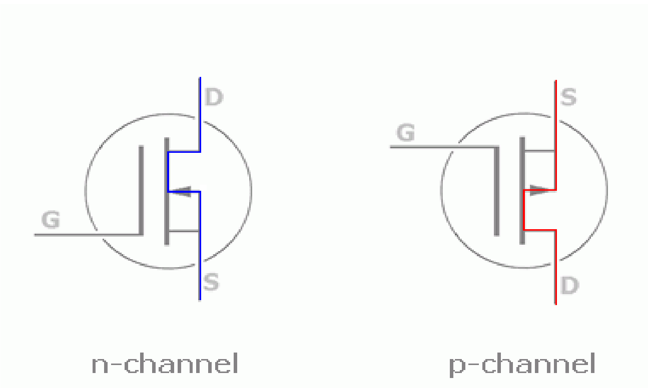
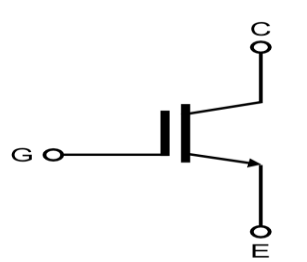
MODEL ANSWER

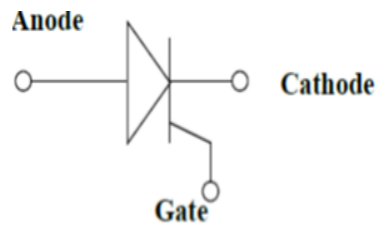
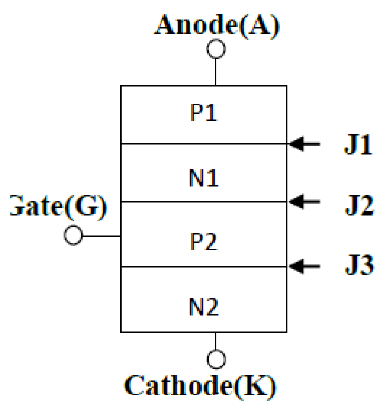
SUMMER– 17 EXAMINATION

Subject Title: Power Electronics 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 anyequivalent 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.	Answer	Marking Scheme
Q.1	(A)	**Attempt any SIX:**	12M
	a)	**Draw the symbol of MOSFET and IGBT**	2M
	Ans:	**Symbol of MOSFET :**  **Symbol of IGBT :** 	1M 1M
	b)	**Draw the structural diagram and symbol of SCR.**	2M

	Ans:	**Symbol :**  **Diagram :** 	**1M** **1M**
	c)	**List any four methods of triggering SCR.**	**2M**
	Ans:	***Note: Any four triggering method can be considered.*** **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 • D.C Gate triggering • A.C Gate triggering • Pulse Gate triggering	**(½ M Each Method)**
	d)	**Define rectification.State any two devices used for rectification.**	**2M**
	Ans:	**Definition :** **Rectification:** The conversion of a.c input voltage into d.c output voltage is called as rectification. **Two devices Used for rectification are :** • SCR	**1M** **1M**

		• Diode	
	e)	**Give the classification of chopper.Define inverter.**	**2M**
	Ans:	**<u>DC chopper can be classified as :</u>** **1.<u>According to input/output voltage levels</u>** • Step –Up chopper • b.Step – Down chopper **2. <u>According to direction of output voltage and current</u>** • Class A Chopper • Class B Chopper • Class C Chopper • Class D Chopper • Class E Chopper **3<u>. According to Circuit operation</u>** • First Quadrant Chopper • Two quadrant Chopper • Four Quadrant Chopper **4.<u>According to Commutation method</u>** • Voltage Commuted Chopper • Current Commuted Chopper • Load Commuted Chopper • Impulse Commuted Choppe **<u>Defination of Inverter</u>**: 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.	**1M** **1M**
	f)	**Define any two performance parameters of inverter.**	**2M**
	Ans:	**<u>Performance parameters of inverters :</u>** **Harmonic factor of nth harmonics(HF_n):** The harmonic factor is a measure of contribution of individual harmonics. It is defined as the ratio of the rms voltage of a particular harmonic component to the rms value of fundamental component. **<u>OR</u>** $$HF_n = \frac{E_{n\,rms}}{E_{1\,rms}}$$ **<u>Total Harmonic Distortion (THD):</u>** It is a measure of closeness in a shape between the output voltage waveform and its	**1M each**

fundamental component. It is defined as the ratio of the rms value of its total harmonic component of the output voltage and the rms value of fundamental component.

<u>OR</u>

$$THD = \frac{\sqrt{\sum_{n=2,3,\ldots}^{\infty} E_{n_{rms}}^2}}{E_{1_{rms}}}$$

$$= \sqrt{\frac{E_{0_{rms}}^2 - E_1^2}{E_1}}$$

<u>Distortion factor (DF):</u>

It indicates the amount of harmonics that remain in the outut voltage waveform,after the waveform has been subjected to second order attenuation.

<u>OR</u>

$$DF = \sqrt{\frac{\sum_{n=2,3,\ldots}^{\infty} \left(\frac{E_{n_{rms}}}{n^2}\right)^2}{E_{1_{rms}}}}$$

<u>Lowest-Order Harmonics(LOH):</u>

The lowest frequency harmonic ,with a magnitude greater than or equal to three percent of the magnitude of the fundamental component of the output voltage, is known as Lower order harmonic.

g) **State the function of freewheeling diode in any rectifier in circuit.** **2M**

Ans: Freewheeling diode serves two main function: **2M**

- It prevents reversal of load voltage except for small diode voltage drop.
- It transfers the load current away from the main rectifier ,thereby allowing all of its thyristors to regain their blocking states.

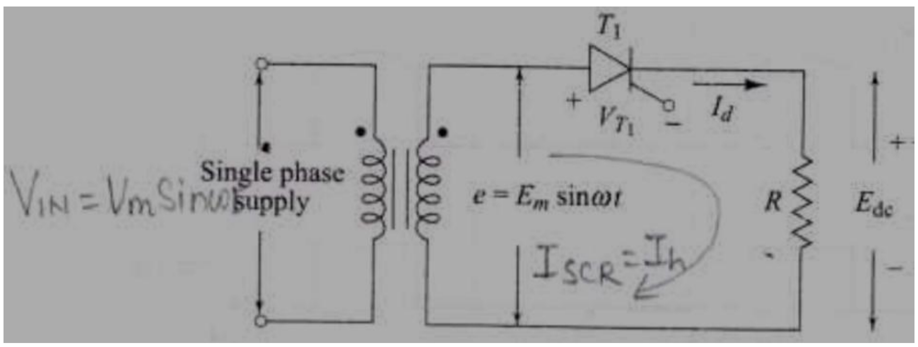
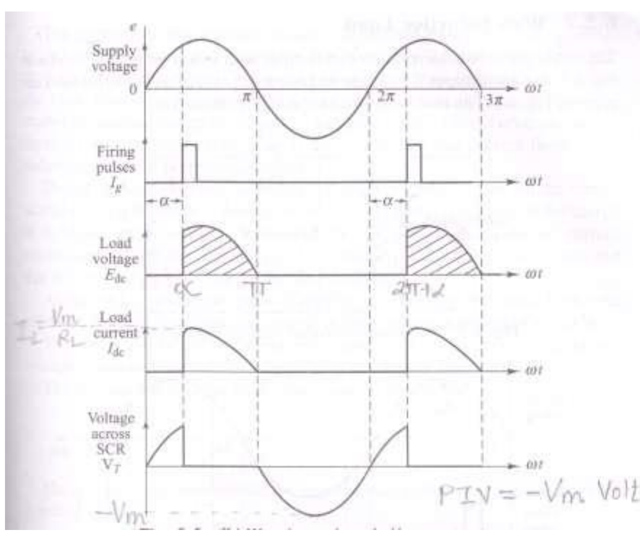
h) **Define the term commutation of SCR.** **2M**

Ans: Commutation is the process by which we can turn OFF a thyristor. **2M**

So the process of switching OFF a thyristor or SCR is known as Commutation.

B) **Attempt any TWO:** **8M**

a) **Define holding current and latching current. State their typical values.** **4M**

	Ans:	**<u>Holding current:</u>** It is the minimum value of anode to cathode current below which the device stops conducting and return to its off state. **<u>Latching current</u>:** It is the minimum anode to cathode current required to keep the device in the on state after the trigger pulse has been removed. Typical value of holding current and Latching current varies with SCR to SCR. And holding current is always less than Latching current. ***<u>Note:- Please give marks accordingly.</u>***	**1½M** **1½M** **1M**
	b)	**Draw and explain single phase half wave controlled rectifier with resitive load.State the equations of average voltage and current.**	**4M**
	Ans:	**<u>Diagram :</u>**  **<u>Waveform (optional) :</u>**  **<u>Working :</u>** During the positive half cycle of the input ,T1 (SCR1) if forward biased and with the application of gate pulse ,SCR1 (T1) is turned ON at an angle α. Thus we obtain load	**1M** **1M** **1M**

voltage and load current at the output.

During negative half cycle of the input SCR1 is reverse biased and thus load voltage and load current is zero.

Average output voltage $E_{dc} = \frac{E_m}{2\Pi}(1+\cos\alpha)$

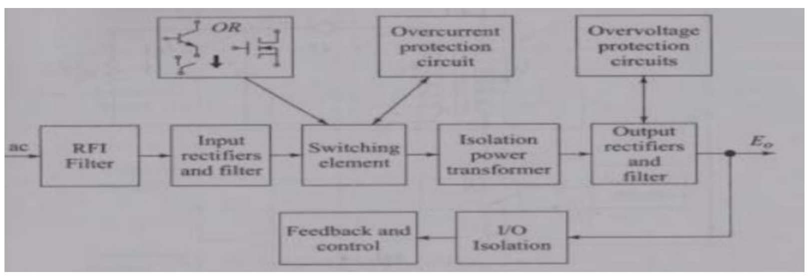
Average output current $I_{dc} = \frac{E_m}{2\Pi}(1+\cos\alpha)/R$

