UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

MAIN EXAMINATION MAY 2012

TITLE OF PAPER: **POWER ELECTRONICS**

COURSE CODE: **EE 422**

TIME ALLOWED: **THREE HOURS**

Student Name:	
Student Number:	

INSTRUCTIONS:

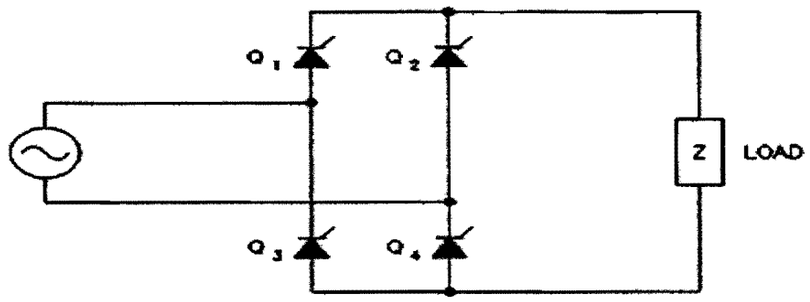
1. Answer all questions.
2. Give your answers on the question paper, and if more space is required, complete your answer on the back of the paper or in your answer book and mention about the place of your answer completion.
3. Put the question sheet inside the answer book upon submission of your exam paper.
   (DON'T FORGET TO SUBMIT BOTH OF THE ANSWER BOOK AND QUESTION PAPER)
4. Marks for different questions are indicated on the beginning of the question.
5. Rough work maybe done in the examination answer book and crossed through.

DO NOT OPEN THIS PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATOR

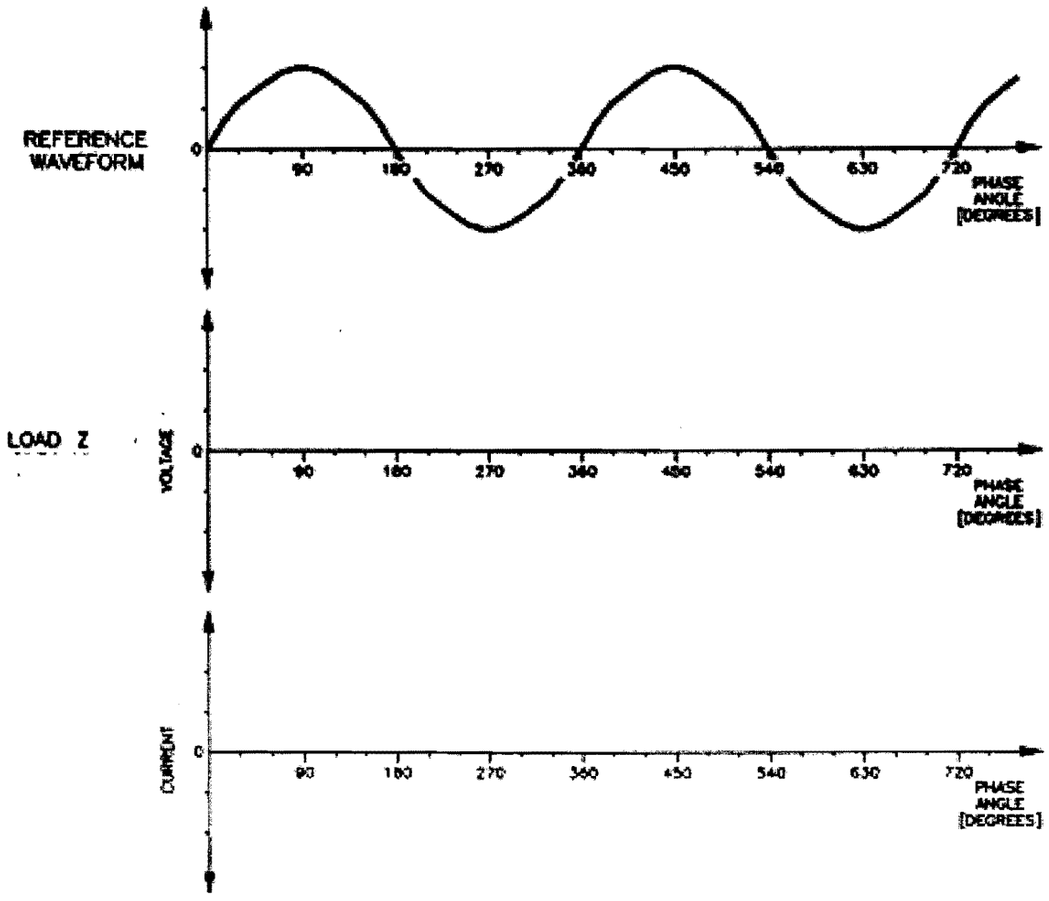
This paper starts at page 1 and ends at page 17.

