Summer – 2017 Examinations

Model Answers **Subject Code: 17638 (PEL)**

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 should assess the understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given 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 should give credit for any equivalent figure/figures drawn.

5) Credits to 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 (as long as the assumptions are not incorrect).

6) In case of some questions credit may be given by judgment 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

1 a) Attempt any THREE of the following: **12**

1 a) i) List turn on methods of thyristor and explain any two of them.

Ans:

Turn-on or Triggering Methods of Thyristor:

1 mark for list (any four)

1) Forward voltage Turn-on
2) Thermal Turn-on (Temperature triggering)
3) Radiation Turn-on (Light triggering)
4) dv/dt Turn-on
5) Gate Turn-on
   - (i) D.C. Gate turn-on
   - (ii) A.C. Gate turn-on
   - (iii) Pulse Gate turn-on

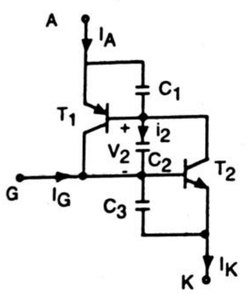
1) Forward Voltage Turn-on:

When the forward anode-to-cathode voltage V_{AK} is greater than forward breakover voltage V_{BO} sufficient leakage current flows. The energy of leakage current carriers arriving at reverse biased junction is sufficient to dislodge additional carriers. These carriers in turn dislodge more carriers and this carrier multiplication due to regenerative action results in avalanche breakdown of junction. The anode current is sharply increased. This type of turn on may damage device by thermal runaway. Therefore this method is normally not adopted for turning on SCR, however it is employed to switch four layer diodes into conduction.

1½ marks for each explanation of any two methods = 3 marks

2) dv/dt turn-on or Triggering of Thyristor:

Any p-n junction has capacitance. Under transient conditions, these capacitances influence the characteristics of SCR. Fig. shows two-transistor transient model of SCR wherein the junction capacitances have been shown external to the transistors. If SCR is in forward blocking state and rapidly rising voltage is applied between anode and cathode, the high current will flow through the device to charge the capacitors. The current through capacitor C_2 (junction J_2) can be expressed as:



Two-traisistor transient model of thyristor

$$i_2 = \frac{d(q_2)}{dt} = \frac{d}{dt}(C_2V_2) = V_2\frac{dC_2}{dt} + C_2\frac{dV_2}{dt}$$

where, C_2 = capacitance of junction J_2

V_2 = voltage across junction J_2

q_2 = charge in the junction J_2

If the rate of rise of the voltage $\frac{dV_2}{dt}$ is large, then current i_2 would be large. As these capacitor currents are basically leakage currents, the transistor leakage currents i_{CBO1} and i_{CBO2} would be increased. The high values of leakage currents may cause $(\alpha_1 + \alpha_2)$ tending to unity and result in unwanted turn-on of the SCR by regenerative action. The rapidly rising anode voltage produces charging current through the junction capacitance, leading to gate terminal. This current then acts as gate current and SCR is triggered.

3) **Temperature:**
High temperature generates the additional carriers and hence leakage current is increased. At high temperatures, the leakage current in a reverse biased p-n junction is doubled approximately with 8°C rise in junction temperature. This increase in currents cause anode current I_A to increase, which further causes α_1 and α_2 to increase. Due to regenerative action, $(\alpha_1+\alpha_2)$ may tend to be unity and thyristor may be turned on. Such turn-on may cause thermal runaway and therefore it is avoided.

4) **Gate Turn-on:**
With anode voltage positive with respect to cathode, if positive voltage is applied to gate with respect to cathode, the gate current is injected into the structure. In two-transistor analogy, the gate current I_G increases the emitter current of T_2i.e cathode current I_K, which further leads to increase in current gain α_2. So collector current I_{C2} which is base current I_{B1} is increased. This causes I_{C1} and I_{E1}i.e anode current I_A to increase. Thus emitter currents and current gains tend to increase in regenerative action and finally thyristor is turned on. This is the method normally adopted for turning on the conventional thyristors.

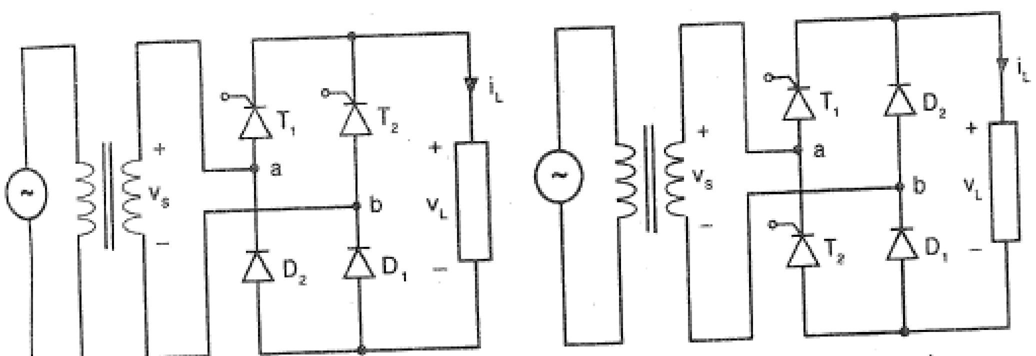
5) **Radiant Energy (Light) Turn-on:**
If light is allowed to strike the junctions of thyristor, due to incident radiant energy, considerable numbers of electron-hole pairs are released. This increase in current carriers, results in leakage currents to increase above a level when the regenerative action starts and the thyristor is turned on.

1 a) ii) Draw circuit diagram of single phase full wave half controlled converter using RL load. Sketch waveform of output voltage and output current.

Ans:

Single phase full wave half controlled converter:

<u>Circuit diagrams for Symmetrical and Asymmetrical Configurations:</u>

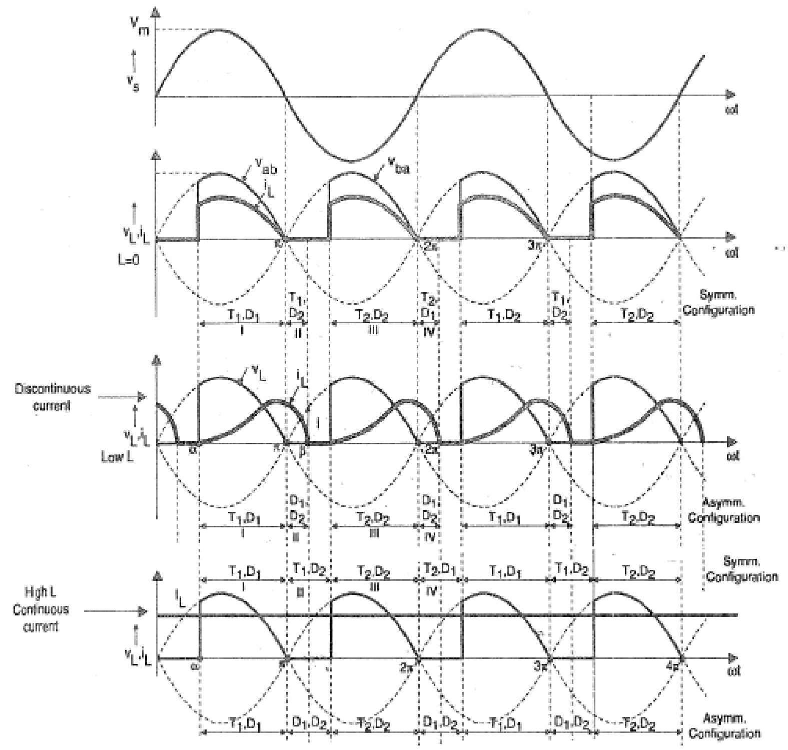


(a) Symmetrical configuration

(b) Asymmetrical configuration

2 marks for any one circuit diagram

Waveforms for Load Voltage and Load Current for inductive load:



1 mark for waveforms for discontinuous conduction

1 mark for waveforms for continuous conduction

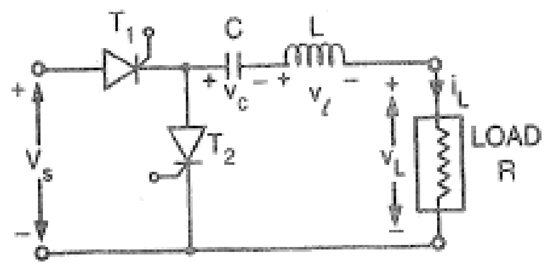
1 a) iii) Define inverter. Draw circuit diagram of basic series inverter.

Ans:

Inverter:

Inverter is a circuit configuration which converts DC supply to AC supply with controlled voltage and frequency. The output voltage can be single-phase or three-phase in nature. — 2 marks for definition

Circuit diagram of basic series inverter: — 2 marks for labeled circuit diagram, 1 mark for unlabeled diagram



1 a) iv) Define chopper. List various types of chopper and state basic principle of chopper.

Ans:

Chopper:

Chopper is a circuit configuration which is a DC to DC converter, which converts Direct voltage into a controlled Direct voltage. — 1 mark for definition

The controlled output DC voltage is obtained by chopping input DC voltage.