OR

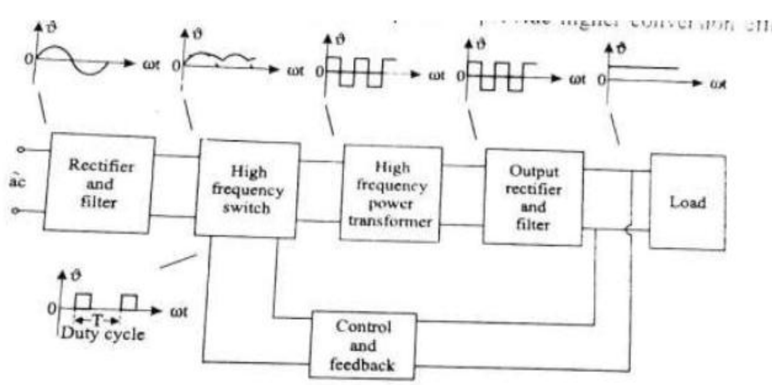
$I_{dc} = E_{dc}/R$ **1M**

c)	**Draw and explain the block diagram of SMPS.**	**4M**

Ans: **Diagram :** **2M**

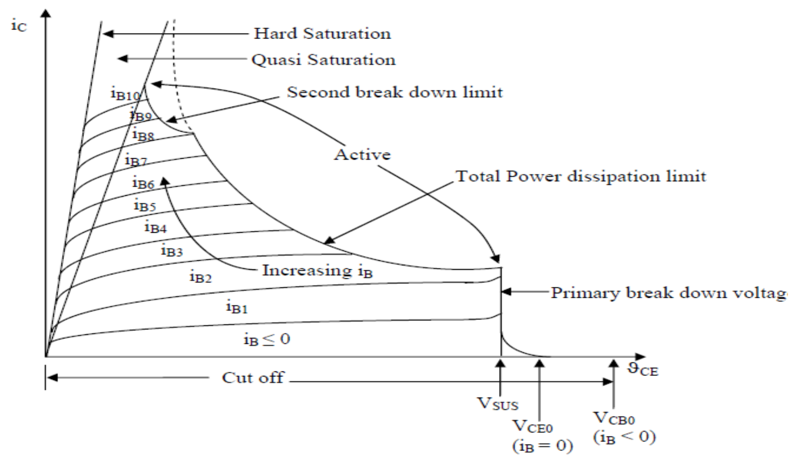


OR

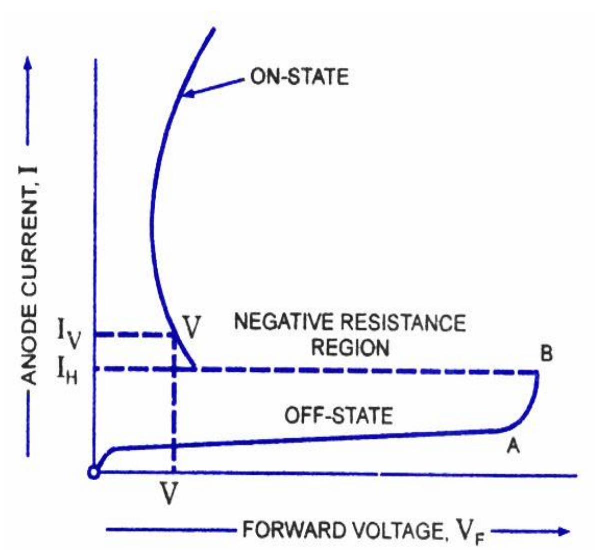


Description of working: **2M**

SMPS converts unregulated AC or DC voltage into a regulated voltage. In case of AC it first converted into unregulated DC. This is fed to a high frequency step-up chopper. 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 for the load. The output is fed back to the chopper

<table>
<tr><td></td><td></td><td>to control which is used to control the switching frequency.</td><td></td></tr>
<tr><td>Q 2</td><td></td><td>Attempt any Four:</td><td>16M</td></tr>
<tr><td></td><td>a)</td><td>Draw the characterstics of power BJT,Explain Quasi-saturation.</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td><u>Diagram :</u>


In the quasi saturation region the base-collector junction is forward biased but the lightly doped drift region is not completely shorted out by excess minority carrier injection from the base. The resistivity of this region depends to some extent on the base current. Therefore, in the quasi saturation region, the base current still retains some control over the collector current although the value of β decreases significantly. Also, since the resistivity of the drift region is still significant the total voltage drop across the device in this mode of operation is higher for a given collector current compared to what it will be in the hard saturation region</td><td>2M

2M</td></tr>
<tr><td></td><td>b)</td><td>Draw the characterstics and explain the working of SCS.</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td>
</td><td>2M</td></tr>
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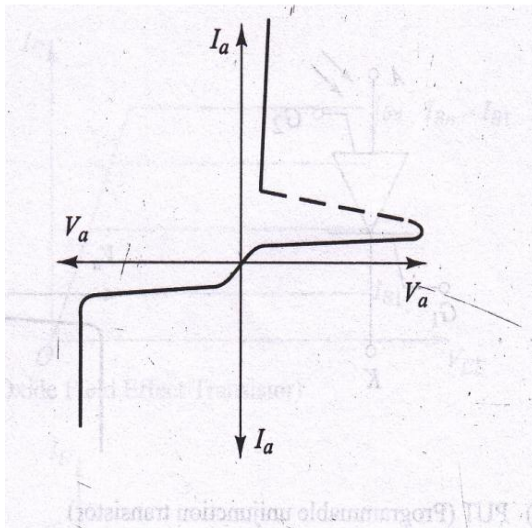
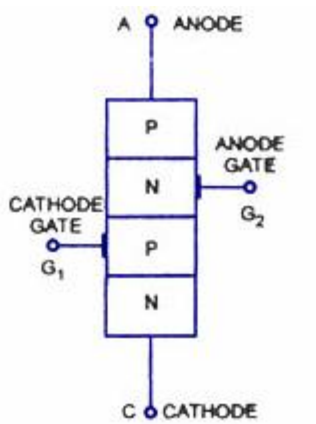
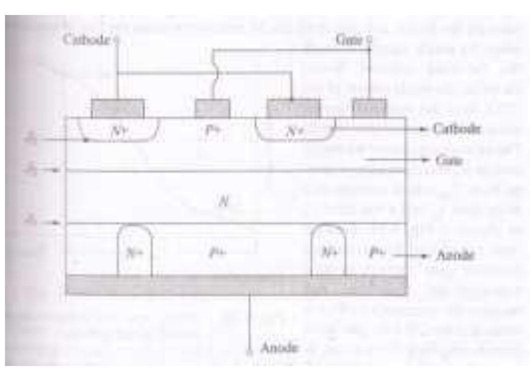
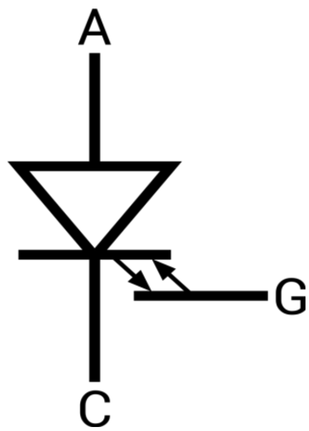
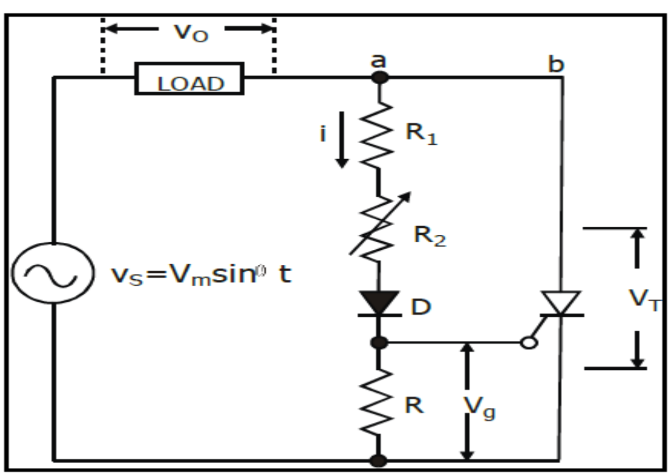
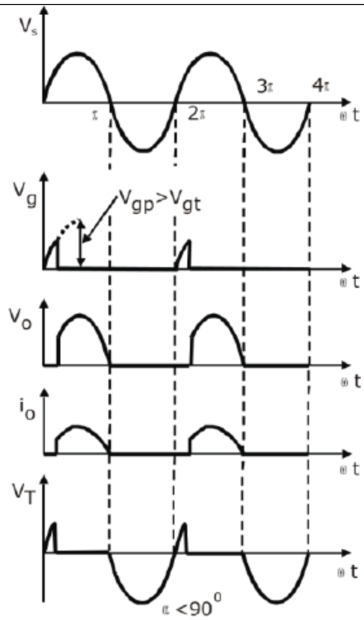
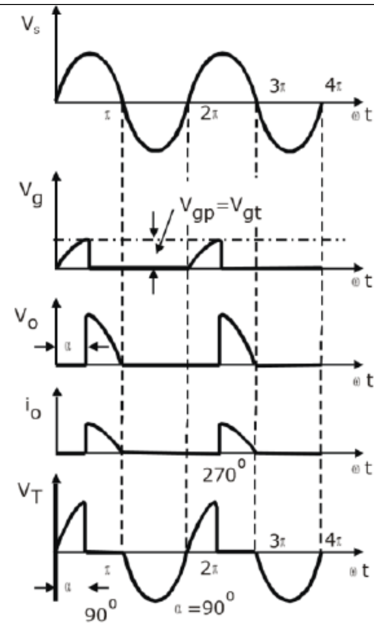
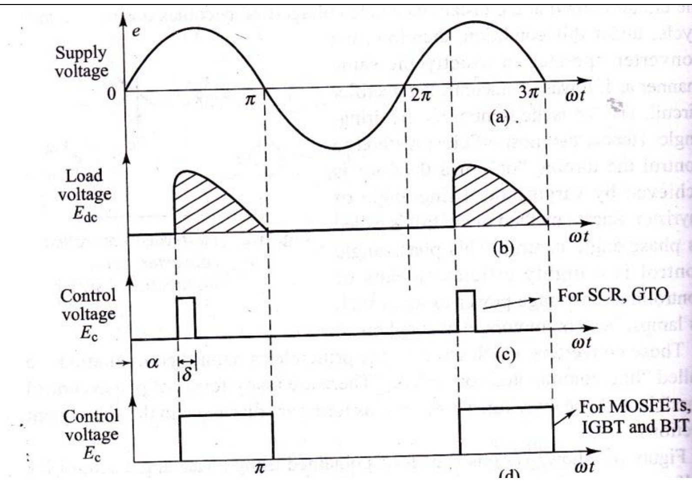
		  *(a) Basic Structure* **<u>Silicon controlled switch</u>** <u>(SCS)</u> **is**, four layer three junction P-N-P-N silicon device with four terminals namely cathode C, cathode gate G_1, anode gate G_2 and the anode A, SCS can be turned ON by applying positive pulse at the cathode gate or by applying negative pulse at the anode gate	2M
	C)	**Draw the structural diagram and symbol of GTO. Describe its working.**	**4M**
	Ans:	**<u>Diagram :</u>** 	**1M**

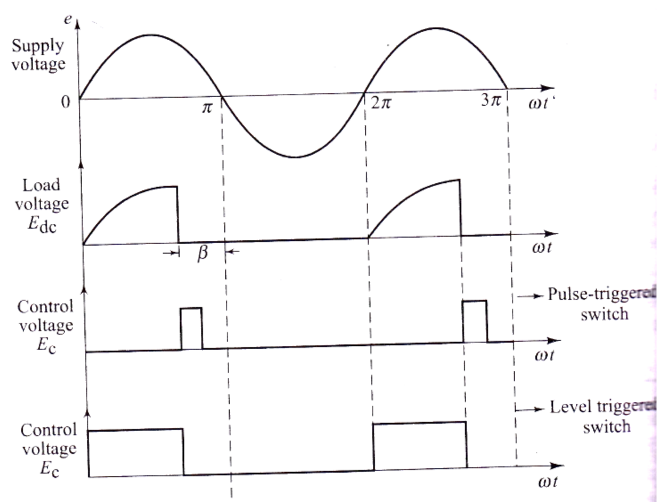
		Symbol : 	**1M**
		Working : • The turn ON operation of GTO is similar to a conventional thyristor. When the anode terminal is made positive with respect to cathode by applying a positive gate current, the hole current injection from gate forward bias the cathode p-base junction. • This results in the emission of electrons from the cathode towards the anode terminal. This induces the hole injection from the anode terminal into the base region. This injection of holes and electrons continuous till the GTO comes into the conduction state. • To turn OFF a conducting GTO, a reverse bias is applied at the gate by making the gate negative with respect to cathode. A part of the holes from the P base layer is extracted through the gate which s-uppress the injection of electrons from the cathode. • In response to this, more hole current is extracted through the gate results more suppression of electrons from the cathode. Eventually, the voltage drop across the p base junction causes to reverse bias the gate cathode junction and hence the GTO is turned OFF	**2M**
	d)	**Draw the circuit diagram of Resistance trigerring. Explain the working with necessary waveforms.**	**4M**
	Ans:	**Diagram:**  **Waveform:**	**2M**

