**NATIONAL
SENIOR CERTIFICATE**

GRADE 12

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

NOVEMBER 2022

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 14 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   C ✓   (1)

1.2   B ✓   (1)

1.3   D ✓   (1)

1.4   A ✓   (1)

1.5   D ✓   (1)

1.6   B ✓   (1)

1.7   D ✓   (1)

1.8   C ✓   (1)

1.9   A ✓   (1)

1.10   D ✓   (1)

1.11   A ✓   (1)

1.12   B ✓   (1)

1.13   C ✓   (1)

1.14   B ✓   (1)

1.15   A ✓   (1)
[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 The employer should be respected ✔
The employer should not be discriminated against. ✔
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. (2)

2.2 Move in an orderly manner. ✔
Follow the evacuation route as displayed in your workshop. ✔
Move to the designated assembly point in a calm and orderly manner. (2)

2.3 Misusing equipment is a dangerous practice which might damage the
equipment ✔ and render it unsafe, compromising the safety and or threatens
the health of others. ✔ (2)

2.4 An employer shall not dismiss an employee ✔ without the correct procedures
being followed.
An employer shall not reduce the remuneration of an employee as
punishment.
Alter terms of condition of employment to one that is less favourable. ✔
Alter a position relative to other employees employed by that employer to
disadvantage them. (2)

2.5 Quantitative risk analysis ✔
Qualitative risk analysis ✔ (2)
[10]

QUESTION 3: RLC CIRCUITS

3.1 Inductance is the created back-emf in an inductor that tends to oppose ✓ a changing electric current passing through it. ✓
Inductance is the tendency of a coil to oppose a change in current flowing through it when connected to an AC supply. (2)

3.2 3.2.1
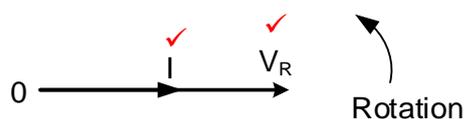
(2)

3.2.2
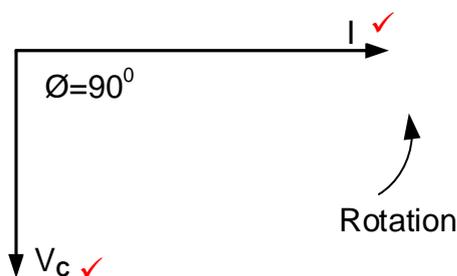
(2)

3.3 3.3.1
$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad ✓$$
$$= \sqrt{25^2 + (94 - 13)^2} \quad ✓$$
$$= 84{,}77 \ \Omega \quad ✓$$

(3)

3.3.2
$$\theta = Cos^{-1}\frac{R}{Z} \quad ✓ \qquad \theta = Tan^{-1}\frac{(X_L - X_C)}{R}$$
$$= Cos^{-1}\frac{25}{84{,}77} \quad ✓ \qquad = Tan^{-1}\frac{(94 - 13)}{25}$$
$$= 72{,}85° \quad ✓ \qquad = 72{,}85°$$

(3)

3.3.3
$$L = \frac{X_L}{2 \times \pi f} \quad ✓ \qquad \text{No mark for manipulation}$$
$$= \frac{94}{2 \times \pi \times 60} \quad ✓$$
$$= 0{,}25 \ H \quad ✓$$
$$= 250 \ mH$$

(3)

3.3.4 A lagging power factor is when the current lags the voltage ✓ in an RLC circuit. (1)

3.3.5 At resonance, the circuit becomes resistive ✓ because the capacitive reactance and inductive reactance cancels each ✓ other, resulting with an in-phase relationship between current and voltage. (2)

3.4   3.4.1

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

$$= \sqrt{11^2 + (9-7)^2}$$ ✓

$$= 11,18 \text{ A}$$ ✓

(3)

3.4.2

$$\text{Cos}\theta = \frac{I_R}{I_T}$$ ✓

$$= \frac{11}{11,18}$$ ✓

$$= 0,98$$ ✓

(3)

3.4.3 $P = V \times I \times \text{Cos}\theta$ ✓

$$= 110 \times 11,18 \times 0,98$$ ✓

$$= 1205,20 \text{ W}$$

$$= 1,21 \text{ kW}$$ ✓

(3)