Question 1: Solve the following questions (20 marks)

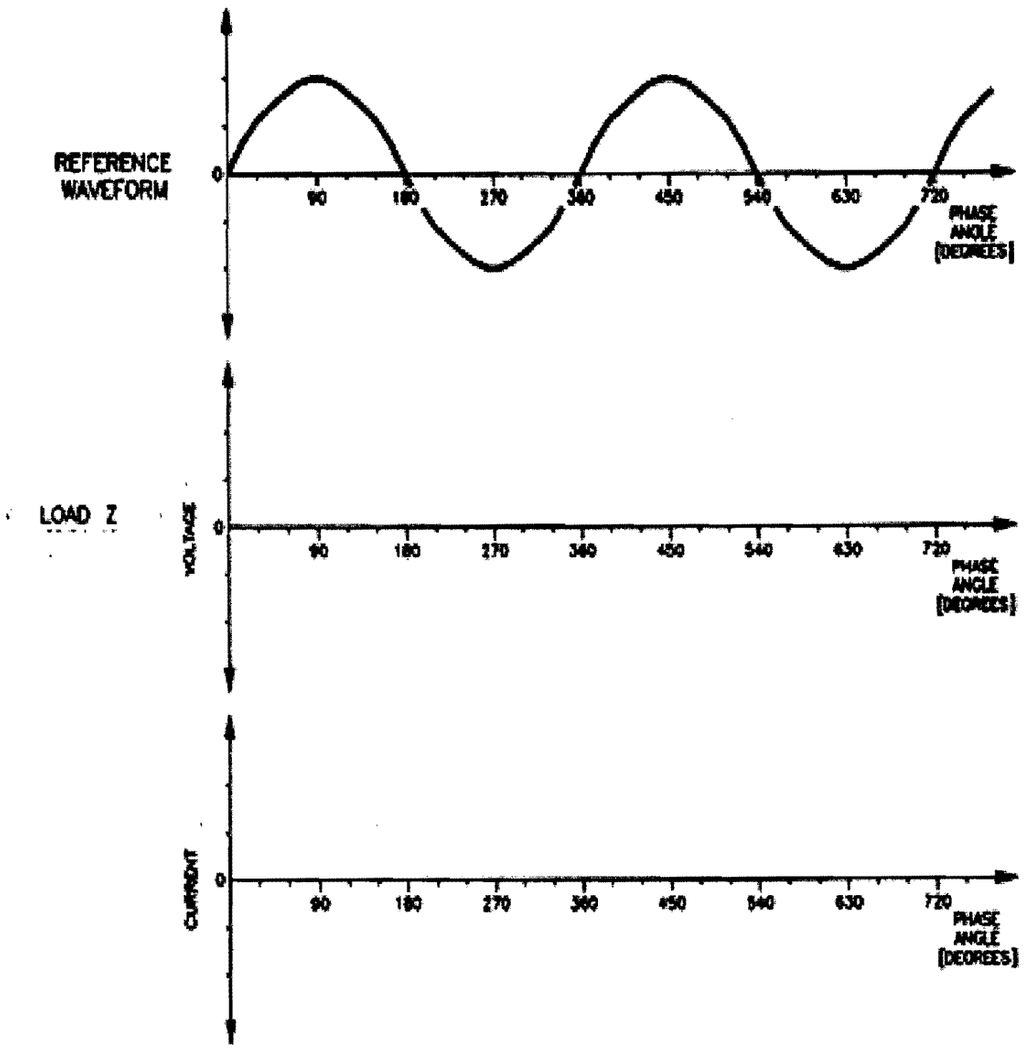
In the following fully controlled single-phase bridge rectifier.



a) Draw the load voltage and load current for resistive load when the firing angle is 60°.



b) Draw the load voltage and load current for inductive load when the firing angle is 60°.

