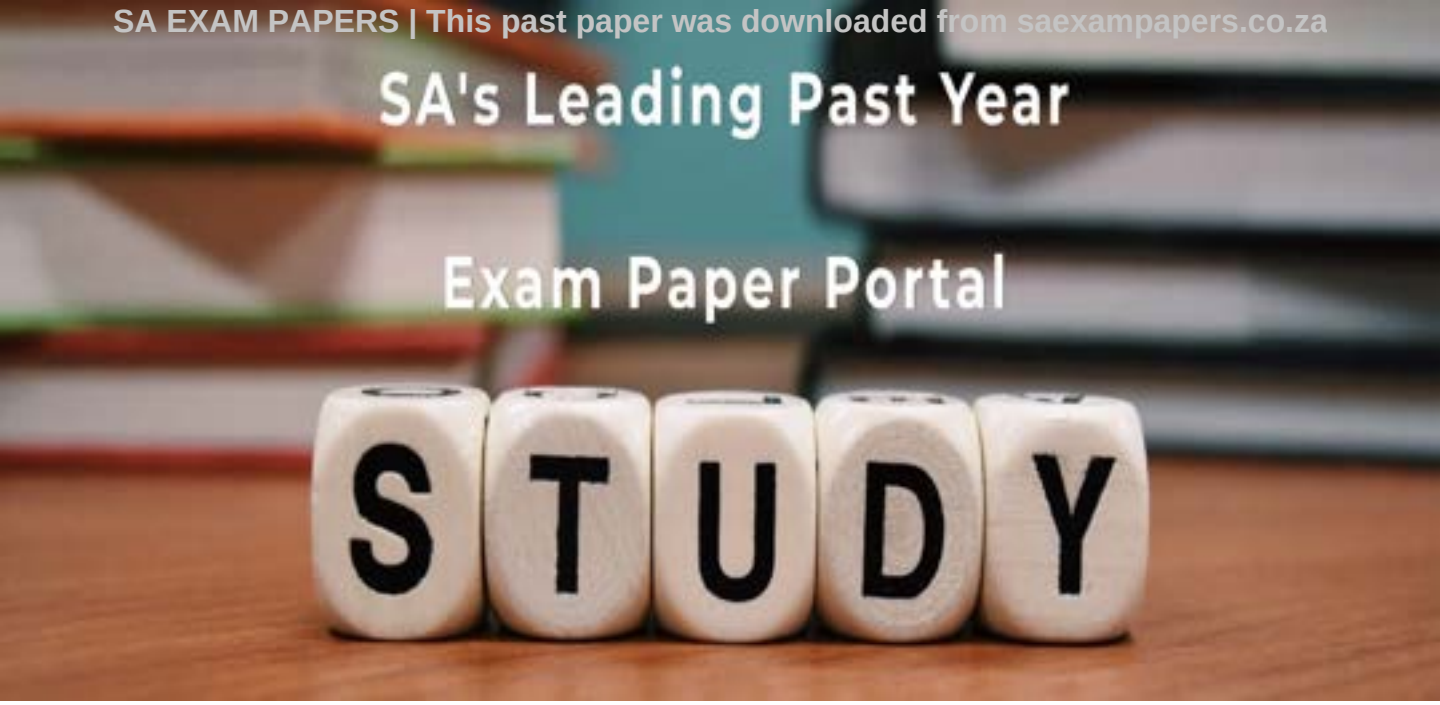


basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

NOVEMBER 2024

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 16 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 memorandum 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	B ✓	(1)
1.2	A ✓	(1)
1.3	B ✓	(1)
1.4	A ✓	(1)
1.5	C ✓	(1)
1.6	B ✓	(1)
1.7	D ✓	(1)
1.8	D ✓	(1)
1.9	C ✓	(1)
1.10	B ✓	(1)
1.11	D ✓	(1)
1.12	A ✓	(1)
1.13	B ✓	(1)
1.14	D ✓	(1)
1.15	C ✓	(1)

