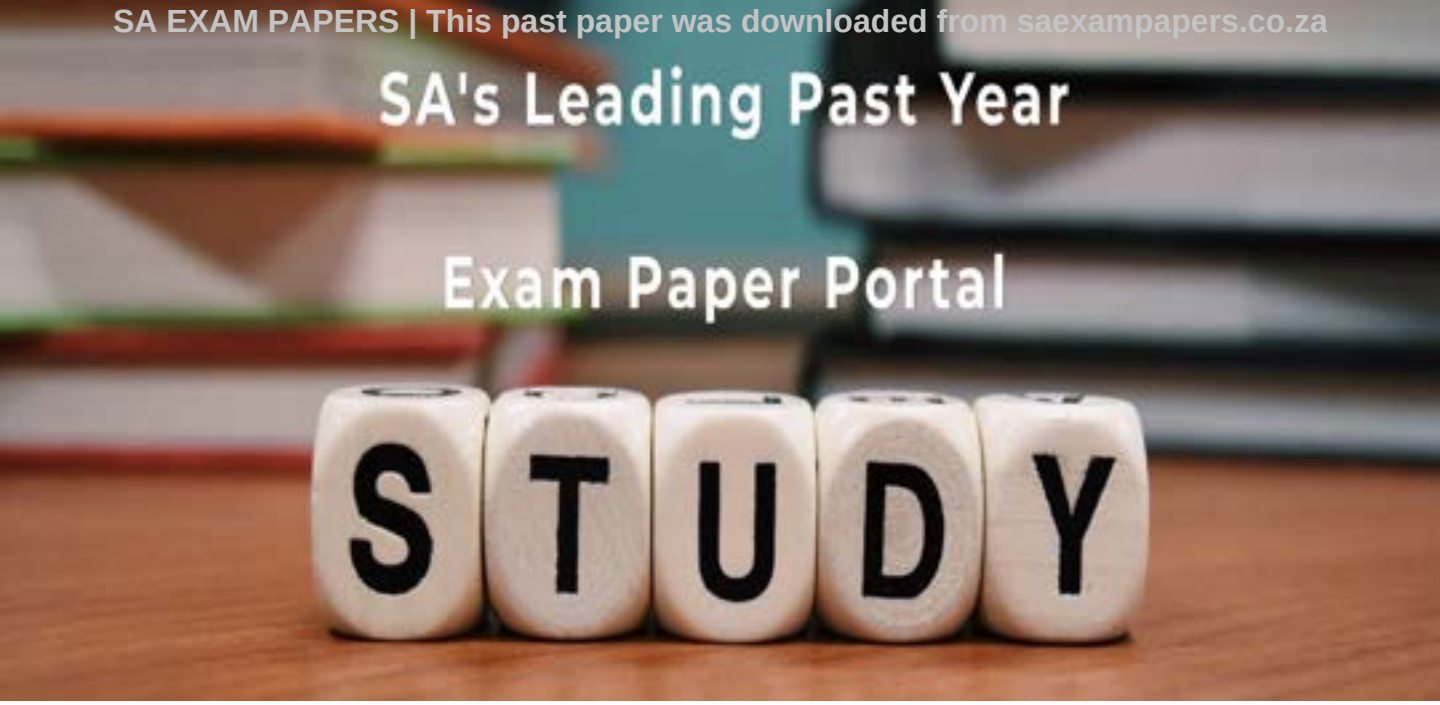

Province of the
EASTERN CAPE
EDUCATION

Iphondo leMpuma Kapa: Isebe leMfundo
Provinsie van die Oos Kaap: Department van Onderwys
Porafensie Ya Kapa Botjahabela: Lefapha la Thuto

NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2024

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

MARKS: **200**

TIME: **3 hours**

This question paper consists of 17 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 the answer correctly to TWO decimal places. Show the units for ALL answers of calculations.
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 The layer(s) of the skin that is/are affected by a third-degree burn would be …

A the outer layer.
B the second layer.
C all layers of skin.
D None of the above-mentioned. (1)

1.2 The phase angle of the current in a predominantly inductive, RLC circuit is …

A leading.
B lagging.
C in phase.
D zero. (1)

1.3 The opposition by a capacitor against the flow of alternating current in a RLC circuit is the …

A inductive reactance.
B impedance.
C capacitive reactance.
D inductance. (1)

