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India's Best Institute for IES, GATE & PSUs

Detailed Solutions

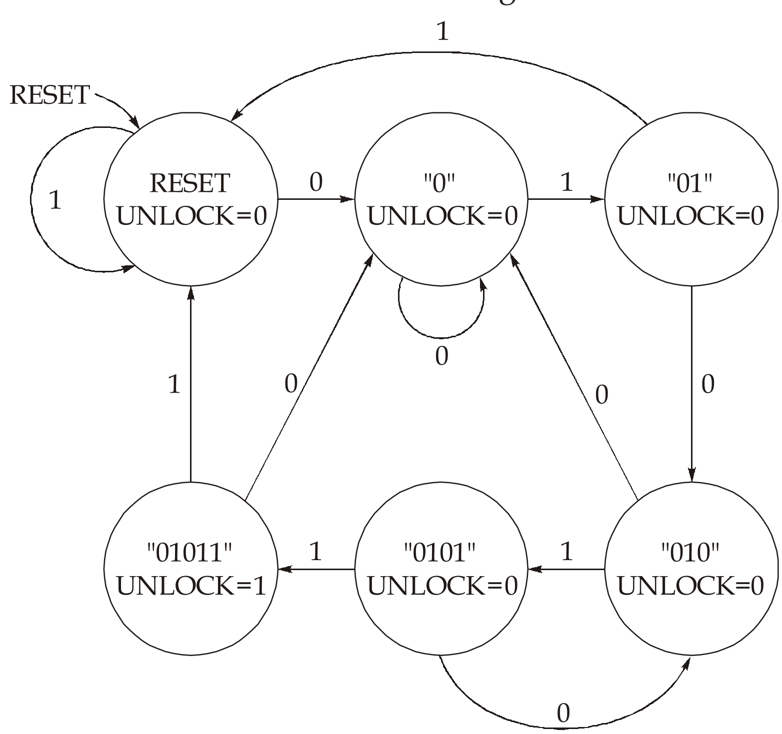
ESE-2023 Mains Test Series

E & T Engineering Test No : 7

Section A : Advanced Electronics + Electronic Measurements and Instrumentation

Q.1 (a) Solution:

For the required combination "01011" the state diagram can be drawn as below:



Q.1 (b) Solution:

With a large number of readings, a simple tabulation of data is very convenient.

Reading, x	Deviation $d = x - \frac{\Sigma x}{n}$	Deviation d^2
101.2	–0.1	0.01
101.7	0.4	0.16
101.3	0.0	0.00
101.0	–0.3	0.09
101.5	0.2	0.04
101.3	0.0	0.00
101.2	–0.1	0.01
101.4	0.1	0.01
101.3	0.0	0.00
101.1	–0.2	0.04
$\Sigma x = 1013.0$	$\Sigma\|d\| = 1.4$	$\Sigma d^2 = 0.36$

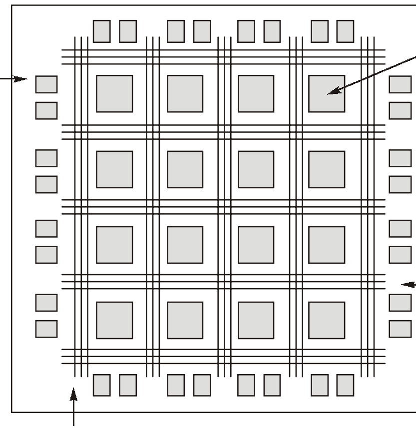
(i) Arithmetic Mean, $\bar{x} = \frac{\Sigma x}{n} = \frac{1013.0}{10} = 101.3\ \Omega$

(ii) Standard deviation $\sigma = \sqrt{\frac{\Sigma d^2}{n-1}} = \sqrt{\frac{0.36}{9}} = 0.2\ \Omega$

(iii) Probable error = 0.6745 σ = 0.6745 × 0.2 = 0.1349 Ω

Q.1 (c) Solution:

Field programmable gate array (FPGA) is a fully fabricated IC chip in which the interconnections can be programmed to implement different functions. An FPGA chip has thousands of logic gates which are to be connected to implement any logic function. A typical FPGA architecture is shown below.



It has the following three main components:

- I/O buffers
- Array of configurable logic blocks (CLBs)
- Programmable interconnects

In the FPGA-based design, first a behavioural netlist is written to describe the functionality of the design. This is done using the hardware description languages such as Verilog or VHDL. Then the netlist is synthesized to come up with the gate level design. The next step is to map the logic blocks into available logic cells. This process is called the technology-mapping. This is followed by placement and routing, which configures the CLBs and defines interconnections. The next step is to generate the bit-stream and download the bit-stream into an FPGA chip with the help of a software interface. Then the FPGA chip can function as desired as long as the power is ON, or it is reprogrammed.

Q.1 (d) Solution:

The special arrangements incorporated in electrodynamometer wattmeter to make it a low power type of wattmeter are as follows:

(i) Pressure coil current: The pressure coil circuit is designed to have a low value of resistance; so that the current, flowing through it is increased to give an increased operating torque. The pressure coil current in a low power factor wattmeter may be as much as 10 times the value employed for high power factor wattmeters.

(ii) Compensation for pressure coil current: The power being measured in a low power factor circuit is small and current is high on account of low power factor.

If ordinary wattmeter is used, it result into large power loss in the current coil and therefore, it will give large error.

Hence, it is absolutely necessary to compensate for the pressure coil current in a low power factor wattmeter.

(iii) Compensation for inductance of pressure coil: The error caused by pressure coil inductance is $VI \sin \phi \tan \beta$. Now, with the low power factor, the value of ϕ is large and therefore, the error is correspondingly large. Hence, in a low power factor wattmeter, this is compensated by connecting a capacitor across a part of series resistance of the pressure coil circuit.

(iv) Small control torque: Low power factor wattmeter are designed to have a small control torque so that they give full scale deflection for power factor as low as 0.1.

Q.1 (e) Solution:

(i) The emf generated in thermocouple for maximum deflection with series resistance R_s is given by

$$\text{emf}(E) = i(R_m + R_s + R_e)$$

$$E = 0.4 \times 10^{-3}[100 + R_s + 18]$$

$$66.6 \times 10^{-3} = 0.4 \times 10^{-3}[100 + R_s + 18]$$

$$\therefore \quad R_s = 48.5\ \Omega$$

(ii) Current in the circuit with increased resistance of 2 Ω in R_e is given as

$$i' = \frac{66.6 \times 10^{-3}}{100 + 48.5 + 2 + 18}$$

$$i' = 0.395 \text{ mA}$$

$$\therefore \quad \text{Approximate error in temperature} = \frac{0.395 - 0.4}{0.4} \times 900$$

$$= -11.25°\text{C}$$

(iii) Change in resistance of coil with a temperature increase of 10°C

$$= 100 \times 0.00426 \times 10 = 4.26\ \Omega$$

The current in the circuit with increased resistance of coil

$$i'' = \frac{66.6 \times 10^{-3}}{100 + 4.26 + 48.5 + 18}$$

$$i'' = 0.39 \text{ mA}$$

$$\therefore \quad \text{Approximate error in temperature} = \frac{i'' - i}{i} \times T$$

$$= \frac{0.39 - 0.4}{0.4} \times 900 = -22.5°\text{C}$$

Q.2 (a) Solution:

State table of Moore-machine,

Present State	Input X	Next State	Output Z
q_0	0	q_1	0
	1	q_2	0
q_1	0	q_1	0
	1	q_3	1
q_2	0	q_4	1
	1	q_2	0
q_3	0	q_4	1
	1	q_2	0
q_4	0	q_1	0
	1	q_3	1

Here, the states q_1 and q_4 are equivalent and the states q_2 and q_3 are equivalent.
So, reduced state table,

Present State	Input X	Next State	Output Z
q_0	0	q_1	0
	1	q_2	0
q_1	0	q_1	0
	1	q_2	1
q_2	0	q_1	1
	1	q_2	0

Excitation table: Let state q_0 = 00, q_1 = 01, q_2 = 10

Present State Q_1	Q_0	Input X	Next State Q_1^+	Q_0^+	J-K FF Inputs J_1	K_1	J_0	K_0	Output Z
0	0	0	0	1	0	X	1	X	0
0	0	1	1	0	1	X	0	X	0
0	1	0	0	1	0	X	X	0	0
0	1	1	1	0	1	X	X	1	1
1	0	0	0	1	X	1	1	X	1
1	0	1	1	0	X	0	0	X	0

K-Map for J_1:

Q_1 \ Q_0X	00	01	11	10
0	0	1	1	0
1	X	X	X	X

$J_1 = X$

K-Map for K_1:

Q_1 \ Q_0X	00	01	11	10
0	X	X	X	X
1	1	0	X	X

$K_1 = \bar{X}$

K-Map for J_0:

$Q_1 \backslash Q_0X$	00	01	11	10
0	1	0	X	X
1	1	0	X	X

$$J_0 = \bar{X}$$

K-Map for K_0:

$Q_1 \backslash Q_0X$	00	01	11	10
0	X	X	1	0
1	X	X	X	X

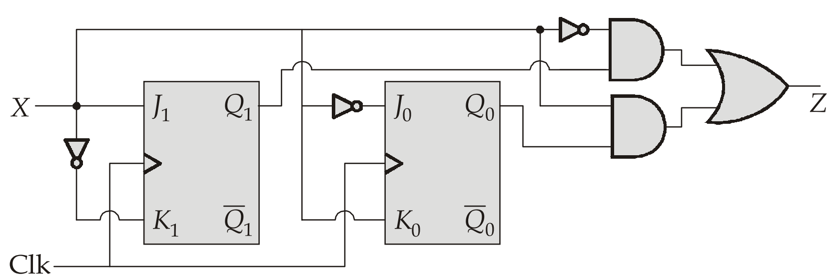
$$K_0 = X$$

K-Map for output Z:

$Q_1 \backslash Q_0X$	00	01	11	10
0	0	0	1	0
1	1	0	X	X

$$Z = Q_0X + Q_1\bar{X}$$

Circuit:



Q.2 (b) Solution:

Resistance of fixed (field) coils,

$$R_1 = 3\ \Omega$$

Reactance of fixed coils at 50 Hz,

$$X_1 = 2\pi \times 50 \times 0.12 = 37.7\ \Omega$$

Reactance of moving coil at 50 Hz,

$$X_2 = 2\pi \times 50 \times 0.003 = 0.9425\ \Omega$$

Let the current being measured be I

and current flowing through fixed coil be I_1,

$$I_1 = \frac{IR_2}{R_1 + R_2} = \frac{I \times 30}{30 + 3} = 0.909\ I$$

Let current flowing through moving coil be I_2,

$$I_2 = \frac{I\,R_1}{R_1 + R_2} = \frac{3I}{33} = \frac{I}{11}$$

Deflection, $\theta \propto I_1 I_2$

$$= K I_1 I_2 = 0.0826\, K I^2$$

with A.C impedance of fixed coils,

$$Z_1 = \sqrt{(3)^2 + (37.7)^2} = 37.8\ \Omega$$

Phase angle, $\alpha_1 = \tan^{-1}\dfrac{37.7}{3} = 85.4°$

Impedance of moving coil $Z_2 = \sqrt{(30)^2 + (0.9425)^2} = 30\ \Omega$

Phase angle, $\alpha_2 = \tan^{-1}\dfrac{0.9425}{30} = 1.8°$

Current through fixed coil, $I_1 = \dfrac{Z_2\angle\alpha_2}{Z_1\angle\alpha_1 + Z_2\angle\alpha_2} \times I = 0.5904 I\angle{-47.7°}$

Current through moving coil, $I_2 = \dfrac{Z_1\angle\alpha_1}{Z_1\angle\alpha_1 + Z_1\angle\alpha_2} \times I = 0.7431 I\angle 36°$

Phase difference between I_1 and I_2 is

$$\phi = -47.7° - 36°$$

$$= -83.7°$$

$\therefore$ $\cos\phi = 0.1097$

Deflection with a.c.

$$\theta = K I_1 I_2 \cos\phi$$

$$= K \times 0.5904 \times I \times 0.743 \times I \times 0.1097$$

$$= 0.048\ K I^2$$

$$\text{Percentage error} = \frac{\text{Reading on a.c.} - \text{Reading on d.c.}}{\text{Reading on d.c.}}$$

$$= \frac{0.048 K I^2 - 0.0826 K I^2}{0.0826 K I^2} \times 100 = -41.96\%$$

Q.2 (c) Solution:

(i) The total number of dopant atoms per unit area of semiconductor can be given by,

$$Q(t) = \frac{2C_s}{\sqrt{\pi}}\sqrt{Dt}$$

Given that, t = 1 hour = 3600 s, $C_s = 10^{19}$ cm^{-3} and $D = 2 \times 10^{-14}$ cm^2/s.

So, $$Q(t) = 2\times 10^{19} \times \sqrt{\frac{2\times 10^{-14}\times 3600}{\pi}} = 9.57\times 10^{13}\ \text{atoms/cm}^2$$

(ii) The concentration at a particular distance (x) from the surface can be given by,

$$C(x, t) = C_s \operatorname{erfc}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$C(x, t) = 10^{15}$ cm^{-3} at,
$$x = 2\sqrt{Dt}\operatorname{erfc}^{-1}\left[\frac{C(x,t)}{C_s}\right]$$

$$= 2\sqrt{2\times10^{-14}\times3600}\operatorname{erfc}^{-1}\left[\frac{10^{15}}{10^{19}}\right]\text{cm}$$

$$= 2\times2.75\times\sqrt{7200}\times10^{-7}\ \text{cm} = 466.7\ \text{nm}$$

(iii) The gradient of the diffusion profile can be given by,

$$\frac{dC}{dx} = -\frac{C_s}{\sqrt{\pi Dt}}e^{-x^2/4Dt}$$

So,
$$\left.\frac{dC}{dx}\right|_{x=0} = -\frac{C_s}{\sqrt{\pi Dt}} = -\frac{10^{19}}{\sqrt{\pi\times2\times10^{-14}\times3600}} = -6.65\times10^{23}\ \text{cm}^{-4}$$

(iv)
$$\left.\frac{dC}{dx}\right|_{x=466.7\text{ nm}} = -6.65\times10^{23}\times e^{-(466.7\times10^{-7})^2/(4\times2\times10^{-14}\times3600)}\ \text{cm}^{-4}$$

$$= -3.45\times10^{20}\ \text{cm}^{-4}$$

Q.3 (a) Solution:

(i) **Strain Gauge:** If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both length and diameter of conductor change. Also, there is a change in the value of resistivity of the conductor when it is strained and this property is called piezoresistive effect. Therefore, resistance strain gauge are known as piezoresistive gauges. The strain gauge are used for measurement of strain and associated stress in experimental stress analysis. Also, many other detectors and transducers notably the load cells, torque meters, diaphragm type pressure gauges, temperature sensors, accelerometers and flow meters, employ strain gauges as secondary transducers.

The Gauge factor is given as

$$G_f = 1 + 2\nu + \frac{\Delta\rho/\rho}{\in}$$

Since, the change in value of resistivity of a material is neglected.

$$G_f = 1 + 2\nu$$

$$\text{Poission ratio, } \nu = \frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{\Delta D/D}{\Delta L/L}$$

where, $\Delta D = 0.02$ mm, $D = 1.5$ mm

$\Delta L = 1$ mm, $L = 24$ mm

$$\therefore \quad \nu = \frac{\frac{0.02}{1.5}}{\frac{1}{24}} = 0.32$$

$$\text{Gauge factor } G_f = 1 + 2(0.32) = 1.64$$

Now, the change in the value of resistance of the gauge when strained is given by

$$\frac{\Delta R}{R} = G_f \times \frac{\Delta L}{L}$$

$$\Delta R = 1.64 \times \left(\frac{1}{24}\right) \times 120$$

$$\Delta R = 8.2\ \Omega$$

(ii) Given; Current $I_{\text{FSD}} = 100$A, $I_M = 10$ A; Resistance $R = 0.018\ \Omega$, Inductane $L = 180\ \mu$H

1. Multiplying power of shunt,

$$m = \frac{I_{FSD}}{I_M} = \frac{100}{10} = 10$$

In order to extend the range of Ammeter, we need shunt with parameter R_{sh} and L_{sh}.

We know that,

$$\text{Shunt resistance, } R_{\text{sh}} = \frac{R}{m-1} = \frac{0.018}{10-1} = \frac{0.018}{9} = 0.002\ \Omega$$

In order that the meter read correctly at all frequencies, the time constants of meter and shunt circuits should be equal. Under this condition,

$$\frac{L}{R} = \frac{L_{\text{sh}}}{R_{\text{sh}}}$$

$\therefore$ Inductane of shunt,

$$L_{\text{sh}} = \frac{L}{R} R_{sh} = \frac{180 \times 10^{-6}}{0.018} \times 0.002$$

$$L_{\text{sh}} = 20\ \mu\text{H}$$

2. With DC, current through the meter for a total current of 100 A is,

$$I_{MFSD} = \frac{R_{sh}}{R + R_{sh}} \times I_{FSD}$$

$$= \frac{0.002}{0.002 + 0.018} \times 100$$

$$I_{MFSD} = 10 \text{ A}$$

3. With 50 Hz, the current through the meter for a total current of 100 A is,

$$I_{MFSD} = \frac{\sqrt{R_{sh}^2 + \omega^2 L_{sh}^2}}{\sqrt{(R_{sh} + R)^2 + \omega^2 (L_{sh} + L)^2}} \times I_{FSD}$$

$$= \frac{\sqrt{(0.002)^2 + (2\pi \times 20 \times 10^{-6})^2}}{\sqrt{[0.002 + 0.018]^2 + \left[2\pi \times 50 \times 200 \times 10^{-6}\right]^2}} \times 100$$

