ESE-2021
(MAINS)

QUESTIONS WITH DETAILED SOLUTIONS

ELECTRICAL ENGINEERING

PAPER-I

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ELECTRICAL ENGINEERING

ESE_MAINS_2021_PAPER – I

Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

S.No	NAME OF THE SUBJECT	Marks
01	Engineering Mathematic	84
02	Electrical Materials	62
03	Electric Circuits and Fields	72+32
04	Electrical and Electronic Measurements	82
05	Computer Fundamentals	64
06	Basic Electronics Engineering	84

SECTION - A

1(a) The average number of mistakes committed by a typist is 3 per page. Find the probability that the typist commits

(i) no mistake

(ii) at least two mistakes per page **[12M]**

Solution:

$\lambda = 3$

Let X = number of mistakes committed.

(i) $P(X=0) = \dfrac{\lambda^0 e^{-\lambda}}{0!} = e^{-3}$

(ii) $P(X \geq 2) = 1 - P(x < 2)$

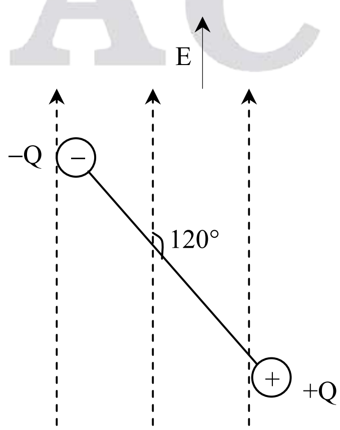
$= 1 - \{P(x=0) + P(x=1)\}$

$= 1 - \{e^{-3} + \lambda e^{-x}\}$

$= 1 - \{e^{-3} + 3e^{-3}\}$

$= 1 - 4e^{-3}$

1(b) An electric dipole is placed in a uniform electric field of strength 7×10^{6} V/m as shown in the figure. The charge on each dipole is opposite in nature and each equal to the charge of an electron. Both charges are separated by a distance of 2 angstrom. Both, field and dipoles are in same plane. Calculate the magnitude and direction of the dipole moment and torque. [12M]



Solution:

Given:

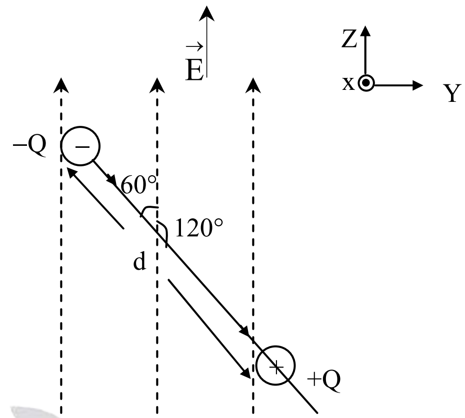
Electric field strength

$\vec{E} = 7 \times 10^{6}\ \hat{a}_z$ V/m

$Q = 1.6 \times 10^{-19}$ C

Spacing, $d = 2\ A° = 2 \times 0.1 \times 10^{-9}$

$= 2 \times 10^{-10}$m



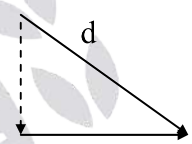
Dipole moment, $\vec{P} = Q\vec{d}$, $\theta = 60°$

$\vec{P} = Q\,[d \sin 60°\ \hat{a}_y - d \cos 60°\ \hat{a}_z]$

$= 1.6 \times 10^{-19} \times 2 \times 10^{-10} \times \dfrac{1}{2}\left[\sqrt{3}\hat{a}_y - \hat{a}_z\right]$

$\therefore\ \vec{P} = (2.77\,\hat{a}_y - 1.6\ \hat{a}_z) \times 10^{-29}$ C- m

Magnitude of dipole moment, P = 3.2 C – m



Torque, $\vec{\tau} = \vec{P} \times \vec{E}$

$= (2.77\ \hat{a}_y - 1.6\ \hat{a}_z) \times 7 \times 10^{6}\ \hat{a}_z \times 10^{-29}$

$\vec{\tau} = 19.40 \times 10^{-23}\ \hat{a}_x$ N-m

Magnitude of torque, $\tau = 19.40 \times 10^{-23}$ N-m

1(c) Define magnetostriction. Explain different types of magnetostriction. [12M]

Solution:

Magnetostriction: It is the ability of material that generates mechanical strain (or) change in physical dimension by applying magnetic filed.

Types of magnetostriction:

1. Longitudinal magnetostriction:

   It is the ability of material that can generate mechanical strain in longitudinal direction by applying magnetic field.

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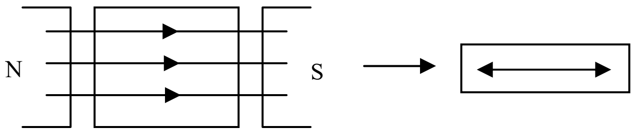
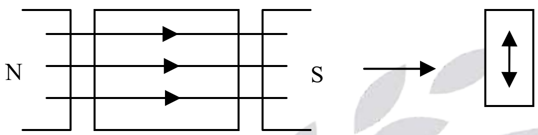


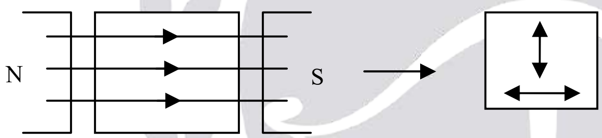
2. Transverse magnetostriction:

   It is the ability of material that can generate mechanical strain in transverse direction by applying magnetic field.

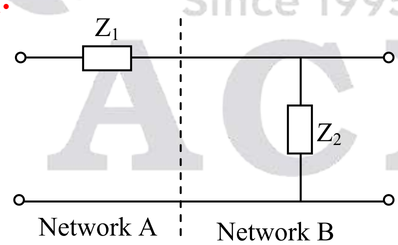


3. Volumetric magnetostriction:

   It is the ability of material that can generate mechanical strain in volumetrically by applying magnetic field.



1(d) The equivalent ABCD constants of a network are obtained by cascade connection of two networks as shown in the figure. The value of constant B of equivalent network is 5+j40. Calculate the value of z_1.



[12M]

Solution:

$$\text{Network A} = \begin{bmatrix} 1 & Z_1 \\ 0 & 1 \end{bmatrix}$$

$$\text{Network B} = \begin{bmatrix} 1 & 0 \\ \frac{1}{z_2} & 1 \end{bmatrix}$$

$$\text{Eq Network} = \begin{bmatrix} 1 & Z_1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{1}{Z_2} & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1+\frac{Z_1}{Z_2} & Z_1 \\ \frac{1}{Z_2} & 1 \end{bmatrix}$$

$$= \begin{bmatrix} A & B \\ C & D \end{bmatrix}$$

So, here 'B' parameter equivalent of network itself is 5 + j40 given

Hence, $Z_1 = B = (5 + j40)\ \Omega$

1(e) Write a C-program to check whether a number is a perfect number or not. [12M]

Solution:

Two ways to write c-program for this: 1. Using for loop

2. Using while loop.

<u>Using for loop</u>

```
#include < stdio.h>
#include < conio.h>
void main ()
{
   int num, rem, sum=0, i;
   printf ("Enter a number \n");
   scanf ("%d", & num);
   for (i = 1; i<num; i++)
       {
         rem = num%i;
         if(rem = =0)
         {
           sum = sum +i;
          }
       }
```

```
  if (sum = = num)
       printf("%d is a perfect number");
  else
             printf("\n %d is not a perfect number");
  getch();
}
```

Using while loop

```
#include <stdio.h>
#include <conio.h>
  void main()
  {
      int i = 1, num, sum=0;
      printf("Enter any number \n");
      scanf ("%d", & num);
      while (i< num)
            {
                 if (num% i = = 0)
                   sum = sum +i;
                   i++;
            }
  if (sum = = num)
      printf("\n %d is perfect number", num);
  else
     printf("\n %d is not a perfect number", num);
  getch();
}
```

2(a) (i) Expand $f(x) = e^{-x}$, $-\pi < x < \pi$ in a complex Fourier series. [10M]

(ii) Find the frequency spectrum of the periodic square wave given by the extension of the function [10M]

$$f(x) = \begin{cases} 0, & \frac{-1}{2} < x < \frac{-1}{4} \\ 1 & \frac{-1}{4} < x < \frac{1}{4} \\ 0 & \frac{1}{4} < x < \frac{1}{2} \end{cases}$$

Solution:

(i) Given that $f(x) = e^{-x}$, $-\pi < x < \pi$ ....(1)

We know that $f(x) = \sum_{n=-\infty}^{\infty} C_n e^{inx}$ ......(2)

Where $C_n = \frac{1}{2\pi}\int_{-\pi}^{\pi} f(x) e^{-inx}\, dx$

$$= \frac{1}{2\pi}\int_{-\pi}^{\pi} e^{-x}\, e^{-inx}\, dx$$

$$= \frac{1}{2\pi}\int_{-\pi}^{\pi} e^{-(1+in)x}\, dx$$

$$= \frac{1}{2\pi}\left[\frac{e^{-(1+in)x}}{-(1+in)}\right]_{-\pi}^{\pi}$$

$$= \frac{-1}{2\pi(1+in)}\left[e^{-(1+in)\pi} - e^{(1+in)\pi}\right]$$

$$C_n = \frac{-1}{2\pi(1+in)}\left[e^{-\pi}(\cos n\pi - i\sin n\pi) - e^{\pi}(\cos n\pi + i\sin n\pi)\right]$$

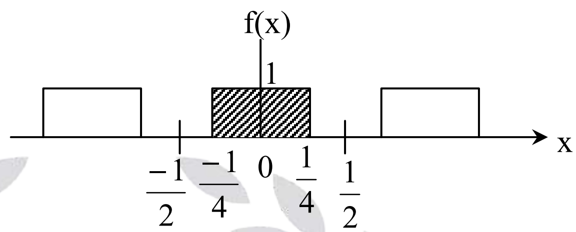
$$= \frac{-1}{2\pi(1+in)}\left[e^{-\pi}(-1)^n - e^{\pi}(-1)^n\right]$$

$$= \frac{(-1)^n}{\pi(1+in)}\left[\frac{e^{\pi} - e^{-\pi}}{2}\right]$$

$$= \frac{(-1)^n (1-in)}{(1+n^2)} \sinh \pi \qquad \ldots\ldots (3)$$

$$\therefore e^{-x} = \sum_{n=-\infty}^{\infty} \frac{(-1)^n (1-in)}{(1+n^2)} \sinh\pi . e^{-inx}$$

(ii) $C_0 = \dfrac{(1)\left(\frac{1}{2}\right)}{1} = \dfrac{1}{2}$



$T = 1 \Rightarrow \omega_0 = 2\pi$

$$C_n = \frac{1}{T}\int_0^T x(t) e^{-jn\omega_0 t} dt$$

$$= \frac{1}{1}\int_{-\frac{1}{4}}^{\frac{1}{4}} (1) e^{-jn(2\pi)t} dt$$

$$= \left[\frac{e^{-j2\pi nt}}{-j2\pi n}\right]_{-\frac{1}{4}}^{\frac{1}{4}}$$

$$= \frac{e^{j2\pi\frac{n}{4}} - e^{-j2\pi\frac{n}{4}}}{2j\pi n}$$

$$= \frac{\sin\left(\frac{\pi n}{2}\right)}{\pi n}$$

$\Rightarrow C_1 = \dfrac{1}{2}$

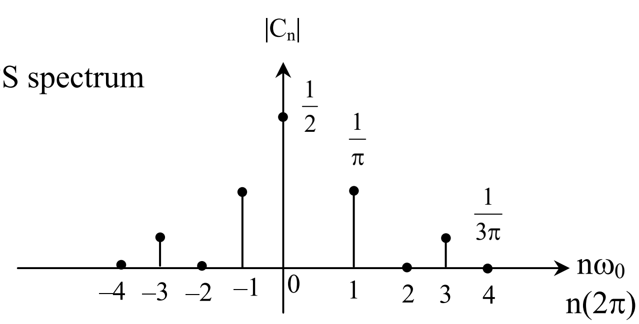
$\Rightarrow C_2 = 0$

$$C_3 = \frac{\sin\frac{3\pi}{2}}{3\pi}$$

$$= -\frac{1}{3}\pi$$

$C_4 = 0$

Exponential FS spectrum



2(b) (i) What is piezoelectricity? Explain the construction and working of a piezoelectric device. State any two applications of piezoelectric devices. [10M]

Solution:

PIEZO-ELECTRIC TRANSDUCERS

A piezo-electric material is one in which an electric potential appears across certain surfaces of a crystal if the dimensions of the crystal are changed by the application of a mechanical force. This potential is produced by the displacement of charges. The effect is reversible i.e, conversely, if a varying potential is applied to the proper axis of the crystal, it will change the dimensions of the crystal thereby deforming it. This effect is known as **piezo-electric effect**. Elements exhibiting piezo-electric qualities are called as electro-resistive elements.

