

• Try to avoid calculation mistake



• Improve presentation

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# ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

## Electrical Engineering

### Test-6 : Power Electronics & Drives + Engineering Mathematics + B.E.E.-1 + Analog Electronics-1 + Electrical Materials-1 + Electrical Machines-2

Name : .....

Roll No : .....

Test Centres	Student's Signature
Delhi <input checked="" type="checkbox"/> Bhopal <input type="checkbox"/> Jaipur <input type="checkbox"/> Pune <input type="checkbox"/> Hyderabad <input type="checkbox"/>	

- #### Instructions for Candidates
- Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
  - There are Eight questions divided in TWO sections.
  - Candidate has to attempt FIVE questions in all in English only.
  - Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
  - Use only black/blue pen.
  - The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
  - Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
  - There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

#### FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	25
Q.2	
Q.3	
Q.4	32
Section-B	
Q.5	47
Q.6	47
Q.7	32
Q.8	
<b>Total Marks Obtained</b>	<b>183</b>

Signature of Evaluator

Cross Checked by

Sourabh  
Uman

## IMPORTANT INSTRUCTIONS

**CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.**

### DONT'S

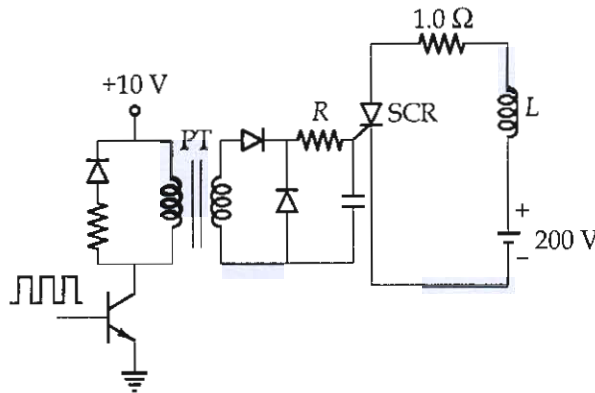
1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

### DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

### Section A : Power Electronics & Drives + Engineering Mathematics

- Q.1 (a) A 1 : 1 Pulse transformer (PT) is used to trigger the SCR in the figure. The SCR is rated at 1.5 kV, 250 A with  $I_L = 250$  mA,  $I_H = 150$  mA, and  $I_{Gmax} = 150$  mA with  $I_L = 250$  mA,  $I_{Gmin} = 100$  mA. The SCR is connected to an inductive load, where  $L = 150$  mH in series with a small resistance and the supply voltage is 200 V DC. The forward drops of all transistors / diodes and gate-cathode junction during ON state are 1.0 V.
- (i) Find the resistance  $R$ .



- (ii) Find the minimum approximate volt-second rating of the pulse transformer suitable for triggering the SCR (Volt-second rating is the maximum of product of the voltage and the width of the pulse that may be applied).

[12 marks]





$x = 1 \Rightarrow y = 1$   
 $x = 2 \Rightarrow y = 4$   
 $x = 3 \Rightarrow y = 9$   
 $x = -1 \Rightarrow y = 1$   
 $x = -2 \Rightarrow y = 4$

$$y = x^2 \Rightarrow x^2 - y = 0$$

$$\left[ \begin{array}{c} -x \\ -y \end{array} \right] \cdot \left[ \begin{array}{c} 1 \\ 0 \end{array} \right] = 0$$

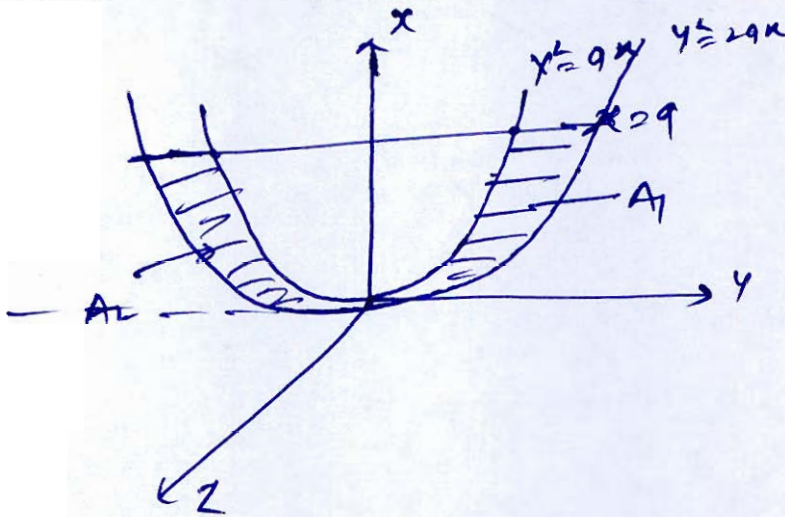
$$\left[ \begin{array}{c} -x \\ -y \end{array} \right] \cdot \left[ \begin{array}{c} 1 \\ 0 \end{array} \right] = 0$$

$$-x = 0 \Rightarrow x = 0$$

$$-y = 0 \Rightarrow y = 0$$

- Q.1 (b) Find the area of that part of the surface of the paraboloid of the paraboloid  $y^2 + z^2 = 2ax$ , which lies between the cylinder,  $y^2 = ax$  and the plane  $x = a$ .

[12 marks]



$$y^2 + z^2 = 2ax, \quad y^2 = ax, \quad x \leq a$$

at  $x = a$ 

$$y^2 = 2a^2 \Rightarrow y = \sqrt{2}a$$

$$\text{and } y^2 + z^2 = 2a \cdot a \Rightarrow z^2 = a^2 \Rightarrow z = a$$

$$\text{Now } z = 0, \quad y^2 = 2ax$$

So

$$A_1 = \int_0^a \int_{\sqrt{ax}}^{\sqrt{2ax}} dy dx = \int_0^a (\sqrt{2ax} - \sqrt{ax}) dx$$

$$A_1 = \sqrt{a} \left[ \frac{\sqrt{2} x^{3/2}}{3/2} - \frac{x^{3/2}}{3/2} \right]_0^a$$

$$A_1 = \sqrt{a} \left[ \frac{2\sqrt{2}}{3} a^{3/2} - \frac{2}{3} a^{3/2} \right]$$

$$A_1 = \sqrt{a} \left[ \frac{2\sqrt{2}}{3} a^2 - \frac{2}{3} a^2 \right]$$

$$A_1 = (\sqrt{2} - 1) \frac{2}{3} a^2$$

3

Go through the  
made easy  
solution

Now

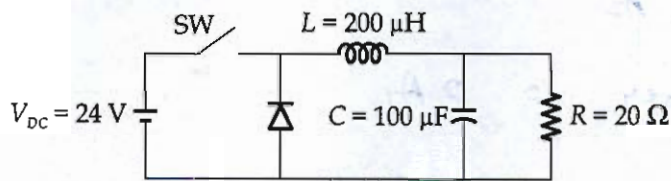
$$A_3 = A_1 = A_2$$

So total Area  $= 2A_1$

$$A = \frac{2 \times (\sqrt{2} - 1) \times 2}{3} a^2$$

$$A = 0.552 a^2$$

- Q.1 (c) A buck converter is shown below. For the switching frequency of 10 kHz and duty ratio of 0.4, find the output voltage.



[12 marks]

### Solution

first we will check about continuous or Dis-contin- mode.

$$\text{So } \dot{I}_{L \text{ max}} = \frac{\Delta I_L}{2} \Rightarrow I_0 = \frac{D(1-D)V_S}{2fL_c}$$

According to given data

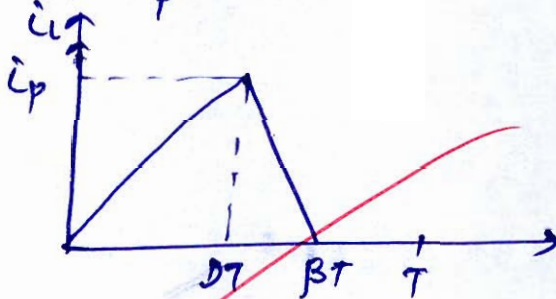
$$V_0 = DV_S, \quad I_0 = \frac{DV_S}{R}, \quad D = 0.4$$

$$\text{So } \frac{0.4 \times 24}{20} = \frac{0.4 \times 0.6 \times 24}{2 \times 10 \times 10^3 \times L_c}$$

$$L_c = 600 \mu\text{H}$$

As  $L < L_c$  so this is discontinuous mode

of operation.



for  $V_{L \text{ avg.}} = 0$ , so

$$(V_S - V_0)DT - V_0(\beta T) = 0$$

$$V_0 = V_S \frac{D}{\beta}$$

$$\text{Now } \hat{I}_{\text{avg.}} = \frac{1}{2} \times \beta T \times \hat{I}_p = \frac{1}{2} \times \beta \hat{I}_p \quad \text{--- (1)}$$

Now peak value of inductor current, for  $\alpha T < \beta T$

$$L \frac{dI_L}{dt} = V_S - V_0$$

$$L \times \frac{\hat{I}_p}{\beta T} = V_S - V_S \cdot \frac{D}{\beta}$$

$$\hat{I}_p = V_S \left(1 - \frac{D}{\beta}\right) \times \frac{D}{fL} \quad \text{--- (2)}$$

from (1) and (2)

$$\frac{1}{2} \times \beta \times \frac{V_S D (1 - D/\beta)}{fL} = \hat{I}_{\text{avg.}} = \frac{V_S D}{\beta R}$$

$$\frac{1}{2} \times \beta \times \left(\frac{\beta - 0.4}{\beta}\right) = \frac{fL}{R}$$

$$\beta - 0.4 = \frac{2 \times 10 \times 10^3 \times 200 \times 15}{20} = 0.2$$

$$\beta = 0.6$$

So

$$V_0 = V_S \frac{D}{\beta} = 24 \times \frac{0.4}{0.6}$$

$$V_0 = 16 \text{ Volt.}$$

6

Go through  
the made easy  
solution

Q.1(d)