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 Workplace means any premises or place where a person performs work ✓ in the course of employment. ✓ (2)

2.2 Your right to fair labour practices. ✓
Your right to work reasonable hours. ✓
Your right to belong to a trade union.
Your right to earn a living wage.
Your right not to be discriminated against.
Your right to work in a safe environment. (2)

2.3 Poor ventilation reduces the correct amount of oxygen ✓ which might lead to drowsiness. ✓
NOTE: If reference is made to other effects that relates to poor ventilation like drowsiness, accidents etc. the answer will be accepted on merit. (2)

2.4
- To dismiss an employee without due process. ✓
- To reduce the rate of remuneration without due process. ✓
- Alter the terms of conditions of his/her employment to terms of conditions that is less favourable to him/herself.
- Harassment and verbal abuse.
- Alter position relative to other people.
- Treat employees unfair because of race.

NOTE: If a learner only mentions an infringement of rights only 1 mark will be awarded. Duplicate mentioning of rights will not be awarded. (2)

2.5 Equipment may be damaged making it unsafe ✓ endangering the life of other users ✓ which might lead to an accident/injury. (2)
[10]

QUESTION 3: RLC CIRCUITS

3.1 3.1.1 Inductive reactance is the opposition to the flow of current ✓ when an inductor is connected to an ac supply. ✓
Inductive reactance is the opposition offered to the flow of alternating current by an inductor. (2)

3.1.2 Bandwidth is the range of frequencies ✓ for which the circuit output voltage (or) current value equals 70,7 % or more of its maximum amplitude. ✓
NOTE: A band of frequencies centred around the resonant frequency without mentioning 70,7% of the amplitude will be awarded 1 mark.
The bandwidth of an RLC circuit refers to the range of frequencies over which an RLC circuit effectively responds to an input signal and transmits more than 50% of the power to a load. (2)

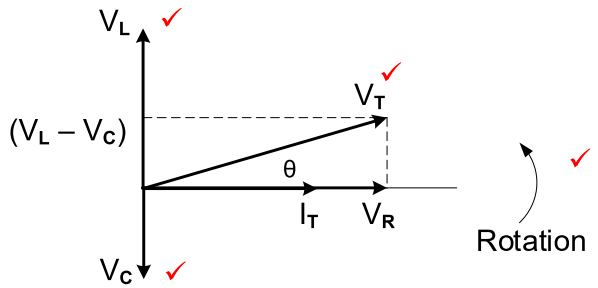
3.2 3.2.1 Lagging ✓ (1)

3.2.2
$$V_L = IX_L \quad ✓$$
$$I = \frac{V_L}{X_L}$$
$$= \frac{3{,}45}{150} \quad ✓$$
$$= 23\ mA \quad ✓$$
$$= 0{,}023\ A$$ (3)

3.2.3
$$X_L = 2\pi fL$$
$$L = \frac{X_L}{2\pi f} \quad ✓$$
$$= \frac{150}{2\pi(50)} \quad ✓$$
$$= 477{,}46\ mH \quad ✓$$
$$= 0{,}48\ H$$ (3)

3.2.4
$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad ✓$$
$$R = \sqrt{Z^2 - (X_L - X_C)^2} \quad ✓$$
$$= \sqrt{106{,}42^2 - (150 - 113{,}6)^2}$$
$$= 100\ \Omega \quad ✓$$ (3)

3.2.5



NOTE: Rotation and V_T are compulsory marks, thereafter any two correctly placed labels.
X_L and X_C will not be accepted as the given diagram to complete from the question paper indicated voltage values. (4)

3.2.6 A decrease in frequency caused the inductive reactance to decrease ✓ and the capacitive reactance to increase. ✓ When these two values move closer to one another their effects cancel each other out decreasing the impedance ✓ causing the current to increase and the phase angle to decrease. (3)

3.3 3.3.1

$$I_R = \frac{V_T}{R} \quad \checkmark$$

$$= \frac{230}{60} \quad \checkmark$$

$$= 3{,}83\ A \quad \checkmark$$

(3)

