basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE/
NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

NOVEMBER 2020

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: OCCUPATIONAL HEALTH AND SAFETY

1.1   Any article or part thereof which is manufactured, provided or installed ✓ in the
        interest of the health or safety of any person. ✓   (2)

1.2   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.   (1)

1.3   • If a person dies. ✓
        • A major incident. ✓
        • An incident where the health and safety of any person has been/was
          endangered.   (2)

1.4   • 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 mentions only a violation of rights 1 mark will be awarded.
          Duplicate mentioning of rights will not be awarded.   (3)

1.5   In an emergency it can be pushed and it would immediately cut all electric
        power ✓ to all the equipment, stopping them, ✓ thus making the workshop
        safe.   (2)
                                                                                                        [10]

QUESTION 2: RLC CIRCUITS

2.1   2.1.1   If V_X lags V_R by 35°

$V_R = 20$ V

$\theta = 35°$ ✔

✔

$V_X = 30$ V
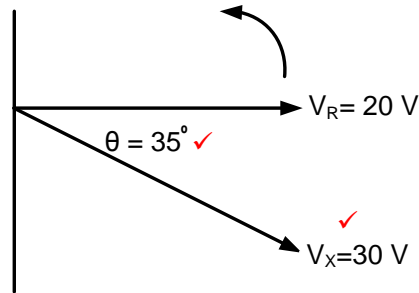
(2)

2.1.2   The voltages represent an RC circuit ✔ because, V_R is always in phase with I_T and V_X lags V_R by 35°. ✔
Because V_R is in phase with I_T and V_X is lagging V_R, thus proving that the circuit is predominantly capacitive as I_T leads V_X. (2)

2.2   2.2.1

$$X_L = 2 \times \pi \times f \times L$$ ✔
$$= 2 \times \pi \times 60 \times 20 \times 10^{-3}$$ ✔ ✔
$$= 7,54 \ \Omega$$ ✔

(3)

OR

$$X_L = \frac{V_L}{I_T}$$

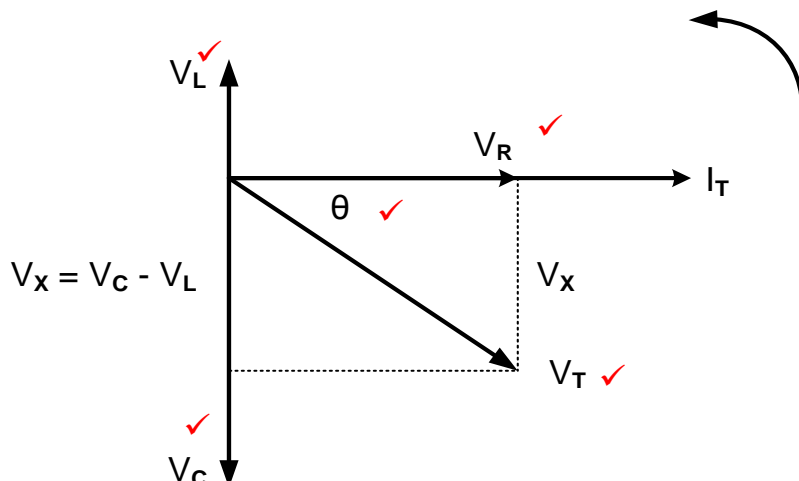$$X_L = \frac{49}{6.5}$$

$$X_L = 7,54 \ \Omega$$

2.2.2

$$V_C = I \times X_C$$ ✔
$$= 6,5 \times 25$$ ✔ ✔
$$= 162,5 \ V$$ ✔

(3)

2.2.3   The voltage is lagging, ✔ because the capacitive reactance is greater than the inductive reactance (V_C is greater than V_L). ✔ (2)

2.2.4

NOTE: 5 marks, 1 mark for each correct label of which V_L, V_C and V_R are priority marks and therafter any other two correct labels. (5)

2.3   2.3.1   Phasor diagram of a parallel RLC ✓ circuit at resonance. ✓ (2)

2.3.2   The voltage drop across the components in a parallel circuit is the same, ✓ hence the voltage is used as the reference. (1)

OR

The applied voltage is common across all components.