Find the Fourier series of the function defined as  $f(x) = \begin{cases} x+\pi & \text{for } 0 < x < \pi \\ -x-\pi & \text{for } -\pi < x < 0 \end{cases}$  and

$$f(x+2\pi) = f(x).$$

Solution  $T = 2\pi$ ,  $\omega = \frac{2\pi}{T} = 1$  [12 marks]

$$a_0 = \frac{1}{T} \int_0^T f(x) dx = \frac{1}{2\pi} \left[ \int_0^{\pi} (x+\pi) dx + \int_{-\pi}^0 (-x-\pi) dx \right]$$

$$a_0 = \frac{1}{2\pi} \left[ \left( \frac{x^2}{2} + \pi x \right) \Big|_0^{\pi} - \left( \frac{x^2}{2} + \pi x \right) \Big|_{-\pi}^0 \right] = \frac{1}{2\pi} \left[ \frac{3\pi^2}{2} - \left\{ 0 - \left( \frac{\pi^2}{2} - \pi^2 \right) \right\} \right]$$

$$a_0 = \frac{1}{2\pi} \left[ \frac{3\pi^2}{2} - \frac{\pi^2}{2} \right] = \frac{\pi}{2}$$

$$a_n = \frac{2}{T} \left[ \int_0^{\pi} (x+\pi) \cos nx dx + \int_{-\pi}^0 (-x-\pi) \cos nx dx \right]$$

$$a_n = \frac{1}{\pi} \left[ \int_0^{\pi} (x+\pi) \cos nx dx - \int_{-\pi}^0 (x+\pi) \cos nx dx \right]$$

$$a_n = \frac{1}{\pi} \left[ \left( (x+\pi) \frac{\sin nx}{n} - \int \frac{\sin nx}{n} \right) \Big|_0^{\pi} - \left( (x+\pi) \frac{\sin nx}{n} - \int \frac{\sin nx}{n} \right) \Big|_{-\pi}^0 \right]$$

$$a_n = \frac{1}{\pi} \left[ \left( (x+\pi) \frac{\sin nx}{n} + \frac{\cos nx}{n^2} \right) \Big|_0^{\pi} - \left( (x+\pi) \frac{\sin nx}{n} + \frac{\cos nx}{n^2} \right) \Big|_{-\pi}^0 \right]$$

$$a_n = \frac{1}{\pi} \left[ \left( \frac{\cos n\pi}{n^2} - \frac{1}{n^2} \right) - \left( \frac{1}{n^2} - \frac{\cos n\pi}{n^2} \right) \right]$$

$$a_n = \frac{2}{\pi n^2} [(-1)^n - 1]$$

$$b_n = \frac{1}{\pi} \left[ \int_0^{\pi} (\pi + u) \sin nx \, du - \int_{-\pi}^0 (\pi + u) \sin nx \, du \right]$$

$$b_n = \frac{1}{\pi} \left[ \left[ -(\pi + u) \frac{\cos nx}{n} + \frac{\sin nx}{n^2} \right]_0^{\pi} - \left[ (\pi + u) \frac{\cos nx}{n} + \frac{\sin nx}{n^2} \right]_{-\pi}^0 \right]$$

$$b_n = \frac{1}{\pi} \left[ \left[ -\left[ 2\pi \frac{\cos n\pi}{n} \right] - \left( -\frac{\pi}{n} \right) \right] - \left[ \pi \frac{\cos 0}{n} - 0 \right] \right]$$

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

So Fourier Series,

$$f(x) = a_0 + \sum_{n=1}^{\infty} (a_n \cos n\omega_0 x + b_n \sin n\omega_0 x)$$

$$f(x) = \frac{\pi}{2} + \sum_{n=1}^{\infty} \left[ \frac{2}{\pi n^2} [(-1)^n - 1] \cos nx + \frac{2}{n} (-1)^{n+1} \sin nx \right]$$

5

Q.1 (e) A single-phase full-controlled thyristor converter bridge is used for regenerative braking of a separately excited DC motor with the following specifications:

Rated armature voltage	210 V
Rated armature current	10 A
Rated speed	1200 rpm
Armature resistance	1 Ω
Input to the converter bridge	240 V at 50 Hz
The armature of the DC motor is fed from the full-controlled bridge and the field current is kept constant.	

Assume that the motor is running at 600 rpm and the armature terminals of the motor are suitably reversed for regenerative braking. If the armature current of the motor is to be maintained at the rated value, find the triggering angle of the converter bridge in degrees.

[12 marks]

given 1-φ full converter

$$So \quad V_o = \frac{2V_m \cos \alpha}{\pi} = \frac{2 \times 240\sqrt{2}}{\pi} \cos \alpha$$

As given  $N_{rated} = 1200 \text{ rpm}$ ,  $V_t = 210 \text{ V}$ ,  $I_a = 10 \text{ A}$

$$V_t = E_b + I_a r_a = K_m \omega + I_a r_a$$

$$210 = K_m \times \frac{2\pi \times 1200}{60} + 10 \times 1$$

$$K_m = 1.592 \text{ V-sec/rad-A}$$

Now At 600 rpm

$$E_b = \frac{K_m \times 2\pi N}{60} = \frac{1.592 \times 2\pi \times 600}{60} = 100 \text{ Volt}$$

Now for regenerative Braking

$$V_o = -E_b + I_a r_a$$

$$\frac{2 \times 240\sqrt{2}}{\pi} \cos \alpha = -100 + I_a r_a$$

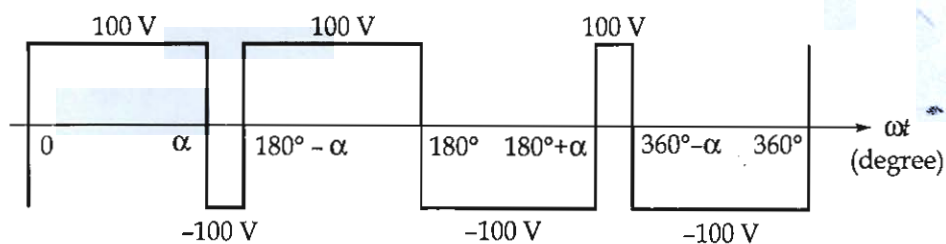
$$\frac{2 \times 24 \times 2}{\sqrt{2}} \cos \alpha = -100 + (0 \times 1)$$

$$\alpha = 114.60^\circ$$

Good  
APPROACH

11

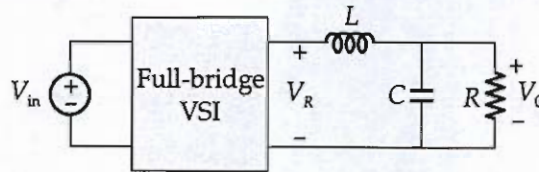
- Q.2 (a) (i) The figure shows below, one period of the output voltage of an inverter.  $\alpha$  should be chosen such that  $60^\circ < \alpha < 90^\circ$ . If rms value of the fundamental component is 50 V, find the value of  $\alpha$  in degree.



[10 marks]



- Q.2 (a) (ii) The single-phase full-bridge voltage source inverter (VSI), shown in the figure below, has an output frequency of 50 Hz. It uses unipolar pulse width modulation with switching frequency of 50 kHz and modulation index of 0.7. For  $V_{in} = 100$  V DC,  $L = 9.55$  mH,  $C = 63.66$  mF and  $R = 5$   $\Omega$ . Find the amplitude of the fundamental component in the output voltage  $V_0$  (in Volt) under steady-state. Also calculate the power absorbed by load 'R'. Considering only fundamental frequency.



[10 marks]



Q.2(b) (i) Solve:

$$\frac{dx}{dt} + y = \sin t; \frac{dy}{dt} + x = \cos t, \text{ where } y(0) = 0, x(0) = 2.$$

**[10 marks]**

Q.2 (b) (ii) Prove that orthogonal matrices of order two are of the form,

$$\begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \text{ or } \begin{bmatrix} \cos\theta & \sin\theta \\ \sin\theta & -\cos\theta \end{bmatrix}$$

[10 marks]



- Q.2 (c) (i) Using Runge-Kutta method of fourth order, solve  $\frac{dy}{dx} = \frac{y^2 - x^2}{y^2 + x^2}$ , with  $y(0) = 1$  at  $x = 0.2, 0.4$ .

