Province of the
EASTERN CAPE
EDUCATION

NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2022

ELECTRICAL TECHNOLOGY: POWER SYSTEMS MARKING GUIDELINE

MARKS: 200

This marking guideline consists of 10 pages.

INSTRUCTIONS TO MARKERS

1. All calculations 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.

   2.6 Markers should consider that learners answers may deviate slightly from the marking guideline depending on how and where in the calculation rounding off was used.

3. These marking guidelines are only a guide with model answers.

4. 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	1.1	A ✓	(1)
	1.2	C ✓	(1)
	1.3	B ✓	(1)
	1.4	C ✓	(1)
	1.5	D ✓	(1)
	1.6	B ✓	(1)
	1.7	A ✓	(1)
	1.8	D ✓	(1)
	1.9	C ✓	(1)
	1.10	B ✓	(1)
	1.11	A ✓	(1)
	1.12	D ✓	(1)
	1.13	C ✓	(1)
	1.14	B ✓	(1)
	1.15	A ✓	(1)
			[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 An occurrence of catastrophic proportions, ✓ resulting from the use of machinery or activities at work. ✓ (2)

2.2 The learner does not know safe practices. ✓
The learner knows better but intentionally conducts the act. (1)

2.3 2.3.1 Running could cause you to trip or collide with another learner. ✓ This could result in you injuring yourself with nearby equipment or machinery. ✓ (2)

2.3.2 This could cause the outlet to exceed its rated current ✓and could lead to short circuits, fires or damaged appliances. ✓ (2)

2.4 First, I would define all the various threats to safety in the workshop. ✓
Secondly, I would determine the extent of all the vulnerabilities in the workshop. ✓
Finally, I would devise countermeasures should a risk occur. ✓ (3)

[10]

QUESTION 3: RLC CIRCUITS

3.1 3.1.1 It would remain the same. ✓ (1)

3.1.2 $X_L = 31{,}83\ \Omega$ ✓ (1)

3.1.3 (a)
$$X_L = 2\pi fL \checkmark$$
$$= 2 \times \pi \times 50 \times 0{,}5 \checkmark$$
$$= 157{,}08\ \Omega \checkmark$$
(3)

(b)
$$Z = \sqrt{R^2 + (X_L - X_C)^2} \checkmark$$
$$= \sqrt{120^2 + (157{,}08 - 31{,}83)^2} \checkmark$$
$$= 173{,}46\ A \checkmark$$
(3)

(c)
$$V_c = I \times X_C \checkmark$$
$$= 1{,}38 \times 31{,}83 \checkmark$$
$$= 43{,}93\ V \checkmark$$
(3)

(d)
$$X_C = \frac{1}{2\pi fC}$$
$$C = \frac{1}{2\pi fX_C} \checkmark$$
$$= \frac{1}{2\times\pi\times50\times42{,}44} \checkmark$$
$$= 0{,}000075\ F = 75\ \mu F \checkmark$$
(3)

(e)
$$I = \frac{V_R}{R} \checkmark$$
$$= \frac{240}{120} \checkmark$$
$$= 2\ A \checkmark$$
(3)

3.2 0 A ✓ (1)

3.3 The small band of frequencies ✓ centred around the resonant frequency. ✓
The frequencies between the upper cut-off frequency and the lower cut-off frequency, centred around the resonant frequency. (2)

3.4 Z is maximum ✓
I is minimum ✓
$X_L = X_C$ (2)

3.5 3.5.1
$$I_T = \sqrt{I_R{}^2 + (I_C - I_L)^2} \checkmark$$
$$= \sqrt{0{,}83^2 + (0{,}63 - 0{,}5)^2} \checkmark$$
$$= 0{,}84\ A \checkmark$$
(3)

3.5.2
$$I = \frac{V}{R}$$
$$V = I.R \checkmark$$
$$= 0{,}83 \times 120{,}487 \checkmark$$
$$= 100\ V \checkmark$$
(3)

3.5.3 $Z = \frac{V}{I_T}$ ✓
$= \frac{100}{0,84}$ ✓
$= 119,05\ \Omega$ ✓ (3)

