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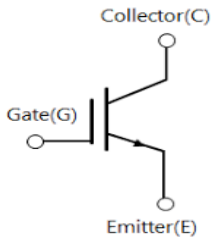
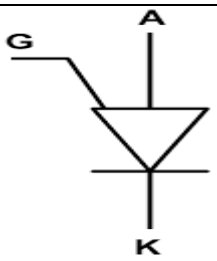
SUMMER-19 EXAMINATION

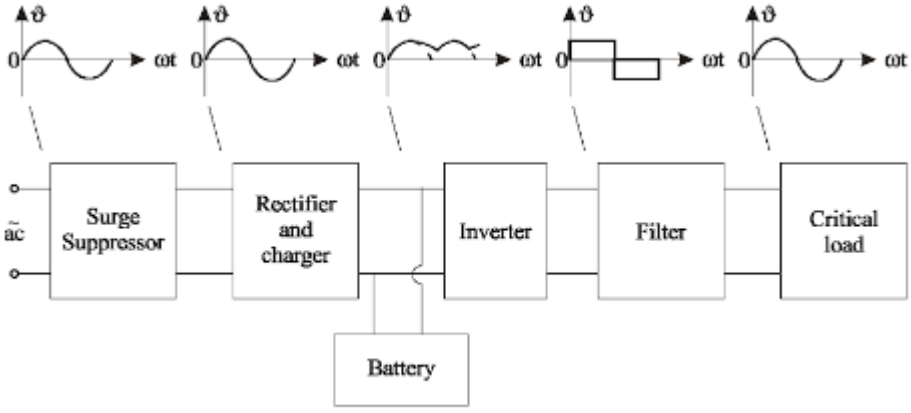
Subject Name: Basic power electronics **Model Answer** **Subject Code:** 22427

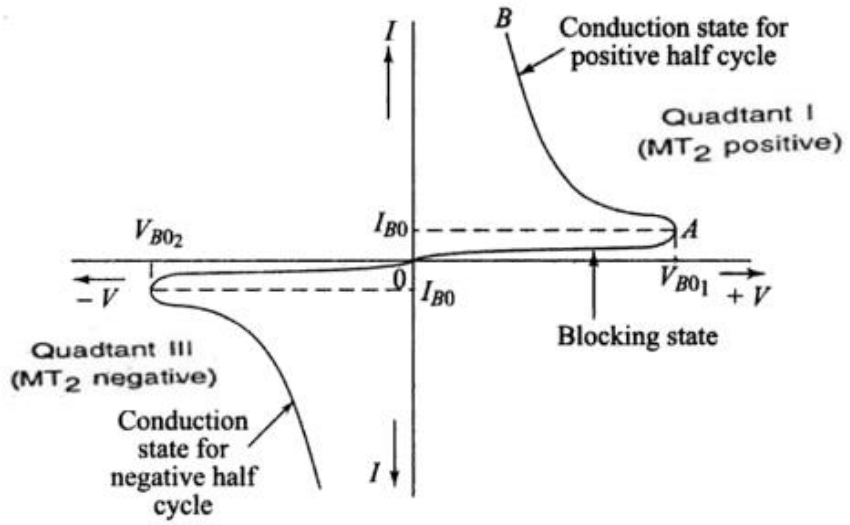
Important Instructions to examiners:

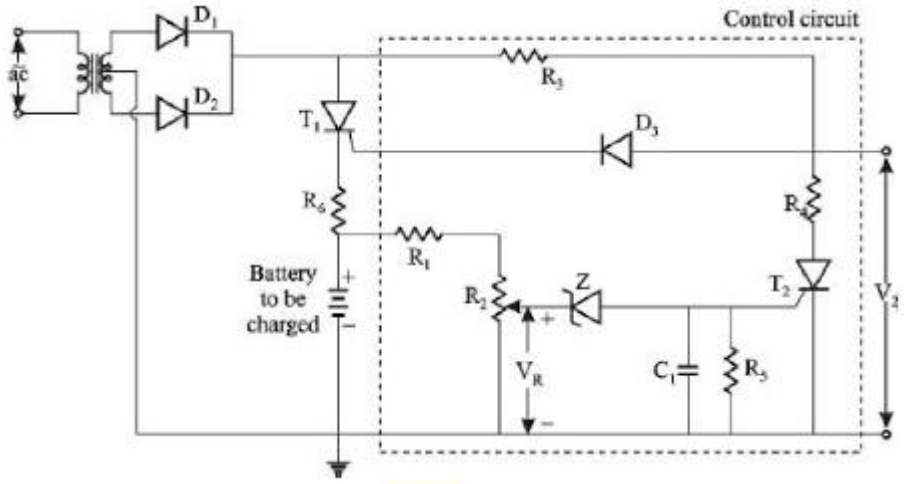
1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given moreImportance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. The figures drawn by candidate and model answer may vary. The examiner may give credit for anyequivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constantvalues may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

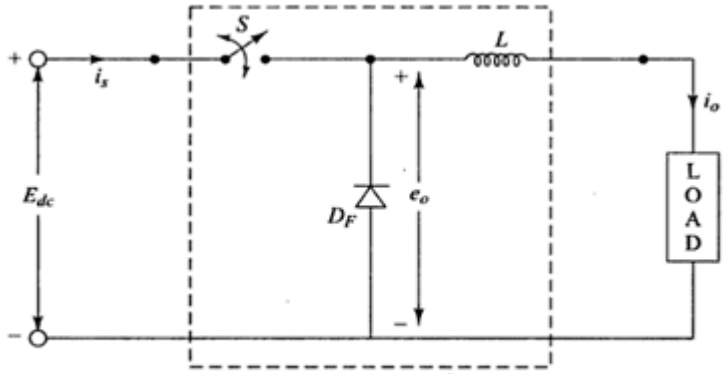
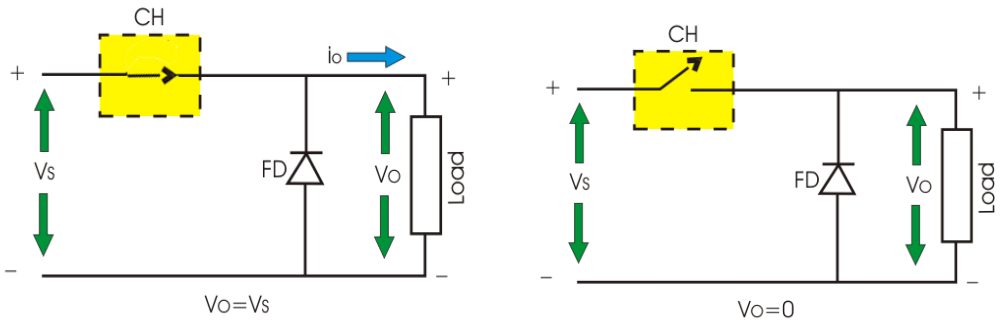
Q. No.	Sub Q. N.	Answers	Marking Scheme
1	**(A)**	**Attempt any FIVE of the following:**	**10- Total Marks**
	(a)	**Define holding and latching current**	**2M**
	Ans:	• **Latching current**: It is the minimum anode current required to maintain the SCR in the conduction state, even when the gate signal has been removed. • **Holding current**: It is the minimum anode current required to hold the SCR in the ON state. When the anode current goes below the holding current, the device will go to OFF state.	**1M** **1M**
	(b)	**Draw the symbol of IGBT and PUT.**	**2M**
	Ans:	 **IGBT**  **PUT**	**Each Symbol 1 M**

