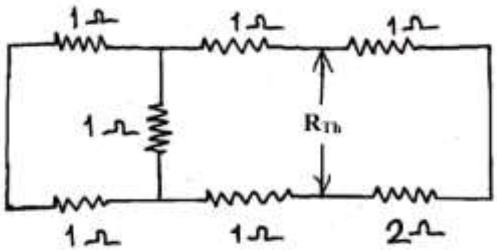


Fig. No. 11

Ans:



NOTE: Assume unspecified value of resistance equal to 1Ω

Referring to the figure, the Thevenin's equivalent resistance is given by,

$R_{Th} = (1+2)||\{1+1||(1+1)+1\}$

= 3||{1+(2/3)+1}

= 3||2.67

= (3×2.67)/(3+2.67)

= **1.41Ω**

1 mark for circuit diagram

3 marks for stepwise solution

6 f) Explain the concept of initial condition in switching circuits for the elements R, L, C.

Ans:

For the three basic circuit elements the initial conditions are used in following way:

i) Resistor:

At any time it acts like resistor only, with no change in condition.

1 mark for Resistor

ii) Inductor:

The current through an inductor cannot change instantly. If the inductor current is zero just before switching, then whatever may be the applied voltage, just after switching the inductor current will remain zero. i.e the inductor must be acting as open-circuit at instant t = 0. If the inductor current is I_0 before switching, then just after switching the inductor current will remain same as I_0, and having stored energy hence it is represented by a current source of value I_0 in parallel with open circuit.

As time passes the inductor current slowly rises and finally it becomes constant. Therefore the voltage across the inductor falls to zero$\left[v_L = L\frac{di_L}{dt} = 0\right]$.

1.5 marks for L

iii) Capacitor:

The voltage across capacitor cannot change instantly. If the capacitor voltage is zero initially just before switching, then whatever may be the current flowing, just after switching the capacitor voltage will remain zero. i.e the capacitor must be acting as short-circuit at instant t = 0. If capacitor is previously charged to some voltage V_0, then also after switching at t = 0, the voltage across capacitor remains same V_0. Since the energy is stored in the capacitor, it is represented by a voltage source V_0 in series with short-circuit.

1.5 marks for C

Model Answers

Winter – 2018 Examinations

Subject & Code: Electrical Circuits & Networks (17323)

As time passes the capacitor voltage slowly rises and finally it becomes constant. Therefore the current through the capacitor falls to zero$\left[i_C = C\frac{dv_C}{dt} = 0\right]$.
The initial conditions are summarized in following table:

Element and condition at $t = 0^-$	Initial Condition at $t = 0^+$