[10 marks]

- Q.2 (c) (ii) Assuming that the following values of  $y$  belong to a polynomial of degree 4, compute the next three values:

$$\begin{array}{l} x: 0 \quad 1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6 \quad 7 \\ y: 1 \quad -1 \quad 1 \quad -1 \quad 1 \quad - \quad - \quad - \end{array}$$

[10 marks]



- Q.3 (a) (i) Apply factorization method to solve the equations:  
 $3x + 2y + 7z = 4$ ;  $2x + 3y + z = 5$ ;  $3x + 4y + z = 7$

[10 marks]

- Q.3 (a) (ii) Apply Gauss-Jordan method to solve the equations:  
 $x + y + z = 9$ ;  $2x - 3y + 4z = 13$ ;  $3x + 4y + 5z = 40$

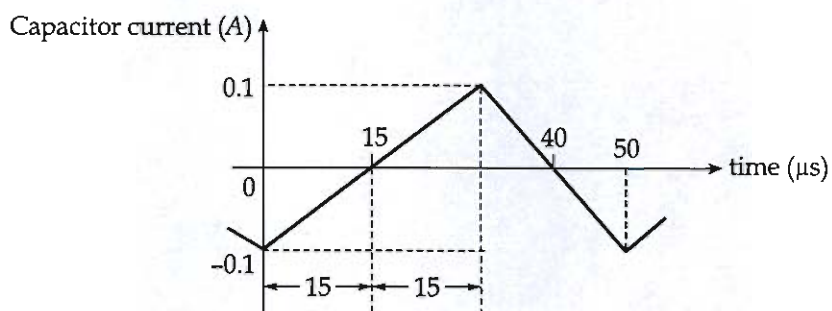
[10 marks]



- Q.3 (b) (i) Find the positive root of  $x^4 - x - 10$  correct to the three decimal places, using Newton-Raphson method.

[10 marks]

- Q.3 (b) (ii) The steady state capacitor current of a conventional DC-DC buck converter, working in CCM, is shown in one switching cycle. If the input voltage is 30 V, find the value of the inductor used in mH.



[10 marks]



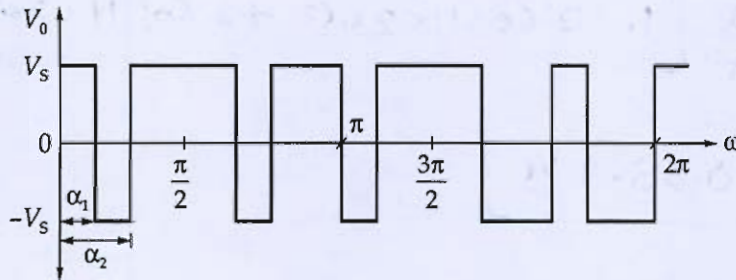
- Q.3 (c) A 4-pole, 3-phase, 400 V, 50 Hz, Y-connected induction motor is fed from an inverter such that the phase voltage of inverter is a six-step waveform. The motor speed is controlled by maintaining  $V/f$  constant a value corresponding to rated voltage and rated frequency.
- (i) Determine the expression for fundamental voltage and harmonics of the inverter output voltage.
  - (ii) Calculate the DC input voltage required to feed the inverter for operating the motor at 60 Hz, 50 Hz and 40 Hz.
  - (iii) Calculate the firing angles if the DC input voltage to the inverter is obtained from a 3-phase semi-converter from a 500 V (line to line), 50 Hz source while the inverter output corresponding to 60 Hz.

[20 marks]





- Q.4 (a) (i) A single phase full bridge bipolar PWM inverter employs selective harmonics elimination technique. The output voltage waveform of the inverter is shown in the figure below. For  $\alpha_1 = 23.62^\circ$  and  $\alpha_2 = 33.3^\circ$ , 3<sup>rd</sup> and 5<sup>th</sup> harmonics have been eliminated.
- Find the magnitude of 7<sup>th</sup>, 9<sup>th</sup> and 11<sup>th</sup> harmonics.
  - By how much percentage inverter has been derated? What are the disadvantages of this method?



Solution

[12 marks]

① As it is symmetric to origin, so

$$b_n = \frac{2}{T} \int_{\langle T \rangle} V_o \sin n\omega t dt$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2\pi} = 1$$

$$b_n = \frac{2 \times 4}{2\pi} \int_0^{\pi/2} V_o \sin nt dt$$

$$b_n = \frac{4V_s}{\pi} \left[ \int_0^{\alpha_1} V_o \sin nt dt + \int_{\alpha_1}^{\pi} -V_o \sin nt dt + \int_{\pi}^{\pi+\alpha_2} V_o \sin nt dt \right]$$

$$b_n = \frac{4V_s}{\pi} \left[ \left( -\frac{\cos nt}{n} \right)_0^{\alpha_1} - \left( -\frac{\cos nt}{n} \right)_{\alpha_1}^{\pi} - \left( \frac{\cos nt}{n} \right)_{\pi}^{\pi+\alpha_2} \right]$$

$$b_n = \frac{4V_s}{n\pi} \left[ -\cos n\alpha_1 + \frac{1}{n} + \frac{\cos n\alpha_2}{n} - \cos n\alpha_1 - (0 - \cos n\alpha_2) \right]$$

$$b_n = \frac{4V_s}{n\pi} \left[ 1 - 2\cos n\alpha_1 + 2\cos n\alpha_2 \right]$$

Now

$$b_7 = \frac{4V_s}{7\pi} \left[ 1 - 2\cos 7 \times 23.62 + 2\cos 7 \times 33.3 \right]$$

$$\boxed{b_7 = 0.3166 V_s}$$

$$b_9 = \frac{4V_s}{9\pi} \left[ 1 - 2 \cos 9 \times 23.62 + 2 \cos 9 \times 33.3 \right]$$

$$b_9 = 0.5203 V_s$$

$$b_{11} = \frac{4V_s}{11\pi} \left[ 1 - 2 \cos 11 \times 23.62 + 2 \cos 11 \times 33.3 \right]$$

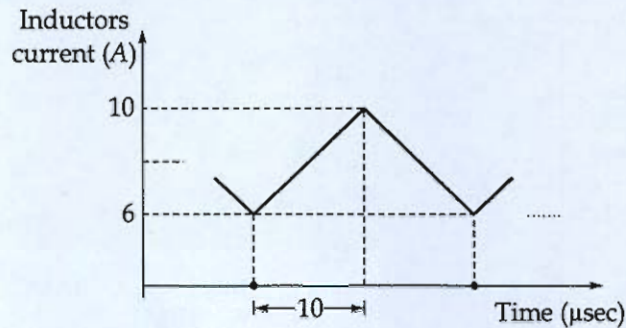
$$b_{11} = 0.3869 V_s$$

8

Incomplete  
selection



- Q.4 (a) (ii) The steady state current flowing through the inductor of a DC-DC boost converter is given in the figure below. The value of the output capacitor is  $150 \mu\text{F}$ . If the peak-to-peak ripple in the output voltage of the converter is  $0.2 \text{ V}$ . Find the switching frequency of the converter, in kHz.



[8 marks]

Solution

from above waveform

$$\Delta I_L = 4 \text{ A}, \quad DT = 10 \mu\text{sec}$$

$$\text{Given } \Delta V_o = 0.2 \text{ V}, \quad C = 150 \mu\text{F}$$

$$\Delta V_o = \frac{\Delta I_L \cdot \Delta t}{C}$$

$$f = \frac{\Delta I_L \cdot \Delta t}{\Delta V_o \cdot C} = \frac{D \times I_o}{0.2 \times 150 \times 10^{-6}}$$

①

$$\Delta I_L = \frac{\Delta V_o}{fL} = 4$$

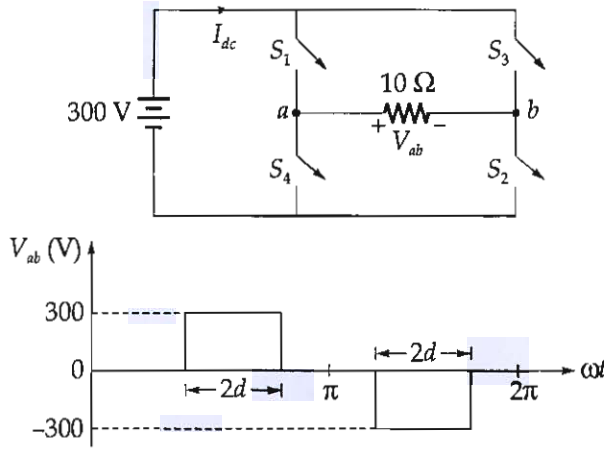
②

②

Incomplete  
solution

Q.4 (b)

(i) A single-phase full bridge inverter fed by a 300 V DC produces a symmetric quasi-square waveform across 'ab' as shown in figure below. The switch control signals of the converter are generated using sinusoidal pulse width modulation index,  $M = 0.8$ . Find the input voltage current  $I_{dc}$ , in amps.



[8 marks]

