- You have **90 minutes** to answer the questions.
- Please write your **name** and **roll number** at appropriate places.
- Write the **key steps** of your solution of the problems in the space provided.
- You can solve the problems in the supplementary sheets provided but it will not be graded.

Name: ______________________ Roll number: __________ **Full Marks: 25**

Question	1	2	3	4	5	6	Total
Marks							

1. For the circuit shown in Figure 1, the voltage source $v_s(t)$ is given as

$$v_s(t) = 20\sin(2\pi 50 \times t) \text{ V}.$$

Plot the waveform of $i_R(t)$. You can assume that the forward voltage drop of the diode is zero. Label the figure appropriately. **3 marks**

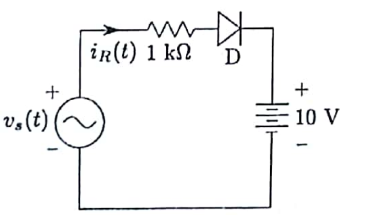
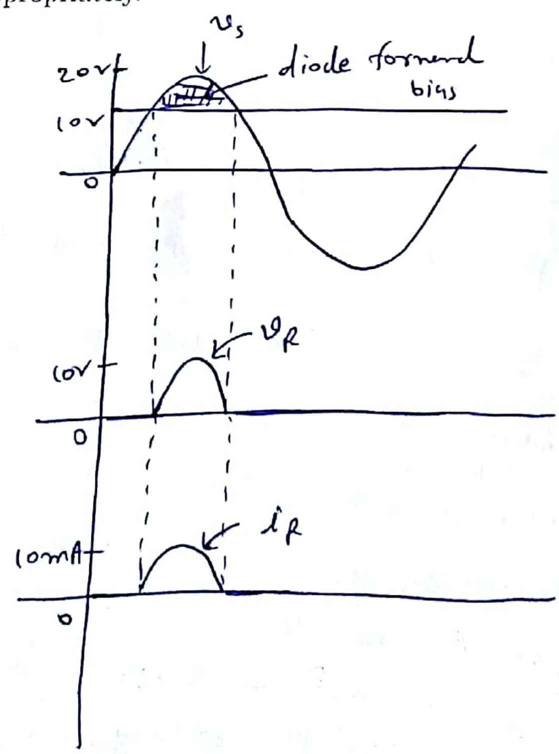


Figure 1: Circuit for Problem 1



(1) - plot
(2) - label

2. A separately excited DC motor runs at 1800 rpm under no-load with 200 V applied to the armature. The field voltage is maintained at its rated value. For the same field and armature voltage, the speed of the motor, when it delivers a torque of 5 N-m, is 1600 rpm. The rotational losses and armature reaction are neglected. 2+2=4 **marks**

- Find the value of the armature resistance of the DC motor.
- For the DC motor to deliver a torque of 2.5 N-m at 1600 rpm, find the value of the armature voltage needed to be applied.

No load $\Rightarrow I_a = 0$ (0.5) $\Rightarrow V_t = E_b = k\phi\omega \Rightarrow k\phi = \dfrac{200}{1800 \times \frac{2\pi}{60}} = 1.061$ (0.5)

$T = k\phi \dfrac{(V_t - k\phi\omega)}{R_a}$ (0.5) $\Rightarrow R_a = \dfrac{1.061\left(200 - 1.061 \times 1600 \times \frac{2\pi}{60}\right)}{5} = 4.7\Omega.$ (0.5)

$V_t = \dfrac{R_a T}{k\phi} + k\phi\omega = 188.8V.$ (0.5) (0.5)

+ (0.5) for using same $k\phi$
+ (0.5) for calculating E_b

3. The rotor of the DC machine of Problem 2 is now mechanically coupled to the rotor of a 50 Hz, three-phase, 4-pole induction machine. The DC machine is energized first with appropriate armature and field voltage and the machines are found to rotate at 1600 rpm. Subsequently the induction machine is connected to a 50 Hz, three-phase source with the phase sequence being consistent with the direction of rotation. 1.5+1.5+1=4 marks

- Is the induction machine operating in generating or motoring mode?
- Is the dc machine operating in generating or motoring mode?
- The final speed will be (a) >1600 rpm, (b) <1500 rpm, (c) between 1500 rpm and 1600 rpm.

Synchronous Speed of Induction machine $N_s = \dfrac{120f}{P} = \dfrac{120 \times 50}{4} = 1500$ rpm. (0.5)

$N_r = 1600$ rpm $\Rightarrow$ DC machine is in no load. DC machine is in motoring mode and $N_r > 1600$ rpm

$\therefore$ $N_r < 1600$ rpm, DC machine is in generating mode. (0.5) (0.5)

$N_r < 1500$ rpm $= N_s$, Induction machine is in Motoring mode ~~and N_r~~ generating mode. (0.5)

and $N_r > 1500$ rpm $= N_s$ induction machine is in motoring and other in generating; Contd

Since one of them has to be in motoring condition. (1) is the only feasible mode.

