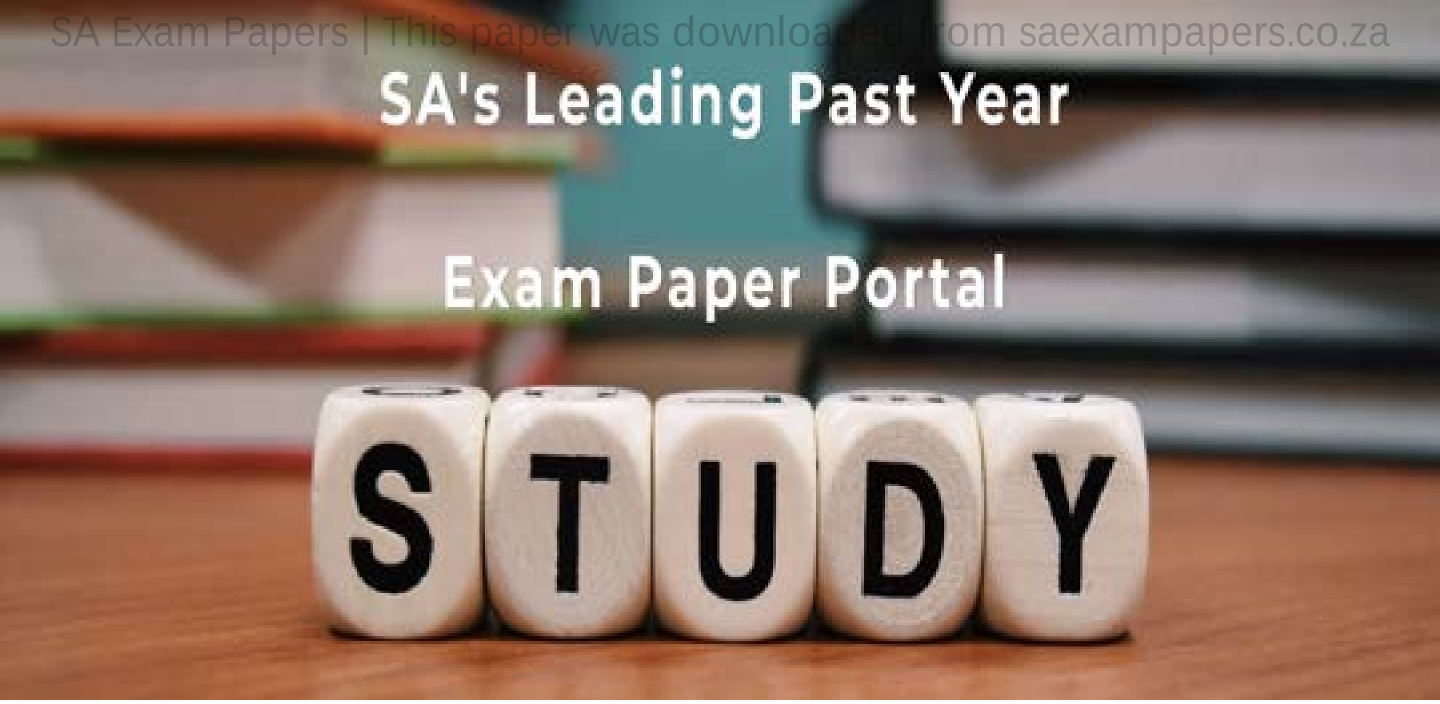
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NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2023

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

MARKS: **200**

TIME: **3 hours**

This question paper consists of 18 pages, including a 2-page formula sheet.

INSTRUCTIONS AND INFORMATION

1. This question paper consists of SEVEN questions.
2. Sketches and diagrams must be large, neat and fully labelled.
3. Show ALL calculations and round off answer correctly to TWO decimal places.
4. Number the answers correctly according to the numbering system used in this question paper.
5. You may use a non-programmable calculator.
6. Show the units for ALL answers of calculations.
7. A formula sheet is provided at the end of this question paper.
8. Write neatly and legibly.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Various options are given as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (1.1 to 1.15) in the ANSWER BOOK, for example 1.16 D.