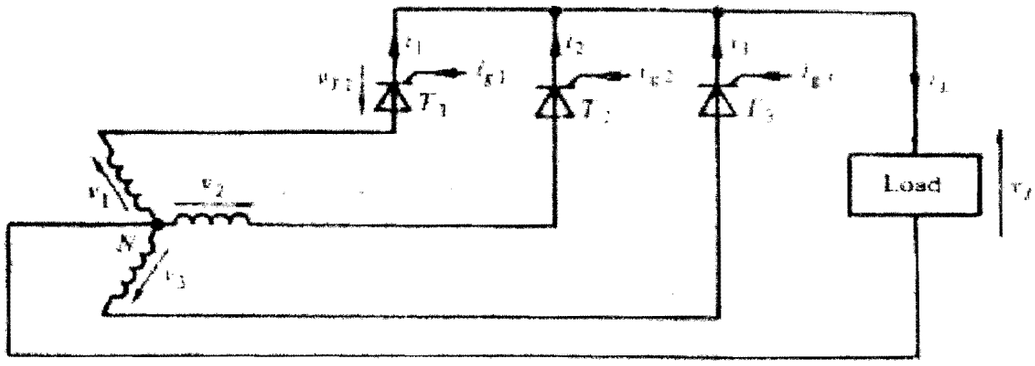


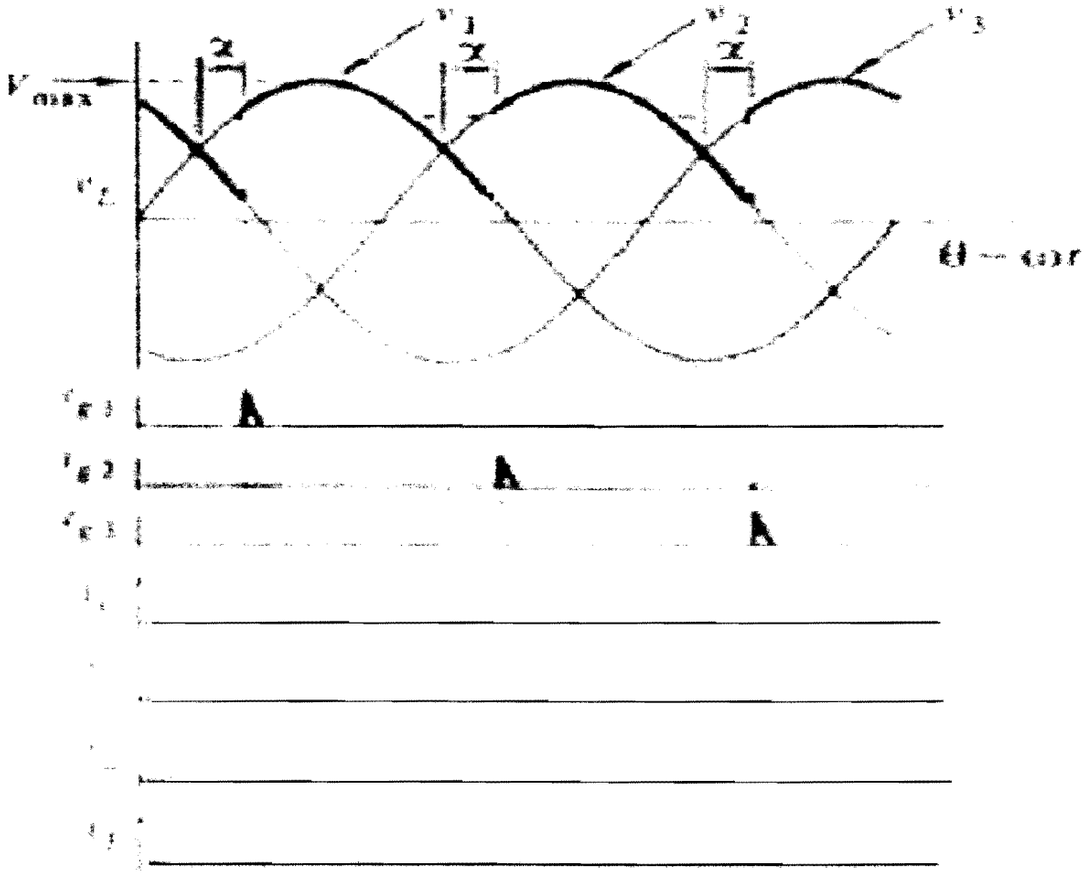
c) Derive an expression for the average load voltage when the load is inductive.

d) A separately excited d.c. motor is driven from a 240V, 50Hz supply using a fully controlled single phase thyristor bridge, similar to that shown in a. The motor has an armature resistance R_a of 1.2 ohm and an armature voltage constant K_φ of 0.7 V/rad-s. The field current is constant at its rated value. Determine the values of armature current and torque for an armature speed of 1200 rev/min and a firing angle delay of 60° and calculate the limits of the firing angle delay for this speed. (Calculate: $I_{Lav}, T_{ind}, \alpha_1, \alpha_2$)

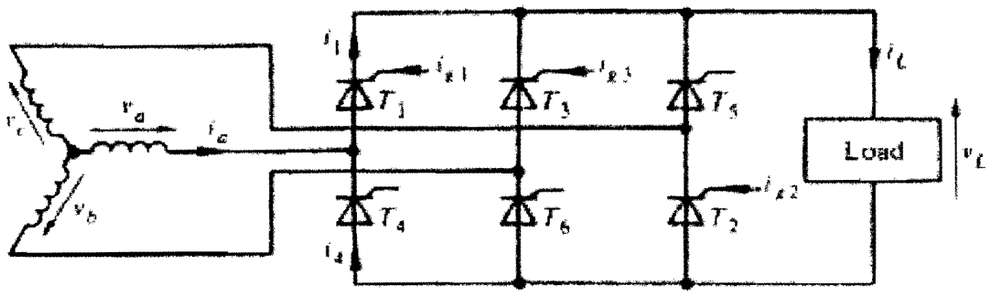
Question 2: Solve the following questions (26 marks)