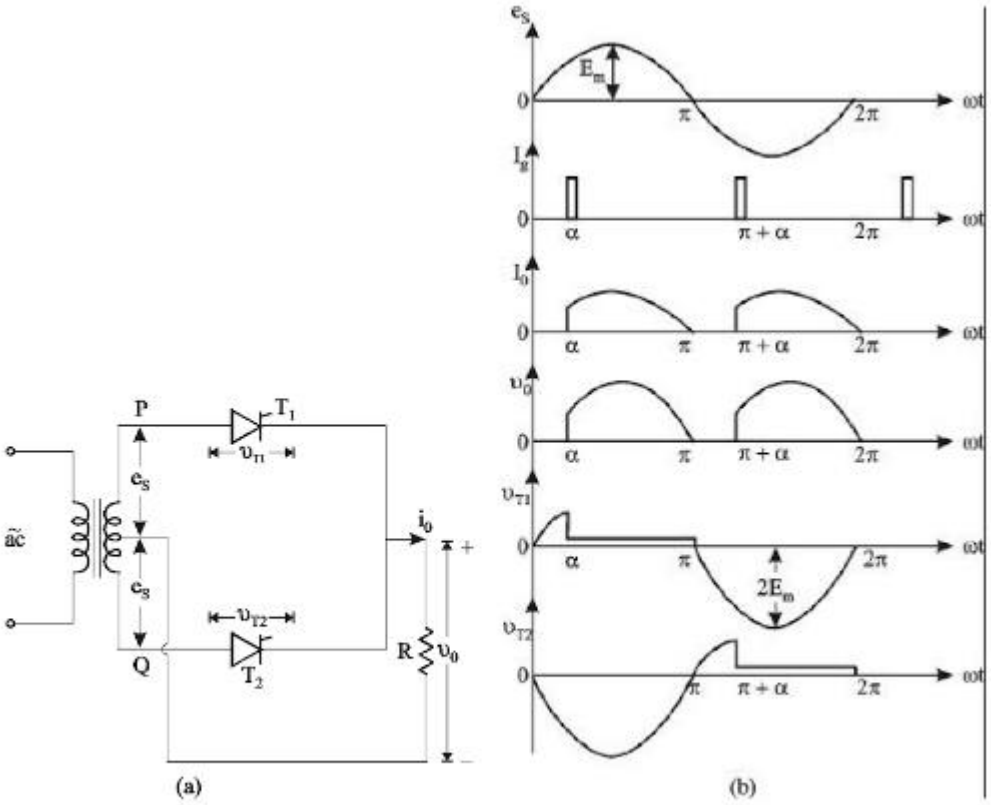
	(c)	**List different turn-on methods of SCR.**	**2M**
	Ans:	➢ Forward voltage triggering ➢ dv/dt triggering. ➢ Temperature triggering ➢ Light/illumination /radiation triggering. ➢ Gate triggering	**2M**
	(d)	**State the use of freewheeling diode in controlled rectifier.**	**2M**
	Ans:	• Load current becomes continuous i.e. ripple free. • It prevents reversal of load voltage and hence gives more average d.c utput voltage. • Input power factor is improved. • It prevents transfer of reactive power from load to supply.	**Each point ½ marks**
	e)	**List two applications of inverter.**	**2M**
	Ans:	**Two applications of inverter: (Any two)** • Uninterrupted power supply. • AC motor speed controller. • Centrifugal fans and pumps. • Conveyors. • Induction heating. • Aircraft power supply • High voltage DC transmission lines **Note: Any other relevant applications should be considered.**	**1 M Each**
	f)	**Define Chopper. State its types.**	**2M**
	Ans:	**Definition:** A chopper is a static device that converts fixed dc voltage to a variable dc voltage. **Types:** • Step up chopper • Step down chopper	**1M** **1M**
	g)	**Draw the basic block diagram of UPS.**	**2M**

	Ans:	 Block diagram of a UPS.	**2M**

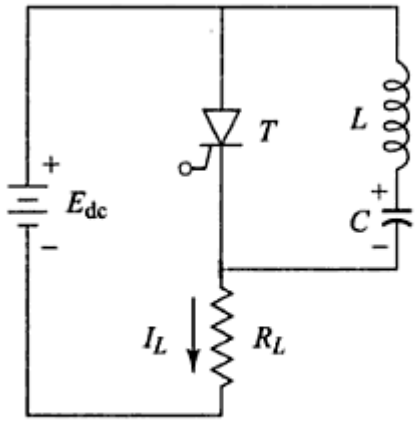
Q. No.	Sub Q. N.	Answers	Marking Scheme
2		**Attempt any THREE of the following:**	**12- Total Marks**
	a)	**Describe with neat sketch the V-I characteristics of TRIAC.**	**4M**
	Ans:	**V-I characteristics of TRIAC:** 	**V-I characteristics - 2M**

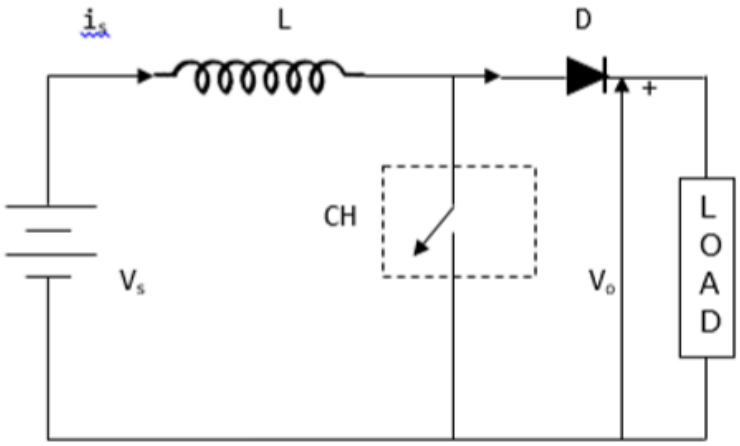
		Description: TRIAC characteristics lie in two quadrants as shown in the figure above. Graphs for mode1 & mode 2 lie in the first quadrant while mode3 & mode 4 in fourth quadrant. Both the graphs are identical. Each graph can be divided into 2 regions as below, 1) Blocking region (OFF state): In the first quadrant, when MT2 is made positive w.r.t. MT1 with a positive or negative gate current, the graph lies in the first quadrant. Initially, till the breakover voltage of the device is applied, only a small leakage current flows indicated by the region OA. 2) Conduction region (ON state): After the breakover voltage(V_{BO1}) is applied, the device goes into conduction with a sharp increase in current but with a considerable reduction in the voltage across the device. This region of the graph is indicated by the region AB.	**2M**
	b)	**Describe with circuit diagram the operation of battery charger using SCR.**	**4M**
	Ans:	**Circuit Diagram:**  **Working:** • The figure above shows battery charger circuit using SCR. • A 12V discharged battery is connected in series with an SCR T1.The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer. • The diodes D1 and D2 provide full wave rectified output across the SCR, T1 and the battery to be charged. • R3 –D3 provide trigerring circuit for T1. AS T1 is ON battery starts charging. • When the battery is full, voltage provided by the voltage divider circuit will become the zener voltage making the SCR T2 to switch ON. • When T2 is ON a short circuit results in the voltage divider circuit R3 & R4, making T1	**2M – circuit diagram** **2M - working**