1.1. An attempt to numerically determine the probabilities of various adverse events and the likely extent of the losses if the event occurs is known as …

A risk analysis.
B quantitative risk analysis.
C qualitative risk analysis.
D dangerous practices. (1)

1.2 During resonance in a series RLC circuit …

A Z = R.
B Z < R.
C Z > R.
D Z is maximum. (1)

1.3 When increasing the frequency of a RLC circuit, the resistance will …

A also increase.
B decrease.
C remain the same.
D double its value. (1)

1.4 The power expended in a purely inductive or capacitive circuit is known as the … power.

A real
B true
C reactive
D apparent (1)

1.5 The active current of a three-phase system is …

A $I_L \cos\theta$.
B $I_L \sin\theta$.
C $I_L \tan\theta$.
D I_L. (1)

1.6 An advantage of power factor correction for the consumer is …

A more current used.
B reduced monthly electricity bill.
C more maintenance of equipment.
D reduced lifespan of equipment. (1)

1.7 The total power measured when using the two-wattmeter method was 2,75 kW. If W_1 measured 2,2 kW, the reading of W_2 is …

A 55 kW.
B 0,075 kW.
C 550 W.
D 750 W. (1)

1.8 A factor that can contribute to excessive heating in transformers is …

A sufficient ventilation.
B correct load.
C proper cooling.
D insufficient transformer oil. (1)

1.9 The function of transformers in distribution networks is to …

A increase the voltages to the required values.
B change the AC voltages to the required DC voltage values.
C reduce the voltage to the required values.
D generate the required voltages. (1)

1.10 Synchronous speed is the …

A maximum speed that the motor is allowed to work properly.
B speed of rotation of the magnetic field in the stator winding.
C speed when maximum load is connected to the motor.
D difference between rotor speed and slip. (1)

1.11 The stator windings of a three-phase induction motor may be connected …

A in star only.
B in star or delta.
C in delta only.
D None of the above. (1)

1.12 Starters stay energised after the start button is released because a …

A N/O main contact is connected in parallel with the start button.
B N/C main contact is connected in parallel with the start button.
C N/O main contact is connected in series with the start button.
D N/C main contact is connected in series with the start button. (1)

1.13 … sensors are used to detect the presence of metal objects and whether they are ferrous or nonferrous.

A Capacitive proximity
B Ultrasonic proximity
C Level
D Inductive proximity (1)

1.14 … are bits in the storage memory which can be used to hold data and behave as relays.

A Latching contacts
B Markers or flags
C Timers
D Strain gauges (1)

1.15 A timer whose contact would not operate until a pre-set delay time has passed, after it has been energised in the logic sequence is known as a(n) …

A off-delay timer.
B digital counter.
C on-delay timer.
D stopwatch. (1)

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 State TWO factors needed, to ensure a strong work ethic in a company. (2)

2.2 Define a *critical incident* in a workshop. (2)

2.3 Name ONE safety precaution you would observe when handling concentrated chemicals at a Printed Circuit Board (PCB) workstation. (1)

2.4 Differentiate between an *unsafe act* and a *calculated risk* in a workshop. (2)

2.5 Explain why you must protect yourself when helping a person who is being shocked by electricity. (1)

2.6 Explain why a person should not interfere with, or misuse, equipment in the workshop that is provided for health and safety. (2)

[10]

QUESTION 3: RLC CIRCUITS

3.1 Define *inductive reactance* with reference to RLC circuits. (2)

3.2 Draw a full, labelled cycle of the waveforms representing the phasor diagram in FIGURE 3.2.

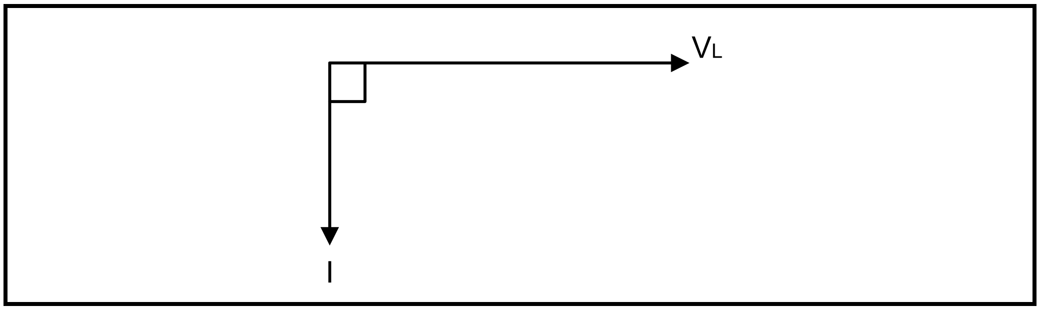

FIGURE 3.2: VOLTAGE AND CURRENT PHASOR DIAGRAM (3)