Solution

As  $m_a = 0.8$

So

$V_o = m_a V_{dc} = 0.8 \times 300$

~~$V_o = 240 \text{ Volt}$~~

As

$\frac{2d}{\pi} = (1 - m_a) \frac{\pi}{\pi}$

2

As  $\pi \neq 1$

$2d = (1 - 0.8) \times 180 = 36^\circ$

So

$V_{or} = V_{dc} \sqrt{\frac{2d}{\pi}} = 300 \sqrt{\frac{36}{180}}$

$V_{or} = 134.164 \text{ Volt}$

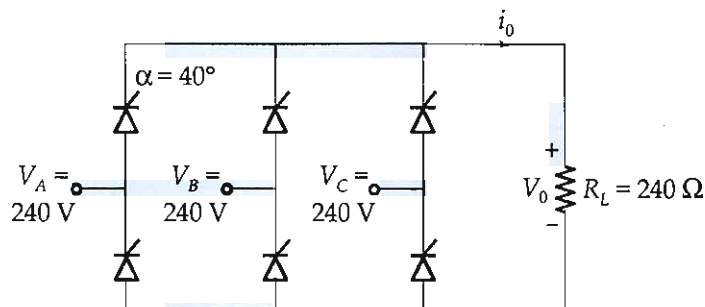
Wrong value calculated

So

~~$I_{or} = \frac{V_{or}}{R} = \frac{134.16}{10}$~~

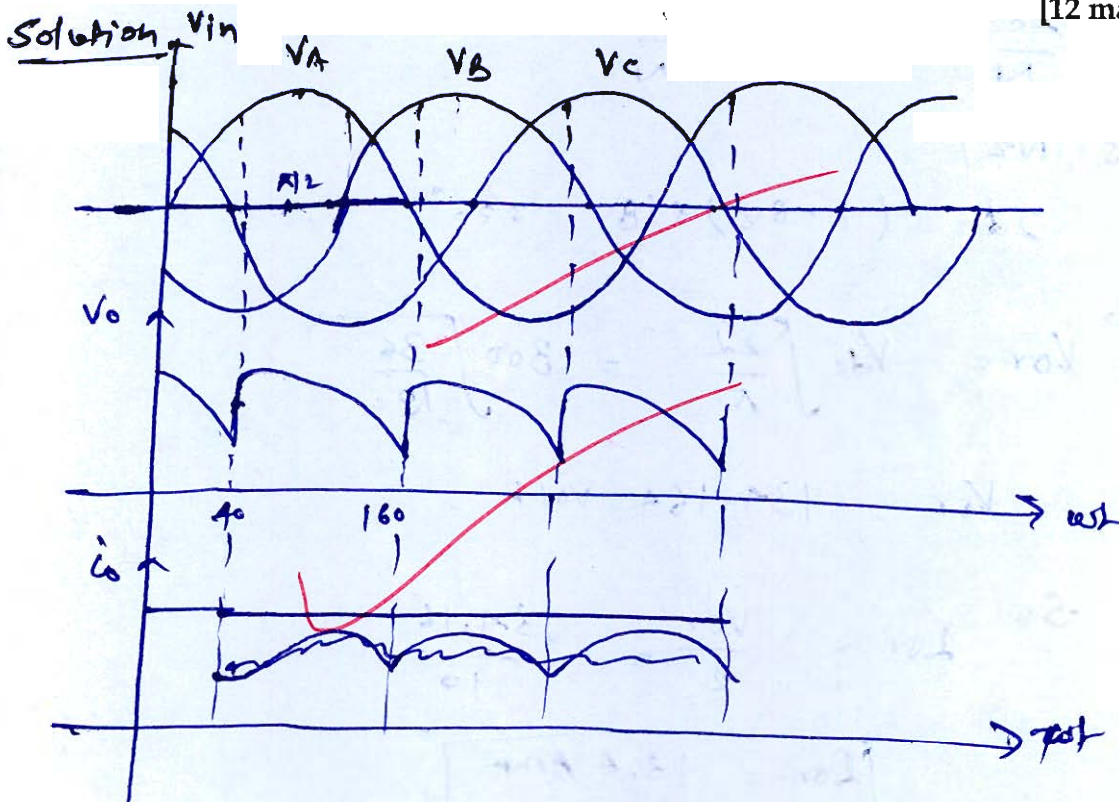
$I_{or} = 13.4 \text{ Amp}$

Q.4 (b) (ii) For the three-phase full controlled bridge rectifier circuit shown with purely resistive load :



1. Sketch the output voltage and current waveforms.
2. Derive the expression for average output voltage and current.

[12 marks]



$$Y_0 \approx \frac{1}{\sqrt{3}} \int_{\alpha+\pi/3}^{\alpha+2\pi/3} V_m \sin \omega t \, d(\omega t)$$

$$V_{o_{avg}} = \frac{V_m}{\sqrt{3}} \left[ -\cos \omega t \right]_{\alpha+\pi/3}^{\alpha+2\pi/3}$$

$$V_{o_{avg}} = \frac{3V_m \cos \alpha}{\pi}$$

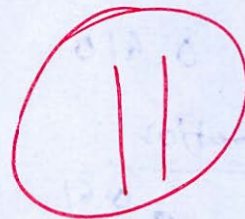
$$V_{o_{avg}} = \frac{3 \times 240\sqrt{3} \times \sqrt{2}}{\pi} \cos 40^\circ$$

$$V_{o_{avg}} = 430.26 \text{ Volt}$$

$$I_{o_{avg}} = \frac{V_{o_{avg}}}{R_L}$$

$$I_{o_{avg}} = \frac{430.26}{240}$$

$$I_{o_{avg}} = 1.8 \text{ Amp.}$$



Good  
Approach

- Q.4 (c) (i) Using Newton-Raphson method evaluate to two decimal figures, the root of the equation  $e^x = 3x$  lying between 0 and 1.

[10 marks]

Solution  $f(x) = e^x - 3x$

Let  $x_0 = 0.5$   $\{0 < x_0 < 1\}$

Now  $f'(x) = e^x - 3$

$f'(x_0) = e^{0.5} - 3 = -1.3512$

and  $f(x_0) = e^{0.5} - 3 \times 0.5 = 0.1487$

Using N-R method

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} = 0.5 - \frac{0.1487}{-1.3512}$$

$x_1 = 0.610$

Second iteration

$f(x_1) = e^{0.61} - 3 \times 0.61 = 0.0104$

$f'(x_1) = e^{0.61} - 3 = -1.1595$

So

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)} = 0.610 - \frac{0.0104}{-1.1595}$$

$x_2 = 0.6189$

So Root  $x = 0.6189$

Good  
Approach

- Q.4 (c) (ii) A tennis match of best of 5 sets is played by two players A and B. The probability that first set is won by A is  $\frac{1}{2}$  and if he loses the first, then probability of his winning the next set is  $\frac{1}{4}$ , otherwise it remains same. Find the probability that A wins the match.

[10 marks]

Solution

$$P_w(A) = \frac{1}{2}$$

$$, P_L(A) = 1 - \frac{1}{2} = \frac{1}{2}$$

Q. 10

Answer

10. 10

10/10

**Section B : Basic Electronics Engineering-1 + Analog Electronics-1  
+ Electrical Materials-1 + Electrical Machines-2**

- Q.5 (a) A Ge diode has resistivity of  $2 \Omega\text{-cm}$  and  $1 \Omega\text{-cm}$  on  $p$ -side and  $n$ -side respectively. Assume typical Ge parameters and find the built-in potential of the diode. What will be the built-in potential if the material is Si instead of Ge?

[12 marks]

Solution  $\rho_p = 2 \Omega\text{-cm}$ ,  $\rho_n = 1 \Omega\text{-cm}$

for Ge;  $\mu_n = 3800$ ,  $\mu_p = 1300$

$$n_i = 2.25 \times 10^{13} / \text{cm}^3$$

for  $n$ -side, conductivity is given by

$$\sigma_n = n e \mu_n \quad (N_D \approx n)$$

$$\frac{1}{\rho_n} = N_D e \mu_n$$

$$\frac{1}{1} = N_D \times 1.6 \times 10^{-19} \times 3800$$

$$N_D = 1.65 \times 10^{15} / \text{cm}^3$$

for  $p$ -side

$$\frac{1}{\rho_p} = N_A e \mu_p$$

$$N_A = \frac{1}{\rho_p e \mu_p} = \frac{1}{2 \times 1.6 \times 10^{-19} \times 1300}$$

$$N_A = 2.40 \times 10^{15} / \text{cm}^3$$

Now

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

$$V_B = 26 \ln \left[ \frac{2.4 \times 1.65 \times 10^{30}}{(2.25 \times 10^{13})^2} \right] \text{ mV}$$

$$V_B = 233.12 \text{ mV}$$

$$V_B = 0.23 \text{ Volt}$$

for Si  $\mu_n = 1300$ ,  $\mu_p = 650$   
 $n_i = 1.5 \times 10^{10} / \text{cm}^3$

So  $N_D = \frac{1}{S_n \mu_n} = \frac{1}{1 \times 1.6 \times 10^{-19} \times 1300}$

$N_D = 4.807 \times 10^{15} / \text{cm}^3$

And  $N_A = \frac{1}{S_p \mu_p} = \frac{1}{2 \times 1.6 \times 10^{-19} \times 600}$

$N_A = 5.208 \times 10^{15} / \text{cm}^3$

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

$V_B = 25 \ln \left( \frac{5.2 \times 4.807 \times 10^{30}}{2.25 \times 10^{20}} \right)$

$V_B = 0.67 \text{ Volt}$

9

Improve Presentation

- Q.5 (b) A 28 slots, 2 pole, lap wound dc machine has 16 turns per coil. The effective axial length of machine 20 cm and radius of armature is half of the axial length. The pole cover 75% of armature periphery. Determine the value of induced emf in the armature for armature moving with the speed of 1750 rpm. Assuming average flux density per pole to be 1.08 T, and winding to be double layered.

[12 marks]

Solution

$$S = 28, P = 2, A = 2$$

$$l = 20 \text{ cm}, r = 10 \text{ cm}$$

$$B = 1.08 \text{ T}$$

for Double layer winding

$$\text{No. of coil} = \text{No. of slots.}$$

$$= 28$$

$$\text{No. of Turns} = 28 \times 16$$

$$(Z) \text{ No. of conductor} = 28 \times 16 \times 2 = 896$$

$$\text{Now } \phi = B \cdot A = B \cdot \frac{\pi D L}{P} \times 0.75$$

$$\phi = \frac{1.08 \times \pi \times 2 \times 10 \times 10^{-2} \times 20 \times 10^{-2}}{2} \times 0.75$$

$$\phi = 0.0508 \text{ wb.}$$

Now induced emf is given by

$$E = \frac{\phi Z N P}{60 A}$$

$$E = \frac{0.0508 \times 896 \times 1750 \times 2}{60 \times 2}$$

$$E = 1829.35 \text{ Volt}$$

11

Good  
Approach



Q.5 (c) In a factory, the following are the loads:

Induction motors : 1000 hp  
0.7 lagging power factor  
0.85 average efficiency

Lighting and heating load : 100 kW

A 3- $\phi$  synchronous motor is installed to provide 300 hp to a new process. The synchronous motor operates at 92% efficiency. Determine the kVA rating of the synchronous motor if the overall factory power factor is to be raised to 0.95 lag. Determine the power factor of the synchronous motor.