		to switch OFF. • This prevents over charging of the battery.	
	c)	**Name the suitable chopper to decrease the output voltage and also explain its operation with neat circuit diagram**	**4M**
	Ans:	**Step down chopper** is the suitable chopper to decrease the output voltage.  Basic chopper circuit • When CH is turned ON, Vs directly appears across the load as shown in figure. So VO = VS as in fig(a). • When CH is turned off, Vs is disconnected from the load. So output voltage VO = 0 as in fig(b). • Thus the average output voltage becomes lesser than the input voltage.  **Note: Mode Diagram is optional.**	**1M - Name** **2M – circuit diagram** **1M - explanation**
	d)	**Explain with circuit diagram and waveform the operation of single phase center tapped full wave controlled rectifier with R load.**	**4M**

	Ans:	 **Figure** **Full-wave mid-point controlled rectifier: (a) circuit diagram; (b) waveforms for a pure resistive load.** **Working:** • For the positive half cycle of applied voltage, SCR_1 conducts during the period α to π radians where α is the firing angle. • During the negative, SCR_2 conducts for an interval ($\pi+\alpha$) to 2πradians. • The firing angle α may be changed by changing the gate current.	**1.5 M – Circuit diagram** **1.5 M – Waveform** **1M - Working**

Q. No.	Sub Q. N.	Answers	Marking Scheme
3		**Attempt any THREE of the following :**	**12- Total Marks**
	a)	**Explain class B commutation with neat circuit diagram.**	**4M**

	Ans:	 *Class B commutation circuit* **Explanation:** • This is also a self commutation circuit in which commutation of SCR 'T' is achieved automatically by L and C components. • When the DC supply is applied to the circuit, the capacitor charges with upper plate positive and lower plate negative up to the supply voltage Edc. When the SCR is triggered, the current flows in two directions, one through Edc + –T – RL – Edc - and another commutating current through L and C components. • Once the SCR is turned ON, the capacitor starts discharging through C+ – L – T – C-. When the capacitor is fully discharged, it starts charging with a reverse polarity. Hence a reverse voltage applied across the SCR which causes the commutating current to oppose load current I_L. • When the commutating current is higher than the load current, the SCR will automatically turn OFF and the capacitor charges with original polarity. • The desired frequency of ON/OFF depends on the values of L and C. This type of commutation is mostly used in chopper circuits. **Note: Waveform is optional.**	**Circuit diagram : 2M** **Explanation : 2M**
	b)	**A single phase full wave controlled rectifier is supplied with a voltage V = 230 sin 314t.if firing angle 'α' is 30^0. Find:**	**4M**

		(i) Average dc output voltage **(ii) Load current for the load resistance of 100 Ω**	
	Ans:	**Given:** V= 230 sin 314 t $\alpha = 30^0$ $R_L = 100\ \Omega$ **Required:** Vdc = ? I_L = ? **Solution:** Average output voltage = $\frac{Vm}{\pi}(1 + \cos\alpha)$ $= \frac{230}{\pi}(1 + \cos 30)$ = 73.211 * 1.866 = 136.6 V Load current $I_L = \frac{Vdc}{RL} = \frac{136.6}{100}$ = 1.366 A	**Average output voltage : 2M** **Load current : 2M**
	c)	**Draw circuit diagram of step up chopper. State its output voltage expression and draw its input output wave forms.**	**4M**
	Ans:	**Circuit diagram:**  **Output voltage expression**	**Circuit diagram : 2M** **Output voltage expression: 1M** **Waveforms : 1M**

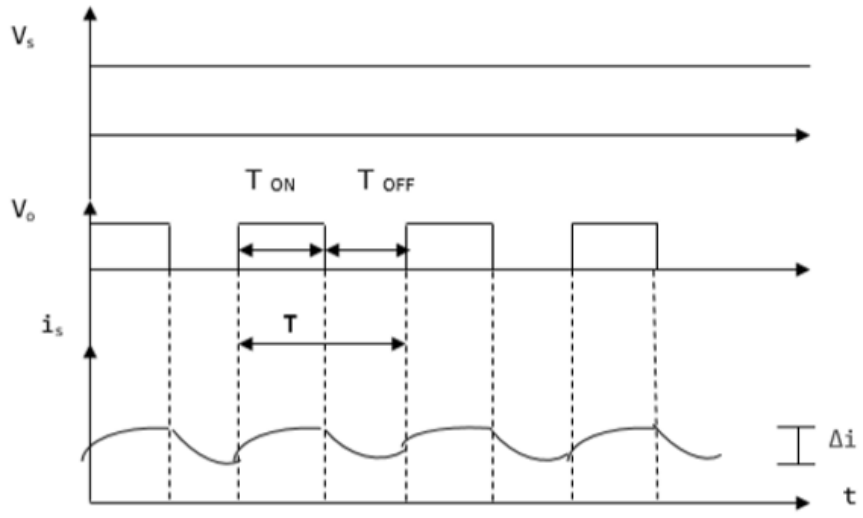
Vo = Vs / (1- D)