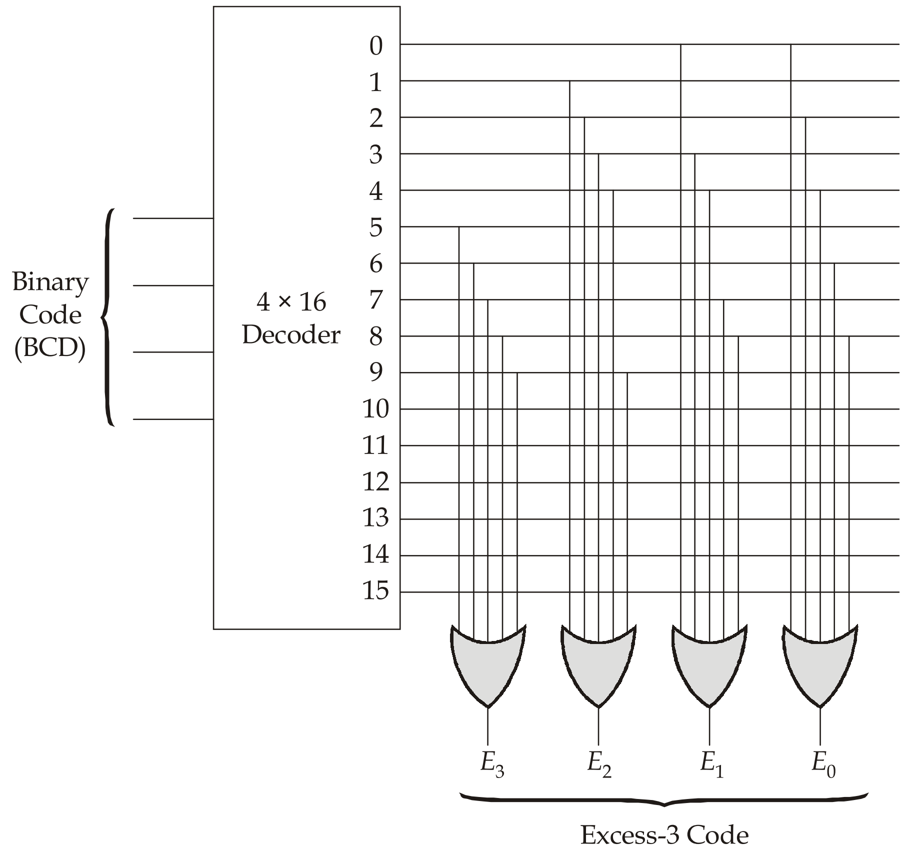
$$I_{MFSD} = 3.03 \text{ A}$$

4. $$\text{Error} = \frac{3.03 - 10}{10} \times 100 = -69.7\%$$

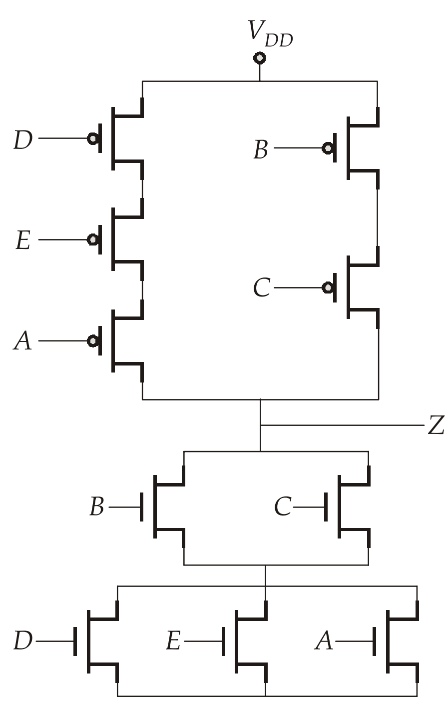
Q.3 (b) Solution:

(i)

Binary				**Excess-3**			
A	B	C	D	E_3	E_2	E_1	E_0
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
0	1	1	0	1	0	0	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	0	1	1	1	0	0



(ii) Given, $$Z = \overline{(D+E+A)(B+C)}$$



Two same-type transistors in parallel have their transconductances added if on at same time. If both transistors are in parallel and the L values are the same for both, we can add the widths to get an effective single transistor equivalent,

i.e., $$(W/L)_{eq} = (W/L)_a + (W/L)_b.$$

Two same-type transistors in series have their resistances added if on at same time. If both transistors are in series and the W values are the same for both, we can add the lengths to get an effective single transistor equivalent,

i.e., $$(W/L)_{eq} = 1\ /\ [(W/L)_a + (W/L)_b].$$

$$\left(\frac{W}{L}\right)_{n,\,eq} = \frac{1}{\dfrac{1}{\left(\frac{W}{L}\right)_D+\left(\frac{W}{L}\right)_E+\left(\frac{W}{L}\right)_A}+\dfrac{1}{\left(\frac{W}{L}\right)_B+\left(\frac{W}{L}\right)_C}}$$

$$= \frac{1}{\dfrac{1}{30}+\dfrac{1}{20}}$$

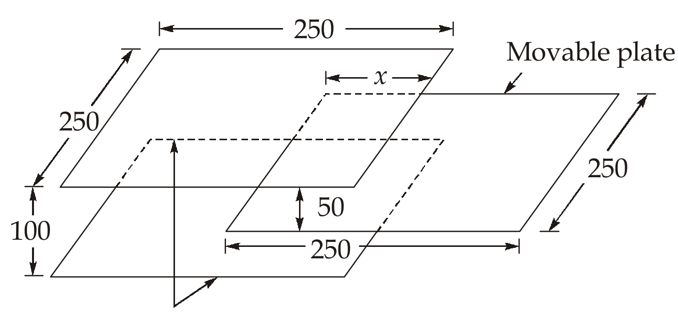
$$\left(\frac{W}{L}\right)_{n,\,eq} = 12$$

$$\left(\frac{W}{L}\right)_{p,\,eq} = \frac{1}{\dfrac{1}{\left(\frac{W}{L}\right)_D}+\dfrac{1}{\left(\frac{W}{L}\right)_E}+\dfrac{1}{\left(\frac{W}{L}\right)_A}}+\frac{1}{\dfrac{1}{\left(\frac{W}{L}\right)_B}+\dfrac{1}{\left(\frac{W}{L}\right)_C}}$$

$$= \frac{1}{\dfrac{1}{15}+\dfrac{1}{15}+\dfrac{1}{15}}+\frac{1}{\dfrac{1}{15}+\dfrac{1}{15}} = 12.5$$

Q.3 (c) Solution:

The arrangement of plates is shown below when the movable plate has moved in a distance x mm.



Area of plates: $A = 250 \times x\ \text{mm}^2 = 250x \times 10^{-6}\ \text{m}^2$

Distance between the plates $d = 50\ \text{mm} = 50 \times 10^{-3}\ \text{m}$

The capacitance of the arrangement is

$$C_{eq} = C_1 + C_2 \text{ [There are two capacitors in parallel]}$$

Since all the dimensions are same $\therefore \quad C_1 = C_2$

$$\therefore \quad C_{eq} = 2\,C = \frac{2 \times \varepsilon_0 A}{d}$$

$$\therefore \quad C_{eq} = \frac{2 \times 8.85 \times 10^{-12} \times 250x \times 10^{-6}}{50 \times 10^{-3}}$$

$$C_{eq} = 8.85x \times 10^{-14}\text{ F}$$

On account of the movement of the movable plate, the effective capacitance changes. Rate of change of capacitance is given by

$$\frac{dC}{dx} = 0.0885 \times 10^{-12}\,\frac{\text{F}}{\text{mm}}$$

Let x_0 be the initial displacement of moving plate in mm.

$\therefore$ Net displacement $= x - x_0$

Hence, $$x - x_0 = \frac{1}{2}\frac{V^2}{K}\frac{dC}{dx}$$

For $V = 12\text{ kV} = 12000\text{ V}$, $x = \dfrac{250}{4} = 62.5\text{ mm}$

$$62.5 - x_0 = \frac{1}{2}\left[\frac{(12000)^2}{K}\right] \times 0.0885 \times 10^{-12}$$

$$62.5 - x_0 = \frac{6.372 \times 10^{-6}}{K} \quad ...(1)$$

For $V = 32\text{ kV} = 32000\text{ V}$, $x = \dfrac{250}{2} = 125\text{ mm}$

$$\therefore \quad 125 - x_0 = \frac{1}{2}\left[\frac{(32000)^2}{K}\right] \times 0.0885 \times 10^{-12}$$

$$\therefore \quad 125 - x_0 = \frac{45.31}{K} \times 10^{-6} \quad ...(2)$$

On solving equation (1) and (2),

we get, $$x_0 = 52.3\text{ mm and } K = 0.623 \times 10^{-6}\text{ N/m}$$

Let the voltage applied for a displacement moving plate of three quarter way in be V.

Hence, for $x = 0.75 \times 250 = 187.5$ mm, Voltage is V.

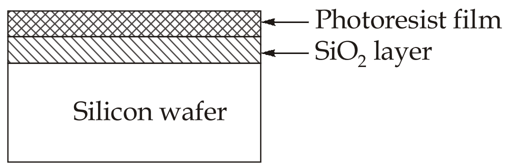
$$\therefore \quad 187.5 - 52.3 = \frac{1}{2} \times \frac{V^2}{0.623 \times 10^{-6}} \times 0.0885 \times 10^{-12}$$

$$\therefore \quad V = 43.6\text{ kV}$$

Q.4 (a) Solution

Step 1 : Photoresist Application

Laying a film of a photoresist (light sensitive liquid) on the wafer surface which is covered by the oxide layer. For ideal case, the film should be uniform, highly adherent and free from dust.

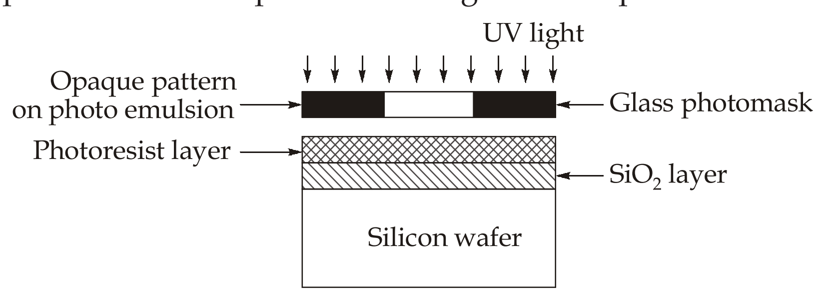


Step 2 : Prebake

Here, the wafer covered with photoresist is put into an oven to drive off the solvents. It also hardens the wafer and form semisolid film.