3.4.4 The circuit has a lagging power factor ✓ as the inductive current is greater than the capacitive current. ✓ (2)

3.5   3.5.1 A parallel ✓ RLC ✓ circuit
NOTE:
Because of the error in the prescribed textbook 1 mark will be allocated if the learner indicates that response A = series RLC (2)

3.5.2 The impedance will be maximum ✓ and the current will be minimum ✓ (2)

3.5.3 When the frequency increase to resonant frequency the impedance increases. ✓ When the frequency increase above the resonant frequency, the impedance decreases. ✓
NOTE:
The impedance increases with an increase in frequency = 1 mark
The impedance decreases with an increase in frequency = 1 mark (2)

[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 4.1.1 The phasor diagram represents positive phase sequence ✓ because the direction of rotation is anti-clockwise✓.(R -Y- B) phase sequence (2)

4.1.2 Phase voltage,✓because it is the voltage between R (Line 1) and neutral (N)✓ (2)

4.2 Active power or real power refers to the capacity of a circuit for performing work in a particular time. ✓ (1)

4.3 By stepping up the voltage in transmission lines, the current flowing through the lines are reduced ✓ which reduces copper losses. ✓ (2)

4.4
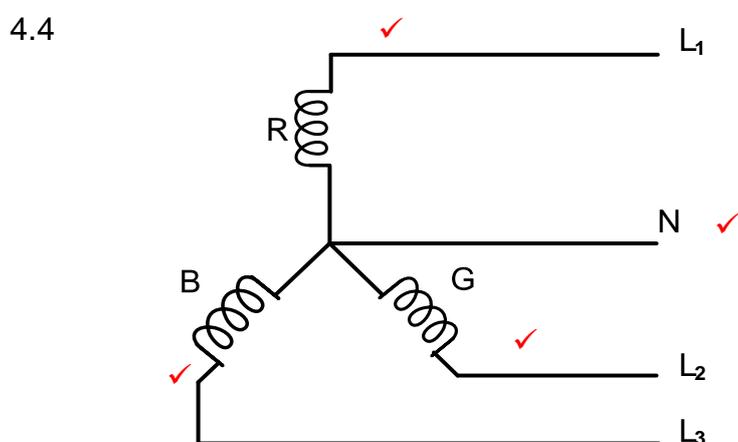
NOTE: 3 marks = 1 mark for each correct phase or line.
1 mark for the neutral. (4)

4.5
- Power is distributed to substations at 22 kV (towns, industrial and farms) ✓
- It is then stepped down to 11 kV for intermediate substations. ✓
- It is finally stepped down to 380 V/220 V at distribution substations. (shops, office, schools and homes) ✓ (3)

4.6 4.6.1
$$I_{PH} = \frac{I_L}{\sqrt{3}} \quad ✓$$
$$= \frac{15}{\sqrt{3}} \quad ✓$$
$$\quad ✓$$
$$= 8,66\ A$$ (3)

4.6.2
$$Z_{PH} = \frac{V_{PH}}{I_{PH}} \quad ✓$$
$$= \frac{400}{8,66} \quad ✓$$
$$= 46,19\ \Omega \quad ✓$$ (3)

4.6.3 $Cos\ \theta = pf$ ✓
         $\theta = Cos^{-1} pf$
           $= Cos^{-1}(0,85)$ ✓
           $= 31,79\ °$ ✓ (3)

4.6.4 $P = \sqrt{3}V_L I_L Cos\ \theta$ ✓
         $= \sqrt{3} \times 400 \times 15 \times 0,85$ ✓
         $= 8833,46\ W$ ✓
         $= 8,83\ kW$ (3)