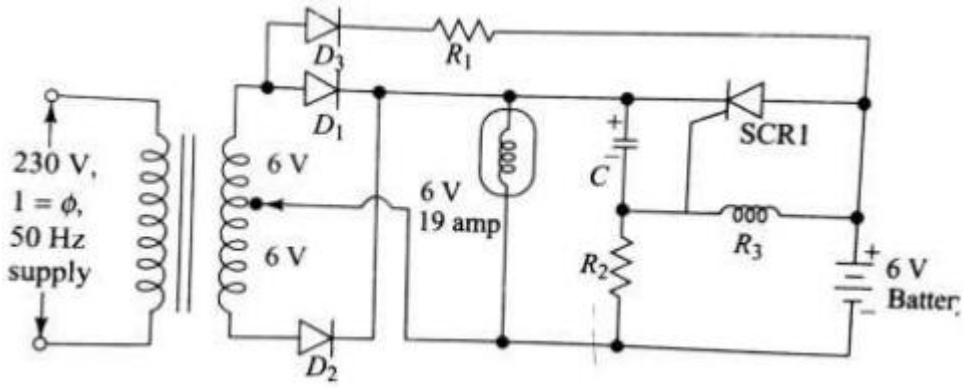
Where

Vs = Input voltage

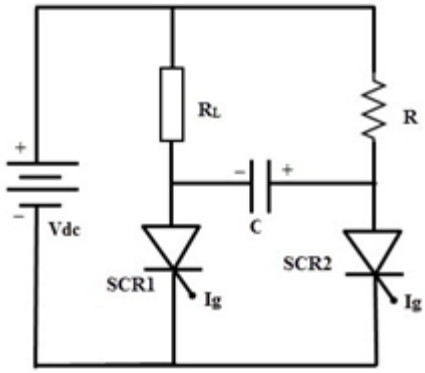
D- duty cycle

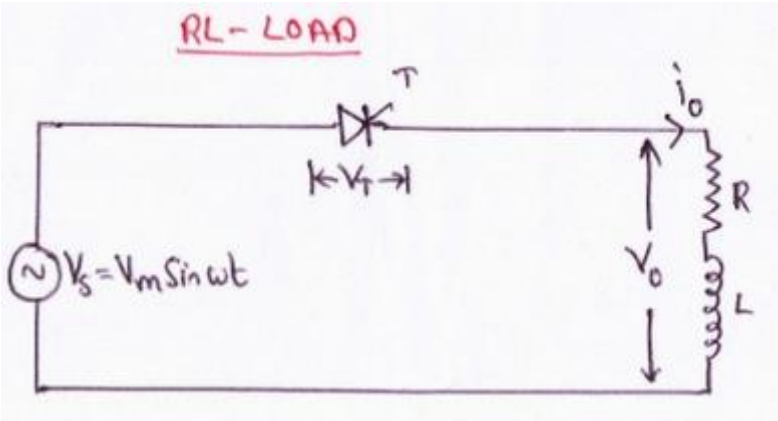
Current and Voltage Waveforms

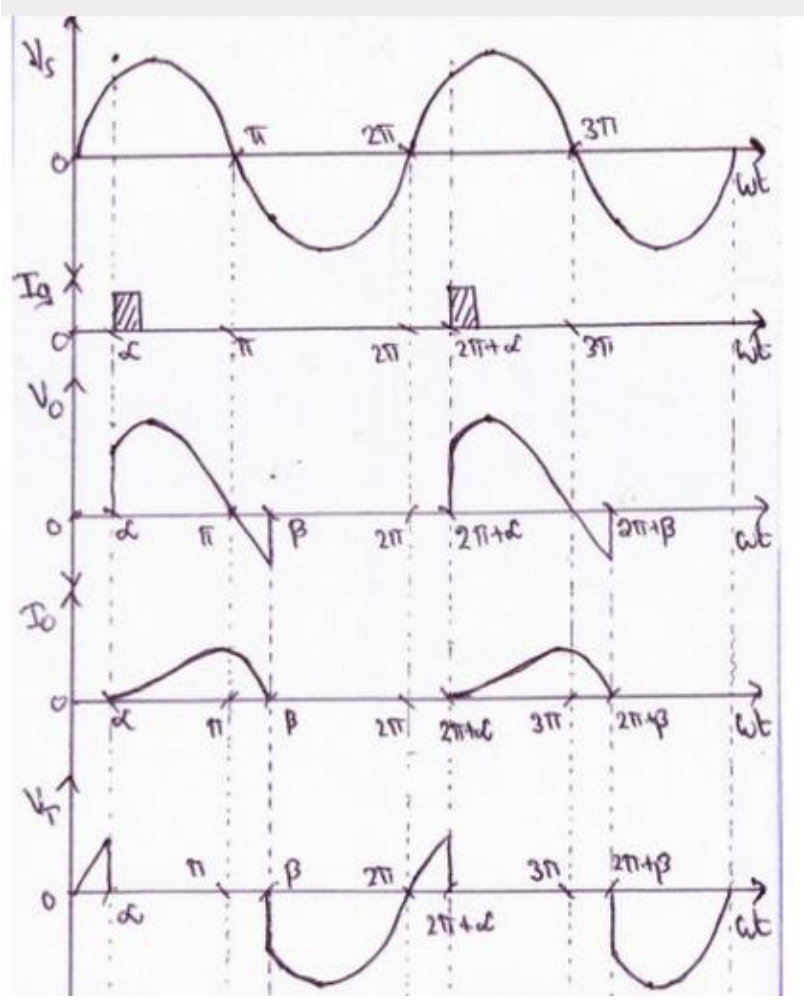


	d)	**Explain with circuit diagram the operation of emergency lighting system.**	**4M**
	Ans:	 Working:-	**Circuit diagram : 2M** **Working : 2M**

		• Fig. above shows a simple emergency lighting circuit. The 230v ac supply is applied as input. Supply is stepped down using a Center tapped transformer. The full wave rectifier converts ac to dc voltage. • When supply is ON, voltage appears across it and the lamp glows. Pulsating current also flows through D3 & R1 to charge the battery. Thus battery charging is carried out. • The capacitor C gets charged with upper plate positive to some voltage less than secondary voltage of transformer. Due to capacitor voltage, gate cathode junction of SCR1 gets reverse biased. The anode is at battery voltage & cathode is at rectifier output voltage, which is slightly higher, hence SCR1 is reverse biased & cannot conduct. The lamp glows due to rectifier output dc voltage. • If power fails, the capacitor C discharges through D3, R1 & R3 until the cathode of SCR, is less positive than anode. At the same time the junction of R2 & R3 becomes positive & establishes a sufficient gate to cathode voltage to trigger the thyristor. Once the thyristor turns ON, the battery discharges through it, & turns the lamp ON. When power is restored, the thyristor is connected & commutated & capacitor C is recharged.	