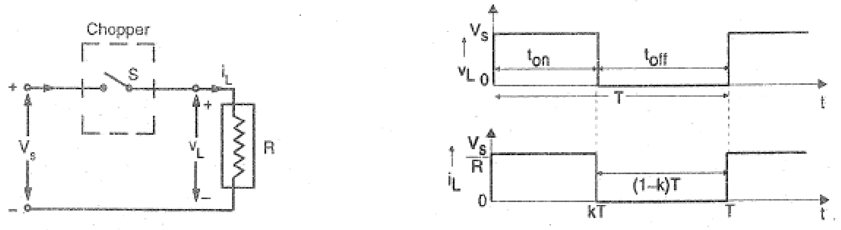
Types of Choppers:

The choppers are classified according to following manner:

1) According to Input and Output voltage levels:
   i) Step-down chopper: $V_{out} \leq V_{in}$
   ii) Step-up chopper: $V_{in} \geq V_{out}$
2) According to the direction of output voltage and current:
   i) Class A (type A) chopper
   ii) Class B (type B) chopper
   iii) Class C (type C) chopper
   iv) Class D (type D) chopper
   v) Class E (type E) chopper
3) According to operation:
   i) Single-quadrant chopper
   ii) Two-quadrant chopper
   iii) Four-quadrant chopper
4) According to commutation method:
   i) Voltage commutated choppers
   ii) Current commutated choppers
   iii) Load commutated choppers
   iv) Impulse commutated choppers

1 mark for types based on any two criteria

Principle of DC chopper:



(a) Basic circuit (b) Waveforms

1 mark for circuit diagram

A chopper is a high-speed On/Off semiconductor switch. During period t_{on}, the chopper is on and the load voltage is equal to the source voltage. During period t_{off}, the chopper is off and the load voltage is zero. In this manner, chopped DC voltage is produced at the load terminals. The average load voltage is given by,

1 mark for explanation

$$V_{Lav} = \frac{1}{T}\int_0^T v_L dt = \frac{1}{T}\left[\int_0^{t_{on}} v_L dt\right] = \frac{1}{T}\int_0^{t_{on}} V_s dt = \frac{V_s(t)_0^{t_{on}}}{T}$$

$$= \frac{t_{on}}{t} V_s = k\, V_s$$

where k is the duty cycle.

Duty cycle of chopper is defined as the ratio of the on time t_{on} of chopper to the period T (= $t_{on} + t_{off}$) of the on-off cycle of chopper.

1 b) Attempt any ONE of the following: 06

1 b) i) State the principle of cyclo-converter. Draw and describe single phase midpoint cyclo-converter with R load.

Ans:

Principle of cycloconverter:

Cycloconerter is a circuit configuration which converts AC into AC of controlled voltage (rms value) and different frequency. Each cycloconverter has two converters: P-converter and N-converter. When SCRs in P-converters are fired in alternate positive and negative half cycles, we get positive voltage across load. Similarly, when SCRs in N-converter are fired in alternate positive and negative half cycles, we get negative voltage across load. Thus for fixed frequency input AC supply, we can obtain positive or negative voltage across load for longer duration (half-cycle) i.e output frequency is reduced.

1 mark for principle

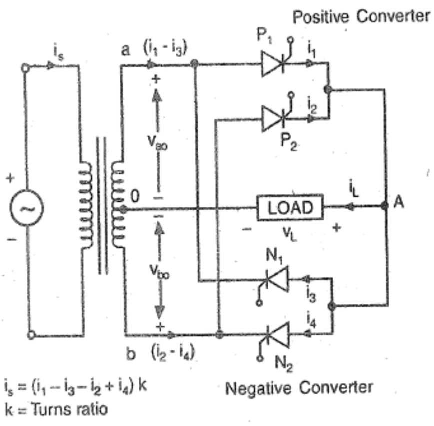
Single-phase mid-point and bridge cycloconverter:

Single-phase mid-point cycloconverter is as shown in fig(a).

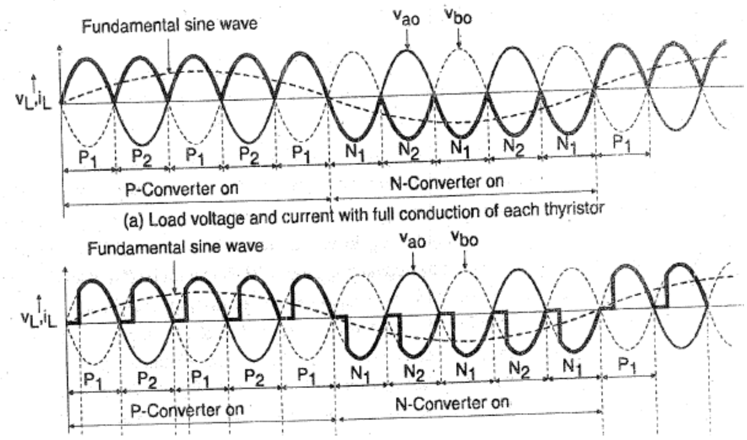
2 marks for circuit diagram

The basic operation is reflected in waveforms. In waveform diagram it is seen that the positive half cycle of output voltage is fabricated/formed/obtained from five half cycles of input AC, so the output frequency is 1/5th of input supply frequency. When the positive half-cycle is desired at output, the SCRs P_1 and P_2 are alternately fired in positive and negative half cycles of input respectiely. Similarly, when the negative half-cycle is desired at output, the SCRs N_1 and N_2 are alternately fired in negative and positive half cycles of input respectiely. Since the load is purely resistive, the load voltage and load current have identical waveforms, as shown below.

2 marks for explanation



(a) Single-phase Mid-point cycloconverter



1 mark for waveforms

1 b) ii) Compare uncontrolled rectifier and controlled rectifier (any six points).

Ans:

Sr. No.	Uncontrolled Rectifier	Controlled Rectifier
1	Only diodes are used	Solid-state switching devices are used such as SCRs, IGBTs etc.
2	No control over output DC voltage	Output DC voltage can be controlled.
3	No control over conduction of load	Control over conduction of load

1 mark for each of any six points = 6 marks

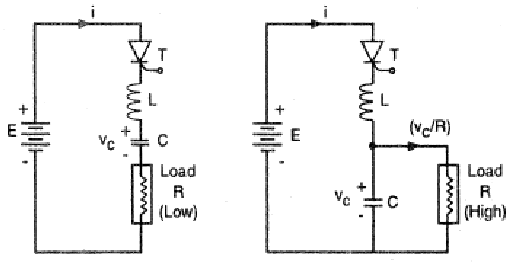
	current	current
4	Freewheeling action for inductive load is inherent	Freewheeling diode need to be connected across load for freewheeling action for inductive load
5	The load voltage cannot become negative at any instant; it is either zero or positive.	The load voltage can become negative
6	The output DC voltage is always positive	The output DC voltage can be positive, zero or even negative
7	The inversion operation is not possible.	The inversion operation is possible
8	The power flow is always from AC side to DC load side.	The power flow can be from AC side to DC side (rectification) or from DC side to AC side (inversion)

2 **Attempt any <u>FOUR</u> of the following:** 16

2 a) How SCR commutates in class A method? Explain with diagram.

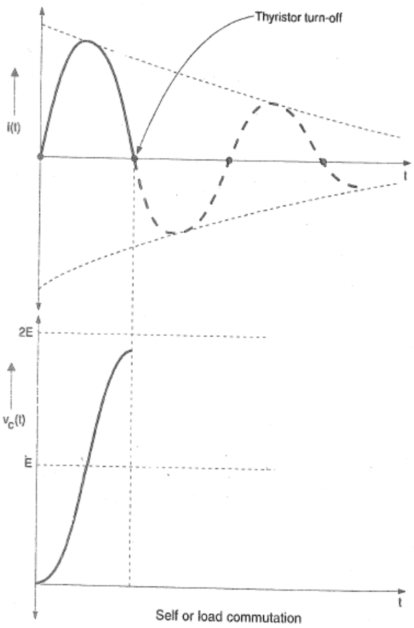
Ans:

Class A: Load Commutation



(a) Load in series with L and C (b) Load in parallel with C

1 mark for circuit diagram



Self or load commutation

1 mark for current waveform

2 marks for explanation

The class A or load commutation (also called self-commutation or resonant commutation) is employed in thyristor circuits supplied from DC source. The commutating components include inductor (L) and capacitor (C). The load resistance (R) and these commutating elements L and C are so chosen that there is a natural tendency for the load current that flows through the thyristor to become zero. When the load resistance (R) is very low, the elements L, C and R are connected in series. However, if load resistance (R) is high, then capacitor (C) is connected across it and then this parallel combination is connected in series with inductor (L) and thyristor as shown in the figure.

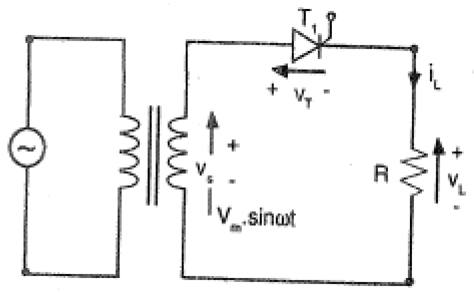
The load resistance R in series with L and C forms a series R-L-C circuit connected across DC source through the thyristor as shown. Initially the thyristor is off, hence entire supply voltage E appears across it and therefore it is forward biased. If a gate pulse is applied, the device can be turned on. Once turned on, it acts as short-circuit, thereby connecting series RLC circuit across DC source. When series RLC circuit

(Load circuit) is underdamped, the current is oscillating having natural zero values even though the supply is DC voltage. Referring to waveform of current, when the thyristor is turned on at t = 0, the current starts to flow, then attains peak and finally falls to zero. During this, the capacitor voltage rises towards 2E. When current reaches to natural zero value, the capacitor voltage is higher than the supply voltage E and hence the thyristor gets reverse biased. Thus the zero-current and reverse-bias cause the thyristor to turn-off.

2 b) With neat circuit diagram, explain working principle of single phase half wave controlled rectifier with resistive load. Draw waveforms across load for firing angle 90°.

Ans:

Single-phase Half-wave controlled Rectifier with Resistive Load:

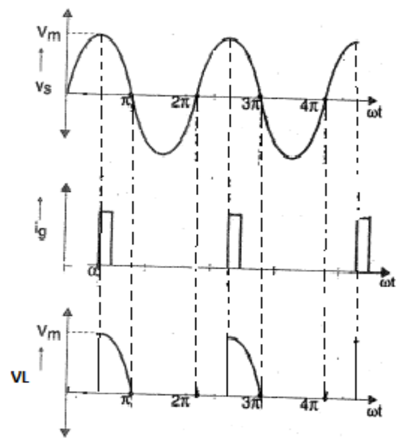


(a) Circuit arrangement

1 mark for circuit diagram

2 mark for explanation

The circuit diagram of 1 ϕ half wave controlled rectifier with resistive load is as shown in the fig. (a). During positive half cycle of input voltage v_s, the thyristor anode is positive with respect to its cathode. Thus thyristor is forward biased. If a short pulse is applied to gate of the thyristor at $\omega t = \alpha$ (here 90°), it is turned on and conducts for rest of the positive half cycle. When the input voltage starts to reverse and become negative after $\omega t = \pi$, thyristor anode becomes negative with respect to its cathode, hence thyristor get reverse biased and it is turned off. During off-state of thyristor, the supply voltage v_s appears across thyristor and load voltage remains zero. Thus during each positive half cycle, the supply voltage appears across load resistance from firing instant to end of that half cycle and during negative half cycle, load voltage remains zero. The waveforms of supply voltage v_s, gate pulses and load voltage v_L are also shown in the figure.



