SUMMER– 18 EXAMINATION

Subject Name: Power Electronics **Model Answer** Subject Code: 17444

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.

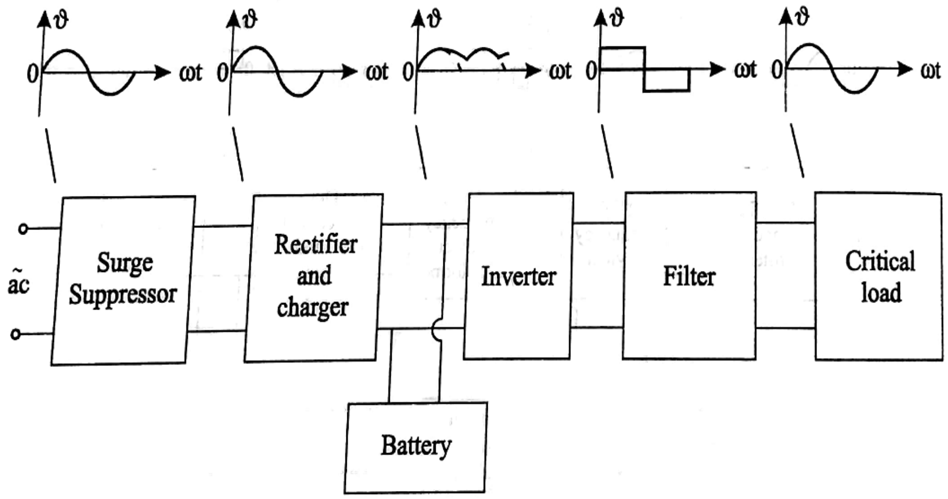
Q. No.	Sub Q. N.	Answers	Marking Scheme
1	**A**	**Attempt any SIX:**	**12- Total Marks**
	a	**Name any two triggering devices used for triggering SCR.**	**2M**
	Ans:	UJT, PUT, SUS,LASCR	**1M each for any two**
	b	**State any two advantages of IGBT.**	**2M**
	Ans:	1) High operating speed 2) Wide RBSOA 3) High voltage control capability 4) Active di/dt control 5) Inherent over-current protection	**1M each for any two**
	c	**List two applications of TRIAC.**	**2M**
	Ans:	TRIAC is used as a switching device in the following applications: 1) Fan speed regulator 2) Flasher circuit 3) Temperature controller 4) Lamp dimmer	**1M each for any two**

		5) In AC voltage stabilizer 6) Proximity detector	
	d	**State the classification of Chopper.**	**2M**
	Ans:	**DC chopper can be classified as :** **1.According to input/output voltage levels** a. Step –Up chopper b. Step – Down chopper **2. According to direction of output voltage and current** a. Class A Chopper b. Class B Chopper c. Class C Chopper d. Class D Chopper e. Class E Chopper **3. According to Circuit operation** a. First Quadrant Chopper b. Two quadrant Chopper c. Four Quadrant Chopper **4. According to Commutation method** a. Voltage Commuted Chopper b. Current Commuted Chopper c. Load Commuted Chopper d. Impulse Commuted Chopper	2M
	e	**State difference between forced commutation and natural commutation.(any 2 points)**	**2M**
	Ans:	(see table below)	**1M each for any two points**

Sr No.	Parameter	Natural commutation	Forced commutation
1	Need of external commutating	Not required	Required

	components		
2	Types of supply	AC source	DC source
3	Cost of commutation circuit	No additional cost for commutation	Commutation circuits are costly
4	Power dissipation	Less as no power loss takes place in the commutating components	More as some power loss takes place in the commutating components

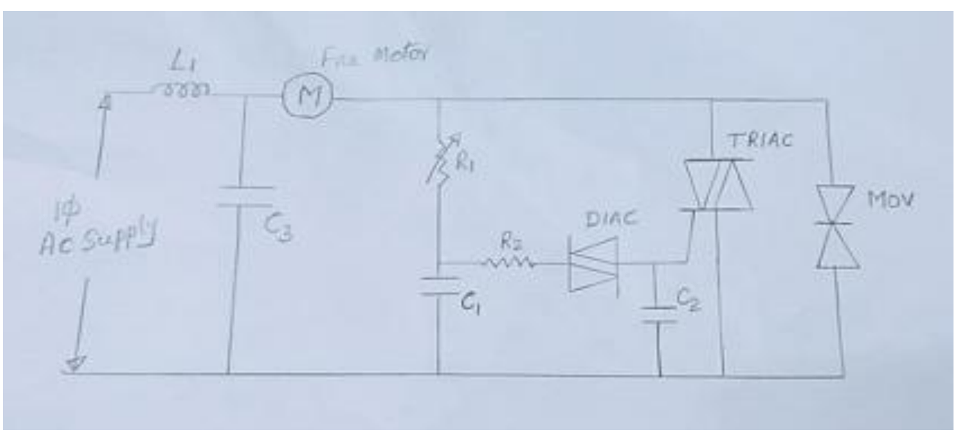
f	**List two applications of Inverter.**	**2M**
Ans:	1) Variable speed AC motor drives 2) Induction heating 3) Aircraft power supply 4) High voltage DC transmission lines 5) Battery vehicle drives 6) Regulated voltage and frequency power supply	**1M each for any two**
g	**Define firing angle and conduction angle.**	**2M**
Ans:	**Firing angle**: It is the angle measured from the zero crossing point of the input sine wave to the point at which the thyristor is “triggered” or turned ON. It is represented as α. **Conduction angle:** : It is the angle for which the thyristor remain ON before being commutated. $\beta = \pi - \alpha$	**1M each**
h	**Draw labelled basic block diagram of UPS.**	**2M**
Ans:		2M(waveforms optional)



	B	**Attempt any TWO:**	**8- Total Marks**
	a	**What is poly-phase rectifier? State its need.**	**4M**
	Ans:	**Poly-phase rectifier:** It is a three-phase rectifier which converts three-phase AC voltage at the input to a DC voltage at the output. It has diodes / SCRs connected in each phase which alternatively operates for an equal fraction of an alternating current cycle. Its output voltage varies less than that in an ordinary half-wave or full wave rectifier. **Need of poly phase rectifier:** The capacity of 1Ø rectifiers are limited (normally upto 2 kW only). Moreover a 1Ø rectifier produces relatively high ac ripple voltage at its output. So it requires a large smoothing reactor to smoothen the output voltage. This increases the cost of 1Ø rectifier with more output. As the no. of pulses in the output is more, poly phase rectifier produces a smoother output, reducing the cost of filtering. As number of phases are more the average output of poly phase rectifier is more and hence can be used for higher power applications.	**2M** **2M**
	b	**Compare between step-up and step- down chopper. (any 4 points)**	**4M**
	Ans:		1M each

Sr No.	Parameter	Step-up chopper	Step-down chopper
1	Position of chopper switch	In parallel with load	In series with load
2	Output voltage	More than input voltage	Less than input voltage
3	Expression of output voltage	$V_o = V_{dc} / (1-\alpha)$ Volts Where, α= Duty Cycle V_{dc}= Input voltage	$V_o = V_{dc}.\ \alpha$ Volts
4	application	Battery charging, voltage booster	Motor speed control

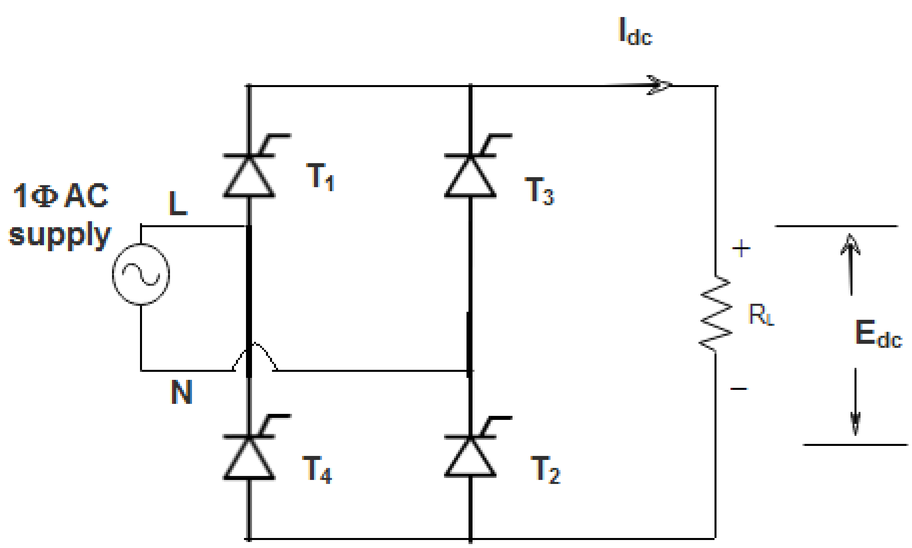
c	**Draw the neat circuit diagram of fan speed regulator using TRIAC. Describe its working.**	**4M**
Ans:	Circuit diagram:	Diagram:2M