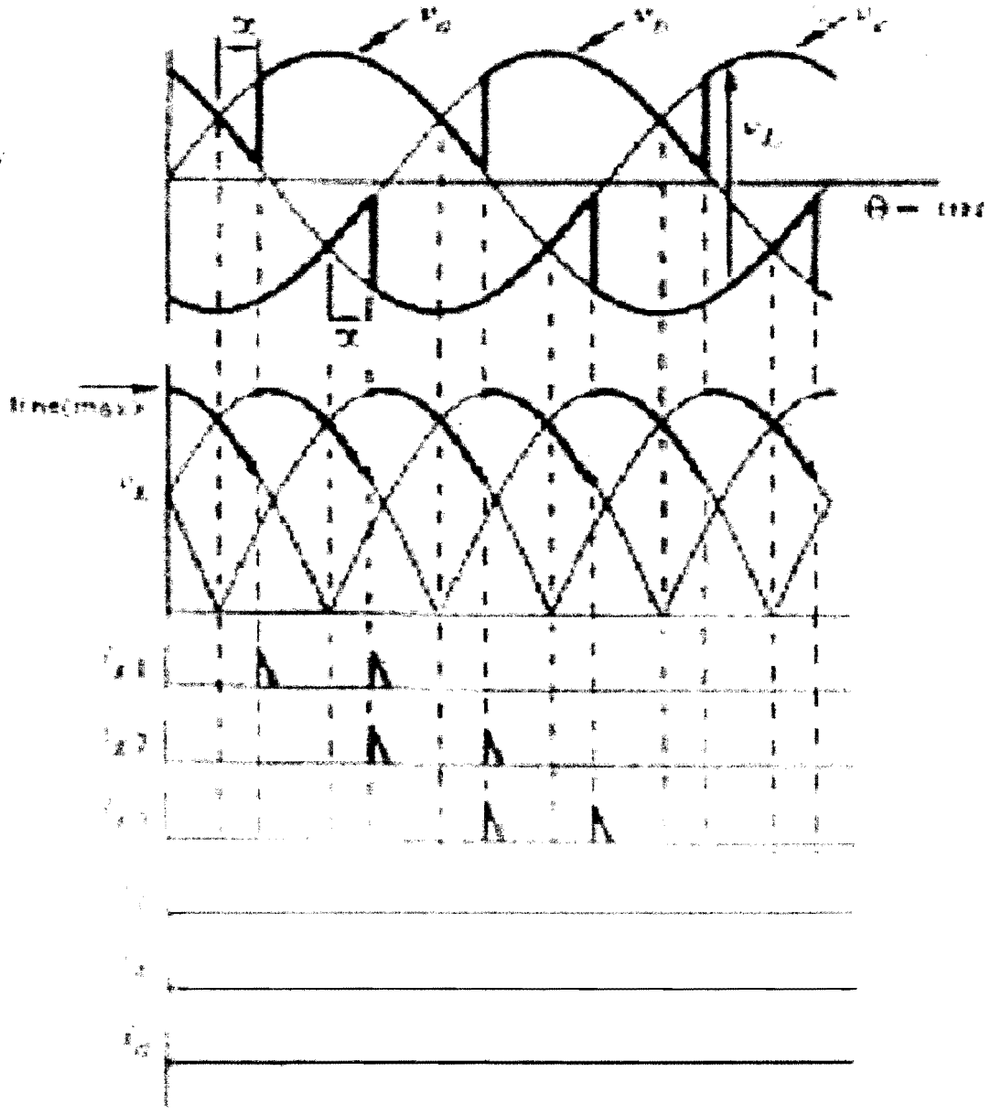
a) In the following three-phase half wave converter with inductive load, draw the load voltage, load current and the currents through thyristor 1, thryristor 2 and thyristor 3. Note: Use different color than black color in your sketch.





b) In the following three-phase full wave converter with inductive load, draw the load voltage and the currents through thyristor 1, thyristor 4 and phase a. Note: Use different color than black color in your sketch.





c) In the previous three-phase full wave converter shown in b, mention the sequence of load voltages that will be applied to the load and through which thyristors the voltage will be applied, starting from that the voltage v_{cb} will be applied to the load through T5 and T6 in the first period in the diagram.

Sequence Number	The voltage through load	From thirystor	To thyristor
1	$v_{cb} = v_{cn} - v_{bn}$	T5	T6
2			
3			
4			
5			
6			
7			

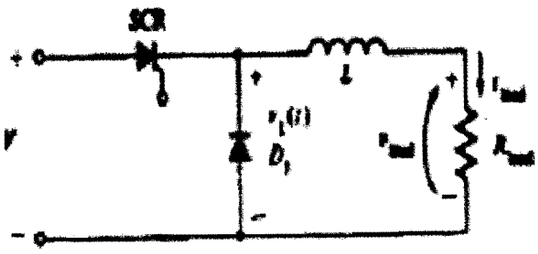
d) Derive an expression for the average load voltage of a three-phase half wave converter with inductive load, similar to that shown in a.

e) Provide an expression for the average load voltage of a three-phase full wave converter with inductive load, similar to that shown in b. Distinguish between the two cases when the converter will work in rectifier mode or inverter mode?
Note: You can estimate the average load voltage based on your answer in d.

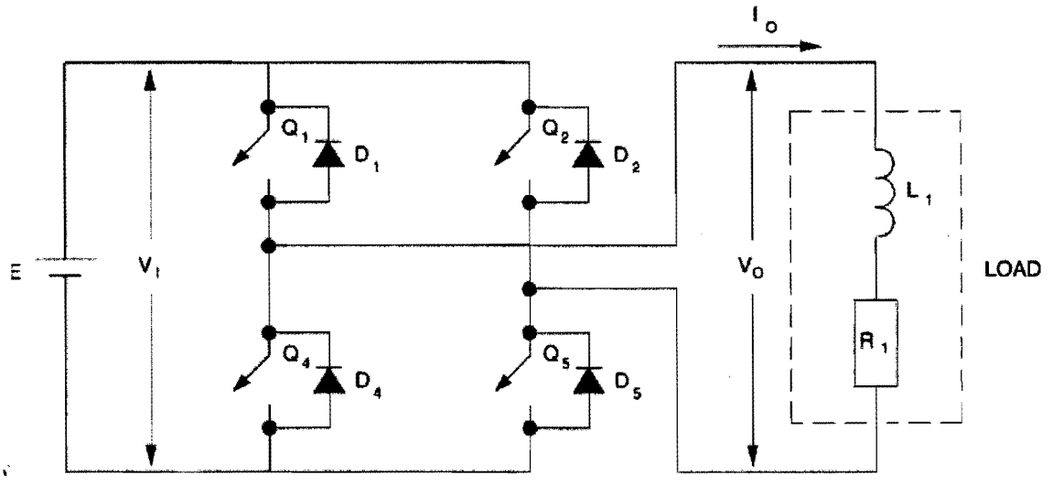
f) A three-phase fully-controlled full wave converter, similar to that shown in b, has highly inductive load of 20 ohm resistance, and a three phase supply of 230V (line to neutral) at 50Hz. Determine average value of load voltage, rms value of load current, rms value of supply phase current, load power and converter power factor for firing angle delay of α =60°.
(Calculate: V_{Lav}, I_{Lrms}, I_{Srms}. P_{load}, P_f)