(Take 1 hp = 746 W)

[12 marks]

Solution

$$\text{Induction motor } \phi/p = \frac{1000 \times 746}{0.85}$$

$$P_{\text{induction}} = 877.64 \text{ kW}$$

$$\text{Lighting and heating load} = 100 \text{ kW}$$

Now Real power of synchronous motor

$$P_{\text{syn}} = \frac{300 \times 746}{0.92} = 243.26 \text{ kW}$$

$$\text{So Total Real power} = 877.64 + 100 + 243.26$$

$$P_T = 1220.90 \text{ kW}$$

Now Overall power factor will be = 0.95 lag.

So Total Reactive power =

$$Q_T = P_T \tan \phi$$

$$Q_T = 1220.90 \tan(\cos^{-1} 0.95) = 401.29 \text{ kVar}$$

Now Induction machine will take Reactive power of

$$Q_{\text{induction}} = P_{\text{induction}} \times \tan \cos^{-1} 0.7$$

$$Q_{\text{induction}} = 877.64 \times \tan \cos^{-1} 0.7$$

$$Q_{\text{induction}} = 895.37 \text{ Lag. (kVar)}$$

$$\text{So } Q_{\text{syn}} = Q_T - Q_{\text{inductive}}$$

$$Q_{\text{syn}} = 401.21 - 895.37$$

$$Q_{\text{syn}} = -494.08 \text{ kVAr (leading)}$$

$$\text{So } S_{\text{syn}} = P_{\text{syn}} + jQ_{\text{syn}}$$

$$S_{\text{syn}} = 243.26 - j494.08$$

$$\text{So } \phi_{\text{syn}} = \tan^{-1} \left( \frac{494.08}{243.26} \right) = 63.78$$

$$\text{So } \boxed{\cos \phi_{\text{syn}} = 0.4417 \text{ leading}}$$

11

Good  
Approach

- Q.5(d) A 440 V, 50 Hz,  $\Delta$ -connected, 4-pole alternator has a direct axis reactance of  $0.1 \Omega$  and quadrature axis reactance of  $0.075 \Omega$ . Its armature resistance may be neglected. At full load, this generator supplies 1000 A at 0.85 lagging power factor. Calculate the active and reactive power developed in this generator.

[12 marks]

Solution

$$I_a = 1000 \angle -31.78^\circ, \quad \phi = 31.78^\circ$$

$$\tan \psi = \frac{V_a \sin \phi + I_a X_q}{V_a \cos \phi + I_a r_a}$$

$$\tan \psi = \frac{440 \times \sin 31.78 + 1000 \times 0.075}{440 \times 0.85 + 0}$$

$$\psi = 39.36^\circ$$

As  $\psi = \delta + \phi$

$$\text{so } \delta = 39.36 - 31.78$$

$$\delta = 7.58^\circ$$

Now

$$E_g = V \cos \delta + I_d X_d + I_q r_a$$

$$\text{so } I_d = I_a \sin \psi = 1000 \sin 39.36 = 634.19 \text{ A}$$

$$E_g = 440 \cos 7.58 + 634.19 \times 0.1$$

$$E_g = 499.57 \text{ Volt}$$

$$Q_{dev} = \sqrt{3} E_g I_a \sin \psi = \sqrt{3} \times 499.57 \times 1000 \sin 39.36$$

$$Q_{dev} = 548.75 \text{ KVAR}$$

$$P_{dev} = \sqrt{3} E_g I_a \cos \psi = \sqrt{3} \times 499.57 \times 1000 \cos 39.36$$

$$P_{dev} = 669.59 \text{ KW}$$

Wrong value  
calculated

6

23

60/0%

2.3  
4.1

1.5

0.7

1.0

2.3  
4.1

2.3  
4.1

2.3

2.3

2.3

2.3

1.0

1.0

2.3 + 4.1

2.3  
4.1

2.3 + 4.1

1.0

2.3 + 4.1

2.3 + 4.1

2.3 + 4.1

2.3 + 4.1

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2.3 + 4.1

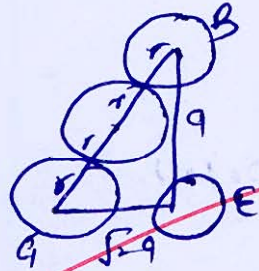
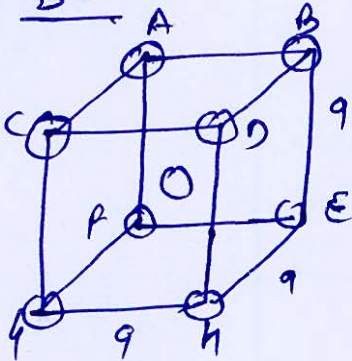
1.0

2.3 + 4.1

2.3 + 4.1

- Q.5 (e) (i) Derive relation for atomic radius of unit cell for BCC crystal system and FCC crystal system.
- (ii) Enumerate different type of physical properties which get affected by structural imperfection in a crystal. Explain briefly about different types of point defects and line defects.

[12 marks]

SolutionBCC

$$BE = a$$

$$GE = \frac{\sqrt{3}a}{2}$$

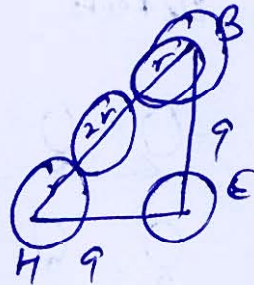
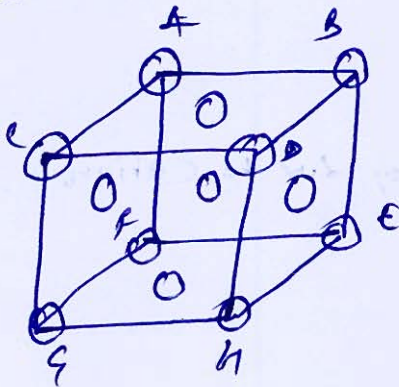
so

$$4r^2 = BE^2 + GE^2$$

$$4r^2 = a^2 + 2a^2$$

so

$$r = \frac{\sqrt{3}a}{4}$$

FCC

$$BH^2 = BE^2 + HE^2$$

$$2 \times 4r^2 = \frac{a^2 + a^2}{2}$$

so

$$a^2 = 8r^2$$

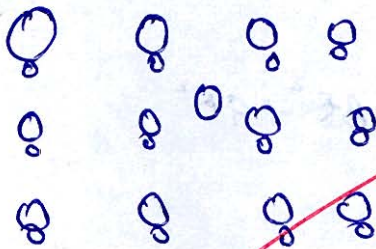
$$r = \frac{a}{2\sqrt{2}}$$

So BCC:  $r = \frac{\sqrt{3}a}{4}$

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

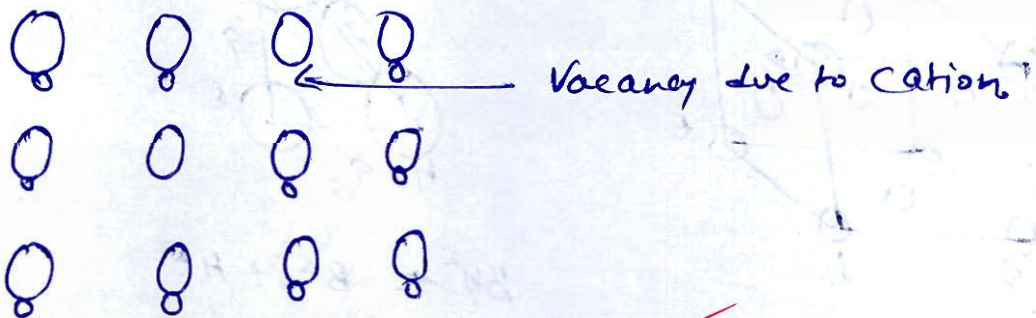
## (11) Point Defects.

### (A) Interstitial Defect.



When a ~~foreign~~ atom takes place at interstitial position in a atom, then this type of defect is called as interstitial defect.

### (B) Vacancy Defects



— when an cation/anion left its position then there will be a vacancy created, which is called as ~~vacancy~~ defect.

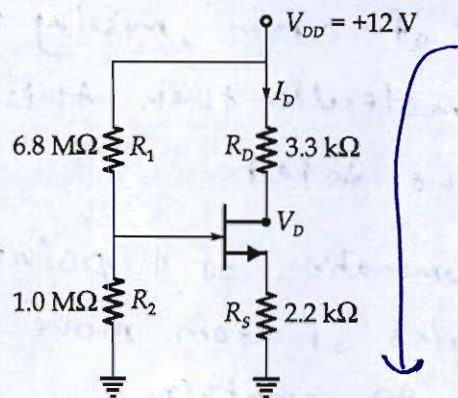
## Line Defect

- when a series of atoms, missing their position from an molecule then this will create a line defect.
- it is a summation of a point defect when a series of atoms move from one position to another.

10

~~Information~~  
Elaborate it more

- Q.6 (a) (i) Determine  $I_D$  and  $V_{GS}$  for JFET with voltage divider bias as shown in figure. The internal parameter values of this JFET are such that  $V_D \approx 7$  V.



