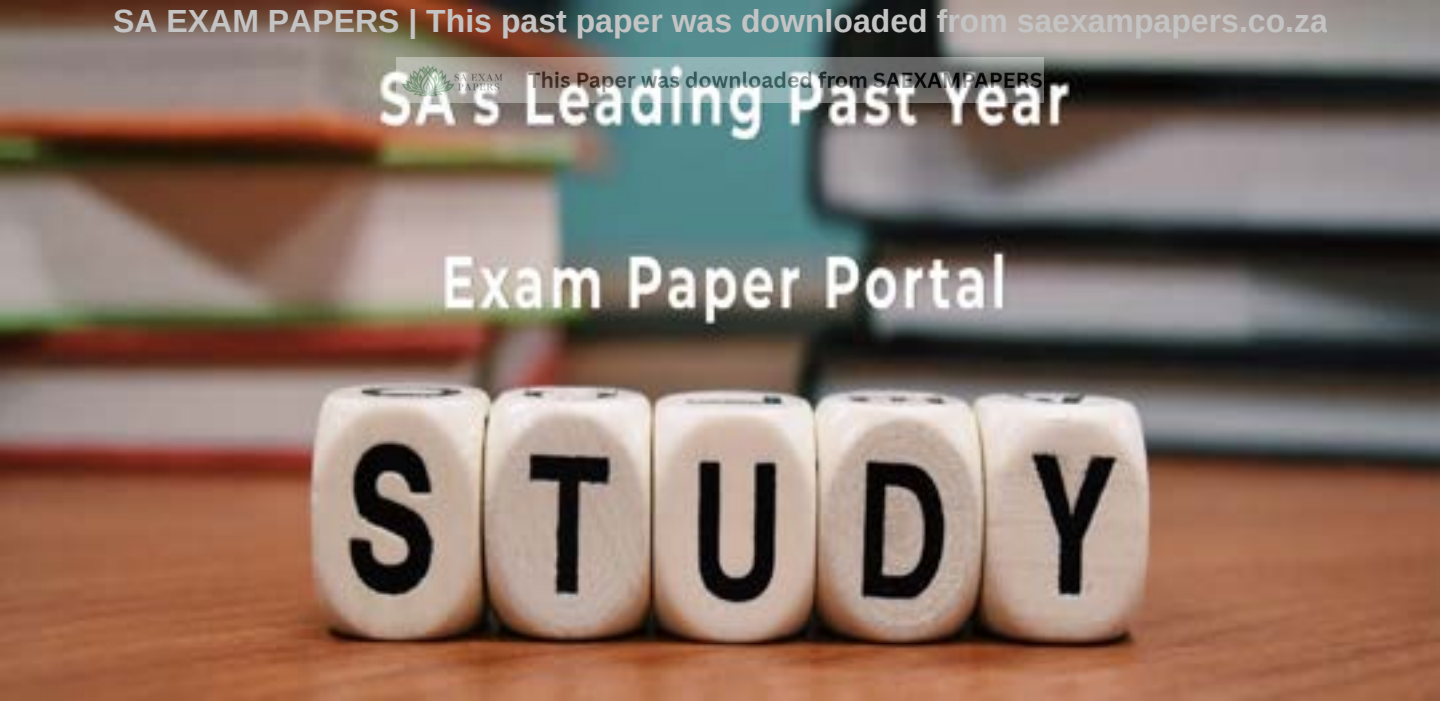


basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

MAY/JUNE 2025

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 15 pages.

INSTRUCTIONS TO THE MARKERS

1. All questions with multiple answers imply that any relevant, acceptable answer should be considered.

2. Calculations:

   2.1 All calculations must show the formulae.

   2.2 Substitution of values must be done correctly.

   2.3 All answers MUST contain the correct unit to be considered.

   2.4 Alternative methods must be considered, provided that the correct answer is obtained.

   2.5 Where an incorrect answer could be carried over to the next step, the first answer will be deemed incorrect. However, should the incorrect answer be carried over correctly, the marker has to re-calculate the values, using the incorrect answer from the first calculation. If correctly used, the candidate should receive the full marks for subsequent calculations.