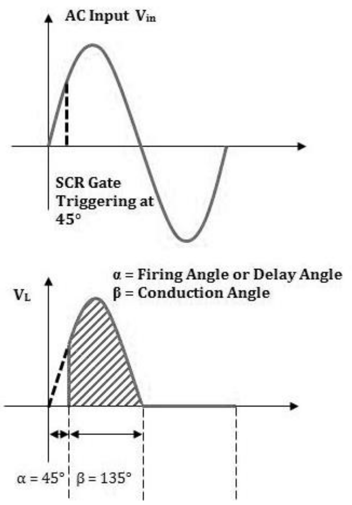
1 mark for waveform

2 c) Define firing angle and conduction angle. Draw the output voltage waveform for full wave controlled rectifier with R load and RL load.

Ans:

Firing Angle(α):

Firing angle is defined as the angle between the instant the SCR would conduct if it would be a diode and the instant it is triggered or fired.



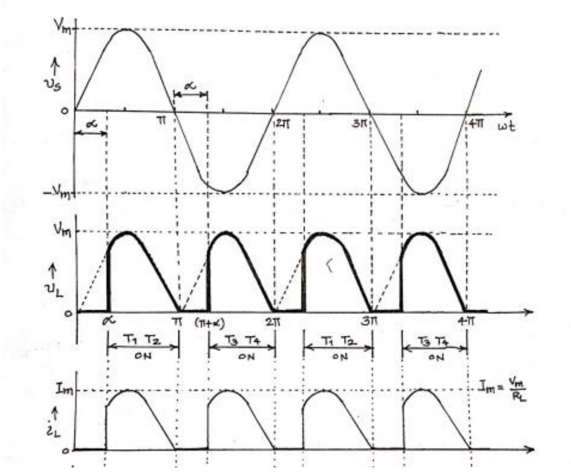
Firing angle or delay angle can be defined as the angle measured from the angle that gives maximum average output voltage to the angle when the SCR is actually triggered or fired by gate pulse.

Conduction Angle (β):
Conduction angle is defined as the angle between the instant the SCR is triggered or turned on and the instant at which the SCR is turned off.

½ mark for each of 2 definitions = 1 mark

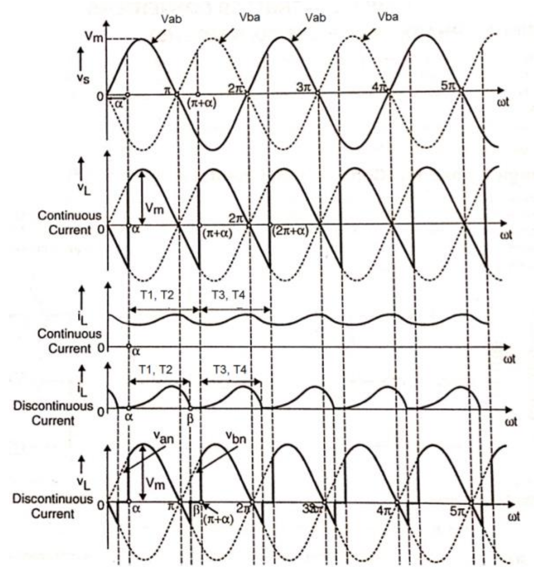
Assuming that the SCR is turned off naturally at the end of positive half cycle, the relation between the firing or delay angle (α) and conduction angle (β) can be expressed as:
$\alpha + \beta = \pi$ radian or 180°

Output voltage waveform for full wave controlled rectifier with R load:
The input and output voltage current waveforms for full wave controlled bridge rectifier with R load are shown in the following figure.



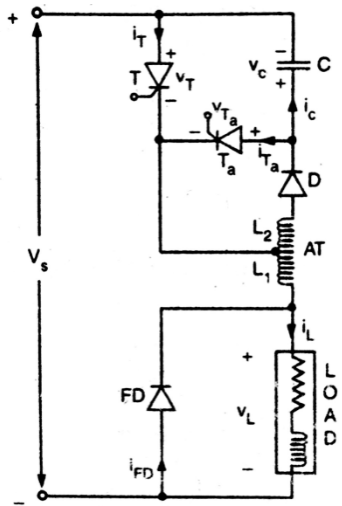
1½ mark

Output voltage waveform for full wave controlled rectifier with RL load:
The input and output voltage current waveforms for full wave controlled bridge rectifier with RL load are shown in the following figure.



1½ mark

2 d) Draw circuit diagram of Jones chopper.
Ans:



Jones chopper

4 marks for labeled diagram

2 to 3 partially labeled,

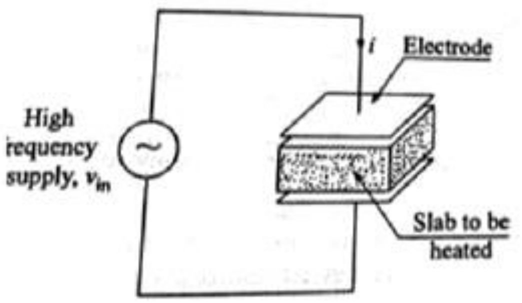
1 marks for unlabeled diagram

2 e) Describe the working principle of dielectric heating with block diagram.

Ans:

Principle of Dielectric Heating:

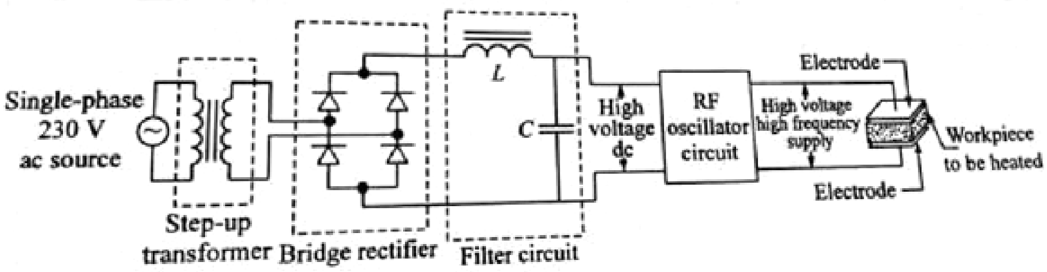
The non-conducting materials (also called insulators or dielectric materials) whenever subjected to an alternating electric field, some power loss takes place in them and heat is generated. This power loss is called “Dielectric Loss”. The process wherein the heating takes place due to dielectric loss is known as “Dielectric Heating”.



2 marks for principle explanation

When dielectric material is subjected to an alternating electric field, the rapid reversal of the field distorts and agitates the molecular structure of the material. The internal molecular friction generates heat uniformly throughout all parts of the material. Even though the material is poor conductor of heat and electricity, thick layers of material can be heated in minutes instead of hours.

Thyristors are used inverter which converts DC into high frequency AC. This high-frequency supply is applied across the electrodes to heat up the work-piece dielectric material, as shown in the following diagram.

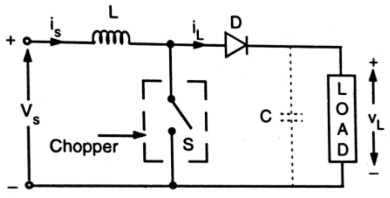


2 marks for block diagram

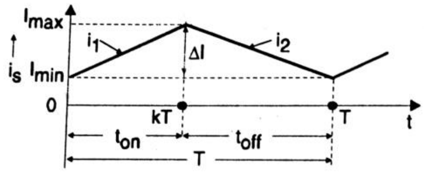
2 f) Describe step-up chopper with neat diagram.

Ans:

Step-up Chopper:



(a) Basic circuit arrangement



(b) Current waveform

The circuit diagram for step-up chopper is shown in fig.(a). When the switch S is on (closed) for time t_{on} the inductor L is placed across the DC supply source V_s and the current through inductor rises linearly as shown in fig.(b). During this time interval, energy is stored in the inductor. If the switch is opened and maintained off for time t_{off} , the inductor voltage changes its polarity and aids the DC source to force the current through D and load. The load voltage is thus the sum of supply voltage V_s and inductor voltage v_l. Therefore, the output load voltage is greater than the input dc voltage. Hence it is termed as Step-up chopper. During this time interval t_{off}, the energy stored in the inductor is given out and the current falls as shown in fig.(b). The waveform of supply current i_s for continuous conduction is shown in fig.(b). When the chopper is on, the voltage across inductor is given by:

2 marks for diagrams

1 mark for explanation

$v_l = V_s = L\frac{di_s}{dt}$ for ($0<t<t_{on}$)

$$\therefore V_s = L\frac{(I_{max} - I_{min})}{t_{on}} = L\frac{\Delta I}{t_{on}}$$

Peak to peak ripple current in inductor is $\Delta I = \frac{V_s}{L}t_{on}$

When the chopper is off, i.e switch S is open, the instantaneous output voltage is:

$$v_L = V_s + L\frac{di_L}{dt} = V_s + L\frac{di_s}{dt} = V_s + L\frac{\Delta I}{t_{off}} = V_s + L\frac{V_s}{L}\frac{t_{on}}{t_{off}}$$

$$= V_s\left[1 + \frac{t_{on}}{t_{off}}\right] = V_s\left[1 + \frac{t_{on}/T}{t_{off}/T}\right] = V_s\left[1 + \frac{k}{(T - t_{on})/T}\right]$$

$$= V_s\left[1 + \frac{k}{1-k}\right] = V_s\left[\frac{1 - k + kt_{on}}{1-k}\right]$$

$$\therefore v_L = V_s\left[\frac{1}{1-k}\right]$$

1 mark for mathematical treatment

From this equation, it is clear that for k<1, the load voltage v_L is greater than supply voltage V_s , and the circuit acts as a step-up chopper.