Common piezo-electric materials include Rochelle salts, ammonium dihydrogen phosphate, lithium_ sulphate, dipotassium tartrate, potassium dihydrogen phosphate, quartz and ceramics A and B. Except for quartz and ceramics A and B, the rest are man-made crystals grown from aqueous solutions under carefully controlled conditions. The ceramic materials are poly-crystalline in nature. They are, basically, made of barium titanate. They do not have piezo-electric properties in their original state but these properties are produced by special polarizing treatment.

The materials that exhibit a significant and useful piezoelectric effect are divided into two categories

Natural group and

Synthetic group.

Quartz and Rochelle salt belong to natural group while materials like lithium sulphate, ethylene diamine tartrate belong to the synthetic group.

The piezo-electric effect can be made to respond to (or cause) mechanical deformations of the material in many different modes. The modes can be: thickness expansion, transverse expansion, thickness shear and face shear. The mode of motion affected depends on the shape of the body relative to the crystal axis and location of the electrodes. A piezo-electric element used for converting mechanical motion to electrical signals may be thought as charge generator and a capacitor. Mechanical deformation generates a charge and this charge appears as a voltage across the electrodes. The voltage is $E = Q/C$.

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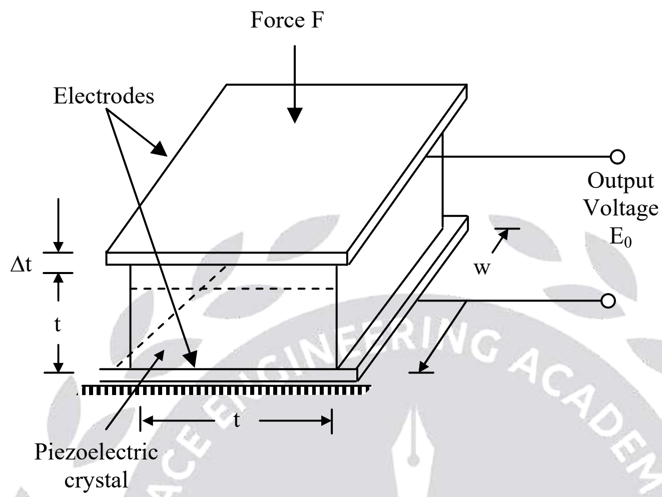
The piezo-electric effect is direction sensitive. A tensile force produces a voltage sit one polarity while a compressive force produces a voltage of opposite polarity

A piezo-electric crystal is shown in Fig.



Applications:

(i) The desirable properties expected out of a piezo-electric material are, stability, high output, insensitivity to temperature variations, insensitivity to variations in humidity and also the ability to be formed into a usable component. Undoubtedly the most stable material is quartz. However, its output is low. Rochelle salt, on the other hand provides, the highest output out of any of the piezo-electric materials. But it required protection from moisture and hence cannot be used above a temperature of 45°C.

Because of its stability, quartz is commonly used for stabilizing electronic oscillators. The crystal is ground to proper shape and is connected in an appropriate electronic circuit whose frequency is controlled by it.

(ii) The use of piezo-electric transducer elements is confined primarily to dynamic measurements. The voltage developed by application of strain is not held under static conditions. Hence, the elements are primarily used in the measurement of such quantities as surface roughness and in accelerometers and vibration pickups.

(iii) Ultrasonic generator elements also use barium titanate, a piezo-electric material. Such elements are used in industrial cleansing apparatus and also in underwater detection system known as sonar.

2(b) (ii) A pn junction is doped with an acceptor ion concentration $N_A = 2\times10^{16}$ cm^{-3} and a donor ion concentration $N_D = 9\times10^{15}$ cm^{-3}. Determine the capacitance of the device with $V_R = 2V$. Dielectric constant of silicon $\varepsilon_{Si} = 11.7\times8.85\times10^{-14}$ F/cm [10M]

Solution:

$N_A = 2\times10^{16}/cm^3$

$N_D = 9\times10^{15}/cm^3$

$V_R = 2V$

Capacitance $C = \frac{\varepsilon A}{w}$

$$\Rightarrow C' = \frac{C}{A} = \frac{\varepsilon}{w}$$

$(\varepsilon)_{si} = 11.7\times8.85\times10^{-14}$ F/cm

w – width of the depletion region

$$w = \sqrt{\frac{2\varepsilon V_j}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)},\ V_j = V_0 + V_R$$

$$V_0 = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$= 0.026\times\ln\left[\frac{2\times10^{16}\times9\times10^{15}}{(1.5\times10^{10})^2}\right]$$

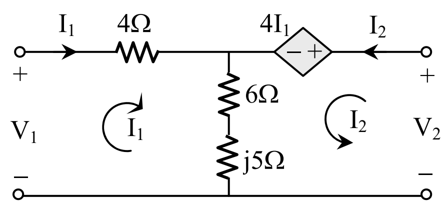
$$= 0.713\ V$$

$$w = \sqrt{\frac{2\times11.7\times8.85\times10^{-14}(0.713+2)}{1.6\times10^{-19}}\left(\frac{1}{2\times10^{16}}+\frac{1}{9\times10^{15}}\right)}$$

$w = 7.52\times10^{-5}$ cm

$$C' = \frac{C}{A} = \frac{\varepsilon}{w} = \frac{11.7\times8.85\times10^{-14}}{7.52\times10^{-5}} = 0.138\ nF/cm^2$$

2(c) Draw the equivalent z parameter circuit of a network as shown in the figure and determine whether the circuit is (i) reciprocal, and (ii) symmetrical [20M]

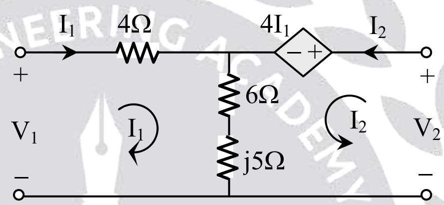


Solution:

Z - parameter equation

$V_1 = Z_{11} I_1 + z_{12} I_2$

$V_2 = Z_{21} I_1 + z_{22} I_2$



KVL in (i)

$V_1 = 4I_1 + 6 (I_1 + I_2) + j5 (I_2 + I_1)$

or, $V_1 = (6 + j5)I_2 + (10 + j5) I_1$

KVL in (ii)

$-V_2 + 4I_1 + (6 + j5) (I_1 + I_2) = 0$

$\Rightarrow V_2 = 4 I_1 + 6 I_1 + 6I_2 + j5I_1 + j5I_2$

$\Rightarrow V_2 = (10 + j5)I_1 + (6 + j5)I_2$

$z_{11} = 10 + j5 \quad z_{12} = 6 + j5$

$z_{21} = 10 + j5 \quad z_{22} = 6 + j5$

For symmetrical,

$z_{11} = z_{22}$, but it is not

Hence, it is not symmetric

For reciprocals

$z_{12} = z_{21}$ but it is not

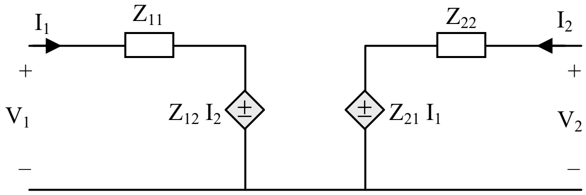
Hence, it is not reciprocal

Now, equivalent circuit

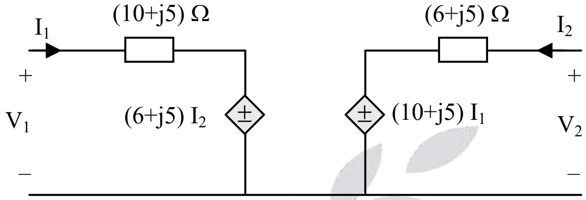
From equation

$V_1 = Z_{11} I_1 + Z_{12} I_2$

$V_2 = Z_{21} I_1 + Z_{22} I_2$



So, to our given N/W equivalent Z-parameter circuit is,



3(a) (i) An elastic membrane in the x_1x_2-plane with boundary circle $x_1^2 + x_2^2 = 1$ is stretched so that a point P(x_1, x_2) goes over into the point Q(y_1, y_2) given by

$$y = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = AX = \begin{bmatrix} 5 & 3 \\ 3 & 5 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}.$$

Find the principal directions, i.e., the directions of the position vector X of P for which the direction of the position vector Y of Q is same or exactly opposite. What shape does the boundary circle take under this deformation? [10M]

Solution:

$$\begin{matrix} A & X & Y \end{matrix}$$

$$\begin{pmatrix} 5 & 3 \\ 3 & 5 \end{pmatrix}\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} y_1 \\ y_2 \end{pmatrix}$$

$|A| = (25 - 9) = 16 \neq 0$

$\therefore$ The given transformation is regular

$\therefore\ X = A^{-1}\,Y$

$$\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \frac{1}{16}\begin{pmatrix} 5 & -3 \\ -3 & 5 \end{pmatrix}\begin{pmatrix} y_1 \\ y_2 \end{pmatrix}$$

$$= \begin{pmatrix} \dfrac{5y_1 - 3y_2}{16} \\ \dfrac{-3y_1 + 5y_2}{16} \end{pmatrix}$$

$$\therefore\ x_1 = \left(\frac{5y_1 - 3y_2}{16}\right) \qquad \text{..... (1)}$$

$$\text{and } x_2 = \left(\frac{-3y_1 + 5y_2}{16}\right) \qquad \text{..... (2)}$$

$$\left(x_1^2 + x_2^2\right) = 1 \qquad \text{(Given)}$$

$$\left(\frac{5y_1 - 3y_2}{16}\right)^2 + \left(\frac{-3y_1 + 5y_2}{16}\right)^2 = 1$$

$$(5y_1 - 3y_2)^2 + (5y_2 - 3y_1)^2 = 256$$

$$(25y_1^2 - 30y_1 y_2 + 9y_2^2) + (25y_2^2 - 30y_1y_2 + 9y_1^2) = 256$$

$$(34y_1^2 - 60y_1y_2 + 34y_2^2) = 256$$

$$(17y_1^2 - 30y_1y_2 + 17y_2^2) = 128$$

It is in the form $(ax^2 + 2hxy + by^2 + 2gx + 2fy + c) = 0$

$$(ab - h^2) = (17)^2 - (-15)^2$$

$$= (289 - 225)$$

$$= 64 > 0$$

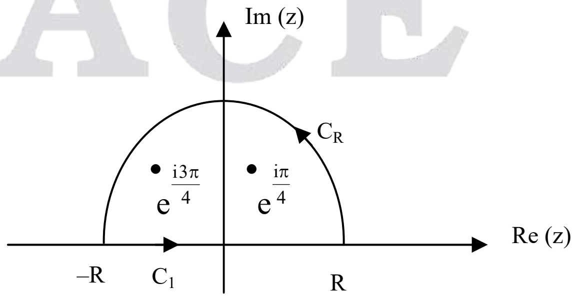
Hence the shape of the required boundary is an ellipse.