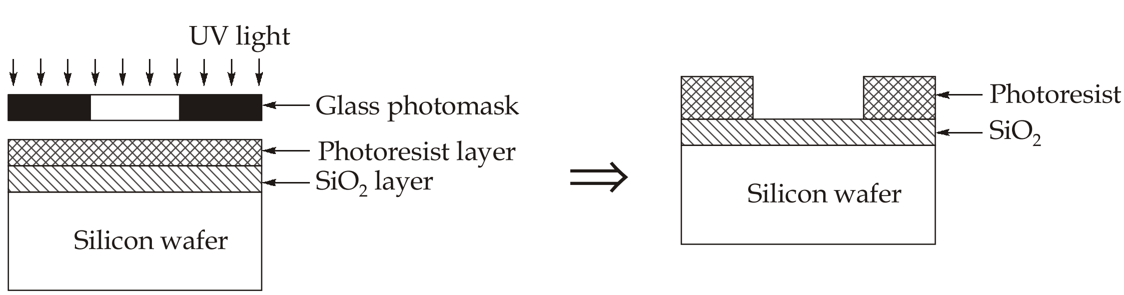
Step 3 : Alignment and Exposure

Then the wafer having photoresist is placed in apparatus called mask aligner (used to align mask to the pattern) in very close proximity (25 to 125 μm) to a photomask. Photomask should be correctly lined up with reference masks or a pre-existing pattern on the wafer as shown in the figure below. Then after alignment, the wafer is brought near to photomask.After this the UV light is turned on and the areas which are not covered by photomask are exposed to UV light. The exposure time is 3 to 10 sec.



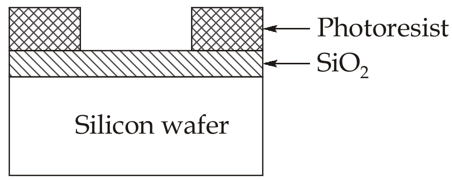
Step 4 : Development

The exposed photoresist (positive) becomes soft which can be removed easily by developer solution and the unexposed photoresist remains hard which is not soluble in developer solution.



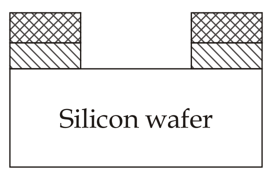
Step 5 : Post Bake

After these steps, wafers are post bake in an oven at a temperature of 150°C for 30 to 60 min. It is used to toughen the remaining photoresist material and the wafer become more adhesive and resistant to hydrofluoric acid (HF) used for etching process.



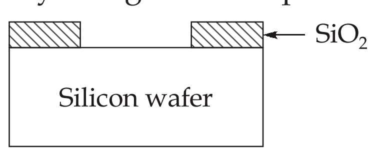
Step 6 : Oxide Etching

After post bake, the remaining resist is hardened and acts as a convenient mask through which the oxide layer can be etched away to expose areas of semiconductor underneath. For this process, the wafers are immersed in HF acid solution. HF is a diluted solution of H_2O and HF typically 10 : 1.



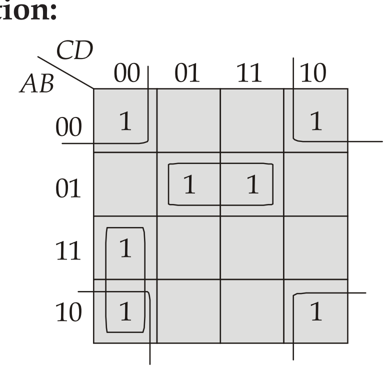
Step 7 : Photoresist Stripping

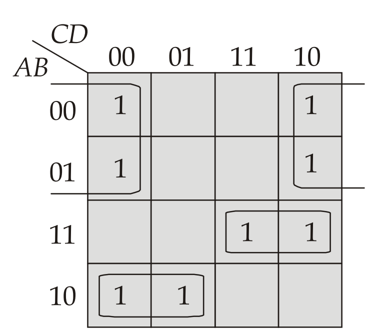
Here, the removal of photoresist material takes place with the mixture of sulphuric acid and hydrogen peroxide and by using abrasion process.

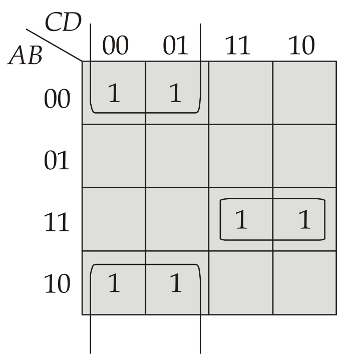


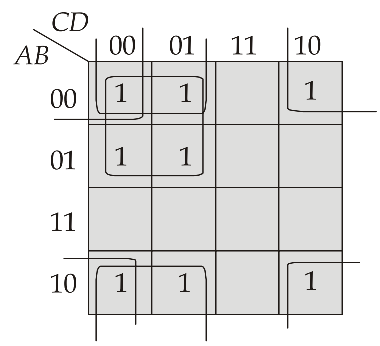
Q.4 (b) Solution:

Minimization:





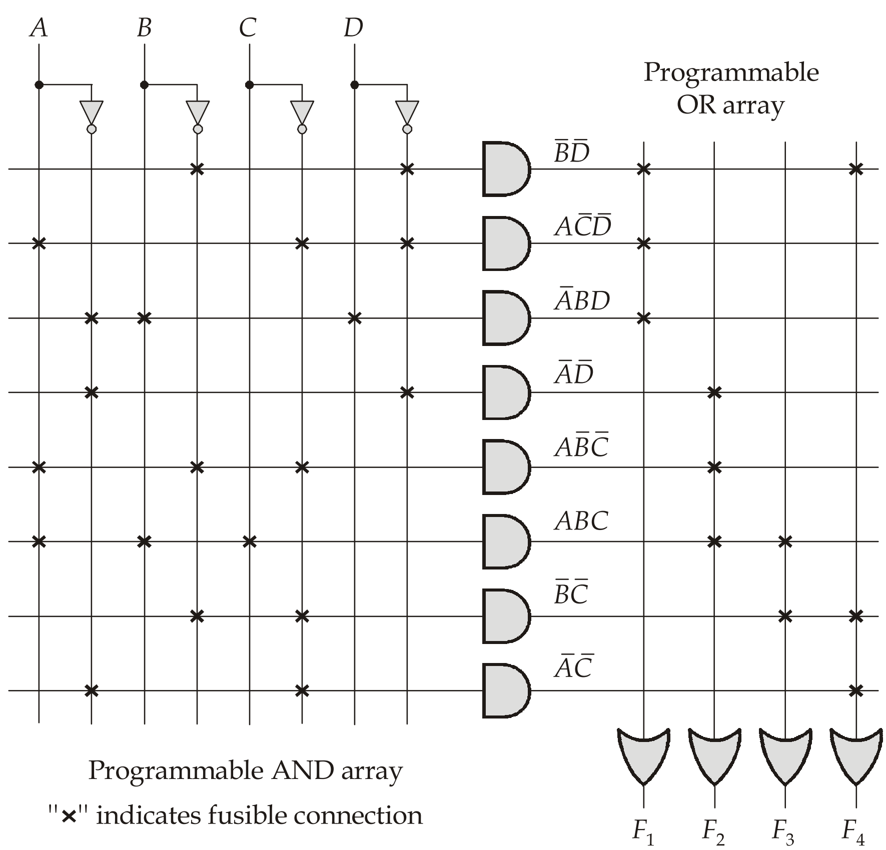




$$F_1 = \bar{B}\bar{D} + A\bar{C}\bar{D} + \bar{A}BD$$
$$F_2 = \bar{A}\bar{D} + A\bar{B}\bar{C} + ABC$$
$$F_3 = \bar{B}\bar{C} + ABC$$
$$F_4 = \bar{A}\bar{C} + \bar{B}\bar{D} + \bar{B}\bar{C}$$

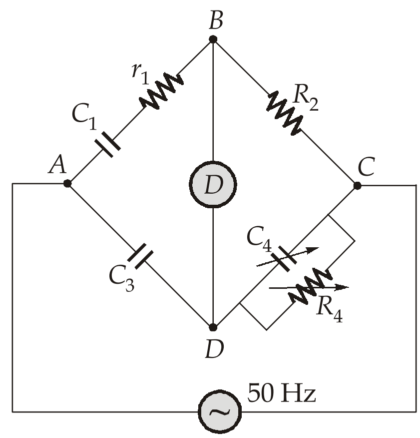
$\Rightarrow$ Total 8 unique product term so, design is possible

Implementation:



Q.4 (c) Solution:

(i) For the schering bridge, the circuit diagram is given as



Given, $R_2 = 280\ \Omega$, $C_3 = 300 \times 10^{-6}\ \mu F$, $R_4 = 416\ \Omega$, $C_4 = 1\ \mu F$, $f = 50$ Hz

(ii) Under the balanced condition,

$$Z_1 Z_4 = Z_2 Z_3$$

$$\left(r_1 + \frac{1}{j\omega C_1}\right)\left(\frac{R_4}{1 + j\omega R_4 C_4}\right) = \frac{R_2}{j\omega C_3}$$

$$(j\omega C_1 r_1 + 1)(R_4)(j\omega C_3) = R_2[(j\omega C_1)(1 + j\omega R_4 C_4)]$$

$$(1 + j\omega C_1 r_1) j\omega C_3 R_4 = j\omega R_2 C_1 [1 + j\omega R_4 C_4]$$

$$j\omega C_3 R_4 - \omega^2 C_1 r_1 C_3 R_4 = j\omega R_2 C_1 - \omega^2 R_2 R_4 C_1 C_4$$

Separating real and imaginary parts we get,

$$\omega C_3 R_4 = \omega R_2 C_1$$

$$C_1 = \frac{R_4 C_3}{R_2} \quad ...(1)$$

and

$$r_1 = \frac{C_4}{C_3} \cdot R_2 \quad ...(2)$$

(iii) The value C_1 can be found from equation (1)

$$C_1 = \frac{R_4}{R_2} C_3$$

Substituting the given values,

$$C_1 = \frac{416}{280} \times 300 \times 10^{-6} \times 10^{-6}$$

$$C_1 = 445.71 \times 10^{-12}\ F$$

$$C_1 = 445.71\ pF$$

The value of r_1 can be found from equation (2)

$$\therefore \quad r_1 = \frac{10^{-6}}{300\times10^{-6}\times10^{-6}}\times280$$

$$r_1 = 933.33\ \text{k}\Omega$$

(iv) Now, Loss tangent = Dissipation factor

$$\tan\delta = \omega C_1 r_1$$

$$\tan\delta = 2\pi \times 50 \times 445.71 \times 10^{-12} \times 933.33 \times 10^{3}$$

$$\tan\delta = 0.131$$

$$\delta = 7.46$$

Section B : Electromagnetics-1 + Basic Electrical Engineering-1
Computer Organization and Architecture-2 + Materials Science-2

Q.5 (a) Solution:

Virtual memory: Virtual memory is the separation of user logical memory from physical memory. This technique provides larger memory to the user by creating virtual memory space. It facilitates the user to create a process which is larger than the physical memory space. We can have more processes executing from the memory at a time.