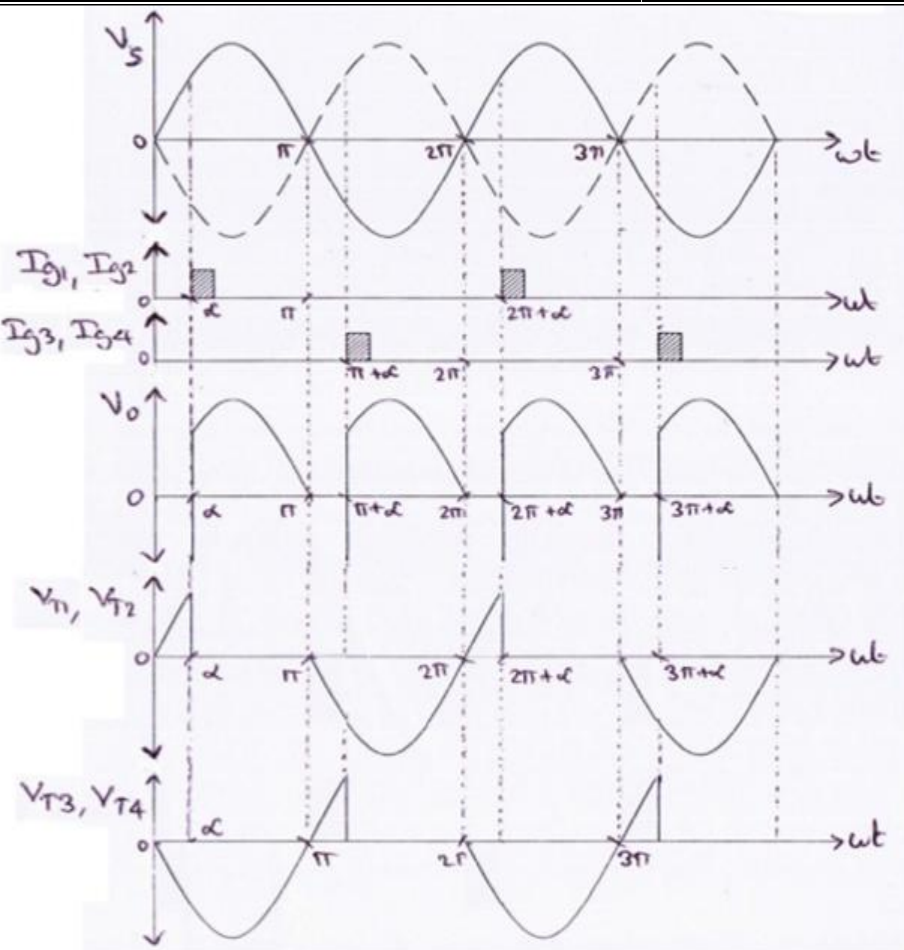
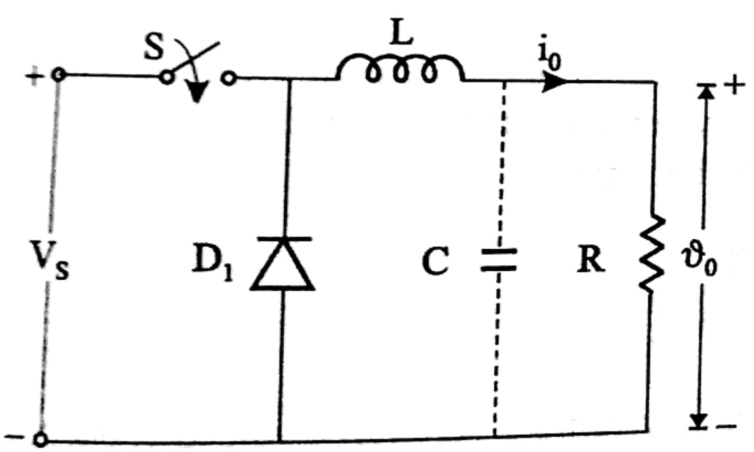


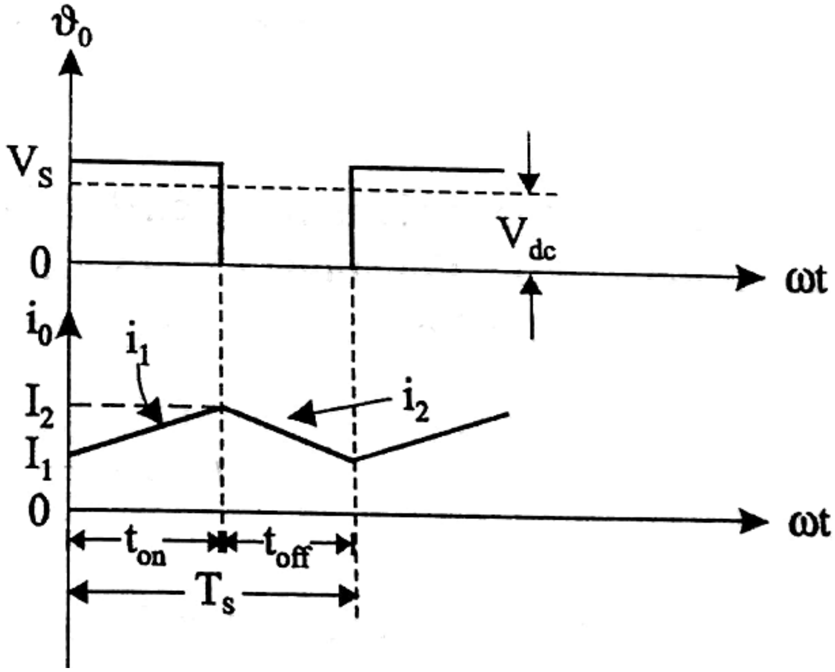
Working: Fan speed regulator circuit using TRIAC-DIAC shown above works on the principle of phase control. DIAC along with the double time constant circuit provides triggering pulse to the TRIAC. Double time constant circuit reduces the hysteresis effect caused by DIAC. Conduction angle of TRIAC can be increased or decreased using

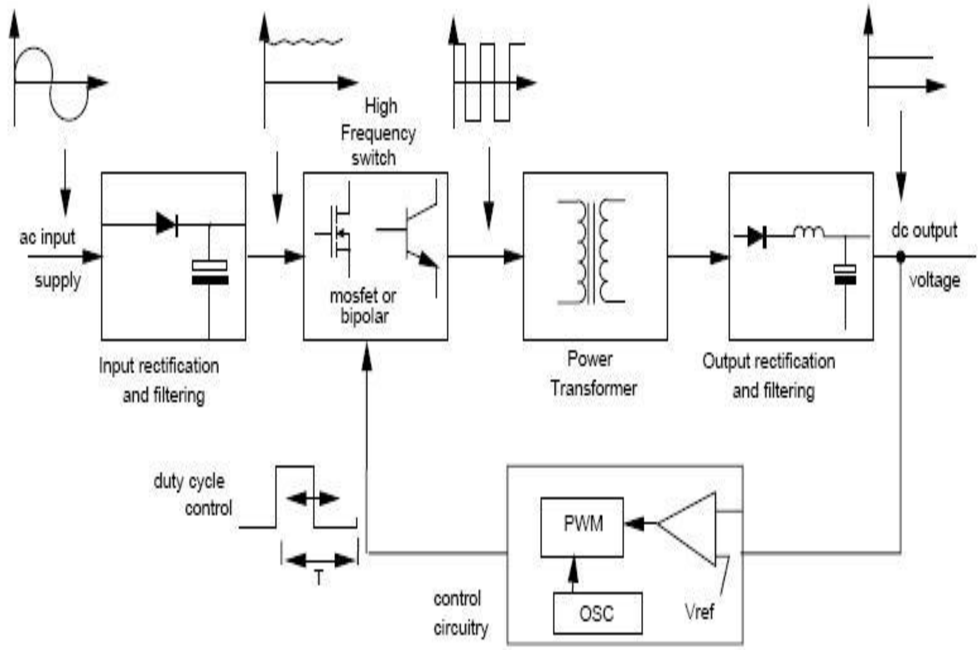
Working:2M

		R_1. As R_1 is reduced, the conduction angle of TRIAC increases increasing the output voltage and speed of fan. A 'MOV' is connected parallel to the TRIAC to protect it against voltage transients and surges. **Note: (any other relevant diagram may also be considered)**	

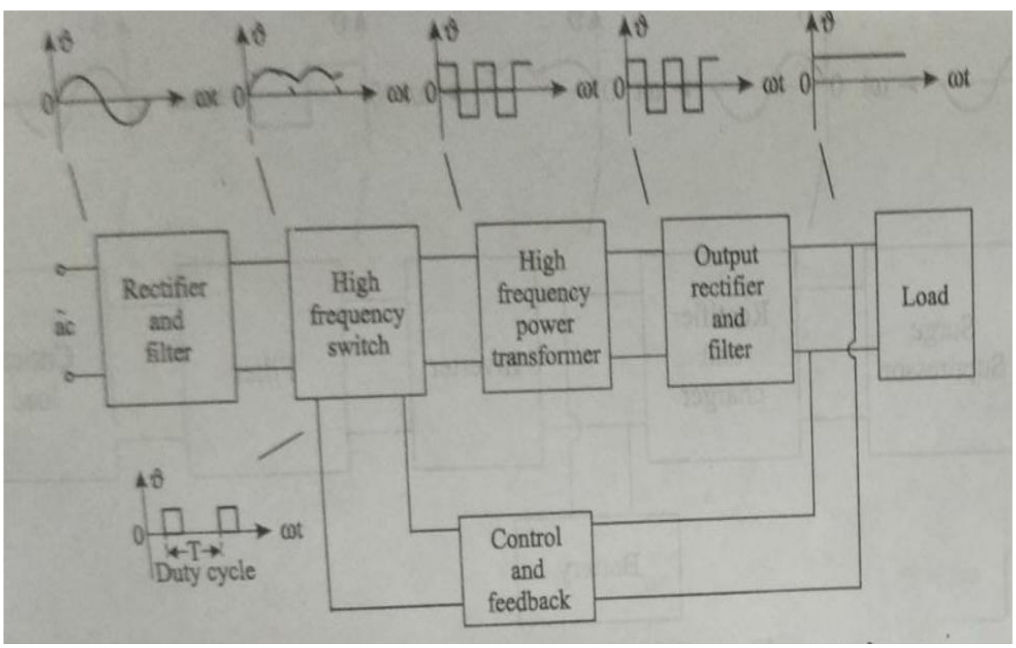
Q. No.	Sub Q. N.	Answers	Marking Scheme
2		**Attempt any FOUR:**	**16- Total Marks**
	a	**Draw the single phase full wave bridge type controlled rectifier. Draw the waveforms of input voltage, load voltage and voltage across SCR.**	**4M**
	Ans:	**Circuit diagram:**  **Waveforms:**	Diagram:2M Waveforms:2 M