If a large capacitor C connected across the load, the output voltage will be continuously available. During t_{on} capacitor will charge and during t_{off} it will discharge and provide output voltage.

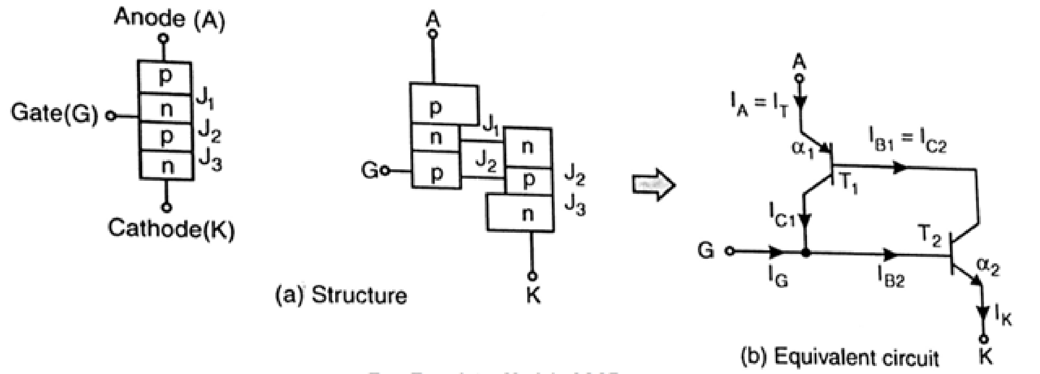
3 Attempt any FOUR of the following: 16

3 a) Explain two transistor analogy of SCR with a neat diagram.

Ans:

Two-transistor Analogy of SCR:

A simple p-n-p-n structure of thyristor can be visualized as consisting of two complimentary transistors: one pnp transistor T_1 and other npn transistor T_2 as shown in the fig. The collector current of transistor is related to emitter current and leakage current as:



Two Transistor Model of SCR

2 marks for diagram any one diagram

I_C

$= \alpha I_E + I_{CBO}$

where, α = common-base current gain

I_{CBO}= leakage current from collector to base with emitter open

For transistors T_1 and T_2, we can write,

$I_{C1} = \alpha_1 I_A + I_{CBO1}$ and $I_{C2} = \alpha_2 I_K + I_{CBO2}$

From KCL applied to T_1, we can write

$$I_A = I_{C1} + I_{C2} = \alpha_1 I_A + I_{CBO1} + \alpha_2 I_K + I_{CBO2}$$

From KCL applied to entire equivalent circuit,

$I_K = I_A + I_G$ and substituting in above equation,

2 marks for explanation

$I_A = \alpha_1 I_A + I_{CBO1} + \alpha_2(I_A + I_G) + I_{CBO2} = I_A(\alpha_1 + \alpha_2) + \alpha_2 I_G + I_{CBO1} + I_{CBO2}$

$I_A(1 - [\alpha_1 + \alpha_2]) = \alpha_2 I_G + I_{CBO1} + I_{CBO2}$

$$I_A = \frac{\alpha_2 I_G + I_{CBO1} + I_{CBO2}}{1 - [\alpha_1 + \alpha_2]}$$

From this equation it is clear that the anode current depends on the gate current, leakage currents and current gains.

If $(\alpha_1 + \alpha_2)$ tends to be unity, the denominator $1 - [\alpha_1 + \alpha_2]$ approaches zero, resulting in a large value of anode current and SCR will turn on. The current gains vary with their respective emitter currents. When gate $I_G$current is applied, the anode current I_A is increased. The increased I_A, being emitter current of T_1, increases the current gain α_1. The gate current and anode current together form cathode current, which is emitter current of T_2. Thus increase in cathode current results in increase in current gain α_2. Increased current gains further increase the anode current and the anode current further increases the current gains. The cumulative action leads to the loop gain to approach unity and the anode current drastically rises which can be controlled by external circuit only.

3 b) Describe with neat diagram three phase fully controlled bridge converter with RL load.

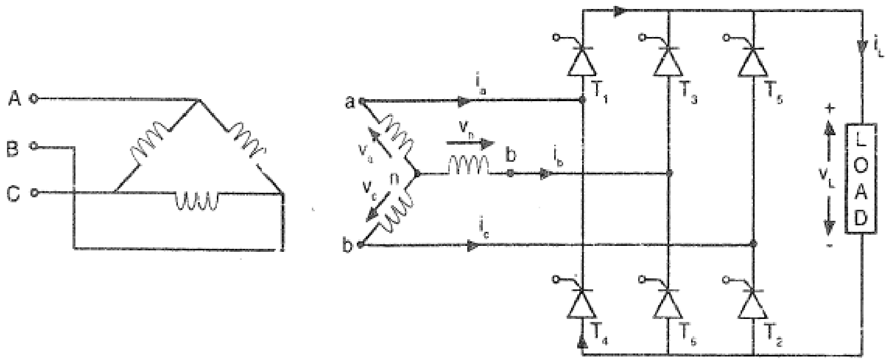
Ans:

Three-phase full controlled bridge converter:

The circuit diagram of 3ϕ fully controlled bridge converter is shown in fig.(a). Six thyristors are connected in bridge to obtain full wave rectification. One of the upper thyristors T_1, T_3, T_5 carry current from secondary winding to load and one of the lower thyristors T_2, T_4, T_6 carry current back from load to secondary winding. The pair of the thyristors which is connected to those lines having a positive instantaneous line-to-line voltage is fired. If v_{ab} is positive, then the thyristor connected to phase ai.e T_1 and thyristor connected to phase b i.e T_6 are fired. The

2 marks for description

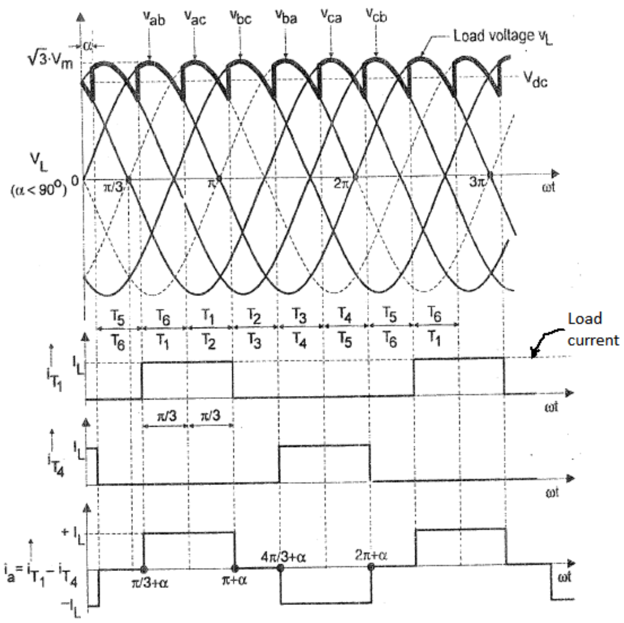
thyristors are fired at an interval of $\pi/3$ rad or 60°. Each thyristor conducts for $2\pi/3$ rad or 120°. The fig.(b) shows the waveforms of line voltage, output load voltage, thyristor currents, line current and load current.



(a) Circuit arrangement

2 marks for circuit diagram (Waveforms optional)

At $\omega t = 0$, the line voltage v_{cb} is higher than any other line voltage, hence thyristor T_5 connected to phase c and thyristor T_6 connected to phase b are fired at delay angle α. After firing T_5 and T_6, the load voltage becomes equal to v_{cb}. The upper load terminal gets connected to phase c and voltage v_{ac} appears across T_1 and voltage v_{bc} across T_3. As both v_{ac} and v_{bc} are negative, both T_1 and T_3 are reverse biased. Similarly the lower load terminal gets connected to phase b through T_6 and voltage v_{ba} appears across T_4 and voltage v_{bc} across T_2. As both v_{ba} and v_{bc} are negative, both T_4 and T_2 are reverse biased. Thus firing of a pair of thyristors causes all other thyristors to be reverse biased. This condition is continued till $\omega t = \pi/3$. After this the line voltage v_{ab} becomes higher than v_{cb}. At $\omega t = \pi/3$, the line voltage v_{ac} crosses zero value and becomes positive, due to which T_1 get forward biased. So a gate pulse is applied to T_1 at $\omega t = (\pi/3)+\alpha$. Once T_1 is turned on, the upper load terminal gets connected to phase a, causing line voltage v_{ca} across conducting T_5. As v_{ca} is negative, T_5 get reverse biased and turned off. The load current get shifted fromT_5 to T_1. However, the thyristor T_6 remains on and continue to carry load current with T_1. The load voltage then becomes equal to v_{ab}. In this way the thyristors are fired in sequence and successively line voltages appear across load as



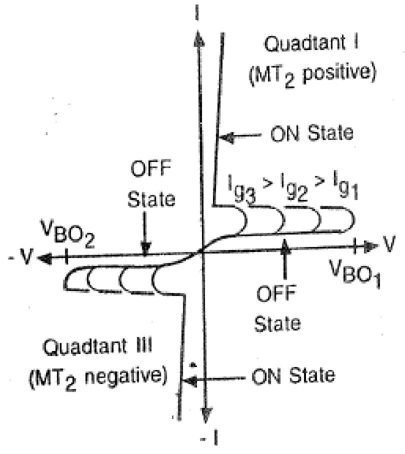
(b) Waveforms

shown in fig.(b).Since the load is inductive (R-L), for highly inductive nature, the load current becomes constant. The thyristors carry current in the form of rectangular pulses and input line current has quasi-square waveform.

3 c) Draw VI characteristic of TRIAC. Give two application of TRIAC.