It increases degree of multiprogramming. With the virtual memory technique, we can execute a process which is only partially loaded in the memory.

This concept states that, declare some portion of a secondary memory as main memory and store the program into secondary memory. Later, transfer the program from secondary memory to the main memory in a form of pages based on the CPU demand called Demand Paging.

Virtual memory concept is implemented using

(i) Paging (ii) Segmentation

Advantages of Virtual memory:

1. A process can execute without having all its pages in physical memory.
2. A user process can be larger than physical memory.
3. Higher degree of multiprogramming.
4. Less I/O for loading and unloading for individual user processes.
5. Higher CPU utilization and throughput.
6. Allows address spaces to be shared by several processes.
7. Memory is used more efficiently because the only sections of a job stored in memory are those needed immediately while those not needed remain in secondary storage.

Disadvantages of Virtual memory:

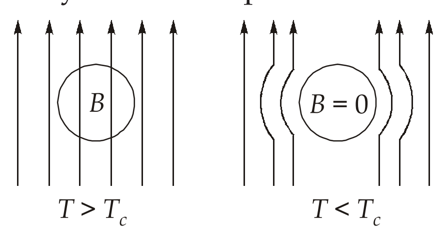
1. Increased processor hardware costs.
2. Increased overheads for handling pages interrupts.
3. Increased software complexity to prevent thrashing.

Q.5 (b) Solution:

(i) Meissner Effect:

Superconductors not only exhibits zero resistance but also spontaneously expel all magnetic flux when cooled through the superconducting transition, that is they are also perfect diamagnets. This is called as Meissner effect.

Meissner effect is not a consequence of zero resistance and Lenz's law. The flux is expelled as the superconductor is cooled in constant magnetic field. There is no time rate of change of the magnetic induction. Lenz's law does not apply. Perfect diamagnetism is an independent property of superconductors and shows that superconductivity involves a change of thermodynamic state, not just a spectacular change in electrical resistance. Figure below shows the illustration of Meissner effect that is one of the popular symbols of superconductivity.



It has been observed that when a long superconductor is cooled in a longitudinal magnetic field from above the transition temperature, the lines of induction are pushed out. Hence, inside the specimen, $B = 0$. We know from magnetic properties of materials that $B = \mu_0(H + M)$. For $B = 0$, $H = -M$, consequently since $\chi_m = \dfrac{M}{H} = -1$, we may state that magnetic susceptibility of superconductor is negative, this is referred to as perfect diamagnetism. This phenomenon is called Meissner effect. One of the Maxwell's equation is

$$\nabla \times \vec{E} = \frac{-\partial B}{\partial t}$$

and ohm's law, $J = \sigma E$ (or) $E = \rho J$

with $\rho = 0$, $E = 0$, so $\dfrac{\partial B}{\partial t} = 0$, but this is not so because the flux exclusion from normal to superconducting state takes place. A perfect diamagnetism and zero resistivity are two independent essential properties of superconducting state.

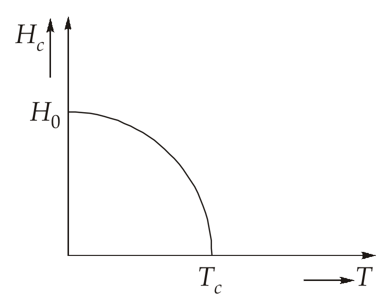
(ii) Silsbee's Rule:

The critical value of magnetic field for destruction of superconductivity, H_c is a function of temperature. At critical temperature $T = T_c$, $H_c = 0$.

With only small deviations, the critical field H_c varies with temperature according to parabolic law

$$H_c = H_0\left(1-\left(\frac{T}{T_C}\right)^2\right)$$

H_0 is the critical field at absolute zero and T_c is the transition temperature. For any particular superconductor, the shape of variation of H_c with temperature is shown in figure below.



The magnetic field which causes a superconductor to become normal from a superconducting state is not necessarily an external applied field it may arise as a result of electric current flow through the superconductor.

In a long superconductor wire of radius r, the superconductivity may be destroyed when a current I exceeds the critical current value I_C, which at the surface of wire will produce a critical field H_c, given by $I_C = 2\pi r H_c$ called silsbee's rule.

(iii) Frequency effect:

Superconductivity is observed for d.c. and upto radio frequencies. It is not observed for higher frequencies. For a superconductor, the resistance is zero only when the current is steady or varies slowly. When the current fluctuates or alternates, small absorption of energy roughly proportional to rate of alternation occurs. When the frequency of alternation rises above 10 MHz, appreciable resistance arises, and at infrared frequencies (10^{13} Hz) the resistivity is same in the normal and superconducting states, and is independent of temperature.

Q.5 (c) Solution:

We know;

The intensity of the electric field in a perfect conductor is zero.

(i) Point $A(3, -2, 1)$ lies in region $y < 0$ i.e., inside perfect conductor and hence No electric field intensity exist.

$$\therefore \text{Electric flux density } (D)\big|_{A(3,-2,1)} = 0$$

(ii) Point 'B' lies in Dielectric medium having surface charge density of $D = 5\hat{a}_y \text{ nC/m}^2$

We know;
$$|\bar{D}| = \rho_s$$

$$\Rightarrow \quad |\bar{E}| = \frac{\rho_s}{\epsilon} = \frac{\rho_s}{\epsilon_0 \epsilon_r}$$

$$= \frac{5\times10^{-9}\cdot\hat{a}_y}{\frac{1}{36\pi}\times10^{-9}\times3}$$

Therefore,
$$E = 188.49\, a_y \text{ V/m}$$

Q.5 (d) Solution:

(i) Given:

$$\text{Set size} = 2$$

$$\text{Block size} = 4$$

$$\text{Main memory size} = 128\text{ K} \times 32 \Rightarrow 2^7 \times 2^{10} \text{ words}$$

$$= 2^{17} \text{ words}$$

$$\text{Main memory address bits} = \log_2 2^{17} = 17 \text{ bits}$$

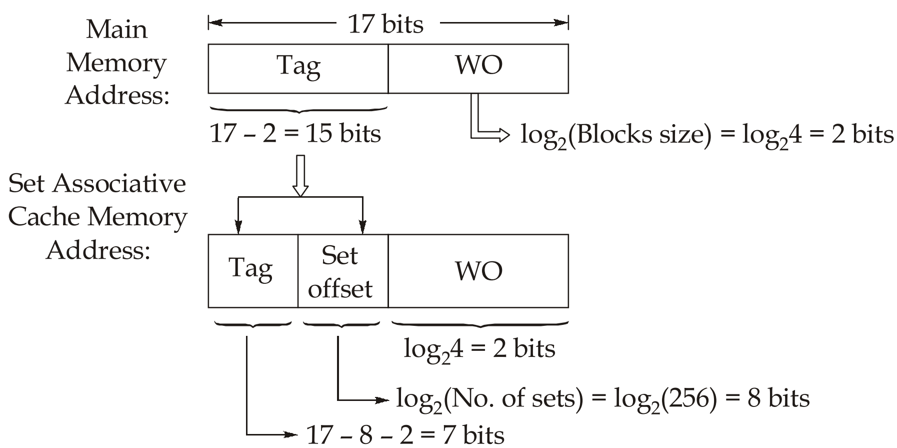
$$\text{Cache memory size} = 2048 \text{ words}$$

$$= 2^{11} \text{ words}$$

$$\text{No. of lines in cache memory} = \frac{\text{CM size}}{\text{Block size}} = \frac{2^{11}}{2^2} = 2^9$$

$$\text{No. of blocks in main memory} = \frac{\text{MM size}}{\text{Block size}} = \frac{2^{17}}{2^2} = 2^{15}$$

$$\text{No. of sets } [S] = \frac{\text{No. of lines in CM}}{\text{P-way}} = \frac{2^9}{2} = 2^8 = 256 \text{ sets}$$



(ii) Size of tag directory = No. of lines in CM * Tag space

$= 2^9 \times 7$ bits

$= 3584$ bits

$= 448$ bytes

Q.5 (e) Solution:

We know; $\%\text{Reg.} = \%R_{02} \cos\theta_2 \pm \%X_{02} \sin\theta_2$

For maximum regulation, lagging power factor required.