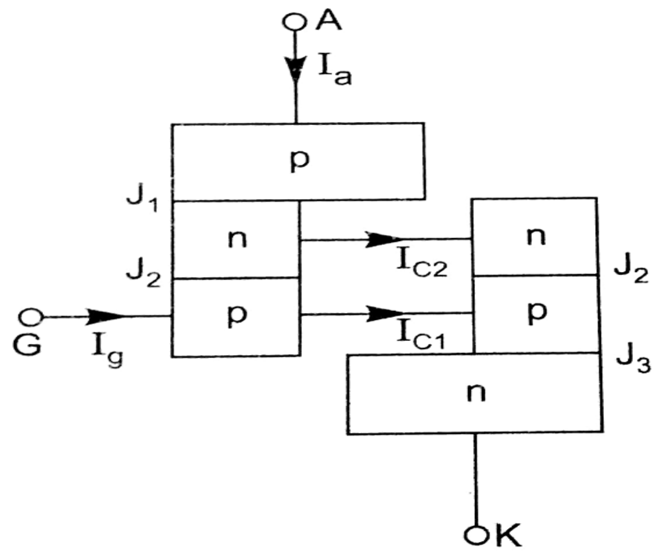
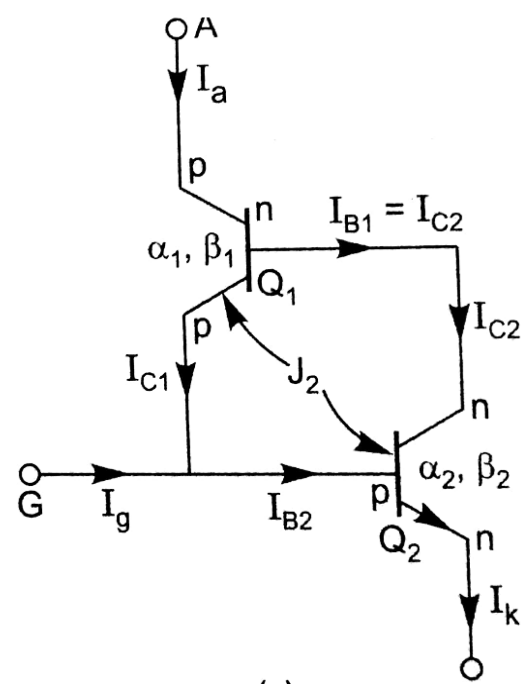
			
	b	**Draw circuit of step down chopper and explain its working with neat waveforms.**	**4M**
	Ans:	**Circuit diagram:**  **Waveforms:**	Circuit diagram:2M

		 When the switch (Power MOSFET) is closed, the supply voltage Vs appears across the load and when it is open the load is disconnected from the supply. Thus the average DC output voltage is controlled by controlling the switching on period Ton and switching off period Toff. Equation of the output voltage is, $V_o = V_S \times \alpha$, where α is the duty cycle. Freewheeling diode provides path for the load current when the switch is OFF. The inductor filters out the ripples in the load current.	Waveforms:1 M Working:1M
	c	**State the function of SMPS. Sketch block diagram of SMPS and label it well.**	**4M**
	Ans:	Function of SMPS: The function of a switched mode power supply (SMPS) is to convert AC or an unregulated DC input voltage into a regulated DC output voltage at the output. It uses a switching device which is turned ON and OFF at high frequency. **Block diagram:**	Function:1M Block diagram:3M

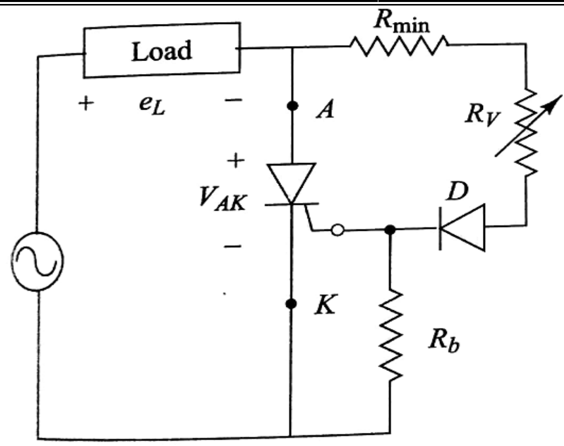

High
Frequency
switch
ac input
supply
mosfet or
bipolar
dc output
voltage
Input rectification
and filtering
Power
Transformer
Output rectification
and filtering
duty cycle
control
T
PWM
OSC
Vref
control
circuitry

(OR)


ωt
ac
Rectifier
and
filter
High
frequency
switch
High
frequency
power
transformer
Output
rectifier
and
filter
Load
T
Duty cycle
Control
and
feedback

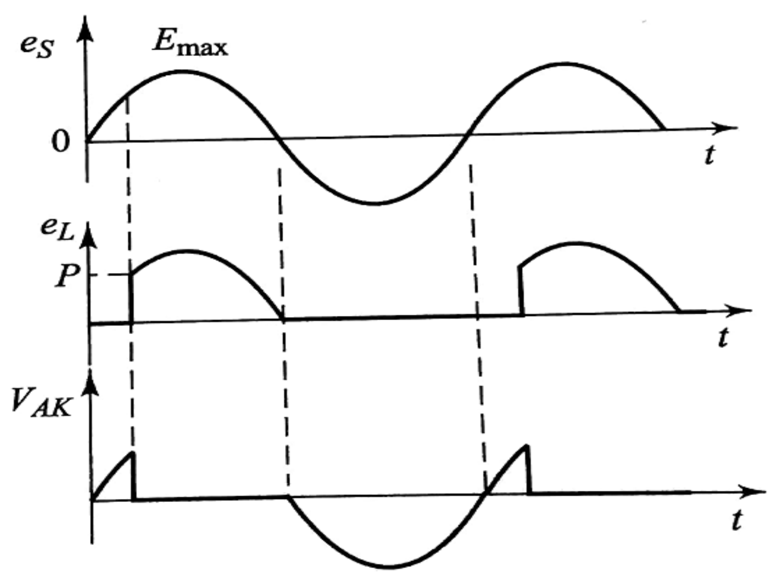
	d	**Sketch equivalent circuit of SCR using BJT. Describe its working principle.**	**4M**
	Ans:	**Diagram:**  **(OR)**  **Working principle:** Figure above shows the two transistor analogy of SCR, which can be used to explain its working. The circuit consists of NPN and PNP transistors, where the collector of one transistor is attached to the base of the other and vice	Diagram-2M **Working principle-2M**

		versa. When the gate is made positive a small input current flows between the base and emitter of Q_2, producing a large collector current I_{C2}. I_{C2} is the base current of Q_1 cause a large base current for Q_2. Therefore a positive feedback exist between the transistors making them to go into saturation. Equation for the anode current can be derived as $$I_a = \frac{\alpha_2 I_g}{1-(\alpha_1+\alpha_2)}$$ Where α_1 & α_2 are the current gains of Q1 & Q2 respectively. if $(\alpha_1+\alpha_2)$=1, the value of I_a is infinite, or suddenly reaches a very high value and the SCR latches into conduction from an OFF state. This characteristics is known as regenerative action. According to this, the turn ON condition of a SCR is, $$(\alpha_1+\alpha_2) \geq 1$$	
	e	**State different trigger methods and describe R-triggering method for SCR with circuit diagram and waveforms.**	**4M**
	Ans:	**Different triggering methods of SCR are:** 1. Forward voltage triggering 2. Thermal or temperature triggering 3. Radiation or Light triggering 4. dv/dt triggering 5. Gate triggering i) D.C Gate triggering ii) Pulse Gate triggering iii) A.C Gate triggering a) R-triggering b) RC-triggering **R-triggering:** **Circuit diagram:**	Listing-1M Diagram-1M Description-1M Waveforms-1M



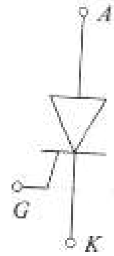
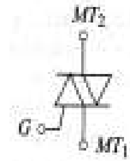
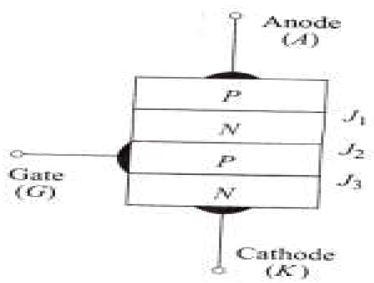
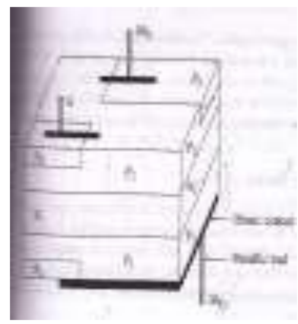
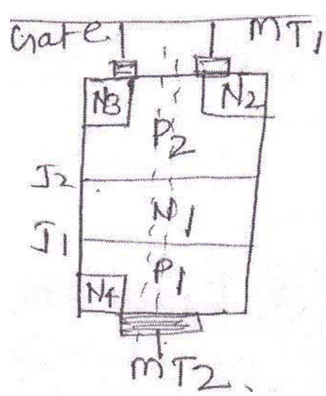
Description: As e_S goes positive, the SCR becomes forward biased and will not conduct until sufficient gate current flows. A positive e_S forward biases diode and SCR's gate-cathode junction causing a gate current. At Ig = Ig(min) SCR turns 'ON'. At point 'P', $e_L = e_S$ and varies till the negative cycle appears. For negative cycle of e_S SCR turns 'OFF' as the load current becomes less than the holding current. The purpose of the diode is to block the negative cycle from appearing at the gate. The load voltage can be controlled by varying the resistance Rv. A lesser Rv will cause more gate current and a fast switching into conduction. R_{min} will limit the gate current within its maximum limit.

Waveforms:



	f	**Define distortion factor and lowest order harmonics with respect to inverter.**	**4M**
	Ans:	Distortion Factor (DF): Distortion factor indicates the amount of harmonics that remain in the output voltage waveform, after the voltage waveform has been subjected to second order attenuation. $DF = \sqrt{\frac{\sum_{n=2,3...}^{\infty}\left\{\frac{V_{n(rms)}}{n^2}\right\}^2}{V_{1(rms)}}}$ Lowest Order Harmonics(LOH): The lowest frequency harmonic, with a magnitude greater than or equal to 3% of the magnitude of the fundamental component of the output voltage is known as lowest order harmonic.	2M each
Q. No.	Sub Q. N.	Answers	Marking Scheme
3		**Attempt any FOUR:**	**16- Total Marks**
	a	**Differentiate SCR and TRIAC with respect to (i) symbol, (ii) layered diagram, (iii) operating quadrant, (iv) application.**	**4M**
	Ans:		**1M each**

Parameter	**SCR**	**TRIAC**

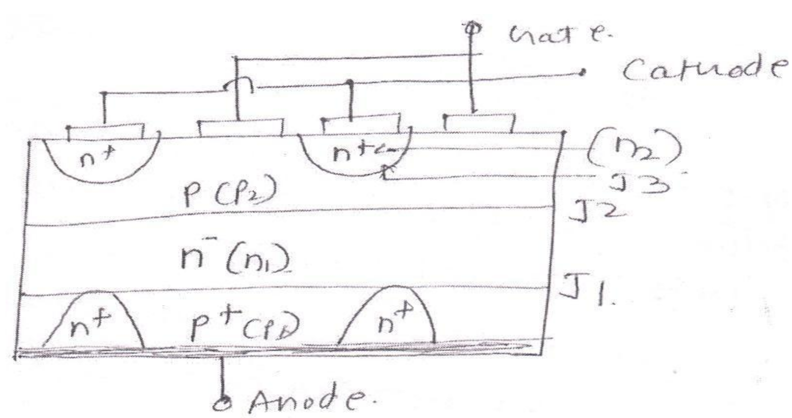
Symbol		
Layer diagram	 (a)	 **(OR)** 
Operating quadr-ant	Only 1st quadrant	Depending upon supply polarity either 1st quadrant Or 3rd quadrant
Applications	Controlled Rectifies, in inverters, Battery charger, speed control of DC and AC motors, chopper, cyclo converters, UPS,	As a static switch in AC voltage stabilizer, Light, dimmer, speed control of fan, power

		emergency lighting system, static circuit breaker, flasher.	switches.	