3.3 A series RLC circuit has a resistor of unknown value, a capacitor with a capacitance of 200 ɥF and an inductor with a reactance of 31,55 Ω connected to a 110 V/60 HZ AC supply. The impedance of the circuit is 101,65 Ω.

Given:

$C = 200$ ɥF
$X_L = 31,55\ \Omega$
$V_S = 110$ V
$f = 60$ Hz
$Z = 101,65\ \Omega$

Calculate:

3.3.1 The capacitive reactance (3)

3.3.2 The current flowing through the circuit (3)

3.3.3 The value of the resistor in the circuit (3)

3.3.4 The inductance of the inductor (3)

3.4 A coil with a negligible resistance has an inductance of 50 mH and is connected in series with a 60 ɥF capacitor and a 100 Ω resistor. The circuit is connected to a 220 V supply with a variable frequency.
Calculate the resonant frequency of the circuit.

Given:

$L = 50$ mH
$C = 60$ ɥF
$V_S = 220$ V (3)

3.5 Refer to FIGURE 3.5 below and answer the questions that follow.

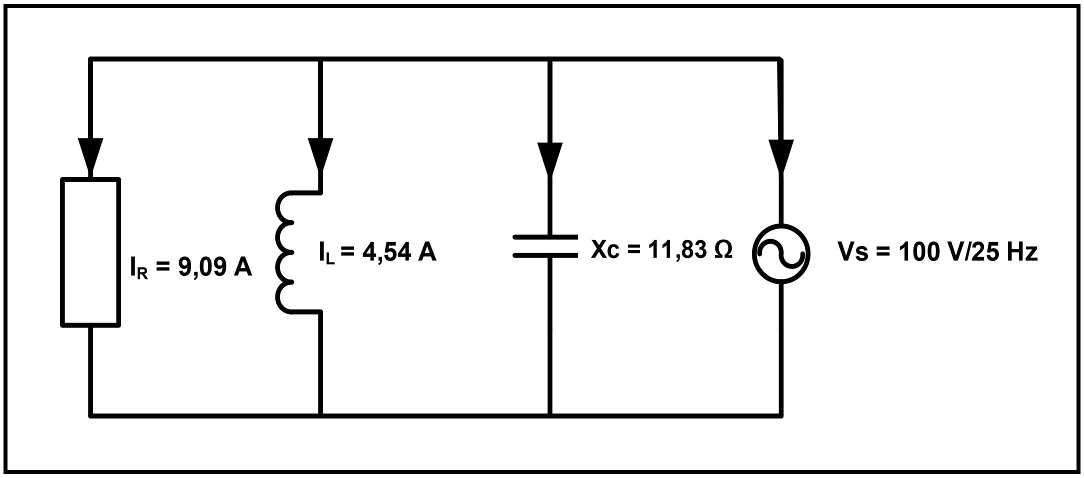

FIGURE 3.5: PARALLEL RLC CIRCUIT

Given:

I_R = 9,09 A
I_L = 4,54 A
X_C = 11,83 Ω
V_S = 100 V
f = 25 Hz

Calculate:

3.5.1 The current flowing through the capacitor (3)

3.5.2 The total current flowing through the circuit (3)

3.5.3 The power factor (3)

3.5.4 State, with a reason, whether the current is leading or lagging the voltage (2)

3.6 Define *selectivity* of a resonant circuit. (2)

3.7 Name TWO factors that determine the *quality factor(Q)* of a resonant circuit. (2)
[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 Match the term in COLUMN A with the explanation in COLUMN B. Write only the letter (A–C) next to the question numbers (4.1.1 to 4.1.3) in the ANSWER BOOK for example 4.1.4 D.

