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Detailed Solutions

ESE-2023 Mains Test Series

Electrical Engineering Test No : 7

Section A : Computer Fundamentals + Electrical & Electronic Measurements

Q.1 (a) Solution:

An array is a collection of fixed number of values of single type. That is why, we need to declare the size of an array before we use it. Sometimes, the size of array we declared may not be sufficient. To solve this issue, we can allocate memory manually during run time. This is known as dynamic memory allocation in C programming.

There are 4 library functions defined under <stdlib h> makes dynamic memory allocation in C-programming. They are Malloc(), Callo(C), Realloc(C) and free(C).

Malloc() : "Malloc" stands for memory allocation. The Malloc() function reserve a block of memory of specified number of bytes. And, it returns a pointer of type void which can be casted into pointer of any form.

Syntax: Ptr : (Cast-type*) Malloc (byte-size)

Example : (int*) Malloc (100*Size of (int)) :

Calloc () : It is contiguous allocation.

It allocates multiple blocks of memory and initialize them with zero.

Syntax : Ptr : (Cast-type*) Calloc (n, element-size);

Example : (float*)Calloc(25, Size of (float));

Relloc () : If the dynamically allocated memory is insufficient or more than required, we can change the size of previously allocated memory using relloc () function.

Syntax : Ptr = realloc (Ptr, x);

Free () : Dynamically allocated memory created with either Calloc () or Malloc () does not get freed on their own. We must ex explicitly use free () to release the space.

Syntax : Free (Ptr);

This statement frees the space allocated in the memory pointed by Ptr.

Q.1 (b) Solution:

Given : $V_L = 230$ V, $I_L = 6$ A, $t = 10$ hours

$$\cos\phi = 1$$

Meter constant, $K = 520$ rev/kWh

N = Number of Revolution

$$\Rightarrow \quad \text{Energy consumption} = \text{kWh} \times t$$

$$= \frac{V_L I_L \cos\phi}{1000} \times 10$$

$$= 13.8 \text{ kWh}$$

$$\text{Meter constant} = \frac{N}{\text{kWh}}$$

$$\Rightarrow \quad N = K \times \text{kWh} = 520 \times 13.8$$

$$= 7176 \text{ revolution}$$

Now, if meter makes 1722 revolution, $I_L = 9$ A and $\cos\phi = 0.77$, $t = 1$ sec.

Then, Meter constant,

$$K = \frac{1722}{\frac{230 \times 9 \times 0.707}{1000} \times h}$$

$$520 = \frac{1722}{1.4634 \times h}$$

$$h = \frac{1722}{520 \times 1.4634}$$

$$= 2.263 \text{ hours}$$

Therefore, $\text{Time} \simeq 2.263$ hours

Q.1 (c) Solution:

```
# include <stdio.h>
# define MAX_SIZE 100
int stack [MAX_SIZE];
int top = –1;
```

```
void push (int data)
if (top == MAX_SIZE-1)
{
   if (top == MAX_SIZE-1)
   {
       printf ("overflow stack !\n");
       return;
   }
   top ++;
   stack [top] = data;
}
int pop ()
{
   if (top == –1)
   {
       printf ("stack is empty !\n");
       return –1;
   }
int data = stack[top];
   top --;
   return data;
}
int Main ()
   {
       push (1);
       push (2);
       push (3);
       push (4);
       push (5);
       push (3);
   printf ("Elements in the stack are: ");
```

```
while (top! = –1)
{ printf ("%d", pop ());
}
printf ("\n");
return 0;
}
```

O/P : Elements in stack are : 3 5 4 3 2 1

Q.1 (d) Solution:

Given : Voltage across instruments for full deflection = 100 mV.

Current in instrument for full-scale deflection,

$$I = \frac{V}{R} = \frac{100 \times 10^{-3}}{20} = 5 \times 10^{-3} = 5 \text{ mA}$$

Deflection torque, T_d :

$$T_d = BINA = BIN(l \times d)$$
$$= 100 \times B \times 30 \times 10^{-3} \times 25 \times 10^{-3} \times 5 \times 10^{-3}$$
$$= 375 \times 10^{-6} B \text{ N-m}$$

∴ Controlling torque for deflection $\theta = 120°$

$$T_c = k\theta$$
$$= 0.375 \times 10^{-6} \times 120$$
$$T_c = 45 \times 10^{-6} \text{ N-m}$$

At equilibrium,

$$T_c = T_d$$

$$\Rightarrow \quad 375 \times 10^{-6} B = 45 \times 10^{-6}$$

$$\Rightarrow \quad B = 0.12 \text{ Wb/m}^2$$

Now, resistance of winding,

$$R_c = 0.3 \times 20 = 6\ \Omega$$

Mean length of turn L_{mt} :

$$L_{mt} = 2(l + d)$$
$$= 2(30 + 25) = 110 \text{ mm}$$

Let A be the area of cross-section of wire and ρ be the resistivity.

Resistance of coil, R_c :

$$R_c = \frac{N\rho \cdot L_{mt}}{A}$$

Therefore, cross-section of wire,

$$A = \frac{100 \times 1.7 \times 10^{-8} \times 110 \times 10^{-3}}{6}$$

$$= 31.17 \times 10^{-9} \text{ m}^2$$

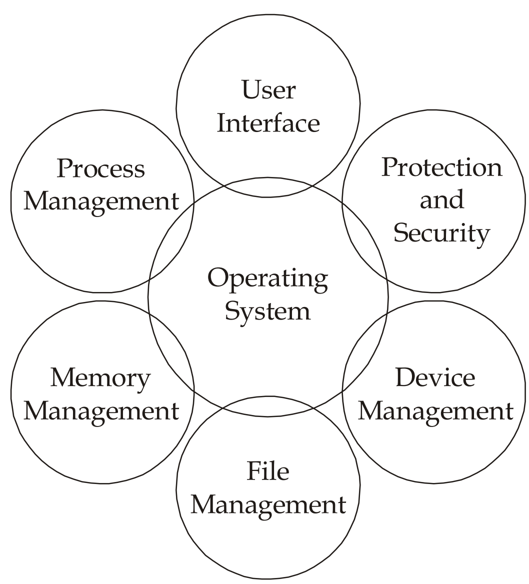
Diameter of wire,

$$d = \left(\frac{4}{\pi} \times 31.17 \times 10^{-3}\right)^{1/2} = 0.2 \text{ mm}$$

Q.1 (e) Solution:

Operating system is a large and complex software consisting of several components. Each component of operating system has its own set of defined inputs and outputs. Different components of OS perform specific tasks to provide the overall functionality of operating system.

The main functions of OS are as follows :



Process Management : The process management activities handled by the OS are :

1. Control access to shared resources like file, memory, I/O and CPU.
2. Control execution of applications.
3. Create, execute and delete a process (system process of user process).
4. Cancel or resume process.

5. Schedule a process.
6. Synchronization.

Memory Management : The activities of memory management handled by OS are :

1. Allocate memory
2. Free memory
3. Re-allocate memory to a program when a used block is freed.
4. Keep track of memory usage.

File Management :

1. Create and delete both files and directories.
2. Provide access to files.
3. Allocate space for files.
4. Keep back-up of files.
5. Secure files

Device Management : The device management tasks handled by OS are :

1. Open, close and write device drivers.
2. Communicate, control and monitor the device driver.

Protection and Security : OS protects the resources of the system. User authentication, file attributes like read, write, encryption and back-up of data are used by OS to provide basic protection.

User Interface or Command Interpreter : Operating system provides an interface between the computer user and computer hardware. The user interface is a set of commands or a graphical interface via which the user interacts with the applications and the hardware.

Q.2 (a) Solution:

(i) Gantt Chart for FCFs :

P_1	P_2	P_3	P_4	P_5
0–8	8–14	14–15	15–24	24–27

0 8 14 15 24 27

Gantt Chart for SJF :

P_3	P_5	P_2	P_1	P_4
0–1	1–4	4–10	10–18	18–27

0 1 4 10 18 27

Gantt Chart for non-pre-emptive : Here top priority process will be served first.

P_2	P_3	P_4	P_5	P_1
0–6	6–7	7–16	16–19	19–27

0 6 7 16 19 27

Gantt Chart for Round-Robin (Time Quantum = 1 ms)

P_1	P_2	P_3	P_4	P_5	P_1	P_2	P_4	P_5	P_1	P_2	P_4	P_5	P_1	P_2	P_4	P_1	P_2	P_4	P_1	P_2	P_4	P_1	P_4	P_1	P_4	P_4
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

(ii)

Process	Turn Around Time (TAT)			
	FCFs	SJF	Non-Preemptive	RR
P_1	8	18	27	25
P_2	14	10	6	21
P_3	15	1	7	3
P_4	24	27	16	27
P_5	27	4	19	13

TAT = Completion Time – Arrival Time

or

TAT = Burst Time + Waiting Time

(iii) Waiting Time : W.T. = TAT – BT

Process	Waiting Time (W.T.)			
	FCFs	SJF	Non-Preemptive	RR
P_1	0	10	19	17
P_2	8	4	0	15
P_3	14	0	6	2
P_4	15	18	7	18
P_5	24	1	16	10

(iv) Average Waiting Time of FCFs :

$$(\text{WT})_{\text{avg}} = \frac{0+8+14+15+24}{5} = 12.2 \text{ ms}$$

Average Waiting Time for SJF :

$$(\text{WT})_{\text{avg}} = \frac{10+4+0+18+1}{5} = \frac{33}{5} = 6.6 \text{ ms}$$

Average Waiting Time for Non-preemtive :

$$(\text{WT})_{\text{avg}} = \frac{19+0+6+7+16}{5} = \frac{48}{5} = 9.6 \text{ ms}$$

Average Waiting Time for R.R. :

$$(\text{WT})_{\text{avg}} = \frac{17+15+2+18+10}{5} = 12.4 \text{ ms}$$

Therefore, SJF algorithms having minimum average waiting time of 6.6 ms over all processes.