2.3.3   In a parallel resonant circuit impedance is at maximum, ✓ and the total current is at minimum. ✓ (2)

OR

The relationship between impedance and current in a parallel RLC circuit is inversely proportional.

2.4   2.4.1
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$ ✓
$$= \frac{1}{2 \times 3,142\sqrt{300 \times 10^{-3} \times 150 \times 10^{-6}}}$$ ✓
$$= 23,73\,Hz$$ ✓
(3)

2.4.2
$$Q = \frac{1}{R} \times \sqrt{\frac{L}{C}}$$ ✓
$$= \frac{1}{20} \times \sqrt{\frac{300 \times 10^{-3}}{150 \times 10^{-6}}}$$ ✓
$$= 2,24$$ ✓
(3)

OR

If candidates calculate X$_L$ or Xc they can use the following formulae:
$$X_L = 2\pi f L$$
$$X_L = 2\pi(23,73)(300 \times 10^{-3})$$
$$X_L = 44,73\,\Omega$$

$$Q = \frac{X_L}{R} \qquad\qquad Q = \frac{X_C}{R}$$

$$Q = \frac{44.73}{20} \qquad\qquad Q = \frac{44.73}{20}$$

$$Q = 2{,}24 \qquad\qquad Q = 2{,}24$$

2.4.3 $Z = 20\ \Omega$ ✔
        $Z = R$ at resonance   ✔   (2)

2.4.4

$$C = \frac{1}{4 \times \pi^2 \times L \times fr^2}$$ ✔

$$= \frac{1}{4 \times 9{,}87 \times 300 \times 10^{-3} \times 4 \times 10^6}$$ ✔

$$= 2{,}111 \times 10^{-8}\,F$$ ✔

$$= 21{,}11\ nF$$ (3)

OR

$$C = \frac{1}{(2\pi f_r)^2 \times L}$$

$$= \frac{1}{(2 \times 3{,}14 \times 2000)^2 \times 300 \times 10^{-3}}$$

$$= 2{,}113 \times 10^{-8}\,F$$

$$= 21{,}13\ nF$$

For resonance. Calculating X_L first and then since $X_L = X_C$

$$X_L = 2\pi f L$$

$$= 2\pi(2000)(300 \times 10^{-3})$$

$$= 3769{,}91\ \Omega$$

$$C = \frac{1}{2\pi f X C}$$

$$= \frac{1}{2\pi(2000)(3769{,}91)}$$

$$= 21{,}11\ nF$$

2.5.   2.5.1 Q_1 ✔   (1)

2.5.2   Reading the values from the graph where $f_1 = 30000$ Hz and $f_2 = 35000$ Hz the following can be deduced:

$$f_r = \frac{f_1 + f_2}{2}$$ ✔

$$= \frac{30000 + 35000}{2}.$$ ✔

$$= 32500\ Hz$$ ✔

$$= 32{,}5\ kHz$$ (3)

NOTE: If the candidate deduced the value 32,5 kHz directly from the graph, full marks will be awarded.

2.5.3   Deducing the indicated bandwidth of Q_1 from the graph as 35 kHz - 30 kHz the candidate will be able to calculate as follows:

$$BW = f_2 - f_1$$
$$= 35000 - 30000$$
$$= 5000\,Hz$$
$$BW = \frac{f_r}{Q}$$
$$Q = \frac{f_r}{BW}$$
$$= \frac{32500}{5000}$$
$$= 6,5$$

✔ **OR** ✔ ✔

$$BW = \frac{f_r}{Q} \quad \text{and} \quad BW = (f_2 - f_1)$$
$$(f_2 - f_1) = \frac{f_r}{Q}$$
$$Q = \frac{f_r}{(f_2 - f_1)}$$
$$= \frac{32500}{(35000 - 30000)}$$
$$= 6,5$$

(3)

[40]

QUESTION 3: THREE-PHASE AC GENERATION

3.1   3.1.1   Reactive power is the power in an AC circuit when the current is out of phase with the voltage ✔ as a result of the capacitive and/or the inductive load. ✔

Reactive power is the power that is wasted and not used to do work on the load.
NOTE: If only the formula is explained or written only 1 mark will be awarded.