4.6.5

(3)
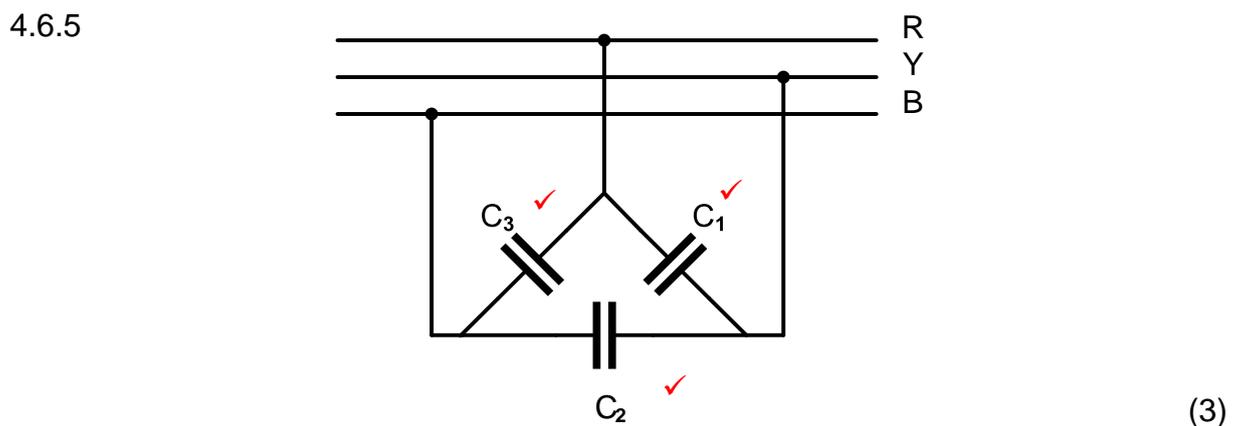
4.7   4.7.1   It can measure both balanced and unbalanced loads. ✓
               The power consumption of each phase can be determined. ✓ (2)

        4.7.2   Three wattmeters are required for an unbalanced load. ✓
               The terminals of the load must be available to connect the wattmeters if no neutral line exists, or if the load is in delta.
               The power factor cannot be determined and must be measured separately. (1)

        4.7.3   Because it is a balanced load $P_1 = P_2 = P_3$

             $P_T = P_1 + P_2 + P_3$ ✓ $P_T = 3 \times P_1$
               $= 450 + 450 + 450$ ✓ $= 3 \times 450$
               $= 1350\ W$ ✓   OR $= 1350\ W$
               $= 1,35\ kW$ $= 1,35\ kW$ (3)

[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Mutual induction is when the magnetic flux of one coil ✔ cuts the conductors of an adjacent coil ✔ and induces an emf inside that coil without being electrically connected. ✔ (3)

5.2 5.2.1 Transformer ratio ✔
Voltage rating ✔
Current rating ✔
Power rating
Efficiency
Size
Power factor
Frequency (3)

5.2.2 Star ✔ (1)

5.3 5.3.1 Copper losses are losses due to the internal resistance ✔ of the copper conductors in the coils, which occur in the form of heat when current flows. ✔ (2)

5.3.2 Iron losses are caused by eddy currents ✔ and the changing magnetic field ✔ inside the iron core. These losses are in the form of heat, because of the frequently changing magnetic flux inside the iron core. (2)

5.4 Dry type transformers are equipped with tubular radiators around which air circulates, ✔ cooling the windings ✔ therefore controlling insulation failure. (2)

5.5 A core type transformer has three limbs ✔ and the coils are wound around all three limbs.
A shell type transformer has five limbs ✔ and the coils are wound around the central section of the core. (2)

5.6 Under normal conditions the three voltages sums to zero. If there is an earth fault on one of the phases, ✔ the difference in voltage will energize the relay✔ isolating the transformer from the supply. ✔ (3)

5.7 5.7.1 $P = \sqrt{3}V_{L2}I_{L2}Cos\,\theta$ ✔

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

✔

$$= \frac{200\,000}{\sqrt{3} \times 400 \times 0,8}$$

$$= 360,84\,A$$ ✔ (3)

5.7.2   In star I$_L$=I$_{PH}$ ✓

$I_{ph2} = I_{L2}$

$= 360,84\ A$ ✓✓

(3)

5.7.3

$S = \dfrac{P}{Cos\theta}$ ✓ $S = \sqrt{3}\ V_L\ I_L$

$= \dfrac{200\ 000}{0,8}$ ✓ $= \sqrt{3}\ \times\ 400\ \times 360,84$

$= 250\ 000\ VA$ ✓ $= 249\ 997\ VA$

$= 250\ kVA$ $= 250\ kVA$

(3)