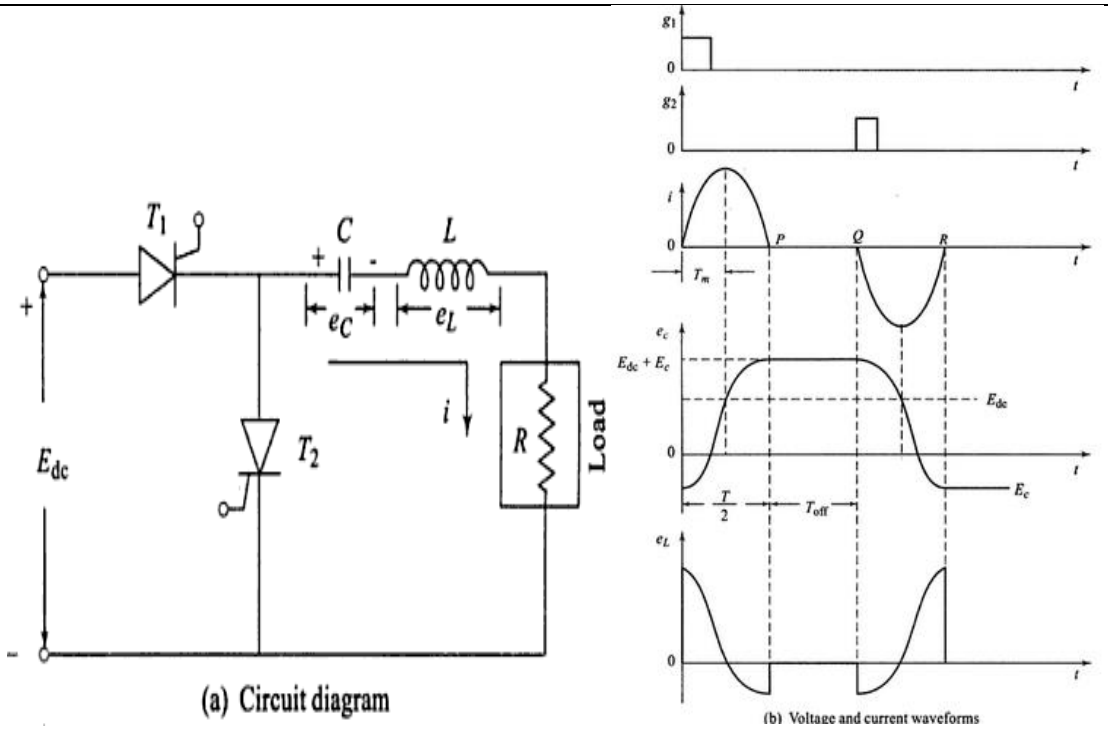
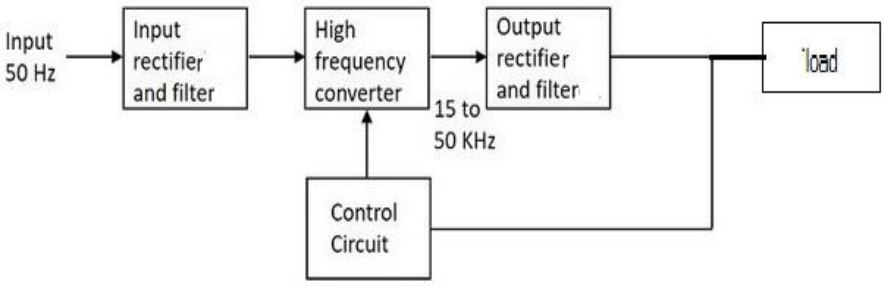
Q. No.	Sub Q. N.	Answers	Marking Scheme
4		**Attempt any THREE of the following :**	**12- Total Marks**
	(a)	**Explain with circuit diagram the operation of class C commutation.**	**4M**
	Ans:	**Circuit Diagram:**  Working:- • At first, when the SCR1 is triggered load current flows IL starts flowing through (Vdc+,	**Circuit diagram : 2M** **Working : 2M**

		RL, SCR1, Vdc-). • At the same time, capacitor 'C' will charge through Vdc+, R, C, SCR1, Vdc- with right side plate positive. • When it is fully charged to Vs charging current becomes zero. • To turn off SCR1, SCR2 is triggered. • When SCR2 is turned ON the reverse voltage across 'C' is applied across SCR1, turning it OFF. • Now capacitor will start charging through Vdc+, RL, C, SCR2, Vdc- with left side plate positive. • Similarly, as SCR1 is turned ON the reverse voltage across 'C' is applied across SCR2, turning SCR2 OFF. **Note: Waveform is optional.**	
	(b)	**Describe the operation of single phase half wave controlled rectifier with RL load.**	**4M**
	Ans:	**Circuit diagram:** 	**Circuit diagram : 1M** **Working : 2M** **Waveforms : 1M**

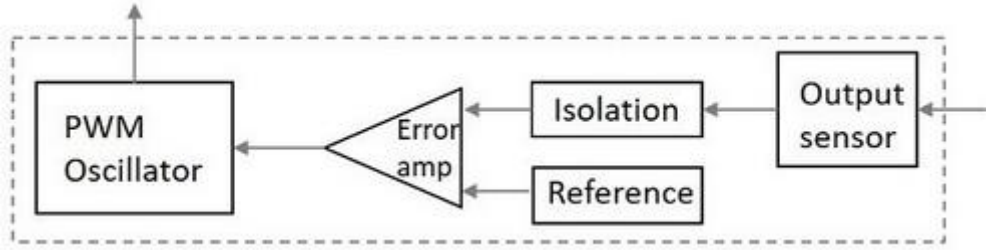


Working:

- During positive half cycle of input voltage, thyristor T is forward biased but it does not conduct until gate signal is applied to it.
- When a gate signal is given to thyristor T at wt = α, it gets turned ON and begins to conduct.
- When thyristor is ON the input voltage is applied to the load, but due to the inductor present in the load, current through load builds up slowly.
- During negative half cycle of input voltage, thyristor T is reverse biased but current through thyristor is not zero due to inductor.
- The current through inductor slowly decays to zero.
- So here thyristor will conduct for some time during the negative half cycle and turns OFF at wt = β.
- Now the load receives voltage during positive half cycle and for a small duration in negative half cycle.
- The average value of voltage can be varied by varying firing angle α.

	(c)	**Explain operation of series inverter with neat circuit diagram and waveform.**	**4M**
	Ans:	 **Working:** • When S1 (T1) is triggered the capacitor starts charging with left side plate positive with respect to right and when the voltage on capacitor is slightly greater than Edc T1 turns off; but there is no discharge path for capacitor hence it holds the charge. • When trigger pulse is applied to T2, T2 start conducting and current starts flowing in opposite direction. • In this way due to charge and discharge of capacitor and switching of T1 and T2 current will flow in RC. • Hence sinusoidal current starts flowing in the load.	**Circuit diagram : 1M** **Working : 2M** **Waveforms : 1M**
	(d)	**Draw and explain the block diagram of SMPS.**	**4M**
	Ans:	**Circuit diagram:** 	**Block diagram : 2M** **Working : 2M**

Control Circuit:

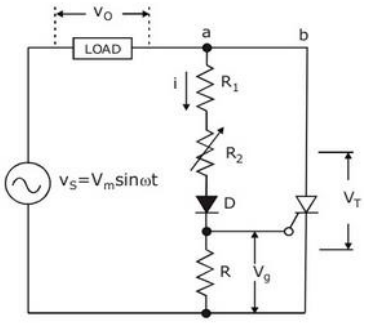
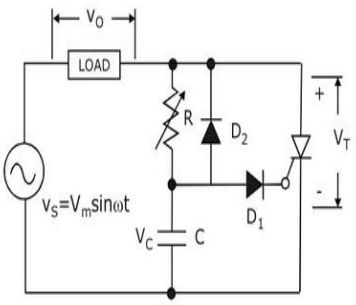