1.4 A RLC circuit has a maximum impedance and a minimum current during … resonance.

A series
B parallel
C the frequencies before
D the frequencies after (1)

1.5 Self-contained units controlled from the main control centres are called …

A switchgear.
B distribution networks.
C substations.
D power stations. (1)

1.6 A step-down transformer is used to …

A increase the power.
B decrease the power.
C decrease the voltage
D increase the voltage. (1)

1.7 A three-phase system is generated when three coils are placed 120° apart and rotated in a …

A uniform magnetic field.
B vacuum.
C triangle.
D All the above-mentioned. (1)

1.8 A delta-star transformer is used …

A mainly in heavy industries where a high-power transfer is essential.
B as a step-down transformer in high voltage supply lines.
C mainly for interior wiring of premises.
D extensively in distribution systems where a four-wire system is required. (1)

1.9 Air Natural (AN) is a cooling method used for …

A dry transformers.
B oil immersed transformers.
C relays.
D contactors. (1)

1.10 The purpose of a no-volt relay is to ...

A allow a motor to automatically start after a power failure is restored.
B increase the voltage of a three-phase motor.
C prevent a motor from automatically starting when a power failure is restored.
D monitor the amount of current drawn by a motor. (1)

1.11 The start button used in a motor control circuit is …

A normally open pushbutton.
B open-relay contact.
C normally closed pushbutton.
D closed-relay contact (1)

1.12 … helps avoid cogging and reduces magnetic hum.

A An armature
B A skewed rotor
C The stator
D A cooling fan (1)

1.13 An example of a PLC output is a …

A normally open contact.
B motor.
C sensor.
D marker or flag. (1)

1.14 A PLC's hardware is …

A all the physical parts and components that make up the device.
B the machine language that is installed on a computer.
C the plc processor.
D Both A and C. (1)

1.15 … detect the presence of metal objects and whether they are ferrous or nonferrous.

A Capacitive proximity sensors
B Inductive proximity sensors
C Ultrasonic proximity sensors
D All the above (1)

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 Explain why the misuse of equipment in a workshop is considered an unsafe act. (2)

2.2 State TWO recommended ways to stop bleeding. (2)

2.3 Write down any TWO standard treatments for shock. (2)

2.4 Define a *medical emergency*. (2)

2.5 List ONE unsafe condition that must be avoided in a workshop. (1)

2.6 Name ONE important personal protection item used when working with chemicals. (1)

[10]

QUESTION 3: RLC CIRCUITS

3.1 State the phase relationship between the current and voltage in a pure capacitive AC circuit. (1)

3.2 Define the following with reference to RLC circuits connected across an alternating voltage supply.

3.2.1 *Phasor diagram* (2)

3.2.2 *Resonant frequency* (2)

3.3 A series circuit with resistance of 600 Ω, inductance 100 mH and capacitance 4 µF is connected across a 120 V / 60 Hz supply.

Given:

R = 600 Ω
L = 100 mH
C = 4 µF
V_S = 120 V
F = 60 Hz

Calculate:

3.3.1 The reactance of the inductor (3)

3.3.2 The reactance of the capacitor (3)

3.3.3 The circuit impedance (3)

3.3.4 The circuit current (3)

3.5 Find the resonant frequency of a circuit with a 100 mH coil connected in series with a 0,022 µF capacitor. (3)

3.6 Refer to FIGURE 3.6 below and answer the questions that follow.

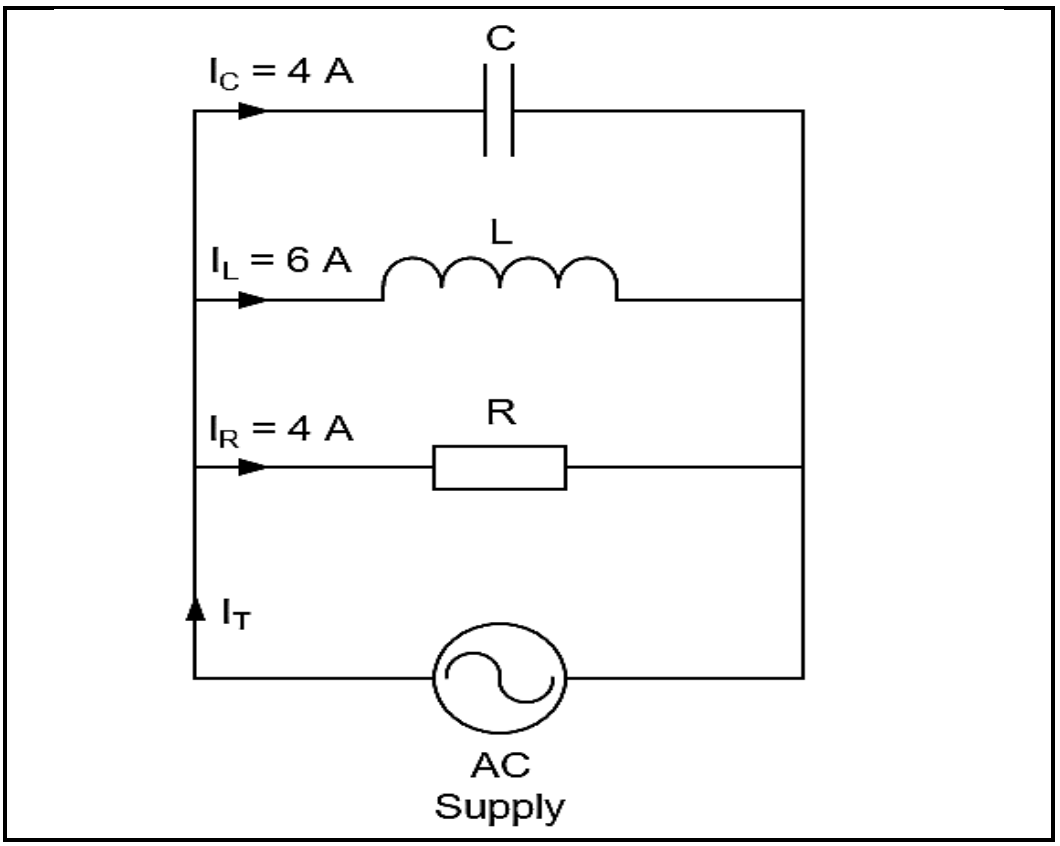

FIGURE 3.6: PARALLEL RLC CIRCUIT

Given:

I_C = 4 A
I_L = 6 A
I_R = 4 A

3.6.1 Calculate the total current. (3)

3.6.2 Calculate the phase angle. (3)

3.6.3 Draw a labelled phasor diagram for FIGURE 3.6. (3)

3.6.4 Motivate, with a reason, if the circuit is predominantly capacitive or inductive. (3)

3.7 State THREE conditions that will occur if the power factor is at unity in a RLC series circuit. (3)

[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 State THREE disadvantages of a three-phase generation in comparison with a single-phase generation. (3)

4.2 Explain the term *apparent power*. (1)

4.3 Name the THREE network stages of the national power grid in the CORRECT order. (3)

4.4 A three-phase generator delivers power to a star-connected load. The phase voltage of the load is 230 V with a line current of 35 amperes. The phase angle is 18°.

Given:

$V_{PH} = 230$ V
$I_L = 35$ A
$\theta = 18°$

Calculate the following:

4.4.1 The line voltage (3)

4.4.2 The apparent power (3)

4.4.3 The reactive power (3)

4.4.4 The true power (3)

4.5 Two watt-meters indicate 10 kW and 3 kW respectively when they are connected to measure the input power to the load. Calculate the total power in kW.

Given:

$W_1 = 10$ kW
$W_2 = 3$ kW (3)