Ans:

V-I Characteristic of TRIAC:



V-I Characteristics

2 marks for labeled characteristics

1 mark for unlabeled characteristics

Applications of TRIAC:

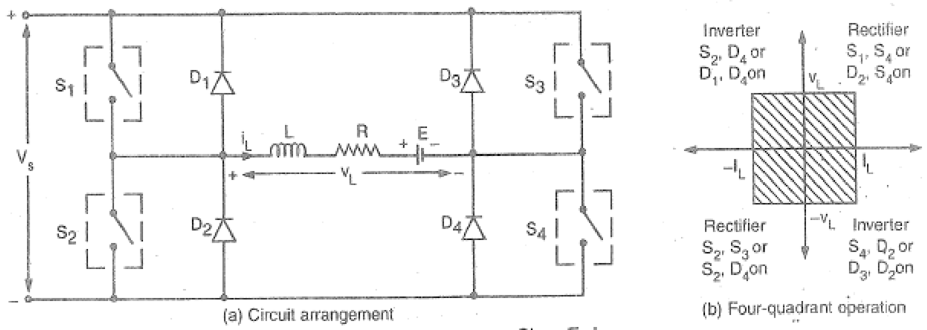
1) Lamp dimmer
2) Fan regulator
3) Heating control
4) Zero voltage switched relay
5) Small AC motor control

1 mark for each of any two applications

3 d) Explain the operation of four quadrant chopper with quadrant diagram.

Ans:

Four quadrant chopper:(Class E Chopper)



Class E chopper

1 mark for Diagram

1 mark for 1 to 2 quadrants operation

2 marks for 3 quadrants operation

3 marks for all 4 quadrant operation

The circuit arrangement of Class E chopper (four quadrant chopper) is shown in Fig. (a). In this chopper, the load current i_L and load voltage v_L can be either positive or negative, exhibiting four quadrant operation, as shown in the fig.(b). The reference direction for i_L and positive reference polarity for v_L is as shown in the circuit.

The operation of this chopper in different quadrants is as follows:

First Quadrant Operation:

- Both v_L and i_L are positive.
- During power transfer from input dc source to load, the conducting devices

are S_1 and S_4.

- During free-wheeling, the conducting devices are D_2 and S_4.

Second Quadrant Operation:

- The load voltage v_L is positive but the load current i_L is negative.
- The power is transferred from load to input dc source, the conducting devices are D_1 and D_4.
- During free-wheeling, the conducting devices are S_2 and D_4.

Third Quadrant Operation:

- Both the load voltage v_L and the load current i_L are negative.
- The power is transferred from input dc source to load, the conducting devices are S_2 and S_3.
- During free-wheeling, the conducting devices are S_2 and D_4.

Fourth Quadrant Operation:

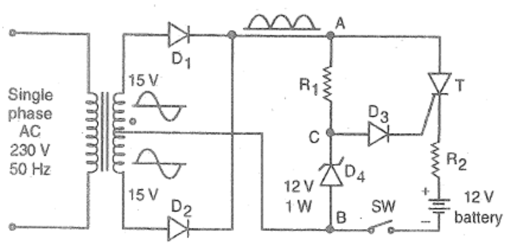
- The load voltage v_L is negative but the load current i_L is positive.
- The power is transferred from load to input dc source, the conducting devices are D_2 and D_3.
- During free-wheeling, the conducting devices are S_4 and D_4.

3 e) Draw circuit diagram of battery charger circuit using SCR. Explain its working.

Ans:

Battery charger circuit using SCR:

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 D_1 and D_2 forms full wave rectifier and pulsating DC supply appears across terminals A and B. When SCR is off, its cathode is held at the potential of discharged battery. During each positive half-cycle, when the potential of point C rises to sufficient level so as to forward bias diode D_3 and gate-cathode junction of SCR, the gate pulse is provided and SCR is turned on. When SCR is turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and charging current is passed till the end of that half-cycle. Due to Zener diode D_4, the maximum voltage at point C 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 D_3 and gate-cathode junction of SCR cannot be forward biased, since the potential of point C can reach up to 12V. Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.



Automatic battery charger using SCR

2 marks for Labeled circuit diagram,

1 mark for unlabeled circuit diagram,

2 marks for Description

4 a) Attempt any THREE of the following: **12**

4 a) i) Describe speed control of 3ϕ induction motor with variable frequency square wave inverter method.

Ans:

Variable frequency control of induction motor:

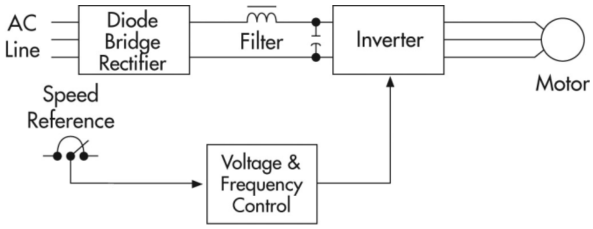
The speed of an induction motor can be controlled by varying the supply frequency. When the supply frequency is changed, the synchronous speed N_s (=120f/P) is changed and accordingly the motor speed get changed.

If the supply frequency f is changed to f* such that f* = β.f, the synchronous speed at new frequency f*becomes,

$N_S^* = \frac{120f^*}{P} = \frac{120\beta f}{P} = \beta N_s$ and the slip becomes $s^* = \frac{\beta N_S - N}{\beta N_S} = 1 - \frac{N}{\beta N_S}$ 1 mark

The maximum torque developed at any supply frequency is inversely proportional to the square of frequency. Therefore, maximum torque gets reduced in inverse proportion when frequency is increased.

When the frequency is changed, the values of the reactances in the equivalent circuit are changed and therefore circuit currents are also changed. If the frequency is increased above its rated value, the reactances are also increased, the currents fall, the flux and maximum torque get decreased but synchronous speed is increased and motor speed is also increased. 1 mark



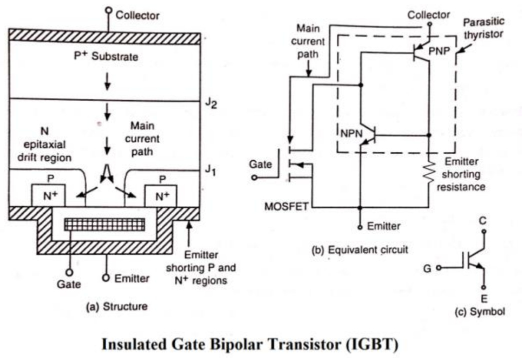
1 mark for Figure

With a Square wave inverter indicated in figure, the supply frequency to the motor can be easily adjusted for variable speed. However, if rated airgap flux is to be maintained at its rated value at all speeds, the supply voltage to the motor should be varied in proportion to the frequency. In the figure, the dc voltage obtained from diode rectifier remains constant, however, properly firing the switching devices of inverter, the voltage and frequency can be controlled within the inverter. The firing pulses to switching devices are supplied according to the requirement of speed. 1 mark

4 a) ii) Draw construction of IGBT. Give any two advantages of IGBT.

Ans:

Construction of IGBT:



Insulated Gate Bipolar Transistor (IGBT)

2 marks for diagram (Equivalent circuit is optional)

Advantages of IGBT:

1) An IGBT is a latch-proof device i.e after turn-on it is not latched into on state, gate voltage is continuously required to maintain it on.
2) It has lower switching and conduction losses.

3) The switching frequency of IGBT is upto 20 kHz.
4) Turn-on time of IGBT is less than that of SCR.
5) The turn-off time of IGBT (< 2μsec) is much less than that of SCR (200 μsec)
6) An IGBT is a voltage controlled device.
7) It has high input impedance.

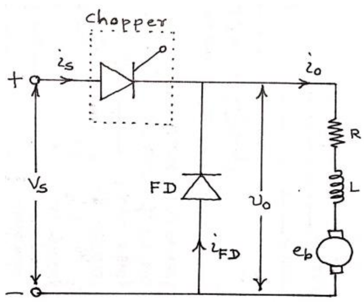
1 mark for each of any two advantages

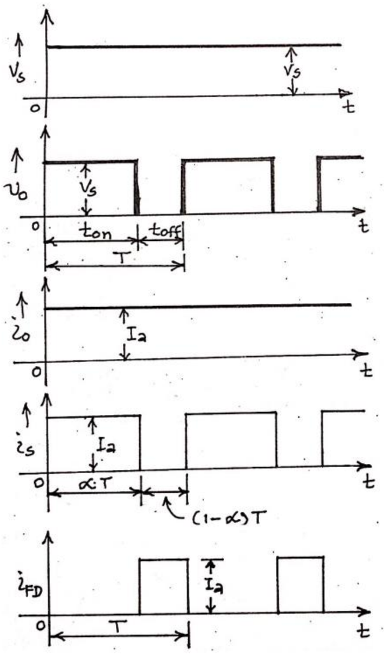
4 a) iii)Describe the speed control of DC motor using step down chopper.

Ans:

Speed control of DC series motor using step down chopper:

Figure shows the basic arrangement for speed control of DC series motor using step down chopper. Armature current is assumed continuous and ripple free. The waveforms for the source voltage V_s, Motor terminal voltage v_0, motor current i_0, dc source current i_s and freewheeling diode current i_{FD} are also shown.





1 mark for circuit diagram

1 mark for waveforms

1 mark for explanation

1 mark for mathematical treatment

Average motor voltage is given by,

$$V_0 = \frac{t_{on}}{T} V_s = \alpha V_s = f t_{on} V_s$$

where α = duty cycle = $\frac{t_{on}}{T}$

and f= Chopping frequency = $\frac{1}{T}$

Power delivered to motor is given by,

Power delivered to motor = Average motor voltage × Average motor current

$$= V_t I_a = \alpha\, V_s I_a$$

Motor voltage equation can be expressed as,

$$V_0 = \alpha\, V_s = E_b + I_a(R_a + R_{se})$$

The back emf is proportional to speed, $E_b \propto \omega_m \therefore E_b = K_m \omega_m$

Thus voltage equation becomes, $V_0 = \alpha\, V_s = K_m \omega_m + I_a(R_a + R_{se})$

The speed can be obtained as, $\omega_m = \frac{\alpha\, V_s - I_a(R_a + R_{se})}{K_m}$

It is seen that by varying the duty cycle α of the chopper, armature terminal voltage can be controlled and thus speed of the dc series motor can be regulated.

OR

Any alternate circuit and its description

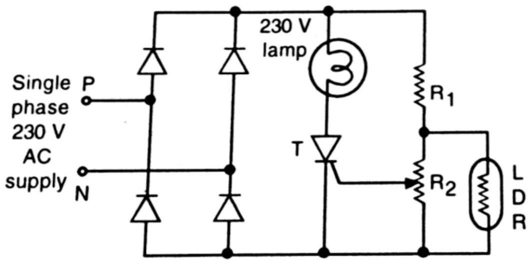
4 a) iv) Describe automatic street light circuit using SCR.