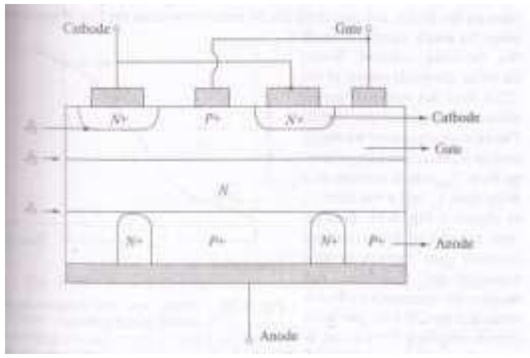
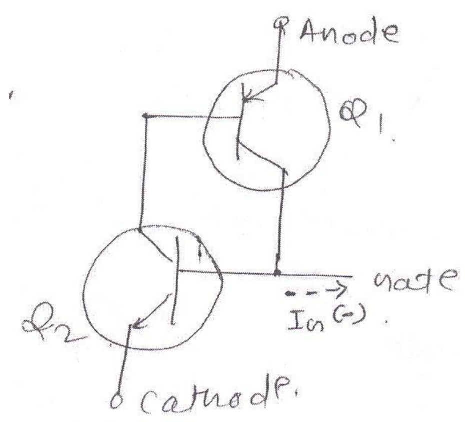
b	**Compare controlled and uncontrolled rectifiers. (any 4 points)**	**4M**
Ans:		**1M each for any 4 points**

Parameter	**Controlled Rectifier**	**Uncontrolled Rectifier**
Device used	SCR and Diodes	Only Diodes.
Control of Load Voltage	Load voltage can be controlled.	Load voltage cannot be controlled.
Direction of Power Flow	Source to load and sometimes load to source.	Source to load only.
Free Wheeling diode	Required if inductive load.	Not necessary.
Triggering circuit	Required.	Not required.
Application	DC motor controller, Battery chargers.	Power supply.

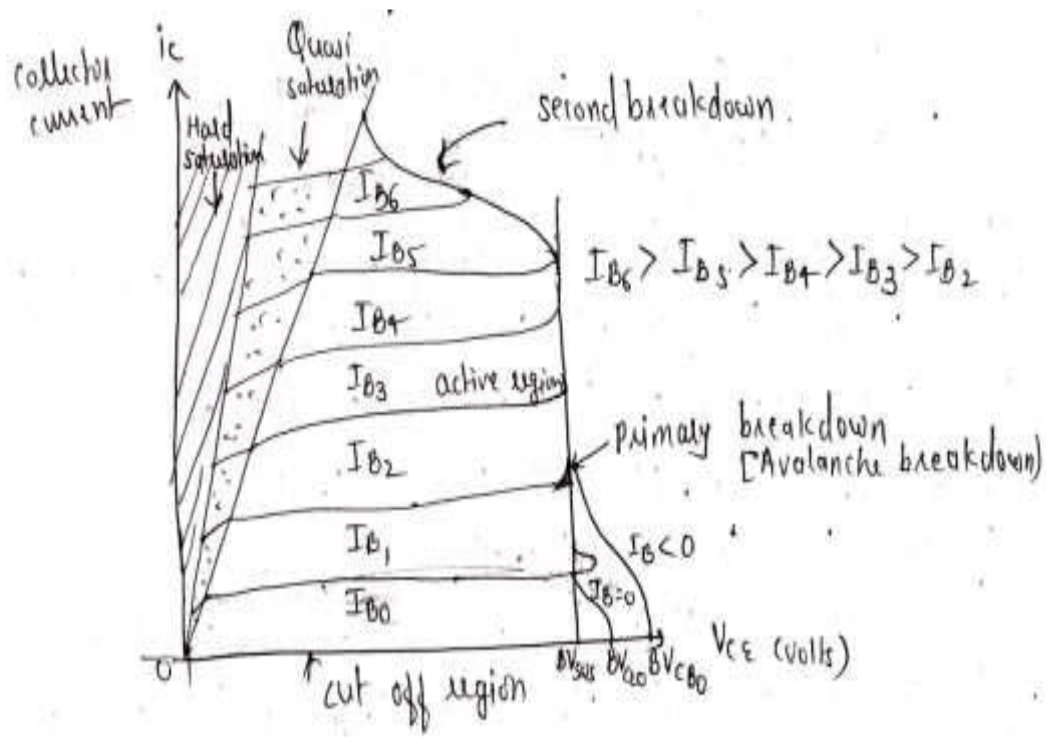
c	**Draw constructional diagram of GTO and state its operating principle.**	**4M**
Ans:		**2M**



(Or)

		 **Operating Principle:-** The working principle of GTO may be explained with the help of its two transistor analogy. According to it, both the transistor Q1 and Q2 are in saturation when the GTO is in it's on state. GTO switches regeneratively into the ON state with a positive gate signal applied to the base of NPN transistor. The internal regeneration can be reduced with the reduction in the current gain of the PNP transistor. Ie, it can be turned OFF by taking current from the gate. Thus a positive gate current turns the device ON while a negative gate current turns it OFF.  **Two transistor analogy of GTO**	**2M**
	d	**Draw VI characteristics of power transistor. Label different regions.**	**4M**

Ans: **4M**



e **Describe the effect of freewheeling diode in controlled rectifier.** **4M**

Ans: Effects of freewheeling diode : 4M

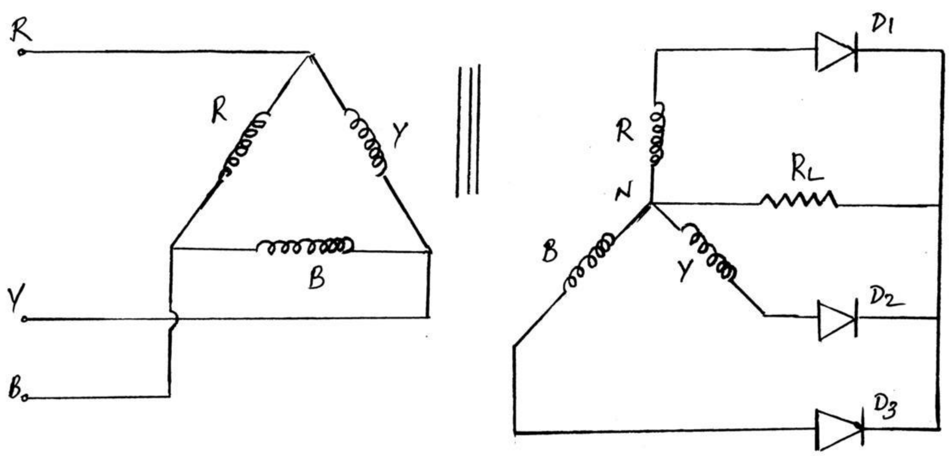
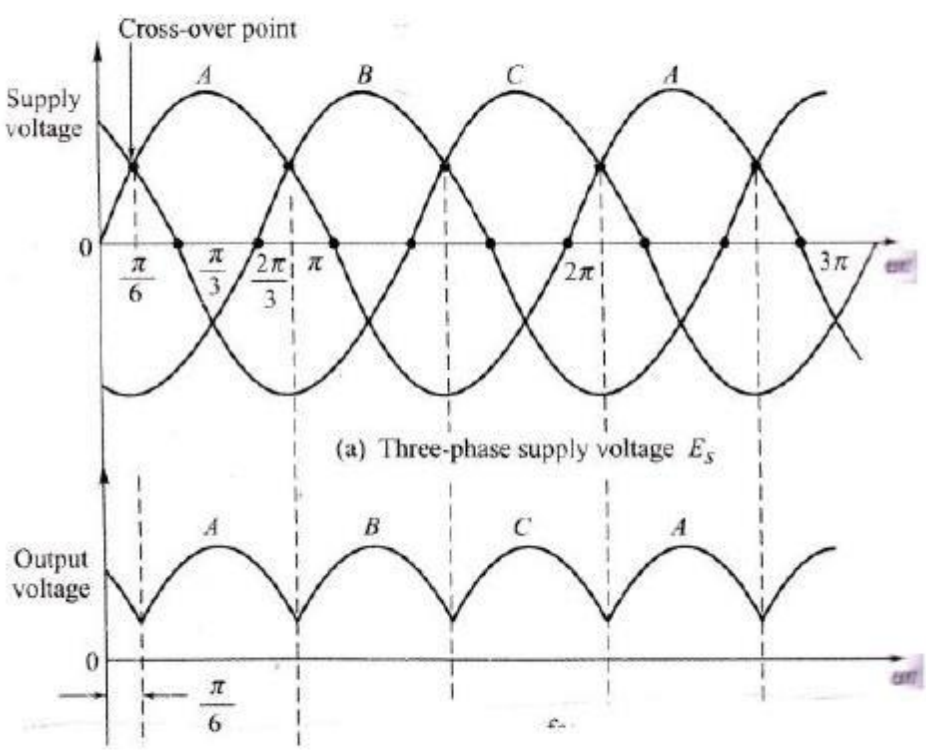
With a freewheeling diode connected in a controlled rectifier with RL load, the thyristor will not be able to conduct beyond 180^0 (a problem with RL load). During negative half-cycle as the current changes its direction, emf is induced in the inductor. This energy is dissipated in the load resistance through the freewheeling diode. Hence at 180^0, current through the SCR is cut-off and a reverse voltage appears across the SCR turns it OFF instantly. Its effects in the circuit can be,

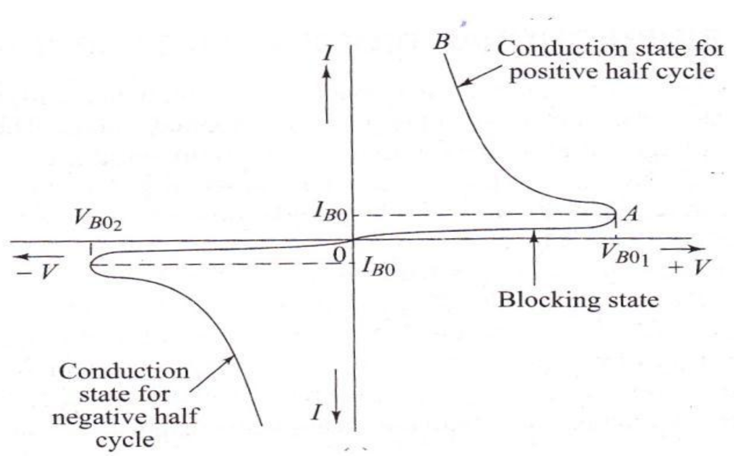
(i) The load voltage does not become negative and hence gives more average d.c. output voltage than without freewheeling diode.