$1500 < N_r < 1600$

$\therefore$ DC in motoring mode and IM in generating mode (1)

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4. For the circuit shown in Figure 2, calculate the value of i_R when (a) $V_{dc} = 3$ V, (b) $V_{dc} = 10$ V. The diodes D_1 and D_2 are assumed to be ideal with zero forward voltage drop. **3 marks**

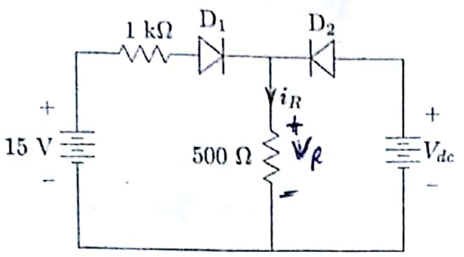


Figure 2: Circuit for Problem 4

(a) $V_{dc} = 3$ V

case - I → D_1 - OFF, D_2 - OFF
$V_R = 0 < 15$ V ⇒ D_1 should be on (not consistant)

case-2 → D_1 - ON, D_2 - OFF (0.5)
$V_R = 5$ V > 3 V ⇒ consistance.
$\therefore\ i_R = \frac{5}{500} = 10$ mA (1)

(b) $V_{dc} = 10$ V

case - 1 → D_1 - OFF, D_2 - OFF
$V_R = 0 < 15$ V ⇒ D_1 - ON (Not consistance)

case-2 → D_1 - ON, D_2 - OFF
$V_R = 5$ V < 10 V ⇒ D_2 - ON (Not consistance)

case-3 → D_1 - OFF, D_2 - ON
$V_R = 10$ V < 15 V ⇒ D_1 - ON (Not consisten)

case-4 → D_1 - ON, D_2 - ON (0.5)
$i_R = \frac{10}{500} = 20$ mA (1)

5. For the circuit shown in Figure 3, the zener diode Z can be assumed to have zero forward voltage drop. The zener breakdown voltage (V_Z) is 5 V. Calculate the value of i_R when (a) R = 150 Ω, (b) R = 50 Ω. What is the power dissipated in the zener diode in both the cases? **3 marks**

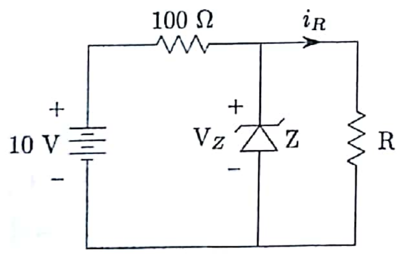


Figure 3: Circuit for Problem 5

(a) $R = 150\ \Omega$

$\therefore\ V_R = \frac{150}{250} \times 10 = 6$ V > 5 V (V_Z)

$\therefore$ zener breakdown

$\therefore\ V_R = V_Z = 5$ V

$i_R = \frac{5}{150} = \frac{1}{30}$ A $= 33.33$ mA (1)

$i_Z = \left(\frac{10-5}{100}\right) - i_R = 50$ mA $- 33.33$ mA $= 16.67$ mA

$\therefore\ P_Z = V_Z i_Z =$ ~~250 mW~~ 83.35 mW (1)

(b) $R = 50\ \Omega$

$\therefore\ V_R = \frac{50}{150} \times 10 = 3.33$ V < 5 V (V_Z)

$\therefore$ Zener does not beakdown

$\therefore\ i_R = \frac{10}{150} = \frac{1}{15}$ A $= 66.6667$ mA (0.5)

& $P_Z = 0$ W (0.5)

Cont.

6. The transformers in Figure 5 and Figure 4 are ideal and

$$v_{AN}(t) = \sqrt{2} \times 110 \sin(2\pi 50 \times t) \text{ V},$$
$$v_{BN}(t) = \sqrt{2} \times 110 \sin\left(2\pi 50 \times t - \frac{2\pi}{3}\right) \text{ V},$$
$$v_{CN}(t) = \sqrt{2} \times 110 \sin\left(2\pi 50 \times t + \frac{2\pi}{3}\right) \text{ V}.$$

The three-phase transformer is constructed by appropriate connections of three single-phase ideal transformers of turns ratio 1:2. The transformer is connected to a balanced star-connected three-phase resistive load of resistance 5 Ω per phase. For both the circuits, calculate the rms value of the primary side line currents $i_A(t)$, $i_B(t)$ and $i_C(t)$ and that of the secondary side line currents $i_a(t)$, $i_b(t)$ and $i_c(t)$.
If the equivalent load seen at the source terminals A, B, C be a star-connected balanced load of impedance Z per phase, calculate the value of Z for both the cases. **8 marks**