$\therefore$ $\%\text{Reg.} = \%R_{02} \cos\theta_2 + \%X_{02} \sin\theta_2$

Now, $\dfrac{d}{d\theta_2}(\%\text{Reg.}) = 0$

We get, $\tan\theta_2 = \dfrac{X_{02}}{R_{02}}$

We have; $\cos\theta_2 = 0.4 \Rightarrow \theta_2 = 66.42°$

$\tan\theta_2 = 2.29, \sin\theta_2 = 0.92$

Now; $X_{02} = R_{02}\tan\theta_2 = 2.29\, R_{02}$

We have, $\%\text{Reg. (max)} = 5\%$ (at lagging P.F)

$\because$ $$\%\text{Reg.} = \frac{I_2R_{02}\cos\theta_2 + I_2X_{02}\sin\theta_2}{E_2} \times 100$$

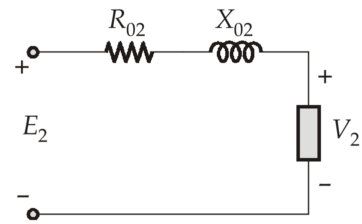
$$5 = \frac{I_2R_{02}(0.4) + I_2X_{02}(0.92)}{230} \times 100$$

$11.5 = I_2R_{02}(0.4) + I_2(0.92)(2.29R_{02})$

$11.5 = I_2R_{02}[0.4 + 0.92 \times 2.29]$

$I_2R_{02} = 4.58$

To get full-load voltage at P.F of 0.8 lead



$$V_2 = E_2 - [I_2R_{02}\cos\theta - I_2 X_{02}\sin\theta]$$

$$= E_2 - [I_2R_{02}\cos\theta - I_2 R_{02}(2.29)\sin\theta]$$

$\because$ $$\cos\theta = 0.8$$

$$\sin\theta = 0.6$$

$\therefore$ $$V_2 = 230 - [4.58 \times 0.8 - 4.58 \times 2.29 \times 0.6]$$

$$= 230 + 2.62$$

$$= 232.62 \text{ Volt}$$

Q.6 (a) Solution:

(i) **File system:** The file system is basically a way of arranging the files in a storage medium like a hard disk.

Database Management System: Database management system is basically a software that manages the collection of related data. It is used for storing data and retrieving the data effectively when it is needed.

File System	Database Management System
1. File system is a collection of data. In this system, the user has to write the procedures for managing the database.	1. Database management system is a collection of data in which the user is not required to write the procedures.
2. File system provides the detail of the data representation and storage of data.	2. DBMS gives an abstract view of data that hides the details.
3. It is very difficult to protect a file under the file system.	3. DBMS provides a good protection mechanism.
4. File system can't efficiently store and retrieve data.	4. DBMS contains a wide variety of sophisticated techniques to store and retrieve the data.
5. Redundancy is not controlled in file system as the files and application programs are created by different programmers, so there exists a lot of duplication of data .	5. Redundancy is controlled in DBMS due to centralization of the database.
6. In file system, concurrent access has many problems like redirecting the file while other deleting or updating some information.	6. DBMS takes care of concurrent access of data using some form of locking.
7. Unauthorized access is not restricted in file system.	7. Unauthorized access is restricted in DBMS.
8. Data lost in file system can't be recovered.	8. DBMS provides backup and recovery.
9. Data is isolated in file system.	9. DBMS provide multiple user interface.
10. A file-processing system is usually designed to allow predetermined access to data (i.e.; compiled programs)	10. A database management system is designed to allow flexible access to data (i.e., queries)
11. A file-processing system coordinates only the physical access.	11. A DBMS coordinates both the physical and the logical access to the data.
12. A file processing system is usually designed to allow one or more programs to access different data files at the same time. A file can be accessed by two programs concurrently only if both programs have read-only access to the file.	12. A DBMS system is designed to coordinate multiple users accessing the same data at the same time.

(ii) Given: Surfaces = 24

Cylinders = Track = 14000

(The number of cylinders of a disk drive exactly equals the number of tracks on a single surface in the drive)

$$\text{No. of sectors per track} = 400$$

$$\text{Data in each sector} = 512 \text{ bytes}$$

1. The maximum number of bytes that can be stored on this disk is given as

$$\text{capacity} = 24 \times 14000 \times 400 \times 512$$

$$= 6.88128 \times 10^{10} \text{ Bytes}$$

2.

$$7200 \text{ Rotation} \rightarrow 60 \text{ sec}$$

$$1 \text{ Rotation time} \rightarrow \frac{60 \times 1}{7200} \text{sec}$$

$$1 \text{ rotation time} = 1 \text{ track time}$$

$$\text{Data in one track} = 400 \times 512 \text{ bytes}$$

$$\therefore \quad \text{Data transfer rate} = \frac{400 \times 512}{60 \times 1} \times 7200 \text{ Bytes/sec}$$

$$= 24.576 \times 10^6 \text{ Bytes/sec}$$

Q.6 (b) Solution:

(i) For alternator:

$$P = 6, N_s = 1400 \text{ rpm}$$

We know,

$$N_s = \frac{120f}{P}$$

$$f = \frac{N_s \cdot P}{120} = \frac{1400 \times 6}{120}$$

$$f = 70 \text{ Hz}$$

Hence, the induction motor is supplied at 70 Hz.

For induction motor:

$P = 4, f = 70$ Hz, $N = 1000$ rpm

$$N_s = \frac{120f}{P} = \frac{120 \times 70}{4} = 2100'$$

$$\text{Slip}(s) = \frac{N_s - N}{N_s} = \frac{2100 - 1000}{2100}$$

$$s = 0.523$$

Now; Rotor frequency (f') = s.f

$$= 0.523 \times 70$$

$$= 36.66 \text{ Hz}$$

(ii) Given: $P = 4, f = 50$ Hz, $T_{sh} = 120$ N-m, $f' = 1.5$ Hz

$$T_{mech} = 15 \text{ N-m}$$

$$\text{slip } (s) = \frac{f'}{f} = \frac{1.5}{50} = 0.03$$

$$\text{Rotor speed } (N) = (1-s)\cdot N_s$$

where;
$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4}$$

$$N_s = 1500 \text{ rpm}$$

$\therefore$
$$N = (1 - 0.03)\cdot 1500 = 1455 \text{ rpm}$$

i.e.,
$$\text{Rotor speed } (\omega_r) = \frac{2\pi N}{60}$$

$$= \frac{2\pi(1455)}{60}$$

$$= 152.36 \text{ rad/s}$$

Now; total torque developed at motor is given as:

$$T_{total} = \text{Shaft torque } (T_{sh}) + \text{Mechanical loss } (T_{mech})$$

$$= 120 + 15$$

$$= 135 \text{ N-m}$$

$$\therefore \quad \text{Shaft power output } (P_0) = T_{total} \times \omega_r$$

$$= 135 \times 152.36$$

$$P_0 = 20.568 \text{ kW}$$

Q.6 (c) Solution:

(i) From the incident E field, it is evident that the propagation vector is

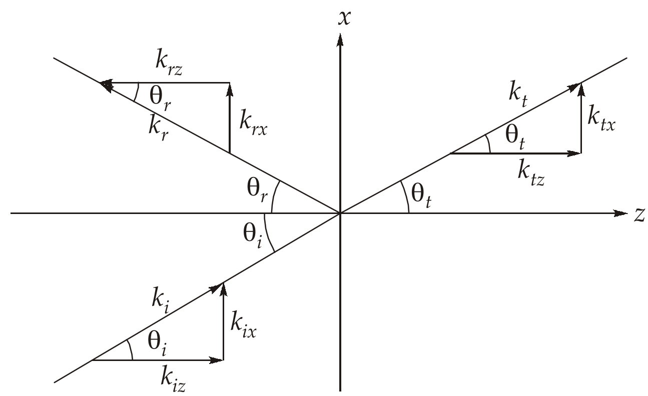
$$k_i = 4a_x + 3a_z \rightarrow k_i = 5 = \omega\sqrt{\mu_0\varepsilon_0} = \frac{\omega}{c}$$

Hence,
$$\omega = 5c = 15 \times 10^8 \text{ rad/s}$$

A unit vector normal to the interface ($z = 0$) is a_z. The plane containing k and a_z is y = constant, which is the xz-plane, the plane of incidence. Since, E_i is normal to this plane, we have perpendicular polarization.

(ii) The propagation vectors are illustrated in figure where it is clear that

$$\tan\theta_i = \frac{k_{ix}}{k_{iz}} = \frac{4}{3} \rightarrow \theta_i = 53.13°$$



(iii) Let; $E_r = E_{r0}\cos(\omega t - k_r \cdot r)a_y$

which is similar to the form of the given E_i. The unit a_y is chosen in view of the fact that the tangential component of E must be continuous at the interface. From figure

$$k_r = k_{rx}\, a_x - k_{rz} a_z$$

where $k_{rx} = k_r \sin\theta_r,\ k_{rz} = k_r \cos\theta_r$

But $\theta_r = \theta_i$ and $k_r = k_i = 5$ because both k_r and k_i are in the same medium. Hence,

$$k_r = 4a_x - 3a_z$$

To find E_{r0}, we need θ_t. From Snell's law

$$\sin\theta_t = \frac{n_1}{n_2}\sin\theta_i = \frac{c\sqrt{\mu_1\varepsilon_1}}{c\sqrt{\mu_2\varepsilon_2}}\sin\theta_i$$

$$= \frac{\sin 53.13^\circ}{\sqrt{2.5}}$$

or $\theta_t = 30.39^\circ$

$$\Gamma_\perp = \frac{E_{r0}}{E_{i0}} = \frac{\eta_2\cos\theta_i - \eta_1\cos\theta_t}{\eta_2\cos\theta_i + \eta_1\cos\theta_t}$$

where $\eta_1 = \eta_0 = 377\ \Omega$, $\eta_2 = \sqrt{\frac{\mu_0\mu_{r2}}{\varepsilon_0\varepsilon_{r2}}} = \frac{377}{\sqrt{2.5}} = 238.4\ \Omega$

$$\Gamma_\perp = \frac{238.4\cos 53.13^\circ - 377\cos 30.39^\circ}{238.4\cos 53.13^\circ + 377\cos 30.39^\circ} = -0.389$$