3.3.2

$$X_C = \frac{V_T}{I_C} \quad \checkmark$$

$$= \frac{230}{9{,}2} \quad \checkmark$$

$$= 25\ \Omega \quad \checkmark$$

(3)

3.3.3 $I_T = I_R = 3{,}83$ A ✓
$X_C = X_L$ which indicates that the circuit is at resonance ✓ (2)

3.3.4 $X_C = X_L$ ✓

$$Q = \frac{R}{X_L} \quad \checkmark$$

$$= \frac{60}{25} \quad \checkmark$$

$$= 2{,}4$$

(3)

3.3.5

$$BW = \frac{f_r}{Q} \quad \checkmark$$

$$= \frac{50}{2{,}4} \quad \checkmark$$

$$= 20{,}83\ Hz \quad \checkmark$$

(3)
[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 The load can be balanced in a three-phase system. ✓
Both single-phase and three-phase loads can be powered from a three-phase system. ✓
Supply of power is constant.
A Three-phase system is more economical.
A three-phase system can be connected in star or delta. (2)

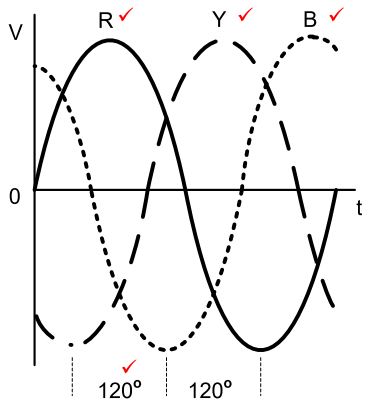
4.2 4.2.1 22 kV ✓
50 Hz ✓ (2)

4.2.2 Nuclear fuel ✓
Wind ✓
Water
Solar (2)

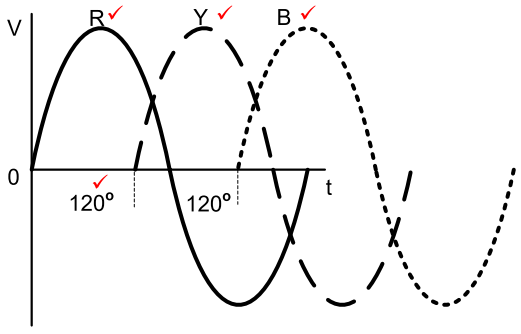
4.2.3
- After generation the voltage is stepped up ✓ to a value between 220 kV to 765 kV.
- It is then transmitted over long distances ✓ by means of cables made of aluminium and steel
- to distribution stations where it is stepped down ✓ before it is distributed further. (3)

4.3 4.3.1 Star ✓ (1)

4.3.2



OR



NOTE: If a candidate gives the correct sequence but in a different order, marks will be awarded. E.g. Y, B, R or V_2, V_3, V_1 etc. (4)

4.4 4.4.1

$P = SCos\theta$ ✓

$= (14000)(0,85)$ ✓

$= 11\ 900\ W$ ✓ (3)

4.4.2

$I_L = \frac{S}{\sqrt{3}\ V_L}$ ✓

$= \frac{14\ 000}{\sqrt{3}(400)}$ ✓

$= 20,21\ A$ ✓

OR

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

$= \frac{11900}{\sqrt{3}(400)(0,85)}$

$= 20,21\ A$ (3)

4.4.3

$I_{PH} = \frac{I_L}{\sqrt{3}}$ ✓

$= \frac{20,21}{\sqrt{3}}$ ✓

$= 11,67\ A$ ✓ (3)

4.4.4

$Z_{PH} = \frac{V_{PH}}{I_{PH}}$ ✓

$= \frac{400}{11,67}$ ✓

$= 34,27\ \Omega$ ✓ (3)

