SUMMER – 2022 EXAMINATION

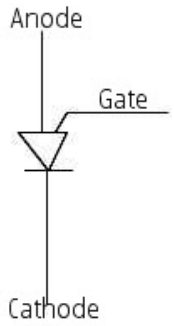
Subject Name: Basic Power Electronics **Subject Code:** 22427

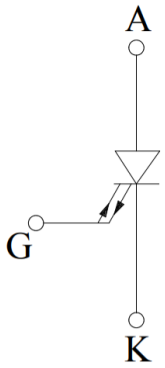
Model Answer

Important Instructions to examiners:

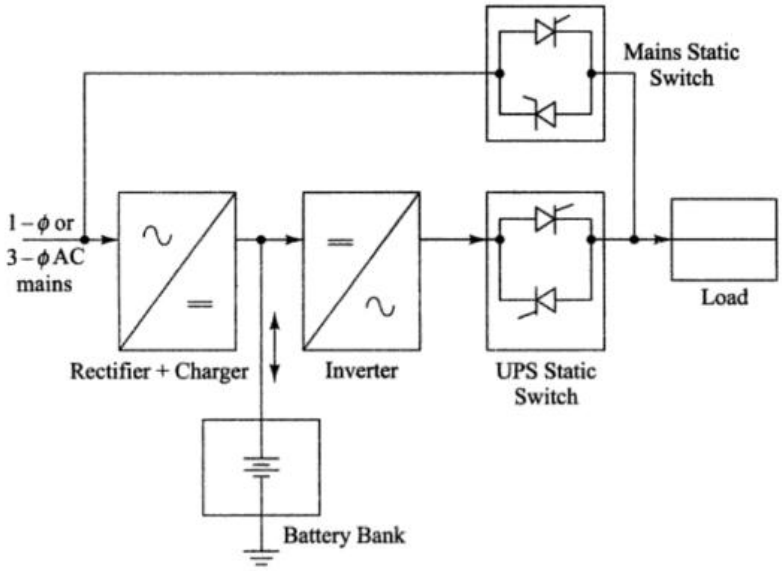
1) **The answers should be examined by key words and not as word-to-word as given in the model answer scheme.**
2) **The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.**
3) **The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.**
4) **While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.**
5) **Credits may be given step wise for numerical problems. In some cases, the assumed constant values 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.**
8) **As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.**

Q. No.	Sub Q. N.	Answers	Marking Scheme
1	(A)	**Attempt any FIVE of the following:**	**10- Total**

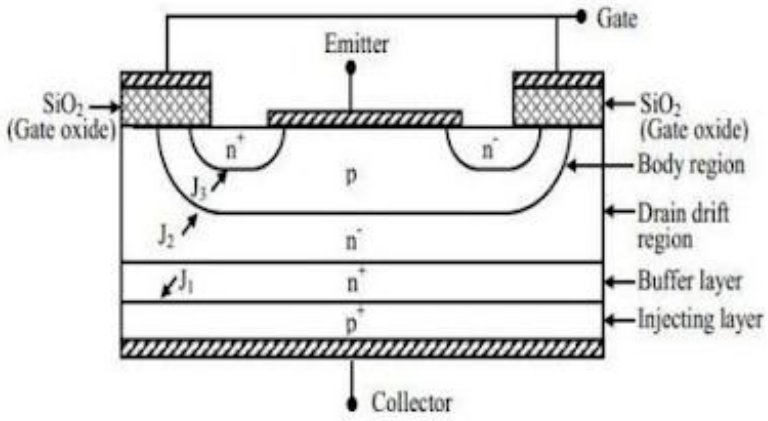
			Marks
	(a)	**State two applications of power MOSFET.**	**2M**
	Ans:	**Applications of power MOSFET:** 1. **Uninterruptible Power Supplies (UPS)** 2. **Small motor control.** 3. **Switch Mode Power Supplies (SMPS)** 4. **Power-Over-Ethernet** 5. **Solar inverters.** 6. **Automotive applications.**	**2M: Any tw applications**
	(b)	**Draw the symbol of PUT and GTO.**	**2M**
	Ans:	1. **Symbol of PUT**  2. **Symbol of GTO**	**1M : Each symbol**

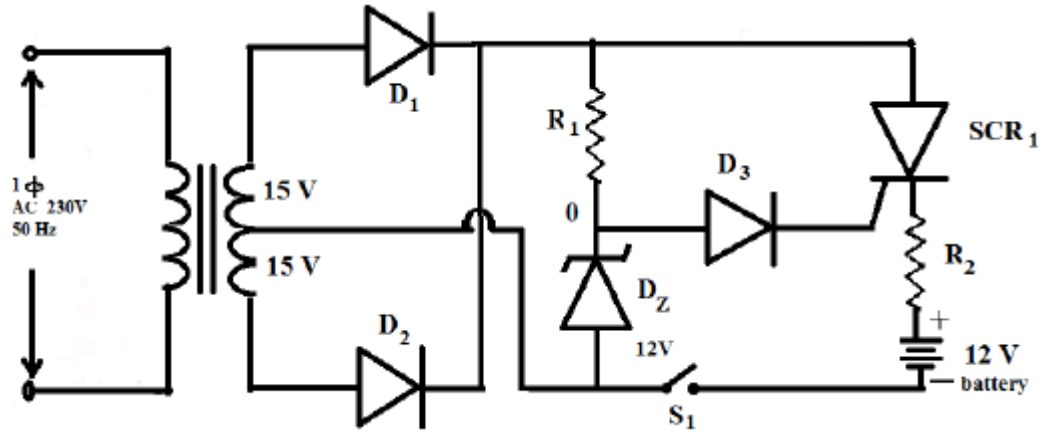
			
	(c)	**Define commutation and state its types.**	**2M**
	Ans:	**Definition: Commutation of SCR is defined as the process of turning off an conducting SCR / thyristor.** **There are mainly two types of SCR commutation techniques:** **1. Natural Commutation and** **2. Forced Commutation.** **Forced commutation techniques (Optional)** • **Class-A Commutation** • **Class-B Commutation** • **Class-C Commutation**	**1M : Definition** **1M: types**
	(d)	**Define inverter and state its types**	**2M**
	Ans:	**Definition: An Inverter is a circuit that converts a fixed dc input voltage into an ac output voltage of variable frequency and of fixed or variable magnitude.** **Types of inverter (any one)** **1) According to nature of input source :** **a) Voltage source inverter (VSI)**	**1M : Definition** **1M: types (any one)**

		b) Current source inverters (CSI) **2) According to the wave shape of the output voltage.** **a) Sine wave inverter** **b) Square wave inverter** **c) Quasi square wave inverter** **d) Pulse width modulated inverter** **3) According to the method of commutation:** **a) line commutated inverter** **b) forced commutated inverter** **4) According to the connection of thyristor and commutation components :** **a) Series inverter** **b) Parallel inverters** **c) Bridge inverters which are further classified as half bridge and full bridge** **5) According to the semiconductor device used :** **a) Thyristorized inverter** **b) Transistorized inverter** **c) MOSFET based inverter** **d) IGBT based inverter**	
	e)	**Draw the block diagram of UPS.**	**2M**

	Ans:		**2M: block diagram**
	f)	**State two advantages of gate triggering.**	**2M**
	Ans:	**Advantages of gate triggering :** 1. **Gate drive is discontinuous or doesn't need continuous pulses and hence gate losses are reduced in greater amount.** 2. **It is simple and reliable.** 3. **It is efficient and also easy to implement.**	**2M: any two advantages**
	g)	**Define firing angle and conduction angle.**	**2M**
	Ans:	1. **Firing angle** **It is the angle of sine wave at which SCR is turned ON. This is denoted as " α" and varies from 0 to 180^0.** 2. **Conduction angle** **The angle for which SCR remains ON is called as conduction angle. θ =π-α.**	**1M : each definition**