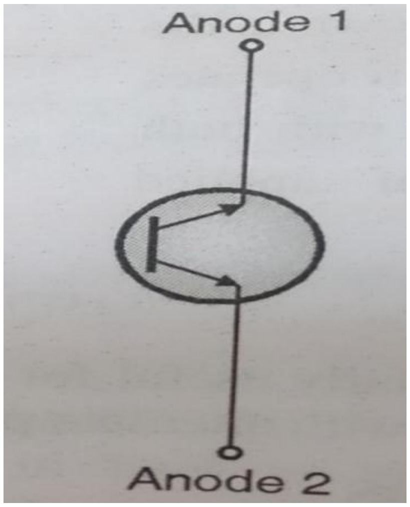
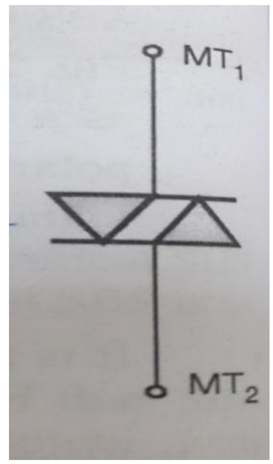
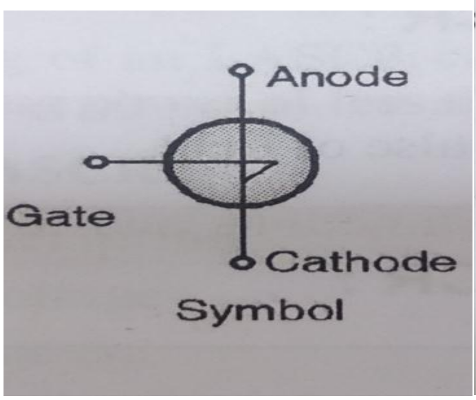
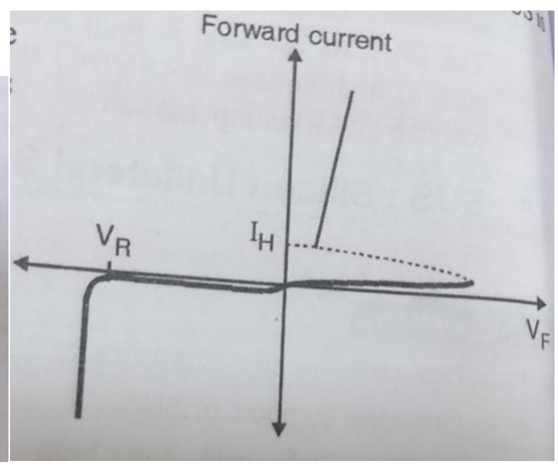
(ii) Load current becomes continuous i.e. ripple free.

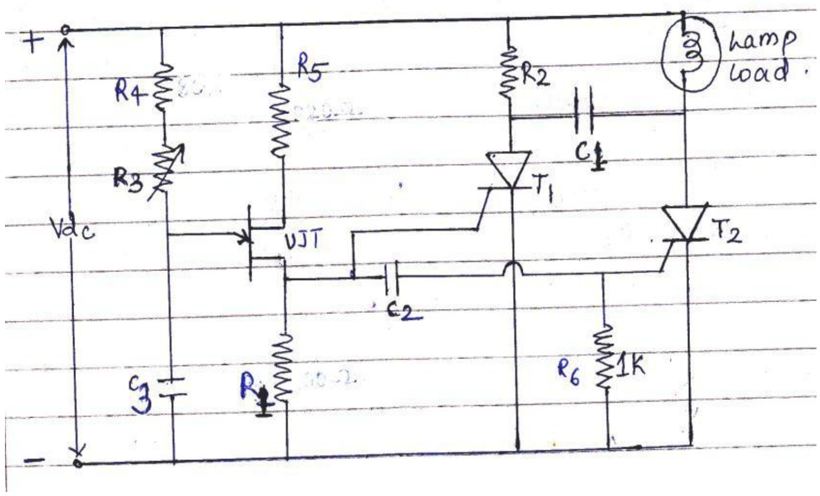
(iii) It prevents reversal of load voltage.

(iv) Input power factor is improved.

	f	**Sketch circuit of three phase uncontrolled half wave rectifier with resistive load. Draw its input and output waveforms.**	**4M**
	Ans:	 	**2M** **2M**
Q. No.	Sub Q. N.	Answers	Marking Scheme
4		**Attempt any FOUR:**	**12- Total Marks**

	a	**State the need of Inverter. List four applications of Inverters.**	4M
	Ans:	In most of the industrial applications, inverter is a part of a DC link converter. Its first stage is a AC to DC rectifier and second DC to AC inverter. In this system the AC power at line frequency is rectified and filtered and then inverted into AC at an adjustable voltage and frequency which is required in UPS, low power portable electronics systems, AC motor speed control etc. so inverter is an essential part of a two stage static frequency converter. Applications • Variable speed a c motor drivers • Induction heating • Aircraft power supplies • Uninterrupted power supplies (UPS) • High voltage d c transmission lines • Battery vehicles drives • Regulated voltage and frequency power supplies	2M 2M
	b	**Draw symbol and characteristics of DIAC and SUS.**	**4M**
	Ans:	**VI characteristics of DIAC** 	**1M**

		Symbol of DIAC  **or**  Symbol and Characteristics of SUS  	**1M** **1M +1M**
	c	**Describe the working of DC flasher circuit using SCR with neat diagram.**	**4M**
	Ans:	‘	**2M**



Low power dc flasher:

Above figure shows low power flasher circuit. Here UJT operates as a relaxation oscillator & produces a train of trigger pulses to the thyristor gates through resistor R_1. **2M**

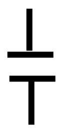
When thyristor T_2 is triggered, the lamp load glows. when the next pulse trigger thyristor T_1, thyristor T_2 is turned off by the commutating capacitor C_1. Since the commutating pulses have a longer duration than the trigger pulses, thyristor T_2 cannot be re-triggered at this time.

Thyristor T_2 can again be retriggered by the next pulse. At a time anyone thyristor should be triggered if both thyristor conduct together the flash circuit fails. This can be prevented by making thyristor T_1 turned off independently from the commutating capacitor. This can be done by using resistor R_2 of very large value so that thyristor T_2 is unable to remain on, except to discharge the capacitor C_1. During reminder of the cycle T_1 is off & capacitor C_1 is always able to develop a commutating voltage for T_2.

The flash rate can be changed by varying the value of variable resistance R_3.

d **Explain dv/dt turn on method of SCR.** 4M

Ans: **dv/dt triggering :** In construction of SCR there are four layers and three junctions J_1 , J_2 & J_3. Under forward bias condition junction J_1 & J_3 are forward biased whereas junction J_2 is reverse biased. This reverse biased junction J_2 behaves as a capacitor. Now if the forward voltage is applied suddenly a charging current will flow through capacitor. Thus device turns on. 4M



$C_j \ = junction\ J_2$

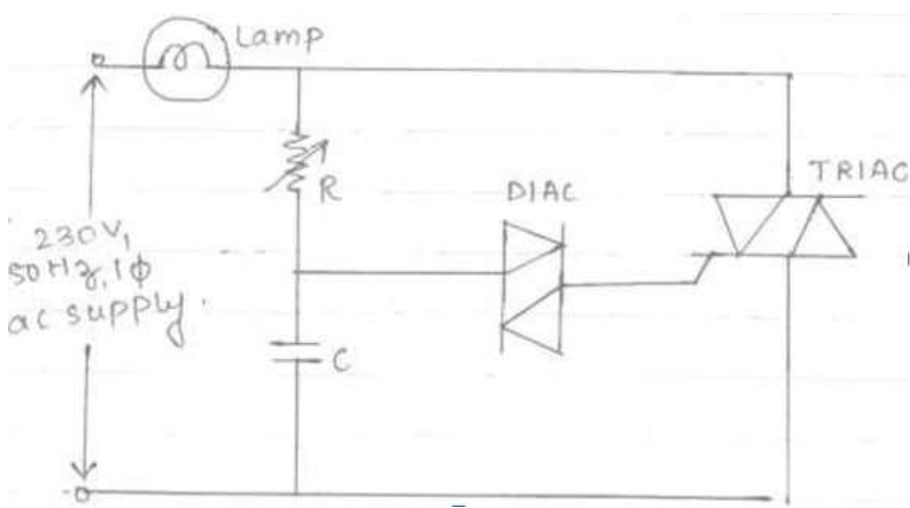
If V = voltage applied across the device
C_j = junction capacitance
Then the instantaneous current i_c due to suddenly applied voltage is