4.4.5

$pf = Cos\theta$ ✓

$\theta = Cos^{-1}(pf)$

$= Cos^{-1}(0,85)$ ✓

$= 31,78^{\circ}$ ✓

OR

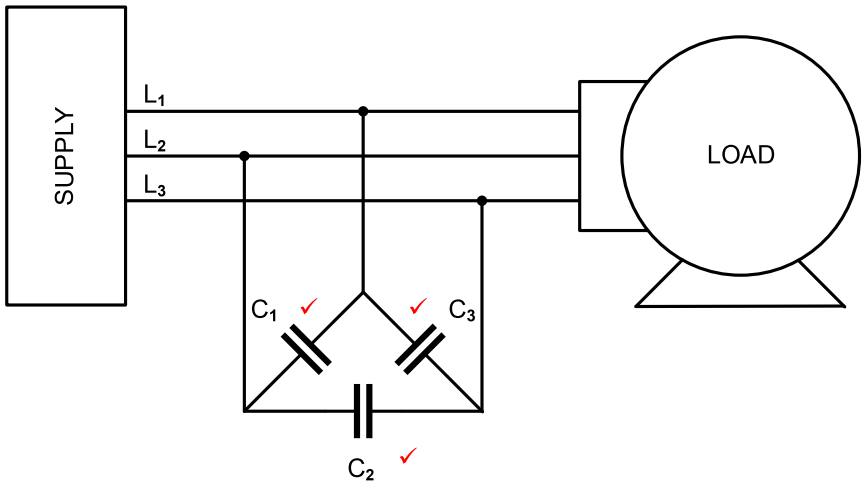
$Cos\theta = \frac{P}{S}$

$\theta = Cos^{-1}\left(\frac{11900}{14000}\right)$

$= 31,78^{\circ}$ (3)

4.5 4.5.1 Synchronous motors. ✓
Phase advancers. (1)

4.5.2



NOTE: Because the capacitors are not labelled in the prescribed textbook, an exception is made to the rule of labelling. 3 Marks will be awarded if the capacitors are correctly drawn without labels. (3)

4.5.3 The two-wattmeter method ✓ would be preferred because there is no neutral connection available, ✓ one can only connect between the lines. (2)
[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Transformers are used for raising or lowering the voltage ✓ in an AC circuit with a corresponding decrease or increase ✓ in current. (2)

5.2 A transformer is an electrical device that operates on the principle of electromagnetic induction ✓ to transfer electrical energy from one electric circuit to another without changing ✓ the frequency. (2)

5.3 5.3.1 Core-type. ✓ (1)

5.3.2 The laminated iron core reduces the circulating currents ✓ (eddy currents) inside the core material reducing the heat ✓ generated by them making the transformer more efficient.
The laminations are designed to increase the efficiency of a transformer by reducing the heat generated in the core of the transformer. (2)

5.3.3 The iron core in the core-type transformer is almost entirely surrounded by windings ✓ whereas in the shell-type transformer the windings are almost entirely surrounded by the iron core. ✓
Core type transformer has three limbs
Shell type transformers has five limbs (2)

5.3.4 The iron core of a transformer is continuously subjected to magnetic polarity changes while switched on. ✓ Before the magnetic polarity can be reversed, the residual magnetism in the core has to be forced to zero. ✓ The power used in destroying this residual magnetism is converted into heat. ✓ (3)

5.4 5.4.1

$$V_{PH} = \frac{V_L}{\sqrt{3}} \quad ✓$$

$$= \frac{380}{\sqrt{3}} \quad ✓$$

$$= 219{,}39\ V \quad ✓$$

(3)

5.4.2

$$\frac{N_1}{N_2} = \frac{V_{PH(1)}}{V_{PH(2)}} \quad ✓$$

$$N_1 = N_2 \times \frac{V_{PH(1)}}{V_{PH(2)}}$$

$$= 80 \times \frac{6000}{219{,}39} \quad ✓$$

$$= 2188 \text{ turns} \quad ✓$$

(3)

5.4.3

$$TR = \frac{N_1}{N_2} \quad ✓$$
$$= \frac{2188}{80} \quad ✓$$
$$= 27{,}35:1 \quad ✓$$
$$= 27:1$$