Q.2 (b) Solution:

Case 1 :

$$I_m = 1 \text{ mA}$$
$$R_m = 25\ \Omega$$
$$I = 100 \text{ mA}$$
$$I = I_m\left(1+\frac{R_m}{R_{sh}}\right)$$

$\Rightarrow$
$$100 = 1\times\left(1+\frac{25}{R_{sh}}\right)$$

$\Rightarrow$
$$\frac{25}{R_{sh}} = 99$$
$$R_{sh} = \frac{25}{99} = 0.2525\ \Omega$$

Instrument resistance for 10°C rise in temperature,

$$R_{mt} = 25(1 + 0.004 \times 10)$$
$$R_m = 26\ \Omega$$

Shunt resistance for 10°C rise in temperature

$$R_{sh,T=10^\circ} = 0.2525(1 + 0.00015 \times 10) = 0.2529\ \Omega$$

Current through the meter 100 mA in the main circuit for 10C rise in temperature.

$$I = I_m\left[1+\frac{R_m}{R_{sh}}\right]_{T=10^\circ C}$$
$$100 = I_{mt}\left[1+\frac{26}{0.2529}\right]$$

$\Rightarrow$
$$I_{m|T=10^\circ} = 0.9633 \text{ mA}$$

But normal meter current is 1 mA.

Error due to rise in temperature

$$= (0.9633 - 1) \times 100 = -3.667\%$$

Case II : As Voltmeter

Total resistance in the meter circuit

$$= R_m + R_{sh} = 25 + 75 = 100\ \Omega$$

$$I = I_m\left[1+\frac{R_m}{R_{sh}}\right]$$

$$100 = 1\times\left[1+\frac{100}{R_{sh}}\right]$$

$$R_{sh} = \frac{100}{100-1} = 1.01\ \Omega$$

The resistance of instrument circuit for 10°C rise in temperature.

$$R_{m|T=10^\circ} = 25(1 + 0.004 \times 10) + 75(1 + 0.00015 \times 10)$$

$$R_m = 101.11\ \Omega$$

Shunt resistance for 10°C rise in temperature.

$$R_{sh|T=10^\circ} = 1.01(1 + 0.00015 \times 10) = 1.0115\ \Omega$$

$$I_1 = I_m\left(1+\frac{R_m}{R_{sh}}\right)$$

$$100 = I_m\left(1+\frac{101.11}{1.0115}\right)$$

$$I_{m|T=10^\circ} = 0.9905\text{ m}$$

$$\text{Error} = (0.9905 - 1) \times 100 = -0.95\%$$

Q.2 (c) Solution:

(i) Data given :

$$I_m = 1 \times 10^{-3}\text{ A}$$

$$R_m = 50\ \Omega$$

$$I_1 = 1\text{ A};\ I_2 = 5\text{ A};\ I_3 = 10\text{ A};\ I_4 = 20\text{ A}$$

$$m_1 = \frac{I_1}{I_m} = 1000$$

$$m_2 = \frac{I_2}{I_m} = 5000$$

$$m_3 = \frac{I_3}{I_m} = 10000$$

$$m_4 = \frac{I_4}{I_m} = 20000$$

$$R_{sh1} = \frac{R_m}{m_1 - 1} = \frac{50}{1000 - 1} = 0.05\ \Omega$$

$$R_{sh2} = \frac{R_m}{m_2 - 1} = \frac{50}{5000 - 1} = 0.01\ \Omega$$

$$R_{sh3} = \frac{R_m}{m_3 - 1} = \frac{50}{10000 - 1} = 0.005\ \Omega$$

$$R_{sh4} = \frac{R_m}{m_4 - 1} = \frac{50}{20000 - 1} = 0.0025\ \Omega$$

∴ The resistance of various sections of universal shunt are :

$$R_1 = R_{sh1} - R_{sh2} = 0.05 - 0.01 = 0.04\ \Omega$$

$$R_2 = R_{sh2} - R_{sh3} = 0.01 - 0.005 = 0.005\ \Omega$$

$$R_3 = R_{sh3} - R_4 = 0.005 - 0.0025 = 0.0025\ \Omega$$

$$R_4 = R_{sh4} = 0.0025\ \Omega$$

(ii) CPU Special Registers :

1. Program Counter (PC)
2. Instruction Register (IR)
3. Memory Address Register (MAR)
4. Memory Data Register (MDR)
5. Accumulator (AC)

1. **Program Counter :** It is the register that holds the address of next instruction to be fetched. The size of program counter is exactly equal to the address bus size of processor.
2. **Instruction Register :** It holds the opcode of instruction after it is being fetched. After fetching an instruction, opcode will be placed in IR (from MDR) and later it sends to control register for completing its decoding and execution. Size of IR exactly equal to MDR size.
3. **Memory Address Register :** It is a memory address register that holds the address of memory register.

   In basic processor it is connected to the address bus and its size is equal to the address bus size.

   During instruction fetch, MAR is used to hold program address and during data read and data write operation MAR holds the data memory register address.

4. **Memory Data Register (MDR) :** It is used to hold the content of memory register while performing read/write operation from memory.

   It is connected to data bus.

   Its size is equal to data bus size while feting the instructions. Initially, the opcode of instruction is placed in MDR.

5. **Accumulator (AC) :** The accumulator is an internal CPU register which uses default locations to store any calculation performed by ALU.

Q.3 (a) Solution:

(i) Given : $r_p = 96\ \Omega,\ r_s = 0.88\ \Omega,\ x_p = 67.2\ \Omega,\ x_{1e} = 115\ \Omega$

Now, $$n = \frac{E_p}{E_s} = \frac{1000}{100} = 10$$

(a) Phase angle error can be given as :

$$\theta = \frac{\frac{I_s}{n}(x_{1e}\cos\Delta - r_{1e}\sin\Delta) + I_e x_p - I_m r_p}{nV_s}$$

At no-load, $I_s = 0$ A

$$\theta = \frac{I_e x_p - I_m r_p}{nV_s} \quad \text{...(1)}$$

$$\cos\phi = 0.4,\ I_o = 0.03\text{ A},\ I_e = I_o\cos\phi_o = 0.012\text{ A}$$

$$I_m = I_o\sin\phi = 0.02749\text{ A}$$

Now from eqn. (1)

$$\theta = \frac{0.012\times 67.2 - 0.02749\times 96}{10\times 100}\text{ rad}$$

$$= -1.8326\times 10^{-3}\text{ rad} = -0.105° = -6.3'$$

(b) At unity pf, $\cos\Delta = 1,\ \sin\Delta = 0$

$$\therefore \quad \theta = \frac{\frac{I_s}{n}x_{1e}\cos\delta + I_e x_p - I_m r_p}{nV_s}$$

$$0 = \frac{\frac{I_s}{10}\times 115 + 0.012\times 67.2 - 0.02749\times 96}{10\times 100}$$

$$\therefore \quad I_s = 0.1593\text{ A}$$

$\therefore$ Load in VA $= V_s I_s = 100 \times 0.1593 = 15.93$ VA

(ii) Given : $I_g = 2$ mA, $\theta = 75$, $\theta_1 = 250$, $V = 125$ V, $T' = 4$ sec

$$Q = \frac{\sqrt{JK}}{G} \cdot \theta' \text{ and } T' = 2\pi\sqrt{\frac{J}{K}}$$

$$\therefore \quad \frac{Q'}{T'} = \frac{K}{G} \cdot \frac{\theta'}{2\pi} \qquad \text{...(1)}$$

where, J = moment of inertia

K = control constant of the suspension

Now, $GI_g = K\theta$

$$\frac{K}{G} = \frac{I_g}{\theta} \qquad \text{...(2)}$$

On putting eqn. (2) in eqn. (1)

$$Q = \frac{I_g}{\theta} \times \frac{\theta'}{2\pi} \times T' \qquad \text{...(3)}$$

But $\theta' = \theta_1\left(1 + \frac{\lambda}{2}\right)$, where λ = logarithmic decrement

$$\therefore \quad Q = \frac{I_g}{\theta} \cdot \frac{T'}{2\pi} \times \theta_1 \times \left[1 + \frac{\lambda}{2}\right] \qquad \text{...}(\lambda = 0)$$

$$\therefore \quad Q = \frac{2 \times 10^{-3}}{75} \times \frac{4}{2\pi} \times 250 \times 1 = 4.2441 \times 10^{-3} \text{ C}$$

$$\therefore \quad C = \frac{Q}{V} = \frac{4.2441 \times 10^{-3}}{125} = 33.953 \ \mu\text{F}$$

Q.3 (b) Solution:

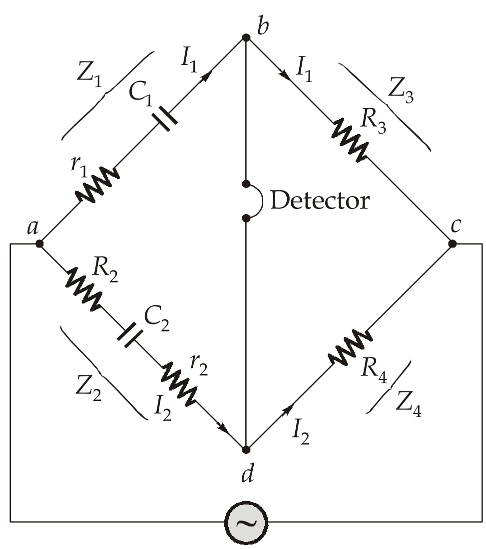
```
/* Menu driven program */
# include <stdio.h>
int main ()
{
    int choice, num, i;
    unsigned long int fact;
    while (1)
    {
```

```
printf ("\n\n1.Factorial\n")
printf("2.prime\n");
printf("3.odd/even\n");
print("4.Exit\n");
printf("\n enter your choice");
scant("%d", & choice);
switch (choice)
{
    Case 1 :
    printf("\n Enter number");
    scanf("%d", & num);
    fact=1;
    for (i=1; i<=num; i+–1)
        fact = fact*i
    printf ("Factorial Value = %\G\n", fact);
    Case 2 :
    printf ("\n Enter number:");
    scanf("%d", & num);
    for (i = 2; i < num; i++)
    {
        if (num % i == 0)
        {
        printf ("Not a prime number\n");
        break;
        }
    }
    if (i == num)
    printf ("\n Prime number");
    break;
    Case 3 :
    printf ("\n Enter number : ");
    scanf ("%d", & num);
```

```
        if (num%2 == 0)
            printf ("Even number \n");
        else
            printf ("Odd number \n ");
            break;
        Case 4 :
        exit (0); \* Terminate program execution*)/
        }
    }
    retrun 0;
}
```

Q.3 (c) Solution:

(i) The bridge is shown in figure.



$$Z_1 = r_1 - j\frac{1}{\omega C_1}\,\Omega$$

$$Z_2 = (R_2 + r_2) - j\frac{1}{\omega C_2}$$

$$= (4.8 + 0.4) - j\frac{1}{2\pi \times 450 \times 0.5 \times 10^{-6}}$$

$$= 5.2 - j707.355\ \Omega$$
$$= 707.3744\angle{-89.57°}\ \Omega$$
$$Z_3 = 200 + j0 = 200\angle 0°\ \Omega$$
$$Z_4 = 2850 + j0\ \Omega = 2850\angle 0°\ \Omega$$

At balance condition, no current flows through the detector.

$$\therefore \quad I_1 = \frac{E}{Z_1 + Z_3}$$

and
$$I_2 = \frac{E}{Z_2 + Z_4}$$

$$I_1Z_1 = I_2Z_2 \text{ for full deflection of detector}$$

$$\therefore \quad \frac{EZ_1}{Z_1 + Z_3} = \frac{EZ_2}{Z_2 + Z_4}$$

$$Z_1Z_4 = Z_2Z_3 \qquad \text{(balance equation)}$$

$$\therefore \quad 2850\left[r_1 - j\frac{1}{\omega C_1}\right] = 200\angle 0° \times 707.3744\angle{-89.5788°}$$

$$\therefore \quad r_1 - j\frac{1}{\omega C_1} = 49.6403\angle{-89.5788°} = 0.3649 - j49.6389\ \Omega$$

Comparing both the sides,

$$r_1 = 0.3649\ \Omega \text{ and } \frac{1}{\omega C_1} = 49.6389\ \Omega$$

$$\therefore \quad C_1 = \frac{1}{2\pi \times 450 \times 49.6389} = 7.125\ \mu\text{F}$$

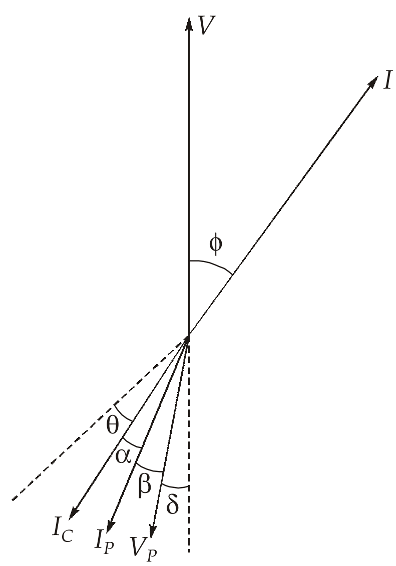
$$\text{Dissipating factor} = \omega r_1 c_1 = 2\pi \times 450 \times 0.3649 \times 7.125 \times 10^{-6}$$
$$= 0.007351$$

(ii)
- Demand Paging is used with virtual memory concept.
- Main memory is divided into equal size blocks known as frames.
- Virtual (user) program is divided into 'pages', where page size is equal to frame size.
- Whenever CPU generates read/write request for a word, that requested word belongs to one of page of a program.

- If demanded page is present in of the frame of main memory, then it is known as 'page hit'.
- If demanded page is not available then this condition is known as 'Page fault' and page fault service routine invoked.
- Page fault service routine loads demanded page into main memory and updates the page table.
- Demand paging suggests to keep all pages of the frame in the secondary memory until they are required. In other words, it says that do not load any page in the main memory until it is required.
- Whenever any page is referred for first time in the main memory, then that page will be found in secondary memory. After that, it may or may not be present in the main memory depending upon the page replacement algorithm.

Q.4 (a) Solution:

(i) Phasor diagram :



Resistance of pressure coil circuit = 250 Ω

Reactance of pressure coil circuit

$$= 2\pi \times 50 \times 7 \times 10^{-3} = 2.2\ \Omega$$

∴ Phase angle of pressure coil,

$$\beta = \tan^{-1}\left(\frac{2.2}{250}\right) \simeq 30.25 = 0.504°$$

Given : Phase angle of CT = $\theta = +75' = 1.25°$

Phase angle of PT = $\delta = -60' = -1°$

Phase angle of load = $\phi = 35°$

∴ Phase angle between wattmeter pressure coil current I_p and current coil current I_c is

$$\alpha = \phi - \theta - \beta - \delta = 35° - 1.25° + 1° - 0.504°$$

$$\therefore \quad \alpha = 34.246°$$

Correction factor for phase angle error,

$$K = \frac{\cos\phi}{\cos\beta \cdot \cos\alpha} = \frac{\cos(35°)}{\cos(0.504°) \times \cos(34.246°)} = 0.991$$

For PT or CT, the percentage ratio error is given by

$$\% \in = \frac{K_n - K_a}{K_a} \times 100$$

where, K_n = Nominal ratio

K_a = Actual ratio

Thus, actual ratio, $$K_a = \frac{K_n \times 100}{100 + \% \in}$$

Thus, for CT, Actual ratio $$= \frac{25 \times 100}{100 - 0.3} = 25.075$$

And, for PT, Actual ratio $$= \frac{110 \times 100}{100 + 0.6} = 109.34$$

Hence, true power of load,

$$P = K \times K_a \text{ of PT} \times K_a \text{ of CT} \times \text{Wattmeter reading}$$

$$P = 0.991 \times 25.075 \times 109.34 \times 450 \times 10^{-3}$$

$$P = 1222.661 \text{ kW}$$

(ii) (a) Given : $P_1 = 1500$ W; $P_2 = 700$ W

Power factor angle is given by

$$\phi = \tan^{-1}\left(\sqrt{3} \cdot \frac{P_1 - P_2}{P_1 + P_2}\right)$$

or $$\phi = \tan^{-1}\left(\sqrt{3} \times \frac{1500 - 700}{1500 + 700}\right)$$

$$\phi = 32.20°$$

$\therefore$ Power factor, $\cos\phi = \cos(32.20°) = 0.8461$ lagging

(b) Given : $P_1 = 1500$ W, $P_2 = -700$ W

$$\phi = \tan^{-1}\left(\sqrt{3}\times\frac{1500+700}{1500-700}\right) = 78.143°$$

$\therefore$ Power factor, $\cos\phi = \cos(78.143°) = 0.205$ lagging

Q.4 (b) Solution:

(i)

$$\text{Sensitivity of LVDT} = \frac{\text{Output Voltage}}{\text{Displacement}}$$

$$= \frac{2\times10^{-3}}{0.5} = 4 \times 10^{-3} \text{ V/mm}$$

$$\text{Sensitivity of instrument} = \text{Amplification factor} \times \text{Sensitivity of LVDT}$$

$$= 4 \times 10^{-3} \times 250 = 1 \text{ V/mm} = 1000 \text{ mV/mm}$$

$$1 \text{ scale division} = \frac{5}{100}\text{V} = 50 \text{ mV}$$

The minimum voltage that can be read on the voltmeter

$$= \frac{1}{5}\times 50 = 10 \text{ mV}$$

$$\because \quad \text{Resolution of instrument} = 10\times\frac{1}{1000} = 10 \times 10^{-3} \text{ mm}$$

(ii) Let S_1 be the value of resistance S for position 1 and S_2 for position 2.