		 **OR** 	**Any one waveform 1M**
		Explaination: *A simple resistance* triggering circuit is as shown. The resistor R_1 limits the current through the gate of the SCR. R_2 is the variable resistance added to the circuit to achieve control over the triggering angle of SCR. Resistor 'R' is a stabilizing resistor. The diode D is required to ensure that no negative voltage reaches the gate of the SCR.	**1M**
	e)	**Define firing angle.Explain the methods of phase control techniques.**	**4M**
	Ans:	Firing angle: The angle at which the SCR is turned ON is called as firing angle and it is denoted by α. **Different methods of phase control techniques are:** • Firing angle control Or phase angle control • Extinction angle control • Pulse width Modulation control ***Note : any one method should be considred*** **1.Firing angle control. Or phase angle control :**	**1M** **Any one method 3M**



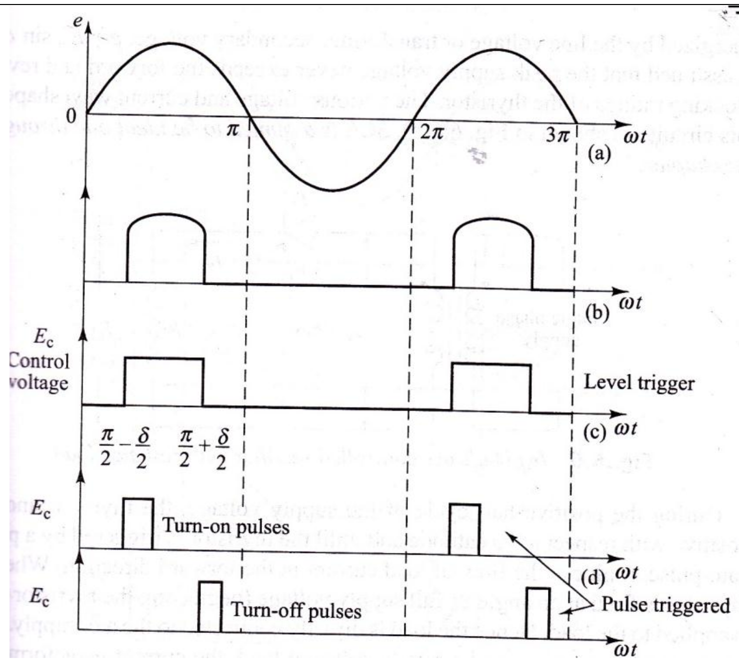
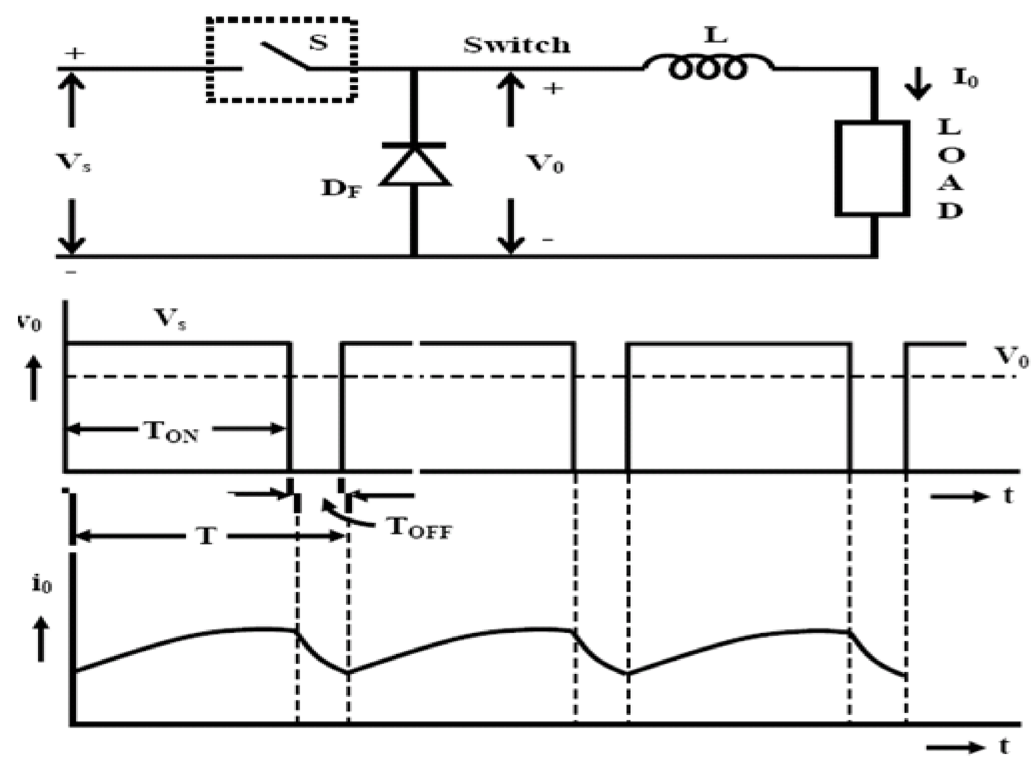
The angle at which the SCR is turned ON is called as firing angle. Lesser is the firing angle more will be the output voltage

2. <u>Extinction angle control :</u>

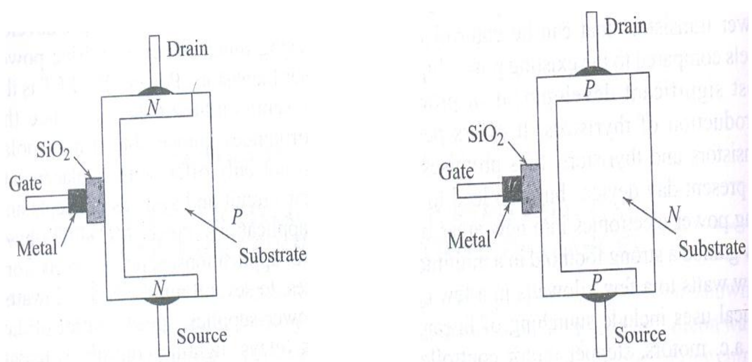


The rising edge of the control pulse coincides with the beginning of the input voltage waveform.angle ß is called as extinction angle. In a pulse triggerd switch ,the control pulse consist of two short pulses one for turning ON and the other for forced Turn off**.**

3.<u>Pulse width Modulation control</u> :

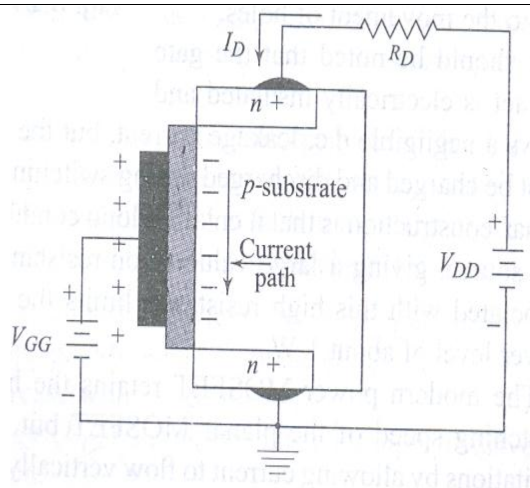
		 The control pulse is symmetrical positioned with respect to positive and negative peaks of the input voltage waveforms.	
	f)	**Draw and explain step-down chopper with relevent waveforms.**	**4M**
	Ans:		**2M** **1M**
		<u>Working:</u> **<u>The diode acts as freewheeling diode.</u>** When chopper is ON, supply is connected across load. Current flows from supply to load. • When chopper is OFF, load current continues to flow in the same direction through	**1M**

		FWD due to energy stored in inductor‘ L’. • Load current can be continuous or discontinuous depending on the values of ‘L’ and duty cycle ‘d’	
Q. 3		**Attempt anyFour:**	**16M**
	a)	**State the types of power MOSFETS.Explain the working of any one type with a constructional diagram.**	**4M**
	Ans:	**<u>There are two types of power MOSFETs:</u>** 1) Depletion Enhancement or DE MOSFET 2) Enhancement MOSFET	**1M**
		<u>Constructional diagram of DE MOSFET:</u>	**1M**



(a) *N*-channel (b) *P*-channel

		<u>Working :</u> DE MOSFETs can be operated in either of the two modes, the depletion mode or the enhancement mode. Depletion Mode: with a negative gate voltage, the negative charges on the gate repel conduction electrons from the channel leaving it positively charged. Now the n channel is depleted of some electrons, thus decreasing its conductivity. At asufficiently high negative gate to source voltage, the channel is totally depleted and the drain current is zero. Enhancement mode: with a positive gate voltage, the channel gets negatively charged increasing its conductivity. **<u>Enhancement MOSFET:</u>** **<u>Diagram :</u>**	**2M**



(b) Induced channel ($V_{GS} > V_{GS(ith)}$)

N channel enhancement MOSFET

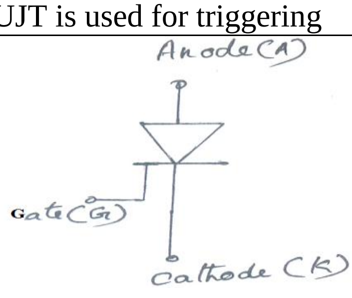
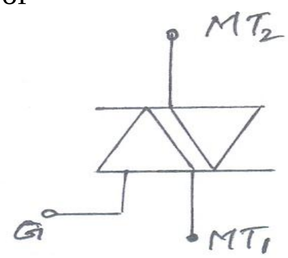
Working:

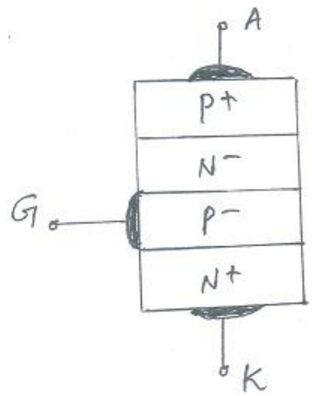
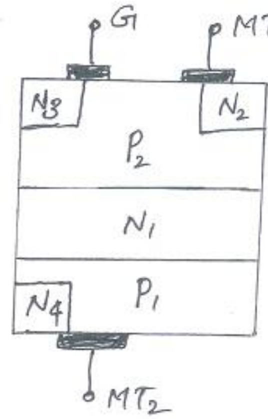
Enhancement only MOSFETs have no physical channel. For an N channel enhancement MOSFET, a positive gate voltage above a threshold induces a channel by creating a thin layer of negative charges in the substrate region adjacent to the SiO2 layer. The conductivity of the channel is enhanced by increasing the gate to source voltage. Below the threshold there is no channel and the device stops conducting.