3. This marking guideline is only a guide with model answers. Alternative interpretations must be considered and marked on merit. However, this principle should be applied consistently throughout the marking session at ALL marking centres.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

1.1	C ✓	(1)
1.2	B ✓	(1)
1.3	B ✓	(1)
1.4	A ✓	(1)
1.5	C ✓	(1)
1.6	D ✓	(1)
1.7	D ✓	(1)
1.8	D ✓	(1)
1.9	B ✓	(1)
1.10	A ✓	(1)
1.11	C ✓	(1)
1.12	B ✓	(1)
1.13	A ✓	(1)
1.14	D ✓	(1)
1.15	C ✓	(1)

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 Health and safety equipment refer to any artefact which is manufactured, provided or installed ✓ in the interest of the health or safety of any person. ✓ (2)

2.2 Removing safety guards/covers from machinery before using it. ✓
Removing the earth pin from a 3-pin plug intended for use in a three-wire earth system. ✓
Removing an emergency stop button from a motor control circuit. (2)

2.3 The purpose of the act is to provide health and safety for people at work in general. ✓
To create a safe environment for those who work with machinery. ✓ (2)

2.4 Every employer is required by law ✓ to make employees conversant with the hazards to their health and the safety attached to any work that they perform. ✓ (2)

2.5 An employee/learner with good discipline stays focused and completes his/her tasks set out for the duration in time. ✓
An employee/learner with good discipline will not fool around with or disturb others in the workshop in such a way that it might cause an accident. ✓ (2)
[10]

QUESTION 3: RLC CIRCUITS

3.1 Reactance is the opposition offered ✓ against the flow of alternating current ✓ by the inductor.
Reactance is the ratio of voltage to current in an AC circuit when the voltage and current is 90º out of phase. (2)

3.2 3.2.1

$$X_C = \frac{1}{2\pi fC} \quad ✓$$
$$= \frac{1}{2\pi(60)(100 \times 10^{-6})} \quad ✓$$
$$= 26{,}53\ \Omega \quad ✓$$

(3)

3.2.2 Series $I_T = I_R = I_L = I_C$

$$I_T = \frac{V_R}{R} \quad ✓$$
$$= \frac{74{,}28}{12} \quad ✓$$
$$= 6{,}19\ A \quad ✓$$

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$
$$= \sqrt{12^2 + (26{,}53 - 11{,}31)^2}$$
$$= 19{,}38\ \Omega$$

$$I_T = \frac{V_T}{Z}$$
$$= \frac{120}{19{,}38}$$
$$= 6{,}19\ A$$

(3)

3.2.3
$$V_L = I_T \times X_L \quad ✓$$
$$= 6{,}19 \times 11{,}31 \quad ✓$$
$$= 70{,}01\ V \quad ✓$$

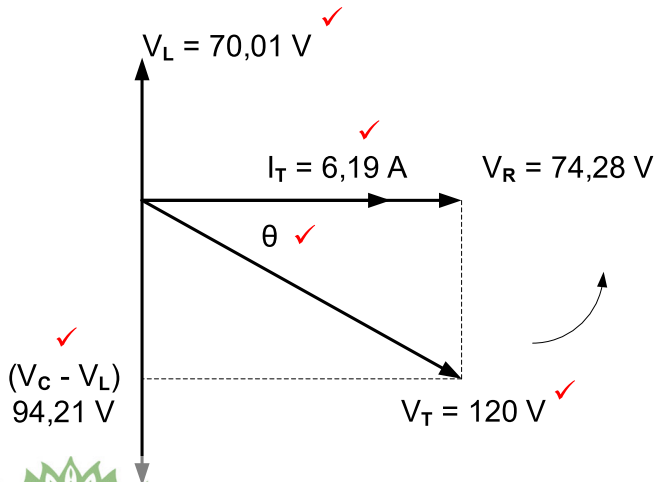
(3)

3.2.4 At resonance $X_L = X_C$

$$X_C = \frac{1}{2\pi fC} \quad ✓$$
$$C = \frac{1}{2\pi f X_C}$$
$$= \frac{1}{2\pi(60)(11{,}31)} \quad ✓$$
$$= 234{,}53\ \mu F \quad ✓$$

(3)

3.3



(5)

3.4 3.4.1

$$I_T = \sqrt{{I_R}^2 + (I_C - I_L)^2} \quad ✓$$
$$= \sqrt{0{,}48^2 + (0{,}71 - 0{,}51)^2} \quad ✓$$
$$= 0{,}52\ A \quad ✓$$ (3)

3.4.2

$$Cos\theta = \frac{I_R}{I_T} \quad ✓$$
$$\theta = Cos^{-1}\left(\frac{0{,}48}{0{,}52}\right) \quad ✓$$
$$= 22{,}62° \quad ✓$$

$$Tan\theta = \frac{(I_C - I_L)}{I_R}$$
$$\theta = Tan^{-1}\left(\frac{0{,}71 - 0{,}51}{0{,}48}\right)$$
$$= 22{,}62°$$ (3)