COLUMN A TERM	COLUMN B EXPLANATION
4.1.1 Transmission	A Network of over 25 000 km high voltage power lines to various bulk users
4.1.2 Substation equipment	B The generated electricity transported along overhead high voltage power lines
4.1.3 National grid	C Self-contained units controlled from the main control centres

(3 x 1) (3)

4.2 State TWO disadvantages of a three-phase system when compared to a single-phase system. (2)

4.3 Draw a neatly labelled phasor diagram of a balanced, three-phase, 3-wire system. (4)

4.4 List THREE methods used to improve the power factor of an inductive load in an AC system. (3)

4.5 Refer to FIGURE 4.5 below and answer the questions that follow.

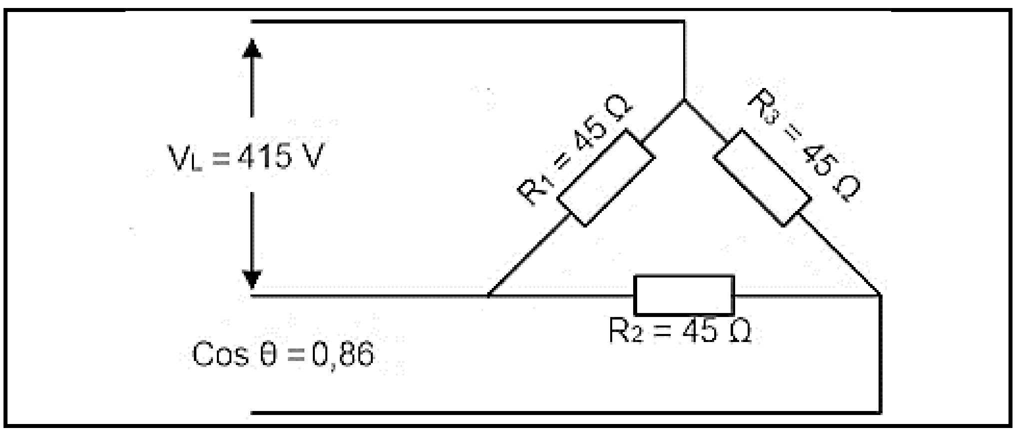

FIGURE 4.5: BALANCED THREE-PHASE DELTA CONNECTED LOAD

Given:

$V_L = 415$ V
$R_1 = R_2 = R_3 = 45\ \Omega$
$\cos\theta = 0{,}86$

Calculate:

4.5.1 The phase voltage of the load (2)

4.5.2 The line current (6)

4.5.3 The power consumed by the load (3)

4.5.4 The efficiency if the input power was 12 kW (3)

4.5.5 The phase angle (3)

4.6 The three-wattmeter method was used to determine the power of a three-phase system. The meter readings were $W_1 = 2$ kW, $W_2 = 1\ 780$ W and $W_3 = 3,5$ kW respectively.
Calculate the total power of the load. (3)

4.7 Describe how you would connect two, watt meters to a three-phase load, to determine the power factor. (3)

[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 State TWO types of losses that occur in the laminated core of a three-phase transformer. (2)

5.2 Mention what would happen if the heat generated in a transformer is not dissipated properly. (2)

5.3 Write down whether the following statements are 'true' or 'false'. Write only the word TRUE or FALSE next to the question numbers (5.3.1 to 5.3.3) in the ANSWER BOOK.

5.3.1 The core of a shell type transformer is enclosed. (1)

5.3.2 The balanced earth fault relay operates when an earth fault causes a difference in voltage between the three phases. (1)

5.3.3 The Bucholtz relay monitors the flow of the generated gas when a fault occurs. (1)

5.4 Name ONE function of the oil used in oil immersed transformers. (1)

5.5 FIGURE 5.5 shows a three-phase transformer with a primary voltage of 11 kV and a secondary voltage of 380 V. It has a load of 20 kW at a power factor of 0,88. The efficiency of the transformer is 89,9%.