(Note: any one to be considered)

b) **Compare SCR & TRIAC with any four points** **4M**

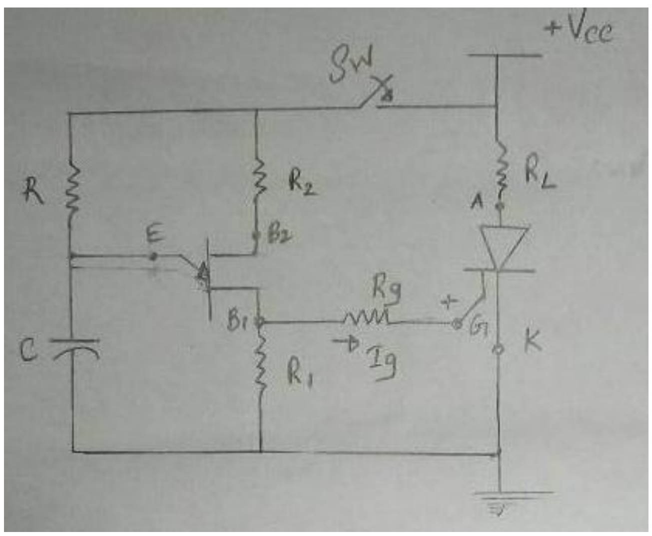
Ans: **1M Each**

Sr No.	SCR	TRIAC
1	Is a unidirectional device	Is a bidirectional device
2	The gate current can only be positive	The gate current can be positive or negative
3	Operates only in the first quadrant	Operates in either Ist or 3rd quadrant
4	Anti parallel SCRs are used for power control of inductive loads	TRIAC is not suitable for power control of inductive loads
5	UJT is used for triggering	DIAC is used for triggering
6		Symbol 

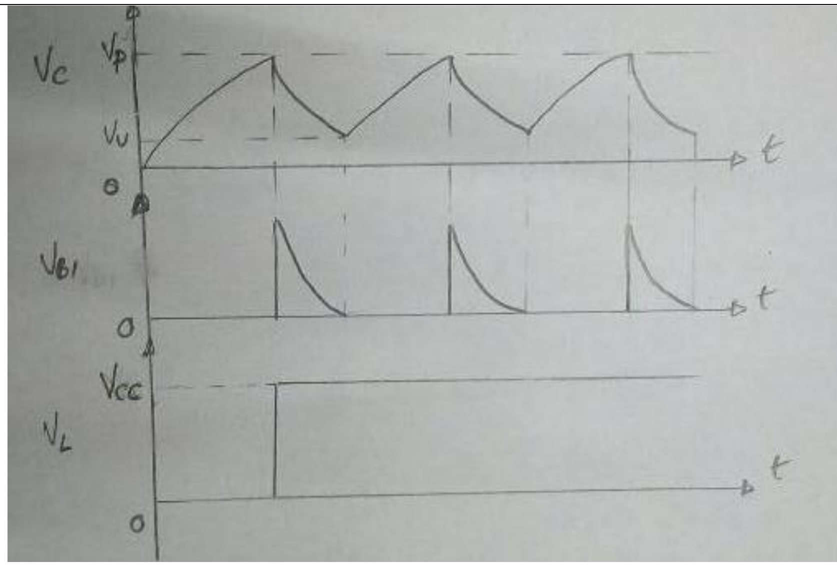
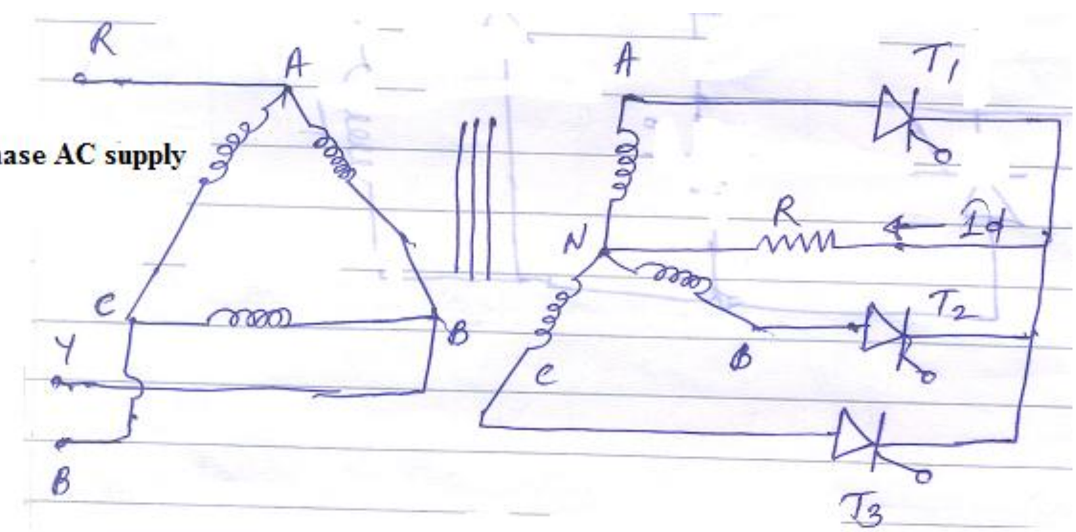
7	Constructional dia.  	Constructional dia. 
8	Used in applications like, controlled rectifiers, inverters, battery charger, speed control of DC & AC motors etc.	Used as a static switch fan regulator, lamp dimmer, AC voltage stabilizer etc.

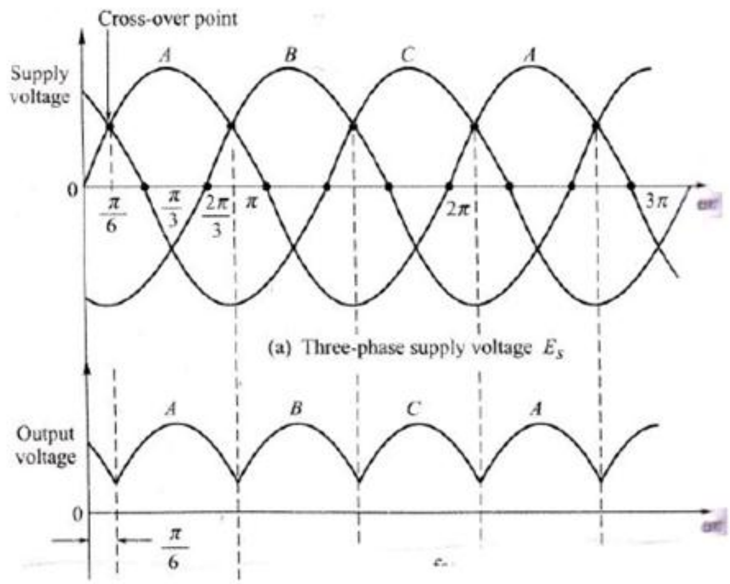
c) **Explain pulse triggering of SCR,with a neat circuit diagram and necessary waveforms.** **4M**

Ans: **<u>Diagram :</u>** **2M**

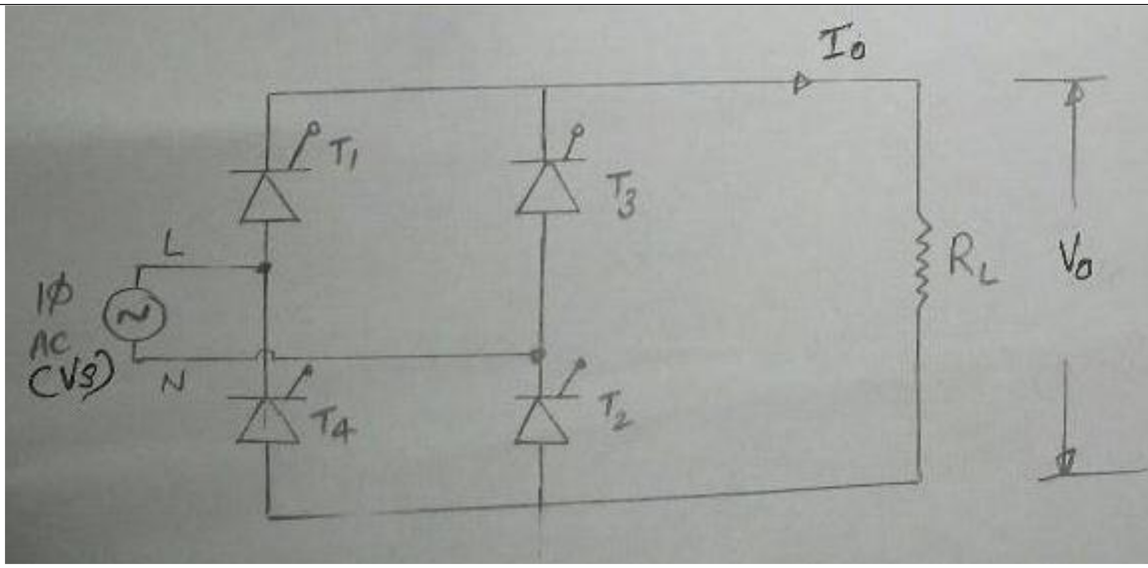


<u>Waveforms:</u> **1M**

			1M
		Workimg: Fig. shows the basic circuit of SCR pulse triggering using UJT. The first pulse at B_1 occurs T seconds after the switch is closed, for which the SCR will be turned on. Once the SCR is on subsequent pulses have no effect. The circuit may cause premature triggering of SCR if the voltage at B_1 is sufficient with UJT OFF. The requirement to avoid this is to maintain VB_1 as, $V_{B1(off)} < (Ig * Rg) + Vg$	
	d)	**Draw the circuit diagram and waveforms of 3-phase half wave contrlled rectifier.**	**4M**
	Ans:	**Diagram :** 	**2M**
		Waveforms ; for α **= 30^0**	**2M**

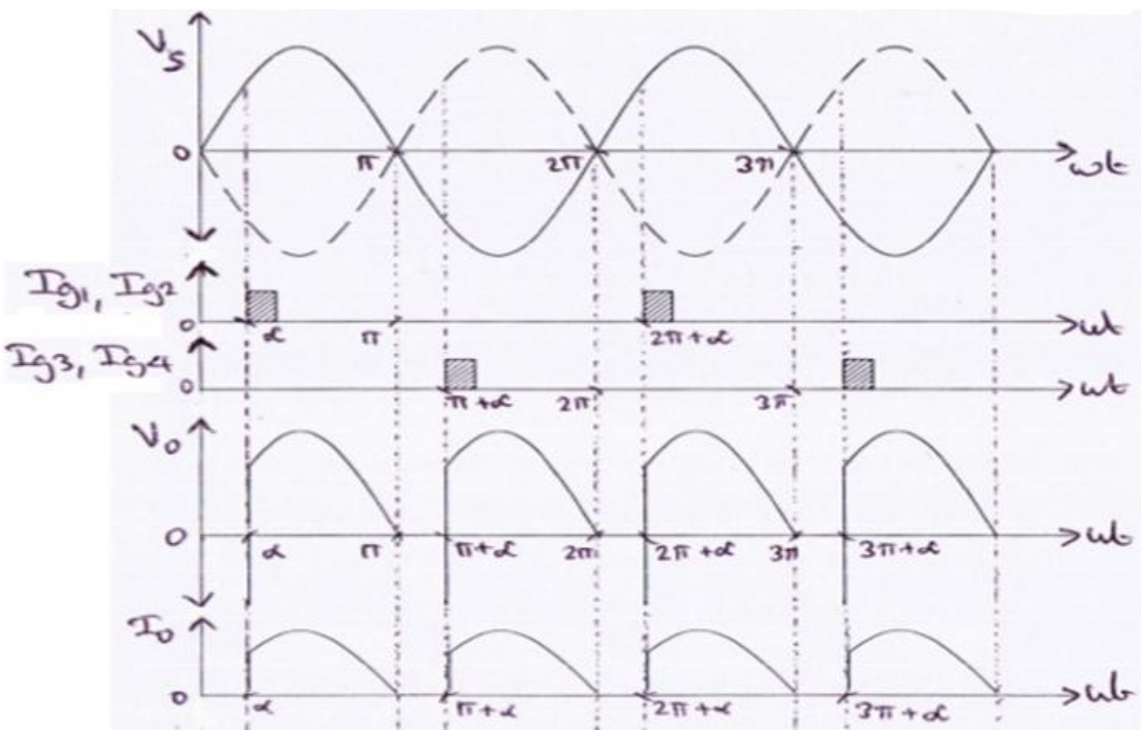


	e)	**Give a detailed classification of invrters.**	**4M**
	Ans:	**<u>1)According to nature of input source :</u>** a) Voltage source inverter (VSI) b) Current source inverters (CSI) **<u>2) According to the wave shape of the output voltage.</u>** a) Sine wave inverter b) Square wave inverter c) Quasi square wave inverter d) Pulse width modulated inverter **<u>3) According to the wave inverter :</u>** a) line commutated inverter b) forced commutated inverter **<u>4) According to the connection of thyristor and commutation components :</u>** a) Series inverter b)Parallel inverters c) Bridge inverters which are further classified as half bridge and full bridge. **<u>5) According to the semiconductor device used :</u>** a) Thyristorised inverter b) Transistorized inverter c) MOSFET based inverter d) IGBT based inverter	**(4M A detailed list to be given)**
	f)	**Draw a fully controlled bridge configration of single phase rectifier.Explain working with necessray waveforms.**	**4M**
		<u>Diagram :</u>(with R- load):	**2M**