3.4.3

$$X_L = \frac{V_T}{I_L} \quad ✓$$
$$= \frac{48}{0{,}51} \quad ✓$$
$$= 94{,}12\ \Omega \quad ✓$$ (3)

3.4.4

$$X_L = 2\pi fL \quad ✓$$
$$f = \frac{X_L}{2\pi L}$$
$$= \frac{94{,}12}{2\pi(0{,}3)} \quad ✓$$
$$= 49{,}93\ Hz \quad ✓$$ (3)

3.5 3.5.1 Curve Q_2 ✓ (1)

3.5.2

$$f_r = \frac{f_1 + f_2}{2} \quad ✓$$
$$= \frac{30\,000 + 90\,000}{2} \quad ✓$$
$$= 60\,000\ Hz \quad ✓$$
$$= 60\ kHz$$ (3)

[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 Coal ✓ (1)

4.2 Transmission ✓
Distribution ✓ (2)

4.3
- Electricity is generated at 22 kV at the power station.
- There after the three-phase voltage is stepped up (220 kV-765 kV) for the transmission stage. ✓
- After transmission, at the first distribution station this ultra-high three-phase voltage is stepped down to a lower voltage (11kV) used by large industries. ✓
- There after it is stepped down to a lower three-phase voltage for small industries (400 V) and domestic households (230 V) through a transformer with a secondary star connection. ✓ (3)

4.4 4.4.1

$$S = \frac{P}{Cos\theta} \quad ✓$$

$$= \frac{30\,000}{0{,}85} \quad ✓$$

$$= 35294{,}12\ VA \quad ✓$$

$$= 35{,}29\ kVA$$ (3)

4.4.2

$$Cos\theta = pf \quad ✓$$

$$Cos\theta = 0{,}85$$

$$\theta = Cos^{-1}(0{,}85) \quad ✓$$

$$= 31{,}79° \quad ✓$$ (3)

4.4.3

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

$$Q = S \times sin\theta$$

$$= 35294{,}12 \times sin(31{,}79) \quad ✓$$

$$= 18593{,}21\ VA_R \quad ✓$$

$$= 18{,}59\ kVA_R$$ (3)

4.4.4

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

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

$$= \frac{30\,000}{\sqrt{3}(400)(0{,}95)} \quad ✓$$

$$= 45{,}58\ A \quad ✓$$ (3)

4.5

$$P = \sqrt{3}V_L I_{L1} cos\theta \quad ✓$$

$$I_{L1} = \frac{P}{\sqrt{3}V_L cos\theta}$$

$$= \frac{30\,000}{\sqrt{3}(400)(0{,}85)} \quad ✓$$

$$= 50{,}94\ A \quad ✓$$

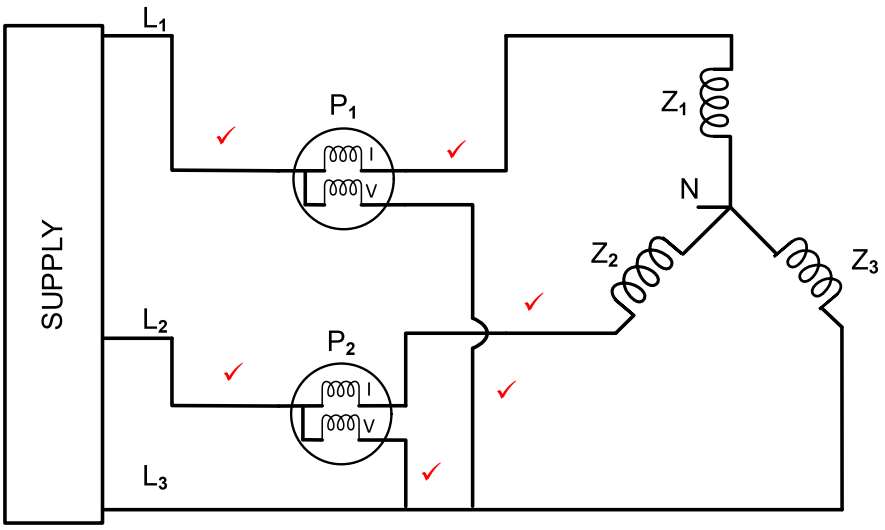
Therefore, the current before power factor correction (50,94 A) is greater than the current after power factor correction (45,58 A) ✓ (4)