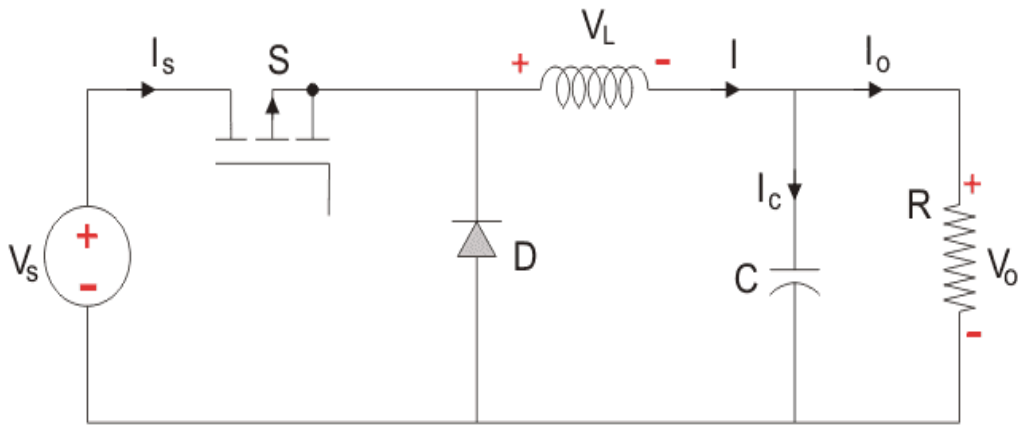
Q.	Sub	Answers	Marking

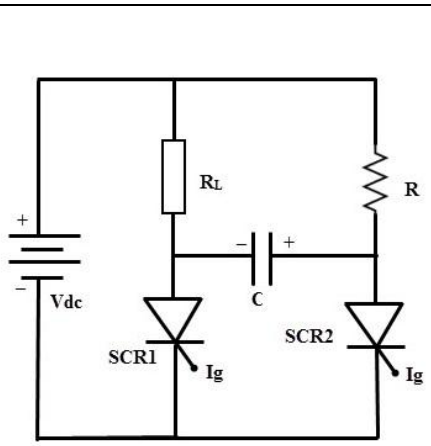
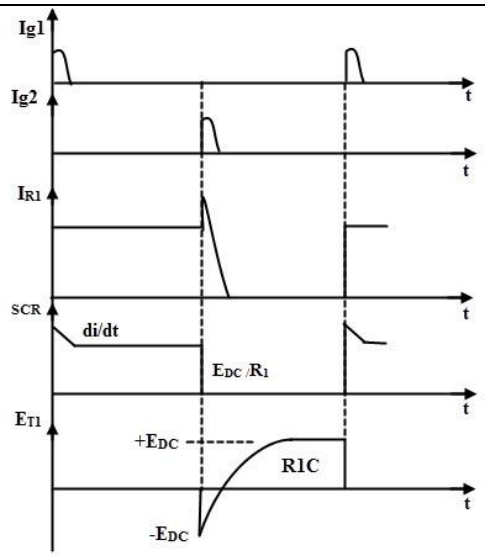
No.	Q. N.		Scheme
2		**Attempt any THREE of the following:**	**12-Total Marks**
	a)	**Draw the constructional details of IGBT and mark the layers.**	**4M**
	Ans:		**4M**
	b)	**Describe the operation of battery charger with neat diagram.**	**4M**
	Ans:	**Working :** • **The figure shows the battery charger circuit using SCR.** • **A 12V discharged battery is connected in the circuit and switch SW is closed. The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer.** • **The diodes D1 and D2 forms full wave rectifier which provides pulsating DC output.** • **When SCR is off, its cathode is held at the potential of discharged battery.** • **During each positive half-cycle, as diode D3 is forward biased gate pulse is provided to SCR and SCR is turned ON when sufficient anode to cathode voltage appears.**	



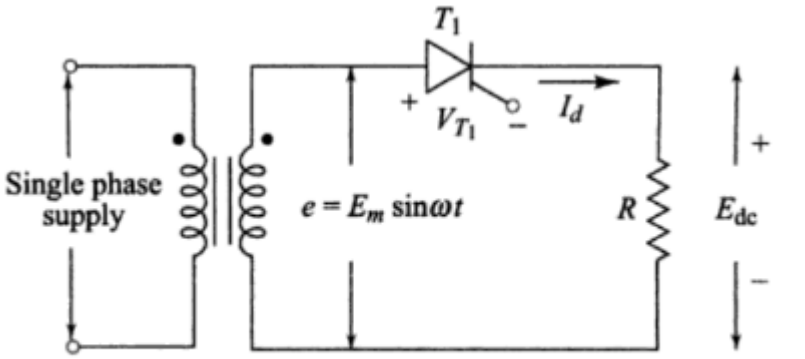
- **When SCR is turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply voltage, SCR is fired and charging current is passed till the end of that half-cycle.**
- **Due to Zener diode Dz, the maximum voltage is held at 12V. Due to the charging process, the battery voltage rises and finally attains full value of 12V.**
- **When the battery is fully charged, the cathode of SCR is held at 12V. So the diode D3 and gate-cathode junction of SCR cannot be forward biased.**
- **Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.**

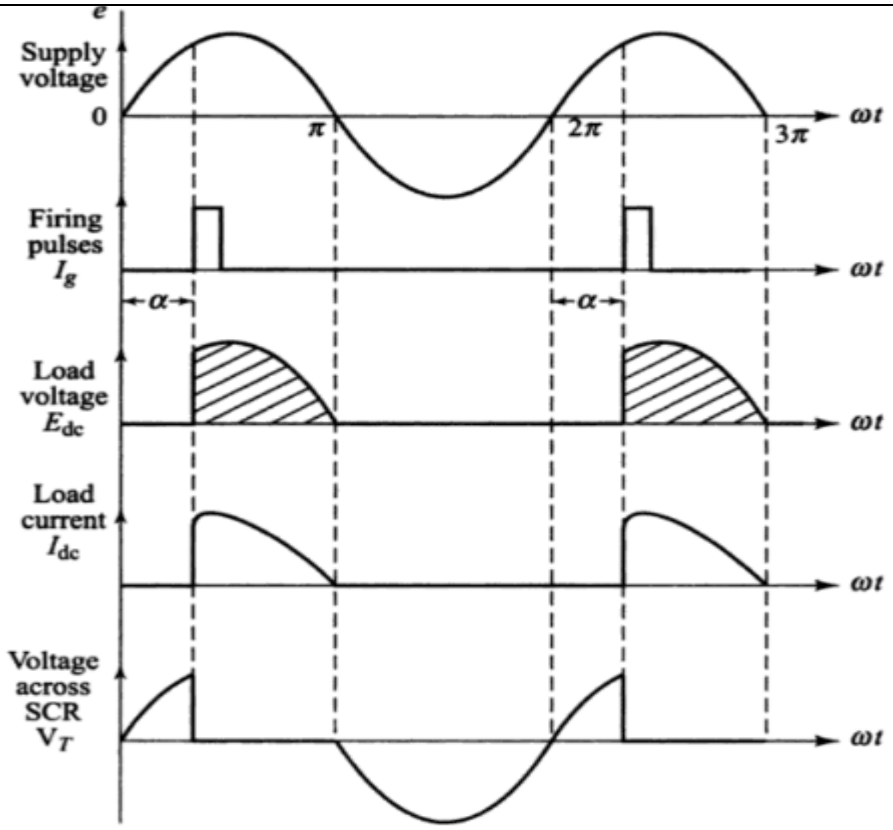
	c)	**With a neat diagram explain the operation of step down chopper using MOSFET.**	**4M**

	Ans:	 **Working:** • **The enhancement type of power MOSFET acts as a switch.** • **The control signal is applied at gate terminal of MOSFET.** • **When gate voltage is high, MOSFET is turned ON and Vs directly appears across the load . So $V_O = V_S$.** • **When gate voltage is low, MOSFET is turned off, Vs is disconnected from the load. So output voltage $V_O = 0$.** • **Here, the energy stored in the inductor is released and is ultimately dissipated in the load resistance, and this helps to maintain the flow of current through the load.**	**2M : circuit diagram** **2M : workin**
	d)	**Draw and explain complementary commutation circuit.**	**4M**

	Ans:	  **Working:-** • **At first the SCR1 is triggered. So it conducts and load current IL (Vdc+, RL, SCR1, Vdc-) starts flowing through it.** • **The capacitor 'C' will charge through Vdc+, R, C, SCR1, Vdc- with right plate positive.** • **When it is fully charged to Vs capacitor 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 SCR1 OFF.** • **Now capacitor will start charging through Vdc+, RL, C, SCR2, Vdc- with left plate positive.** • **Similarly, as SCR1 is turned ON the reverse voltage across 'C' is applied across SCR2, turning SCR2 OFF.**	**1M : Circuit diagram** **2M: Workin** **1M: Waveforms**