3(a) (ii) Using the contour integration, evaluate the integral $\int_{-\infty}^{\infty} \frac{dx}{1+x^4}$. [10M]

Solution:

$$I = \int_{-\infty}^{\infty} \frac{1}{1+x^4}\,dx$$

$$\text{Let } f(z) = \frac{1}{1+z^4}$$



$$\lim_{R\to\infty} \int_{C_R} f(z)\,dz = 0$$

$$\lim_{R\to\infty} \int_{C_1} f(z)\,dz = \int_{-\infty}^{\infty} f(x)\,dx = I$$

By the reside theorem

$$I = \lim_{R\to\infty} \int_{C_1+C_R} f(z)dz = 2\pi i \sum \text{residues of f inside the contour}$$

The poles of f are all simple and at

$$e^{\frac{i\pi}{4}},\ e^{\frac{i3\pi}{4}},\ e^{\frac{i5\pi}{4}},\ e^{\frac{i7\pi}{4}}$$

Only $e^{\frac{i\pi}{4}}$ and $e^{\frac{i3\pi}{4}}$ are inside the contour

We compute their residues as limits using L' hospital rule.

For $z_1 = e^{i\pi/4}$:

$$\text{Res}(f, z_1) = \lim_{z\to z_1} (z - z_1)\, f(z) = \lim_{z\to z_1} \frac{z - z_1}{1+z^4}$$

$$= \lim_{z\to z_1} \frac{1}{4z^3} = \frac{1}{4e^{\frac{i3\pi}{4}}} = \frac{e^{-i3\frac{\pi}{4}}}{4}$$

For $z_2 = e^{i3\frac{\pi}{4}}$:

$$\text{Res}(f, z_2) = \lim_{z\to z_2} (z-z_2)\, f(z) = \lim_{z\to z_2} \frac{z - z_2}{1+z_4} = \lim_{z\to z_2} \frac{1}{4z^3}$$

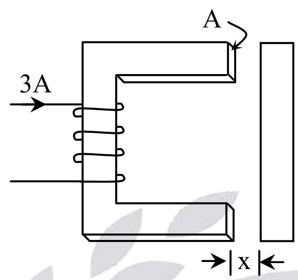
$$= \frac{1}{4e^{\frac{i9\pi}{4}}} = \frac{e^{\frac{-i\pi}{4}}}{4}$$

So, $I = 2\pi i(\text{Res}(f, z_1) + \text{Res}(f, z_2))$

$$= 2\pi i \left(\frac{-1-i}{4\sqrt{2}} + \frac{1-j}{4\sqrt{2}}\right) = 2\pi i\left(\frac{-2i}{4\sqrt{2}}\right)$$

$$= \frac{\pi}{\sqrt{2}}$$

3(b) The magnetic circuit of a relay is shown in the figure. Calculate the energy that coil carries and the force on the armature of the relay when 3 Amp current flows in the coil. The air gap x is 2 cm, cross-section area of core is 50 cm^2 and the number of turns in the coil is 2000. Neglect the fringing effect and the reluctance of magnetic circuit in the core. [20M]



Solution:

Given:

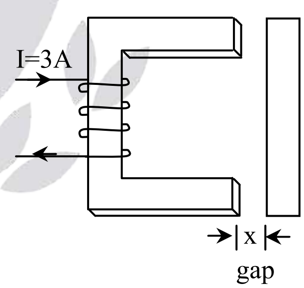
I = 3A

N = 2000 turns

A = 50 cm^2

Gap length, x = 2 cm

Energy stored per unit volume carried by the coil is



$$W = \frac{B^2}{2\mu_0}$$

Where, $B = \mu_0 \frac{NI}{l_g}$ (Neglecting reluctance in the core)

l_g = gap length

$l_g = x + x$ ($\because$ as there are two air-gaps under each pole)

$$B = \mu_0 \frac{NI}{2x}$$

$$W = \frac{\left(\mu_0 \frac{NI}{2x}\right)^2}{2\mu_0}$$

$$= \frac{\mu_0^2 N^2 I^2}{8\mu_0 x^2}$$

$= \frac{\mu_0 N^2 I^2}{8x^2}$

$= \frac{4\pi \times 10^{-7} \times (2000)^2 \times (3)^2}{8 \times (2 \times 10^{-2})^2}$

$= \frac{4\pi \times 10^{-7} \times 4 \times 10^6 \times 9}{8 \times 4 \times 10^{-4}}$

$= 14.1378 \times 10^3$

$\therefore$ W = 14.137 K J/m^3

Force on armature is given by

$F = \left(\frac{B^2}{2\mu_0}\right)$(Area) ; Area = Total area of the air-gaps between the poles = 2A

$= \frac{B^2}{2\mu_0}(2A)$

$= 14.137 \times 10^3 \times 2 \times 50 \times 10^{-4}$

$= 14.137 \times 10^5 \times 10^{-4}$

$\therefore$ F = 141.37 N

3(c) (i) A capacitor of 0.025 μF has the loss angle, δ = 0.0286°. Calculate the dielectric loss of the capacitor when it carries a current of 100 A at a frequency of 25 kHz. [10M]

Solution:

C = 0.025 μF, δ = 0.0286°

I = 100 A and f = 25 kHz

$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

$V = IX_c = \frac{I}{2\pi f C} = \frac{100}{2\pi \times 25 \times 10^3 \times 0.025 \times 10^{-6}}$

= 25464.8V

Dielectric loss = VI tan δ

= 25464.8 × 100 tan (0.0286°)

= 1271 watt

3(c) (ii) An iron piece of 50 kg mass, 7500 kg/m^3 density is subjected to an AC supply of 50 Hz frequency; its hysteresis loop area is found to be 160 cm^2. The scale factors on ordinate and abscissa are 1cm = 0.008 Wb/m^2 and 1 cm = 20 AT/m, respectively. Calculate the loss of energy per hour due to hysteresis in the specimen. [10M]

Solution:

Volume of sample = $\frac{50}{7500} = \frac{1}{150}\,m^3$

Number of cycle per sec = 50

Hysteresis loss = B × H = 160 × 0.008 × 20

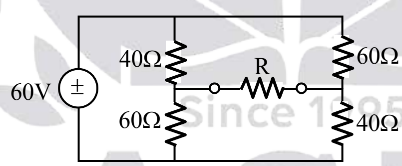
Energy loss/sec = $\frac{1}{150} \times 50 \times 160 \times 0.008 \times 20$

= 8.533 J/sec

= 8.533 × 60 × 60 J/hr

= 30720 J/hr

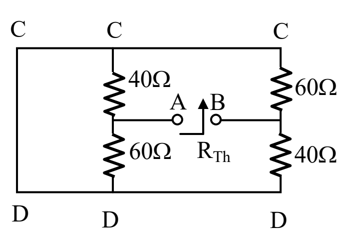
4(a) Determine the value of resistance 'R' which will extract the maximum power from the circuit shown in the figure. Also calculate the value of maximum power. [20M]

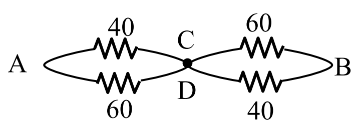


Solution:

Value of 'R' for maximum power transfer will be equal to $R_{Th.}$

To find R_{Th} short the voltage source





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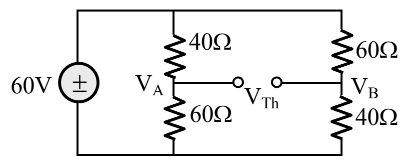
$R_{Th} = 40||60 + 60 || 40$

$= 24 + 24 = 48\ \Omega$

To find V_{Th}:



$$V_A = 60 \times \frac{60}{100} = 36V$$

$$V_B = 60 \times \frac{40}{100} = 24\ V$$

$$V_{Th} = V_A - V_B = 36 - 24 = 12V$$

$$\therefore \text{ Maximum power} = \frac{(V_{Th})^2}{4R_{Th}}$$

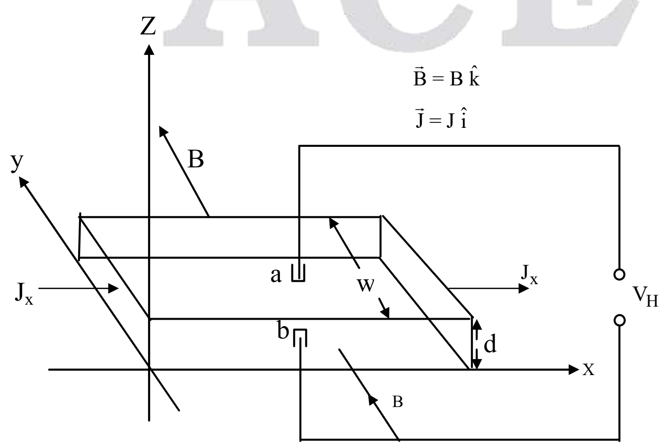
$$= \frac{12\times 12}{4\times 48} = \frac{144}{4\times 48} = 0.75\ W$$

4(b) (i) Define Hall effect. With a sketch, explain the concept of Hall effect and arrive at an equation for Hall voltage V_H. [10M]

Solution:

Hall Effect:

This effect is based on the behaviour of a charge carrier in electric and magnetic fields. It was primarily used to find the sign of the charge carriers in conductors. It is also useful in finding the drift velocity (V_d), carrier concentration, magnetic field strength, conductivity / resistivity of the material, mobility of charge carriers and the type of semiconductor.



Consider a uniform, thick metal strip, with its length along x-axis: 'w' be the width, and d be the thickness of the strip. A uniform transverse magnetic field $\vec{B}$ is applied along the y-axis.

When a current 'i' established along the x-axis, the charge carriers experience a deflecting force along z-axis given by $\vec{F} = q(\vec{V}_d \times \vec{B})$.

From Fleming's left hand rule, we get that, let the charge carriers be +ve (or) –ve, this force deflects charges towards upper surface of the strip. This accumulation of charges develops a potential difference across upper and lower surfaces called Hall potential difference V_{ab}.

If the charge carriers are +ve, Hall PD $V_H = V_{ab} = +ve$

If the charge carriers are –ve, Hall PD $V_H = -ve$

Thus by the sign of Hall emf, we can find the sign of charge carriers. This Hall emf, produces a transverse stall off electric field $E_H = \frac{b}{n}$ 'a' and 'b'. This E_H acts in opposite direction to magnetic force.

$$E_H = \frac{V_H}{d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Soon an equilibrium position is reached where the net force on the carriers is zero. i.e.,

$$qE_H + q(V_d \times B) = 0$$

$$E_H = -(V_d \times B)$$

$$|E_H| = V_d B \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Thus drift velocity can be measured as

$$V_d = \frac{J}{nq} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

We can find the carrier concentration 'n' also. From (2) and (3) we have

$$\frac{E_H}{JB} = \frac{1}{nq} = R_H \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The ratio is defined as Hall coefficient.