(2)

3.1.2   Efficiency is the percentage ratio ✔ of the output power to the input power. ✔
NOTE: If only the formula is explained or written only 1 mark will be awarded.

(2)

3.2
$$V_{PH} = \frac{V_L}{\sqrt{3}}$$ ✔
$$= \frac{380}{\sqrt{3}}$$ ✔
$$= 219,39\,V$$ ✔

(3)

3.3   3.3.1
- The load will draw more current from the supply. ✔
- Large cables may be needed to carry the current. ✔
- Maintenance cost will increase. ✔
- More heat will be generated in the cables. ✔

(4)

3.3.2
- By adding power factor correction capacitors in parallel with a load. ✔
- Use synchronous motors in shunt (parallel) with the load. ✔
- Make use of phase advancers. ✔
- Variable speed drives
- Soft starters

(3)

3.4 Kilo-watt-hour meter/Energy meter. ✓ (1)

3.5 3.5.1
$$I_L = \sqrt{3} \times I_{PH}$$ ✓
$$= \sqrt{3} \times 30$$ ✓
$$= 51,96 \, A$$
$$= 52 \, A$$ ✓ (3)

3.5.2
$$V_L = V_{PH}$$ ✓
$$= 380 \, V$$ ✓

$$Z_{PH} = \frac{V_{PH}}{I_{PH}}$$ ✓

$$= \frac{380}{30}$$ ✓

$$= 12,67 \, \Omega$$ ✓ (5)

When candidates substitute Vph correctly as 380 V without calculating it, two additional marks should be awarded to the 3 mark calculation.

3.5.3
$$P = \sqrt{3} \times V_L \times I_L \times \cos\theta$$ ✓
$$= \sqrt{3} \times 380 \times 52 \times 0,9$$ ✓
$$= 30,8 \, kW$$ ✓ (3)

3.6
$$P_T = P_1 + P_2$$ ✓
$$= 10000 + 3000$$ ✓
$$= 13000 \, W$$
$$= 13 \, kW$$ ✓ (3)

3.7 A wattmeter is used to measure the input power/output power ✓ in an AC system.

Any acceptable application that uses a wattmeter to indicate power usage. (1)

[30]

QUESTION 4: THREE-PHASE TRANSFORMERS

4.1
- A step up transformer steps up alternating voltage ✓ from low voltage to high voltage ✓
- A step up transformer compensates for losses in a transmission system. (2)

4.2
- Overloading ✓
- Lack of ventilation ✓
- Insufficient oil ✓ (3)