Ans:

Automatic Street Lighting Circuit Using SCR:

The circuit configuration of automatic street lighting system using SCR is shown in the fig. This circuit provides automatic glowing of street lamps in the evening. A light dependent resistor (LDR) is used as sensor for sensing the intensity of day light. When sufficient light falls on LDR, its resistance becomes very low as compared to R_2. The R_2 is then bypassed by LDR, and major part of current flowing through R_1, flows through LDR. Since negligibly small current flows through R_2, sufficient gate current is not received by SCR T and it is maintained off. Thus no current can flow through lamp and it remains off.

2 marks for circuit diagram



Automatic street lighting system

In the evening hours, the intensity of day light is reduced. Hence resistance of LDR increases. Therefore current through R_2 also increases. At certain darkness, the resistance of LDR becomes so high that the sufficient current flows through R_2 to provide sufficient gate current to SCR and it is fired. Therefore, current flow through lamp and it glows. Since bridge rectifier provides pulsating DC, the SCR is triggered in every positive pulse and turn-off at the end of pulse at natural current zero value, assuming lamp is purely resistive. However, if the lamp is inductive, the lagging current prevents SCR from turning off at the end of positive pulse. Thus once SCR is turned on, it loses control and separate arrangement is necessary to turn-off the SCR.

2 marks for description

OR

Any alternate circuit and its description

4 b) **Attempt any <u>ONE</u> of the following:** **06**

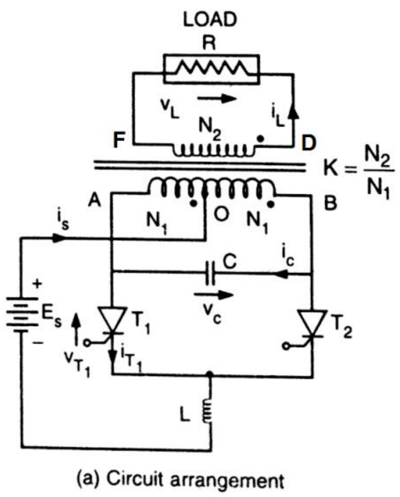
4 b) i) Explain operation of basic parallel inverter with waveform.

Ans:

Basic Parallel Inverter:

The circuit diagram of basic parallel inverter is shown in fig.(a). The load is connected on the secondary side of centre-tapped transformer. The commutating capacitor C is connected across full primary winding, hence appears effectively in parallel with load. This is the reason why the inverter is termed as parallel inverter.

When T_1 is turned on, the DC source voltage E_s appears across half primary winding OA, neglecting small voltage drop in inductor L. Due to auto-transformer action, same voltage E_s is induced in other half primary winding OB. Thus total voltage across full primary becomes $2E_s$ with terminal B positive with respect to A. Since



(a) Circuit arrangement

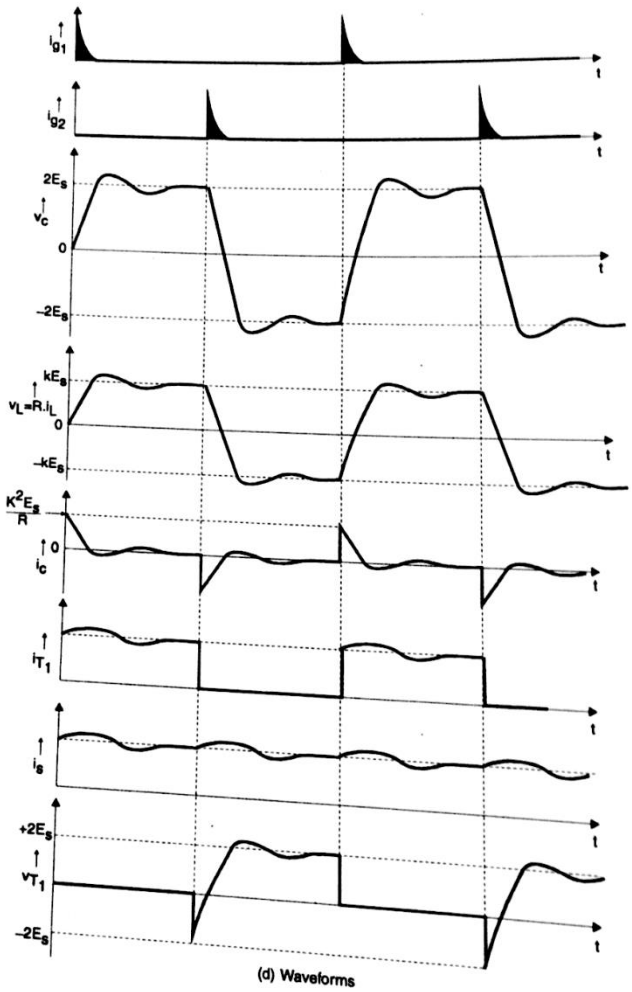
2 marks for circuit diagram

2 marks for explanation

2 marks for waveforms

= 6 marks

capacitor C is in parallel with full primary, it gets charged to $2E_s$ with right plate positive. The voltage is induced in secondary with terminal D positive with respect to terminal F. The charged capacitor C is placed across non-conducting SCR T_2 via conducting SCR T_1. Thus T_2 get forward biased is ready to conduct.


(d) Waveforms

When gate pulse is applied to T_2, it is turned on and charged capacitor C is placed across T_1 via T_2. It causes reverse bias across T_1 and it is turned off. The capacitor then discharges through T_2, L and DC source and recharges with opposite polarity to $-2E_s$. Thus primary voltage gets reversed, which also cause reversal of secondary (load) voltage. It is seen that the charged capacitor always provides forward bias to non-conducting SCR. If that SCR is gate triggered, it is turned on and already conducting SCR is turned off due to reverse bias provided by the capacitor placed across it through just triggered SCR.

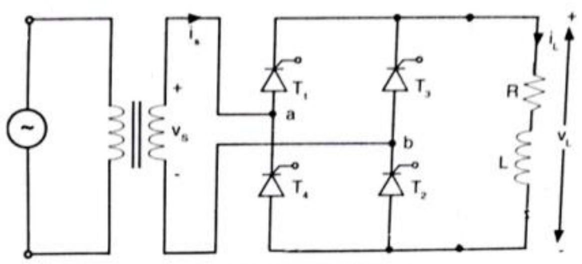
Ideally the voltages across primary and secondary have rectangular waveforms but due to capacitor charging and non-linearities in magnetic circuit, the primary and secondary voltage waveforms appear close to trapezoidal. The waveforms of load voltage, SCR voltage, source current, SCR current and capacitor current are shown in Fig.(b).

4 b) ii) With neat diagram, explain single phase full bridge converter with RL load. Draw input, output waveform.

Ans:

Single phase full bridge converter with RL load:

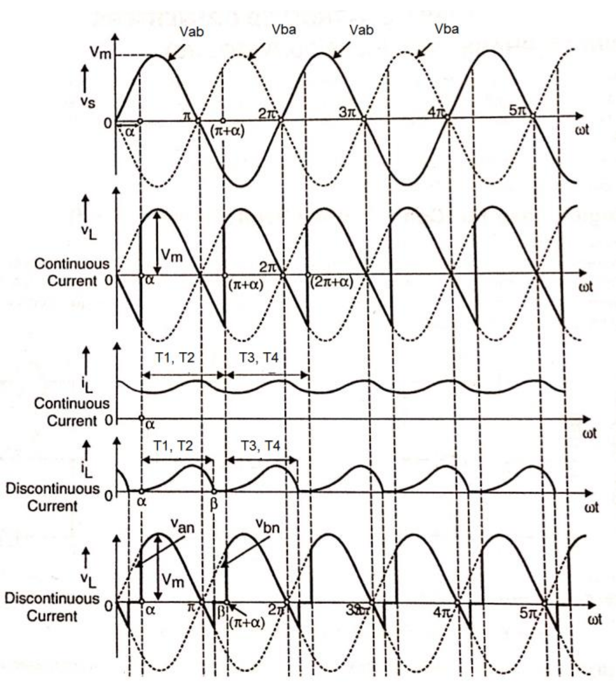
It consists of four SCRs connected in bridge as shown in the circuit diagram. During positive half cycle of input voltage, T_1 and T_2 are forward biased and during negative half cycle, T_3 and T_4 are forward biased. Therefore, T_1-T_2 pair and


(a) Circuit arrangement

2 marks for diagram

T_3-T_4 pair are fired alternately in positive and negative half cycles of input voltage respectively, as shown in the waveform diagram. In each half cycle, the respective SCRs are fired at firing or delay angle α, as shown. Once SCR pair conducts (at delay angle in each half cycle), the input source voltage appears across load, the current flows and if the load is inductive in nature, the conducting SCRs remain into conduction till the fall of current to zero or firing of next pair of SCRs as shown in the waveform diagram.

Due to load inductance, the current lags behind the output voltage and falls to zero after the end of that half cycle. Therefore, during the time interval between voltage zero instant and current zero instant, the reversed supply voltage appears across load for discontinuous conduction. At current zero, the SCRs are turned off and load gets isolated from source, causing load voltage zero till the firing of next pair of SCRs.



(b) Waveforms

2 marks for waveforms

2 marks for explanation

If load inductance is large, the load current never falls to zero. The current attempts to fall, but before it could fall to zero, the next pair of SCR get fired and we get continuous conduction. In this situation, the reversed voltage appears across load after the end of each half cycle till the firing of next pair of SCRs as shown in the waveform diagram.

5 Attempt any FOUR of the following: 16

5 a) State and describe principle of resistance welding with a neat diagram.