4.6 The capacitors in parallel with the load creates leading currents ✓ because of its capacitive reactance ✓ which cancels out some of the lagging currents drawn by the inductive load ✓ improving the power factor in the process. (3)

4.7 4.7.1 The phase angle. ✓
Power factor. (1)

4.7.2 The meters can easily be connected to the lines. ✓
The same connection is used for star or delta connected loads. ✓
It is a more economical method of load measurement. (2)

4.7.3



(6)

4.8 Synchronous motors ✓
Phase advancers (1)
[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Mutual induction ✓ (1)

5.2 To reduce eddy currents in the core. ✓ (1)

5.3 An iron core is needed in the construction of a transformer to provide a magnetic field path ✓ for the magnetic field to be intense enough to produce the rated voltage across the windings ✓ with a minimum of exciting current.

The core provides the magnetic path to intensify/increase the magnetic field to induce an emf across the secondary windings. (2)

5.4 5.4.1

$$P = \sqrt{3}V_{L2}I_{L2}\cos\theta \quad ✓$$

$$I_{L2} = \frac{P}{\sqrt{3}\,V_{L2}\cos\theta}$$

$$= \frac{200 \times 10^3}{\sqrt{3}\,(400)(0{,}8)} \quad ✓$$

$$= 360{,}84\ A \quad ✓$$ (3)

5.4.2

$$S = \frac{P}{\cos\theta} \quad ✓$$

$$= \frac{200 \times 10^3}{0{,}8} \quad ✓$$

$$= 250\ kVA \quad ✓$$

$$S = \sqrt{3}V_{L2}I_{L2}$$

$$= \sqrt{3} \times 400 \times 360{,}84$$

$$= 249{,}98\ kVA$$ (3)

5.4.3

$$S = \sqrt{3}V_{L1}I_{L1} \quad ✓$$

$$I_{L1} = \frac{S}{\sqrt{3}\,V_{L1}}$$

$$= \frac{250 \times 10^3}{\sqrt{3}(6 \times 10^3)} \quad ✓$$

$$= 24{,}06\ A \quad ✓$$ (3)

5.4.4

$$I_{PH1} = \frac{I_{L1}}{\sqrt{3}} \quad ✓$$

$$= \frac{24{,}06}{\sqrt{3}} \quad ✓$$

$$= 13{,}89\ A \quad ✓$$ (3)

5.4.5

Turns ratio: $TR = \frac{N_1}{N_2} = \frac{I_{PH2}}{I_{PH1}}$	✓	$TR = \frac{N_1}{N_2} = \frac{V_{PH1}}{V_{PH2}}$	
$= \frac{I_{PH2}}{I_{PH1}}$	✓	$= \frac{6\,000}{230{,}94}$	
$= \frac{360{,}84}{13{,}89}$		$= 25{,}98 : 1$	
$= 26 : 1$	✓	$= 26 : 1$	(3)

5.5 5.5.1 Delta-delta configuration. ✓ (1)

5.5.2 For a step-down transformer the secondary windings will be thicker✓ to accommodate higher current flow. ✓ (2)

5.5.3 If the sequencing of the phases is incorrect, the phase relationship/sequencing of the magnetically connected phases will cause the secondary phase voltages to be incorrect ✓ and it could cause damage to externally connected equipment. ✓ (2)

5.6 The term *step-up* refers to an increase in voltage ✓ from the primary side to the secondary side according to the turns ratio ✓ of the transformer. (2)

5.7 5.7.1 Directional overcurrent relay ✓ (1)

5.7.2 The Buchholz relay as a safety device detects and responds to internal fault conditions. ✓

The Buchholz relay monitors the gas formation in the oil of the transformer under faulty conditions. (1)

5.7.3 Under normal conditions the three voltages sum to zero. ✓ If there is an earth fault on one of the phases, the difference in voltages will operate the relay, ✓ isolating the transformer. (2)

[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 6.1.1 A – Shaft ✓
B – End bell ✓
C – Foot mount ✓ (3)

6.1.2 To prevent the motor from overheating. ✓

During operation the fan blades on the rotor creates a flow of cool air through and around the motor to prevent the motor from overheating. (1)

6.1.3 Check the stator/frame for cracks. ✓
Check the bearings for smooth rotation. ✓
Check that the mounting bolts and nuts are properly tightened.
Check if the end plates are securely fastened.
Does the shaft turn freely by hand?
Is the motor clean and free from excess grease? (2)