OR

$$TR = \frac{V_{PH(1)}}{V_{PH(2)}}$$
$$= \frac{6000}{219{,}39}$$
$$= 27{,}35:1$$
$$= 27:1$$

(3)

5.4.4

$$S = \sqrt{3} V_L I_L \quad ✓$$
$$I_{L1} = \frac{S}{\sqrt{3} V_{L1}} \quad ✓$$
$$= \frac{200\,000}{\sqrt{3}(6\,000)} \quad ✓$$
$$= 19{,}25\ A$$

(3)

5.5

- Burnt out windings ✓ caused by excessive current which causes too much heat dissipation.
- Electrical short circuits between the primary and secondary windings. ✓
- Windings that short circuit to the core of the transformer.
- Short circuit between adjacent windings, which change the ratios of the transformer.

(2)

5.6 5.6.1 Conservator/oil tank. ✓ (1)

5.6.2 It provides cooling. ✓
It prevents the formation of moisture on the windings. (1)

5.6.3 The Buchholz relay monitors the flow of gas in the transformer, ✓ when the gas reaches a high concentration it triggers the alarm, and disconnects the transformer from its operation. ✓ (2)

[30]

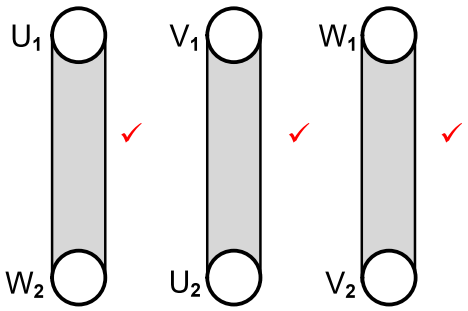
QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 Drill press ✓
Bench Grinder ✓
Lathe (2)

6.2 6.2.1 There is a lower than required insulation resistance reading between coil V and earth. ✓
The insulation resistance between coil V and earth is 100 kΩ and the minimum required insulation resistance between a coil and earth is 1 MΩ. (1)

6.2.2 When the motor is powered any person that touches any bare metal part of the motor may be electrocuted. ✓
Sparking may occur which might create a fire hazard.
If the motor is powered with the indicated fault, the motor can be damaged. (1)

6.2.3



✓ ✓ ✓ (3)

6.3 6.3.1

$$(pole\ pairs)\ p = \frac{poles\ per\ phase}{2} \quad ✓$$

$$= \frac{6 \div 3}{2} \quad ✓$$

$$= 1 \quad ✓ \quad (3)$$

6.3.2

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

$$= \frac{60 \times 50}{1} \quad ✓$$

$$= 3000\ r/min \quad ✓ \quad (3)$$

6.3.3

$$n_r = n_s 1 - \%slip \quad ✓$$

$$= 3000 \times \left(1 - \frac{6}{100}\right) \quad ✓$$

$$= 2820\ r/min \quad ✓ \quad (3)$$

OR

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

$$6 = \frac{3000 - n_r}{3000} \times 100$$

$$n_r = 2820\ r/min$$

6.4 6.4.1 MC_1N/O is a retain/latching contact ✓ that will keep the contactors energised after the start button is released. (1)

6.4.2 Contactor T is an ON-delay timer that creates a time delay ✓ of 5 seconds before switching its contacts. ✓ (2)

6.4.3 MC_2 is connected in series with the normally closed contacts of the timer and MC_3. ✓ This means that it will be energised as soon as the start button is pressed ✓ as is required by a star delta starter. (2)

6.4.4 After 5 seconds the timer T will open its N/C contact de-energising MC_2 ✓ while closing its N/O contact ✓ and energising MC_3 ✓ and in the process changing the motor coil configuration from star to delta in the main circuit. (3)

6.5 6.5.1

$$\eta = \frac{P_{OUT}}{P_{OUT} + losses} \times 100 \quad ✓$$

$$= \frac{30\ 000}{30\ 000 + 5\ 000} \times 100 \quad ✓$$

$$= 85{,}71\ \% \quad ✓$$ (3)