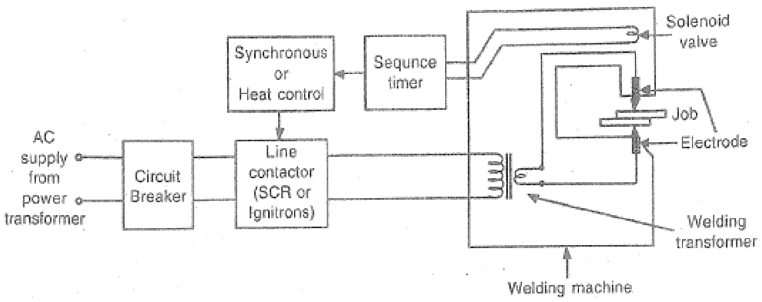
Ans:

Principle of Resistance Welding:

It is the process of welding by fusing together two or more pieces of metal by passing high ac or dc current for short duration through the area of contact.

The block diagram of general resistance scheme is shown in the figure. The AC supply is obtained from power transformer. The circuit breaker is used to switch on

1 mark for principle



Resistance welding scheme

1 mark for diagram

and off the supply either manually or automatically under normal or abnormal conditions. The functions of other blocks are as follows:

1) Line Contactor: It is basically a switch which permits the welding current to flow to heat the metal pieces and make the weld. Since the welding current needs to flow for short duration, the contactor must close and then open quickly. For precise and noise free operation, it can be implemented by solid-state devices such as SCR.
2) Synchronous or Heat Control: An electronic circuit is used to control the firing of SCRs, which controls the voltage supplied to primary winding of welding transformer. By controlling the primary voltage, the welding current in the secondary is controlled to control the heat and weld. 2 marks for description
3) Sequence Timer: It is an electronic timing circuit that provides timing signals to carry out the welding process in a particular sequence. The signals are provided in following sequence:
   i) The signal is provided to solenoid valve, which when opened, applies air pressure so that the electrodes come together and squeeze the metal pieces.
   ii) The signal is then given to heat control unit to start the flow of welding current for welding.
   iii) The signal is then given to heat control unit to stop the welding current.
   iv) The signal is then given to solenoid valve to close it, so that the air pressure is reduced and electrodes are separated.
   v) Finally signal is generated to recycle the operation.

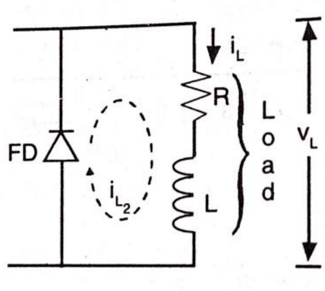
In this way, the resistance welding scheme works.

5 b) State the function of freewheeling diode in converter with a neat diagram.

Ans:

Function of freewheeling diode in converters:

The freewheeling diode (FD) is connected across output or load with its cathode to positive terminal and anode to negative terminal. When the load is highly inductive, the load inductance voltage gets reversed during the fall of load current. The output or load voltage then attempts to reverse but as soon as the reversed voltage becomes more than threshold voltage, the freewheeling diode conducts and provides path for inductive load current. Since diode conducts, it maintains the load voltage nearly equal to zero and prevents from becoming negative. It improves the average load voltage and helps to dissipate the power stored in load inductance.



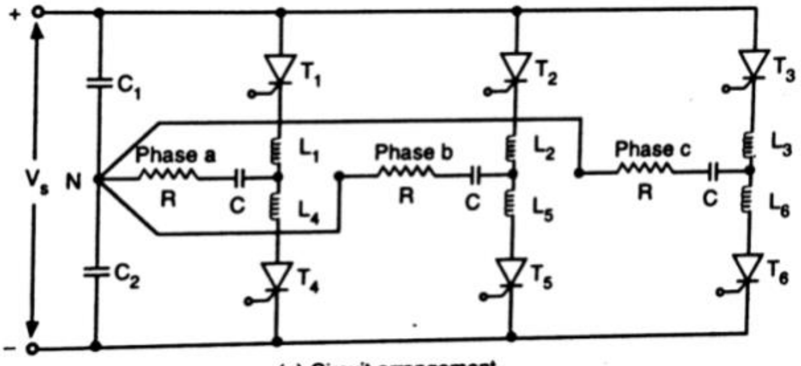
2 marks for function

2 marks for diagram

5 c) Draw circuit diagram of three phase inverter.

Ans:

Circuit diagram of three phase inverter:



(a) Circuit arrangement

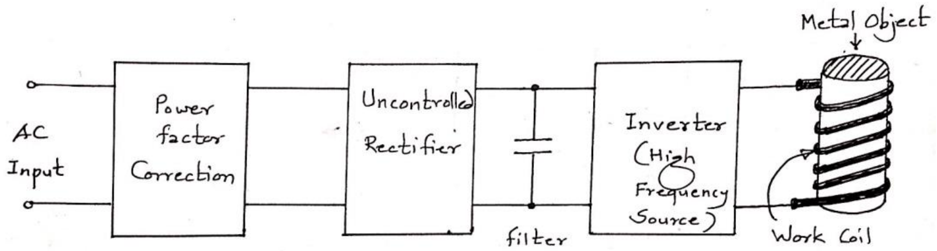
Labeled diagram =4 marks
Partially labeled diagram =2 to 3 marks
Unlabeled =1 mark

OR any other circuit diagram of Bridge Inverter

5 d) Draw block diagram of induction heating and explain any one application of it.

Ans:

Principle of Induction Heating:



2 marks for block diagram

When a conducting object is subjected to a changing magnetic field, according to Faraday's laws of electromagnetic induction, emf is induced in the object. The object, being conductor, offers many short-circuited paths. So the circulating currents flow through these paths. The currents are in the form of eddies (circular in nature), hence called "eddy currents". The eddy currents flowing through resistive paths in metal object cause power loss (i^2R loss) and heat is produced. Since the heat is produced by eddy currents, which are induced by electromagnetic induction, this heating is called "Induction heating".

2 marks for explanation of any one application

Surface hardening of Steel:

The surface hardening of steel objects is required to get tough body and hard surface of the object. In case of steel shaft, it is necessary that the inner portion of shaft must be tough enough to withstand the jerks due to twisting moments and the surface must be hard to offer high resistance to wear and tear. If entire shaft is hardened, it may become brittle and fails to withstand the jerks. So the tough body with hard surface is the necessary requirement of the shaft which can be achieved by surface hardening.

The shaft whose surface is to be hardened is placed inside water cooled, helical coil made up of copper tubing (work coil) as shown in the figure. A heavy current at high frequency (about 400 kHz) is passed through the work coil so as to produce strong high frequency magnetic field through the shaft. Due to high frequency, the induced eddy currents are concentrated near the surface, hence surface is heated. The shaft is then immediately quenched in water or oil. Since the current is maintained for short duration (5 to 10 sec) and then shaft is immediately quenched, the heat is not penetrated deep into the shaft by conduction. Hence the toughness of inner portion remains unaltered, whereas the surface becomes hard due to heat treatment.

5 e) Compare MOSFET inverter with thyristor based inverter (any four points).

Ans:

Comparison between MOSFET inverter with thyristor based inverter:

	MOSFET based Inverter	Thyristor based inverter
1	These are based on Power MOSFETs as switching devices	These are based on SCR as switching devices
2	Power MOSFETs are voltage controlled devices and trigger circuit operates at low power.	SCRs are current controlled devices and triggering circuit consumes more power.
3	Fast turn ON and OFF	Slow turn ON and OFF as compared to MOSFET
4	Inverters operate at higher switching frequency.	Inverters operate at lower switching frequency.
5	Switching losses are less	Switching losses are more
6	Operate at small / medium power rating.	Can operate at higher power rating.
7	Quality of the inverter output waveform can be improved by increasing switching frequency.	Quality of the output waveform is less

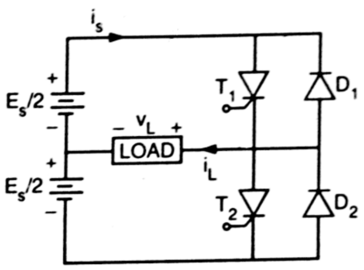
1 mark for each of any four points

5 f) Describe half bridge inverter with circuit diagram.

Ans:

Half bridge inverter:

The circuit diagram of single-phase half-bridge inverter is shown in fig.(a). The circuit configuration requires three-wire DC supply, two SCRs and two diodes. The firing and commutation of SCRs is carried out by separate circuits, which are not shown here. The firing pulses and voltage-current waveforms are shown in fig.(b). The SCRs are turned off by commutation circuits when the gate pulses are removed. The SCRs are turned on alternately, thereby providing alternating voltage to the load.



(a) Circuit arrangement

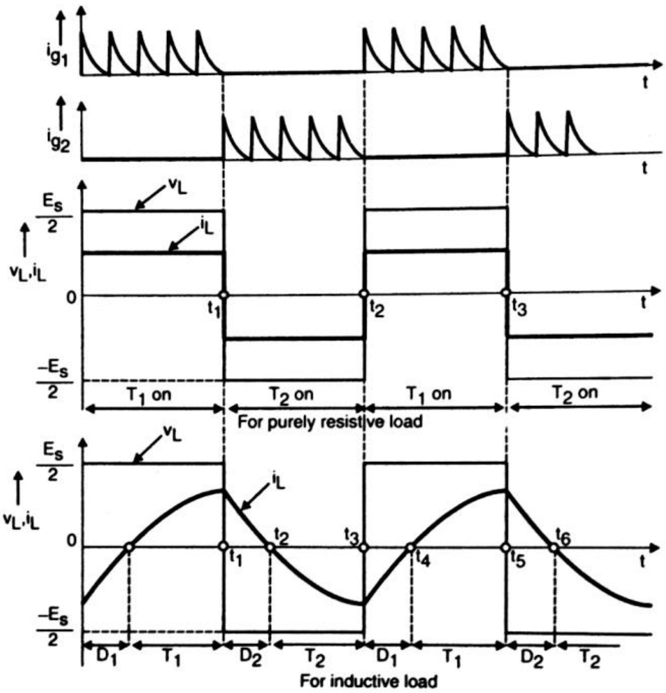
2 marks for diagram

1 mark for description

1 mark for waveforms

Purely Resistive Load:

Referring to waveforms in fig.(b), at t=0, the SCR T_1 is fired by gate pulse train. Once T_1 conducts, the upper source voltage ($E_s/2$) appears across the load. Thus constant voltage $+E_s/2$ appears across load when T_1 is on and T_2 is off. The load current is positive. At instant t = t_1, the gate pulses of T_1 are removed and gate pulses are provided to T_2. Thus at t = t_1, T_1 is turned off and upper source voltage appears across T_1 whereas, T_2 is turned on and lower source voltage appears across load. Therefore load voltage is reversed and reversed current flows. During the period when T_2 is on, constant voltage $–E_s/2$ appears across load. Thus alternate switching of T_1 and T_2 causes alternating voltage across load and the load current follows the load voltage variations. The load voltage and load current both have rectangular waveforms as shown in fig.(b).