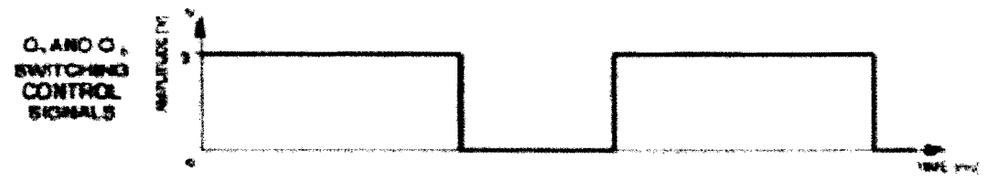
Question 3: Solve the following questions (21 marks)

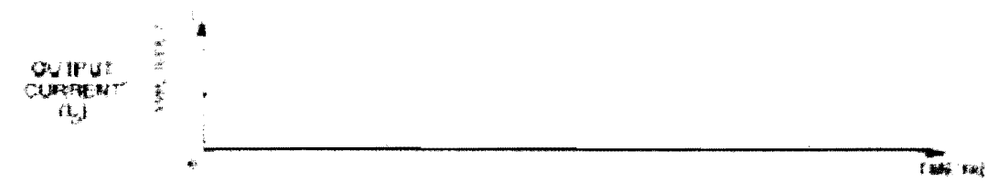
a) A d.c. to d.c. step down chopper has an inductive load of 2 ohm resistance and 20 mH inductance. The source voltage is 30V. The frequency of the chopper is set to 50 Hz and the on-time to 12 ms. Assume the current is continuous with a load current of I_0 at switch-on and a current of I_1 at switch-off, the rms value of load current is given by $I_{Lrms} = \sqrt{I_o I_1 + (I_1 - I_0)^2 / 3}$. Obtain the equations of the load current during the on and off periods and determine the average, maximum, minimum and rms values of load currents
(Calculate: I_{Lav}, I_{Lrms}, $I_1 . I_0$)



b) In the following four-quadrant chopper with inductive load. Given the waveform of the switching control signals applied to electronic switches Q1 and Q5, draw the waveforms of the switching control signals applied to electronic switches Q2 and Q4, the output load voltage and output load current.





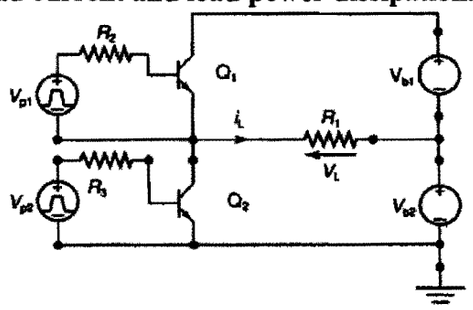


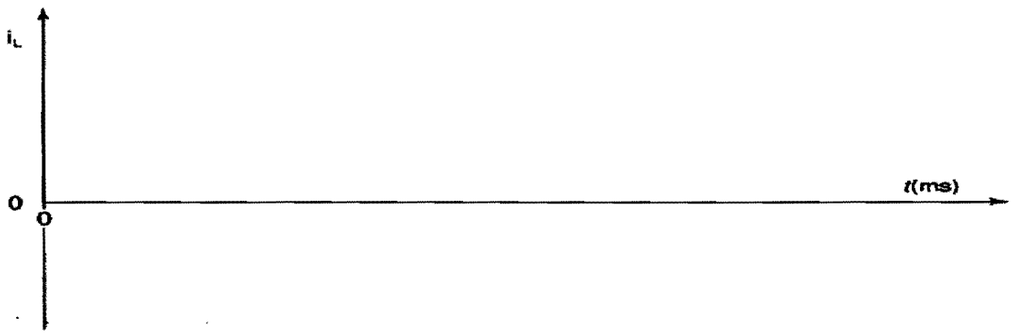
c) A four-quadrant chopper with an inductive load, similar to that shown in b. The battery voltage is 200 V, and the duty cycle of the switching control signal applied to electronic switch Q1 in the four-quadrant chopper is 0.6. Determine the average load voltage.

d) A step-up chopper with inductive load. The battery voltage is 20 V, and the chopper frequency is 50kHz. The On time is $12\,\mu\text{sec}$. Determine the average load voltage.