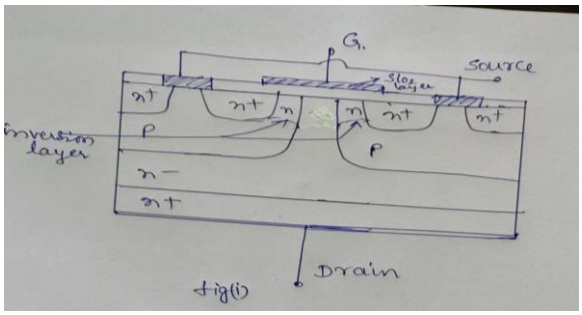
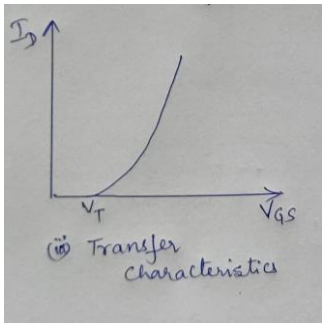
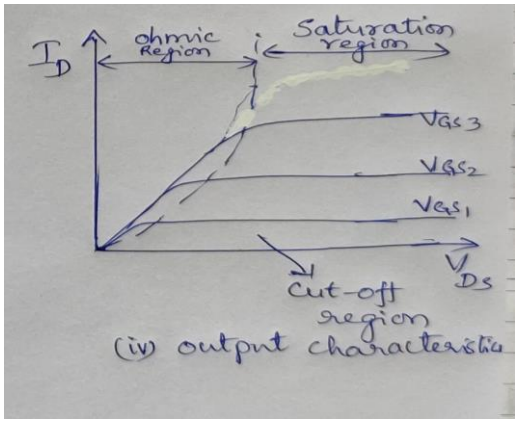
Working:

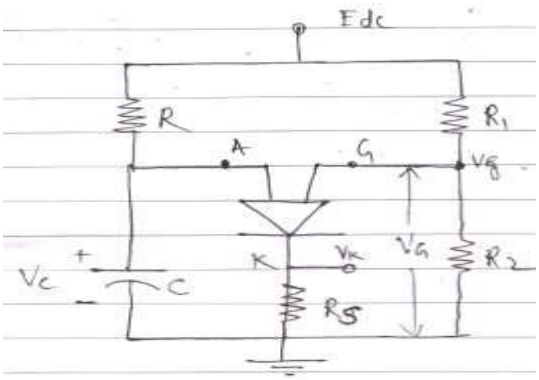
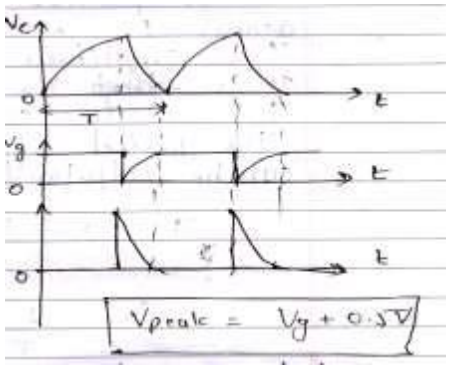
- SMPS converts unregulated AC or DC voltage into a regulated voltage. In case of AC it is first converted into unregulated DC. This is fed to a high frequency step-up chopper which switches ON and OFF according to the variations.
- It uses a high frequency AC conversion stage to facilitate the use of a high frequency transformer for voltage scaling and isolation. The output of transformer is then rectified and filtered, to get a regulated output.
- Regulated output voltage is then given to the control circuit, which is a feedback circuit. The final output is obtained by controlling the chopping frequency according to the feedback signal.
- An output sensor senses the signal and connects it to the control unit. A reference voltage is given as one input along with the signal to the error amplifier, whose output helps to decide whether to increase or decrease the chopping frequency.

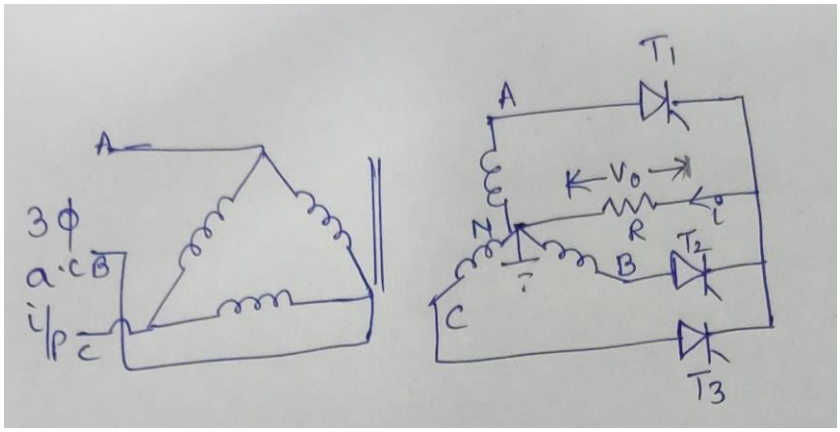
(e) Compare R-triggering and RC- triggering of SCR (any four points) — 4M

Ans: **Each point : 1M**

Parameters	R-triggering	RC -triggering
Circuit diagram		
Firing angle	0-90°	0-180°
Range of power control	less	more
Average output voltage	More	Less

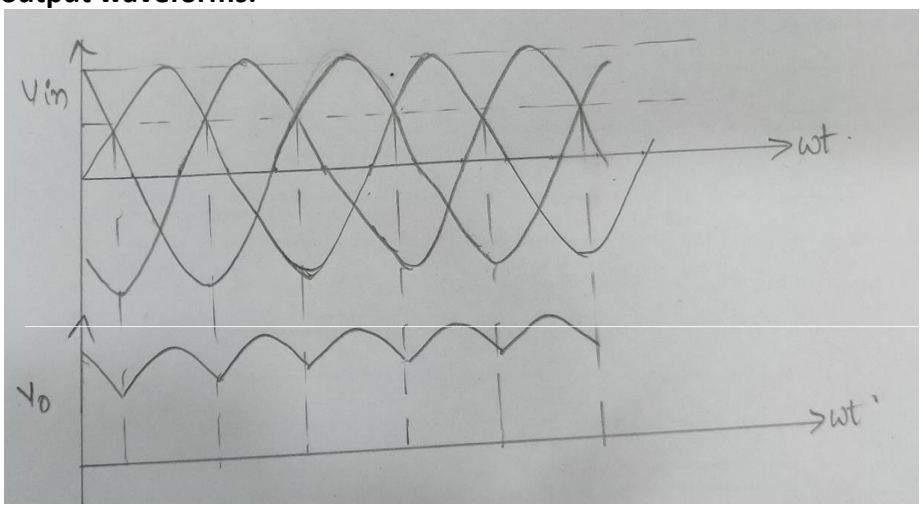
Q. No.	Sub Q. N.	Answers	Marking Scheme
5.		**Attempt any TWO of the following:**	**12- Total Marks**
	a)	**Explain with sketch the operation of power MOSFET.**	**6M**
	Ans:	**Circuit diagram:** (Structure of power MOSFET as shown below or any other equivalent can be considered)  Fig1 V-I characteristics:   **Operation:** Figure 1 shows the construction of N – channel power MOSFET	**2 marks, V-I characteristics: 2 marks, Operation: 2marks**