1M

Wave forms:



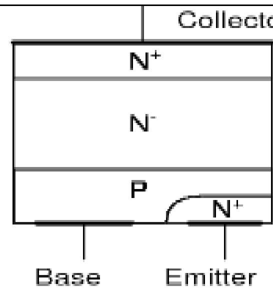
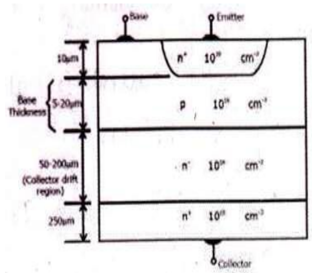
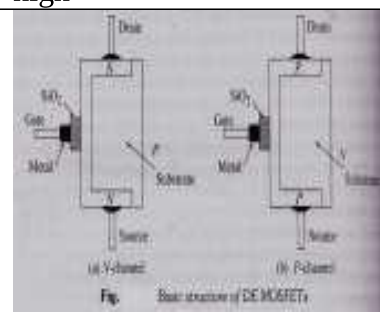
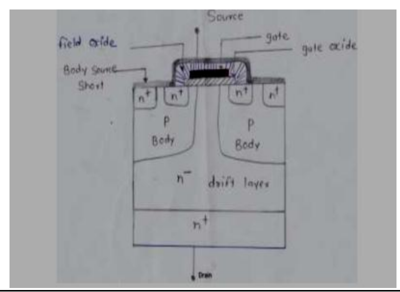
1M

Working:
During positive half cycle of input voltage, SCRs T_1 & T_2 are forward biased and triggered at α. Now voltage is applies to the load through L-T_1-RL- T_2 –N. During negative half cycle at π, T_1 & T_2 turns OFF. At π + α, SCRs T_3 & T_4 are triggered and starts conducting. Now load voltage appears through N- T3 – RL-T4 – L and the cycle repeats.

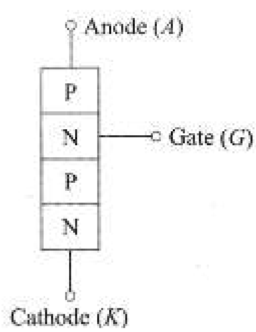
Q. 4	**A)**	**Attempt any FOUR:**	**16M**
	(a)	**Compare 'Power BJT' with 'Power MOSFET' for their performance factor,**	**4M**

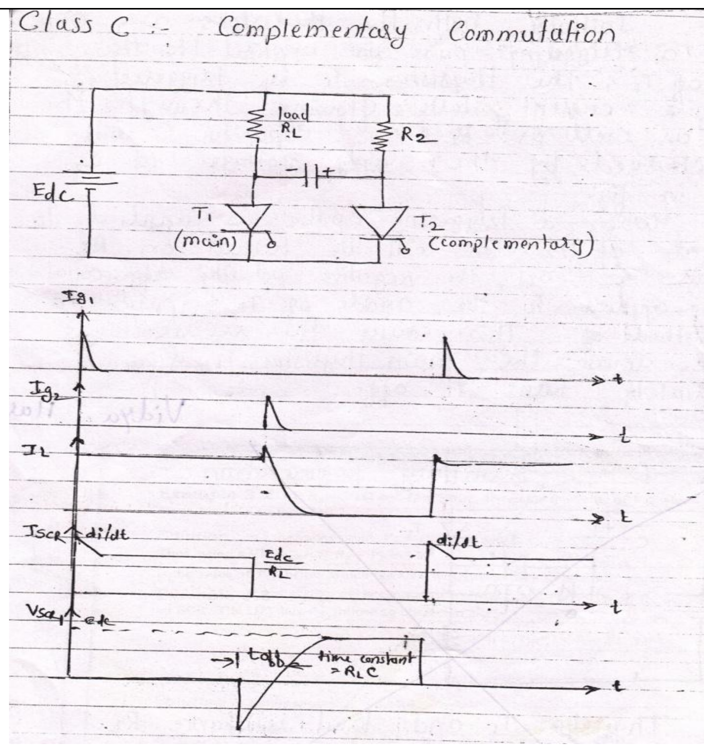
construction and area of applications.

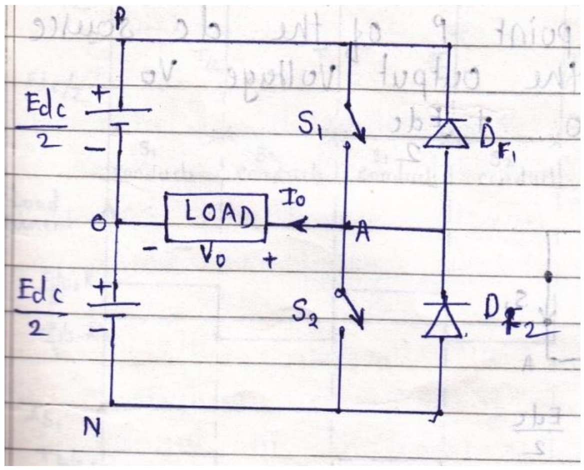
Ans:

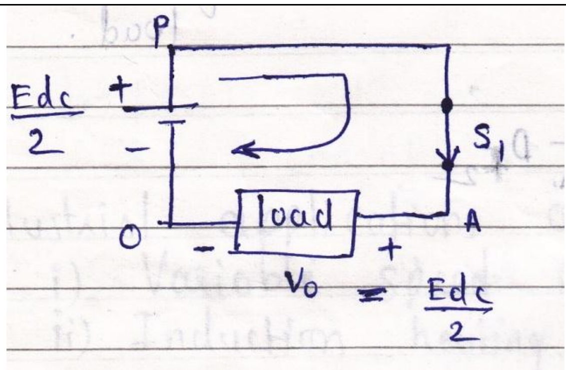
SR NO.	PARAMETER	POWER BJT	POWER MOSFET	
1	Performance factor	Switching speed slow(μs)	Switching speed fast (ns)	**(Any 2-1M each)**
		On state losses are less	On state losses are more than Power BJT	
		Input impedance low	Input impedance high	
2	Construction	 OR 	 	**1M**
3	Area of applications	Losses are low so used in high power applications& Low frequency applications	Losses are higher than power BJT so used in low power applications& High frequency applications	**1M**

(b)	**Explain the working of "PUT" with relevant diagrams. Why it is called programmable?**	**4M**
Ans:	**<u>Diagram :</u>**	**1M**

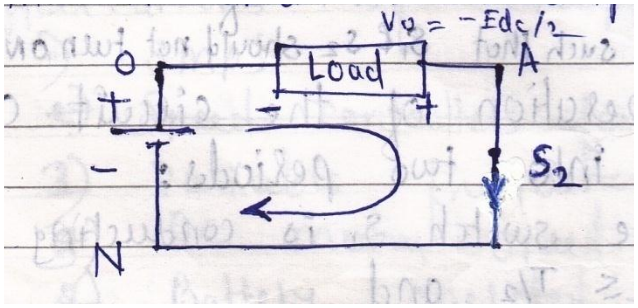


		Working: The PUT is an improved version of a UJT. PUT is a PNPN device, but its operation is so similar to the UJT that it is always considered with the UJT. The PUT behave like a UJT whose trigger voltage V_P can be set by the circuit designer via an external voltage divider. Fig. shows the PNPN structure and the circuit symbol for the PUT. The anode (A) and cathode (K) are the same as for any PNPN device. The gate (G) is connected to the N- region next to the anode. Thus, the anode and gate constitute a P-N junction. It is this P-N junction which controls the “on” and “off” states of the PUT. The gate is usually positively biased relative to the cathode by a certain amount, V_g. When the anode voltage is less than V_g, the anode-gate junction is reverse-biased and the PNPN device is in the “off” state, acting as an open-switch between anode and cathode. When the anode voltage exceeds V_g by about 0.5V, the anode gate junction conducts, causing the PNPN device to turn “on” in the same manner as does forward biasing the gate cathode junction of an SCR. In the “on” state, the PUT acts like any PNPN device between anode and cathode (low resistance and $V_{AK} \approx 1V$). The PUT is also referred to as a complementary SCR (CSCR). **PUT is called programmable :** The PUT is called as programmable because its intrinsic standoff ratio Ƞ and triggering voltage Vp can be changed by external voltage divider .	**2M** **1M**
	(c)	**Explain Complementary commutation with necessary diagrams and waveforms.**	**4M**
	Ans:	 **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,the thyristor $T_{1,}$the thyristor $T_1$is triggerd. Therefore current starts flowing through the load as well as R_2& C. Capacitor C will get charged by the supply voltage Edc as	**2M** **2M**

		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 T1 and positive to the cathode. This causes the reverse bias voltage across the main thyristor T1 and immediately turns it OFF.	
	(d)	**Draw a neat circuit diagram of single phase half bridge inverter. Explain with waveforms.**	**4M**
	Ans:	**<u>Diagram :</u>** 	**2M**
		<u>Explaination:</u> • Figure shows the basic configuration of single phase half bridge inverter. • Switches S_1& S_2 are the gate commuted devices such as power BJTs, MOSFETs, GTO,IGBT, MCT etc. When closed, these switches conducts & current flows in the direction of arrow.	**1M**
		<u>Working:</u> • The operation of the circuit can be divided into two periods: • Period I: Where switch S1 is conducting from $0 \leq t \leq T/2$ and • Period II: Where switch S2 is conducting from $T/2 \leq t \leq T$, o Where T=1/f & F is the frequency of the output voltage waveform. • Switch S_1 is closed for half -time period (T/2) of the desired ac output. • It connects point P of the dc source to point A and the output voltage V_0 becomes equal to + Edc/2	**1M**