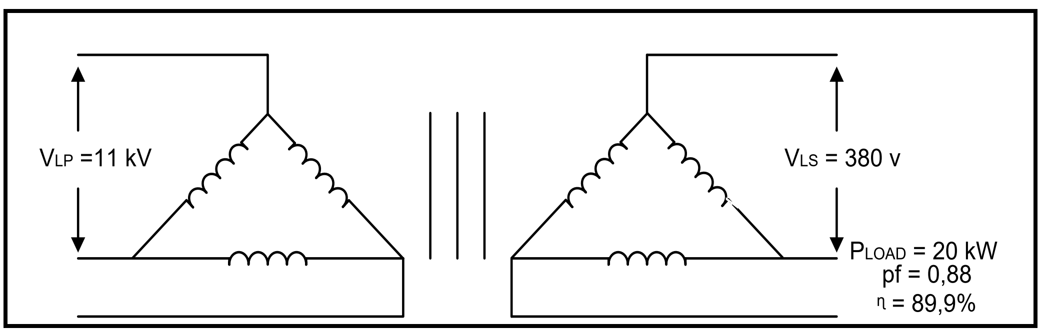

FIGURE 5.5: THREE-PHASE TRANSFORMER

Given:

V_{lp} = 11 kV
V_{ls} = 380 V
$\cos\theta$ = 0,88
P_L = 20 Kw
η = 89,9%

5.5.1 State ONE application of this transformer. (1)

Calculate:

5.5.2 The primary and secondary phase voltages (4)

5.5.3 The secondary line current (3)

5.5.4 The secondary phase current (3)

5.5.5 The apparent power (3)

5.5.6 The transformer ratio (3)

5.5.7 The losses in the transformer (3)

5.6 Explain what effect a decrease in the load will have on the primary current of a transformer. (2)

[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 Briefly discuss the construction of a squirrel cage rotor. (3)

6.2 State the relationship between the slope of the torque and the slip over the normal load range of a motor. (1)

6.3 The rotor speed of an induction motor is 3 400 rpm. The synchronous speed is 3 600 rpm and the motor has 4 pole pairs.

Given:

$N_s = 3\ 600$ rpm
$N_r = 3\ 400$ rpm
$p = 2$

Calculate:

6.3.1 The frequency of the motor (3)

6.3.2 The percentage slip of the motor (3)

6.4 A delta connected three-phase motor with an input power of 10 kW draws 18,99 A when connected to the supply. The motor has a power factor of 0,8 and an efficiency of 90%.

Given:

$P_{input} = 10$ kW
$I_L = 18{,}99$ A
$\cos\theta = 0{,}8$
$\eta = 90\%$

Calculate:

6.4.1 The line voltage of the motor (3)

6.4.2 The output power of the motor (3)

6.4.3 The reactive power at the phase angle of 36,87° (3)

6.5 Name TWO inspections and tests you would perform on an AC motor before installing it. (2)

6.6 Describe how electrical interlocking is achieved in a three-phase forward reverse starter. (2)

6.7 Refer to FIGURE 6.7 of the control circuit of a three-phase motor starter and answer the questions that follow.

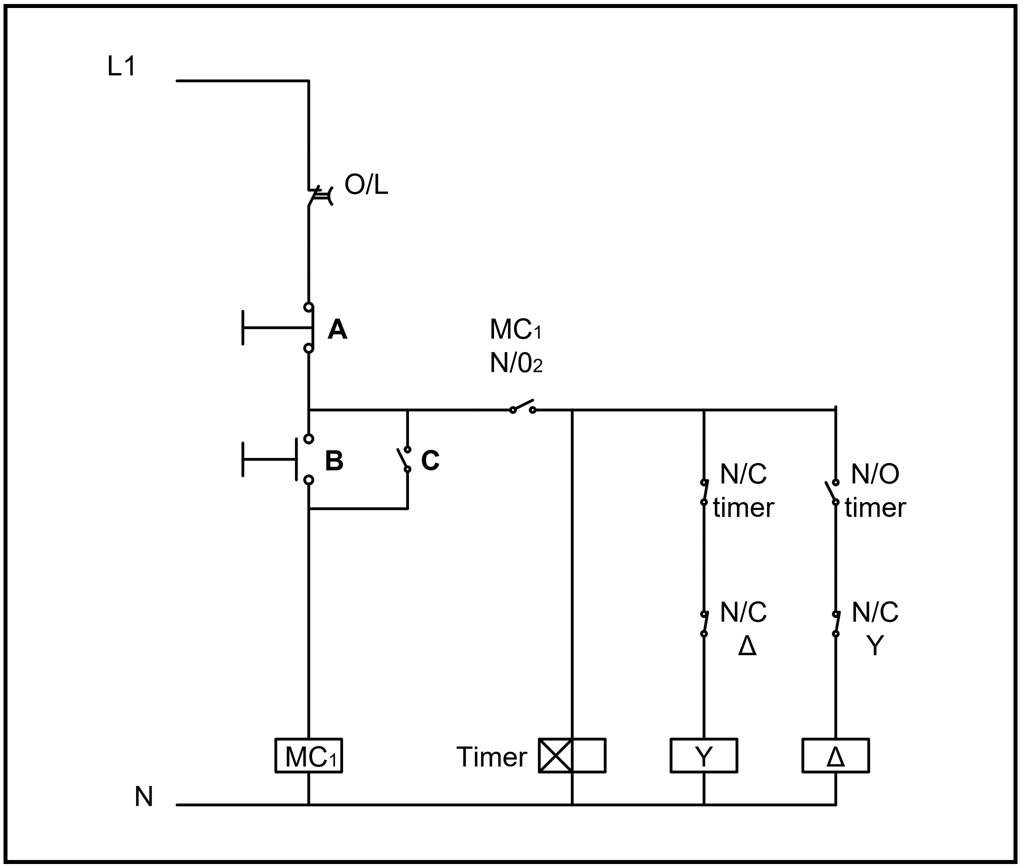

FIGURE 6.7: THREE-PHASE STARTER CONTROL CIRCUIT

6.7.1 Identify the starter shown in FIGURE 6.7. (1)

6.7.2 Label the symbols marked **A** to **C**. (3)

6.7.3 State the purpose of the timer contacts in the circuit. (2)

6.7.4 Determine the setting of the overload in the circuit if the motor nameplate has a rated current of 8 A. (3)

6.7.5 Explain what would happen to the operation of the circuit if the coil of the delta contactor became open circuit. (3)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS

7.1 Briefly describe what a programmable logic controller (PLC) is. (3)

7.2 Explain the term modems with reference to PLC's. (2)

7.3 Refer to the logic gate in FIGURE 7.3 below and answer the questions that follow.

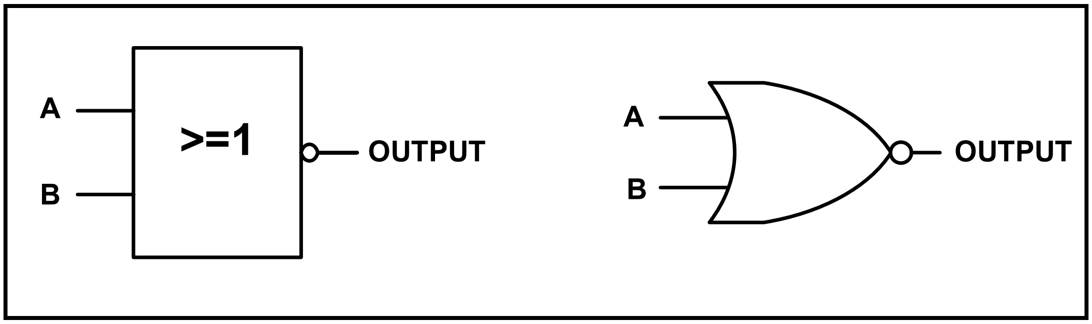

FIGURE 7.3: LOGIC GATE SYMBOL

7.3.1 Identify the logic gate shown in FIGURE 7.3. (1)

7.3.2 Draw the ladder logic diagram that represents the gate in FIGURE 7.3. (3)

7.3.3 Complete the truth table by writing down the output next to the letter.

A	B	OUTPUT
0	0	a
0	1	b
1	0	c
1	1	d

(4)

7.4 State TWO applications of level sensors in industrial and chemical manufacturing plants. (2)

7.5 Describe the basic principle of operation of a variable speed drive when it controls the speed of an AC induction motor. (3)