		• The Power MOSFET has a vertically oriented four layer structure of alternating P and N type ($n^+ p\ n^- n^+$) layers. • The P type middle layer is called as body of MOSFET. In this region, the channel is formed between source and drain. • The n- layer is called as drift region, which determines the breakdown voltage of the device. This n- region is present only in Power MOSFETs not in signal level MOSFET. • The gate terminal is isolated from body by silicon dioxide layer. • When the positive gate voltage is applied with respect to source, the n-type channel is formed between source to drain n allowing electrons to flow. • Hence a positive gate voltage sets up a surface channel for current flow from drain to source.	
	b)	**Describe the operation of PUT as relaxation oscillator.**	**6M**
	Ans:	**PUT Relaxation oscillator:**  **Waveforms of PUT relaxation oscillator**  **Operation:** • As the biasing voltage Edc is applied to the circuit , capacitor starts charging towards	**2marks** **2marks**

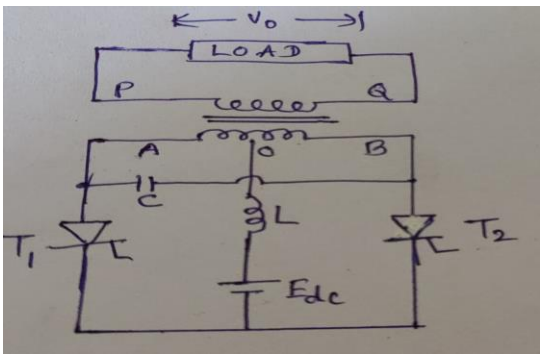
		Edc voltage through resistance R. • As soon as capacitor voltage reaches up to peak point (Vp) voltage, the PUT turns on & the capacitor discharges. A positive going pulse is produced across Rs resistor as amplitude of the pulse is slightly lower than the capacitor peak voltage due to anode cathode 'ON' voltage of 1V. • The peak point voltage (Vp =Vg+ 0.5) is set by the voltage divider consisting of the two resistors R1 & R2. • The voltage at gate remains at Vg volts, the potential on the capacitor reaches the peak point voltage, PUT turns ON Vg drops to approximately zero and the capacitor discharges. • When the discharging current of capacitor falls below the valley current PUT turns OFF & gate voltage returns to Vg volt.	**2marks**
	c)	**Explain the operation of three phase half wave controlled rectifier with circuit diagram and also sketch its input and output waveform**	**6M**
	Ans:	**Circuit diagram:**  **Operation:** • The 3-phase input supply is applied through the star connected supply transformer as shown in the figure. The common neutral point of the supply is connected to one end of the load while the other end of the load connected to the common cathode point • When the SCR T_1 is triggered at $\omega t=(\pi/6 + \alpha)=(30° + \alpha)$, the phase voltage V_{an} appears across the load when T_1 conducts. The load current flows through the supply phase winding *'A-N'* through SCR T_1 as long as T_1 conducts. • When SCR T_2 is triggered at $\omega t=(5\pi/6\alpha)$, T_1 becomes reverse biased and turns-off. The load current flows through the SCR and through the supply phase winding *'B-N'* . When T_2 conducts the phase voltage v_{bn} appears across the load until the SCR T_3 is triggered. • When the SCR T_3 is triggered at $\omega t = (3\pi/2 + \alpha)=(270°+\alpha)$, T_2 is reversed biased and hence T_2 turns-off. The phase voltage V_{cn} appears across the load when T_3 conducts. • When T_1 is triggered again at the beginning of the next input cycle the SCR T_3 turns off as it is	**2marks** **2 marks**

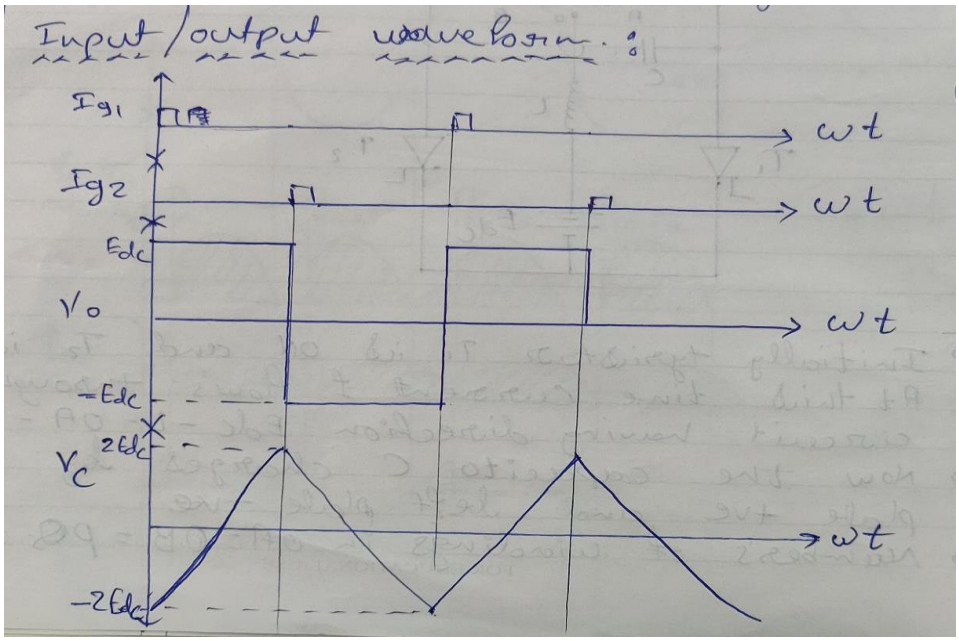
reverse biased naturally as soon as T_1 is triggered.

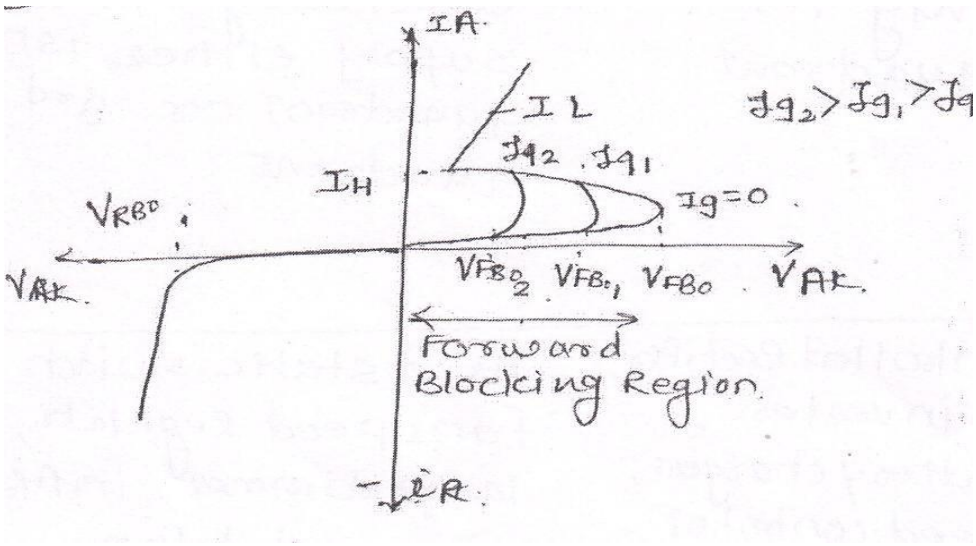
Input & output waveforms:

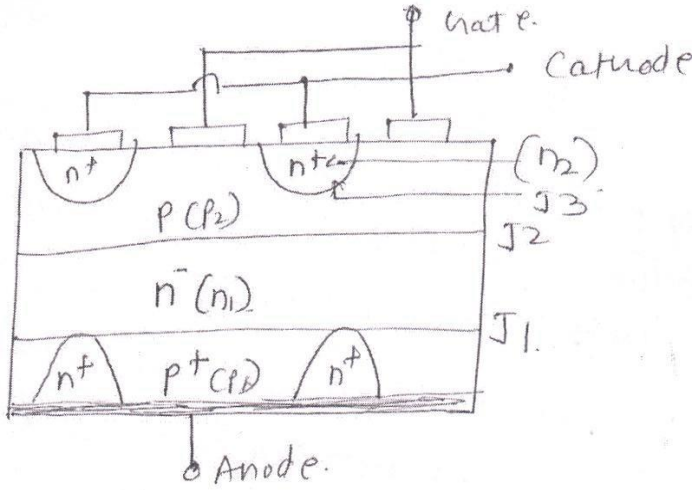


2 marks

Q. No.	Sub Q. N.	Answers	Marking Scheme
6.		**Attempt any TWO of the following :**	**12- Total Marks**
	a)	**Explain with neat circuit diagram the operation of parallel inverter.**	**6M**
	Ans:	**Circuit diagram:**  **Operation:**	**2 marks**

		• Initially, SCR T_1 is triggered and current flows through E_{dc}–L–0 -T_1 – E_{dc}. As the no. of turns in OA is equal to no. of turns in OB and is equal to no. of turns in PQ, the secondary voltage will be E_{dc} as shown above (Q +ve w.r.t. P) • As the rate of change of load current remains constant, the secondary voltage also remains constant as shown below. • Due to transformer action, capacitor is charged up to $2E_{dc}$ with right plate +ve and left plate –ve . • When the capacitor is fully charged up to $2E_{dc}$, SCR T_2 is triggered and the capacitor potential is applied across SCR T_1. Hence SCR T_1 goes into OFF state due to voltage commutation. As SCR T_2 is conducting now current starts flowing through E_{dc} – L– O- B – T_2 – E_{dc}. Since the direction of current is reversed, the direction of load voltage is also reversed as shown below. Hence P is +ve w.r.t Q. • Now the capacitor charges upto 2Edc with left plate +ve & right plate –ve. With this capacitor potential SCRT_1 is triggered. As soon as SCR comes into conduction SCR T_2 goes into off state due to voltage commutation an • and the cycle repeats. **Waveforms:**  	**2 marks** **2 marks**
	b)	**Explain with the characteristics the effect of gate current on break over voltage of SCR.**	**6M**

	Ans:	**Effect of gate current on break over voltage of SCR:**  **Explanation:** • The voltage at which the SCR comes into conduction without any gate current (Ig=0) is called break over voltage V_{BO}. • By the application of minimum required gate current (Ig_1), SCR can be turned on before the break over voltage. • If we increase the gate current (Ig_2) with in the specified limits SCR can be turned ON at a voltage much lesser than the break over voltage. • So by increasing the gate current ($Ig_2>Ig_1>Ig_0$) we can turn on the SCR at smaller voltages. • Once SCR is latched to ON state, gate loses its control unless and until current through SCR is not reduced below holding current or voltage across SCR is reversed, SCR will keep conducting.	**VI characteristics 3 marks** **Explanation 3marks**
	c)	**Draw labeled constructional diagram for GTO and describe its working principle with V-I characteristics.**	**6M**
	Ans:	**Constructional diagram:**	**2marks**

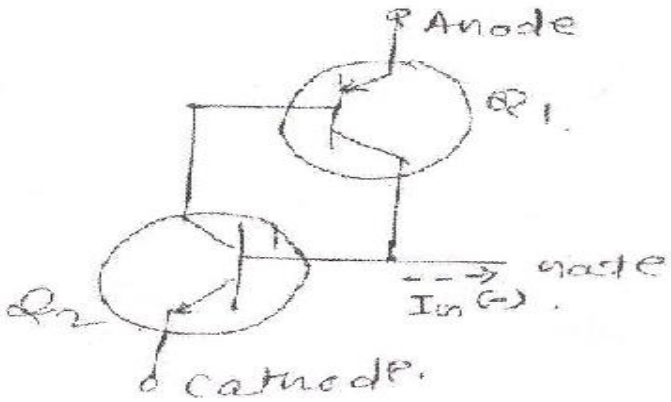


2 marks

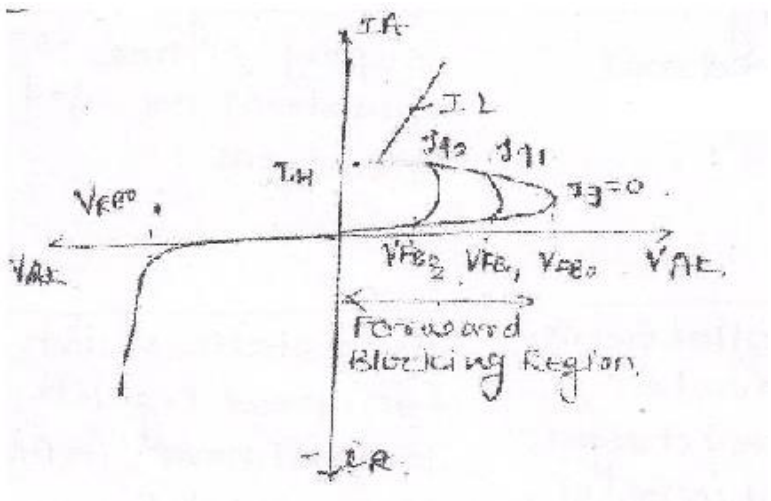
Operating Principle:-

Basic operation of GTO is same as that of the conventional SCR but the major difference between is that the conducting GTO can be turned off by applying a negative gate current to it. Thus positive gate current turns it on and negative gate current turns it off.

- From two transistor model of GTO both transistor Q1 and Q2 are in saturation when the GTO is in it's on state.



- If the base current of Q2 could be made less than the value needed for maintaining it in saturation, then Q2 will come out of saturation and will be in active state, this will reduce the regeneration and GTO will begin to turn off.
- In order to reduce the base current of Q2 & –ve gate current must flow in the direction as shown in diagram A. It can be proved that the negative gate current required for turning off a conducting GTO.

		V-I characteristics: 	**2 marks**