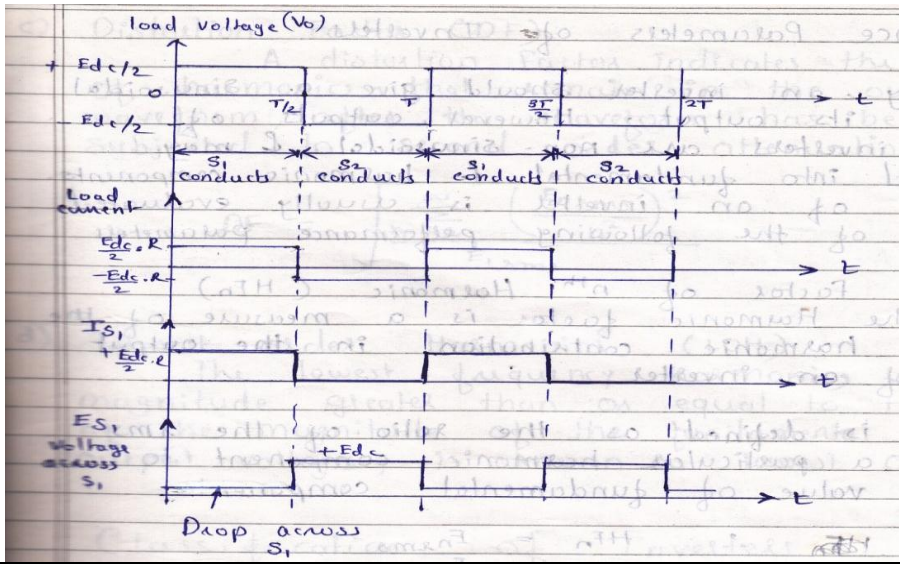


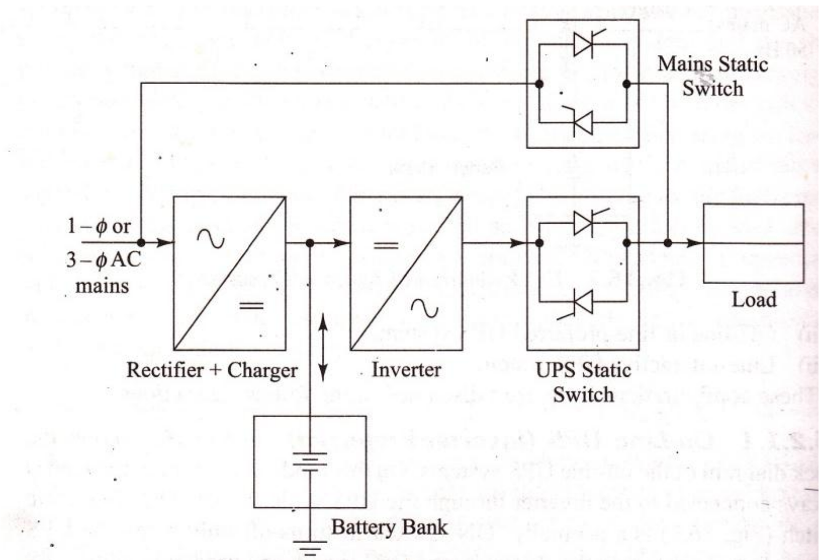
- At t=T/2, gating signal is removed from S_1 and it turns off.For the next half time period(T/2≤t≤T),the gating signal is given to S_2.
- It connects point N of the dc source to point A and the output voltage reverses.



- Thus by closing S_1 and S_2 alternately, for half time periods, a square wave ac voltage is obtained at the output.
- With resistive load,waveshape of load current is identical to that of output voltage.
- Simply by controlling the time periods of the gate-drive signals, the frequency can be varied

Voltage and current waveforms-



	(e)	**Draw and explain on-line UPS**	**4M**
	Ans:	**Diagram:**  **Explanation:-** Block diagram of the on line UPS systems is as shown where the load is connected to the inverter through the UPS static switch. The UPS static switch is normally ON switch. It turns off only when the UPS system fails. In that case the mains static off switch is used only when UPS is to be bypassed. The various operating modes are **Mode 1**:- When the AC mains is on, the inverter circuit will supply the power to the inverter as well as to the battery. Therefore it acts as a rectifier cum charger .Hence its ratings are usually higher. The inverter o/p is connected to the load via UPS static switch. Battery will be charged in this mode. **Mode 2:-**If the supply fails suddenly, the rectifier o/p will be zero and hence the battery bank now supplies power to the inverter without any interruption and delay. There will not be any change in inverter as well as the load. After restoration of the line supply,the charger supplies the inverter and recharges the battery automatically first in constant current mode and then in constant potential mode. **Mode3 :-**In case if the inverter /UPS fails, then the normally OFF mains static switch is turned on which automatically transfers the ac line to the load in less than ¼ cycle period with no phase discontinuity.	**2M** **2M**
	(f)	**Compare three phase controlled and uncontrolled rectifier with resistive load, for any four points.**	
	Ans:	(table below)	**1M Any Four Points**

Sr. No.	Parameter	three phase controlledrectifier	three phase uncontrolled rectifier
1	Devices used	SCR and diodes	Only diodes
2	Control of load voltage	Load voltage can be controlled	Load voltage cannot be controlled
3	Triggering	Required	Not required

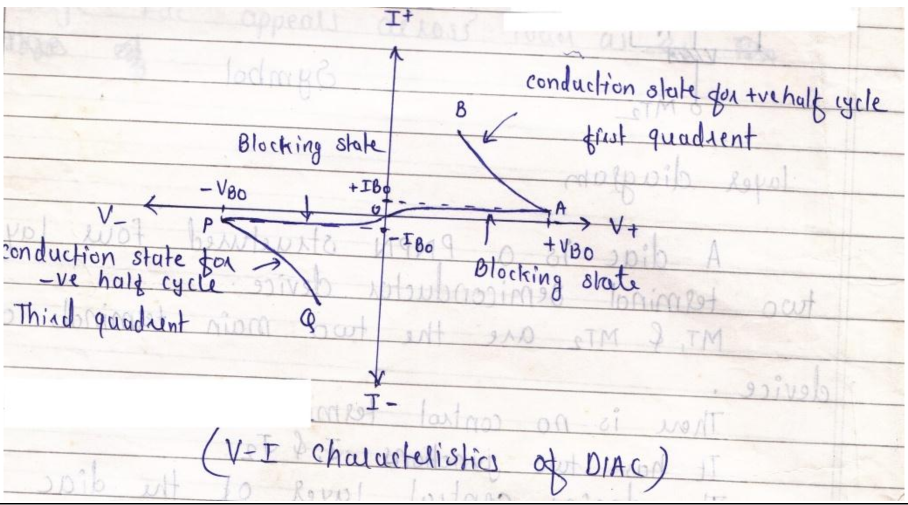
	circuit		
4	Application	DC motor controller, battery chargers	Power Supply

Q.5		Attempt any FOUR:	16M
	a)	**Name any four triggering devices. Draw the characteristics of "DIAC".**	4M

Ans: **Triggering Devices:** — 2M

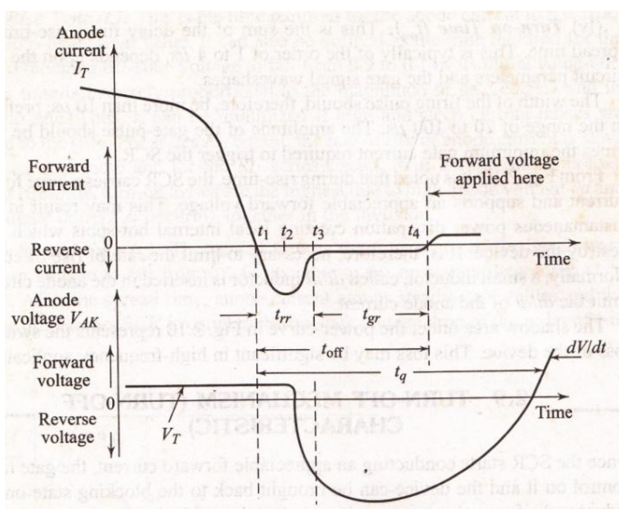
1. UJT
2. PUT
3. SUS
4. SBS
5. DIAC

V-I characteristics of DIAC- — 2M

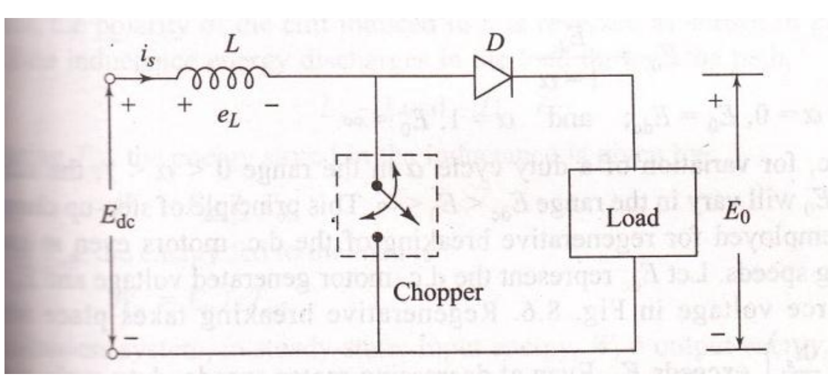


	b)	**With necessary any waveforms explain the turn-off mechanism of SCR.**	4M

Ans: **Diagram :** — 2M

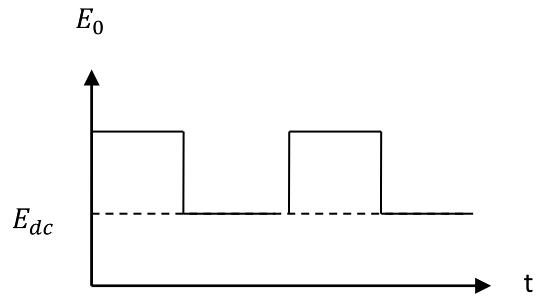


Turn – off mechanism of SCR (turn off characteristics)

		Explaination : • Once the SCR starts conducting the gate has no control on it and the device can be brought back to the blocking state only by reducing the forward current to a level below that of the holding current. • If a forward voltage is applied immediately after reducing the anode current to zero it will not block the forward voltage and will start conducting again , although it is not triggered by a gate pulse . It is therefore necessary to keep the device reverse biased for a finite period before a forward anode voltage can be reapplied. **Turn – off time :** • The turn off time of the thyristor is defined as the minimum time interval between the instant at which the anode current becomes zero and the instant at which the device is capable of blocking the forward voltage . • Turn off time = reverse recovery time + gate recovery time • Toff = trr + tgr **Reverse Recovery time (trr) :** • When the anode forward current becomes zero the anode current flows in the reverse direction after some time a reverse anode voltage is developed and the reverse recovery current continues to decrease .The time required for this process is called reverse recovery time. **Gate recovery time (tgr) :** • After reverse recovery time the thyristor is not able to block a forward voltage because carriers called trapped charges are still present at the junction J2 .The time required for recombination of this trapped charges is called gate recovery time. • SCR turn – off time varies in the range of 10 to 100 μs • In practical application the turn – off time required to the SCR by the circuit (tq) must be greater than the device turn off time (toff)	**2M**
	c)	**Explain the principle of step up chopper with a neat diagram.**	**4M**
	Ans:	**Diagram :**  	**2M**

Waveform :

.