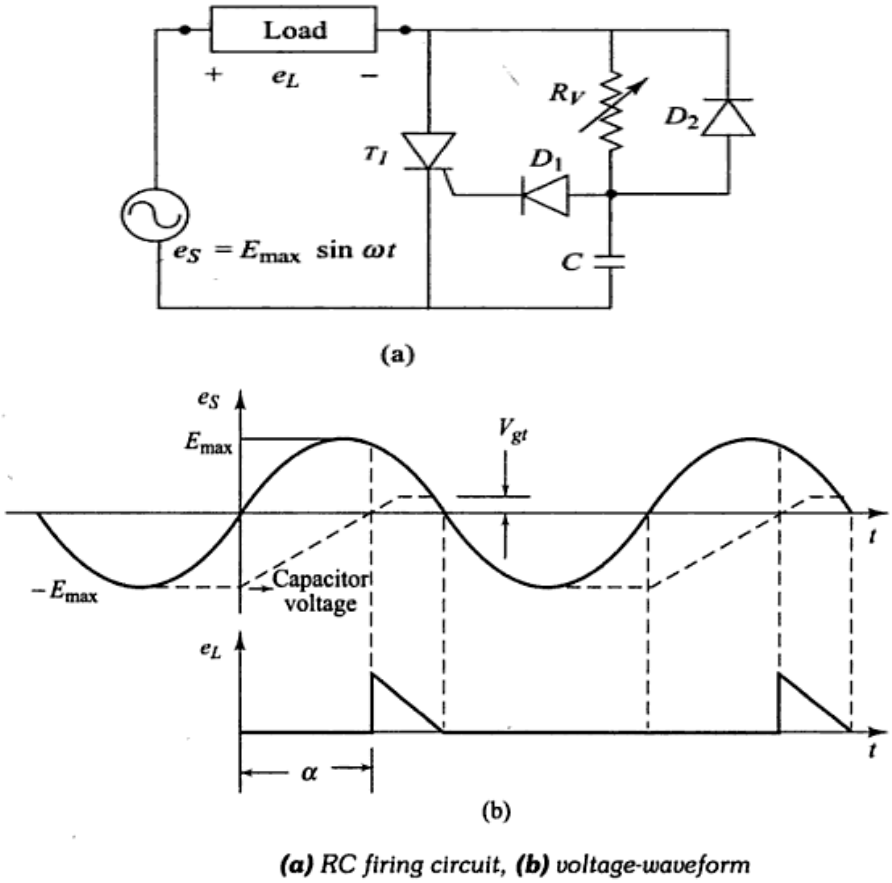
Q.	Sub	Answers	Marking

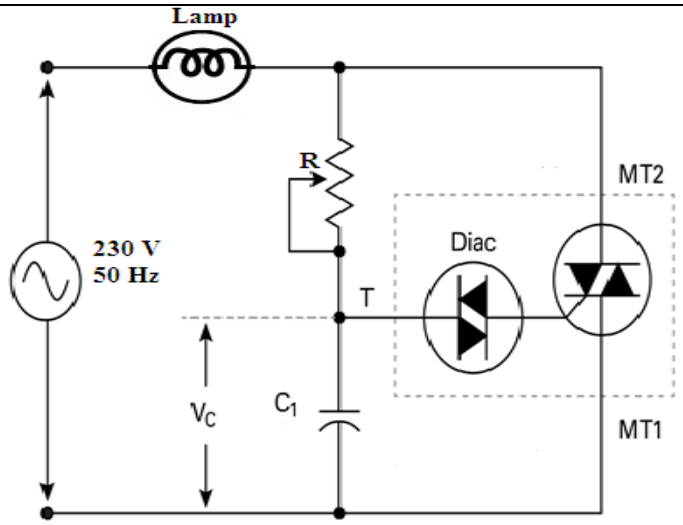
No.	Q. N.		Scheme
3		**Attempt any THREE of the following:**	**12- Total Marks**
	a)	**Draw the circuit diagram of 1ϕH.W.C. Rectifier with "R" load. Explain the working with wave forms**	**4M**
	Ans:	**Circuit Diagram & waveform:**  *Halfwave-controlled rectifier with resistive load*	**3M - Circuit Diagram & waveform:** **1M - workin**