4.6 Name ONE application of a wattmeter in three-phase AC systems. (1)

4.7 FIGURE 4.7 below shows an analogue power factor meter. Answer the questions that follow.

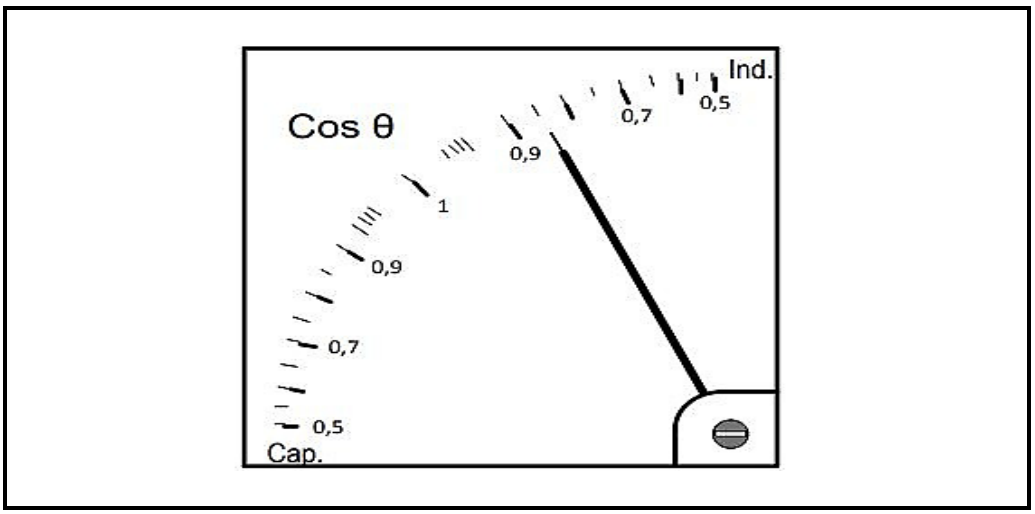

FIGURE 4.7: POWER FACTOR METER

4.7.1 Does the reading show a leading or lagging power factor? (1)

4.7.2 State the cause of this type of reading. (1)

4.7.3 State how the meter reading could be brought closer to unity. (1)

4.8 Explain the effect of stepping up the voltage in transmission lines. (2)

4.9 State TWO quantities, other than power, that can be determined by using the two-wattmeter method. (2)

4.10 Explain how copper losses are reduced in overhead transmission lines. (2)

4.11 Briefly explain why the generated electricity is lower at the point of distribution than at the point of generation. (2)

4.12 State the function of a kilowatt-hour meter. (1)

[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Compare three single-phase transformers with a three-phase transformer if they supply the same three-phase load. Refer to the following factors:

5.1.1 Economic cost (1)

5.1.2 Efficiency (1)

5.2 Name TWO cooling methods used in a dry transformer. (2)

5.3 State the main cause that contributes to heat generation in transformers. (1)

5.4 State TWO safety precautions when working with transformers. (2)

5.5 Name TWO physical characteristics of a three-phase shell-type transformer. (2)

5.6 Name TWO of the most common internal failures of three-phase transformers. (2)

5.7 FIGURE 5.7 below is a diagrammatic representation of a three-phase transformer connection. Answer the questions that follow.