$$\therefore \quad \frac{R+X}{S_1} = \frac{P}{Q}$$

Hence, resistance of loop $R + X = \frac{P}{Q}\cdot S_1 = \frac{5}{10}\times 16 = 8\ \Omega.$

$$\text{Resistance of each cable} = \frac{8}{2} = 4\ \Omega$$

$$\text{Length of each cable} = \frac{4}{0.4} = 10 \text{ km}$$

At position 2, we have

$$\frac{R}{X+S_2} = \frac{P}{Q}$$

$$\frac{R+X+S_2}{X+S_2} = \frac{P+Q}{Q} = \frac{8+7}{X+7} = \frac{5+10}{10}$$

$\Rightarrow$ $X = 3\ \Omega$

Distance of fault from testing end $= \frac{3.0}{0.4} = 7.5$ km

(iii) Multiplying factor, $m = \frac{20000}{2000} = 10$

Capacitance of voltmeter at full scale,

$$C_v = 54 \text{ pF}$$

The multiplying factor with an external capacitance C_s at full scale value,

$$m = 1 + \frac{C_v}{C_s}$$

$$10 = 1 + \frac{54}{C_s}$$

$\Rightarrow$ Capacitance of series capacitor,

$$C_s = \frac{C_v}{m-1} = \frac{54}{10-1} = 6 \text{ pF}$$

Capacitance, $C = \frac{\in A}{d} \Rightarrow 6 \times 10^{-12} = \frac{8.85 \times 10^{-12} A}{25 \times 10^{-3}}$

$\therefore$ Area of plates $A = 0.01694 \text{ m}^2 = 16940 \text{ mm}^2$

The value of capacitance of voltmeter at half scale reading

$$= \frac{54+42}{2} = 48 \text{ pF}$$

$\therefore$ Multiplying factor at half scale;

$$m = 1 + \frac{48}{6} = 9$$

Reading indicated by voltmeter at half scale

$$= \frac{20000}{2} = 1000 \text{ V}$$

Actual reading of voltmeter = 9 × 1000 = 9000 V

$$\text{Percentage error} = \frac{10000 - 9000}{9000} \times 100$$

$$= 11.1\% \text{ high}$$

Q.4 (c) Solution:

(i) Let L = Length of the plot = 150 m

B = Width of the plot = 50 m

Area = $L \times B = 150 \times 50 = 7500 \text{ m}^2$

Now, $A = LB$

$$\therefore \quad \frac{\partial A}{\partial L} = B \text{ and } \frac{\partial A}{\partial B} = L$$

Uncertanity in area

$$W_A = \sqrt{\left(\frac{\partial A}{\partial L}\right)^2 \times w_L^2 + \left(\frac{\partial A}{\partial B}\right)^2 \times w_B^2}$$

$$= \pm\sqrt{B^2 \cdot w_L^2 + L^2 \cdot w_B^2}$$

Case 1 : When there is no uncertainity in measurement of L.

$$w_L = 0$$

Uncertanity in measurement of area,

$$w_A = \pm\sqrt{B^2 w_L^2 + L^2 w_B^2} = \pm\sqrt{L^2 w_B^2} = \pm L w_B$$

$$= 150 \times 0.01 = 1.5 \text{ m}^2$$

Case 2 : When there is uncertanity in measurement of L. The uncertanity in area is not to exceed,

$$1.5 \times 1.5 = \pm 2.25 \text{ m}^2$$

$$w_A = \sqrt{B^2 w_L^2 + L^2 w_B^2}$$

$$2.25 = \sqrt{50^2 \times w_L^2 + (150)^2 \times (0.01)^2}$$

Hence, uncertanity in measurement of L is

$$w_L = \pm 0.0335 \text{ m}$$

(ii) LRU algorithm :

7	0	1	2	0	3	0	4	3	0	3	2	2	7
			2	0	3	0	4	3	0	3	2	2	7
		1	1	2	0	3	0	4	3	0	3	3	2
	0	0	0	1	2	2	3	0	4	4	0	0	3
7	7	7	7	7	1	1	2	2	2	2	4	4	0
Miss	Miss	Miss	Miss	Hit	Miss	Hit	Miss	Hit	Hit	Hit	Hit	Hit	Miss

Initially, all slots are empty, so when 7 0 1 2 are all allocated to the empty slots → 4 page faults 0 is already their so → 0 page fault.

When 3 cause it will take the place of 7 because it is least recently used → 1 page fault.

4 will take place of 1 → 1 page faults.

Now, for the future page reference string → 0 page fault because they are already available in the memory. At last, 7 will replace 4.

Total number of page faults = 7.

Section B : Power Electronics & Drives-1 + Engineering Mathematics-1 + Basic Electronics Engg.-2 + Analog Electronics-2 + Electrical Materials-2

Q.5 (a) Solution:

(i) The rms value is defined as

$$I_r = \left[\frac{1}{T}\int_0^{t_1}(I_m \sin\omega_s t)^2\,dt + \frac{1}{T}\int_{t_2}^{t_3} I_a^2\,dt\right]^{1/2}$$

$$I_r = (I_{r1}^2 + I_{r2}^2)^{1/2} \qquad \text{...(1)}$$

where

$$\omega_s = 2\pi f_s = 31415.93 \text{ rad/sec}$$

$$t_1 = \frac{\pi}{\omega_s} = 100\ \mu\text{s},\ T = \frac{1}{f}$$

$$I_{r1} = \left[\frac{1}{T}\int_0^{t_1}(I_m \sin\omega_s t)^2\,dt\right]^{1/2} = I_m\sqrt{\frac{f\cdot t_1}{2}}$$

$$= 450\times\sqrt{\frac{250\times 100\times 10^{-6}}{2}}$$

$$= 50.31 \text{ A} \qquad \text{...(2)}$$

$$I_{r2} = \left[\frac{1}{T}\int_{t_2}^{t_3} I_a^2 dt\right]^{1/2} = I_a\sqrt{f(t_3 - t_2)}$$

$$= 150\sqrt{250 \times (150) \times 10^{-6}}$$

$$= 29.05 \text{ A} \quad \text{...(3)}$$

Now putting eqn. (2) and eqn. (3) in eqn. (1)

$$I_r = (50.31^2 + 29.05^2)^{1/2}$$

$$I_r = 58.09 \text{ A}$$

(ii) The average current is found from

$$I_{av} = \left[\frac{1}{T}\int_0^{t_1}(I_m \sin \omega_s t)dt + \frac{1}{T}\int_{t_2}^{t_3} I_a dt\right]$$

$$I_{av} = I_{d1} + I_{d2} \quad \text{...(4)}$$

$$I_{d1} = \frac{1}{T}\int_0^{t_1}(I_m \sin \omega_s t)\cdot dt = \frac{I_m f}{\pi f_s} = \frac{450 \times 250}{\pi \times 5000} = 7.162 \text{ A}$$

$$I_{d2} = \frac{1}{T}\int_{t_2}^{t_3} I_a dt = I_a f(t_3 - t_2)$$

$$= 150 \times 250 \times 150 \times 10^{-6} = 5.62 \text{ A}$$

Now, average passing current diode is I_{av} :

$$I_{av} = (7.162 + 5.62)$$

$$I_{av} = 12.782 \text{ A}$$

Q.5 (b) Solution:

Calculation of Complementary Functions :

Characteristics equation,

$$m^3 + 3m^2 + 3m + 1 = 0$$

$$\Rightarrow \quad (m + 1)^3 = 0$$

$$m = -1, -1, -1$$

Therefore, CF :

$$y_{CF} = (C_1 + C_2 x + C_3 x^2)e^{-x}$$

Now, **Calculation of Particular Integral :**

If we try $y_{PI} = Ce^{-x}$, we get

$$-C + 3C - 3C + C = 30$$

which has no solution.

Now try Cxe^{-x} and Cx^2e^{-x}. The modified rule call for

$$y_{PI} = Cx^3e^{-x} \quad \text{...(1)}$$

Then,
$$y'_{PI} = C(3x^3 - x^3)e^{-x} \quad \text{...(2)}$$
$$y''_{PI} = C(6x - 6x^2 + x^3)e^{-x} \quad \text{...(3)}$$
$$y'''_{PI} = C(6 - 18x + 9x^2 - x^3) \quad \text{...(4)}$$

Now, eqn. (1) + eqn. (2) + eqn. (3) + eqn. (4) and omission of correction factor,

$C(6 - 18x + 9x^2 - x^3) + 3C(6x - 6x^2 + x^3) + 3C(3x^2 - x^3) + Cx^3 = 30$

On comparing,

$$6C = 30$$

Hence, $$C = 5$$

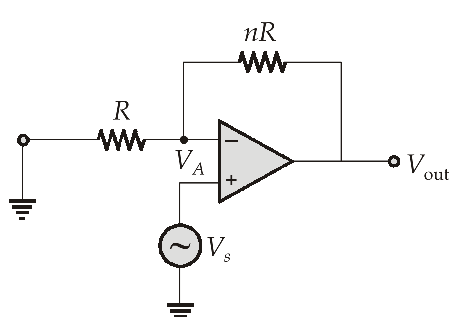
This gives $$y_{PI} = 5x^3e^{-x}$$

Complete solution : $$y = y_{CF} + y_{PI}$$
$$y = (C_1 + C_2x + C_3x^2)e^{-x} + 5x^3e^{-x}$$
$$y(0) = C_1 = 3$$
$$y'(0) = -3 + C_2 = -3 \Rightarrow C_2 = 0$$
$$y''(0) = 3 + 2C_3 = -47 \Rightarrow C_3 = -25$$

Therefore, $$y = (3 - 25x^2)e^{-x} + 5x^3e^{-x}$$

Q.5 (c) Solution:

(i)