4.3
- Oil Natural, Air Forced. ✓
- Oil Natural, Air Natural. ✓
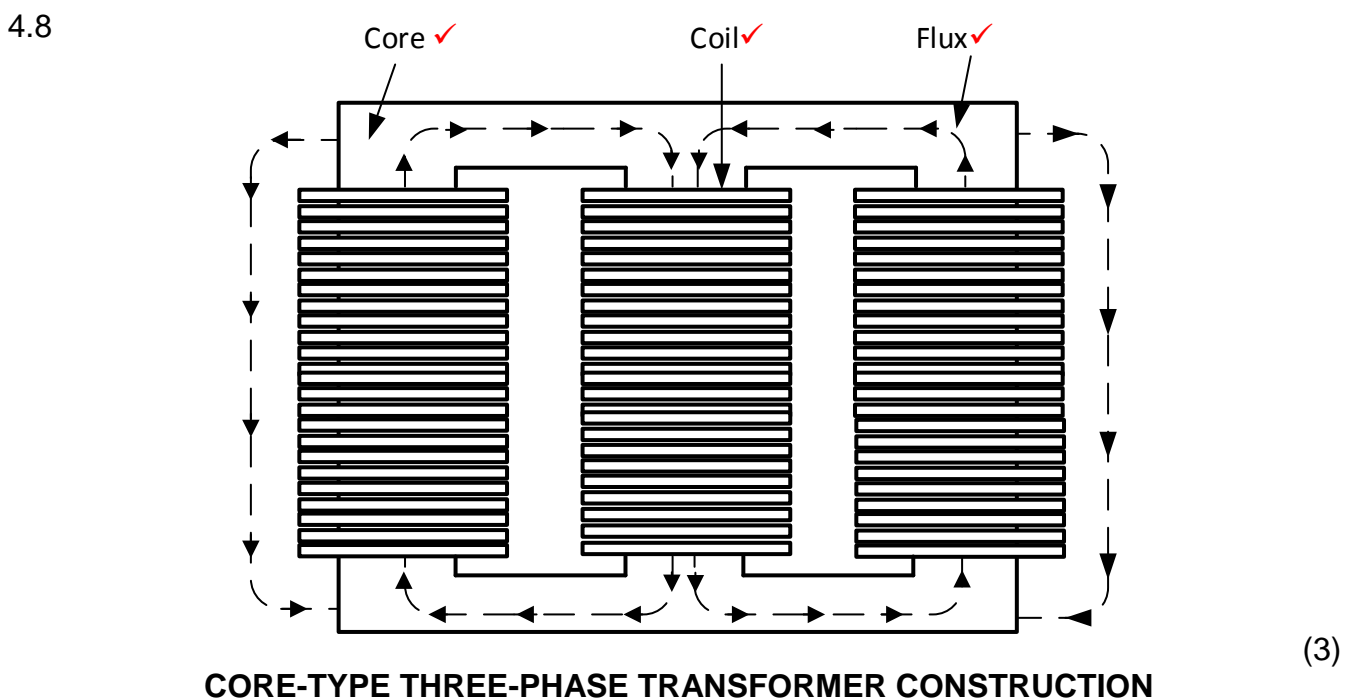- Oil Forced, Air Forced.
- Oil Forced, Water Forced. (2)

4.4   • Temperature rises ✓
       • Insulation failure ✓
       • Short circuits
       • Gas forming due to oil breakdown
       • Explosion   (2)

4.5   If the load is increased, the secondary current will increase ✓ resulting in an
       increase ✓ in the primary current. This increase is due to the increased
       magnetic force that results due to higher current flow.   (2)

4.6   Delta – star ✓
       Star – delta ✓
       Star – star
       Delta – delta
       Step-up
       Step-down
       Isolation transformer   (2)

4.7   • Over current relay✓
       • Balance earth fault relay ✓
       • Restricted earth fault relay
       • Standby earth fault relay
       • Bucholtz relay
       • Fuses
       • Circuit breakers   (2)

4.8

Core ✓   Coil✓   Flux✓

                                                                                      (3)
CORE-TYPE THREE-PHASE TRANSFORMER CONSTRUCTION

4.9 • Ensure the supply is switched off before wiring the transformer ✓
     • Never touch any electrical wires or terminals on an energised transformer with bare hands
     • Wear safety gear (PPE)
     • Be careful of the secondary terminals of a live open circuit transformer
     • Use short wires and ensure that the wires are tightly connected
     • Do not switch the circuit on before it is tested. (1)

4.10 4.10.1 $P_{OUT} = 200\,000 \times 0,85$ ✓
       $= 170\,000\ W$ ✓

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100$$
$$= \frac{170000}{171800} \times 100$$ ✓ ✓

$$= 98,95\ \%$$ ✓ (5)

OR

If the learner calculated the input power by using the given line current, the following answer will be accepted.

$$P_{IN} = \sqrt{3}V_L I_L \times cos\theta$$
$$= \sqrt{3}(11000)(30) \times 0,85$$
$$= 485840,25\ W$$

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100$$
$$= \frac{170000}{485840,25} \times 100$$
$$= 34,99\ \%$$

4.10.2 $$TR = \frac{V_{ph(1)}}{V_{ph(2)}}$$ ✓

$$= \frac{11000}{219,39}$$ ✓

$$= 50:1$$ ✓ (3)