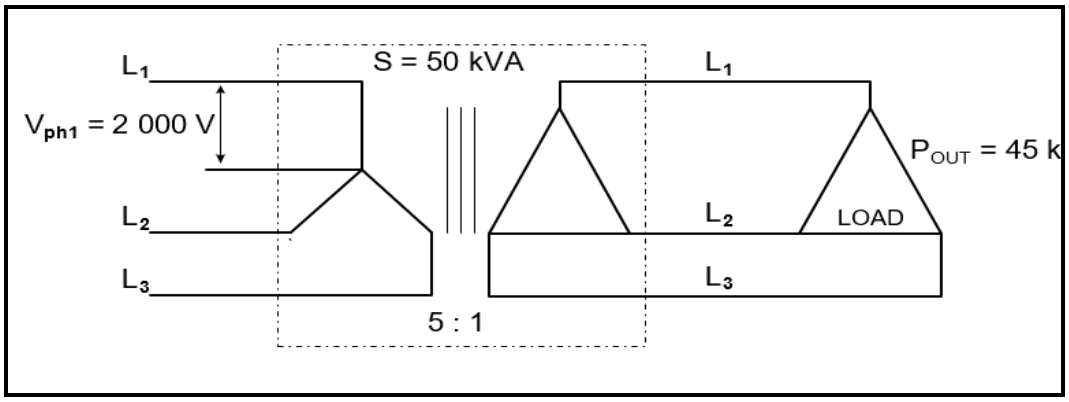

FIGURE 5.7

5.7.1 Identify the type of transformer connection in FIGURE 5.7. (1)

5.7.2 Name TWO applications of the transformer in FIGURE 5.7. (2)

5.7.3 State, with a reason, whether the transformer is a step-up or step-down transformer. (2)

5.8 Refer to the circuit diagram in FIGURE 5.8 below and answer the questions that follow.

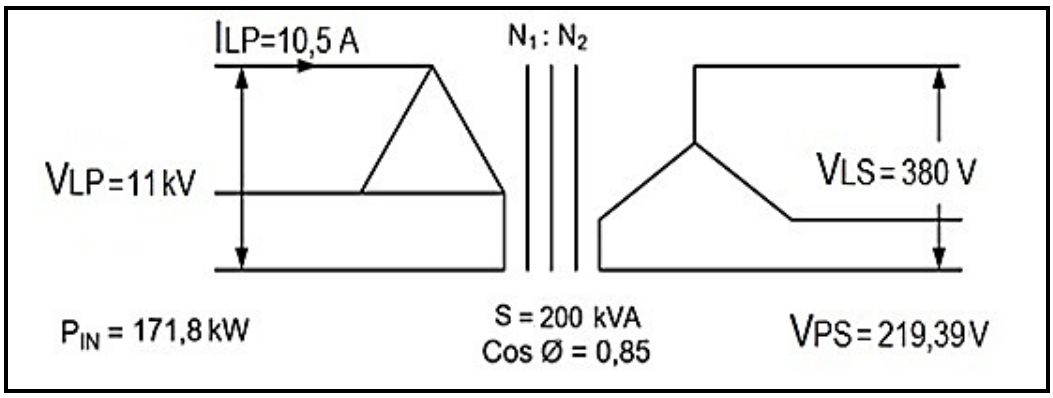

FIGURE 5.8: TRANSFORMER CONNECTION

Given:

$S = 200$ kVA
$V_{LP} = 11$ kV
$V_{LS} = 380$ V
$I_{LP} = 10{,}5$ A
$P_{IN} = 171{,}8$ kW
$\cos\theta = 0{,}85$
$V_{PHS} = 219{,}39$ V

Calculate the:

5.8.1 Efficiency of the transformer if it operates at a power factor of 0,85 lagging (5)

5.8.2 Turns ratio (3)

5.8.3 Secondary line current of the transformer (3)

5.9 Explain why a transformer only operates with an AC supply. (3)
[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 Name THREE mechanical inspections that could be carried out on the rotor and bearings of a motor. (3)

6.2 Name TWO continuity tests to be performed on a three-phase motor. (2)

6.3 State TWO applications of squirrel-cage induction motors where constant speed and torque is essential. (2)

6.4 Differentiate between *synchronous speed* and *rotor speed*. (2)

6.5 FIGURE 6.5 below shows the rotor of an induction motor. Answer the questions that follow.

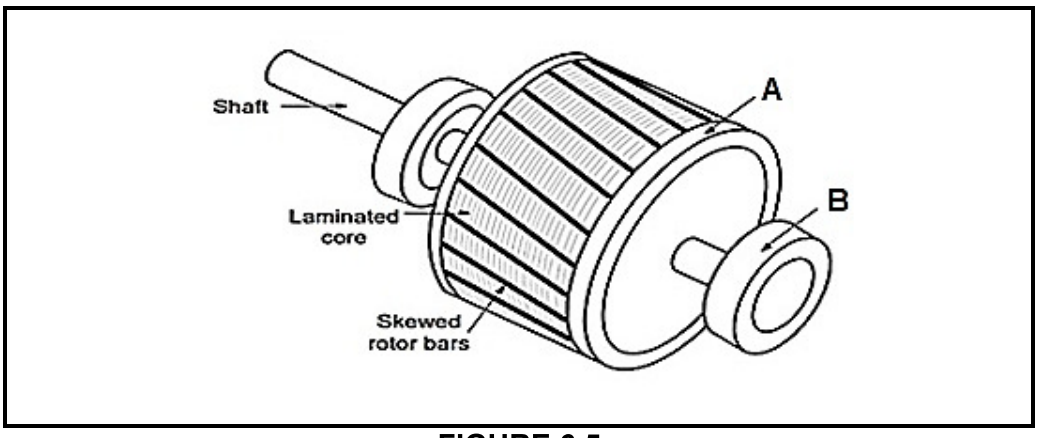

FIGURE 6.5

6.5.1 Name parts **A** and **B**. (2)

6.5.2 State ONE important advantage of using this type of a rotor compared to using a motor with brushes and slip rings. (1)

6.5.3 Give ONE reason why the rotor bars are skewed. (1)

6.6 A three-phase induction motor with 6 pole pairs per phase is connected to a 380V/50Hz supply and has a slip of 0,05 units.