6.5.2

$$I_L = \frac{P}{\sqrt{3}V_L Cos\theta\eta} \quad ✓$$

$$= \frac{30\ 000}{\sqrt{3}(400)(0{,}87)\left(\frac{85{,}71}{100}\right)} \quad ✓$$

$$= 58{,}07\ A \quad ✓$$ (3)

6.5.3

$$\theta = Cos^{-1}(0{,}87) \quad ✓$$

$$= 29{,}54° \quad ✓$$

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

$$= \sqrt{3}(400)(58{,}07)Sin(29{,}54) \quad ✓$$

$$= 19\ 836{,}49\ VA_R \quad ✓$$

$$= 19{,}84\ kVA_R$$

NOTE: If a candidate substitute the phase angle, voltage and current correct without showing the calculation of the phase angle,
3 marks will be awarded for the substitution step.

OR

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

$$= \sqrt{3}(400)(58{,}07)Sin(Cos^{-1}(0{,}87))$$

$$= 19\ 836{,}49\ VA_R$$

$$= 19{,}84\ kVA_R$$

NOTE: 3 marks are allocated to the substitution step. (5)

[35]

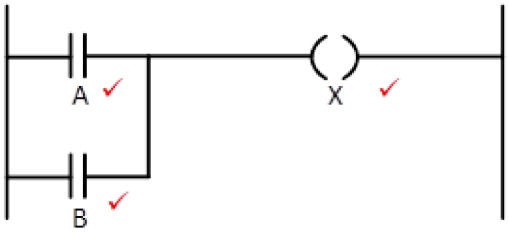
QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1 7.1.1 Input scan ✓
Output scan ✓ (2)

7.1.2 After the PLC has executed the programme instruction, ✓ it processes each rung of the programme ✓ in a line-by-line manner, sequentially. ✓ (3)

7.2 7.2.1 OR gate ✓ (1)

7.2.2



NOTE: Mark the ladder diagram according to the candidate's answer in 7.2.1. (3)

7.2.3 W = 0 ✓
X = 1 ✓
Y = 1 ✓
Z = 1 ✓
NOTE: Mark the truth table according to the candidate's answer in 7.2.1. (4)

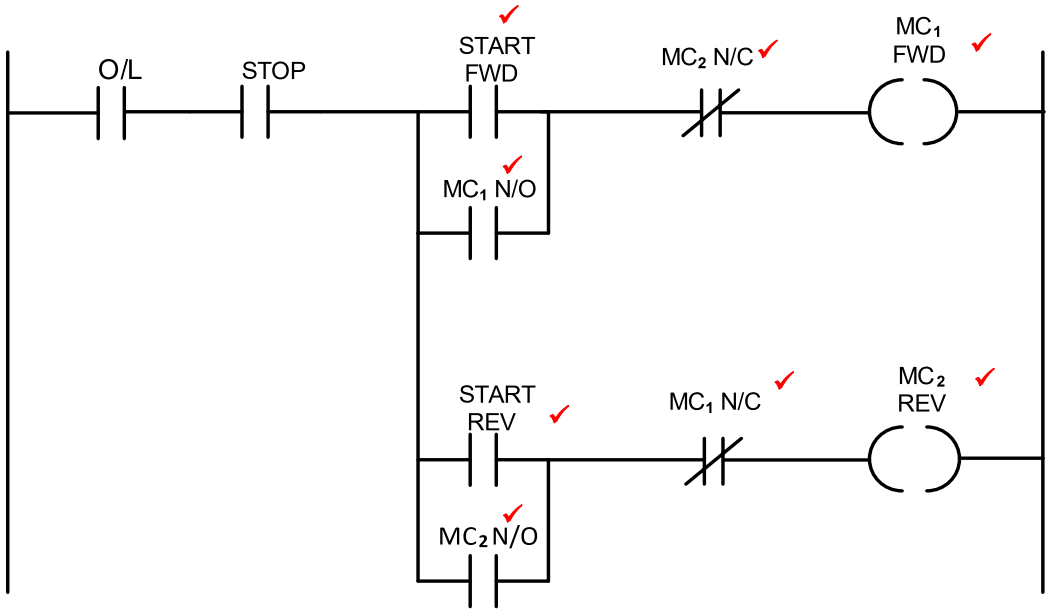
7.3 7.3.1 Discrete/Digital ✓
Analogue ✓ (2)