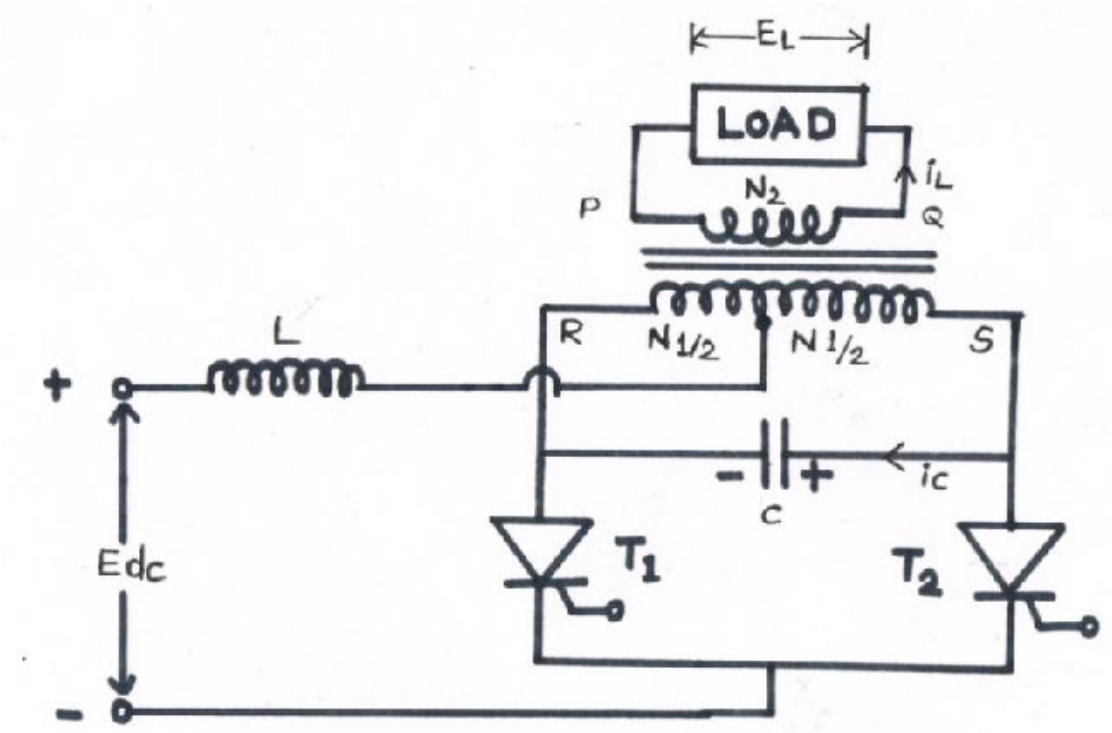


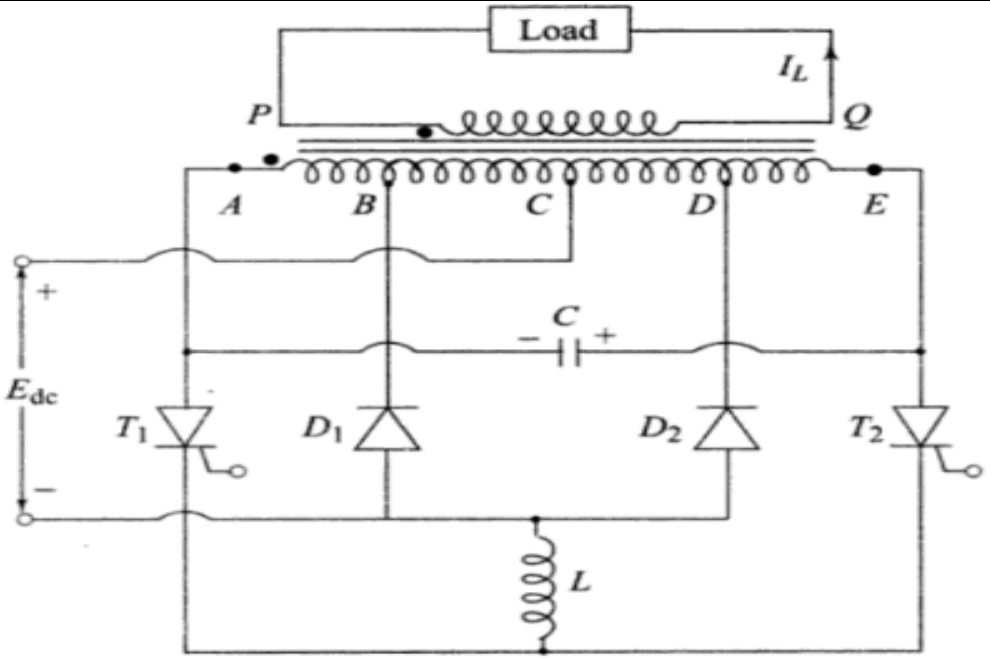
Waveforms for a half-wave circuit

- **During the positive half cycle of input voltage, SCR is forward biased. But as Vm< VBO and gate current is not given, SCR remains off. At ωt = α, sufficient gate current is given to trigger the SCR. Since voltage drop across the SCR can be neglected the entire input voltage appears across RL.**
- **For the remaining entire positive half cycle, SCR is forward biased and remains ON.**
- **Hence output voltage VO is exactly same as the input voltage for the remaining positive cycle from α to π.**
- **During the negative half cycle, at ωt = π, SCR is reverse biased and remains off. It will continue remain off in the next positive half cycle until triggered by gate current at 2π+α.**

	b)	**Draw and explain the operation of a triggering circuit to control the firing angle 0^0 - 180^0.**	**4M**
	Ans:	**Circuit Diagram:**  ***(a)** RC firing circuit, **(b)** voltage-waveform* **Explanation:-** • **A large value of firing angle can be obtained from RC triggering circuit usually in 0-180° range.** • **In the positive half cycle the capacitor is charged through the variable resistance R up to the peak value of applied voltage.** • **The charging rate of the capacitor can be controlled by the variable resistance R.** • **Depending on the voltage across the capacitor & if the gate current is sufficient,**	**2M – Circui Diagram** **2M - Worki**

		the thyristor triggers. • **In negative half cycle the capacitor C is charged up to the negative peak value through the diode D2.** • **Diode D1 is used as a safe guard against the reverse breakdown of the gate – cathode junction in the negative half cycle.**	
	c)	**Draw and explain the operation of light dimmer circuit using TRIAC & DIAC.**	**4M**
	Ans:	 **Explanation:** • **In the above circuit DIAC is used to trigger TRIAC.** • **During the positive half cycle, when the voltage across capacitor is above the breakdown voltage of the DIAC, DIAC turns ON & the capacitor discharge through the TRIAC gate i.e. positive gate signal is given to the TRIAC & thus TRIAC turns ON.** • **So current starts flowing through load.** • **A similar operation takes place in the negative half cycle.** • **The charging rate of capacitor C can be changed by varying the resistance R and hence the firing angle can be controlled.** • **If firing angle is less, intensity of light is more & vice-versa.**	**2M – Circui Diagram** **2M - Worki**

		• **Thus by controlling the firing angle, we can control intensity of light using TRIAC.**	
	d)	**Suggest a suitable inverter to produce square wave output. Draw its neat circuit diagram.**	**4M**
	Ans:	**Parallel Inverter is used to produce square wave.** **Circuit diagram:**  **OR**	**2M - Identificatio** **2M – Circui diagram**



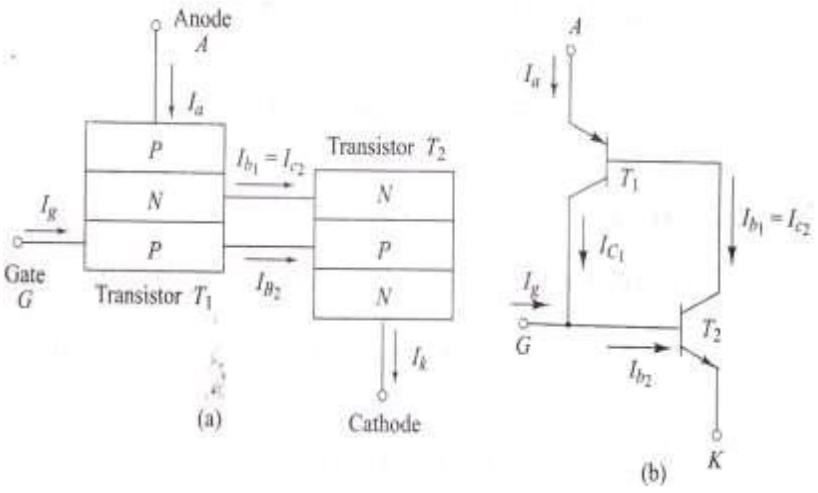
Q. No.	Sub Q. N.	Answers	Marking Scheme
4		**Attempt any THREE of the following:**	**12- Total Marks**
	(a)	**Draw and explain two transistor analogy of SCR.**	**4M**
	Ans:	**Working:-** • **The operation of an SCR can be explained in a very simple way by considering it in terms of two transistors.** • **The SCR can be considered as an npn & pnp transistor, where the collector of one transistor is attached to the base of the other & vice versa.**	**2M – Circui Diagram** **2M - Worki**

- **The collector current of transistor T1 becomes the base of transistor T2 & vice versa**

  &

  Ic1= Ib2

  Ib1=Ic2



- **When the gate current is zero or the gate terminal is open, the only current in circulation is the leakage current, which is very small.**
- **Under these conditions P-N-P-N device is said to be in its forward blocking or high impedance off state.**
- **As soon as a small amount of gate current is given of transistor T2 by applying forward bias to its base emitter junction it generates the collector current.**
- **In this way both transistors feedback each other and the collector current of each goes multiplying. This process is very quick & soon both the transistors drive each other into saturation.**
- **Now the device is said to be in on-state from the OFF-state. This characteristics of the device is known as its regenerative action.**

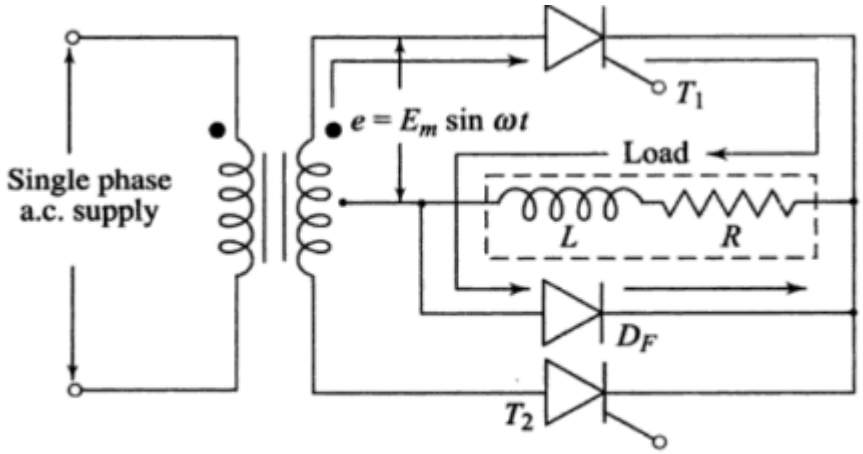
	(b)	**A single phase full wave controlled rectifier is supplied with a voltage V= 100 sin(314t), α=30^0 and load resistance is 50Ω. Find the average output DC voltage and load current.**	**4M**
	Ans:	**Data Given :** **V= 100 sin(314t), α = 30^0 and RL = 50Ω** **Solution:** **Average DC output voltage, Edc = $\frac{Em}{\pi}$ (1 + cos α)** **Edc = $\frac{100}{\pi}$ (1 + cos 30) = 59.40 V** **Edc = 59.40 V** **Average load current, Idc = $\frac{Edc}{R}$** **Idc = $\frac{59.40}{50}$ = 1.18 A** **Idc = 1.18 A**	**2M – load Voltage** **2M – load current**
	(c)	**Describe the effect of free wheeling diode with respect to single phase center tapped fully controlled rectifier with RL load..**	**4M**
	Ans:	**Effect of freewheeling diode :** **With a freewheeling diode connected in a controlled rectifier with RL load, the thyristor will not be able to conduct beyond 180°. During negative half-cycle as the current changes its direction, emf is induced in the inductor. This energy is dissipated in the load resistance through the freewheeling diode. Hence at 180°, current through the SCR is cut-off and a reverse voltage appears across the SCR turns it OFF instantly. Its effects in**	**2M - Circuit diagram** **2M – Description**