4.10.3 $I_{L(2)} = \dfrac{S}{\sqrt{3} \times V_{L(2)}}$ ✓

$= \dfrac{200000}{\sqrt{3} \times 380}$ ✓

$= 303,86\,\text{A}$ ✓ (3)

OR

$I_{L(2)} = \dfrac{P}{\sqrt{3}\,VL\,cos\theta}$

$= \dfrac{170000}{\sqrt{3}\;380\;0.85}$

$= 303,86\,\text{A}$

[30]

QUESTION 5: THREE-PHASE MOTORS AND STARTERS

5.1
- Check that the bolts securing the motor to the frame are tight. ✓
- Check that the end plates are fastened properly. ✓
- Check the bearings for smooth rotation. ✓
- Check the movement of the shaft.
- Check for cracks in the housing. (3)

5.2
- It is cheaper and more robust ✓
- It has slightly high efficiency and power factor ✓
- These motors are explosion proof, since the risk of sparking is eliminated by the absence of slip rings and brushes. ✓
- Reduced maintenance due to absence of brushes. (3)

5.3. 5.3.1 Sequence motor starter ✓ without a timer
NOTE: This cannot be a forward / reverse motor due to no lock-out. (1)

5.3.2 (a) The function of the stop button is to disconnect ✓ the supply from the control circuit ✓ and stops both motors. (2)

(b) The function of MC_1 (N/O_1) is to allow ✓ current to flow in the parallel circuit ✓ even after the start button is released. ✓
It is the hold in contact (one mark only) (3)

5.3.3
- When the start button 1 is pressed the current flows through the stop button and O/L_1. ✓
- MC_1 (Motor 1) will energise ✓
- MC_1NO_1 and MC_1NO_2 ✓ will close.
- Motor 1 will start running. ✓
- When start button 2 is pressed MC_2 (Motor 2) will energise and close holding in contact MC_2NO_1 and switch Motor 2 on. ✓
- The two motors will run respectively ✓ (6)

5.4   5.4.1 $n_s = \dfrac{60 \times f}{p}$ ✓

$= \dfrac{60 \times 50}{6}$ ✓

$= 500\,\text{rpm}$ ✓   (3)

5.4.2 $n_r = n_s(1-S)$ ✓
✓
$= 500 \times (1-0,05)$

$= 475\,\text{rpm}$ ✓   (3)

NOTE:
If the candidate calculated 5% of the synchronous speed
0,05 x 500 = 25 rpm the following can apply:

S = ns – nr
Nr = Ns – slip(revolutions)
Nr = 500 – 25
Nr = 475 r.p.m

5.5   5.5.1 $I_L = \dfrac{P}{\sqrt{3} \times V_L \times \text{Cos}\,\theta}$ ✓

$= \dfrac{18000}{\sqrt{3} \times 380 \times 0,8}$ ✓

$= 34,18\ \text{A}$ ✓   (3)

5.5.2 $P_{app} = \sqrt{3} \times V_L \times I_L$ ✓

$= \sqrt{3} \times 380 \times 34,18$ ✓

$= 22,5\ \text{kVA}$ ✓   (3)

OR

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

$= \dfrac{18000}{0,8}$

$= 22,5\ kVA$

[30]

QUESTION 6: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

6.1 6.1.1 Hardware refers to all the physical parts ✓ (e.g. CPU) of the device that can be seen and touched. ✓ (2)

6.1.2 Software refers to machine/graphical language (e.g. windows, software programmes) that is installed on a computer or written into the PLC ✓ that instructs it to interact ✓ with its input and output hardware. ✓ (3)

6.1.3 An opto-coupler is a semiconductor device that uses light ✓ (e.g. Light Emitting Diode) to transmit a signal between two circuits ✓ that are electrically isolated. ✓ (3)