7.6 Refer to FIGURE 7.6.

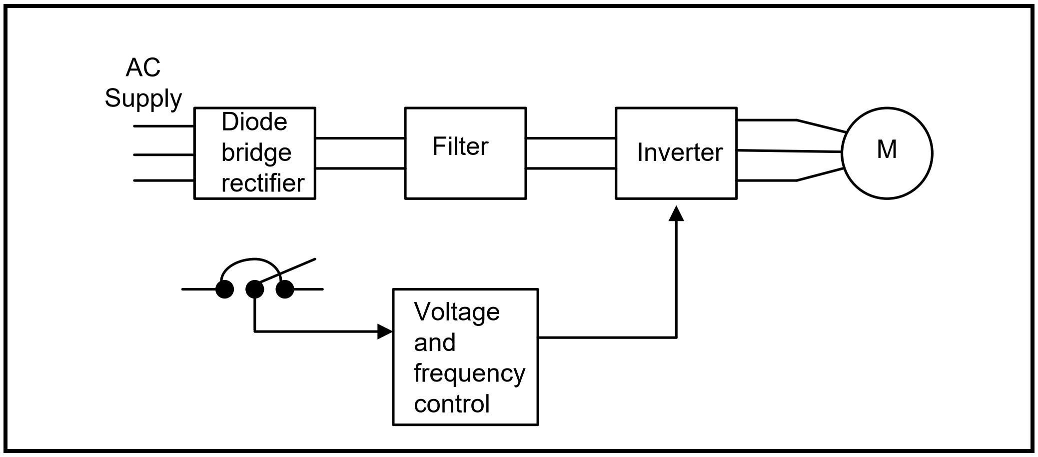

FIGURE 7.6: VARIABLE SPEED DRIVE

Describe the function of each of the following:

7.6.1 Diode bridge rectifier (2)

7.6.2 Filter (2)

7.6.3 Inverter (3)

7.7 Refer to FIGURE 7.7 and answer the questions that follow.

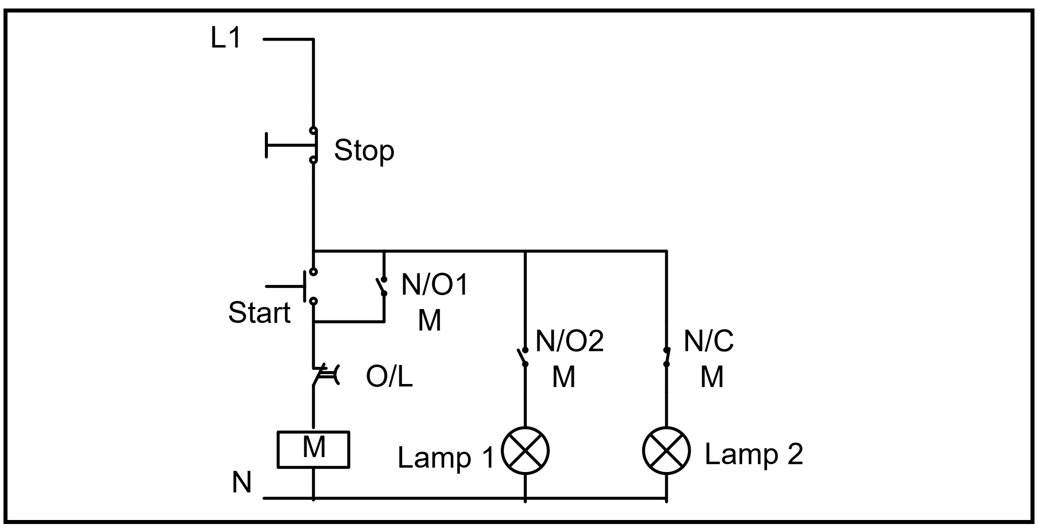

FIGURE 7.7: MOTOR STARTER WITH INDICATING LAMPS

7.7.1 Describe the function of Lamp 1 in the circuit. (2)

7.7.2 Explain the function of the overload connected in series with the motor. (2)

7.7.3 Discuss what would occur if Lamp 2 was fused. (2)

7.7.4 Draw a labellled diagram of the ladder logic for FIGURE 7.7. (9)
[40]

TOTAL: 200

FORMULA SHEET

RLC-CIRCUITS

$X_L = 2\pi fL$ and $X_C = \frac{1}{2\pi fC}$

$f_r = \frac{1}{2\pi\sqrt{LC}}$ and $I = \frac{V}{R}$

$P = VI\cos\theta$

SERIES

$I_T = I_R = I_L = I_C$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$V_L = I \times X_L$ and $V_C = I \times X_C$