the

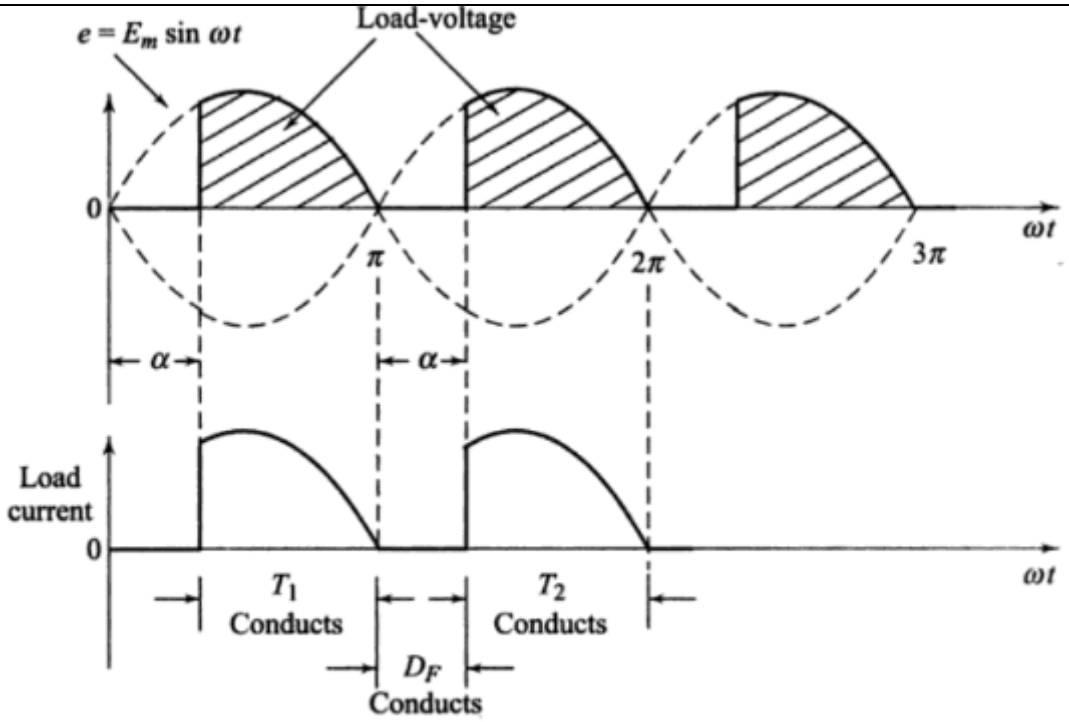
circuit can be,

1) **The load voltage does not become negative and hence gives more average d.c. output voltage than without freewheeling diode.**
2) **Load current becomes continuous i.e. ripple free.**
3) **It prevents reversal of load voltage.**
4) **Input power factor is improved.**

Circuit diagram:

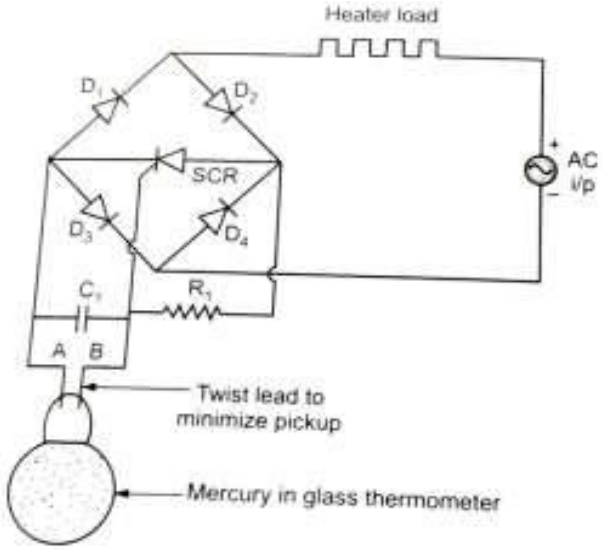


M-2 configuration with freewheeling diode D_f

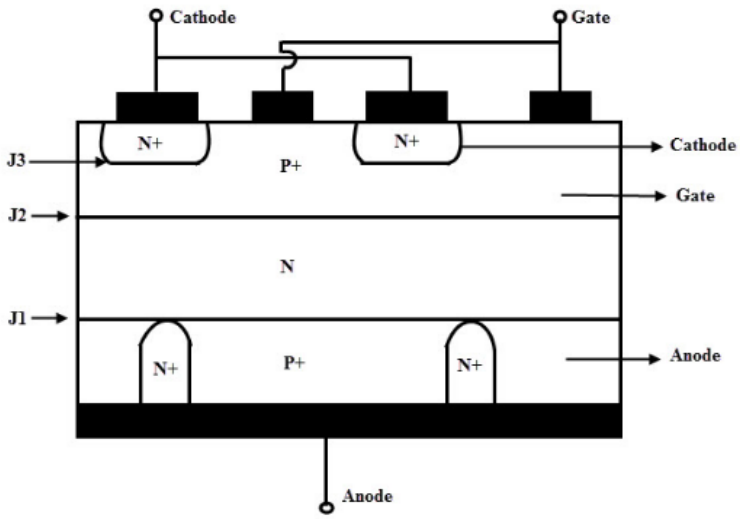


Waveforms

	(d)	**Draw and explain the operation of a temperature control circuit using SCR.**	**4M**
	Ans:	**Circuit diagram:**	**2M - Circuit diagram** **2M – Worki**

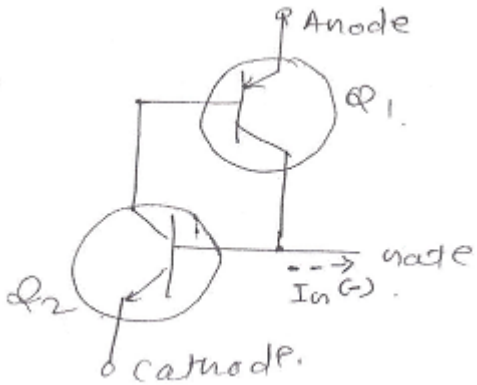


		Working: **Figure shows the temperature control circuit using thermostat as temperature detector and SCR as a switching device. The mercury in glass thermostat is extremely sensitive temperature measuring instrument which is capable of sensing changes in temperature of the order of 0.1^{oC}.** **Mode I:** **When the temperature is less than the desired value, the mercury in the glass thermostat is not able to short the electrodes A & B. Therefore the SCR receives the gate signal in both the half cycles & it will be triggered. Hence the heater will be connected in the AC circuit.** **Mode II:** **As the temperature increases, the mercury level increases and when it reaches the desired value, the electrode A and B are short circuited through mercury. This will short circuit the gate supply to the SCR and SCR will not get the trigger pulse. Hence it is OFF and heater will be disconnected from the circuit.**	
	(e)	**Draw the constructional detail of GTO . explain its working principle.**	**4M**
	Ans:	**Constructional diagram of GTO:**	**2M - Constructio l diagram** **2M - workin principle**