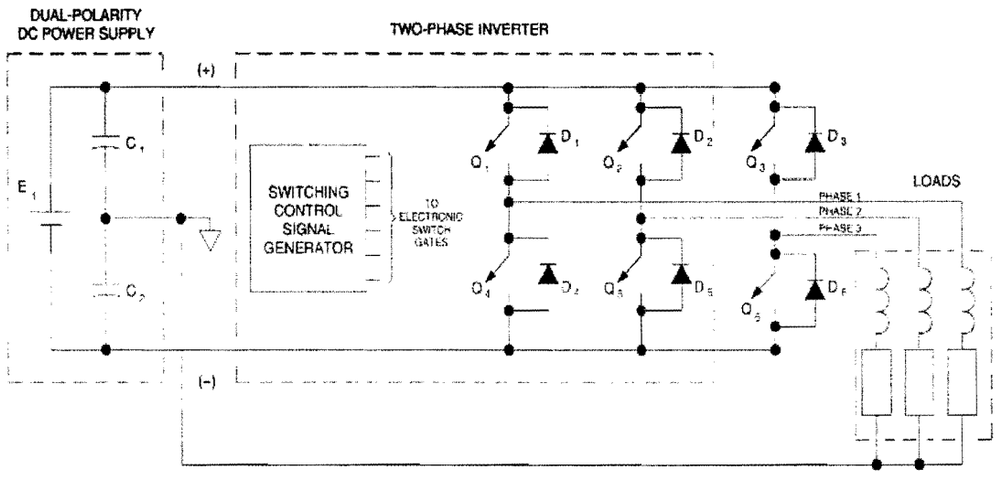
Question 4: Solve the following questions (22 marks)

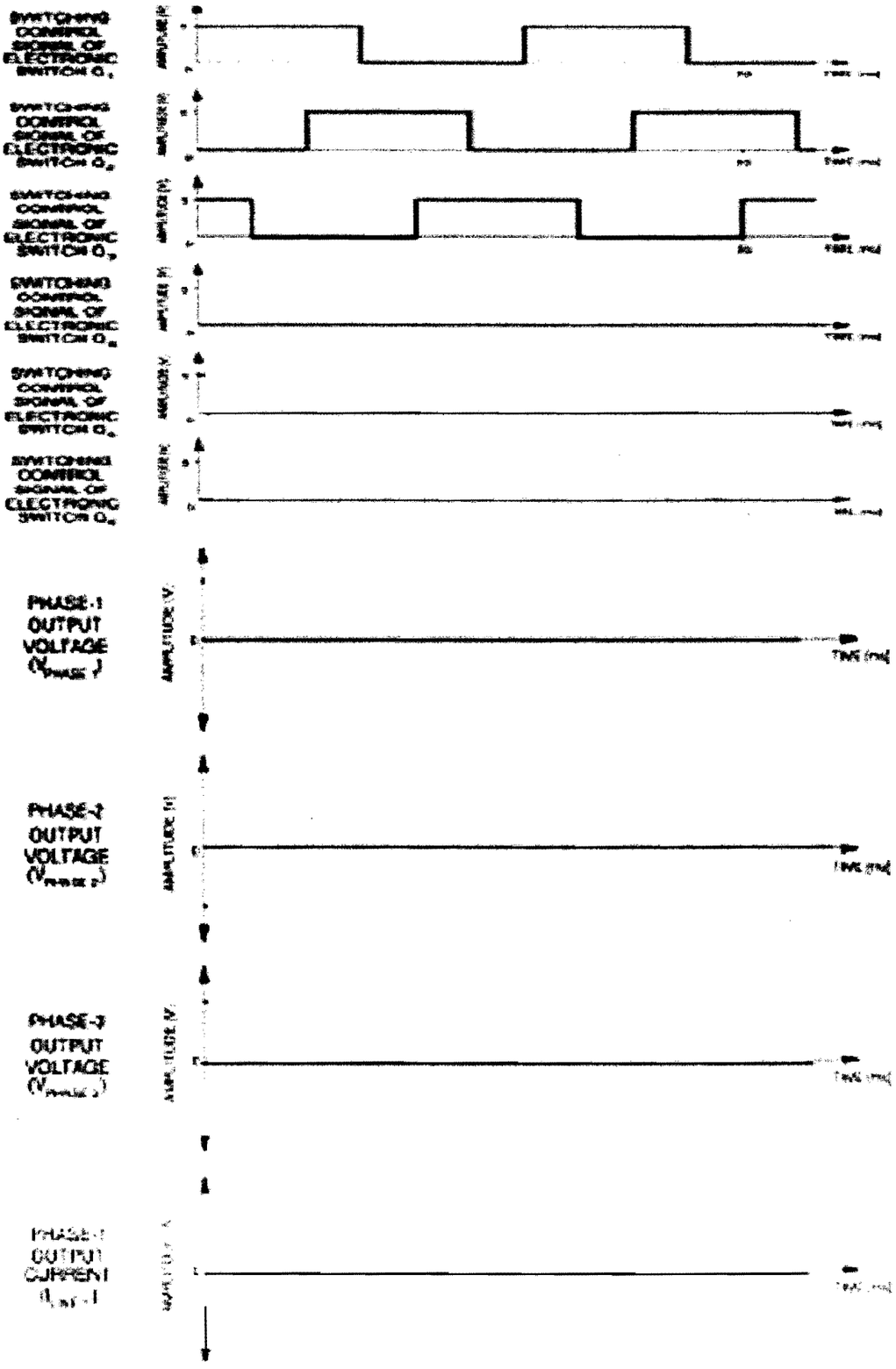
a) A half-bridge inverter has $V_{b1} = V_{b2} = 30$. The load is resistive with R = 10 ohm. The inverter frequency is 200Hz. Sketch and scale the load current waveform and determine the average load current, rms load current and load power dissipation.