6.1.4 (a) Acceptable ✓ – The resistances of the three coils are all within 5% of each other. ✓ (2)

(b) Acceptable ✓ – The reading is larger than 1 MΩ. ✓ (2)

(c) Not acceptable ✓ – The reading is less than 1 MΩ. ✓ (2)

6.2 6.2.1
$$n_s = \frac{60 \times f}{p} \quad ✓$$
$$= \frac{60 \times 50}{3} \quad ✓$$
$$= 1000\ r/min \quad ✓$$ (3)

6.2.2
$$Slip = n_s - n_r \quad ✓$$
$$n_r = n_s(1 - slip)$$
$$= 1000\left(1 - \frac{5}{100}\right) \quad ✓$$
$$= 950\ r/min \quad ✓$$ (3)

6.2.3
$$\eta = \frac{P_{IN} - losses}{P_{IN}} \quad ✓$$
$$= \frac{12\,000 - 500}{12\,000} \quad ✓$$
$$= 95{,}83\% \quad ✓$$ (3)

6.2.4 $P_{OUT} = \sqrt{3}\,V_L I_L\, cos\theta\, \eta$ ✓

$= 12\,000\left(\frac{95{,}83}{100}\right)$ ✓

$= 11499{,}6\,W$ ✓

$= 11{,}5\,kW$ (3)

OR

$P_{OUT} = P_{IN} - losses$

$= 12\,000 - 500$

$= 11\,500\,W$

$= 11{,}5\,kW$

6.2.5 $P_{IN} = \sqrt{3}V_L I_L cos\theta$ ✓

$I_L = \frac{P_{IN}}{\sqrt{3}V_L cos\theta}$

$= \frac{12\,000}{\sqrt{3}(400)(0{,}9)}$ ✓

$= 19{,}25\,A$ ✓ (3)

6.3 6.3.1 ON-delay timer ✓ (1)

6.3.2 Interlocking ✓ (1)

6.3.3 MC_2, ✓ because it is immediately energised when the start button is pressed. ✓ (2)

6.3.4 The motor starts in star and the timer starts timing.
As soon as the 3 seconds is reached the timer's contact will operate causing T N/C to open ✓ de-energizing MC_2 and closing MC_2N/C. ✓
Simultaneously T N/O will close ✓ energising MC_3 which in turn opens MC_3 N/C ✓ ensuring that MC_2 is de-energised. (4)
[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1 Reduced cost ✓
Reduced space
Flexibility
Simplicity (1)

7.2 The PLC scans all of its input terminals to see the state of each device connected to it,✓ reading each condition into the "input table" in its memory.✓

The input scan is the first stage of the programmed scan cycle which reads all the status of the input devices connected to it and store their states in the input memory. (2)

7.3
- All processing is done at low voltages and therefore safer. ✓
- The normal operation of a plant can be observed electronically on a monitor keeping the operator away from dangerous machines. ✓
- All operations are shown on the interface as machines turned on and faulty contactors can be located without having to fault find on a live system.
- Part of a plant can be switched off digitally for repairs to be done. (2)

7.4 7.4.1 The unit that performs all logic operations internally. ✓
It runs the ladder program. ✓ (2)

7.4.2 Soft-wired systems perform many functions digitally ✓ to reduce the amount of wiring in a circuit. ✓ (2)

7.4.3 PLC software is a program that is written into the unit to control its functions. ✓
PLC software is the program used to compile the ladder logic program. ✓ (2)

7.5 An analogue signal is a continuously changing signal. ✓
A digital signal is a signal with a number of discrete steps. ✓ (2)