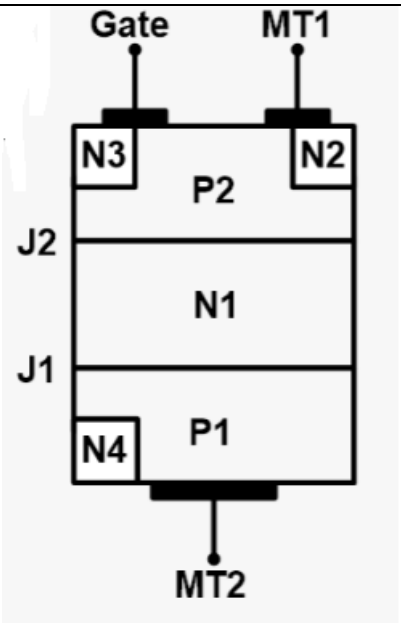
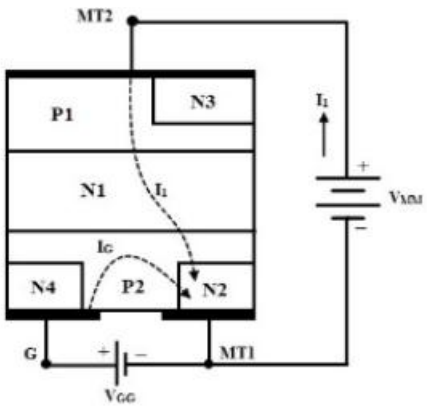


Working Principle:-

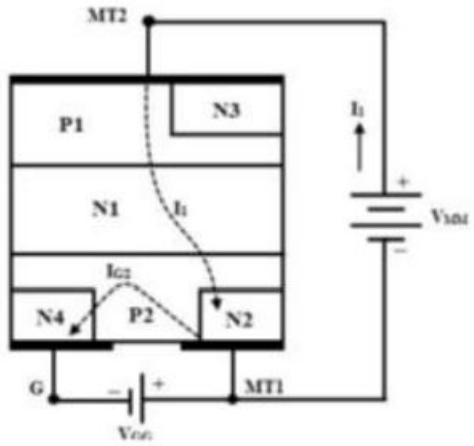
- **Basic operation of GTO is same as that of the conventional SCR but the major difference between is that the conducting GTO can be turned off by applying a negative gate current to it. Thus positive gate current turns it on and negative gate current turns it off.**
- **From two transistor model of GTO both transistor Q1 and Q2 are in saturation when the GTO is in its 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, a negative gate current must flow in the direction as shown in diagram A.**
- **Thus, it can be proved that the negative gate current required for turning off a conducting GTO.**



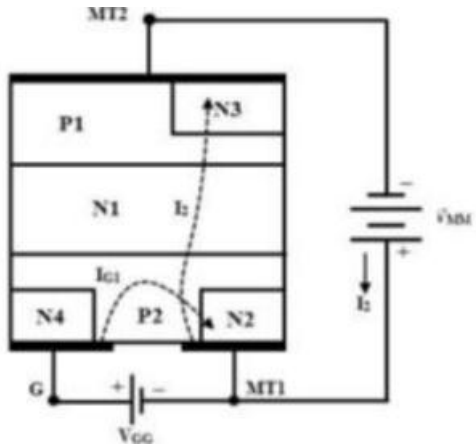
Q. No.	Sub Q. N.	Answers	Marking Scheme
5.		**Attempt any TWO of the following:**	**12- Total Marks**
	a)	**Draw the constructional details of TRIAC. State its mode of operation and explain its V-I characteristics.**	**6M**

	Ans:	 **There are four different operating modes of TRIAC:** **1) MT2 and gate are positive with respect to terminal MT1(Mode1) : Here terminal MT2 is positive with respect to terminal MT1 current flows through path P1- N1-P2-N2.The two junctions P1-N1 and P2-N2 are forward biased whereas junction N1-P2 is blocked. The TRIAC is now said to be positively biased. A positive gate with respect to terminal MT1 forward biases the junction P2-N2 and the breakdown occurs as in a normal SCR.** 	**Construction l Dia 2M** **Modes:2M** **VI char:2M**

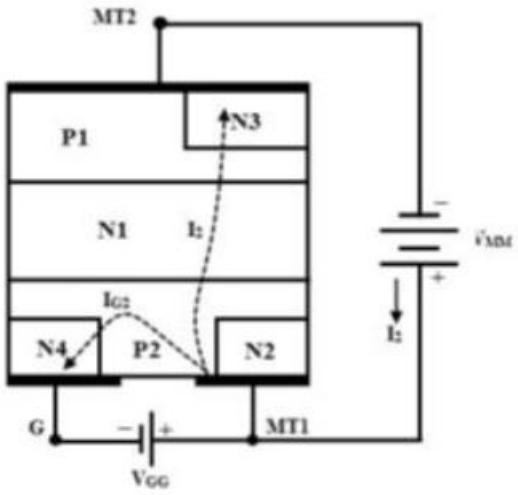
2) MT2 is positive but gate is negative with respect to terminal MT1(Mode2): Though the flow path of current remains the same as in mode 1 but now junction P2-N3 is forward biased and current carriers injected into P2 turn on the TRIAC.

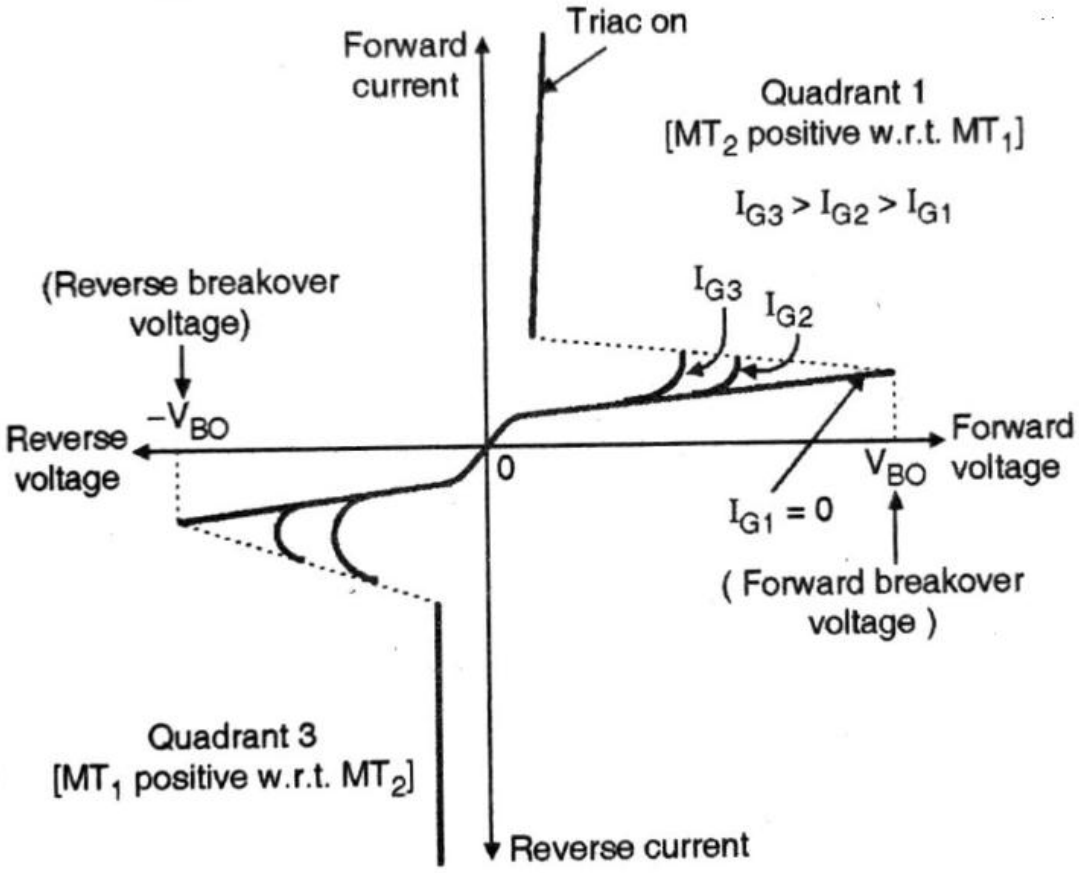


3) MT2 is negative but gate is positive with respect to terminal MT1(Mode3) : Though the flow path of current remains the same as in mode 3 but now junction P2-N2 is forward biased, current carriers are injected and therefore, the TRIAC is turned on.



4) MT2 and gate are negative with respect to terminal MT1(Mode4) : When terminal MT2 is negative with respect to terminal MT1, the current flow path is P2- N1-P1-N4. The two junctions P2-N1 and P1 – N4 are forward biased whereas junction N1-P1 is blocked. The TRIAC is now said to be negatively biased. A negative gate with respect to

		terminal MT1 injects current carriers by forward biasing junction P2-N3 and thus initiates the conduction.  	