Applying KCL at node V_A,

$$\frac{V_A - 0}{R} + \frac{V_A - V_{out}}{nR} = 0$$

$$(n + 1)V_A = V_{out}$$

$$V_A = \frac{V_{out}}{n+1} \qquad ...(1)$$

Also,
$$A_V = \frac{V_{out}}{(V_1 - V_2)}$$

$$A_V(V_S - V_A) = V_{out} \qquad ...(2)$$

Put V_A from eqn. (1) in eqn. (2)

$$V_{out} = A_V\left(V_S - \frac{V_{out}}{(n+1)}\right)$$

$$V_{out}\left[1 + \frac{A_V}{n+1}\right] = A_V V_S$$

Gain,
$$A_{VS} = \frac{V_{out}}{V_S} = \frac{A_V}{1 + \frac{A_V}{n+1}}$$

$$A_{VS} = \frac{A_V(n+1)}{n+1+A_V}$$

(ii)
$$\lim_{A_V \to \infty} A_{VS} = \lim_{A_V \to \infty} \frac{A_V(n+1)}{n+1+A_V}$$

$$= \lim_{A_V \to \infty} \frac{A_V(n+1)}{A_V\left[1 + \frac{(n+1)}{A_V}\right]}$$

$$\lim_{A_V \to \infty} \frac{V_{out}}{V_S} = n+1$$

Q.5 (d) Solution:

From the given circuit,

$$V_S = 0; \quad V_D = V_G = 8 - I_D R_D \qquad ...(1)$$

when $R_D = 3\ \text{k}\Omega$ and $I_D = 2$ mA

$\therefore$
$$V_{GS} = V_G - V_S = V_G = 8 - I_D R_D$$

$$V_{GS} = 8 - 2 \times 3 = 2\ \text{V}$$

Now,
$$K = \frac{I_D}{(V_{GS} - V_T)^2} = \frac{2 \times 10^{-3}}{(2-1)^2} = 2\ \text{mA/V}^2$$

Now, R_D is reduced to 2 kΩ.

Let $R'_D = 2\ k\Omega$

$$V_{GS} = 8 - 2I_D$$

$$I_D = K[V_{GS} - V_T]^2$$

$$= 2[8 - 2I_D - 1]^2$$

$$0.5I_D = (7 - 2I_D)^2$$

$$\Rightarrow \quad 4I_D^2 - 28I_D + 49 = 0.5I_D$$

$$\Rightarrow \quad 4I_D^2 - 28.5I_D + 49 = 0$$

On solving,

$$I_D = 4.22\ \text{mA}; \qquad I_D = 2.898\ \text{mA}$$

$$V_{GS} = 8 - 2 \times 4.226 \qquad V_{GS} = 8 - 2 \times 2.898$$

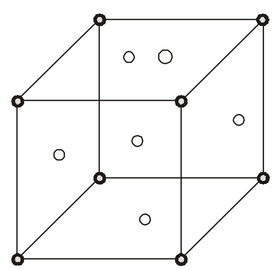
$$= -0.452\ \text{V} \qquad = 2.204\ \text{V}$$

$$V_{GS} < V_T \qquad V_{GS} > V_T$$

Therefore, when R_D is decreased by 1 kΩ, the drain current is 2.898 mA.

Q.5 (e) Solution:

FCC unit cell structure :



In this structure, the eight corners of the cube are occupied by eight atoms and six atoms occupy the centres of six faces of cube. Metals that crystallize in FCC structure are nickel, aluminium, copper, silver, gold, platinum, lead and iron.

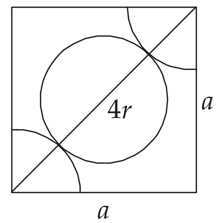
Number of atoms in the unit cell of FCC structure :

$$\text{Total number of atoms} = \frac{1}{8} \times (8 \text{ corner atom}) + (6 \text{ atoms at faces}) \times \frac{1}{2}$$

$$= 4 \text{ atoms}$$

Therefore, the unit cell of FCC structure contains 4 atoms.

Atomic packing factor of FCC :



Now,
$$a^2 + a^2 = 16r^2$$

$$r = \frac{a}{2\sqrt{2}}$$

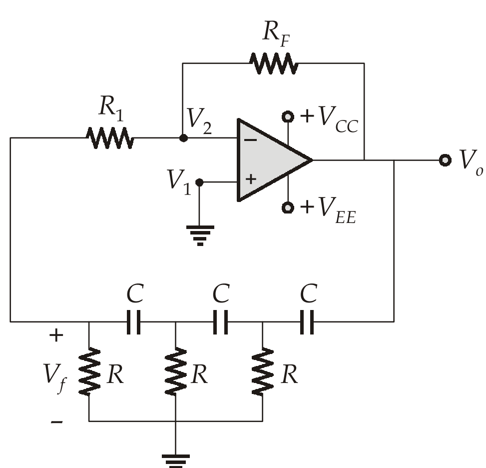
$$\text{Atomic packing factor} = \frac{\text{Volume of atoms in the unit cell}}{\text{Volume of unit cell}}$$

$$= \frac{4\times\frac{4}{3}\pi r^3}{a^3}$$

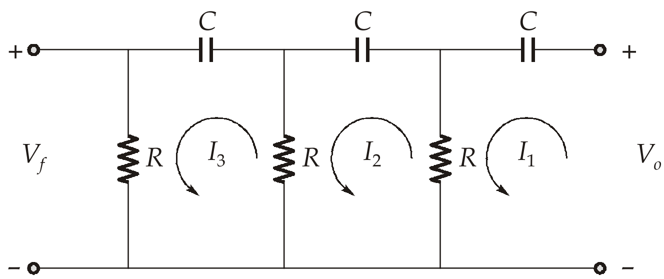
$$= \frac{4\times\frac{4}{3}\pi\times\frac{a^3}{16\sqrt{2}}}{a^3}$$

$$\text{APF} = \frac{\pi}{3\sqrt{2}} = 0.74$$

Q.6 (a) Solution:



Consider the feedback block



Apply KVL in loop (1) :

$$V_o = -jI_1X_C + (I_1 - I_2)R$$

$$V_o = I_1(R - jX_C) - I_2R \quad ...(1)$$

KVL in loop (2) :

$$(I_2 - I_1)R - jI_2X_C + (I_2 - I_3)R = 0$$

$$I_2(2R - jX_C) - I_1R - I_3R = 0 \quad ...(2)$$

KVL in loop (3) :

$$(I_3 - I_2)R - jI_3X_C + I_3R = 0$$

$$I_3(2R - jX_C) - I_2R = 0 \quad ...(3)$$

From eqn. (1), (2) and (3)

$$\begin{bmatrix} V_o \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R - jX_C & -R & 0 \\ -R & 2R - jX_C & -R \\ 0 & -R & 2R - jX_C \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

To calculate I_3, using Cramer's rule

$$I_3 = \frac{D_3}{D} = \frac{\begin{vmatrix} R - jX_C & -R & V_o \\ -R & 2R - jX_C & 0 \\ 0 & -R & 0 \end{vmatrix}}{\begin{vmatrix} R - jX_C & -R & 0 \\ -R & 2R - jX_C & -R \\ 0 & -R & 2R - jX_C \end{vmatrix}}$$

$$= \frac{V_oR^2}{(R - jX_C)(3R^2 - j4RX_C - X_C^2) - 2R^3 + jR^2X_C}$$

$$I_3 = \frac{V_oR^2}{3R^3 - j4R^2X_C - RX_C^2 - j3R^2X_C - 4RX_C^2 + jX_C^3 - 2R^3 + jR^2X_C}$$

$$= \frac{V_o R^2}{R^3 - 5RX_C^2 + j(X_C^3 - 6R^2X_C)} \quad \text{...(4)}$$

$$= \frac{V_o R^2}{R^3 - 5RX_C^2 + j(X_C^3 - 6R^2X_C)}$$

$$= \frac{V_o}{R\left[1 - 5\left(\frac{X_C}{R}\right)^2 + j\left\{\left(\frac{X_C}{R}\right)^3 - \frac{6X_C}{R}\right\}\right]}$$

$$\Rightarrow \quad \frac{I_3 R}{V_o} = \frac{V_f}{V_o} = \beta = \frac{1}{1 - 5\alpha^2 + j(\alpha^3 - 6\alpha)}$$

where, $\alpha = \frac{X_C}{R} = \frac{1}{\omega RC}$

1. Condition for Maintaining the Oscillations :

We know that, $A\beta = 1$ for maintain the oscillations, therefore

$$A \times \frac{1}{1 - 5\alpha^2} = 1 \text{ ... on considering the real part of equation of } B.$$

$$A = 1 - 5 \times 6 = -29$$

$$\Rightarrow \quad A = \frac{-R_f}{R_1} = -29$$

Therefore, $R_f = 29R_1$

2. Frequency of Oscillations :

Equating imaginary part of $\frac{1}{\beta}$ to zero.

$$\Rightarrow \quad \alpha^3 - 6\alpha = 0$$

$$\alpha^2 = 6$$

$$\alpha = \sqrt{6}$$

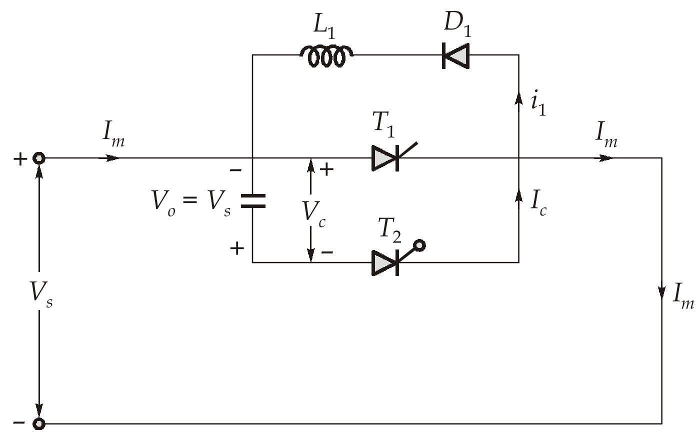
$$\frac{1}{\omega RC} = \sqrt{6}$$

$$\omega = \frac{1}{RC\sqrt{6}}$$

$$f = \frac{1}{2\pi RC\sqrt{6}}$$

Q.6 (b) Solution:

(i) The equivalent circuit during the commutation period is shown in figure below :



Now, from the circuit

$$i_c = i_1 + I_m$$

$$v_c = \frac{1}{c}\int i_c dt + v_c(t=0)$$

$$= -L_1\frac{di_1}{dt} = -L_1\frac{di_c}{dt}$$

The initial conditions $i_{c(t=0)} = I_m$ and $v_{c(t=0)} = -V_o = -V_s$.