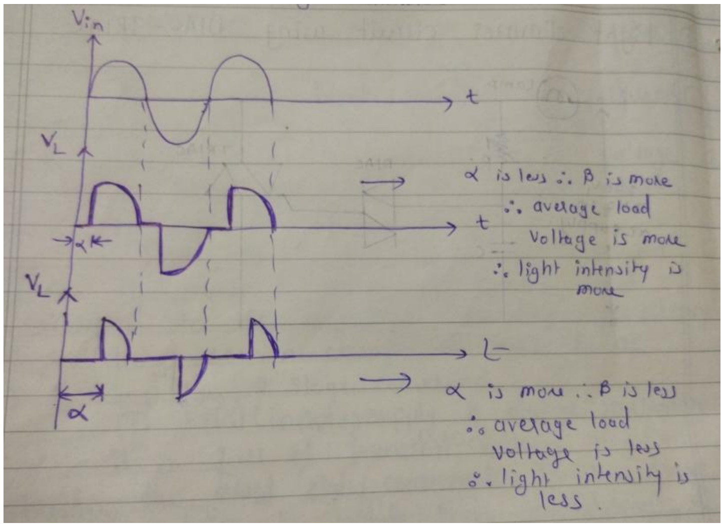
$$i_c \ = C_j \ \frac{dv}{dt}$$

If $\frac{dv}{dt}$ is large the device may turn-on or trigger on, even when the voltage across the device is small.

e **Draw the circuit diagram of light dimmer using DIAC and TRIAC and sketch the input and output voltage waveforms.** **4M**

Ans: **2M**





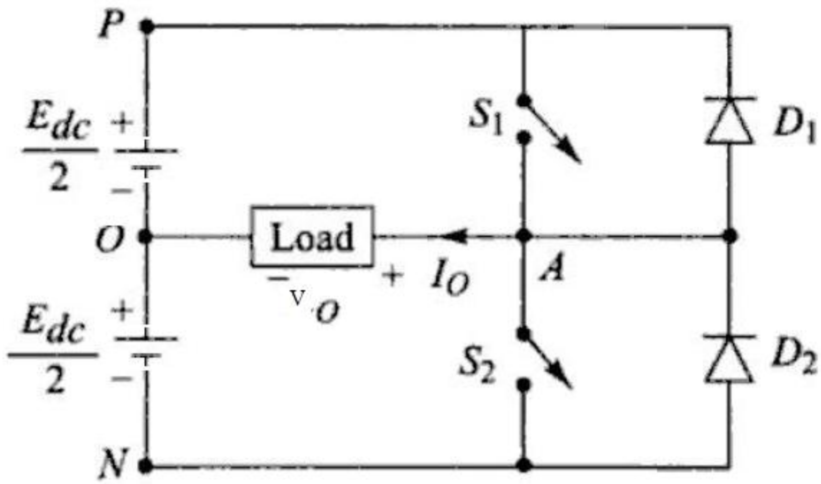
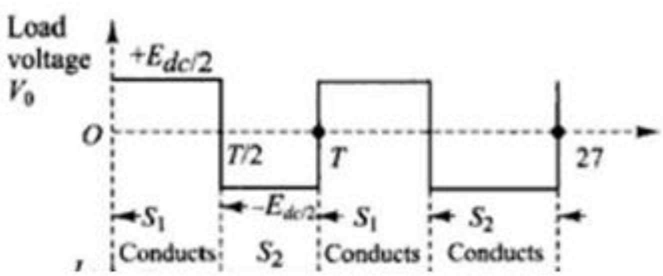
In the above circuit DIAC is used to trigger TRIAC.

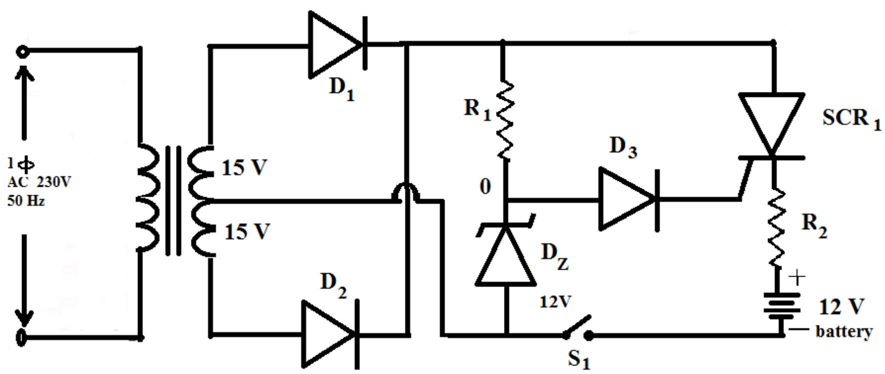
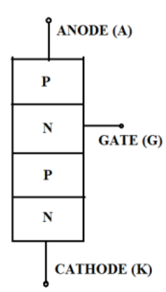
During the positive half cycle (when P is positive) the TRIAC requires a positive gate signal for turning it ON. This is provided by the capacitor C. When the voltage across capacitor is above the breakdown voltage of the DIAC. DIAC turns ON & the capacitor discharge through the TRIAC gate i.e. positive gate signal is given to the TRIAC & thus TRIAC turns ON. So current starts flowing through load.

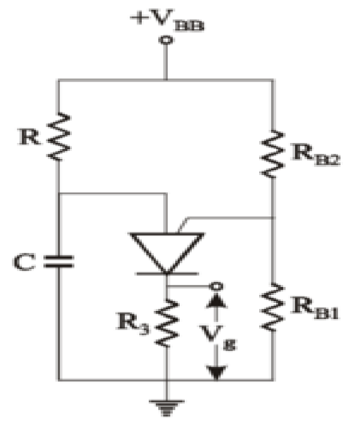
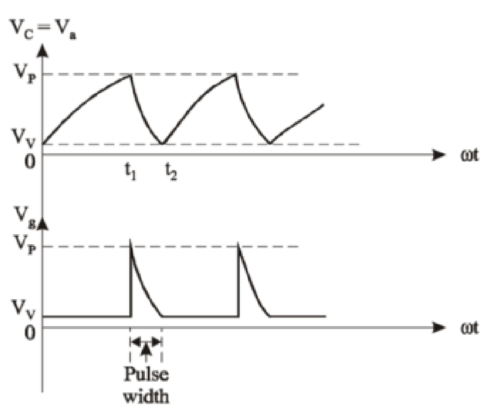
A similar operation takes place in the negative half cycle & a negative gate pulse will be applied when the DIAC breaks down in the reverse direction. The charging rate of capacitor C can be changed by varying the resistance R & hence the firing angle can be controlled.

Thus if firing angle is less intensity of light is more & if firing angle is more intensity of light is less. Thus by controlling α we can control the intensity of light using TRIAC. **2M**

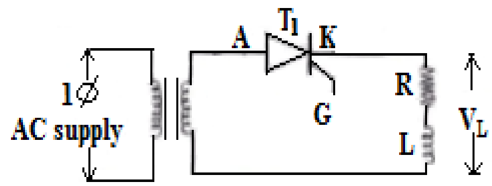
	f	**Draw circuit diagram of single phase half bridge inverter. Explain its working with output voltage waveforms.**	**4M**

	Ans:	 **Voltage Waveforms:**  **Explanation-:** • Figure shows the basic configuration of single phase half bridge inverter. • Switches S1& S2 are the gate commuted devices such as power BJTs, MOSFETs, GTO,IGBT, MCT etc. When closed, these switches conduct & current flows in the direction of arrow. **Working:** • The thyristor S1 is turned on for a time 0 to T/2, which makes the instantaneous voltage across the load $V_0 = \frac{E_{dc}}{2}$ • If thyristor S2 is turned on at instant T/2 and turning S1 off then $-\frac{E_{dc}}{2}$ appears across the load. Thus a square wave is produced across the load. • A precaution must be taken while designing the control circuit so that both the thyristors S1 and S2 shouldn't be turned on at the same time	**2M** **2M**

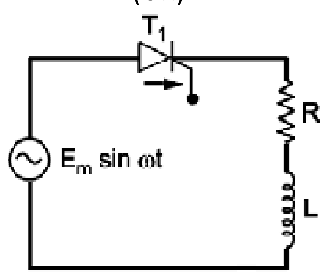
		• Diodes D1 and D2 which are connected parallel carry negative current for inductive loads • Simply by controlling the time periods of the on time of thyristor S1 & S2, the frequency can be varied.	
Q. No.	Sub Q. N.	Answers	Marking Scheme
5		**Attempt any FOUR:**	**16- Total Marks**
	a	**Draw labelled circuit diagram of battery charger using SCR.**	**4M**
	Ans:	circuit diagram (Any relevant diagram can be considered) 	**4M**
	b	**Draw the layer diagram of PUT. With neat circuit diagram, describe its working as relaxation oscillator.**	**4M**
	Ans:	layer diagram of PUT  circuit diagram: PUT relaxation oscillator	**1M** **11/2 M**

		 Working When the supply voltage VBB is applied, the capacitor C starts charging through resistor R. When the voltage across the capacitor exceeds the peak voltage (Vp) the PUT goes into negative resistance mode and this creates a low resistance path from anode (A) to cathode (K). The capacitor discharges through this path. When the voltage across the capacitor is below valley point voltage (Vv) the PUT reverts to its initial condition and there will be no more discharge path for the capacitor. The capacitor starts to charge again and the cycle is repeated. This series of charging and discharging results in a saw tooth waveform across the capacitor as shown in the figure below. Waveform(optional) 	1 1/2 M
	c	**Draw 1∅ HWCR with inductive load. Draw input and output waveforms. Describe its operation.**	**4M**

	Ans:	**Circuit Diagram:**	**Diagram-1½ M**



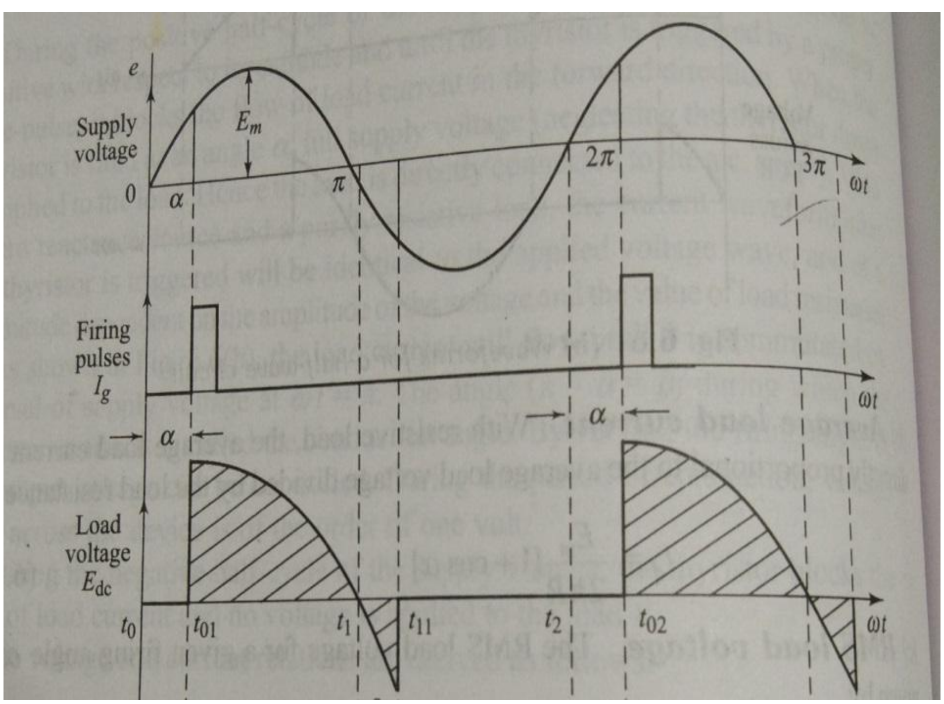
(OR)