[12 marks]

Solution

By voltage Division Rule

$$V_g = \frac{1 \times 12}{1 + 6.8} = 1.54 \text{ Volt}$$

$$V_s = I_D R_S = 2.2 I_D$$

And By Applying KVL

$$-12 + I_D \times 3.3 + V_{DS} + I_D R_S = 0 \quad \text{--- ①}$$

$$V_{DS} = V_D - V_s = V_D - I_D R_S \quad \text{--- ②}$$

from ① and ②

$$-12 + 3.3 I_D + 7 - I_D R_S + I_D R_S = 0$$

$$I_D = \frac{12 - 7}{3.3} = 1.515 \text{ mA}$$

$$\boxed{I_D = 1.515 \text{ mA}}$$

Now

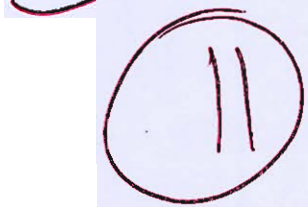
$$V_{GS} = V_g - V_s = 1.54 - I_D R_S$$

$$V_{GS} = 1.54 - 1.515 \times 2.2$$

$$\boxed{V_{GS} = -1.793 \text{ Volt}}$$

$$I_D = 1.515 \text{ mA}$$

$$V_{GS} = -1.79 \text{ Volt}$$



Good Approach

- Q.6 (a) (ii) Certain metal works as superconductor below the critical temperature  $T_c = 7.2^\circ\text{K}$ . The critical magnetic field for the metal at  $0^\circ\text{K}$  is  $7.8 \times 10^5 \text{ Amp/m}$ . What is the critical magnetic field for the metal to be usable as superconductor at  $5^\circ\text{K}$ ?

[8 marks]

Solution

As we know, critical magnetic field is given by

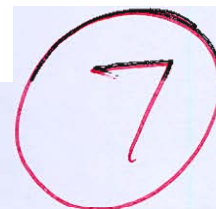
$$H_c = H_0 \left( 1 - \left( \frac{T}{T_c} \right)^2 \right)$$

$$H_0 = 7.8 \times 10^5 \text{ Amp/m}$$

So at  $T = 5^\circ\text{K}$  and  $T_c = 7.2^\circ\text{K}$

$$H_c = 7.8 \times 10^5 \left[ 1 - \left( \frac{5}{7.2} \right)^2 \right]$$

$$H_c = 4.038 \times 10^5 \text{ Amp/m}$$

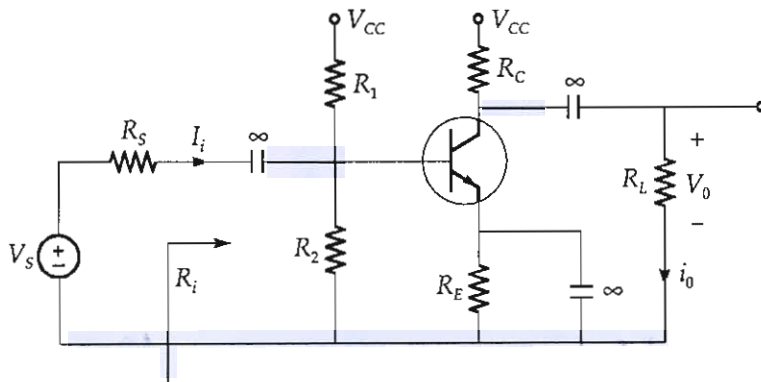


Good Approach

So at  $T = 5^{\circ}\text{K}$ , critical magnetic field will be

$$H_c = 4.038 \times 10^5 \text{ A/m}$$

- Q.6 (b) Consider common emitter amplifier shown below with following specification:  
 $V_{CC} = 10\text{ V}$ ,  $R_1 = 27\text{ k}\Omega$ ,  $R_2 = 15\text{ k}\Omega$ ,  $R_E = 1.2\text{ k}\Omega$  and  $R_C = 2.2\text{ k}\Omega$ ,  $\beta = 100$  and early voltage  $V_A = 100\text{ V}$ .
- (i) Determine the dc bias current  $I_E$ , if the amplifier operates between a source for which  $R_s = 10\text{ k}\Omega$  and a load of  $2.5\text{ k}\Omega$ .
- (ii) Obtain hybrid- $\pi$  model of transistor and find values of  $R_i$  and voltage gain  $V_o/V_s$ .  
 [(Assume,  $V_{BE} = 0.7\text{ V}$ ,  $V_T$  (Thermal voltage) =  $25\text{ mV}$ ].



[20 marks]

SolutionDc Analysis

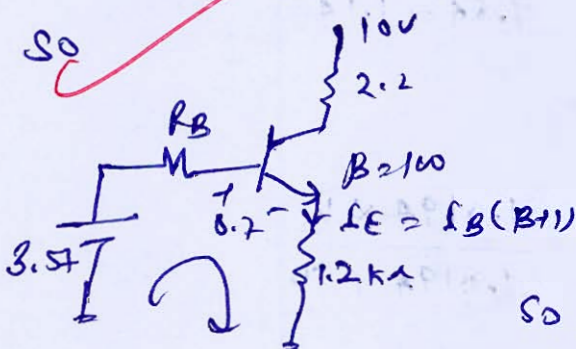
Using Thevenin equivalent.

$$R_B = R_1 \parallel R_2 = \frac{15 \times 27}{15 + 27}$$

$$R_B = 9.64\text{ k}\Omega$$

$$V_{Th} = V_B = \frac{15 \times 10}{15 + 27}$$

$$V_B = 3.57\text{ Volt}$$



Apply KVL into loop

$$-3.57 + I_B R_B + 0.7 + I_B(\beta + 1) \times 1.2 = 0$$

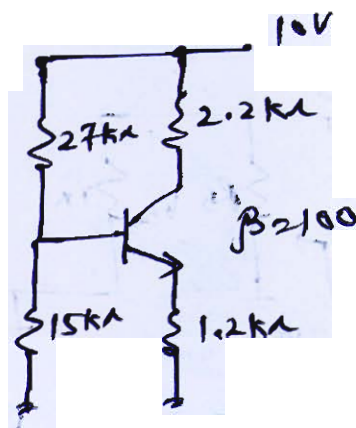
So

$$I_B = \frac{3.57 - 0.7}{9.64 + 1.2 \times (100 + 1)}$$

$$I_B = 21.94\text{ }\mu\text{A}$$

So

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



$$I_E = 2.21 \text{ mA}$$

$$(ii) I_C = \beta I_B = 100 \times 21.16 \mu\text{A}$$

$$I_C = 2.19 \text{ mA}$$

Now

$$g_m = \frac{I_C}{V_T} = \frac{2.19}{25} = 0.08778 \text{ A/V}$$

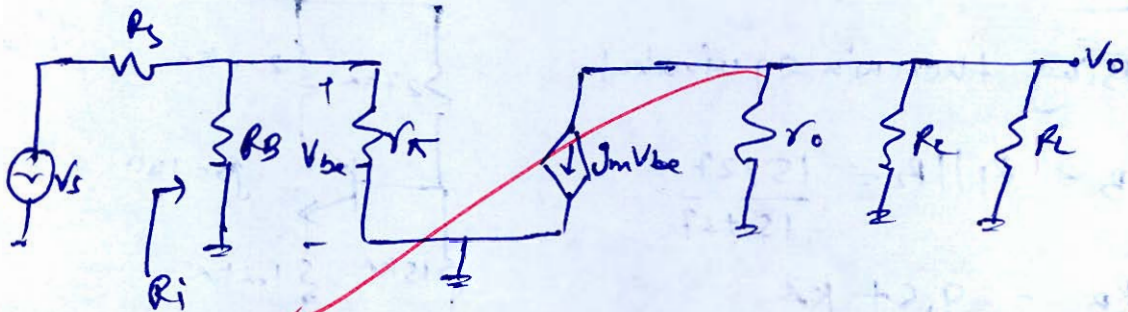
and

$$r_\pi = \beta / g_m = \frac{100}{0.08778} \quad r_o = \frac{V_A}{I_C} = \frac{100 \text{ V}}{2.19 \text{ mA}}$$

$$r_\pi = 1.14 \text{ k}\Omega$$

$$r_o = 45.66 \text{ k}\Omega$$

So  $r_\pi$ -model of above circuit



$$V_o = -g_m V_{be} (R_C \parallel R_L \parallel r_o) \quad \text{--- (1)}$$

Now

$$R_i = R_B \parallel r_\pi = \frac{9.64 \times 1.14}{9.64 + 1.14}$$

$$R_i = 1.0194 \text{ k}\Omega$$

So

$$V_{be} = \frac{R_i \times V_s}{R_i + R_s} = \frac{1.0194 \times V_s}{1.0194 + 10}$$

$$\frac{V_{be}}{V_s} = 0.0925 \text{ V/V} \quad \text{--- (2)}$$

from (1) and (2)

$$\frac{V_o}{V_{be}} \times \frac{V_{be}}{V_s} = -g_m (r_o \parallel R_c \parallel R_L) \times 0.0925$$

$$\frac{V_o}{V_s} = -0.08778 (45.65 \parallel 2.2 \parallel 2.5) \times 0.0925$$

$$A_v = \frac{V_o}{V_s} = -9.26$$

$$\frac{V_o}{V_s} = -9.26$$

$$R_i = 1.0194 \text{ k}\Omega$$

18

Good  
Approach

Q.6 (c) (i) A field test on two similar series machine gave the following data:

Motor :

$$\text{Armature current} = 50 \text{ A}$$

$$\text{Voltage across armature} = 400 \text{ V}$$

$$\text{Voltage across field} = 25 \text{ V}$$

Generator :

$$\text{Terminal voltage} = 350 \text{ V}$$

$$\text{Output current} = 40 \text{ A}$$

$$\text{Voltage across field} = 25 \text{ V}$$

Armature resistance (including brushes) of each machine is  $0.5 \Omega$ . Calculate the efficiency of both machines.