Hence, $E_{r0} = \Gamma_\perp E_{i0} = -0.389(8) = -3.112$

and $E_r = -3.112\cos(15\times10^8 t - 4x + 3z)a_y$ V/m

(iv) Similarly, let the transmitted electric field be

$$E_t = E_{t0}\cos(\omega t - k_t \cdot r)a_y$$

where, $$k_t = \beta_2 = \omega\sqrt{\mu_2\varepsilon_2} = \frac{\omega}{c}\sqrt{\mu_{r_2}\varepsilon_{r_2}}$$

$$= \frac{15\times 10^8}{3\times 10^8}\sqrt{1\times 2.5} = 7.906$$

From figure, $$k_{tx} = k_t \sin\theta_t = 4$$

$$k_{tz} = k_t \cos\theta_t = 6.819$$

$\therefore$ $$k_t = 4a_x + 6.819a_z$$

Notice that $k_{ix} = k_{rx} = k_{tx}$ as expected.

$$\tau_\perp = \frac{E_{t0}}{E_{i0}} = \frac{2\eta_2\cos\theta_i}{\eta_2\cos\theta_i + \eta_1\cos\theta_t} = 1 + \Gamma_\perp = 0.611$$

$$E_{t0} = \tau_\perp E_{i0} = 0.611 \times 8 = 4.888$$

Hence, $$E_t = 4.888\cos(15\times 10^8 t - 4x - 6.819z)a_y \text{ V/m}$$

From E_t, H_t is easily obtained as

$$H_t = \frac{1}{\mu_2\omega}k_t \times E_t = \frac{a_{kt}\times E_t}{\eta_2}$$

$$= \frac{4a_x + 6.819a_z}{7.906(238.4)} \times 4.888a_y\cos(\omega t - k\cdot r)$$

$$H_t = (-17.69a_x + 10.37a_z)\cos(15\times 10^8 t - 4x - 6.819z)\text{mA/m}$$

Q.7 (a) Solution:

(i) We know,

$$H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

Given, at $T = 14$ K, $H_c(T) = 0.176T$

and at $T = 13$ K, $H_c(T) = 0.528T$

$\therefore$ $$0.176 = H_c(0)\left[1 - \left(\frac{14}{T_c}\right)^2\right] \quad ...(1)$$

$$0.528 = H_c(0)\left[1 - \left(\frac{13}{T_c}\right)^2\right] \quad ...(2)$$

Dividing equation (2) by (1)

$$\frac{0.528}{0.176} = \frac{\left[1-\left(\frac{13}{T_c}\right)^2\right]}{\left[1-\left(\frac{14}{T_c}\right)^2\right]}$$

$$3 = \frac{\left[1-\left(\frac{13}{T_c}\right)^2\right]}{\left[1-\left(\frac{14}{T_c}\right)^2\right]}$$

$$3-3\left(\frac{14}{T_c}\right)^2 = 1-\left(\frac{13}{T_c}\right)^2$$

$$2 = 3\left(\frac{14}{T_c}\right)^2 - \left(\frac{13}{T_c}\right)^2 = \frac{419}{T_c^2}$$

After solving, we get,

Transition temperature, $T_c = 14.5$ K

Put the value of T_c in eqn. (1), we get,

$$0.176 = H_c(0)\left[1-\left(\frac{14}{14.5}\right)^2\right]$$

$$H_c(0) = 2.597 \text{ T}$$

Critical field at $T = 0$ K is 2.597 T

Now, critical field at $T = 4.2$ K

$$H_c(T) = H_c(0)\left[1-\left(\frac{T}{T_c}\right)^2\right] = 2.597\left[1-\left(\frac{4.2}{14.5}\right)^2\right]$$

$$H_c(T) = 2.379 \text{ T}$$

Critical field at $T = 4.2$ K is 2.379 T

(ii) Given, $D = 2r = 1 \text{ mm} = 10^{-3}$ m

$$\mu_0 = 4\pi \times 10^{-7}$$

$$B_c(4.2) = 0.0548 \text{ T}$$

Surface magnetic field associated with current I is

$$H_c = \frac{I_c}{2\pi r} \quad \text{or} \quad I_c = 2\pi r H_c$$

$$I_c = \frac{2\pi r B_c(T)}{\mu_0}$$

$$I_c = \frac{(2r)\pi B_c(T)}{\mu_0} = \frac{10^{-3}\times\pi\times 0.0548}{4\pi\times 10^{-7}} = 137 \text{ A}$$

Q.7 (b) Solution:

We have; $A = 8 \text{ cm}^2 = 8 \times 10^{-4} \text{ m}^2$

$d = 3 \text{ mm} = 3 \times 10^{-3} \text{ m}$

(i) Capacitor; $C = \frac{A\varepsilon}{d} = \frac{8\times 10^{-4}\times 2\times 8.854\times 10^{-12}}{3\times 10^{-3}}$

$C = 4.72 \times 10^{-12}$

$= 4.72 \text{ pF}$

(ii) Electric field $(E) = \frac{V}{d} = \frac{40\sin 10^3 t}{3\times 10^{-3}}$

$= 13.33 \sin 10^3 t \text{ kV/m}$

(iii) We know; $D = \varepsilon E$

Displacement current density is given as:

$$J_d = \frac{\partial D}{\partial t} = \frac{\partial \varepsilon E}{\partial t} = \varepsilon\frac{\partial E}{\partial t}$$

$$J_d = \varepsilon\frac{\partial}{\partial t}(13.33\sin 10^3 t)\times 10^3$$

$$= \varepsilon \cdot 13.33 \times 10^3 \times \cos 10^3 t \times 10^3$$

$$= 2 \times 8.854 \times 10^{-12} \times 13.33 \times 10^3 \times 10^3 \cos 10^3 t$$

$$J_d = 2.36 \times 10^{-4} \cos 10^3 t$$

$$J_d = \frac{I_d}{A} = 2.36\times 10^{-4}\cos 10^3 t$$

$$I_d = 2.36 \times 10^{-4} \cos 10^3 t \times 8 \times 10^{-4}$$

$$= 188.8 \cos 10^3 t \text{ nA}$$

Q.7 (c) Solution:

(i) **1.** Assuming that the point charge is located at the origin, we apply Coulomb's or Gauss's law to obtain:

$$E = \frac{Q}{4\pi\varepsilon_0\varepsilon_r r^2}\cdot \hat{a}_r$$

where; polarization $(P) = \chi_e \varepsilon_0 E$

$$= (\varepsilon_r - 1)\, \varepsilon_0\, E$$

∴ Surface density $(\rho_s) = P.a_r$

$$= \frac{(\varepsilon_r - 1)\cdot Q}{4\pi\varepsilon_r \cdot r^2} = \frac{10^{-12}}{4\pi \times 2 \times (0.1)^2}$$

$$\rho_s = 3.978 \text{ pC/m}^2$$

2. From Coulomb's law:

$$\text{Force (F)} = \frac{Q_1 \cdot Q_2}{4\pi\varepsilon_0\varepsilon_r \cdot r^2}\cdot a_r = \frac{(-8)(1)\times 10^{-24}}{4\pi \times \frac{10^{-9}}{36\pi} \times 2 \times (0.1)^2}\cdot a_r$$

$$F = -3.6\, a_r \text{ pN}$$

(ii) We know;

$$\%\eta = \frac{x \times \text{full load kVA} \times \text{P.F.}}{x \times \text{Full load kVA} \times \text{P.F.} + W_I + x^2 \cdot (W_{Cu})_{FL}}$$

P.F = Power Factor

x = load factor

W_1 = iron loss

$(W_{Cu})_{FL}$ = Copper loss at full load

When at full load ⇒ $x = 1$

$$0.98 = \frac{200 \times 10^3}{200 \times 10^3 + W_I + (W_{Cu})_{FL}}$$

$$W_I + (W_{Cu})_{FL} = 4081.63 \text{ W} \quad \text{...(i)}$$

When at half full load; $x = \frac{1}{2}$

$$0.98 = \frac{0.5 \times 200 \times 10^3}{0.5 \times 200 \times 10^3 + W_I + (0.5)^2 (W_{Cu})_{FL}}$$

$$W_I + 0.25(W_{Cu})_{FL} = 2040.81 \text{ W} \quad \text{...(ii)}$$

From (i) and (ii), $W_I = 1360.53$ W

$$(W_{Cu})_{FL} = 2721.09 \text{ W}$$

Now, Total loss at 3/4th of full load

$$W_I = W_I + \left(\frac{3}{4}\right)^2 \cdot (W_{Cu})_{FL}$$

$$= 1360.53 + \frac{9}{16} \times 2721.09 = 2891.14 \text{ watt}$$

Q.8 (a) Solution:

Synthesis of nanomaterials can be done by two important chemical methods: High-temperature thermal decomposition and liquid-liquid interface reaction.