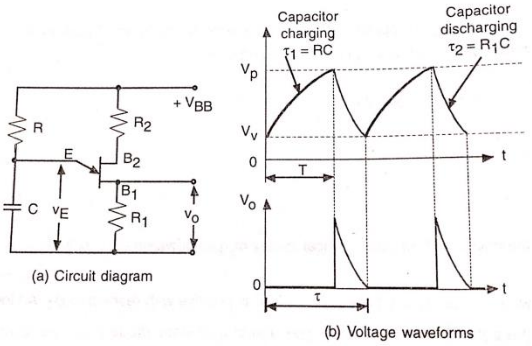
(b) Waveforms

6 **Attempt any <u>FOUR</u> of the following:** **16**

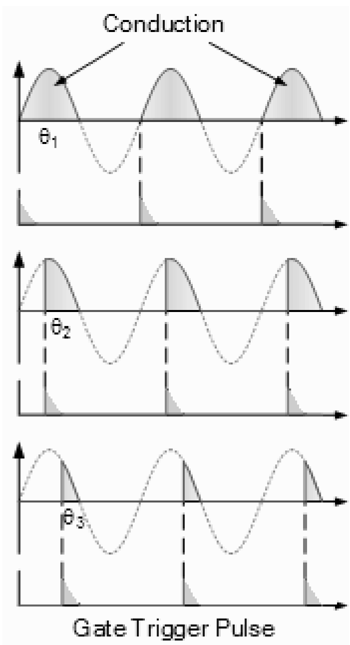
6 a) Draw circuit diagram of UJT triggering of SCR. Draw waveform to show firing angle control.

Ans:

UJT triggering of SCR: (UJT as Relaxation Oscillator)



(a) Circuit diagram
(b) Voltage waveforms
UJT Relaxation oscillator



2 marks for circuit diagram

1 mark for waveforms for phase control

For triggering of SCR, the UJT is used as relaxation oscillator. The circuit diagram of UJT as relaxation oscillator is shown in the figure. The external resistances R_1 and R_2 are small in comparison with the internal base resistances R_{B1} and R_{B2} of UJT. The emitter potential v_E is decided by the capacitor voltage. The capacitor is charged through R. The charging resistance should be such that its load line intersects the device characteristic curve only in the negative resistance region.

When DC supply voltage (pulsating DC from the output of rectifier) V_{BB} is applied the capacitor C begins to charge through R exponentially towards V_{BB}. Initially the capacitor voltage is less than ηV_{BB}, hence emitter-base diode is reverse biased. Even though, reverse leakage current flows, it is very small and emitter circuit of UJT can be treated as open circuit.

1 mark for explanation

When the emitter voltage reaches to the peak point voltage V_P (= $\eta V_{BB} + V_D$), the unijunction emitter-base diode conducts. The UJT is turned on and capacitor C rapidly discharges through low resistance R_1. The discharge current pulse causes voltage pulse across R_1, which can be used to trigger the SCR by applying the output voltage v_o between gate and cathode of SCR.

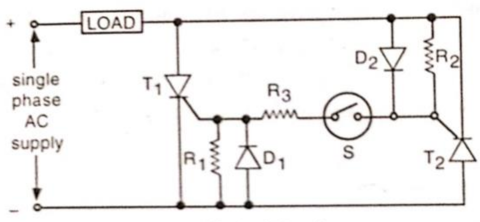
After discharging, the UJT is turned off, the capacitor charging starts and the cycle is repeated. The charging and discharging is repeated and across R_1 we get output pulses. The output pulses can be synchronized with the AC supply such that the pulses can be provided to forward biased SCR at the same instant in the respective half-cycle. If the gate pulse is provided early in the half cycle, the SCR conducts for longer duration in that half-cycle and average output voltage will be more. If the gate pulses are delayed, the conduction angle of SCR get reduced and the output average voltage becomes smaller and smaller, as shown in the waveform.

6 b) With neat diagram describe the working of static AC breaker.

Ans:

Static AC Circuit breaker:

The circuit configuration of static AC circuit breaker using SCR is shown in the figure. When switch 'S' is closed, the SCRs T_1 and T_2 are fired in positive and negative half-cycles respectively. During positive half-cycle, T_1 receives gate current through D_2 || R_2, switch S and R_3 and it conducts. At the end of positive half-cycle, T_1 is turned off due to natural current zero. In the negative half-cycle, T_2 receives gate current through D_1 || R_1, R3andswitch S and it conducts. It is turned off at the end of this negative half cycle due to natural current zero value. When the load current is required to be interrupted, the switch S is opened. It results in blocking of gate currents of both SCRs and hence both SCRs are maintained off. When switch S is opened at any instant in a particular half-cycle, the load current continue to flow through conducting SCR till the end of this half-cycle, however in the next half-cycle the other SCR will not be fired due to non-availability of gate current. Thus the maximum time delay for breaking the circuit is one half-cycle.



AC circuit breaker

2 marks for circuit diagram

2 marks for explanation

6 c) Compare induction heating and dielectric heating on following points:

(i) Principle
(ii) Frequency of generation
(iii) Area of heat generation

(iv) Applications

Ans:

Comparison between Induction and Dielectric Heating:

1 mark for each point

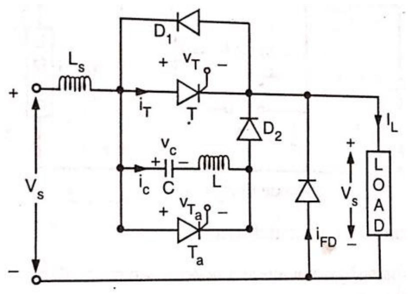
Sr. No.	Particulars	Induction heating	Dielectric Heating
1	Principle	When a conducting object is subjected to a changing magnetic field, emf is induced in it, current flows through it, i^2R power loss takes place and the object is heated.	When a non-conducting object is subjected to an alternating electric field, some power loss, called dielectric loss takes place in it and the object is heated.
2	Frequency	Upto 1 Mhz Change in frequency affects the depth of penetration of heat and also the rate of heating	Upto30 Mhz Change in frequency affect only the rate of heating
3	Area of heat generation	Heating is not uniform throughout the work piece	Heating is uniform throughout the work piece
4	Applications	• Only conducting materials can be heated. • Surface hardening of steel • Annealing of metals • Brazing • Welding • Forging • Drying paints on metals • Melting of metals	• Only non-conducting materials can be heated. • Food processing • Plastic processing • Wood processing • Electronic sewing • Drying and heat treatment of textiles • Chemical processing

6 d) Explain current commutated chopper with the help of diagram.

Ans:

Current commutated chopper:

The circuit arrangement of current-commutated chopper is shown in the figure. The main thyristor is T and the commutation circuit includes auxiliary thyristor T_a, commutating capacitor C, inductor L, diodes D_1 and D_2. The freewheeling diode is connected across load. The commutation is carried out by passage of reverse resonant current pulse through main thyristor T to reduce its forward current to zero.



Current commutated chopper

2 marks for diagram

When supply voltage V_s is given to circuit, the capacitor gets charged through source inductance L_s, L, D_2 and load, with polarity as shown. The final steady state voltage across capacitor is $v_c = V_C$ which is higher than V_s, because the capacitor is overcharged by inductance L and also by source inductance L_s.

2 marks for explanation

The circuit operation can be divided into six modes:

Mode I ($0<t<t_1$): At t = 0 the main thyristor T is fired. Once it turns on, the load gets connected across the source and supply voltage appears across load. The constant load current I_L flows through main thyristor T and load during this mode.
Mode II ($t_1<t<t_2$): This mode begins with firing of auxiliary thyristor T_a at $t = t_1$. Since it is forward biased by capacitor voltage it is turned on and LC circuit gets closed through T_a. The oscillatory current flows through L, T_a and C, discharging C and recharging with opposite polarity.
Mode III ($t_2<t<t_3$): At $t = t_2$ the capacitor current falls to zero and auxiliary thyristor is self-commutated. Then mode III begins, the charged capacitor forces current through L, D_2, T for its discharging. This current being oscillatory and sinusoidal in nature, the net current through main thyristor T falls to zero at particular instant $t = t_3$ and it is commutated.
Mode IV ($t_3<t<t_4$): Once main thyristor is commutated at t_3 the capacitor current i_c is maintained through D_1 and the capacitor voltage polarity gets reversed due to inductance L. At $t = t_4$, the capacitor current i_c becomes equal to load current I_L, the diode current becomes zero and diode D_1 is turned off.
Mode V ($t_4<t<t_5$): In this mode, the capacitor further charges linearly due to constant load current with the polarity shown in the figure. At $t = t_5$, the capacitor voltage becomes equal to V_s, therefore load voltage must be zero to satisfy the KVL. So at $t = t_5$, the freewheeling diode conducts and load voltage falls to zero.
Mode VI ($t_5<t<t_6$): During this mode, the load voltage remains zero due to conducting FD, the capacitor gets overcharged. At the end, the capacitor current falls to zero and FD continue to conduct till the energy in load inductance is dissipated.
After this mode, if main thyristor is fired, mode I starts and the cycle is repeated.

6 e) List advantages and disadvantages of resistance welding.
Ans:
Advantages of Resistance Welding:
1) Clean process, no spark, fumes, smoke etc.
2) Precise control is possible.
3) Superior quality welding is obtained.
4) Human skills are not required.

Disadvantages of Resistance Welding:
1) Specialized equipment is required.
2) Equipment is different for different types of resistance welding.
3) Costly equipment is needed.

1 mark for each of any two advantages and any two disadvantages = 4 marks