Working : 2M

- When the switch is ON, the inductor L is connected to the supply Vs and inductor stores energy during On period TON .Hence, diode DF is reverse biased and isolates the output stage.
- When the switch is OFF, the inductor current is forced to flow through the diode and load for a period TOFF. As the current tends to decrease, polarity of the emf induced in the inductor L is reversed to that of shown in the figure and as a result Voltage across the load Vo becomes

$$\mathbf{E_0 = E_{dc} + L\frac{d_{is}}{d_t}}$$

i.e., the inductor Voltage adds to the source Voltage to force the inductor current into the load.

Output voltage:

$$E_0 = \frac{E_{dc}}{1-\alpha}$$

Where $\alpha = \frac{T_{ON}}{T}$ = duty cycle

For $\alpha = 0$ $E_0 = E_{dc}$

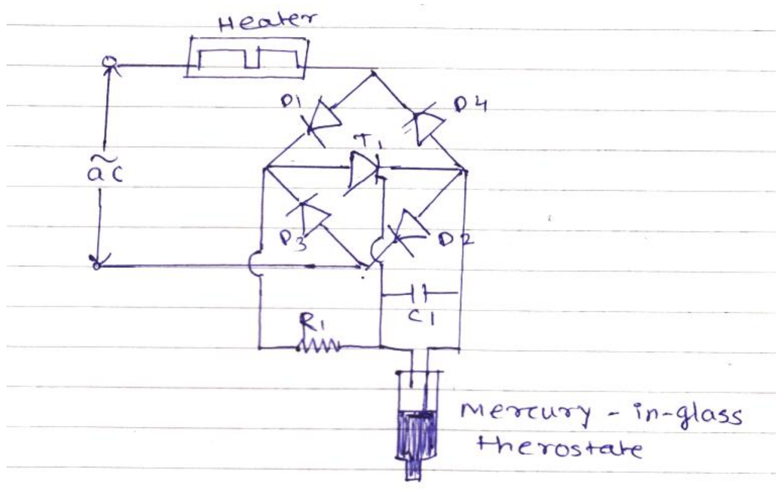
& $\alpha = 1$ $E_0 = \infty$

Hence for variation of a duty cycle α in the range $0 < \alpha < 1$, the output voltage E_0 will vary in the range $E_{dc} < E_0 < \infty$

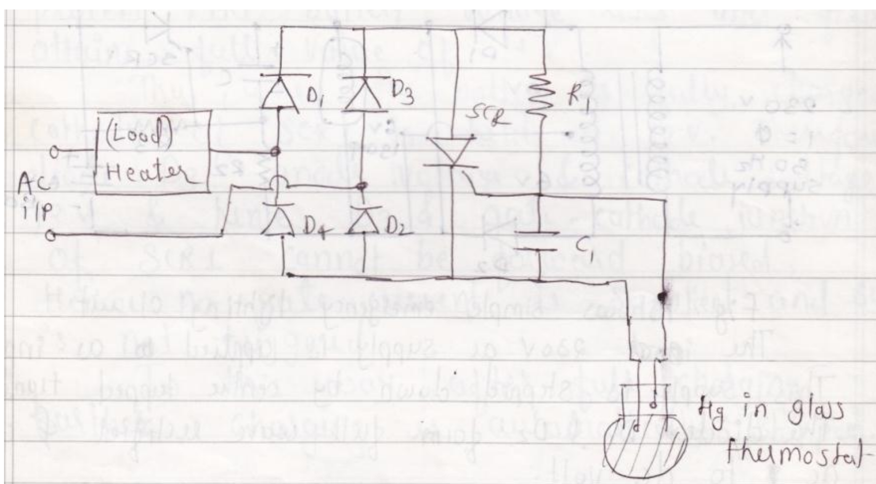
Thus this circuit gives output voltage always greater than the input voltage.

So it is known as step up chopper.

d)	**Draw the step-up of a temperature controller using SCR.**	**4M**
Ans:	**Diagram :**	**4M**

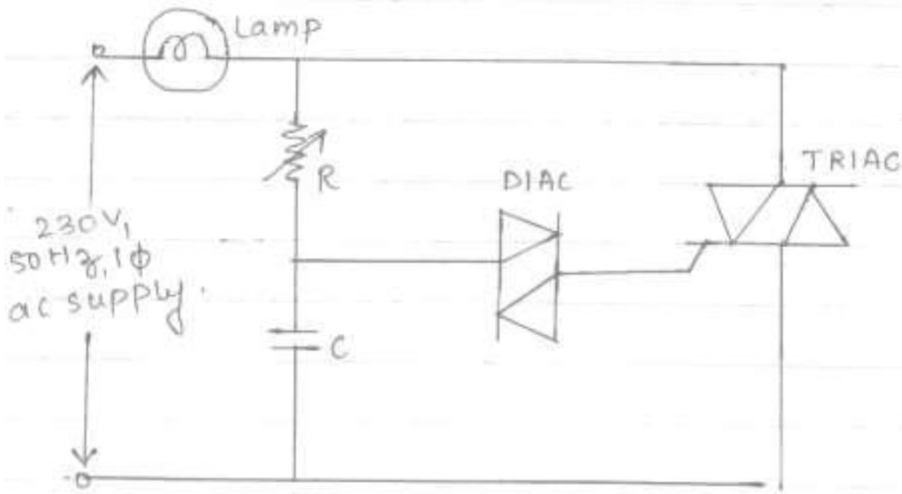


OR

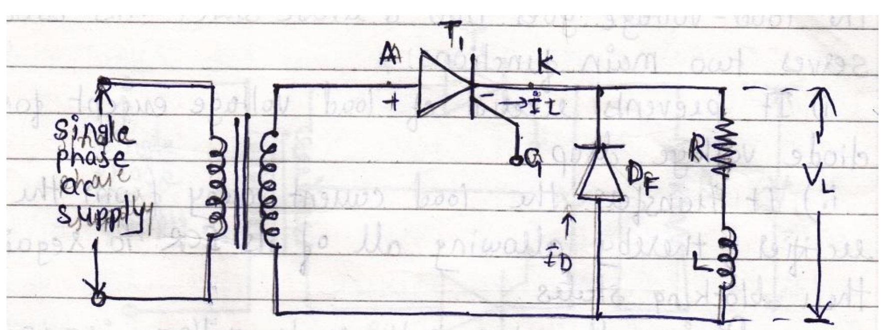


Note:Any other relevant diagram can be considered

e)	**Draw and explain light dimmer circuit using DIAC-TRIAC.**	**4M**
Ans:	**Diagram :**	**2M**

<table>
<tr><td></td><td></td><td>

<u>Explanation:-</u>

In the above circuit DIAC is used to trigger TRIAC.
During the positive half cycle (when P is positive) :TheTRIAC requires a positive gate signal for turning it on . This is provided by the capacitor C , when thevoltage across the capacitor is above the breakdown voltage of the DIAC . DIAC turn ON & the capacitor
discharges 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 and , 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 the α we can control intensity of light using TRIAC
</td><td>2M</td></tr>
<tr><td></td><td>f)</td><td>With necessary diagrams explain how a freewheeling diode improves the power factor of a single phase half wave rectifier connected with inductive load.</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td><u>Diagram :</u>


<u>Explaination:</u>

The diode D_F described as a commutating diode, flywheel diode or by-pass
</td><td>2M

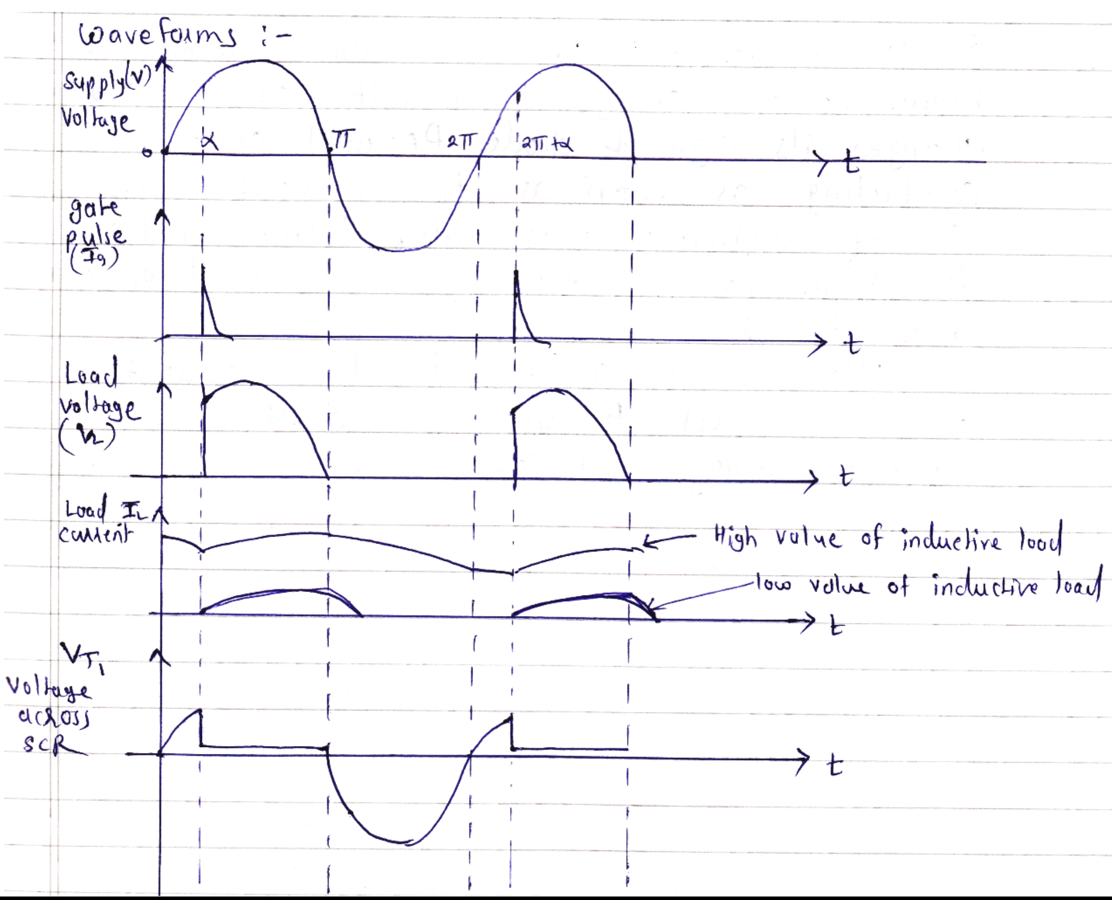
2M</td></tr>
</table>

diode.This diode is commonly described as a commutating diode as its function is to commutate or transfer load current away from the rectifier whenever the load-voltage goes into a reverse state. This diode serves two main functions

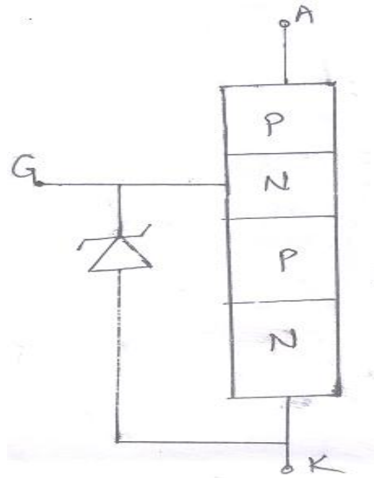
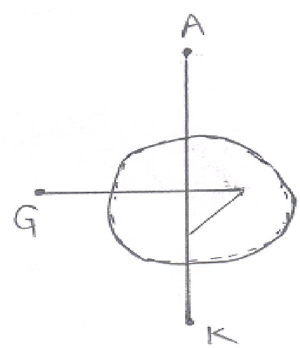
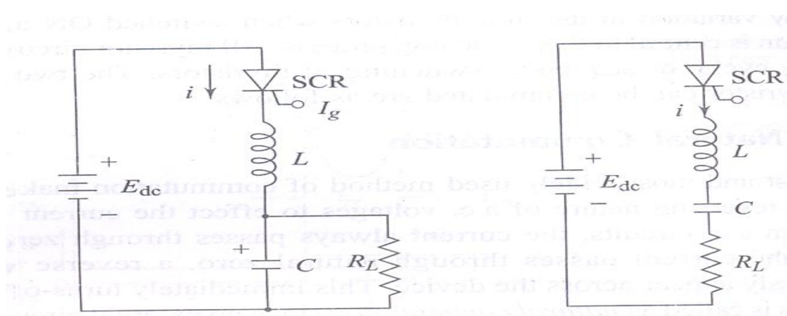
1. It prevents reversal of load voltage except for small diode voltage drop.
2. It transfers the load current away from the main rectifier, thereby allowing all of its SCR to regain their blocking states.