This Hall coefficient R_H is –ve, if the sign 'q' of charge carriers is –ve.

$R_H = \frac{1}{nq}$ is +ve for +ve charge carriers.

$$\frac{E_H}{JB} = \frac{1}{nq}$$

$J = \sigma E$ (Ohm's law)

$$\sigma = \frac{nqE_H}{BE}$$

$$\sigma = \frac{nqV_H}{BEd}$$

$\Rightarrow$ **Hall voltage V_H =** $\dfrac{\sigma BEd}{nq}$

Thus conductivity or resistivity $\left(\rho = \frac{1}{\sigma}\right)$ can be measured. Also we have

$$V_d = \mu E$$

$$\mu = \frac{V_d}{E} = \frac{E_H}{BE}$$

Thus mobility of the carriers can be found.

For monovalent metals, R_H is –ve and for some divalent alkaline earth metals like Mg, Zn etc., R_H = +ve. This is because their filled valance band gives rise to hole conduction.

4(b) (ii) The superconducting state of lead specimen has critical temperature of 7.26 K at zero magnetic field and the critical field is 8×10^5 A/m at 0 K. Estimate the critical field at 5 K for this specimen. [10M]

Solution:

$T_c = 7.26$ K

$H_c = 8 \times 10^5$ A/m

Critical field at 5K = ?

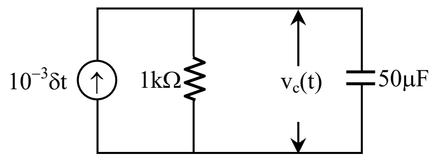
$$H_T = H_C \left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

$$= 8 \times 10^5 \left[1 - \left(\frac{5}{7.26}\right)^2\right]$$

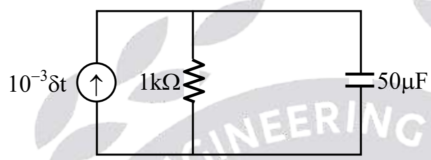
$$= 8 \times 10^5 \times 0.52568$$

$$= 4.205 \times 10^5 \text{ A/m}$$

4(c) A circuit shown in the figure is initially being quiescent and excited by a current impulse. Find the expression for $v_c(t)$ for t > 0 and draw the voltage response. Calculate the value of voltage across the capacitor at t = 50 ms. [20M]

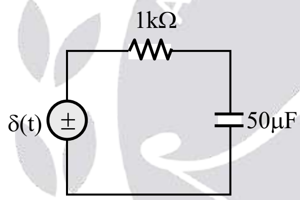


Solution:

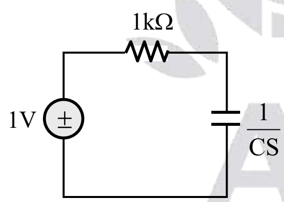


By applying source transformation technique.

⇒



Converting into Laplace domain will make the calculation easy, because given input is not a standard input.



$$\text{Voltage across capacitor, } v_c(s) = \frac{\frac{1}{Cs}}{R+\frac{1}{Cs}}$$

$$= \frac{1}{Cs} \times \frac{Cs}{SCR+1} = \frac{1}{SCR+1}$$

$$= \frac{1}{s\tau+1}$$

$$v_c(t) = \frac{1}{\tau}e^{\frac{-t}{\tau}}$$

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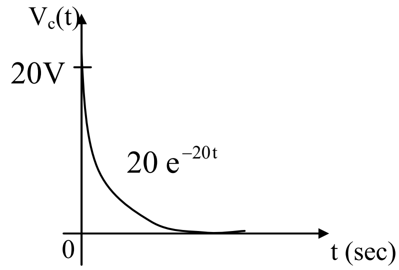
$$v_c(t) = \frac{1\times10^6}{1\times10^3\times50} e^{-\frac{10^6}{1\times10^3\times50}t}$$

$$= 20e^{-20t}u(t)$$



$$v_c(t) = 20\,e^{-20(50\times10^{-3})}$$

$$v_c(t) = \frac{20}{e} = 7.38\ \text{V}$$

SECTION-B

5(a) Form the homogeneous system of equations to balance the chemical equation

$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$.

Solve it by Gauss-Jordan elimination method to obtain the balanced chemical equation. [12M]

Solution:

Let $a(C_2H_6) + b(O_2) \rightarrow c(CO_2) + d(H_2O)$

$\Rightarrow$ $2a = c$ or $(2a - c) = 0$ ………… (1)

$6a = 2d$ or $(3a - d) = 0$ ………. (2)

$2b = (2c + d)$ or $(2b - 2c - d) = 0$ ………… (3)

From (1), (2) & (3)

$$\underset{A}{\begin{bmatrix} 2 & 0 & -1 & 0 \\ 3 & 0 & 0 & -1 \\ 0 & 2 & -2 & -1 \end{bmatrix}} \underset{X}{\begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix}} = \underset{0}{\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}} \quad \text{……………} (4)$$

$$A \sim \begin{bmatrix} 2 & 0 & -1 & 0 \\ 0 & 2 & -2 & -1 \\ 3 & 0 & 0 & -1 \end{bmatrix} \qquad (R_2 \leftrightarrow R_3)$$

$$\sim \begin{bmatrix} 2 & 0 & -1 & 0 \\ 0 & 2 & -2 & -1 \\ 0 & 0 & 3 & -2 \end{bmatrix} \quad (2R_3 - 3R_1)$$

$\therefore$ $3c = 2d$ ……… (5)

$2a = c$ …………. (6)

And $2b = (2c + d)$ …….. (7)

$= (4a + 3a)$ [from (5) and (6) in (7)]

$\therefore$ $2b = 7a$ ………….. (8)

Let $a = 2 \Rightarrow b = 7$ & $c = 4 \Rightarrow d = 6$

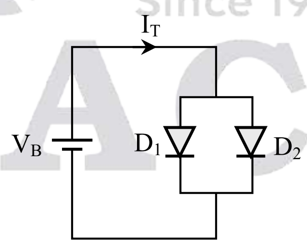
$$\therefore \quad X = \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix} = \begin{bmatrix} 2 \\ 7 \\ 4 \\ 6 \end{bmatrix}$$

i.e., $(2C_2H_6 + 7O_2) \rightarrow (4CO_2 + 6H_2O)$

5(b) The circuit shown below, shows two diodes with reverse saturation currents of I_{S1} and I_{S2} placed in parallel.

(i) Prove the parallel combination operates as a diode. [6M]

(ii) If the total current is I_T, then determine the current carried by each diode. [6M]



Solution:

Let diode specifications are as below:

Reverse saturation currents: I_{s1} for D1 and I_{s2} for D2 (given)

Cut-in voltage voltages: $V_{d1} = V_{d2} = V_d$ (Assume both diodes have same cut in voltage)

Thermal voltage: V_T

Let diode D1 carries I_1 current and diode D2 carries I_2 current. Then

$I_T = I_1 + I_2$ …….. (1)

Also, for diodes D1 and D2

$$I_1 = I_{s1}\left[e^{\frac{V_d}{V_T}} - 1\right] \quad ……………. (2)$$

$$I_2 = I_{s2}\left[e^{\frac{V_d}{V_T}} - 1\right] \quad ………… (3)$$

Total current through both diodes will be (from equation-1)

$$I_T = I_{s1}\left[e^{\frac{V_d}{V_T}} - 1\right] + I_{s2}\left[e^{\frac{V_d}{V_T}} - 1\right]$$

Or

$$I_T = (I_{s1} + I_{s2})\left[e^{\frac{V_d}{V_T}} - 1\right] \quad ……… (4)$$

Let $I_{s1} + I_{s2} = I_s$

Then

$$I_T = I_s\left[e^{\frac{V_d}{V_T}} - 1\right]$$

Which is similar to forward diode current for a diode with reverse saturation current as $I_s = I_{s1} + I_{s2}$.

i.e., parallel comibination of both diodes acts as a diode with reverse saturation current $I_{s1} + I_{s2}$.

(ii) Current through diode -1

$$I_1 = I_{s1}\left[e^{\frac{V_d}{V_T}} - 1\right]$$

From equation (4)

$$I_1 = \left(\frac{I_{s1}}{I_{s1} + I_{s2}}\right)I_T \quad ………….. (5)$$

Current through diode-2

$$I_2 = I_{s2}\left[e^{\frac{V_d}{V_T}} - 1\right]$$

From equation (4)

$$I_2 = \left(\frac{I_{s2}}{I_{s1} + I_{s2}}\right) I_T \qquad \ldots\ldots\ldots\ldots (6)$$

5(c) (i) What are trigraph characters ? How are they useful? Translate the following trigraph sequences into their equivalent symbols: [6M]

(I) ?? = (II) ??) (III) ?? < (IV) ??/ (V) ??– (VI) ??!

Solution:

A trigraph is a three-character sequence that represents a single character. Trigraph sequences are starting from double question marks(??) that the compiler replaces with their corresponding punctuation characters. It can be used in "C" source files with a character set that doesnot contain convenient graphic representations for some punctuation characters.

Whenever any symbol is not present in a character set then trigraph provides a way to represent those characters with a sequence of three characters.

Trigraph	→	Equivalent
(I) ?? =	→	#
(II) ??)	→	]
(III) ?? <	→	{
(IV) ?? /	→	\
(V) ?? –	→	~
(VI) ?? !	→	|

5(c) (ii) From the keywords and identifiers given below, segregate the keywords and identifiers in two separate groups:

(I) break (II) ifloat (III) unsigned (IV) size (V) vshort

(VI) goto (VII) sizeof (VIII) reverse (IX) enum (X) register

(XI) iff (XII) continue [6M]

Solution:

Keywords	Identifiers
I. break	II. ifloat
III. unsigned	IV. size
VI. goto	V. vshort
VII. sizeof	VIII. reverse
IX. enum	XI. iff
X. register	
XII. continue	

5(d) Draw the schematic diagram of a series-series feedback amplifier and obtain expression for

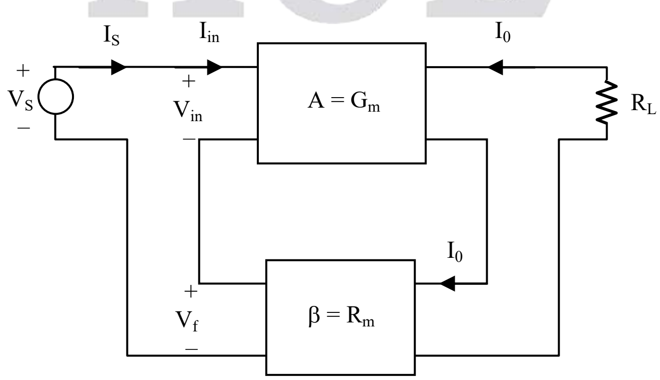
(i) Closed loop gain

(ii) Input impedance

(iii) Output impedance.