Given:

p = 6
f = 50 Hz
s = 0,05 units
V = 380 V

Calculate the following:

6.6.1 Synchronous speed (3)

6.6.2 Rotor speed (3)

6.7 TABLE 6.7 below shows the name plate of a three-phase induction motor. Answer the questions that follow.

MOTOR MANUFACTURER SPECIFICATION	
Phase	3
Voltage	380 V
Current	1,3 A
Speed	1 500 r/min
Power	7,5 kW
Frequency	50 Hz
Cos θ	0,8 lagging
Frame No	22SP27

TABLE 6.7: NAME PLATE OF A THREE-PHASE INDUCTION MOTOR

6.7.1 State the amount of current the motor will draw from the supply at full load. (1)

6.7.2 Explain why the motor is suitable for use in South Africa. (2)

6.7.3 State what the 7,5 kW on the name plate indicates. (1)

6.7.4 Determine the total number of poles. (5)

6.7.5 Calculate the efficiency of the motor at full load if the total loss is 1,2 kW. (5)

6.8 Explain how the direction of rotation of a three-phase induction motor can be changed. (2)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS

7.1 List THREE safety precautions to be considered when connecting a PLC to the supply. (3)

7.2 State THREE important hardware components of a PLC. (3)

7.3 Describe the following terms with reference to a PLC:

7.3.1 Hardware (2)

7.3.2 Software (3)

7.3.3 Opto-coupler (3)

7.4 FIGURE 7.4 below shows the control circuit of a direct-on-line (DOL) starter. Design a PLC ladder logic that will execute the same function.

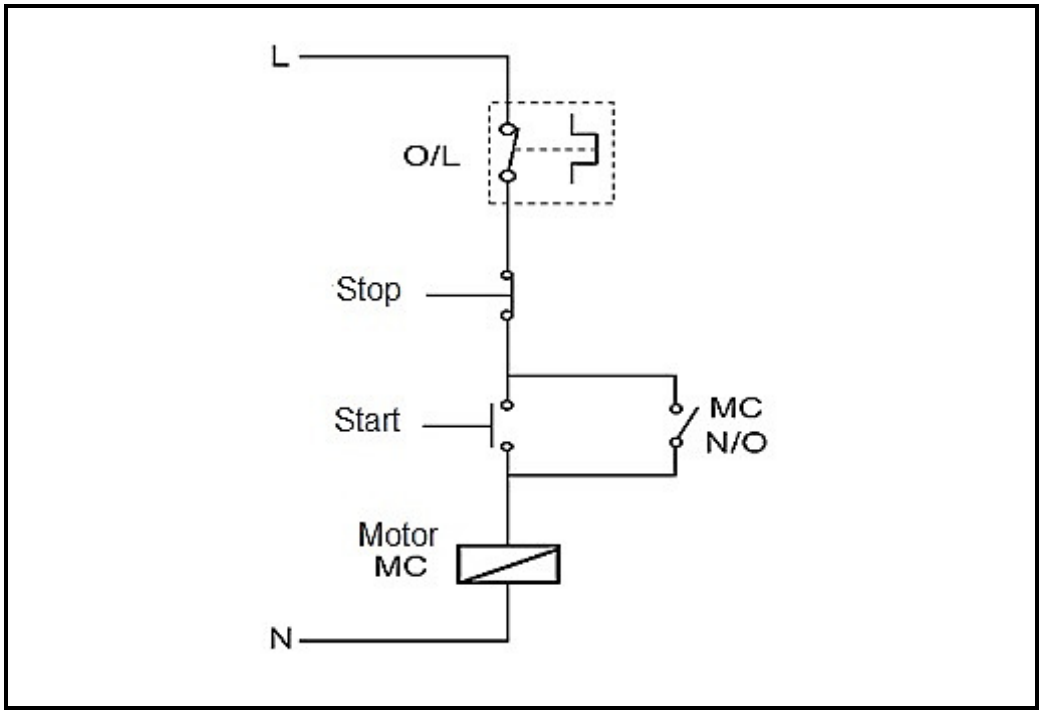

FIGURE 7.4: CONTROL CIRCUIT OF A DIRECT-ON-LINE STARTER (6)