The solutions of these equations yields the capacitor current as

$$i_c = V_o\sqrt{\frac{C}{L_1}}\cdot \sin\omega_1 t + I_m\cos\omega_1 t$$

The voltage across the capacitor is expressed as

$$V_c(t) = I_m\sqrt{\frac{L_1}{C}}\cdot \sin\omega_1 t - V_o\cos\omega_1 t$$

where, $$\omega_1 = \frac{1}{\sqrt{L_1 C}}$$

The available turn-off times or circuit turn-off times is obtained from the condition $V_c(t = t_q) = 0$ and is solved as

$$t_q = \sqrt{CL_1}\cdot \tan^{-1}\left(\frac{V_o}{I_m}\sqrt{\frac{C}{L_1}}\right)$$

Now for $C = 20\ \mu F$, $L_1 = 25\ \mu H$, $V_o = 200$ V and $I_m = 50$ A.

$\Rightarrow \quad t_q = 29.03\ \mu s$

and for $C = 20\ \mu F$, $L_1 = 25\ \mu H$, $V_o = 200$ V and $I_m = 200$ A

$\Rightarrow \quad t_q = 16.32\ \mu s$

Hence, as the load current increases from 50 A to 200 A, the turn off decreases from 29.03 μs to 16.32 μs. The use of extra diode makes the turn-off time loss dependent on the load

(ii) Converter output voltage V_o :

$$V_o = E + I_o R$$

$$V_o = 400 + 20 \times 1 = 420 \text{ V}$$

We know that

$$V_o = \frac{3V_{ml}}{\pi}\cos\alpha - \frac{3\omega L_s I_o}{\pi}$$

$$420 = \frac{3 \times 230 \times \sqrt{6}}{\pi}\cos\alpha - \frac{3 \times 2\pi \times 50 \times 4 \times 10^{-3} \times 20}{\pi}$$

$$420 = 538 \cos \alpha - 24$$

$$538 \cos \alpha = 444$$

Firing angle, $$\alpha = \cos^{-1}\left(\frac{444}{538}\right) = 34.38°$$

Also, output voltage of converter is given as

$$V_o = \frac{3V_{ml}}{\pi}\cos(\alpha + \mu) + \frac{3\omega L_s I_o}{\pi}$$

$$420 = \frac{3 \times 230\sqrt{6}}{\pi}\cos(34.38° + \mu) + \frac{3 \times 2\pi \times 50 \times 4 \times 10^{-3} \times 20}{\pi}$$

$$538 \cos(34.38° + \mu) = 396$$

Overlap angle, $$\mu = \cos^{-1}\left(\frac{396}{538}\right) - 34.38° = 8.22°$$

Q.6 (c) Solution:

(i) When superconducting material is kept in a magnetic field, then it expels the magnetic flux out of its body when cooled below the critical temperature, T_c.

For the normal state ($T > T_c$), the magnetic flux density inside the specimen is given by

$$B = \mu_o(H + M)$$

where H is the applied field and M is the magnetization in superconducting state.

∵ In perfect superconducting state, magnetic flux inside the superconductor is zero.

$$B = 0$$

$$\Rightarrow \quad \mu_o(H + M) = 0$$

$$H = -M$$

$$H = -\chi_m H$$

$$\Rightarrow \quad \chi_m = -1$$

It shows the perfect diamagnetism. Hence, superconductor exhibit perfect diamagnetism and produces strong repulsion to the external magnet.

(ii) Given dimensions : $(6 \times 6 \times 1.3)\ mm^3$

Charge sensitivity, $d = 160$ pC/N

Dielectric constant, $\varepsilon = 1250 \times 10^{-11}$ F/m

Young's modulus, $Y = 12 \times 10^6\ N/m^2$

The voltage generated by the piero-electric material,

$$V_o = Pgt$$

$$= \frac{d}{\varepsilon} \cdot \frac{F}{A} \cdot t$$

where, $$g = \frac{d}{\varepsilon} = \frac{160 \times 10^{-12}}{1250 \times 10^{-11}}$$

$$\therefore \quad V_o = \frac{160 \times 10^{-12}}{1250 \times 10^{-11}} \times \frac{6}{6 \times 6 \times 10^{-6}} \times 1.3 \times 10^{-3}$$

$$V_o = 2.77\ \text{V}$$

Let the deflection caused is 'X'.

$$\frac{F}{A} = Y \cdot \frac{X}{t}$$

$$\frac{F}{A} \cdot \frac{t}{Y} = X$$

$$X = \frac{6}{6 \times 6 \times 10^{-6}} \times \frac{1.3 \times 10^{-3}}{12 \times 10^6} = 18.05\ \mu\text{m}$$

or $$X = 0.018\ \text{mm}$$

(iii) The forbidden energy gap E_g in a semiconductor depends upon temperature.

$$\therefore \quad E_g(T) = 1.21 - 3.60 \times 10^{-4}\ \text{T} \qquad \text{(For Silicon)}$$

Now for a metal, the conduction and valance band must be overlap.

$$\therefore \quad E_g(T) = 0 \text{ for metals.}$$

$$\therefore \quad 1.21eV - 3.60 \times 10^{-4}T = 0$$

$$T = \frac{1.21}{3.60} \times 10^4$$

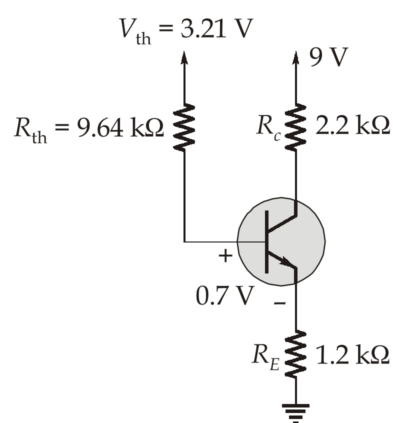
$$\Rightarrow \quad T = 3361.1° \text{ K}$$

Q.7 (a) Solution:

DC Analysis : AC grounded

$$R_{th} = R_1 \parallel R_2 = 27 \parallel 15 = 9.64 \text{ k}\Omega$$

$$V_{th} = \frac{R_2}{R_1 + R_2} \times V_{CC} = 3.21 \text{ V}$$



Assuming the transistor is in active mode :

$$(1 + \beta)I_B = I_E$$

$$101 \times \frac{3.21 - (0.7 + V_E)}{9.64} = \frac{V_E}{1.2}$$

$$\Rightarrow \quad 2.51 - V_E = 0.0795 V_E$$

$$\Rightarrow \quad V_E = 2.325 \text{ V}$$

and
$$I_E = \frac{V_E}{1.2} = \frac{2.325}{1.2} = 1.9376 \text{ mA}$$

Now,
$$I_C = \left(\frac{100}{101}\right) \times I_E = 1.918 \text{ mA}$$

$$V_B = V_E + 0.7 = 2.325 + 0.7 = 3.025 \text{ V}$$

$$V_C = 9 - 2.2 \times I_C = 9 - 2.2 \times 1.918 = 4.78 \text{ V}$$

$$V_{BC} = V_B - V_C = 3.025 - 4.78 = -1.775 \text{ V} \leq 0.4 \text{ V}$$

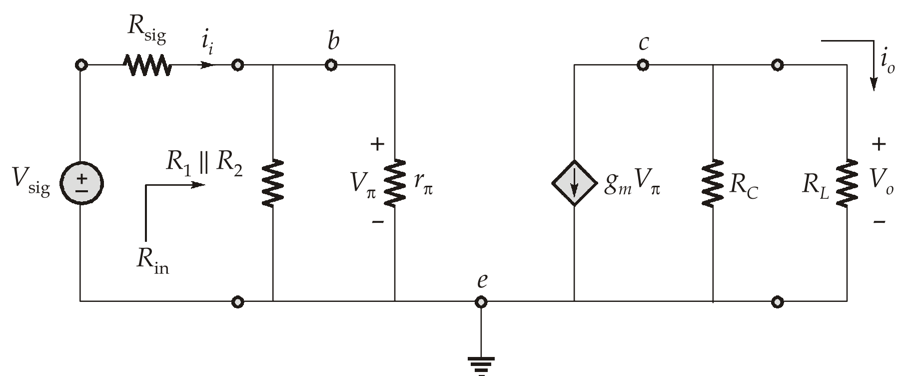
Therefore, BJT is in active mode as assumed.