[10 marks]

Solution

Case 1 Motor

$$E_g = 400 \text{ Volt}, \quad E_f = 25 \text{ Volt}$$

$$\text{So Input voltage } V_t = E_g + E_f + I_a r_a = 400 + 25 + 50 \times 0.5$$

$$V_t = 450 \text{ Volt.}$$

$$P_{in} = V_t \cdot I_a = 450 \times 50 = 22.5 \text{ kW.}$$

$$P_{out} = E_g \times I_a = 400 \times 50 = 20 \text{ kW}$$

So efficiency

$$\% \eta_m = \frac{P_{out}}{P_{in}} \times 100 = \frac{20}{22.5} \times 100$$

$$\% \eta_m = 88.88\%$$

Case 2 : Generator

$$V_t = 350 \text{ V}, \quad E_f = 25 \text{ V}, \quad I_a r_a = 40 \times 0.5$$

$$\text{So } E_g = V_t + E_f + I_a r_a = 350 + 25 + 40 \times 0.5$$

$$E_g = 395 \text{ Volt.}$$

$$\text{So } P_{out} = V_t \cdot I_a = 350 \times 40$$

$$P_{out} = 14 \text{ kW}$$

$$P_{in} = E_g I_a = 395 \times 40 = 15.8 \text{ kW}$$

$$\% \eta_g = \frac{P_{out}}{P_{in}} \times 100 = \frac{14}{15.8} \times 100$$

$$\% \eta_g = 88.6\%$$

4

Wrong value  
calculated

- Q.6 (c) (ii) A 220 V, 20 kW dc shunt motor running at its rated speed of 1200 rpm is to be braked by reverse current braking. The armature resistance is  $0.1 \Omega$  and the rated efficiency of the motor is 88 per cent.

Calculate:

1. the resistance to be connected in series with the armature to limit the initial braking current to twice the rated current,
2. the initial braking torque, and
3. the torque when the speed of the motor falls to 400 rpm.

[10 marks]

Solution

$$I_a = \frac{20 \times 10^3}{220 \times 0.88} = 103.30 \text{ Amp.}$$

$$E_b = V - I_a r_a = 220 - 103.30 \times 0.1$$

$$E_b = 209.66 \text{ Volt}$$

$$\textcircled{1} \quad I_B = 2 I_a \quad (\text{Braking current})$$

By reverse current Braking

$$I_B = \frac{E_b + V}{R_a + R_{ext.}}$$

$$\frac{209.66 + 220}{R_a + R_{ext}} = 2 \times 103.3$$

$$R_{ext.} = 1.976 \Omega$$

② Rated Torque =  $\frac{P}{\omega}$

$$T_{rated} = \frac{20 \times 10^3}{\frac{2\pi \times 1200}{60}} = 159.23 \text{ N-m}$$

Breaking Torque

$$T_B = \frac{E_b I_B}{2\pi N} \times 60 = \frac{209.66 \times 206.2 \times 60}{2\pi \times 1200}$$

$$T_B = 344.87 \text{ N-m}$$

③  $N_2 = 400 \text{ rpm}$

So  $\frac{E_2}{E_1} = \frac{N_2}{N_1}$

$$E_2 = \frac{400}{1200} \times 209.66 = 69.88 \text{ V/1A}$$

So torque.

$$T = \frac{E_2 I_a}{\frac{2\pi N}{60}} = \frac{69.88 \times 103.3}{2\pi \times 400} \times 60$$

$$T = 172.43 \text{ N-m}$$

Wrong value  
calculated

7

- Q.7 (a) (i) A salient pole synchronous motor (with negligible armature resistance and  $X_d = 25.4 \Omega$  and  $X_{eq} = 15.4 \Omega$ /phase) can be loaded to maximum load of 540 kW without field excitation running at 1000 rpm. If the motor is now excited with nominal field current and motor is loaded with a load torque of 3.5 kN-m and the motor draws armature current at 0.8 p.f. (leading) then determine excitation emf and corresponding power angle ( $\delta$ ).
- (ii) Obtain power angle characteristic and derive expression for electrical power output of salient pole synchronous machine with help of phasor diagram.

[20 marks]

Solution ①  $X_d = 25.4 \Omega$ ,  $X_q = 15.4$

$P_{max} = 540 \text{ kW}$  (without field)

As without excitation, power is given by

$$540 \times 10^3 = \frac{V_L^2}{2} \left( \frac{1}{X_q} - \frac{1}{X_d} \right) \sin 2\delta \quad \left[ \text{As } \sin 2\delta \text{ for maximum power.} \right]$$

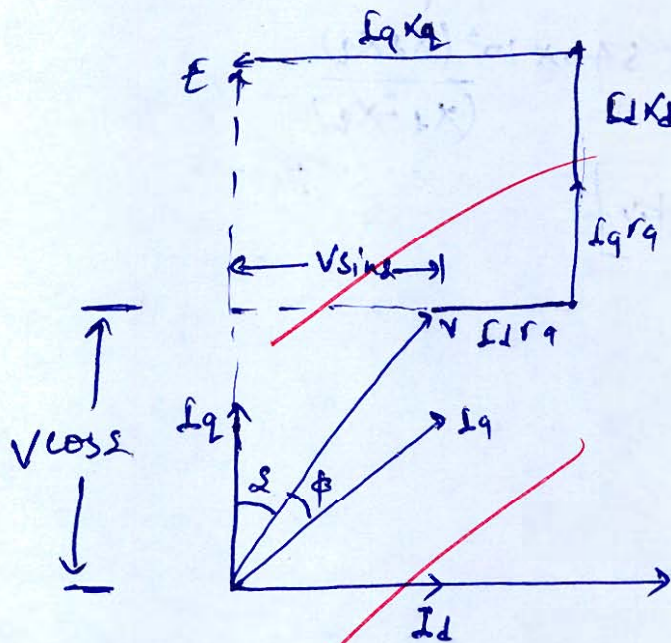
So  $V_L^2 = \frac{2 \times 540 \times 10^3 (X_d X_q)}{(X_d - X_q)}$

$V_L = 6.5 \text{ kv.}$

Now

↓  
for complete  
solution

⑪ Salient pole synchronous machine  
Phasor Diagram



Now let  $r_a = 0$

$$\text{So } V \cos \delta + I X_d = E \quad \text{--- (1)}$$

$$\text{and } V \sin \delta = I X_q$$

$$I_q = \frac{V \sin \delta}{X_q} \quad \text{--- (2)}$$

from ①

$$I_d = \frac{E - V \cos \delta}{X_d}$$

for power developed

$$P = I_d (\text{voltage component of d-axis}) + I_q (\text{voltage component of q-axis})$$

$$P = \left( \frac{E - V \cos \delta}{X_d} \right) V \sin \delta + \frac{V \sin \delta}{X_q} \cdot V \cos \delta$$

$$P = \frac{EV}{X_d} \sin \delta - \frac{V^2}{X_d} \cos \delta \cdot \sin \delta + \frac{V^2}{X_q} \sin \delta \cdot \cos \delta$$

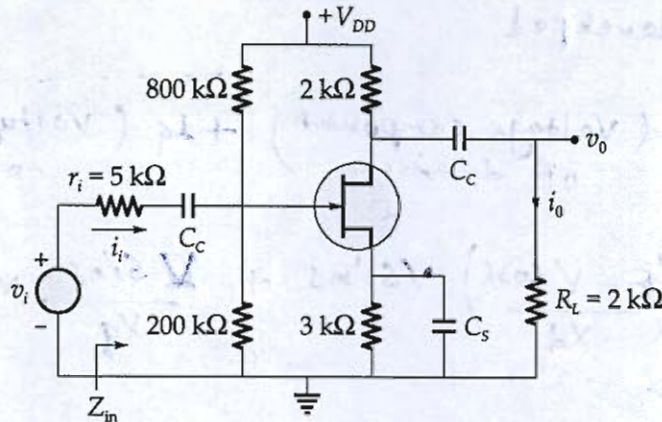
$$P = \frac{EV}{X_d} \sin \delta + \frac{V^2}{2} \left( \frac{1}{X_q} - \frac{1}{X_d} \right) \sin 2\delta$$

Note: As :  $(\sin 2\delta = 2 \sin \delta \cdot \cos \delta)$ .

7

Elaborate it more.

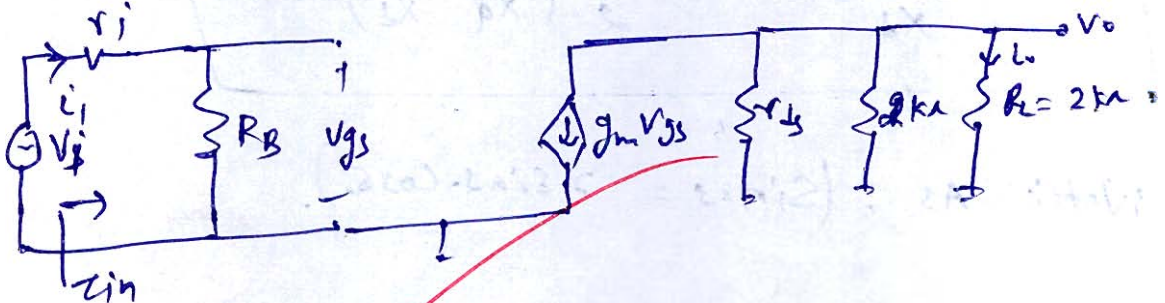
- Q.7 (b) For the JFET amplifier shown in the figure below has  $g_m = 2 \text{ mS}$ ,  $r_i = 5 \text{ k}\Omega$  and  $r_{ds} = 30 \text{ k}\Omega$ . If  $C_C$  and  $C_S$  are large and the amplifier is biased in the pinch off region, find  $Z_{in}$ ,  $A_V = V_o/V_i$  and  $A_I = i_o/i_i$ .