7.5 Name TWO components used in the output module of a PLC to drive a high current inductive load. (2)

7.6 FIGURE 7.6 below shows the different stages in a variable speed drive. Answer the questions that follow.

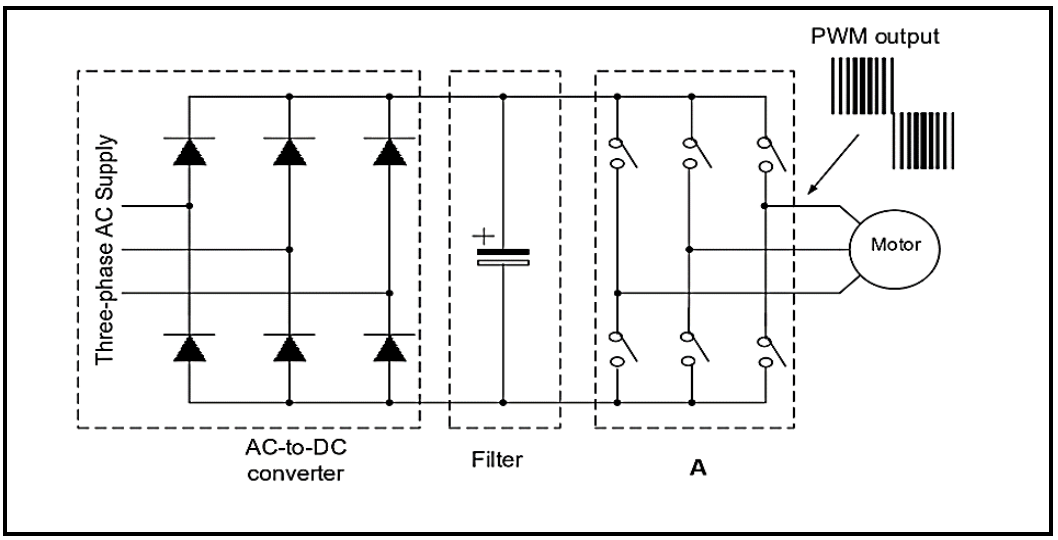

FIGURE 7.6: VARIABLE SPEED DRIVE STAGES

7.6.1 Identify stage **A.** (1)

7.6.2 Name a semiconductor component that could replace the switches used at **A**. (1)

7.6.3 State TWO advantages of using variable speed drives. (2)

7.6.4 Describe vector drives as a method of speed control. (3)

7.7 Explain the difference between an *analogue signal* and a *digital signal*. (2)

7.8 Draw a fully labelled diagram of a PLC scan cycle. (3)

7.9 With reference to sensors:

7.9.1 Explain the term *sensor*. (2)

7.9.2 Name TWO types of sensors other than a proximity sensor. (2)

7.9.3 State TWO uses of a proximity sensor. (2)
[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

$S = \sqrt{3}V_L I_L$

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

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

$P = S\cos\theta$

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

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

$\eta = \frac{P_{OUTPUT}}{P_{OUTPUT}+losses} \times 100$

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

STAR

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

DELTA

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

POWER

$S = \sqrt{3} V_L I_L$

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

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

$P = S \cos\theta$

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

$\eta = \frac{P_{output}}{P_{output} + losses} \times 100\%$

$\text{T. Ratio} = \frac{V_{PHP}}{V_{PHS}} = \frac{N_P}{N_S} = \frac{I_{PHS}}{I_{PHP}}$

THREE-PHASE MOTORS AND STARTERS

STAR

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

DELTA

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

POWER

$S = \sqrt{3} V_L I_L$

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

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

$P = S \cos\theta$

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

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

MOTOR SPEED

$n_s = \frac{60 \times f}{p}$

$\%\text{Slip} = \frac{n_s - n_r}{n_s} \times 100\%$

$n_r = n_s(1 - S)$

$S = n_S - n_R$

Overload setting = 125% × rated current