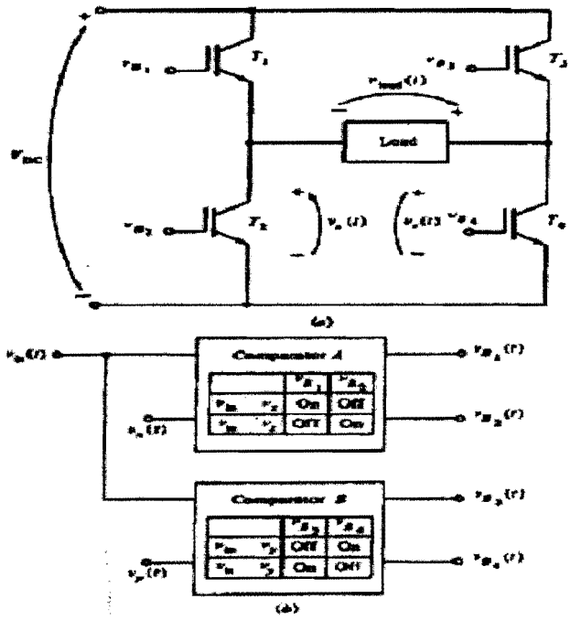


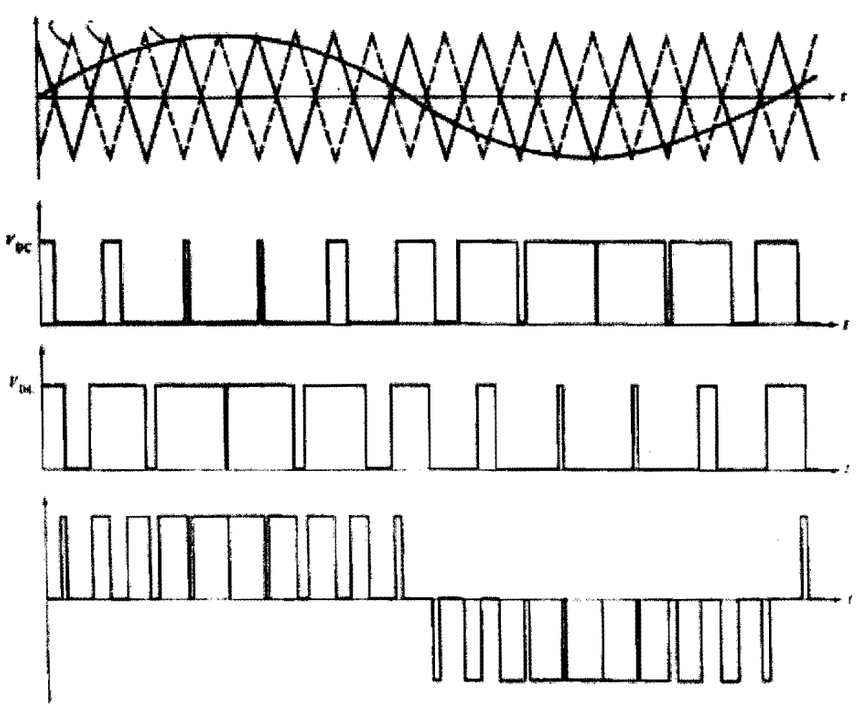
b) In the following three phase inverter with inductive load. Given the waveform of the switching control signals applied to electronic switches Q1, Q2 and Q3, draw the waveforms of the switching control signals applied to electronic switches Q4, Q5 and Q6, the output load voltages at phase 1, 2 and 3 and load current at phase 1.




SWITCHING CONTROL SIGNAL OF ELECTRONIC SWITCH
PHASE-1 OUTPUT VOLTAGE
PHASE-2 OUTPUT VOLTAGE
PHASE-3 OUTPUT VOLTAGE
PHASE-1 OUTPUT CURRENT

c) In the following single phase pulse width modulator, indicate the signals v_x, v_y, v_u, v_v, v_{in}, v_{load} and indicate the proper condition for the on and off state of each transistor in the following comparator tables (< or >).





d) In the voltage source inverter

a) The SCR output current waveform will be roughly square waveform while the line to line output voltage will be approximately triangle.

b) The SCR line to line output voltage will be roughly square waveform while the output current will be approximately triangle.

c) Both the SCR output current output waveform and the line to line output voltage will be square waveform.

e) In the current source inverter

a) The SCR output current waveform will be roughly square waveform while the line to line output voltage will be approximately triangle.

b) The SCR line-to-line output voltage will be roughly square waveform while the output current will be approximately triangle.

c) Both the SCR output current output waveform and the line-to-line output voltage will be square waveform.

f) In three phase current source inverter

a) One thyristor will be on at a time.

b) Two thyristors will be on at a time.

c) Three thyristors will be on at a time.

g) In three phase voltage source inverter

a) One power transistor will be on at a time.

b) Two power transistors will be on at a time.

c) Three power transistors will be on at a time.