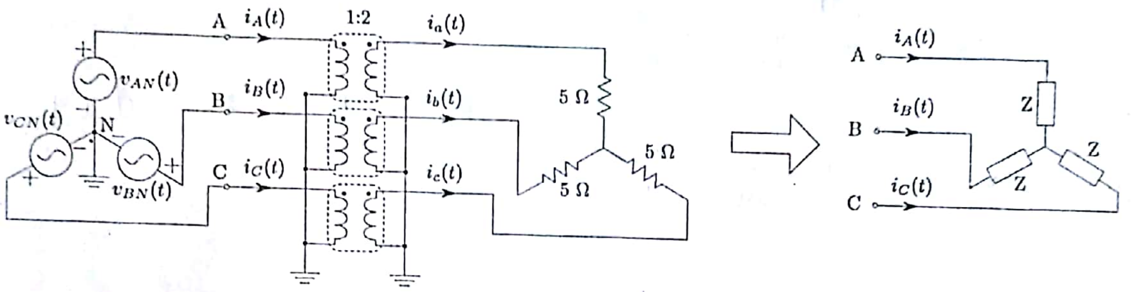
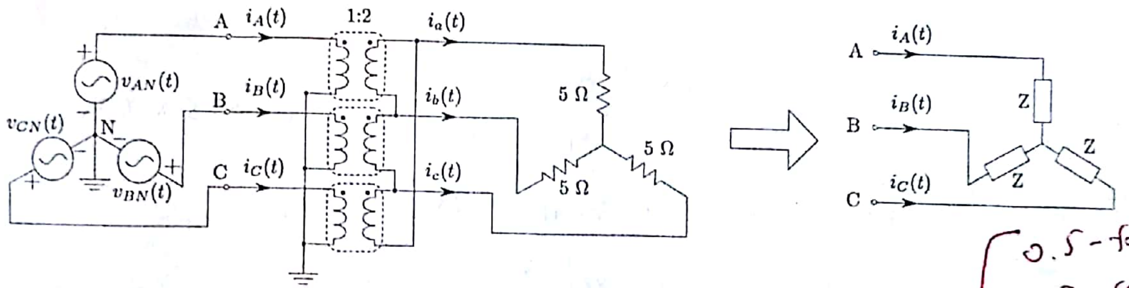


Figure 4: Circuit for Problem 6



[0.5 - formula
0.5 - correct answer]

Figure 5: Circuit for Problem 6

Y - Y

(1) $V_{aN} = 2 \times V_{AN} = \sqrt{2} \times 220 \sin(2\pi 50 \times t)$ V.

(1) $i_a = \frac{V_{aN}}{5} = \sqrt{2} \times 44 \sin(2\pi 50 \times t)$ A $\Rightarrow i_{a,rms} = 44$ A.

(1) $i_A = 2 \times i_a = \sqrt{2} \times 88 \sin(2\pi 50 \times t)$ A $\Rightarrow i_{A,rms} = 88$ A.

Cont.

$\cancel{Z = \frac{V_{AN}}{i_A} = \sqrt{2} \times 100}$

$$Z = \frac{\text{phasor } V_{AN}}{\text{phasor } i_A} = \frac{110\angle 0^\circ}{88\angle 0^\circ} = 1.25\,\Omega.$$ (1)

Y – Δ Connection.

$V_{ab} = 2 \times V_{AN} = \sqrt{2} \times 220 \sin(2\pi 50 t)$.

phase voltage w.r.t. star point of load is

$$= \frac{\sqrt{2} \times 220}{\sqrt{3}} \sin(2\pi 50t - 30^\circ).$$ (1)

$$\therefore\ i_a(t) = \frac{\sqrt{2} \times 220}{\sqrt{3} \times 5} \sin(2\pi 50t - 30^\circ)$$

$$i_{a,rms} = \frac{220}{\sqrt{3} \times 5} = 25.40\ \text{A}.$$

The currents in the secondary windings are

$$i_{as}(t) = \frac{\sqrt{2} \times 220}{\sqrt{3} \times \sqrt{3} \times 5} \sin(2\pi 50t - 30^\circ + 30^\circ).$$ (1)

$$= \frac{\sqrt{2} \times 220}{15} \sin(2\pi 50t)\ \text{A}$$

$$i_A(t) = 2\, i_{as}(t) = \sqrt{2} \times \frac{440}{15} \sin(2\pi 50t)\ \text{A}$$ (1)

$$i_{A,rms} = 29.33\ \text{A}.$$

$$Z = \frac{\text{phasor } V_{AN}}{\text{phasor } i_A} = \frac{110\angle 0^\circ}{\frac{440}{15}\angle 0^\circ} = 3.75\ \Omega.$$

(1)