$V_T = IZ$ and $V_T = \sqrt{{V_R}^2 + (V_L - V_C)^2}$

$\cos\theta = \frac{R}{Z}$ and $\cos\theta = \frac{V_R}{V_T}$

$Q = \frac{X_L}{Z} = \frac{X_C}{Z} = \frac{V_L}{V_S} = \frac{V_C}{V_S} = \frac{1}{R}\sqrt{\frac{L}{C}}$

PARALLEL

$V_S = V_R = V_L = V_C$

$I_R = \frac{V_R}{R}$

$I_L = \frac{V_L}{X_L}$ and $I_C = \frac{V_C}{X_C}$

$I_T = \sqrt{{I_R}^2 + (I_L - I_C)^2}$

$Z = \frac{V}{I_T}$

$\cos\theta = \frac{I_R}{I_T}$

$Q = \frac{X_L}{Z} = \frac{X_C}{Z} = \frac{V_L}{V_S} = \frac{V_C}{V_S} = \frac{1}{R}\sqrt{\frac{L}{C}}$

THREE-PHASE AC GENERATION

STAR

$V_L = \sqrt{3} \times V_{PH}$ and $V_{PH} = I_{PH} \times Z_{PH}$

$I_L = I_{PH}$

DELTA

$V_L = V_{PH}$ and $V_{PH} = I_{PH} \times Z_{PH}$

$I_L = \sqrt{3} \times I_{PH}$

POWER

$S = \sqrt{3}V_L I_L$

$Q = \sqrt{3}V_L I_L \sin\theta$

$P = \sqrt{3}V_L I_L \cos\theta$

$P = S\cos\theta$

$\cos\theta = \frac{P}{S}$

$\eta = \frac{output}{input} \times 100\%$

TWO-WATTMETER METHOD

$P_T = W_1 + W_2$

$\tan\theta = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$

THREE-WATTMETER METHOD

$P_T = W_1 + W_2 + W_3$

FORMULA SHEET	
THREE-PHASE TRANSFORMERS	**THREE-PHASE MOTORS AND STARTERS**
STAR	**STAR**
$V_L = \sqrt{3} \times V_{PH}$ and $I_L = I_{PH}$	$V_L = \sqrt{3} \times V_{PH}$ and $I_L = I_{PH}$
DELTA	**DELTA**
$V_L = V_{PH}$ and $I_L = \sqrt{3} \times I_{PH}$	$V_L = V_{PH}$ and $I_L = \sqrt{3} \times I_{PH}$
POWER	**POWER**
$S = \sqrt{3} V_L I_L$	$S = \sqrt{3} V_L I_L$
$Q = \sqrt{3} V_L I_L \sin\theta$	$Q = \sqrt{3} V_L I_L \sin\theta$
$P = \sqrt{3} V_L I_L \cos\theta$	$P = \sqrt{3} V_L I_L \cos\theta$
$P = S \cos\theta$	$P = S \cos\theta$
$\cos\theta = \frac{P}{S}$	$\cos\theta = \frac{P}{S}$
$\eta = \frac{P_{output}}{P_{output} + losses} \times 100\%$	$\eta = \frac{P_{output}}{P_{input}} \times 100\%$
$\text{T. Ratio} = \frac{V_{PHP}}{V_{PHS}} = \frac{N_P}{N_S} = \frac{I_{PHS}}{I_{PHP}}$	**MOTOR SPEED**
	$n_s = \frac{60 \times f}{p}$
	$\%Slip = \frac{n_s - n_r}{n_s} \times 100\%$
	$S = N_S - N_R$
	$Overload\ setting = 125\% \times rated\ current$