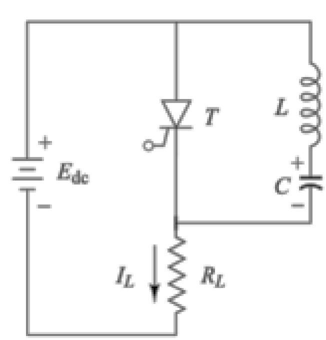


Explanation- 1½ M

Waveform:

waveform 1M



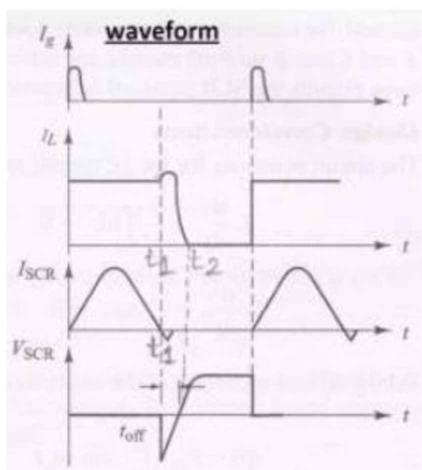
		Operation:(give marks for correct brief explanation) **Mode 1:** (0 to α) (+ve half cycle) SCR anode is a positive w.r.t. cathode but gate pulse is not applied therefore SCR is in off state though it is in forward biased therefore load current is zero therefore load voltage is 0. **Mode 2:** (α to π) (+ve half cycle + gate signal is applied) SCR is forward bias and gate signal is applied therefore SCR turns on at α. When SCR is triggered the load current will increase in a finite time through the inductive load. The supplier voltage from this instant appears across the load. Due to the inductive load the increase in current is gradual, energy is stored in inductor during α to π . **Mode3: (**π to 2 π) (negative half cycle) During negative half cycle, current continues to flow till the energy stored in the inductance is dissipated in the load-register and a part of the energy is feedback to the source, Hence due to energy stored in inductor, current continues to flow up to instant t1.at a capital at instant t1 is load current is zero and due to negative supply voltage SCR turns off. At instant 2 π+ α , when again pulse is applied the above cycle repeats. Hence the effect of the inductive load is increase.in the conduction period.	
	d	**Describe the working of class B commutation with neat circuit diagram.**	**4M**
	Ans:	circuit diagram  	Circuit diagram :2M Working:2M

Working:

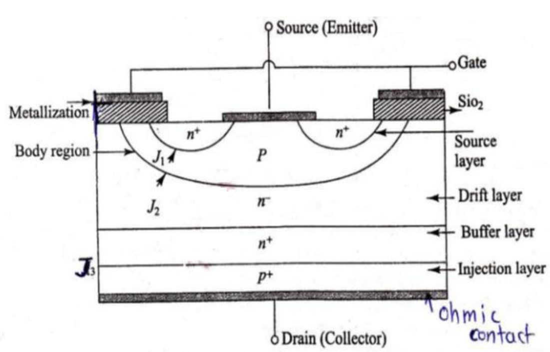
1. As soon as the supply voltage Edc is applied capacitor C charges upto Edc(with upper terminal +ve)
2. When the SCR is triggered, along with load current IL, capacitor current IC flows through thyristor and L,C components, transferring the energy from capacitor to inductor.

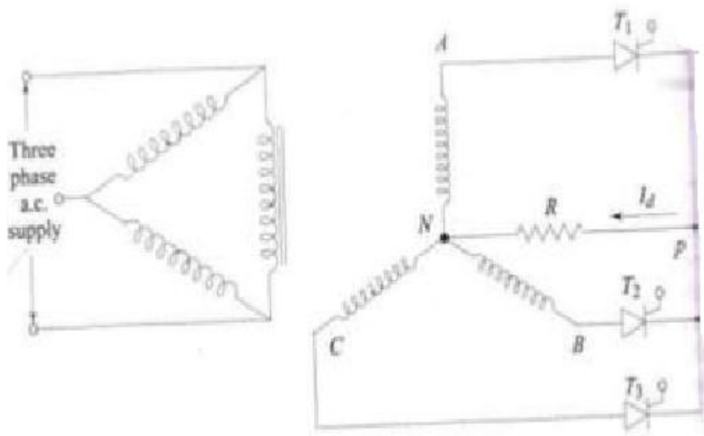
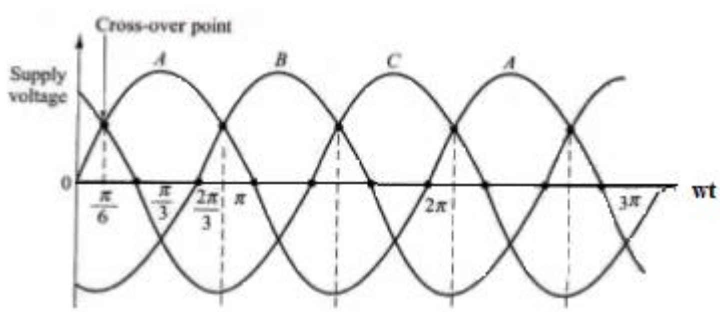
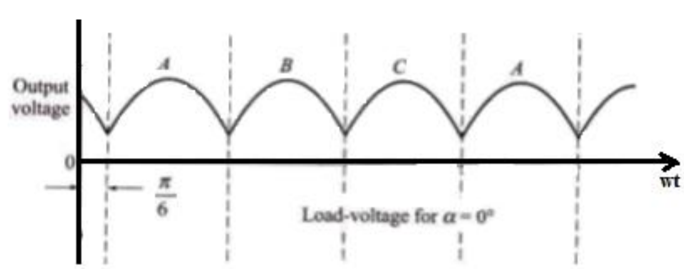
3. When completely discharged, C gets charged by the inductor with opposite polarity. This reverse voltage causes a commutating current opposite to that of the load current.
4. When IC increases above the holding current, the SCR turns OFF.
5. AS SCR is turned OFF, capacitor again charges with original polarity through L & RL and the cycle repeats.

Waveform(Optional)

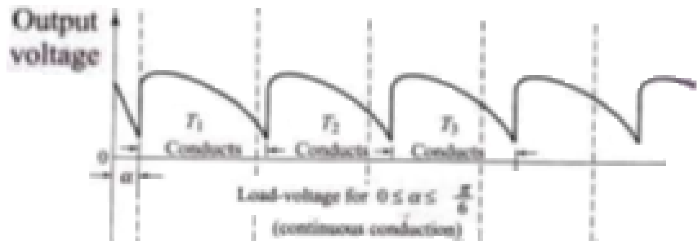


	e	**Draw the labelled constructional diagram of N-channel IGBT.**	**4M**
	Ans:	labelled constructional diagram	Diagram:4M

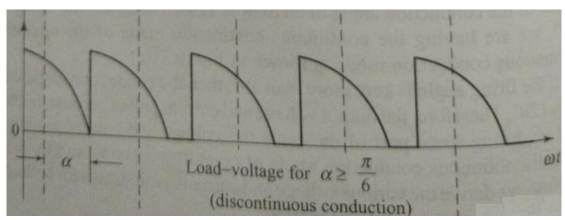


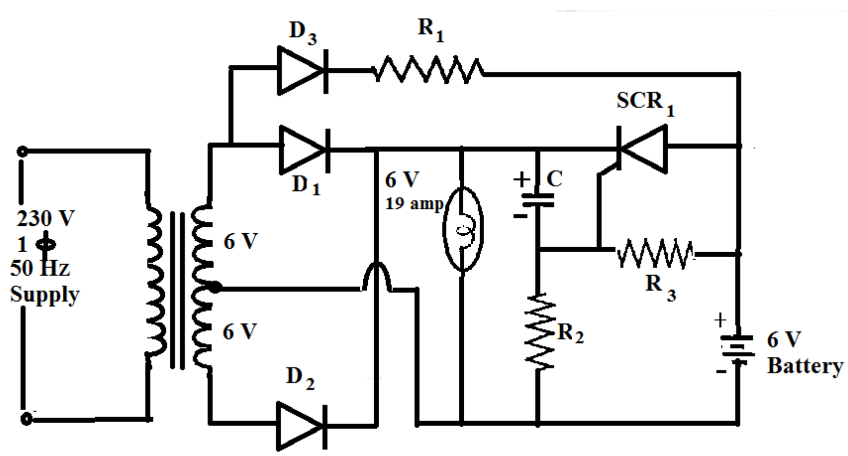
	f	**Draw the circuit diagram of three phase half wave controlled rectifier. Draw the waveforms of input voltage and output voltage.**	**4M**
	Ans:	circuit diagram  **Input waveform**  **Output waveform** 	Digram:2M Waveforms:1 M each