The forward amplifier is characterized by finite input impedance R_i and finite output impedance R_0. [3 + 3 × 3 = 12]

Solution:



$A = \frac{I_0}{V_{in}}$; $\beta = \frac{V_f}{I_0}$

A_f [closed loop gain] $= \frac{I_0}{V_S} = \frac{I_0}{V_{in} + V_f}$

$$A_f = \frac{I_0}{V_{in} + \beta I_0} = \frac{I_0}{V_{in} + \beta A V_{in}}$$

$$\rightarrow A_f = \frac{\frac{I_0}{V_{in}}}{1 + A\beta} = \frac{A}{1 + A\beta}$$

(or) $G_{mf} = \frac{G_m}{1 + G_m R_m}$

(ii) **Input resistance:**

$R_{in\ (Basic\ Amp)} = \frac{V_{in}}{I_{in}}$

$R_{in\ (Feedback)} = \frac{V_S}{I_S} = \frac{V_{in} + V_f}{I_S} = \frac{V_{in} + \beta I_o}{I_S} = \frac{V_{in} + \beta A V_{in}}{I_S}$

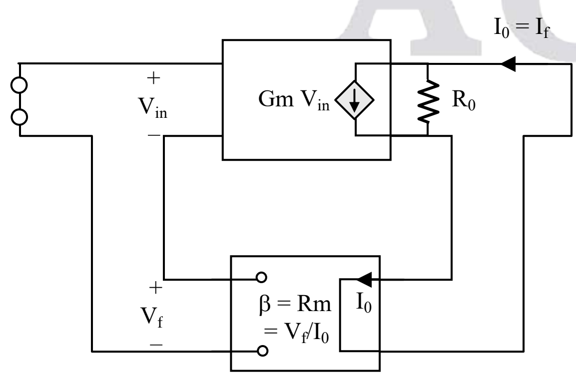
But $I_S = I_{in}$

$\therefore\ R_{inf} = \frac{V_{in}(1 + A\beta)}{I_{in}}$

$R_{inf} = R_{in\ (Basic\ Amp)}\ [1 + A\beta]$

(iii) Output impedance

For calculation of output resistance, the input V_S is short circuited



KVL: $V_{in} + V_f = 0 \rightarrow V_f = -V_{in}$

KCL:

$$I_0 = \frac{1}{R_0} + G_m V_{in}$$

$$= \frac{1}{R_0} + G_m(-V_f)$$

$$= \frac{1}{R_0} + G_m(-\beta I_0)$$

$$I_0[1 + G_m\beta] = \frac{1}{R_0}$$

$$R_{of} = \frac{1}{I_0} = R_0[1 + G_m.\beta]$$

$$\mathbf{R_{of} = R_0[1 + A.\beta]}$$

Where $G_m = A$, $R_m = \beta$

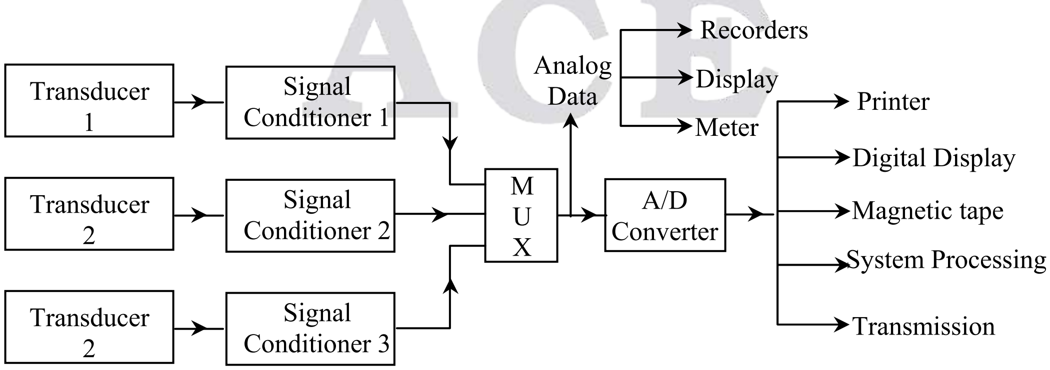
$\therefore$ R_{of} can also be written as

$$\mathbf{R_{0f} = R_{0(Basic\ Amp)}[1 + G_m.R_m]}$$

5(e) With a block schematic, explain the essential functional operations of a generalized data acquisition system. [12M]

Solution:

Block diagram of a general Data Acquisition System (DAS):



→ Data acquisition system (DAS) is a computerized system that collects data from the real world, converts it into the form of electrical signals and do required processing on it for storage, and presentation on computers.

→ Transducers: They are converting physical quantities such as temperature, pressure etc into electrical quantities, or measuring electrical quantities directly. They collect data from the physical world.

Eg: of transducers: Thermocouples, thermistors, Photosensors, Straingage's, Microphase, potentiometer, etc.

→ Signal conditioning unit: The signal produced by the transducers may or may not be very suitable for our system to work properly. It may be very weak, very strong or may have some noise.

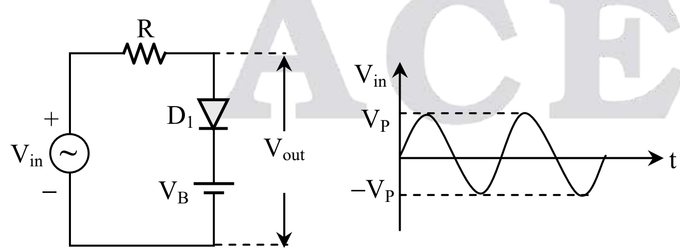
To convert this signal into the most suitable from, amplification and filtration is done respectively by signal conditioning unit.

→ Multiplexer/MUX: the multiplexer receives multiple analog input and provide a single output signal according to the requirements.

→ Analog to digital converters (A/D Converters): the data is converted into digital form by A/D converters. After the conversion of data into digital form, it is displayed with the help of oscilloscopes, numerical displays, panel meters to monitor the complete system.

Also the data can be either permanently or temporarily stored or recorded accorded to the requirement.

6(a) For the diode-resistor-battery circuit shown below, the diode D_1 is assumed to be ideal. Sketch the time-average of V_{out}, as the battery voltage V_B is varied from $-\infty$ to ∞, if the input voltage is a sinusoidal voltage with an amplitude equal to V_P.



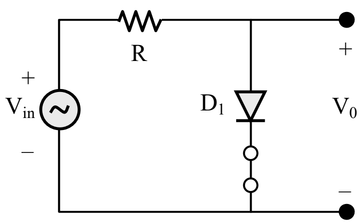
[20M]

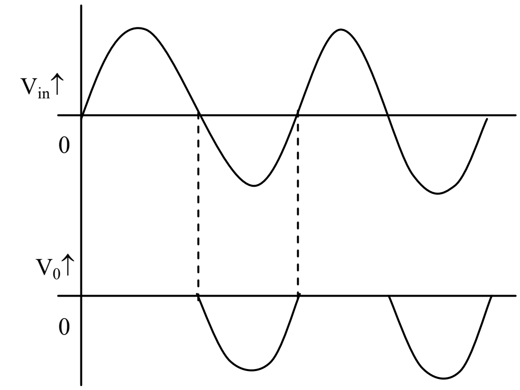
Solution:

Let us sketch V_0 and calculate $V_{0(avg)}$ for different values of V_B.

V_B is varied from $-\infty$ to $+\infty$. Consider $V_B = 0, +\infty, -\infty, \frac{V_P}{2}$ and $\frac{-V_P}{2}$

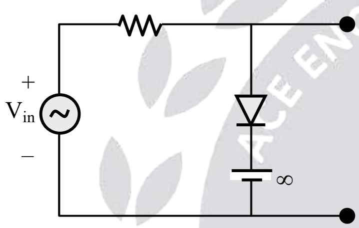
Case: 1 $V_B = 0$

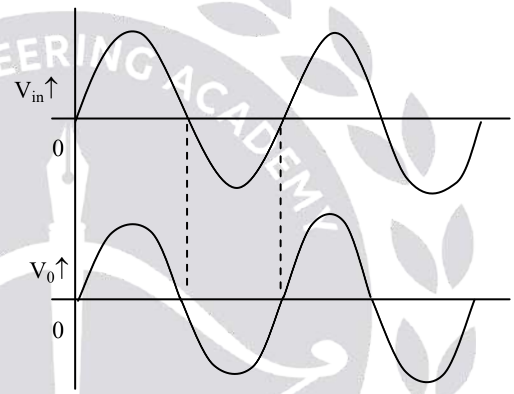




$$\left|V_{o(avg)}\right| = \frac{V_m}{\pi}$$

Case 2: $V_B = +\infty$





$$\left|V_{o(avg)}\right| = 0V$$

Case 3: $V_B = -\infty$

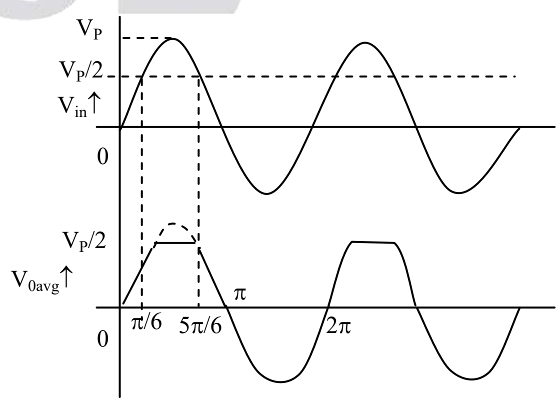
Case 4: $V_B = \frac{V_P}{2}$

(a) $Vin \le \frac{V_P}{2}$ (Diode OFF)

$V_0 = V_{in}$

(b) $Vin > \frac{V_P}{2}$ Diode ON

$V_0 = \frac{V_P}{2}$



$$V_0(avg) = \frac{1}{2\pi}\left[\int_0^{\pi/6} V_p \sin t\,dt + \int_{\pi/6}^{5\pi/6}\frac{V_p}{2}dt + \int_{5\pi/6}^{2\pi} V_p \sin t\right]$$

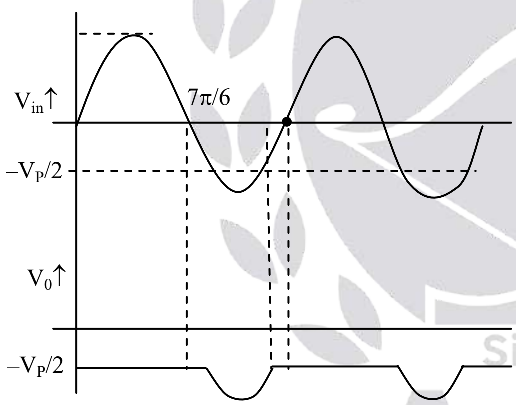
$$= \frac{1}{2\pi}\left[Vp(-\cos t)_0^{\pi/6}\right] + \frac{V_p}{2}\left[5\pi/6 - \pi/6\right] + V_p(-\cos t)_{5\pi/6}^{2\pi}$$

$$= \frac{1}{2\pi}\left[Vp\left[1-\frac{\sqrt{3}}{2}\right] + \frac{V_P}{2}\left[\frac{4\pi}{6}\right] + V_P[-0.866-1]\right]$$

$$= \frac{1}{2\pi}\left[0.1339V_p + 1.0471V_p - 1.866V_P\right]$$

$$= \frac{1}{2\pi}[-0.685] = -0.109$$

Case 5: $V_B = -\frac{V_P}{2}$



$$V_0(avg) = \frac{1}{2\pi}\left[\int_0^{7\pi/6}\frac{-V_P}{2}dt + \int_{7\pi/6}^{11\pi/6} V_p \sin t + \int_{11\pi/6}^{2\pi} -\frac{V_P}{2}\right]$$

$$= \frac{1}{2\pi}\left[\frac{-V_p}{2}\left[\frac{7\pi}{6}\right] + V_p[-\cos t]_{7\pi/6}^{11\pi/6} + \left(\frac{-V_p}{2}\right)\left[2\pi - \frac{11\pi}{6}\right]\right]$$

$$= \frac{1}{2\pi}\left[\frac{-V_p}{2}\left[\frac{7\pi}{6}\right] + V_p[-0.866-0.866]\right]\frac{-V_p}{2}[\pi/6]$$

$$= \frac{V_p}{2\pi}[-1.8325 - 1.732 - 0.2617]$$

$= -0.\ 608V_P$

6(b) A dynamometer ammeter is arranged so that 1% of total current passes through the moving coil and rest through the fixed coil. The mutual inductance between the two coils varies with the angle of displacement of the moving coil from its zero position as follows:

Angle (degree)	0	15	30	60	90	105	120
Mutual inductance μH)	–336	–275	–192	0	192	275	336

If a torque of 10.5 × 10^{-6} Nm is required to give the full scale defection of 120°, calculate the current at half and full scale defection. (Graph sheet attached) [20M]

Solution:

$$\text{Half FSD} = \frac{120}{2} = 60°$$

It is clear from the data given, 'M' varies linearly about θ = 60°

$$\left(\frac{dM}{d\theta}\right)_{\theta=60°} = \frac{192-(-192)}{90-30} = 6.4\ \mu\text{H/deg}$$

$$= 366.7\ \mu\text{H/deg}$$

$$\text{Torque at } \frac{1}{2}\text{FS, } T_d = \frac{1}{2}\times 10.5\times 10^{-6}$$

$$= 5.25 \times 10^{-6}\ \text{Nm}$$

Current through fixed coil, $I_1 = I_C = 0.99I$

Current through moving coil, $I_2 = I_P = 0.01I$

$$\therefore\ T_d = I_C I_P \frac{dM}{d\theta}$$

$$5.25 \times 10^{-6} = 0.99(I)\ 0.01(I)\ 366.7 \times 10^{-6}$$

$$\therefore I = 1.2\ \text{A}$$

At FSD of θ = 120°:

$$\left(\frac{dM}{d\theta}\right)_{120°} = \frac{336-200}{120-77} = 3.16\ \mu H/deg$$

$$= 181.2\ \mu H/rad$$

$T_{dFS} = 10.5 \times 10^{-6}$ Nm

$10.5 \times 10^{-6} = 0.99\ I\ (0.01) I \times 181.2 \times 10^{-6}$

$I = 2.42$ A

6(c) Using any high level language, write a computer program to compute the area enclosed by a curve f(x) = x^2 + 1, between x = A and x = B, by using trapezoidal approximation. [20M]

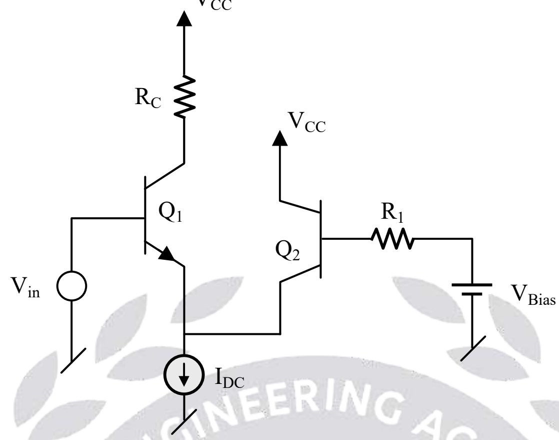
Solution:

```
// Trapezoida1 rule
#include<stdio.h>
float f(float x)
{
   //function given as f(x)=x*x+1
   return x*x+1;
}
   float calcTrap(float a, float b, float n)
{
   float h = (b–a)/n;
   float sum = f(a) + f(b);
   for (int i = 1; i<n; i++)
         sum = sum + 2*f(a+i*h);
   return (h/2)*sum;
}
int main()
{
   //Lets take A as 65 and B as 66
   float a = 65, b=66;
   int n = 5;
   printf("Answer is %6.2f\n", calcTrap(a, b, n));
   return 0;
}
```

Output

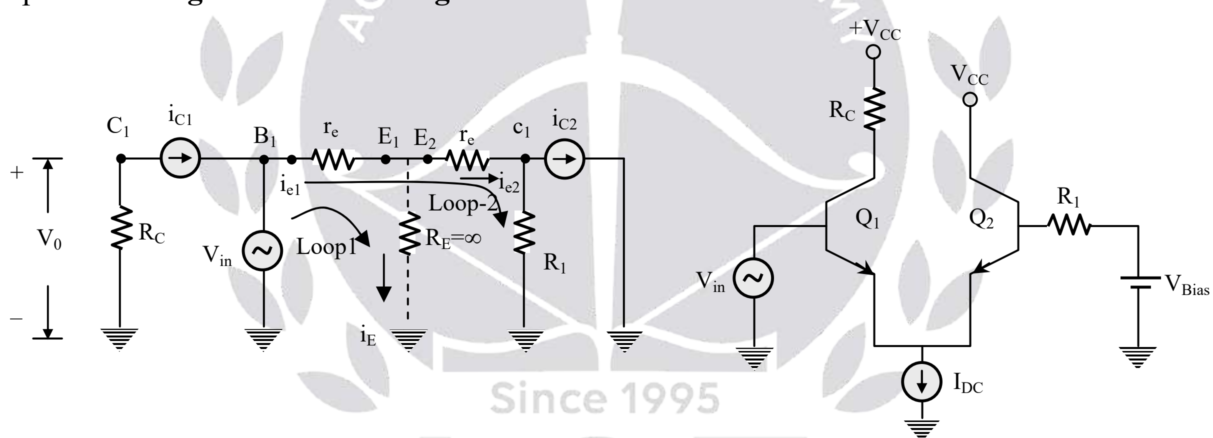
Answer is 4291.34

7(a) Assuming the early voltage $V_A = \infty$, compute the voltage gain and input impedance of the circuit shown below. I_{DC} is an ideal current source while V_{Bias} is an ideal voltage source used to bias Q_1 and Q_2 in the active mode. **[20M]**



Solution:

Step 1: **Small signal Model of the given circuit**



KVL for loop-1:

$V_{in} - i_{e1}\, r_e - i_E\, R_E = 0$ ……(1)

$\Rightarrow V_{in} = i_{e1}\, r_e + i_{e1}\, R_E - i_{e2}\, R_E = i_{e1}\,(r_e + R_E) \;- i_{e2}\, R_E = 0$ ………(2)

$[\; \because i_E = i_{e1} - i_{e2}]$

KVL for loop-2:

$V_{in} - i_{e1}\, r_e - i_{e2}\, r_E = 0 \Rightarrow V_{in} = \; i_{e1} r_e + i_{e2}\, r_e$ ………(3)

Step (2) using Cramer's rule

Online Test Series

GATE – 2022 Online Test Series	ESE – 2022 Prelims Online Test Series	GATE + ESE – 2022 Online Test Series Combination Pack
No. of Tests : 65 + Free 52 Practice Tests of GATE - 2021 Online Test Series Total Tests : 117	No. of Tests : 44 + Free 30 Practice Tests of ESE - 2021 Online Test Series Total Tests : 74	All tests will be available till GATE - 2022 & ESE -2022 (Prelims) examinations respectively.

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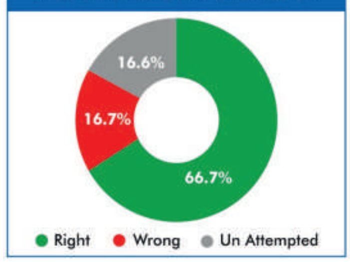
TEST WISE STATISTICS:

TIME

Test Duration : 3 Hours
Your Time : 2Hrs 45Min 23Sec

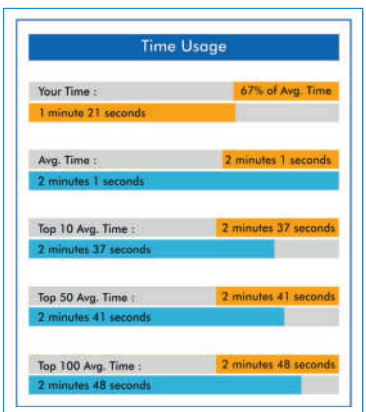
ANSWERS EVALUTION

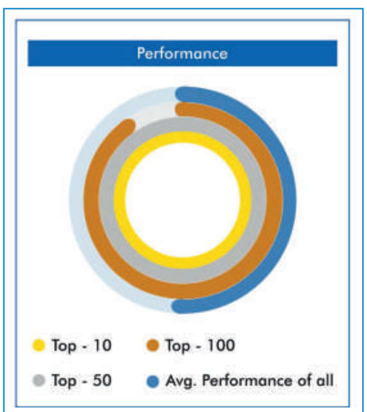


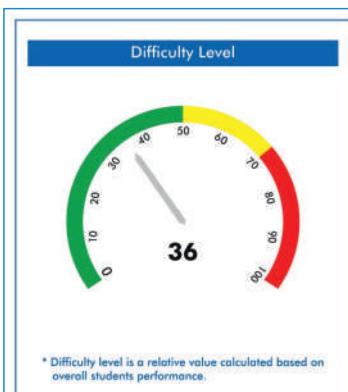
RESULTS

OBTAINED MARKS
76 / 100
AIR 380
* Total Attempted Students (till now) : 11250

QUESTION WISE STATISTICS:







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$$i_{e1} = \frac{\begin{vmatrix} V_{in} & -R_E \\ V_{in} & r_e \end{vmatrix}}{\begin{vmatrix} r_e + R_E & -R_E \\ r_e & r_e \end{vmatrix}} = \frac{r_e V_{in} + R_E V_{in}}{r_e(r_e + R_E) + r_e R_E} = \frac{(r_e + R_E)V_{in}}{r_e(r_e + 2R_E)} \quad \text{..........(4)}$$

Similarly $$i_{e2} = \frac{\begin{vmatrix} r_e + R_E & V_{in} \\ r_e & v_{in} \end{vmatrix}}{\begin{vmatrix} r_e + R_E & -R_E \\ r_e & r_e \end{vmatrix}} = \frac{(r_e + R_E)V_{in} - r_e V_{in}}{r_e(r_e + R_E) + r_e R_E} = \frac{R_E V_{in}}{r_e(r_e + 2R_E)} \quad \text{..........(5)}$$

Step (3)

$V_0 = -i_{c1} R_C = -i_{e1} R_C$ ……. (6) $[\because i_{c1} \approx i_{e1}]$

$$= -\left[\frac{(r_e + R_E)V_{in}}{r_e(r_e + 2R_E)}\right] R_c \quad \text{…….. (7)}$$

$$\frac{V_0}{V_m} = \left[\frac{-R_E}{r_e 2R_E}\right] R_C \quad \text{…………….. (8)} \quad [r_e << R_E]$$

$$= \frac{-R_C}{2r_e} \quad \text{……… (9)}$$

$$\therefore \frac{V_0}{V_m} = A_V = \frac{-R_C}{2r_e} = \frac{-g_m R_C}{2} \quad \text{………… (10)} \left[\because \frac{1}{r_e} = g_m\right]$$

Step (4) Input impedance R_i

$$R_i = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{i_{b1}} = \frac{V_{in}}{\frac{i_{C1}}{\beta}} = \frac{\beta V_{in}}{i_{c1}} \quad \text{…………. (11)}$$

$$= \frac{\beta V_{in}}{\frac{(r_e + R_E)V_{in}}{r_e(r_e + 2R_E)}}$$

$$= \frac{\beta r_e(r_e + 2R_E)}{(r_e + R_E)}$$

$$= \beta \frac{r_e . 2R_E}{R_E} \quad \text{…………… (12)} \quad [\because R_E >> r_e]$$

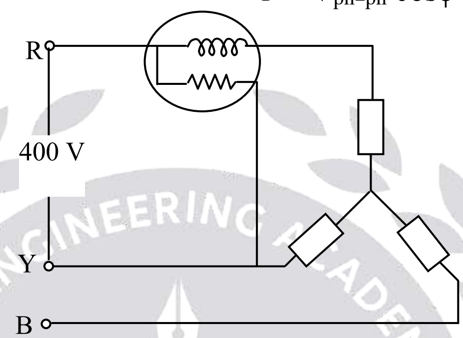
$$\therefore R_i = 2\beta r_e = \frac{2\beta}{g_m} \quad \text{……….. (13)}$$

7(b) (i) A wattmeter reads 4 kW when its current coil is connected in R phase of a symmetrical 3-phase system supplying a balanced 3-phase inductive load of 25A at 400V. What will be the reading of the wattmeter if the connections of the current coil remain unchanged and voltage coil be connected between B and Y phases? Draw the corresponding phasor diagram.