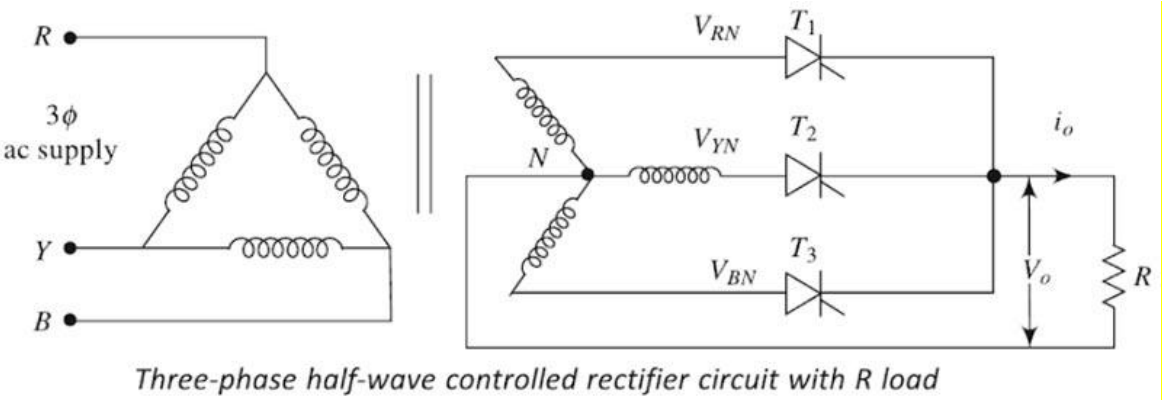


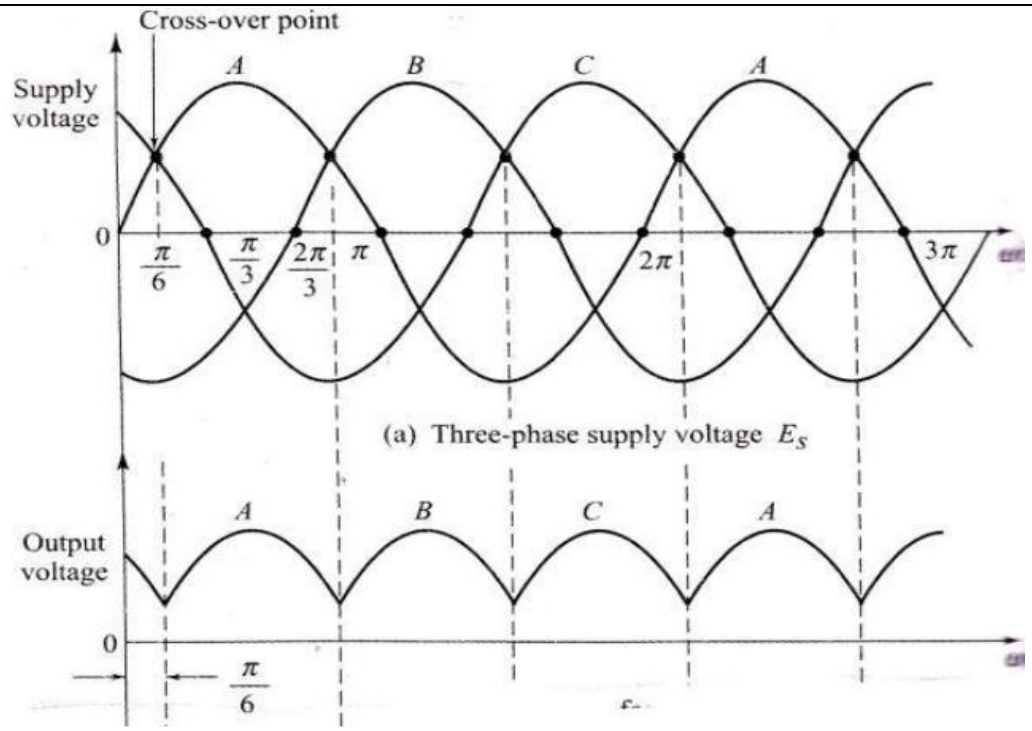
VI characteristics of Triac

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

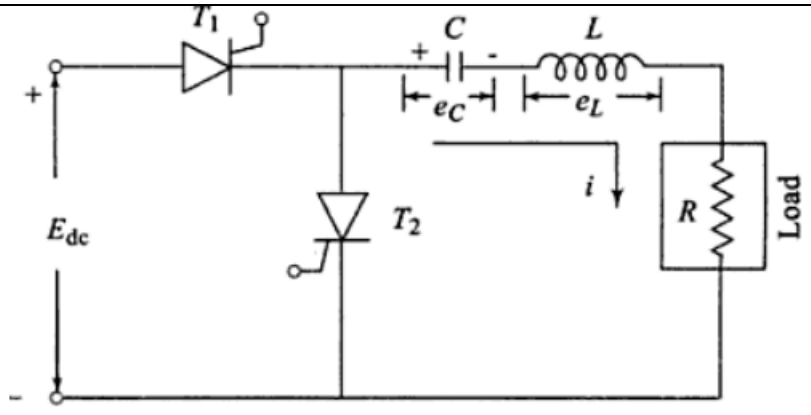
1) Blocking region (OFF state): In the first quadrant, when MT2 is made positive w.r.t. MT1 with a positive or negative gate current, the graph lies in the first quadrant. Initially, till the breakover voltage of the device is applied, only a small leakage current flows.

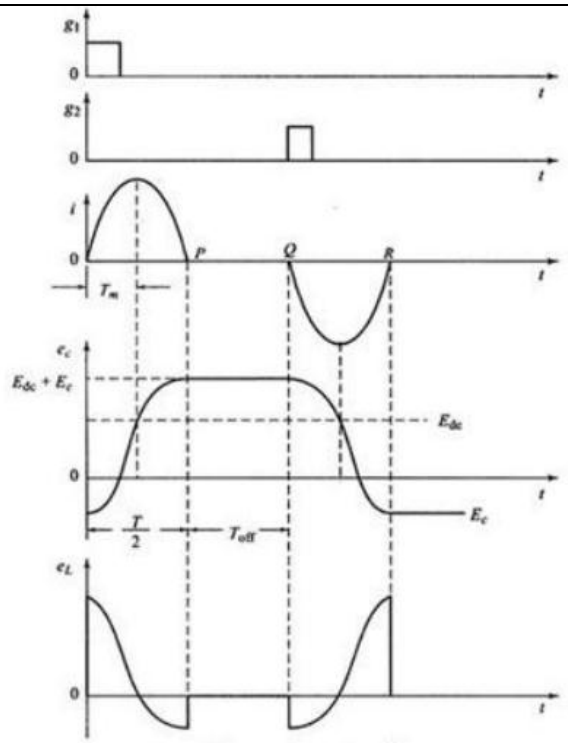
2) Conduction region (ON state): After the breakover voltage(VBO) is applied, the device goes into conduction with a sharp increase in current but with a considerable

		reduction in the voltage across the device.	
	b)	**Explain the operation of three phase half wave controlled rectifier with circuit diagram. Draw i/p-o/p wave forms.**	**6M**
	Ans:	 *Three-phase half-wave controlled rectifier circuit with R load* **The primary is connected in delta and secondary in star. The load is connected to the neutral point. The circuit functions in a manner such that only one SCR is conducting at any given instant, the one which is connected to the phase having the highest instantaneous positive value. Here no SCR can be triggered below a phase angle of 30^o because it remains reverse biased by the other conducting phase.**	**Circuit Dia 2M** **Explanation 2M** **Waveform 2**



Waveforms

	c)	**Explain the operation of series inverter with neat circuit diagram. Draw the waveforms.**	**6M**
	Ans:	 Circuit diagram	**Circuit Dia 2M** **Waveforms 2M** **Explanation 2M**