7.3.2 Irrigation control ✓
Monitoring of rivers and dams ✓
Numerous chemical, petrol and diesel manufacturing by remote monitoring (2)

7.3.3 An inductive proximity sensor is used to detect the presence of metal objects ✓ and whether they are ferrous or nonferrous. ✓

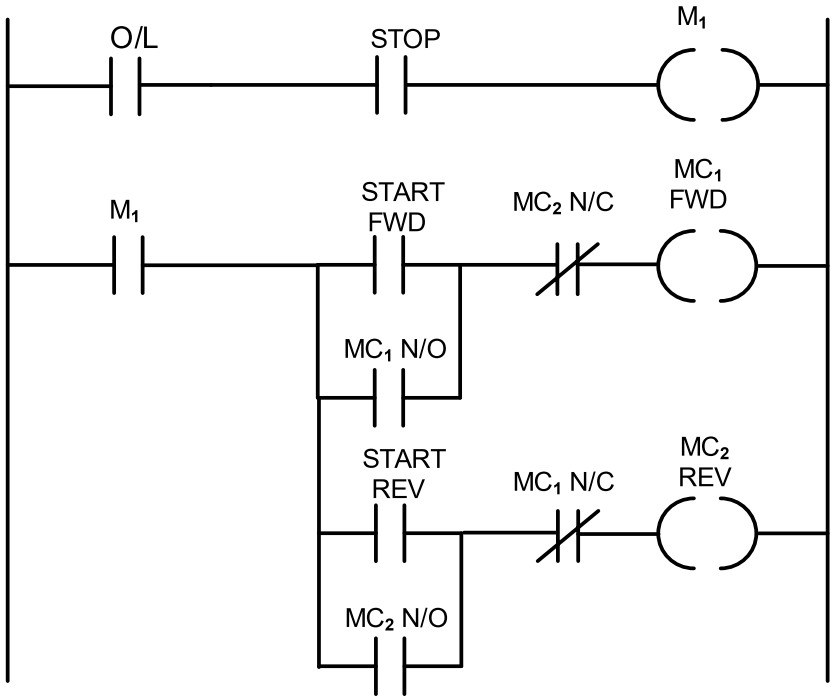
A capacitive proximity sensor uses an electrostatic field which can sense motion, ✓ pressure, ✓ chemical composition of materials and fluids. (4)

7.4



NOTE: - If a candidate closes the O/L or STOP inputs that were given, a mark will be deducted for each one that is closed, because the program will not operate correct according to the given diagram in the question.
- If a candidate connects START REV straight to the L power rail bypassing O/L and STOP, START REV will not be awarded a mark because of the wrong connection of START REV

OR



(8)

7.5 7.5.1 A = Three Phase AC supply ✓
B = AC to DC converter/Rectifier ✓
C = Filter ✓ (3)

7.5.2 AC synchronous squirrel cage induction ✓
AC asynchronous wound rotor ✓
AC synchronous with a permanent magnet
AC synchronous with brushes or brushless (2)

7.5.3 The DC to AC inverter inverts the DC voltage back to an AC voltage. ✓ This is done by switching the IGBT's on and off ✓ at a high frequency.✓. (3)

7.5.4 Pulse width modulation (PWM) is a modulation technique that generates variable-width pulses ✓ to represent the amplitude of an analogue input signal. ✓ The output switching transistor is on more of the time for a high-amplitude signal and off more of the time for a low-amplitude signal. ✓

OR

VSD switching frequency refers to the rate at which the DC bus voltage is switched on and off during the pulse width modulation (PWM) process. The on and off switching of the DC voltage is done by Insulated Gate Bipolar Transistors (IGBTs). (3)
[40]

TOTAL: 200