Now,
$$g_m = \frac{I_C}{V_T} = \frac{1.918}{26} = 73.77 \text{ mS}$$

$$r_\pi = \frac{V_T}{I_B} = \beta \cdot \frac{V_T}{I_C} = \frac{\beta}{g_m}$$

$$= \frac{100}{73.8} \times 10^3 = 1.355 \text{ k}\Omega$$

Hybrid-π Model of Given Amplifier :



$$R_{in} = R_1 \parallel R_2 \parallel r_\pi = R_{th} \parallel r_\pi = 9.64 \parallel 1.355 = 1.188 \text{ k}\Omega$$

$$\frac{V_\pi}{V_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{1.188}{1.188 + 10} = 0.106 \quad \text{...(1)}$$

Also,
$$V_o = \left[-g_m V_\pi \times \frac{R_C}{R_C + R_L}\right] \times R_L$$

$$\frac{V_o}{V_\pi} = -g_m \frac{R_C \cdot R_L}{R_C + R_L} = -73.77 \times 10^{-3} \times \frac{2.2 \times 2}{2.2 + 2}$$

$$\frac{V_o}{V_\pi} = -77.283 \quad \text{...(2)}$$

From eqn. (1) and (2)

Voltage gain, $\frac{V_o}{V_{sig}}$:

$$\frac{V_o}{V_{sig}} = \frac{V_o}{V_\pi} \times \frac{V_\pi}{V_{sig}}$$

$$\frac{V_o}{V_{sig}} = 0.106 \times (-77.283) = -8.192$$

Now, we know that

$$\frac{V_o}{V_\pi} = \frac{i_o \times R_L}{i_i \times R_{in}}$$

$$\Rightarrow \qquad \frac{i_o}{i_i} = \frac{V_o \times R_{in}}{V_\pi \times R_L} = -77.283 \times \frac{1.188}{2}$$

$$\frac{i_o}{i_i} = -45.906$$

Q.7 (b) Solution:

The average output voltage V_o :

$$V_o = \frac{2V_m}{\pi} \cos\alpha$$

$$= \frac{2 \times 230\sqrt{2}}{\pi} \cos 50°$$

$$V_o = 133.10 \text{ Volts}$$

Now the average load current can be given as,

$$I_o = \frac{V_o - E}{R} \qquad \text{(load current is continuous)}$$

$$I_o = \frac{133.10 - 60}{6} = 12.18 \text{ A}$$

Now, the rms value fundamental component of supply current is

$$I_{s1} = \frac{2\sqrt{2} I_o}{\pi} = 0.9 \times 12.18$$

$$= 10.962 \text{ A}$$

Active power input to the converter is

$$P_{in} = V_{sr} . I_{s1} \cos\alpha$$

$$= 230 \times 10.962 \times \cos 50°$$

$$P_{in} = 1620.63 \text{ Watts}$$

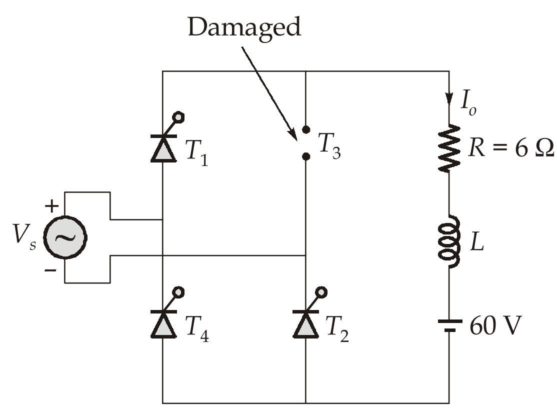
Reactive power input to converter,

$$Q_{in} = P_{in} \tan\alpha$$

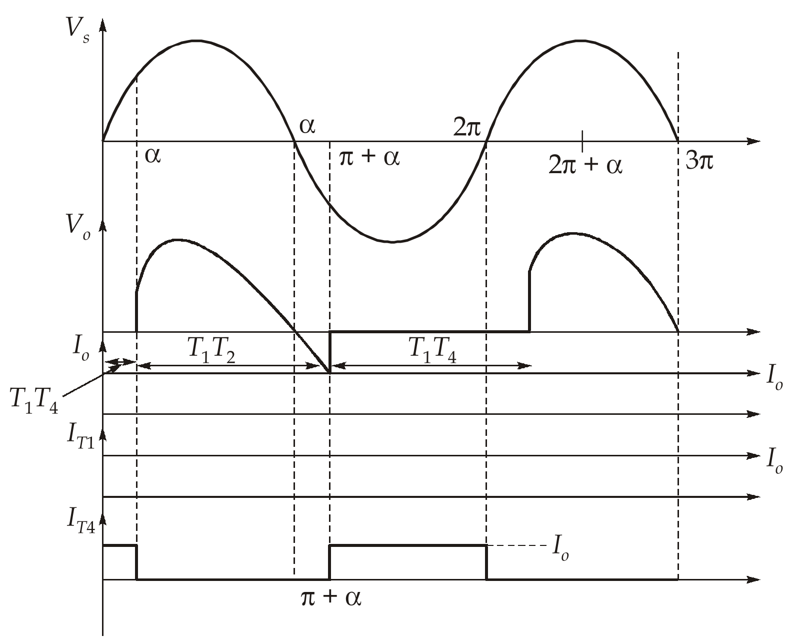
$$= 1620.63 \times \tan 50°$$

$$Q_{in} = 1931.397 \text{ VAR}$$

Now, one of thyristor is damaged :



Waveform :



Now, average load current is given as

$$V_o = \frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin\omega t \cdot d\omega t$$

$$V_o = \frac{V_m}{\pi}\cos\alpha$$

$$V_o = \frac{\sqrt{2} \times 230}{\pi} \cos 50°$$

$$V_o = 66.552 \text{ V}$$

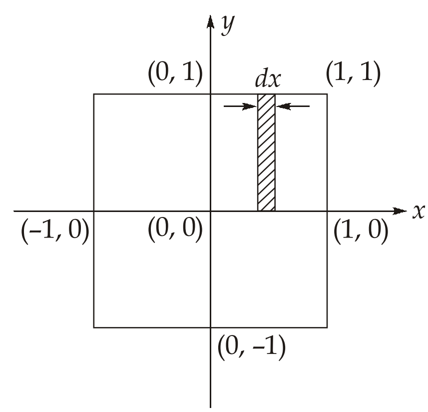
Load current,

$$I_o = \frac{V_o - E}{R} = \frac{66.552 - 60}{6}$$

$$I_o = 1.092 \text{ A}$$

Q.7 (c) Solution:

(i)



Area,
$$A = 4\int_0^1 y\,dx$$

$$= 4\int_0^1 (1 - x^4)^{1/4} dx$$

Let
$$x^2 = \sin\theta \Rightarrow [1 - x^4]^{1/4} = \cos^{1/2}\theta$$

$$dx = \frac{1}{2}(\sin\theta)^{-1/2} \cdot \cos\theta \cdot d\theta$$

$\Rightarrow$
$$A = 4\int_0^{\pi/2} (\cos\theta)^{1/2} \times \frac{1}{2}(\sin\theta)^{-1/2} \cos\theta \cdot d\theta$$

$$= 2\int_0^{\pi/2} (\cos\theta)^{3/2} \cdot (\sin\theta)^{-1/2} \cdot d\theta$$

$$= 2\int_0^{\pi/2} (\cos\theta)^{\frac{1}{2}+1} \cdot (\sin\theta)^{\frac{1}{2}-1} \cdot d\theta$$

Using the Beta function property

$$\int_0^{\pi/2} \sin^m\theta \cdot \cos^n\theta \cdot d\theta = \frac{1}{2}\beta\left(\frac{m+1}{2}, \frac{n+1}{2}\right); (m, n > -1)$$

For $m = \frac{1}{2} - 1$; $n = \frac{1}{2} + 1$

$$\int_0^{\pi/2} (\sin\theta)^{\frac{1}{2}-1} (\cos\theta)^{\frac{1}{2}+1} d\theta = \frac{1}{2}\beta\left(\frac{1}{4}, \frac{5}{4}\right)$$

$$= \frac{\Gamma\frac{1}{4} \times \Gamma\left(\frac{1}{4}+1\right)}{2\,\Gamma\left(\frac{1}{4}+\frac{1}{4}+1\right)} \qquad \left(\because \beta(m, n) = \frac{\Gamma m \cdot \Gamma n}{\Gamma(m+n)}\right)$$

Now,

$$\text{Area} = \frac{2 \times \Gamma\frac{1}{4} \cdot \Gamma\frac{5}{4}}{2\,\Gamma\frac{3}{2}}$$

$$= \frac{\Gamma\frac{1}{4} \times \frac{1}{4}\Gamma\frac{1}{4}}{\frac{1}{2}\Gamma\frac{1}{2}}$$

$$A = \frac{(3.626)^2 \times 1 \times 2}{4 \times \sqrt{\pi}} = 3.7089 \text{ unit square}$$

(ii) We know that,

$$f(x) = 3x - \cos x - 1$$

The root update equation of Newton Raphson method is

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

Given : $x_o = 1$

Therefore, first iteration

$$x_1 = 1 - \frac{3 - \cos(1) - 1}{3 + \sin(1)}$$

$$x_1 = 0.62$$

Now for second iteration

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)}$$

$$= 0.62 - \frac{1.86 - \cos(0.62) - 1}{3 + \sin(0.62)}$$

$$x_2 = 0.6071$$

Therefore, the root of the equation after 2nd iteration is 0.6071.

Q.8 (a) Solution:

(i) Voltage gain with feedback,

$$A_f = -100$$

Output voltage with negative feedback

$$= A_f \times \text{Input voltage}$$

$$V_o = A_f \times \text{Input voltage}$$

$$V_o = -100 \times 0.06$$

$$= -6 \text{ V}$$

Now, voltage gain without feedback,

$$A = \frac{\text{Output voltage without feedback}}{\text{Input voltage}}$$

$$= \frac{-6}{50 \times 10^{-3}} = -120$$

$\because$ Output voltage is same with feedback.