6.2 Input module ✓
Output module ✓
Power supply ✓
Central processing unit (Microprocessor) (3)

6.3
- Supply lines to the PLC should be installed with either a fuse or a circuit breaker. ✓ (protection)
- Correct wiring and connections should be checked before connecting the supply to the PLC. ✓
- Ensure that wiring is of adequate size to carry the required current. ✓
- Ensure that low-voltage signal-carrying wiring is not housed together with mains/ heavy current wiring.
- Avoid over tightening of securing screws. (3)

6.4 6.4.1
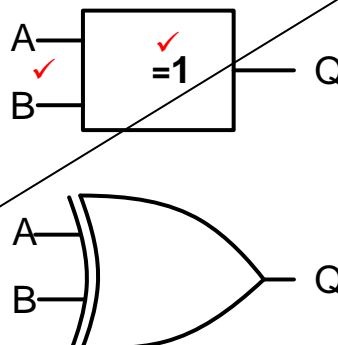
NOTE: One mark for the inputs
One mark for the logic function (2)

NOTE: See examination instruction

6.4.2 (a) 0 ✓

(b) 1 ✓

(c) 1 ✓

(d) 0 ✓ (4)

6.5 The inductive proximity sensor is applied in:
- Counting of metal objects ✓
- Positioning of metal objects
- Detect the presence of metal objects and whether they are ferrous or non-ferrous. (1)

6.6 6.6.1 An ON-delay timer contact ✓
Edge triggered wiping relay (Siemens) (1)

6.6.2
- When the push button (I_1) is pressed, the Timer will be energised. ✓
- The normally closed contact of the Timer will open ✓ (TD)
- The output (Q) will be at low state. ✓ (OFF)
- The output will remain at that off state for 15 seconds.
- When the timer TD times through it will reset to low. ✓
- Contacts TD will close (inverted input) and Q will go high until the timer TD is set via I_1 again. ✓ (5)

6.7 The circuit will not latch ✓ when the start button is released. (1)

6.8 6.8.1 The "Red Lamp" will be ON ✓
The "Green Lamp will be OFF ✓ (2)

6.8.2 The function of the MC (contactor coil) is to close ✓ and open ✓ the contacts the moment it is energised. (i.e. MC/NO$_1$ and MC/NO$_2$ will close and MC/NC$_1$ will open)

OR

The purpose of MC (contactor coil) is to magnetise the core which is connected to the contacts. When the core moves the contacts are closed.