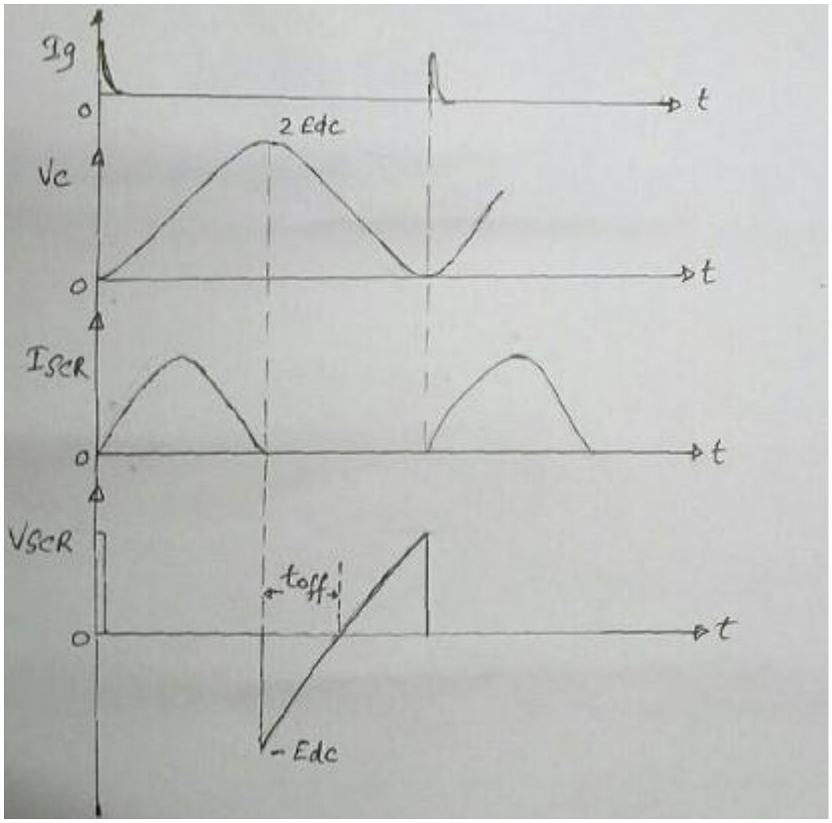
- During the positive half cycle, voltage is induced in the inductance. Now, this induced voltage in inductance coil change its polarity as the di/dt changes its sign & diode D_F will start conducting as soon as the induced voltage is of sufficient magnitude, thereby enabling the inductance to discharge its stored energy into the resistance.
- Hence, after π (180 deg.), the load current will freewheel through the diode and no reverse voltage will appear across the load. Thus improves the power factor.

Waveform (optional) :



Q.6		Attempt any FOUR:	16M
	a)	Draw the structure and symbol of SUS. State the difference between SUS and PUT.	4M
	Ans:	Diagram :	1M

		 **Symbol:**  **Differences between PUT & SUS**: 1) SUS switches at a fixed voltage determined by an internal avalanche diode, whereas PUT can be programmed externally. (major difference) 2) Structure of SUS is similar to that of PUT but with an extra avalanche diode across gate and cathode. 3) Characteristics of SUS is similar to that of SCR, whereas PUT characteristics resembles with UJT.	**1M** **2M**
	b)	**Explain resonant commutation with necessary waveforms.**	**4M**
	Ans:	**Diagram :**  a) Load in parallel with capacitor (b) Load in series with capacitor	**1M**

		Waveforms: 	**1M**
		Working: When the SCR is turned ON by a gate pulse, the capacitor starts charging. As the LC components form an under damped circuit, the charging current is sinusoidal. As soon as the capacitor is fully charged the SCR current reduces to zero and the device turns OFF.this commutation is current commutation	**2M**
c)		**A single phase half wave controlled rectifier is supplied with a voltage V=110 sin (.628t).Find average DC output voltage and current, if the firing angle is 15^0 and $R_{L=}200\Omega$.**	**4M**
Ans:		$v = 110 \sin(628t)$; $\alpha = 15^\circ$; $R_L = 200\Omega$ $V_{dc} = ?$ $I_{dc} = ?$ $V_{dc} = \frac{V_m}{2\pi}[1+\cos\alpha] = \frac{110}{2\pi}[1+\cos(15)]$ $= 34.44$ v $I_{dc} = \frac{V_{dc}}{R} = \frac{34.44}{200} = 0.172A$ $V_{dc} = 34.44v$ $I_{dc} = 0.172A$	**4M**

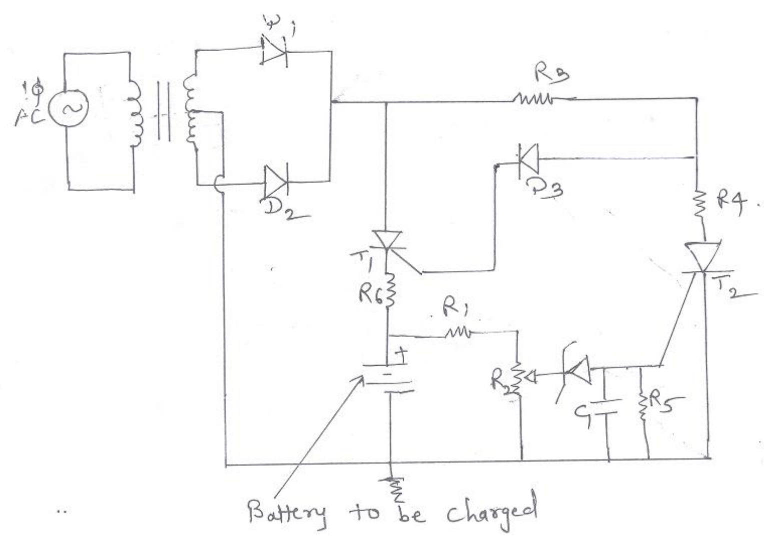
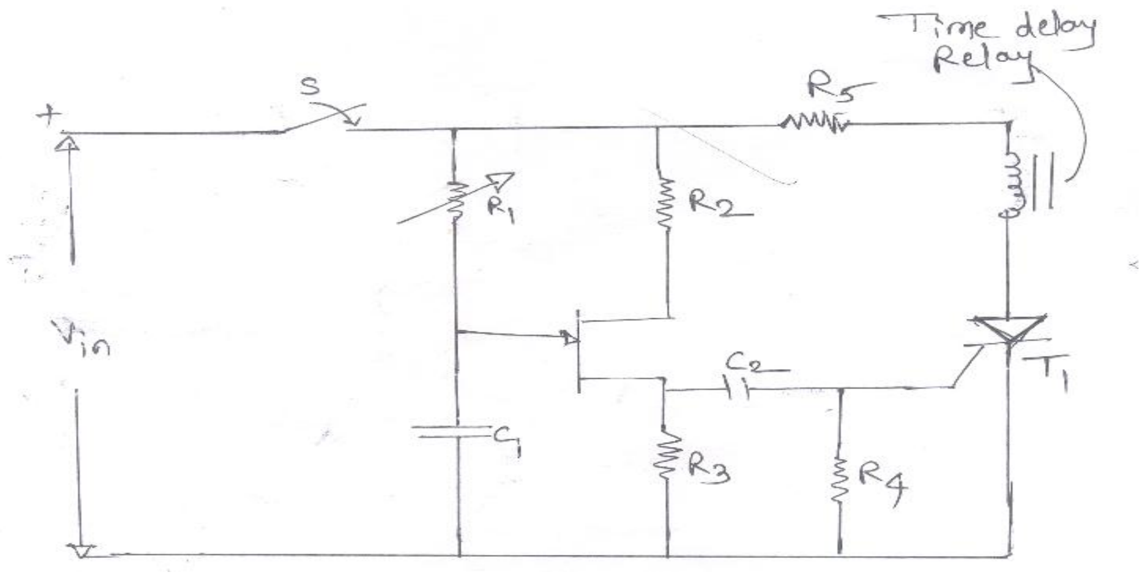
	d)	**State the need of 3-phase rectifier. State the expression for average DC output voltage of a 3-phase controlled rectifier during.** **i) Continues conduction mode** **ii) Discontinues conduction mode**	**4M**
	Ans:	**<u>Need of 3-phase rectifiers:</u>** The capacity of single phase rectifiers are limited normally only upto 2 KW. Hence when higher power is required for the load, poly phase rectifiers are used. A single phase rectifier produces DC voltage high ac ripple at its output. So it require a large smoothing filter ckts to smoothen the output voltage, increasing its cost. As the number of pulses are more a 3 phase rectifier produces a smooth output voltage, reducing the cost of filtering. Expression for average DC output voltage, **<u>Continuous conduction mode:</u>** $$Edc = \frac{3\sqrt{3}}{2\pi} Em.Cos\,\alpha$$ **<u>Discontinuous conduction mode:</u>** $$Edc = \frac{3Em}{2\pi}\{1 + Cos(\alpha + 30)\}$$	**2M** **1M** **1M**
	e)	**Draw the circuit diagram of battery charger and state significance of each component.**	**4M**
	Ans:	**<u>Diagram :</u>**  **<u>Significance of Components:</u>** 1) D1 ,D2 provide full wave rectified output across T1 2) R3-D3 provide triggering current for T1. 3)SCR T1 provides voltage to battery during its charging 4) when the battery is fully charged, the voltage dividing circuit R1-R2 provide zener voltage. 5) zener diode provides gate supply to SCR2 switching it ON. 6) When T2 is ON a short circuit results in the R3-R4 circuit, reducing the T1 current to become less than the holding current and switches it OFF, preventing over charging of battery.	**2M** **2M**
	f)	**Draw electronic timer and state it's working.**	**4M**

		Diagram :  Together, the combination of R1, C1, R2, R3, and UJT Q1 form a relaxation oscillator, which outputs a triggering pulses for triggering SCR. This circuit perform a simple time-delay for the load, where the load (Relay) energizes a certain time *after* the switch is closed. When switch is closed ,capacitor C1 charges through R1 at that time load will not be energized. Due to charging of capacitor when capacitor voltage reaches to peak point voltage (Vp)of UJT ,UJT turns ON and then capacitor get path for discharging. Discharging of capacitor C1 generates triggering pulses for SCR and hence SCR turns ON and it connects load to +V i.e. energizes load after certain time delay. The time delay depends on value of R1 and C1. C2 R4 forms a passive differentiator to condition the UJT signal.	**2M** **2M**