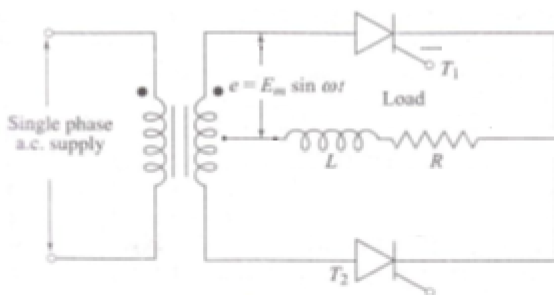
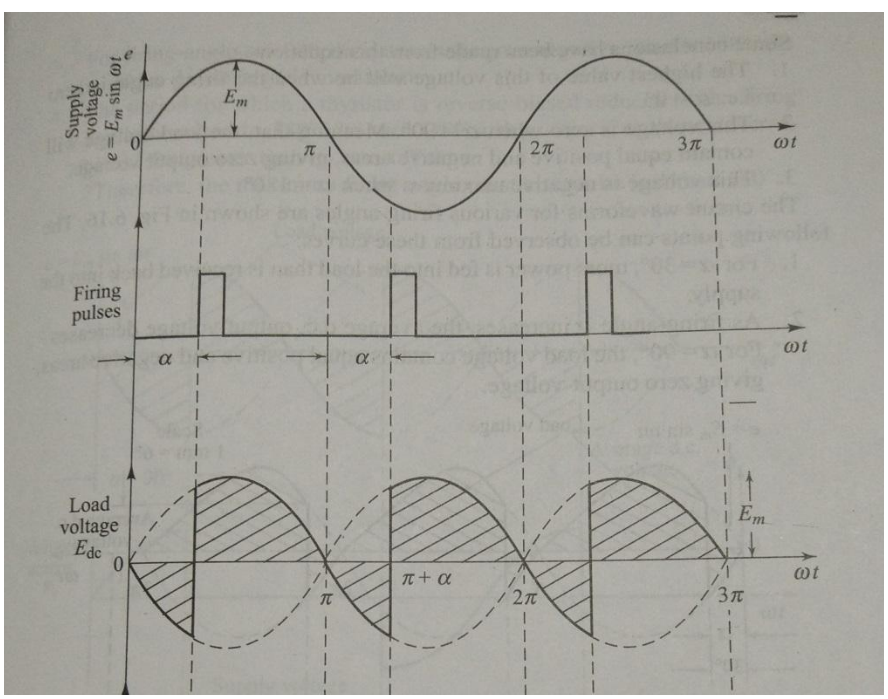
(OR)

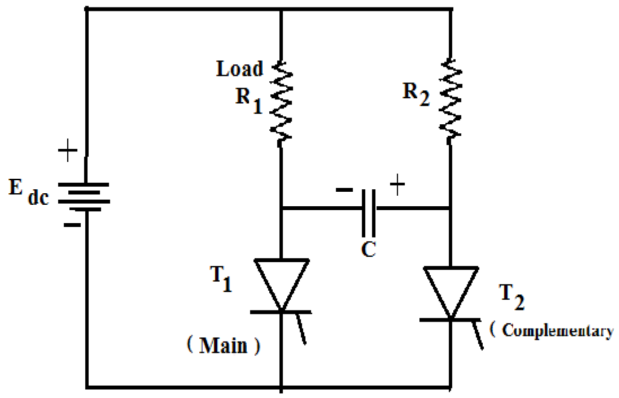
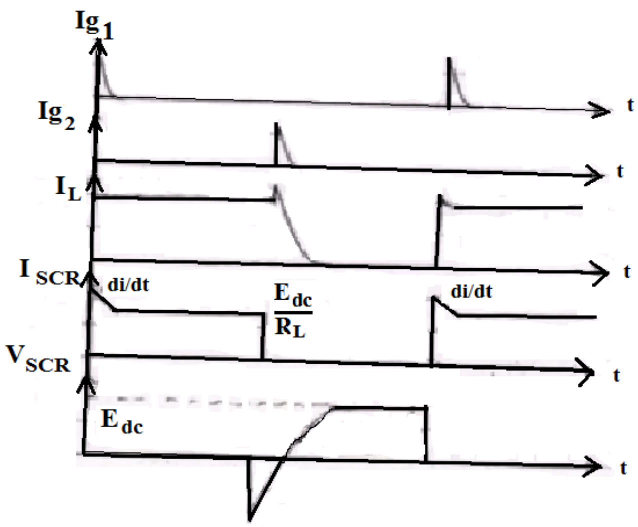

Output voltage
T_1 Conducts
T_2 Conducts
T_3 Conducts
0
α
Load-voltage for 0 ≤ α ≤ π/6
(continuous conduction)

OR


0
α
ωt
Load–voltage for α ≥ π/6
(discontinuous conduction)

Q. No.	Sub Q. N.	Answers	Marking Scheme
6		**Attempt any FOUR:**	**16- Total Marks**
	a	**Draw circuit diagram and explain the working of emergency light system using SCR.**	**4M**
	Ans:	**Diagram:-**  **Working** • Fig. shows simple emergency lighting circuit . • The 230V ac supply is applied as input. This supply is stepped down by tapped transformer. Diodes D_1 & D_2 form full wave rectifier & convert ac voltage to dc volt. • When ac supply is available, 6V dc supply appears across lamp and it glows. • Pulsating current also flows through D_3, R_1 to charge the battery. Thus battery charging is carried out. • The capacitor C gets charged with upper plate +ve 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.	2 marks for circuit diagram Working:02 marks

		• If power fails, the capacitor C discharges through D_3,R_1 & R_3 until the cathode of SCR1 is less positive than anode. At the same time the junction of R_2 & R_3 becomes +ve & 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 commutated & capacitor C is recharged again.	
	b	**Draw single phase center - tapped controlled rectifier with RL load and draw its load voltage waveforms.**	**4M**
	Ans:	Circuit Diagram  Load voltage waveform 	Circuit Diagram 2Marks Load voltage waveform 2Marks

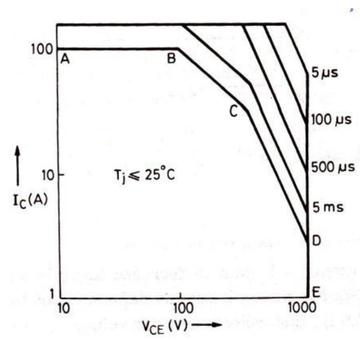
	c	**Explain class C commutation with circuit diagram.**	**4M**
	Ans:	circuit diagram  Waveform (Optional)  **Explanation:** • Here complementary thyristor T_2 is connected in parallel with the main thyristor. • Initially, both the thyristors are OFF. When a triggering pulse is applied to the gate of T_1, thyristor T_1 is triggered. Therefore current starts flowing through the load as well as R_2 & C. Capacitor C will get charged by the supply voltage E_{dc} as shown in fig. • When a triggering pulse is applied to the gate of T_2, T_2 will be turned on. As soon as T_2 is ON, the negative polarity of capacitor C is applied to the anode of T_1 and positive to the cathode. This causes the reverse bias voltage across the main thyristor T_1 and immediately turns it OFF.	circuit diagram 2M Explanation: (2M

	d	**State two applications each for (i) SCR and (ii) PUT.**	**4M**
	Ans:	**Applications of SCR:** **1.** Controlled rectifier **2.** Choppers **3.** Inverters **4.** High voltage DC transmission system **5.** Battery charger circuit **6.** Dc drivers **7.** Subway cars **8.** SMPS **9.** UPS **10.** Emergency lighting system **11.** Electronic timer **12.** Temperature controller **Applications of PUT:** **1.** Time delay circuit **2.** Logic circuit **3.** SCR trigger circuit	2Marks for any two applications 2Marks for any two applications
	e	**Explain the secondary breakdown in power BJT and how it can be avoided?**	**4M**
	Ans:	**Second Breakdown in Power BJT:** In the active region the ratio of collector current to base current (DC current gain (β)) remains fairly constant up to certain value of the collector current after which it falls of rapidly. At still higher levels of collector currents the allowable active region is further restricted by a potential failure mode call "the second breakdown". It appears on the o/p characteristics of the BJT as a precipitous drop in the collector emitter voltage at large collector currents. The collector voltage drop is often accompanied by significant rise in the collector current & a substantial increase in the power dissipation. Most importantly this dissipation is not uniformly spread over the entire volume of the device but is concentrated in highly localized regions. This localized heating is a combined effect of the intrinsic non uniformity of the collector current density distribution across the cross section of the device & the negative temperature coefficient of resistivity of minority carrier device which leads to the formation of "current filaments" (localized across of very high current	2Marks for secondary breakdown in power BJT

density) by a positive feedback mechanism.

Once current filaments are formed, localized "thermal runaway" quickly takes the junction temperature beyond the safe limit & the device is destroyed.

How to avoid secondary breakdown:



FBSOA(logarithmic scale)

Secondary breakdown can be avoided by using power transistor in safe operating area.

The safe operating area (SOA) of a power transistor specifies the safe operating limit of collector current I_C verses collector emitter voltage V_{CE}. For reliable operation of the transistor the collector current & voltage must always lie within this area.

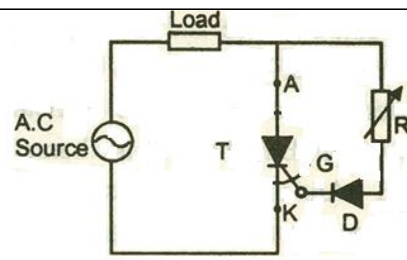
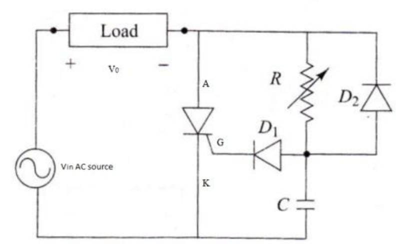
Boundary AB is the maximum limit for dc & continuous current for V_{CE} less than about 80 V. For V_{CE} more than 80V, collector current has to be reduced to BC so as to limit the junction temperature to safe values. For still higher V_{CE} current should further be reduced so as to avoid secondary breakdown limit.

CD defines this secondary breakdown limit

DE gives the maximum voltage capability for this particular transistor.

2 marks for explanation of how to avoid secondary breakdown

f	**Compare R-triggering and RC-triggering of SCR on the basis of (i) circuit diagram, (ii) firing angle, (iii) cost, (iv) average output voltage.**	**4M**
Ans:	(see table below)	One mark for each comparison

<table>
<tr><th>Sr. No.</th><th>Parameter</th><th>R-triggering of SCR</th><th>RC-triggering of SCR</th></tr>
<tr><td>1</td><td>circuit diagram</td><td>
</td><td>
</td></tr>
<tr><td>2</td><td>firing angle</td><td>Can vary From 0 to 90^0</td><td>Can vary From 0 to 180^0</td></tr>
<tr><td>3</td><td>cost</td><td>Less</td><td>more</td></tr>
<tr><td>4</td><td>average output voltage</td><td>Can be controlled from 100% (for $\alpha=0^0$)down to 50% (for $\alpha=90^0$)</td><td>Can be controlled from 100% (for $\alpha=0^0$)down to 0% (for $\alpha=180^0$)</td></tr>
</table>