[20 marks]

Solution

By AC equivalent circuit of above network



$$\text{Now } R_B = \frac{200 \times 800}{200 + 800} = 160 \text{ k}\Omega$$

$$V_o = -g_m V_{gs} (r_{ds} \parallel 2 \parallel 2)$$

$$\frac{V_o}{V_{gs}} = -2 \times 10^{-3} (30 \parallel 2 \parallel 2)$$

$$\frac{V_o}{V_{gs}} = -1.9354 \quad \text{--- (1)}$$

Now According to voltage division rule

$$V_{gs} = \frac{R_B V_i}{R_B + r_i} = \frac{160}{160 + 5} V_i$$

$$\frac{V_{gs}}{V_i} = 0.9696 \text{ V/V.} \quad \text{--- (1)}$$

from (1) and (2)

$$\frac{V_o}{V_i} = \frac{V_{gs}}{V_i} \times \frac{V_o}{V_{gs}} = -1.9354 \times 0.9696$$

$$\boxed{\frac{V_o}{V_i} = -1.8767} \text{ Av.}$$

Now  $Z_{in} = r_i + R_B = 165 \text{ k}\Omega$

$$\boxed{Z_{in} = 165 \text{ k}\Omega}$$

$$\text{Now } i_o = \frac{-\beta_m V_{gs} \times (R_{E1} // 2)}{[(R_{E1} // 2) + 2]} = \frac{-2 \times 10^{-3} V_{gs} \times 1.875 \times 10^3}{(1.875 + 2) \times 10^3}$$

$$i_o = -0.9677 V_{gs} \times 10^{-3} \quad \text{--- (3)}$$

Now  $V_{gs} = i_o \times R_B \quad \text{--- (4)}$

from (3) and (4)

$$\frac{i_o}{i_i} = A_I = -0.9677 \times R_B \times 10^{-3}$$

$$\frac{i_o}{i_i} = -0.9677 \times 165 \times 10^3 \times 10^{-3}$$

$$\boxed{A_I = -159.67}$$

Improve  
Presentation

17

Q.7 (c) Define dielectric strength. Discuss different types of dielectric breakdowns in solids.

[20 marks]

Solution

Dielectric strength

- It is defined as the maximum strength of material upto which it cannot be or its atom will not be polarized.
- it is given in  $\text{KV/cm}$ .
- Material having higher dielectric strength will be capable more to bear the high voltage.

ex. Dielectric strength of Air =  $21 \text{ KV/cm (RMS)}$ .

Types of Dielectric Breakdown

- ① Breakdown due to Impurity
- ② Breakdown due to aging.
- ③ Breakdown due to temperature effect.

6

Incomplete  
solution



Q.8 (a)

A 100-MVA, 14.4 kV, 0.8 pf lagging, Y-connected synchronous generator has a negligible armature resistance and a synchronous reactance of 1.0 per unit. The generator is connected in parallel with a 60 Hz, 14.4 kV infinite bus that is capable of supplying or consuming any amount of real or reactive power with no change in frequency or terminal voltage.

- (i) What is the synchronous reactance of the generator in ohms?
- (ii) What is the internal generated voltage  $E_A$  of this generator under rated conditions?
- (iii) What is the armature current  $I_A$  in this machine at rated conditions?
- (iv) Suppose that the generator is initially operating at rated conditions. If the internal generated voltage  $E_A$  is decreased by 5 percent, what will the new armature current  $I_A$  be?
- (v) Repeat part (iv) for 10, 15, 20 and 25 percent reductions in  $E_A$ .

[20 marks]





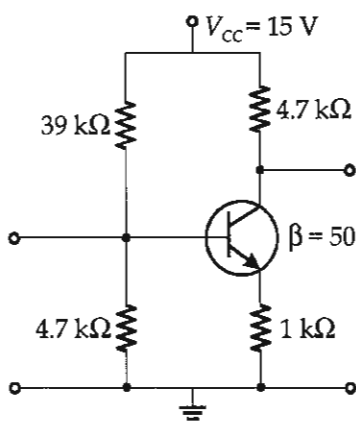
- Q.8 (b)
- (i) Explain about dependence of the loss tangent on temperature and frequency.
  - (ii) The magnetic moment of gadolinium is  $7.1 \mu_B$ . Calculate the magnetic moment per gram if its atomic weight is 157.3.
  - (iii) A certain paramagnetic substance has  $1.2 \times 10^{28}$  atoms/m<sup>3</sup>. Assuming that each atom has moment of one Bohr Magnetron, calculate the susceptibility at 27° C and also the intensity of magnetization when a field of  $10^5$  A/m is applied.

[10 + 6 + 4 marks]





- Q.8 (c) For the circuit shown in figure below, determine the operating point. Find the stability factor. Given:  $V_{BE} = 0.6 \text{ V}$ ,  $\beta = 50$ ,  $V_{CC} = 15 \text{ V}$



[20 marks]

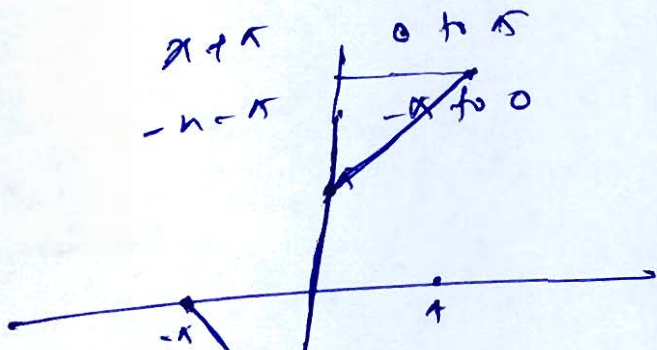




Space for Rough Work

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$9 \sqrt{9^2} \text{ Area}$   
 $\sqrt{2 \cdot 9^2} \text{ Area}$   
 $\text{Base} = \frac{1}{2} \times 4 \times 20$

$V_B = V_T \left( \frac{V_0 \cos \theta}{V_T} \right)$   
 $\frac{9 \cos 60}{2} = \frac{9 \times \beta}{2 \times 2}$



$\text{Cl} = \frac{d_1}{1-D}$   
 $\frac{9}{2\beta}$

$\frac{D V_s}{f L}$

$\frac{1}{2} \times$

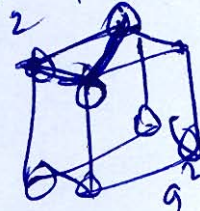
$9^2 - 9^2 = \text{Area}$

$2 \cdot 9^2 = \text{Area}$

$\frac{9}{\sqrt{2}} =$

$\text{Clay} = \frac{R_0}{R} = \frac{V_s R}{\beta R}$   
 $9 \sqrt{2} \cdot 9^2$   
 $9 \sqrt{2} = 3 \cdot 9^2$   
 $\sqrt{2} \cdot \beta = 9$   
 $\beta = \frac{9}{\sqrt{2}}$

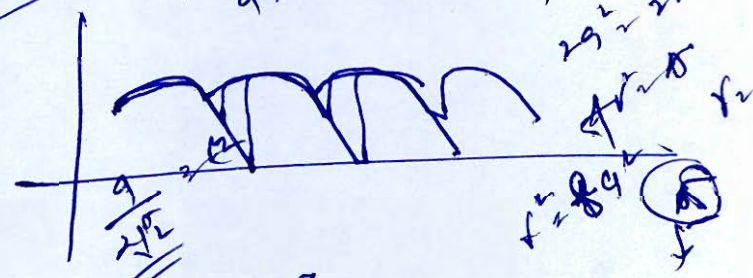
$\frac{6V}{X L} \cdot 8 \cdot 9^2 + \frac{V^2}{2} \left( \frac{1}{2} - \frac{1}{4} \right) 6^2$   
 $9 \sqrt{2} = \frac{9}{\sqrt{2}}$



$9 \sqrt{9^2} = 2 \cdot 9^2$   
 $2 \cdot 9^2 = 2 \cdot 9^2$

$\frac{L \times \beta \times L_p}{2}$   
 $\frac{L \times \beta \times L_p}{2}$

$\frac{9}{2} = 1$   
 $\frac{9}{2} = \frac{9}{2}$

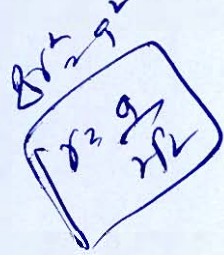


$\frac{9}{2\beta} = \frac{9}{2 \cdot \frac{9}{\sqrt{2}}} = \frac{\sqrt{2}}{2}$

$\frac{2 \cdot 700}{2 \cdot 600} = \frac{2 \cdot 700}{1200}$

$2 \cdot \frac{L_p}{5T} = \frac{V_s - \frac{D}{\beta} V_s}{(V_s - \frac{D}{\beta} V_s) \cdot \frac{XDT}{fL}}$   
 $L_p =$

GO



$\frac{2 \cdot 700}{1200}$