[10M]

Solution:

$P = V_{ph}I_{ph}\cos\phi$



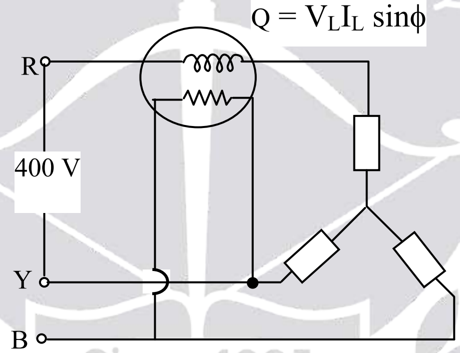
$V_L = 400$ V, $I_L = 25$ A

$$4000 = \frac{400}{\sqrt{3}} \times 25 \times \cos\phi$$

$\cos\phi = 0.69$

$\sin\phi = 0.721$

$Q = V_LI_L \sin\phi$

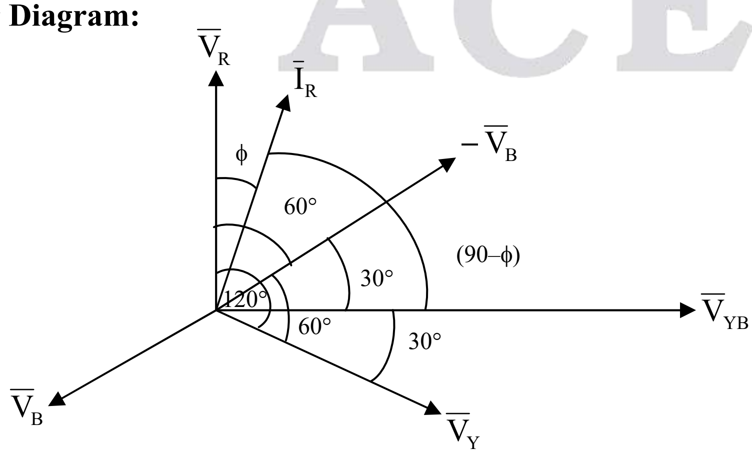


$Q = V_LI_L\sin\phi$

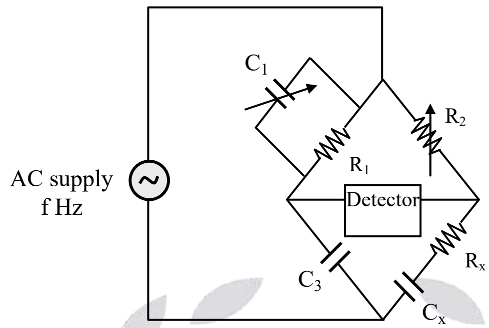
$= 400 \times 25 \times 0.721$

$= 7211$ VAR

Phasor Diagram:



7(b) (ii) The following data is related to the Schering bridge shown the figure. $R_1 = 2\ k\Omega$, $C_1 = 0.5\ \mu F$, $R_2 = 4\ k\Omega$ and $C_3 = 0.5\ \mu F$ at frequency 1 kHz. Determine the unknown resistance and capacitance of the bridge circuit and dissipation factor. [10M]



Solution:

$$R_x \cdot \frac{1}{C_1} = \frac{1}{C_3} R_2 \qquad \frac{1}{C_x} \times R_1 = \frac{1}{C_3} \times R_2$$

$$R_x = \frac{0.5\times10^{-6}}{0.5\times10^{-6}} \times 4k\Omega \qquad C_x = \frac{R_1}{R_2} \times C_3$$

$$= 4\ k\Omega \qquad = \frac{2000}{4000} \times 0.5 \times 10^{-6}$$

$$= 0.25\ \mu F$$

$$d = \omega RC = 2 \times \pi \times 1000 \times 4000 \times 0.25 \times 10^{-6}$$

$$= 6.283$$

7(c) (i) Construct a switching circuit for the Boolean function using logic gates. Simplify the function and draw the simplified circuit using logic gates

L = A.B + A′.B + A.B′ [10M]

Solution:

Given expression

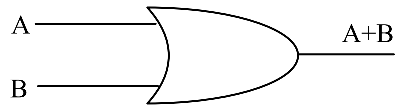
$$L = A.B + \overline{A}B + A\overline{B}$$

$$= A.B + A \oplus B$$

A \ B	0	1
0		1
1	1	1

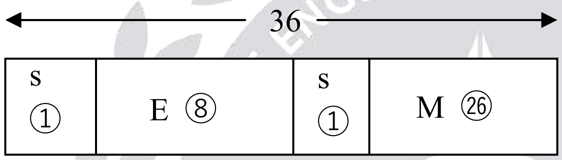
$$\Rightarrow A + B$$

Simplified equation will be OR of A and B



7(c) (ii) A 36-bit floating point binary number has eight bits plus sign for the exponent and twenty-six bits plus sign for mantissa. The mantissa is a normalized fraction. Numbers in the mantissa and exponent are in signed-magnitude form. Determine the largest and smallest positive quantities that can be represented, excluding zero. [10M]

Solution:



Given information: Exponent and mantissa are expressed in signed magnitude format

Smallest +ve number E range is –255 to + 255

$E_{min} = -256$

Normalized $M_{min} = 0.100\ldots.0$ (26)

Minimum value $= 0.1_2 \times 2^{-255} = 2^{-1} \times 2^{-255}$

$= +2^{-256}$

Max. value $= E_{max} = 255$

$M = 111\ldots.1$ (26)

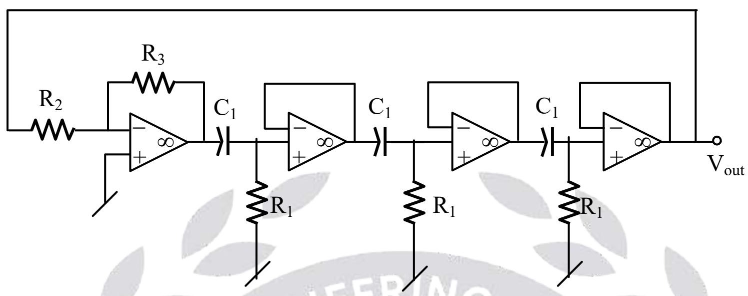
$+\,0.1111\ldots..1 \times 2^{255}$

$= (1-2^{-26}) \times 2^{255}$

$\cong 2^{255}$

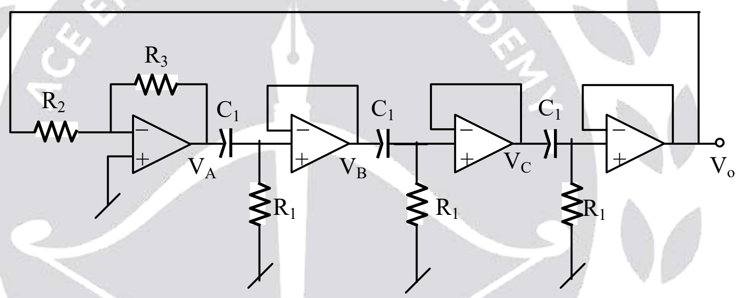
+ve value range is 2^{-256} to 2^{255}

8(a) For the RC phase shift oscillator circuit shown below, determine the condition of oscillation and the frequency of oscillation. What will be the frequency of oscillation (in Hz) if $R_1 = R_2 = 10\ k\Omega$ and $C_1 = 1.0\ nF$? Also calculate the minimum value of R_3 required to sustain sinusoidal oscillations. [20M]



Solution:

$$\frac{V_A}{V_O}\frac{V_B}{V_A}\frac{V_C}{V_B}\frac{V_O}{V_C} = 1$$



$$\left(-\frac{R_3}{R_2}\right)\left[\frac{R_1}{R_1+\frac{1}{SC_1}}\right]\left[\frac{R_1}{R_1+\frac{1}{SC_1}}\right]\left[\frac{R_1}{R_1+\frac{1}{SC_1}}\right] = 1$$

$$\left(\frac{-R_3}{R_2}\right)\left[\frac{SC_1R_1}{1+SC_1R_1}\right]^3 = 1$$

$$\left(\frac{-R_3}{R_1}\right)\left(-j\omega^3C_1^3R_1^3\right) = \left[1 - j\omega^3C_1^3R_1^3 + j3\omega C_1R_1 - 3\omega^2C_1^2R_1^2\right]$$

Both side equate real terms,

$$1 - 3\omega^2C_1^2R_1^2 = 0 \rightarrow 3\omega^2C_1^2R_1^2 = 1$$

$$\omega = \frac{1}{\sqrt{3}C_1R_1} = \frac{1}{\sqrt{3}\left(1\times10^{-9}\right)\left(10\times10^3\right)} = 57.735 rad/sec$$

$$f = \frac{1}{2\pi\sqrt{3}C_1R_1} = 9.18\text{kHz}$$

$$\left(\frac{R_3}{R_1}\right)\left(\omega^3C_1^3R_1^3\right) = 3\omega C_1R_1 - \omega^3C_1^3R_1^3$$

$$\left(\frac{R_3}{R_1}\right)\left(\omega^2C_1^2R_1^2\right) = 3 - \omega^2C_1^2R_1^2$$

$$\left(\frac{R_3}{R_1}\right)\frac{1}{3} = 3 - \frac{1}{3}$$

$R_3 = 8R_1 = 8(10k) = 80\ k\Omega$

8(b) A parallel plate capacitive transducer uses plates of area 450 mm^2 which are separated by a distance 0.3 mm and having air as dielectric. Determine:

(i) The change in capacitance if the transducer is subjected to a linear displacement which reduces distance between plates to 0.27 mm

(ii) The ratio of per unit change of capacitance to per unit change of displacement.