Waveforms

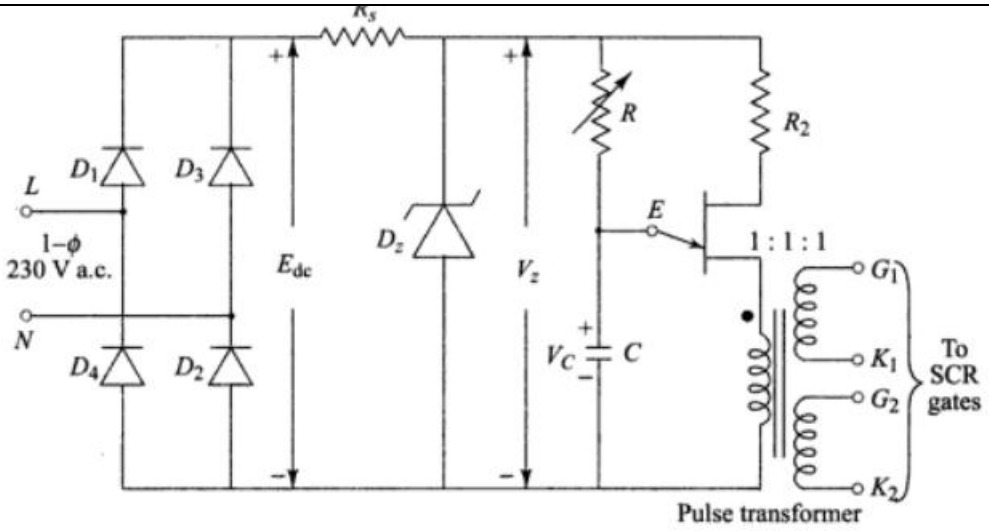
When T1 is triggered the capacitor starts charging with left side plate positive with respect to right and when the voltage on capacitor is slightly greater than Edc T1 turns off; but there is no discharge path for capacitor hence it holds the charge. When trigger pulse is applied to T2, T2 start conducting and current starts flowing in opposite direction. In this way due to charging and discharging of capacitor and switching of T1 and T2 current will flow in RC circuit. Hence sinusoidal current starts flowing in the load.

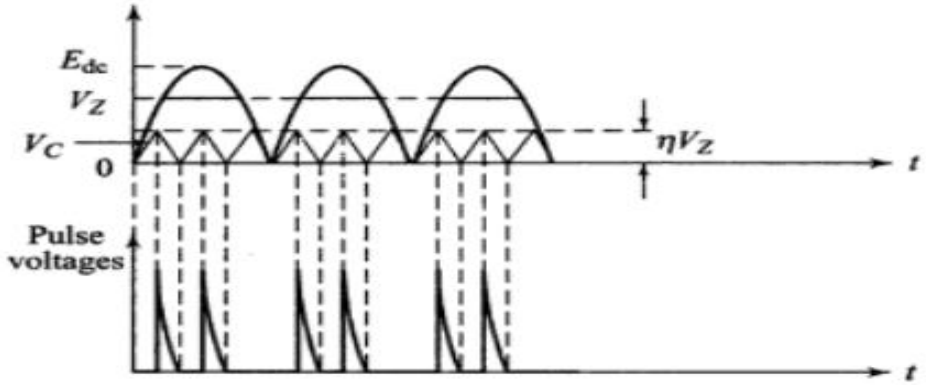
Q. No.	Sub Q. N.	Answers	Marking Scheme

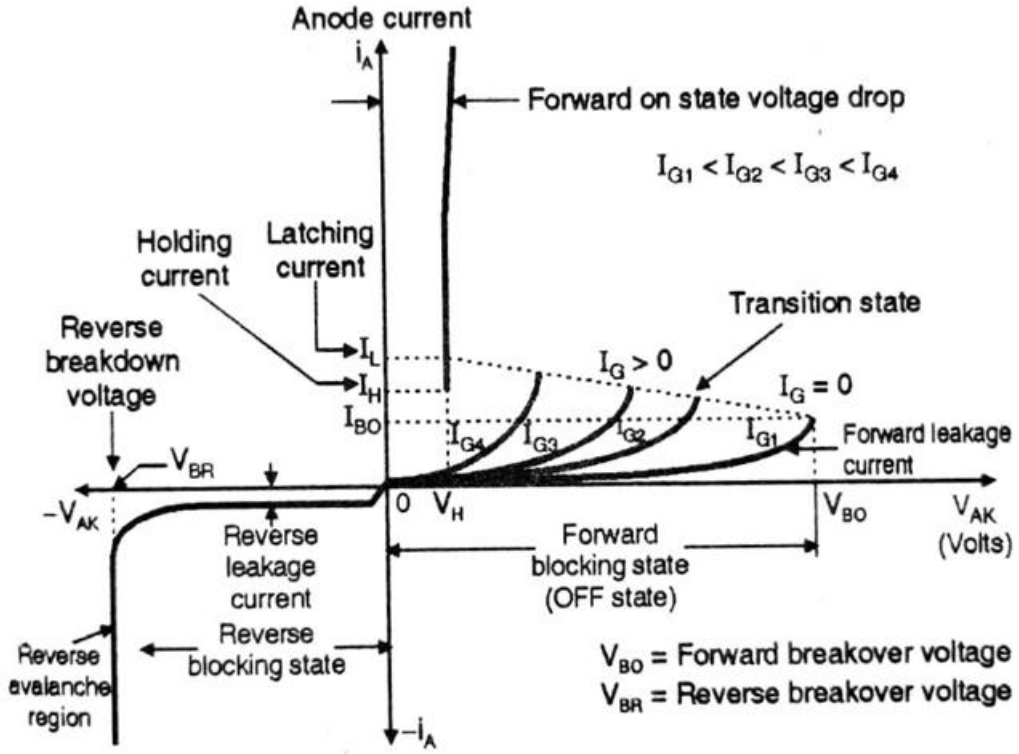
6.		Attempt any TWO of the following :	12- Total Marks
	a)	(i) Define chopper. State its classification. (ii) compare step-down and step-up chopper (any four points)	
	Ans:	A chopper is a static device that converts fixed dc voltage to a variable dc voltage. Types: 1) Step up chopper 2) Step down chopper	i)2M ii)4M

Step down chopper	Step up chopper
The average value of DC output voltage is less than the input source voltage.	The average value of DC output voltage is more than the input source voltage.
The average output voltage is given by formula $V_0 = DV_s$	The average output voltage is given by formula $V_0 = [V_s / (1-D)]$, where D is duty cycle of chopper.
Chopper switch is in series with the load	Chopper switch is in parallel with the load
External Inductance is not required	External Inductance is required for boosting the output voltage.
First quadrant operation	Second quadrant operation.

	b)	Describe the operation of synchronized UJT triggering circuit with circuit diagram	6M

	Ans:	 **Synchronized UJT triggering circuit** **The diode bridge D1−D4D1−D4 rectifies a.c. to d.c. Resistor Rs lowers E dc to a suitable value for the zener diode and UJT. The zener diode Dz is used to clip the rectified-voltage to a fixed voltage Vz. This voltage Vz is applied to the charging circuit RC.** **Capacitor *C* Charges through *R* until it reaches the UJT trigger voltage Vp The UJT then turns "on" and *C* discharges through the UJT emitter and primary of the pulse-transformer. The windings of the pulse transformer have pulse voltages at their secondary terminals. Pulses at the two secondary windings feed the same in phase pulse to two SCRs of a full wave circuit. SCR with positive anode voltage would turn ON. Rate of rise of capacitor voltage can be controlled by varying *R* . The firing angle can be controlled up to about 150∘** **As the zener diode voltage Vz goes to zero at the end of each half cycle, the synchronization of the trigger circuit with the supply voltage across SCRs is achieved. Thus the time time *t* , when the pulse is applied to SCR for the first time, will remain constant for the same value of *R*. The various voltage waveforms are shown below.**	**Circuit Dia 2M** **Explanation 2M** **Waveforms 2M**



	c)	**(i) Draw neat labeled diagram of V-I characteristics of SCR.** **(ii) Explain the effect of gate current on turn on voltage of SCR.**	**6M**
	Ans:	 **VI Characteristics of SCR** **The voltage at which the SCR comes into conduction without any gate current (Ig=0) is called break over voltage VBO. By the application of minimum required**	**VI characterist** **4M** **Effect of gat** **current 2M**

		gate current (Ig1), SCR can be turned on before the break over voltage. If we increase the gate current (Ig2) 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 (Ig3>Ig2>Ig0) 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.	