h) In which type of inverters the rectifier is connected to an inverter through a series inductor

a) The PWM inverter.

b) The current source inverter.

c) The voltage source inverter.

i) In which type of the inverter the rectifier is connected to an inverter through a series inductor and parallel capacitor

a) The PWM inverter.

b) The current source inverter.

c) The voltage source inverter.

j) In the pulse width modulation inverter the control input signal will be compared with

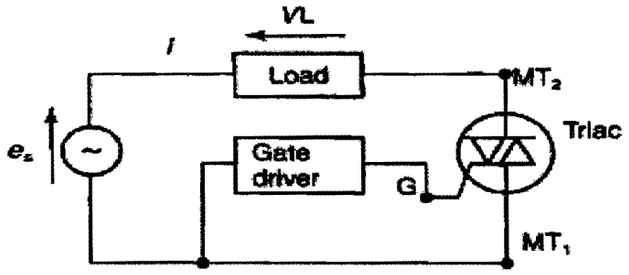
a) Sawtooh signal.

b) Sinusoidal signal.

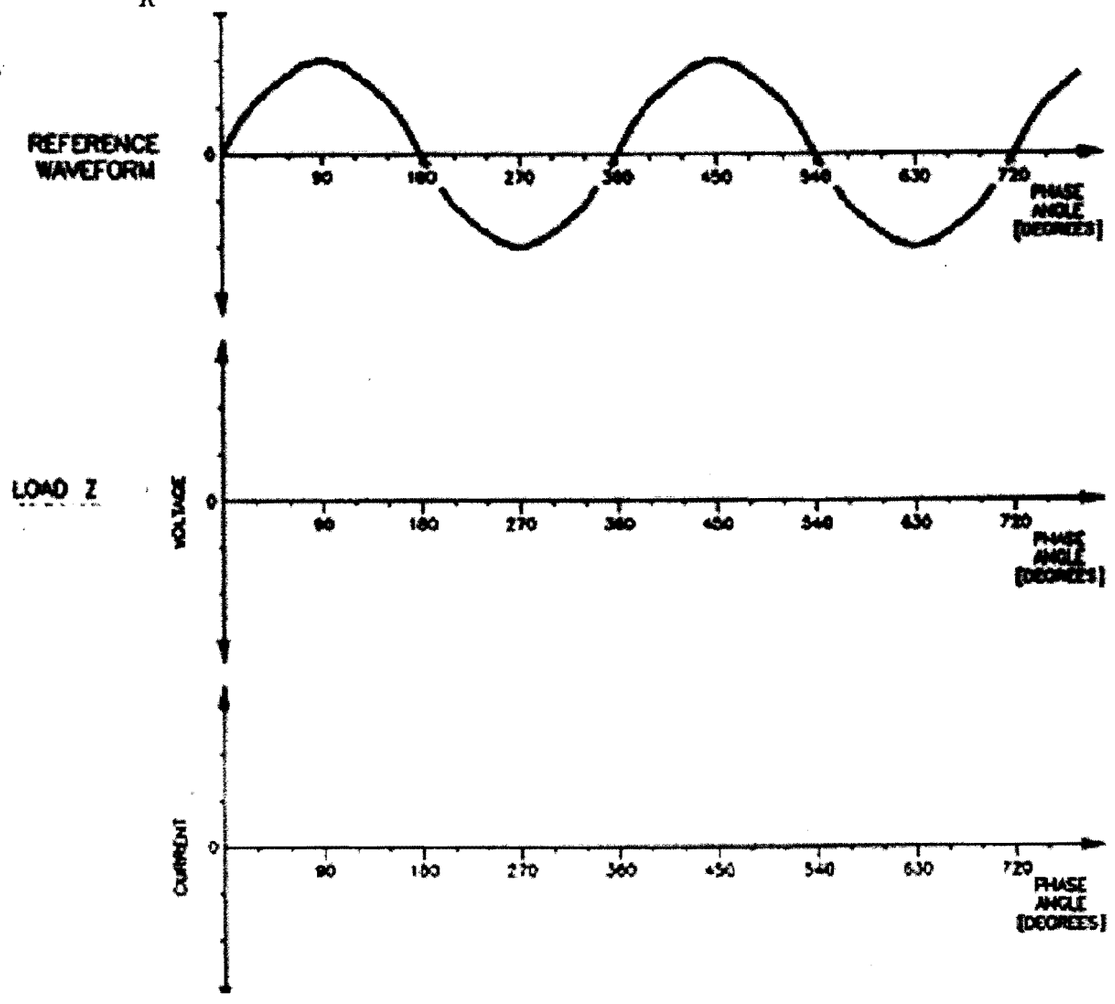
c) Square wave signal.

Question 5: Solve the following questions (11 marks)

In the following AC to AC converter:



a) Draw the load voltage and load current for inductive load when the firing angle α is 90° and the current conduction angle β=120°, assuming $\alpha > \varphi$ where $\varphi = \tan^{-1}(\frac{\omega L}{R})$.



b) Derive an expression for the rms value of load voltage in the previous TRIAC controller.

c) A Triac regulator has a supply of 240V, 50Hz and an inductive load. Calculate the average and rms values of load voltage when the firing delay angle α is 90° and the current conduction angle β=120°.

(Calculate: V_{Lav}, V_{Lrms})