(iii) If a mica sheet of 0.02 mm is inserted in the gap, determine the value of actual capacitance and the change in capacitance for the same displacement and the ratio of per unit change in capacitance to per unit change in displacement. Assume the dielectric constant of mica to be 8. [20M]

Solution:

Initial capacitance

$$C = \varepsilon_0 A / d$$

$$= \frac{8.85\times10^{-12}\times450\times10^{-6}}{0.3\times10^{-3}}\text{F} = 13.27\text{ pF}$$

(i) Change in displacement,

$\Delta d = (0.3 - 0.27)$ mm

$= 0.03$ mm

Capacitance after application of displacement

$$C + \Delta C = \frac{8.85\times10^{-12}\times450\times10^{-6}}{0.27\times10^{-3}}\,F$$

$$= 14.7\text{ pF}$$

Change in capacitance ΔC = 14.75 pF – 13.27 pF

= 1.48 pF

(ii) Ratio= $\frac{\Delta C/C}{\Delta d/d} = \frac{\left(1.48/13.27\right)}{\left(\frac{0.03}{0.3}\right)} = 1.115$

(iii)Initially the displacement between the plate is 0.3 mm. since thickness of mica is 0.02mm, the length of air gap between the plate is 0.28 mm

Initial capacitance of transducer,

$$C = \frac{\varepsilon_0 A}{d_1/\varepsilon_1 + d_2/\varepsilon_2}$$

$$= \frac{8.85\times10^{-12}\times450\times10^{-6}}{(0.28/1 + 0.02/8)\times10^{-3}}\,F \quad = 14.09\text{ pF}$$

When a displacement of 0.03 mm is applied, the length of airgap is reduced to (0.28 – 0.03)mm = 0.25 mm.

Capacitance after application of displacement

$$C + \Delta C = \frac{8.85\times10^{-12}\times450\times10^{-6}}{(0.25/1 + 0.02/8)\times10^{-3}}\,F \quad = 15.77\text{ pF}$$

Change in capacitance ΔC = 15.77 pF – 14.09 pF

= 1.68 pF

(ii) Ratio= $\frac{\Delta C/C}{\Delta d/d} = \frac{\left(1.68/15.77\right)}{\left(\frac{0.03}{0.3}\right)} = 1.06$

Hearty Congratulations to our

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- AIR 1ST EE — AAKASH DHILL
- AIR 1ST ME — SUYASH SHARMA
- AIR 1ST PI — GANESH ADIGAUR
- AIR 1ST XE — VARUN KAUSHIK
- AIR 2nd ME — JAY CHAVDA
- AIR 2nd PI — GOWTHAM GUDIMELLA
- AIR 2nd EC — M POOJASREE
- AIR 2nd ES — ANUSH VERMA
- AIR 3rd ME — MUNISH KUMAR
- AIR 3rd ME — NUKULA VISWA TEJA
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- AIR 6th ME — ABHISHEK MEWAR
- AIR 6th PI — AKASH JAISWAL
- AIR 6th EC — PARAG SAROHA
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- AIR 6th CE — TANMAY MAHAJAN
- AIR 6th XE — MANISH YADAV
- AIR 7th ME — VATSAL PANCHAL
- AIR 7th PI — SACHIN DUBOLIYA
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- AIR 8th CE — RAHUL PATI
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- AIR 8th EE — HEMANT JINDAL
- AIR 9th EC — ABHISHEK SINGH
- AIR 9th EC — ALEESHA ROSE
- AIR 9th EC — SAI VAMSI DOSAPATI
- AIR 9th IN — RAMESH KUMAR
- AIR 9th CS — NIRANJAN NITIN DHOOT
- AIR 9th XE — RACHIT KUMAR
- AIR 10th ME — DEEPESH AGARWAL
- AIR 10th PI — VYOM SHARMA
- AIR 10th IN — PRAGYA KAUSHIK
- AIR 10th CE — GOVIND PRASAD B
- AIR 10th XE — D KUMAR PATIL
- AIR 10th XE — R SHIVAJI NALE

and many more...

Total 57 Ranks in Top 10

ME : 10 | PI : 09 | CE : 08 | EE : 4 | EC : 09 | CS : 03 | IN : 08 | XE : 06

8(c) Show that:

(i). $\int_C (yz-1)dx+(z+xz+z^2)dy+(y+xy+2yz)dz$ **is independent of path of integration from (1, 2, 3) to (4, 5, 6). Hence, evaluate the integral.** **[10 M]**

Solution:

$$\int_C (yz-1)dx+(z+xz+z^2)dy+(y+xy+2yz)dz$$

$$= \int_C yz\,dx - dx + zdy + xz\,dy + z^2\,dy + ydz + xy\,dz + 2y\,zdz$$

$$= \int_{(1,2,3)}^{(4,5,6)} \{yz\,dx + xzdy + xy\,dz\} + (zdy+ydz) + (z^2dy + 2yz\,dz) - dx$$

$$= \int_{(1,2,3)}^{(4,5,6)} d(xyz)+d(yz)+d(yz^2) - dx$$

$$= (xyz+yz+yz^2-x)_{(1,2,3)}^{(4,5,6)}$$

= (120 + 30 + 180 – 4) – (6 + 6 + 18 – 1)

= 326 – 29

= 297

Now, let us calculate the line integral along the path from (1,2,3) to (4,5,6)

Equation of straight line passing through (1,2,3) and (4,5,6)

$$\frac{x-1}{3}=\frac{y-2}{3}=\frac{z-3}{3}=t$$

$x = 3t + 1$, $y = 3t + 2$, $z = 3t + 3$

$dx = 3dt$, $dy = 3dt$, $dz = 3dt$

If $x = 1$, then $t = 0$

If $x = 4$, then $t = 1$

$$\int_C (yz-1)dx+(z+xz+z^2)dy+(y+xy+2yz)dz$$

$$= \int_0^1 \left[\begin{array}{c} \{(3t+2)(3t+3)-1\}(3dt) + \{(3t+3)+(3t+1)(3t+3)+(3t+3)^2\}3dt + \\ \{(3t+2)+(3t+1)(3t+2)+2(3t+2)(3t+3)\}3dt \end{array} \right]$$

$\therefore$ The integral value is independent of path.

$$\int_0^1 \{(3t+2)(3t+3)-1\}(3dt) = \int_0^1 (27t^2+45t+15)dt$$

$$\int_0^1 \{(3t+3)+(3t+1)(3t+3)+(3t+3)^2\}3dt = \int_0^1 (54t^2+99t+45)dt$$

$$\int_0^1 \{(3t+2)+(3t+1)(3t+2)+2(3t+2)(3t+3)\}3dt = \int_0^1 (81t^2+126t+48)dt$$

$$= \int_0^1 (27t^2+45t+15+54t^2+99t+45+81t^2+126t+48)dt$$

$$= \int_0^1 (162t^2+270t+108)dt$$

$$= 297$$

8(c) (ii) Let $\overline{F} = z\hat{j} + z\hat{k}$ represent the flow of a liquid. Find the flux of $\overline{F}$ through the surface S given by that portion of the plane z = 6 – 3x – 2y in the first octant oriented upward. [10M]

Solution:

Given: $\vec{F} = z\vec{j} + z\vec{k}$

Let ϕ: z = 6 –3x – 2y

ϕ: 3x + 2y + z – 6 = 0

$$\hat{n} = \frac{\nabla\phi}{|\nabla\phi|} = \frac{3\vec{i}+2\vec{j}+\vec{k}}{\sqrt{9+4+1}}$$

$$\hat{n} = \frac{3}{\sqrt{14}}\vec{i} + \frac{2}{\sqrt{14}}\vec{j} + \frac{1}{\sqrt{14}}\vec{k}$$

$$\vec{F}\cdot\hat{n} = \frac{2z}{\sqrt{14}} + \frac{z}{\sqrt{14}} = \frac{3z}{\sqrt{14}}$$

Let R be the projection of the surface on xy plane

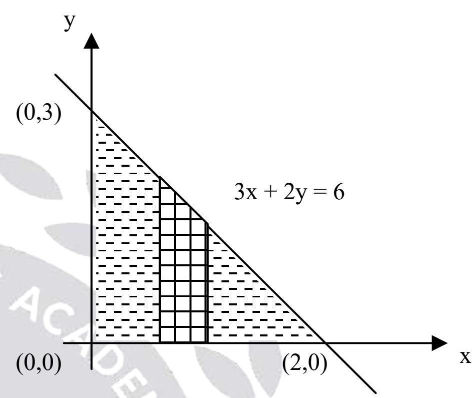
z = 0 and 3x +2y = 6

$$\hat{n}\cdot\hat{k} = \frac{1}{\sqrt{14}}$$

$$ds = \frac{dxdy}{|\hat{n}\cdot\hat{k}|} = \frac{dx\,dy}{\frac{1}{\sqrt{14}}} = \sqrt{14}\ dxdy$$

$$\iint_S \vec{F}\cdot\hat{n}\,ds = \iint_S \frac{3z}{\sqrt{14}}\sqrt{14}\ dx\ dy$$

$$= 3\iint_R (6-3x-2y)\ dx\ dy \qquad \ldots\ldots.(1)$$



$$\iint_S \vec{F}\cdot\hat{n}\,ds$$

$$= 3\int_{x=0}^{2}\int_{y=0}^{\frac{6-3x}{2}} (6-3x-2y)\,dy\,dx$$

$$= 3\int_0^2 \left\{6y - 3xy - y^2\right\}_{y=0}^{\frac{6-3x}{2}}\ dx$$

$$= 3\int_0^2 \left\{3(6-3x) - 3x\left(\frac{6-3x}{2}\right) - \left(\frac{6-3x}{2}\right)^2\right\}dx$$

$$= 3\int_0^2 \left\{18 - 9x - 3x\left(3 - \frac{3}{2}x\right) - \left[\frac{36+9x^2-36x}{4}\right]\right\}dx$$

$$= 3\int_0^2 \left\{18 - 9x - 9x + \frac{9}{2}x^2 - 9 - \frac{9}{4}x^2 + 9x\right\}dx$$

$$= 3\int_0^2 \left\{9 - 9x + \frac{9}{4}x^2\right\}dx$$

$$= 3\left(9x - \frac{9x^2}{2} + \frac{9}{12}x^3\right)_0^2 = 3[18 - 18 + \frac{9}{12}(8)] = 18$$

Hearty Congratulations to our
ESE - 2020 TOP RANKERS
AIR 1 CHARUDATTA S ME
AIR 1 SHASHANK GAUR EE
AIR 1 PRAKASH JHA E&T
AIR 1 GAURAV KUMAR CE
AIR 2 K S SHARADRAO ME
AIR 2 ABHISHEK SINGH EE
AIR 2 PARTH BATRA E&T
AIR 2 PRASHANT SINGH CE
AIR 3 SURAJ KUMAR S ME
AIR 3 VIKASH SHANKAR EE
AIR 3 RAHUL NAREDI E&T
AIR 3 KULDEEP JANGRA CE
AIR 4 SHUBHAM B ME
AIR 4 ANUPAM S EE
AIR 4 SHUBHAM E&T
AIR 4 ANISH BAGGA CE
AIR 5 KAMLESH PARWAR ME
AIR 5 MANOJ KUMAR E&T
AIR 5 PAVITRA GOYAL CE
AIR 6 MD ZUHAIB ME
AIR 6 VISHWA SIMHAA EE
AIR 6 SAURAV KUMAR S E&T
AIR 7 PRATEEK S ME
AIR 7 DINESH KUMAR S EE
AIR 7 RAGHAV PURWAR E&T
AIR 8 V SAIKRISHNA REDDY ME
AIR 8 GAGAN GHUNAWAT EE
AIR 8 RAM KRISHNA E&T
AIR 9 GANESH KUMAR A ME
AIR 9 AKSHAY KUMAR T EE
AIR 9 CHHAVI JAIN E&T
AIR 9 ARPIT JAIN CE
AIR 10 HEMABH TRIVEDI ME
AIR 10 RAJAT DIXIT EE
AIR 10 L KUMARI JAISWAL E&T
AIR 10 AMIT SHARMA CE
and many more...
TOTAL 36 RANKS IN TOP 10
ME 10
EE 09
E&T 10
CE 07