5.7.4 $S = \sqrt{3}V_{L1}I_{L1}$ ✓ $P = \sqrt{3}\ V_L\ I_L\ Cos\theta$

$I_{L1} = \dfrac{S}{\sqrt{3}V_{L1}}$ $200\ 000 = \sqrt{3}\ \times\ 6000\ \times I_L\ \times 0,8$

$= \dfrac{250\ 000}{\sqrt{3}\ \times 6000}$ ✓ $I_L\ = 24,06\ A$

$= 24,06\ A$ ✓

(3)
[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1   Wound rotor ✓
       Cage rotor ✓   (2)

6.2   6.2.1   Rated speed is the maximum speed at which the motor effectively works. ✓
                Full load speed is the speed when maximum load is connected to the motor. ✓   (2)

6.2.2

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

$$= \frac{60 \times 50}{4} \quad ✓$$

$$= 750 \; rpm \quad ✓$$

(3)

6.2.3

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

$$= \frac{750 - 725}{750} \times 100 \quad ✓$$

$$= 3{,}33 \; \% \quad ✓$$

(3)

6.3   Check if there is any play on the axis. ✓
       Check if the axis turns freely by hand. ✓
       Check if the bearings work smoothly when turned by hand.
       Check for any excessive grease and dust on the bearing bushes.   (2)

6.4   6.4.1

$$P = \sqrt{3}V_L I_L Cos \, \theta \quad ✓$$
$$= \sqrt{3} \times 380 \times 5 \times cos(20^0) \quad ✓$$
$$= 3092{,}43 \; W$$
$$= 3{,}09 \; kW \quad ✓$$

(3)

6.4.2

$$Q = \sqrt{3}V_L I_L sin \, \theta \quad ✓$$
$$= \sqrt{3} \times 380 \times 5 \times sin(20^0) \quad ✓$$
$$= 1125{,}55 \; VAr$$
$$= 1{,}13 \; kVAr \quad ✓$$

(3)

6.4.3 $P = \sqrt{3}V_L I_L \cos\theta\eta$ ✓

$\qquad = \sqrt{3} \times 380 \times 5 \times \cos(20^0) \times \dfrac{90}{100}$ ✓

$\qquad = 2783,19\ W$ ✓

$\qquad = 2,78\ kW$ (3)
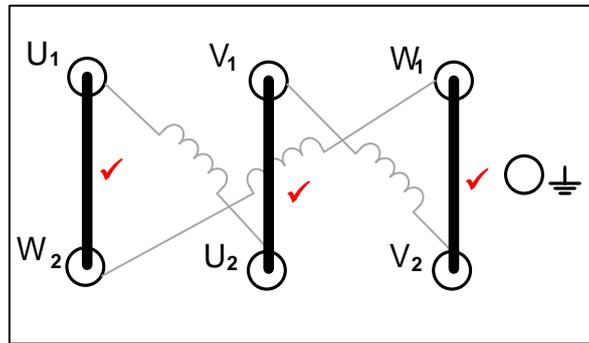
$$\eta = \frac{Poutput}{Pinput} \times 100$$

$$Poutput = Pinput \times \eta$$

$$Poutput = 3092,43 \times \frac{90}{100}$$

$$= 2783,19\ W$$

6.5

(3)

6.6   6.6.1   Overload ✓ Normally Closed contact   (1)

         6.6.2 MC_1N/O_2 is a hold-out contact ensuring that the timer relay ✓ and the star contactor MC_2 ✓ does not energise until MC_1 is energised.✓   (3)

         6.6.3   Interlocking ensures that MC_2 and MC_3 ✓ do not energise simultaneously. ✓   (2)

         6.6.4
- The moment the timer has timed through, T N/C will open, ✓
- de-energising MC_2. ✓
- This closes MC_2N/C and TN/O ✓
- energising MC_3 ✓ which opens MC_3N/C ✓ ensuring that MC_2 remains de-energised.   (5)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1   It is easy to trace a fault with a multimeter ✓ by following a wiring diagram. ✓   (2)