Now, $$A_f = \frac{A}{1 + A\beta}$$

So, $$100 = \frac{120}{1 + \beta \times 120}$$

$\Rightarrow$ $$\beta = \frac{120 - 100}{100 \times 120} = \frac{20}{100 \times 120} = \frac{1}{600}$$

Amount of feedback in dB

$$= 20\log_{10}\left(\frac{1}{1 + A\beta}\right)$$

$$= 20\log_{10}\left|\frac{1}{1+100\times\frac{1}{600}}\right| = -1.338 \text{ dB}$$

(ii) The differential gain of instrument amplifier can be given as

$$A_d = 1+\frac{2R_2}{R_1}$$

For minimum differential voltage gain

$$A_d = A_{d,\min} = 5$$

$$R_1 = R_{1,\max} = 50 \text{ k}\Omega$$

$\because$ A_d will be minimum only when R_1 will be maximum.

Substituting $A_d = 5$, $R_1 = 50 \text{ k}\Omega$

$$5 = 1+\frac{2R_2}{50}$$

$\Rightarrow$ $R_2 = 100 \text{ k}\Omega$

For maximum differential voltage gain

$$A_d = A_{d,\max} = 200$$

Substitute $A_d = 200$, $R_2 = 100 \text{ k}\Omega$ in eqn. (1), we have

$$200 = 1+\frac{2\times 100}{R_1}$$

$\Rightarrow$ $R_1 = \dfrac{200 \text{ k}\Omega}{199} \simeq 1 \text{ k}\Omega$

For maximum A_d, R_1 will have minimum value. Therefore,

$$R_{1(\min)} = 1 \text{ k}\Omega$$

Thus, $R_1 = 1$ to $50 \text{ k}\Omega$ potentiometer

$$R_2 = 100 \text{ k}\Omega$$

$$R_3 = R_4 = \text{say, } 15 \text{ k}\Omega \text{ each}$$

Q.8 (b) Solution:

(i)

$$y^2 + z^2 = 2ax \quad \text{...(1)}$$

$$y^2 = ax \quad \text{...(2)}$$

$$x = a \quad \text{...(3)}$$

Differentiating eqn. (1), we get

$$2z \cdot \frac{\partial z}{\partial x} = 2a \Rightarrow \frac{\partial z}{\partial x} = \frac{a}{z}$$

$$2y + 2z\frac{\partial z}{\partial y} = 0 \Rightarrow \frac{\partial z}{\partial y} = \frac{-y}{z}$$

$$\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2 + 1 = \frac{a^2}{z^2} + \frac{y^2}{z^2} + 1 = \frac{a^2 + y^2}{z^2} + 1$$

$$= \frac{a^2 + y^2}{2ax - y^2} + 1 = \frac{a^2 + y^2 + 2ax - y^2}{2ax - y^2} = \frac{a^2 + 2ax}{2ax - y^2}$$

$$\text{Area, } A = \int_0^a \int_{-\sqrt{ax}}^{\sqrt{ax}} \sqrt{\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2 + 1}\; dxdy$$

$$= \int_0^a \int_{-\sqrt{ax}}^{\sqrt{ax}} \sqrt{\frac{a^2 + 2ax}{2ax - y^2}}\, dxdy$$

$$= \sqrt{a}\int_0^a \int_{-\sqrt{ax}}^{\sqrt{ax}} \sqrt{\frac{a + 2x}{2ax - y^2}}\, dxdy$$

$$= \sqrt{a}\int_0^a \sqrt{a+2x} \cdot dx \int_{-\sqrt{ax}}^{\sqrt{ax}} \frac{1}{\sqrt{2ax + y^2}}\, dy$$

$$= \sqrt{a}\int_0^a \sqrt{a+2x} \cdot dx \left[\sin^{-1}\frac{y}{\sqrt{2ax}}\right]_{-\sqrt{ax}}^{\sqrt{ax}}$$

$$= \sqrt{a}\int_0^a \sqrt{a+2x}\, dx \left[\sin^{-1}\frac{1}{\sqrt{2}} - \sin\left(-\frac{1}{\sqrt{2}}\right)\right]$$

$$= \sqrt{a}\int_0^a \sqrt{a+2x}\, dx \left[\frac{\pi}{4} - \left(-\frac{\pi}{4}\right)\right]$$

$$= \sqrt{a} \cdot \frac{\pi}{2}\int_0^a \sqrt{a+2x}\, dx = \frac{\pi}{2} \cdot \frac{\sqrt{a}}{2} \cdot \frac{2}{3}\left[(a+2x)^{3/2}\right]_0^a$$

$$= \frac{\pi\sqrt{a}}{6}[(3a)^{3/2} - a^{3/2}] = \frac{\pi a^2}{6}\left[3\sqrt{3} - 1\right]$$

(ii) We are looking for vectors x such that $y = \lambda x$. Since $y = Ax$, this gives $Ax = \lambda x$, the equation of an eigen value problem. In components, $Ax = \lambda x$ is

$$5x_1 + 3x_2 = \lambda x_1$$
$$3x_1 + 5x_2 = \lambda x_2$$

or
$$(5 - \lambda)x_1 + 3x_2 = 0$$
$$3x_1 + (5 - \lambda)x_2 = 0 \quad \text{...(2)}$$

The characteristics equation is

$$\begin{vmatrix} 5-\lambda & 3 \\ 3 & 5-\lambda \end{vmatrix} = (5-\lambda)^2 - 9 = 0$$

On solving, $\lambda_1 = 8$ and $\lambda_2 = 2$ .... eigen values for $\lambda = \lambda_1 = 8$, our system (2) becomes

$$-3x_1 + 3x_2 = 0$$
$$3x_1 - 3x_2 = 0$$

Solution $x_2 = x_1$, x_1 arbitrary for instance $x_1 = x_2 = 1$.

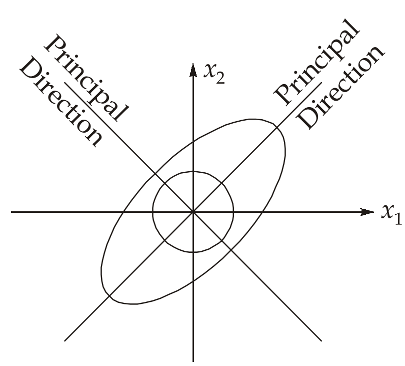
For $\lambda_2 = 2$ our system (2) becomes

$$3x_1 + 3x_2 = 0$$
$$3x_1 + 3x_2 = 0$$

Solution $x_1 = -x_2$, for $x_1 = 1 \Rightarrow x_2 = -1$

We, thus, obtain as eigen vectors of A, $[1 \quad 1]^T$ corresponding to λ_1 and $[1 \quad -1]^T$ corresponding to λ_2. These vectors make 45° and 135° angle with positive x-direction. They give the principal directions.

The eigen values shows that in the principal direction the membranes is stretched by factor 8 and 2 respectively.



Accordingly, if we choose the principal directions of a new cartesian u_1u_2 coordinate system.

Now, if we set $u_1 = r\cos\phi$ and $u_2 = r\sin\phi$, then the boundary points of the unstretched circular membrane has coordinates cos ϕ, sin ϕ. Hence, after stretched, we have

$$z_1 = 8\cos\phi;\ z_2 = 2\sin\phi$$

Since, $\cos^2\phi + \sin^2\phi = 1$. This shows that the deformed boundary is an ellipse as shown in above figure.

$$\frac{z_1^2}{8^2} + \frac{z_2^2}{2^2} = 1$$

Q.8 (c) Solution:

(i) A general scheme for preparing monodisperse nanoparticles requires a single, temporarily short nudeation 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 nano-particles. This method provides a general route for preparing dispersible nanoparticles of most of the transition-metal oxides using metal cupferron complexes are used as single molecular precursors. In this non-hydraultyic route, the cupferron complex (binds metal ion through oxygen) is decomposed by releasing a leaving group such as nitrobenzene at 250°C – 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 nanolayer (surfactant).

The nanoparticle 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 nano-particle super lattices under controlled conditions. Thus, ordered nano-particles assemblies/monolayer thin films are obtained using this method.

(ii) Difference between Paramagnetic Materials and Ferromagnetic Materials :

Paramagnetic Materials	Ferromagnetic Materials
1. A material whose atoms possess a net magnetic moment which are all randomly oriented in the absence of an external magnetizing field is called a paramagnetic materials.	1. A material whose atoms/molecules possess a net magnetic moment which interact strongly through exchange interaction forming domains, each of which are spontaneously magnetized to saturation, is called a ferromagnetic materials.
2. They can be solid, liquid or gas.	2. They are solid.
3. They do not preserve the magnetic properties once the external field is removed.	3. They preserve the magnetic properties after the external field is removed.
4. Permeability is little greater than unity.	4. Permeability is very high.
5. Susceptibility is little greater than unity and positive.	5. Susceptibility is very high and positive.
6. Examples: Lithium, Tantalum, Magnesium, etc.	6. Examples: Iron, Nickel, Cobalt, etc.

Application of Ferrites :

1. Ferrites are used in thermal sensing switches used in refrigerators, air conditioners, electronic ovens etc.
2. It can be used in electric motors, flat rings for loud speakers, correction magnets for TV.
3. They are used in the construction of computer memory system for rapid storage and retrieval of digital information.
4. They are used to make permanent magnets.
5. They are used in the construction of core of transformer.

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