(i) High-temperature thermal decomposition: A general scheme for preparing monodisperse nanoparticles requires a single, temporally short nucleation event followed by slower growth on the existing nuclei This may be achieved by quick addition of reagents into a reaction vessel containing a hot coordinating solvent. The temperature of the solution is sufficient to decompose the reagents, forming a super saturation of species in solution that is relieved by nucleation of nanoparticles. This method provides a general route for preparing dispersable nanoparticles of most of the transition-metal oxides using metal cupferron complexes M^xCup_x with M: metal ion; Cup: N-nitroso-N-phenylhydroxylamine, are used as single molecular precursors. In this non-hydrolytic route, the cupferron complex (which binds metal ion through oxygen) is decomposed by releasing a leaving group such as nitrosobenzene at 250-300°C in a hot coordinating solvent. The resulting product forms a stable suspension consisting of oxide nanoparticles; each nanoparticle in a sample consists of an inorganic crystalline core surrounded by an organic monolayer (surfactant).

The nanoparticles so obtained are freely soluble in non-polar organic solvents and can be readily precipitated from solutions with polar solvents. Further, nanoparticles with uniform size distribution can be achieved through size-selective precipitation procedures and the organic monolayer coordinating each nanoparticle surface enables to self-assemble into nanoparticle superlattices under controlled conditions. Thus, ordered nanoparticles assemblies/monolayer thin films are obtained using this method.

(ii) Liquid-liquid interface reaction: Nanoparticles anchored to surfaces in the form of film are considered to be important because of their potential use in nanodevices. A liquid-liquid interface offers potential to synthesize nanoparticles, as well as casting them into a film.

At a liquid-liquid interface, the particles are highly mobile and rapidly achieve an equilibrium assembly. In contrast to the other techniques, this method is a one-step process enabling synthesis of nanoparticle arrays at the liquid-liquid interface under ambient conditions.

This method involves the reaction of an organometallic compound dissolved in the organic layer with a reducing, a sulphiding, or an oxiding agent in the aqueous layer. The material formed at the interface corresponds to an ultrathin nanocrystalline film consisting of closely-packed nanocrystals coated with the organic species present at the interface.

The novelty of this method is that it involves a finite growth rate of the ultrathin nanocrystalline film with controllable parameters such as temperature and concentration. The nanocrystals in the films can be readily extracted to aqueous or organic layers by adding suitable capping agents. Further, the nanocrystalline film obtained at the interface can be easily transferred onto a solid support such as mica or a polymer film. With appropriate choice of metal precursors and reducing agents, a variety of nanocrystalline films can be fabricated.

The size of the metal nanocrystals formed at the liquid-liquid interface can be controlled by adjusting the various reaction parameters such as contact time, temperature, and concentration of reactants. By this means, the optical and electrical properties of the films can be varied.

(iii) High-energy Ball Milling : Despite the fact that the chemical methods have been widely employed for nanomaterial preparation, the utilisation of physical methods has also been given considerable attention, particularly in the area of nanoengineered materials, wherein large scale fabrication of nanopowders is essential for processing these into bulk shapes. Among the physical methods, mechanical milling has been widely utilised for the preparation of nanohard/nanocomposite magnetic powders owing to its versatility. Mechanical milling is a high-energy deformation process that progressively introduces defect structures (dislocations and vacancies), atomic-scale chemical disorder, and elastic strain energy into the initially crystalline starting powders through the shearing actions of ball-powder collisions. Milling can be used to produce a variety of effects in intermetallic alloys due to complex dependence of the nanostructure on Milling intensity, temperature and other factors. Nanocomposite permanent magnetic materials consisting of hard ($SmCo_5$) and soft (Fe or Fe-Co) magnetic phases have immense potential to exhibit a higher energy product than the conventional single phase hard magnets. It is predicted that the energy product, (BH_{max}) in nanocomposite magnet can be enhanced from that of a single-phase hard magnet, using high saturation magnetisation of the soft phase and the high coercivity of the hard phase if the two phases are spring exchange coupled. Since the magnetic properties and the degree of exchange coupling are strongly dependent on the microstructural parameters, such as crystallite size, phase distribution, and volume fraction of the hard and soft magnetic phases, many efforts have been made to synthesize and characterise the nanostructured magnets by mechanical milling, melt spinning, and thin-film techniques.

Q.8 (b) Solution:

(i) We have; $\varepsilon_r = 3; \ |H_{i0}| = 5.23$

Phase velocity of wave; $V_p = \frac{c}{\sqrt{\varepsilon_r}} = \frac{3\times10^8}{\sqrt{3}}$

$= 1.732 \times 10^8$ m/s

Impedance in dielectric medium:

$$\eta = \frac{\eta_0}{\sqrt{\varepsilon_r}} = \frac{377}{\sqrt{3}} = 217.66\ \Omega$$

The wave is propagating in $\hat{a}_z$ direction. Hence, the direction of electric field is given as:

$$\hat{a}_E = \hat{a}_H \times \hat{a}_P$$

$$\hat{a}_E = \hat{a}_x \times \hat{a}_z = -\hat{a}_y$$

Now, $|E_{i0}| = \eta \cdot |H_{i0}|$

$= 217.66 \times 5.23 = 1138.36$

1. Electric field $E(z, t) = 1138.36\cos(10^6\pi t - \beta z)(-\hat{a}_y)$

2. Now; $\beta = \frac{\omega}{V_p} = \frac{10^6\pi}{1.732\times10^8}$

$= 0.018$ rad/m

3. Average power $= P_{\text{avg}} = \frac{E_0^2}{2|\eta|}$

$$= \frac{(1138.36)^2}{2\times217.66} = 2.97\ \text{kW/m}^2$$

(ii) We have; $\sigma = 8$ S/m, $\varepsilon_r = 40$, $f = 10^6$ Hz

$$\frac{\sigma}{\omega\varepsilon} = \frac{8}{2\pi\times10^6\times8.854\times10^{-12}\times40} = 3595.09$$

We know, Ratio of magnitude of conduction current density to magnitude of displacement current density is known as loss tangent.

$$\tan\theta = \frac{|J_c|}{|J_d|} = \frac{\sigma}{\omega\varepsilon} = 3595.09$$

∴ Ratio of displacement to conduction current density will be:

$$\frac{J_d}{J_c} = \frac{1}{\frac{\sigma}{\omega\varepsilon}} = \frac{1}{3595.09} = 2.78\times10^{-4}$$

Q.8 (c) Solution:

(i) Transaction rollback: If a transaction fails for whatever reason after updating the database, it may be necessary to roll back the transaction. If any data item values have been changed by the transaction and written to the database, they must be restored to their previous values [BFIMs, i.e. Before Image].

The undo-type log entries are used to restore the old values of data items that must be rolled back.

Cascading rollback: If a transaction T is rolled back, and transaction S that has, in the interim, read the value of some data item X written by T must also be rolled back. Similarly, once S is rolled back, any transaction R that has read the value of some data item Y written by S must also be rolled back; and so on. This phenomenon is called cascading roll back and can occur when the recovery protocol ensures recoverable schedules but does not ensure strict or cascadeless schedules. Understandably, cascading roll back can be quite complex and time consuming. That is why almost all recovery mechanisms are designed such that cascading roll back is never required.

(ii) For S_1

Given Schedule:

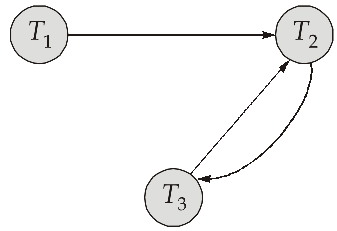
S_1 : $r_1(X); r_2(Z); r_1(Z); r_3(Z); r_3(Y); r_2(Y); w_1(X); w_3(Y); w_2(Z); r_2(Y); w_2(Y)$

T_1	T_2	T_3
$r_1(X)$		
	$r_2(Z)$	
$r_1(Z)$		
		$r_3(Z)$
		$r_3(Y)$
	$r_2(Y)$	
$w_1(X)$		
		$w_3(Y)$
	$w_2(Z)$	
	$r_2(Y)$	
	$w_2(Y)$	

Conflicts in the above transactions are:

$r_1(Z) \rightarrow w_2(Z)$, $r_3(Z) \rightarrow w_2(Z)$, $r_3(Y) \rightarrow w_2(Y)$, $r_2(Y) \rightarrow w_3(Y)$, $w_3(Y) \rightarrow w_2(Y)$, $w_3(Y) \rightarrow r_2(Y)$

$\therefore$ The precedence graph for the above transaction is given below,



There is a cycle. Hence, the schedule is not conflict searilizable.

For S_2

The given schedule:

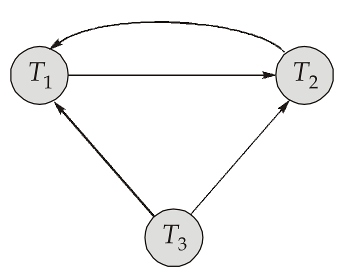
S_2 : $r_1(X)$; $r_2(Z)$; $r_3(X)$; $r_1(Z)$; $w_1(X)$; $r_3(Y)$; $w_2(Z)$; $w_3(Y)$; $w_2(Y)$; $w_1(Z)$

T_1	T_2	T_3
$r_1(X)$		
	$r_2(Z)$	
		$r_3(X)$
$r_1(Z)$		
$w_1(X)$		
		$r_3(Y)$
	$w_2(Z)$	
		$w_3(Y)$
	$w_2(Y)$	
$w_1(Z)$		

Conflicts in the above transactions are:

$r_2(Z) \rightarrow w_1(Z)$, $r_3(X) \rightarrow w_1(X)$, $r_1(Z) \rightarrow w_2(Z)$, $r_3(Y) \rightarrow w_2(Y)$, $w_2(Z) \rightarrow w_1(Z)$, $w_3(Y) \rightarrow w_2(Y)$

$\therefore$ The precedence graph for the above transaction is given below:



There is a cycle. Hence, the schedule is not conflict serializable.

❍❍❍❍