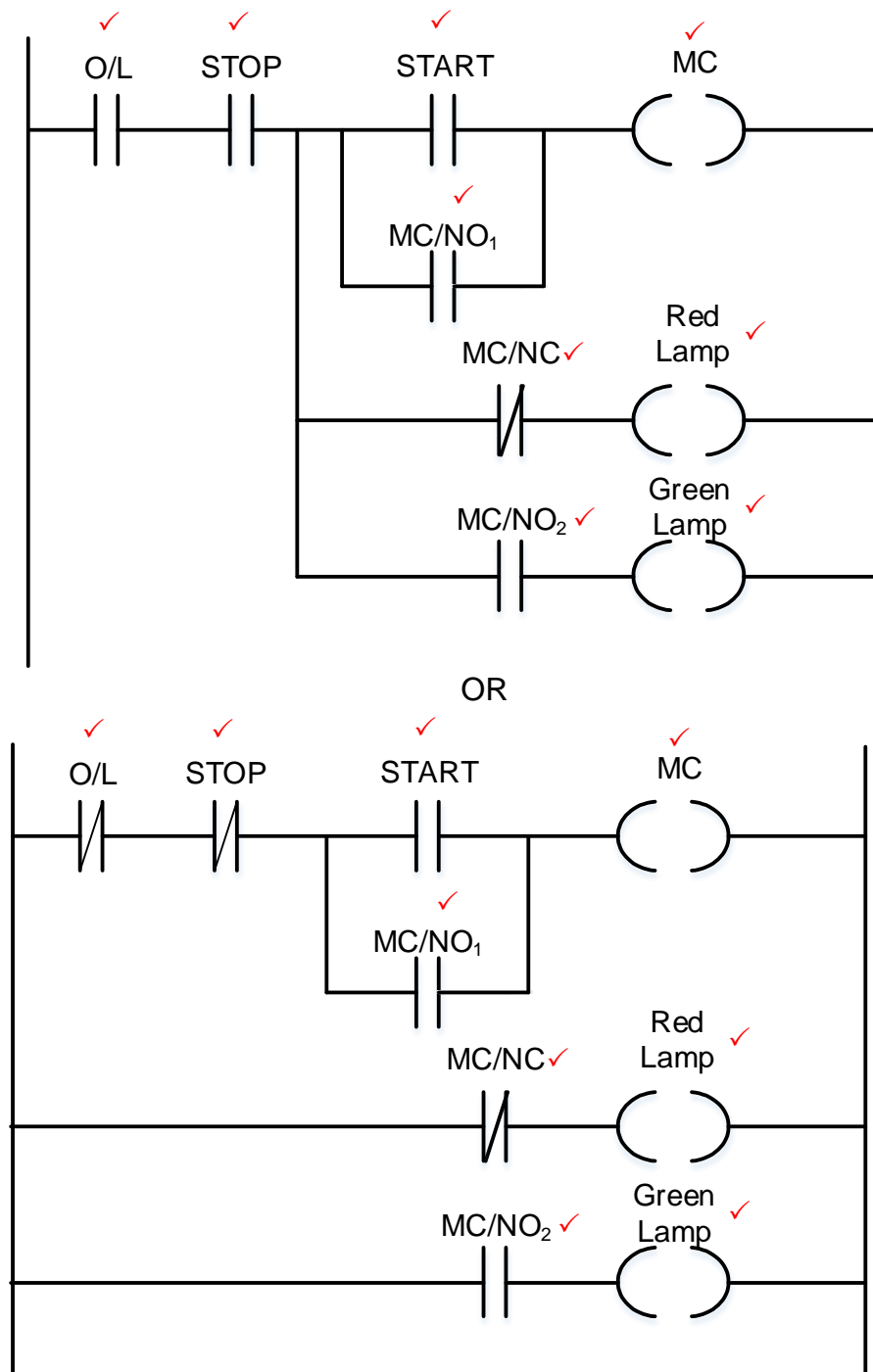When the coil is no longer magnetised, a coil spring opens the contacts again. (2)

6.8.3

OR

(9)

FIGURE 6.8: LADDER LOGIC DIAGRAM

6.9
- When a three-phase AC is applied to the input unit, the diode bridge rectifying ✓ circuit convert AC to DC.
- The DC waveforms contains ripple voltage, ✓
- DC with ripple voltages are smoothed ✓ by filter capacitors
- DC voltages are then converted back [by Insulated Gate Bipolar Transistor (IGBT)] into variable AC voltage ✓ and
- Variable frequency ✓ through the switching circuits will result in variable speed control.

NOTE:
If the following response is given, 2 marks will be awarded.
When a three-phase or single-phase supply is connected to a VSD, its *circuitry* will increase or decrease the frequency of the output AC power signal supplied to the motor. (5)

6.10   Synchronous motor with a permanent magnet stator. ✓
Synchronous motor with brushes or brushless. ✓ (2)

6.11   6.11.1   Pulse A ✓ has shorter on time and Pulse B ✓ has longer on time. (2)

6.11.2   The greater the width of the pulses ✓ the higher ✓ the average voltage. (2)

6.12
- The installation of the system should be done by a qualified, experienced technician. ✓
- Avoid using long cable runaways to reduce losses. ✓
- An energy efficient motor should be considered. ✓
- Harmonics should be kept to a minimum.
- Consider the installation safety instructions. (3)

6.13   6.13.1   Braking Unit ✓ (1)

6.13.2   Braking resistor ✓ (1)

6.14
- When the load goes down, the motor holds back the downwards acceleration, ✓ thus
- Creating excess energy ✓ through induction
- This energy will be fed back to the system to be stored or dissipated as heat at the breaking resistor if excessive. ✓ (3)

[60]

TOTAL: 200