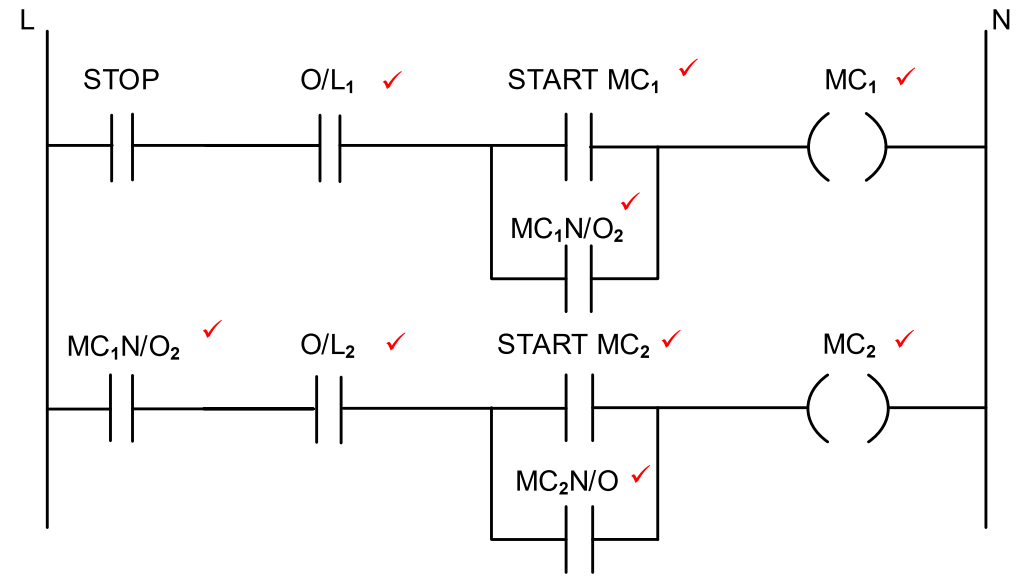
7.6 7.6.1 A sensor is a device that detects and converts an environmental condition ✓ into an electrical signal ✓ that can be used by another device for a particular purpose.

A sensor is a device whose physical characteristics changes due to external conditions. (2)

7.6.2 Temperature sensor ✓
Light sensor ✓
Overload sensor.
Level sensor. (2)

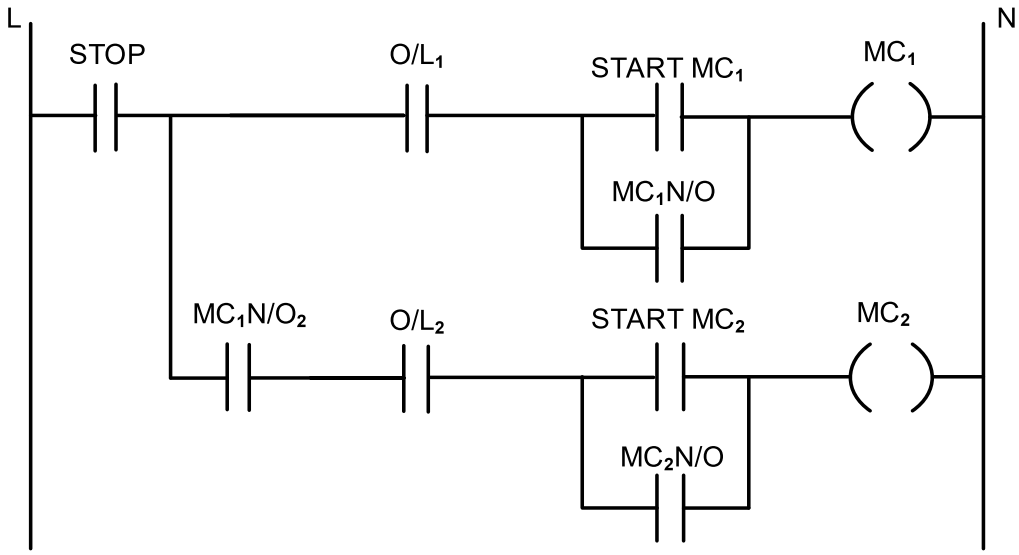
7.6.3 To detect the proximity of an object in relation to its distance. ✓
Used to measure rotating speed. ✓ (2)

7.7



(9)

OR



7.8 7.8.1 The regenerative energy charges the DC capacitors that store it for future use. ✓ (1)

7.8.2 When the regenerative energy becomes excessive, ✓ a braking resistor is connected in the circuit to dissipate the energy in the form of heat. ✓ (2)

7.9	7.9.1	AC to DC Converter ✓ Rectifier	(1)
	7.9.2	Capacitors ✓	(1)
	7.9.3	• The inverter inverts the DC voltage back to AC voltage. ✓ • by switching the Insulated Gate Bipolar Transistor ON and OFF at a different frequency. ✓ • The ON and OFF times (width of the pulses) are carefully controlled (PWM) with three pairs of switches (IGBTs). ✓ • For every pair of switches (IGBTs), one switch (IGBT) controls the positive ✓ part of the output voltage and the other switch (IGBT) controls the negative part of the output voltage. ✓ • The frequency of switching controls the rotation speed.	(5)
	7.9.4	Energy savings ✓ Better speed control of motors ✓ Better power factor Smooth starting of motors	(2) **[40]**
		TOTAL:	**200**