7.2   7.2.1   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.   (2)
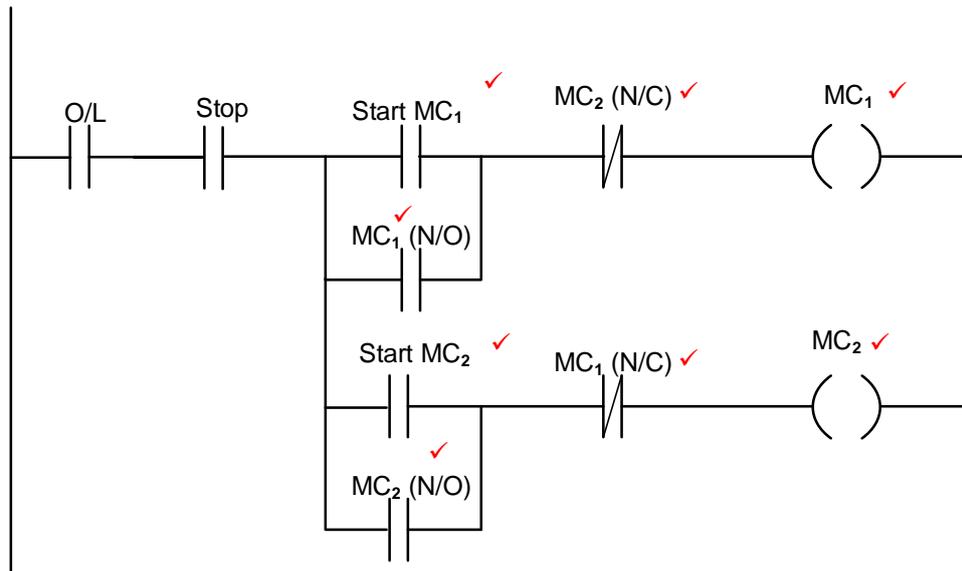
       7.2.2   After receiving data from a temperature sensor, the PLC runs it through the program ✓ and update the outputs ✓ accordingly.   (2)

       7.2.3   Mining drills ✓
                 Battery chargers ✓
                 Electric motors   (2)

7.3   7.3.1   Forward Reverse starter. ✓   (1)

       7.3.2   Latching makes it possible for circuits to be triggered 'on' ✓ and remain 'on' ✓ regardless of whether the activating trigger has been removed. ✓   (3)
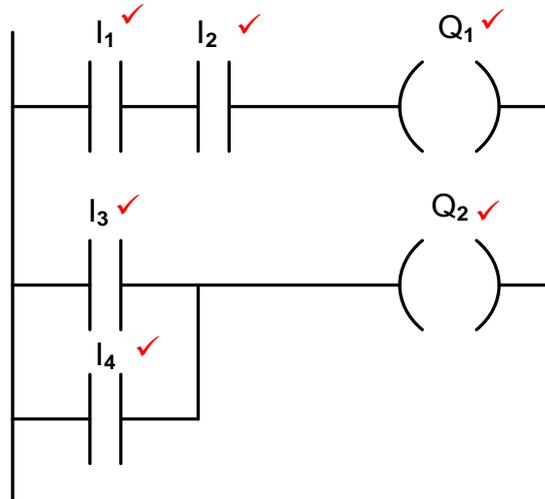
       7.3.3

NOTE:
If a learner makes use of markers and the program operates correct, marks will be awarded accordingly.   (8)

7.4

(6)

7.5   A marker is a storage memory ✓ which indicates that certain processes have been completed and other devices can be switched either ON or OFF. ✓   (2)

7.6   7.6.1   The converter operates on the process of rectification; ✓ each pair of diodes rectify one of the three phases. ✓   (2)

        7.6.2   The filter circuit uses capacitors to smooth out ripple voltages ✓ ensuring a pure DC voltage on the DC bus. ✓   (2)

        7.6.3
- The inverter changes the DC voltages on the DC bus into pulses ✓ using Insulated Gate Bipolar Transistors.
- The duration and width of these pulses are varied by a controller to imitate AC. ✓ (pulse width modulation)
- The varied pulse width changes the frequency applied to the motor ✓ that results in variable speed control. ✓   (4)

        7.6.4   Energy savings ✓
                  Better speed control of motors ✓
                  Better power factor
                  Smooth starting of motors   (2)

7.7   Lifts ✓
        Cranes ✓
        Mine Winding gear
        Electrical Locomotives
        Electric Coal Hauling Trucks   (2)

[40]

TOTAL: 200