3.5.4 $\cos\theta = \frac{I_R}{I_T}$
$\theta = \cos^{-1}\frac{I_R}{I_T}$ ✓
$= \cos^{-1}\frac{0,83}{0,84}$ ✓
$= 8,85°$ ✓
Leading ✓ (4)
[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 Three coils are placed 120 electrical degrees apart and then rotated in a uniform magnetic field. ✓ This produces three single-phase voltages, with each voltage separated by 120°. ✓ (2)

4.2 4.2.1 Star connected three-phase system. ✓ (1)

4.2.2 A – neutral ✓
B – yellow phase ✓ (2)

4.2.3 By connecting one side of each coil to a common point. ✓ (1)

4.2.4 $V_{PH} = \frac{V_L}{\sqrt{3}}$ ✓
$= \frac{440}{\sqrt{3}}$ ✓
$= 254,03\ V$ ✓ (3)

4.3 4.3.1 It is defined as the ratio of the real power flowing ✓ to the apparent power in a circuit. ✓ (2)

4.3.2 The power factor is directly related to the current level. ✓ (1)

4.4 $\eta = \frac{output}{input} \times 100\%$ ✓
$= \frac{220 \times 6,5}{380 \times 4,5} \times 100\%$ ✓
$= 83,63\%$ ✓ (3)

4.5 4.5.1 $V_L = V_{PH}$ ✓
$= 380\ V$ ✓ (2)

4.5.2 $\text{Power factor} = \cos\theta$
$\theta = \cos^{-1}\text{power factor}$ ✓
$= \cos^{-1}(0,89)$ ✓
$= 27,13°$ ✓ (3)

4.5.3 $S = \sqrt{3}V_L I_L$ ✓
$= \sqrt{3} \times 380 \times 27$ ✓
$= 17\,770{,}84\ \text{VA} = 17{,}77\ \text{kVA}$ ✓ (3)

4.5.4 $P = \sqrt{3}V_L I_L \cos\theta$ ✓
$= \sqrt{3} \times 380 \times 27 \times 0{,}89$ ✓
$= 15\,816{,}05\ \text{W} = 15{,}82\ \text{kW}$ ✓ (3)

4.6 $P_{TOT} = W_1 + W_2 + W_3$
$W_3 = P_{TOT} - (W_1 + W_2)$ ✓
$= 28{,}75 - (12 + 7{,}5)$ ✓
$= 9{,}25\ \text{kW}$ ✓ (3)

4.7 A lagging power factor draws more current from the load. ✓
The higher currents increase the energy lost and requires larger conductors and equipment. ✓
This results in the electrical utilities charging a higher cost to commercial consumers. ✓ (3)

4.8 $tan\theta = \sqrt{3}\left[\frac{W_1 - W_2}{W_1 + W_2}\right]$
$\theta = \tan^{-1}[\sqrt{3} \times \left(\frac{16{,}6 - 5{,}5}{16{,}6 + 5{,}5}\right)]$
$= 41{,}02°$ ✓
$Power\ factor = cos\theta$
$= \cos(41{,}02)$ ✓
$= 0{,}75$ ✓ (3)

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QUESTION 5: THREE-PHASE TRANSFORMERS

5.1
- Iron losses ✓
- Copper losses ✓ (2)

5.2 The Bucholtz relay monitors the flow of gas ✓
A severe fault will cause a lot of gas and the relay will operate immediately ✓
For slow faults, the gradual build-up of gas will trigger the relay as soon as a certain concentration is reached ✓ (3)

5.3
5.3.1 B ✓ (1)
5.3.2 D ✓ (1)
5.3.3 A ✓ (1)
5.3.4 C ✓ (1)

5.4
$\mathrm{V_{LP}} = \mathrm{V_{PP}} = 6\,600\ \mathrm{V}$ ✓
$\mathrm{V_{PS}} = \frac{V_{LS}}{\sqrt{3}}$
$= \frac{381{,}05}{\sqrt{3}}$ ✓
$= 220\ V$ ✓
$turns\ ratio = V_{PP} : V_{PS}$ ✓
$= 6\,600 : 220$ ✓
$= 30 : 1$ ✓ (6)

5.5
5.5.1 $V_{LS} = \sqrt{3}V_{PS}$
$V_{PS} = \frac{V_{LS}}{\sqrt{3}}$ ✓
$= \frac{11\,000}{\sqrt{3}}$ ✓
$= 6\,350{,}85\ \mathrm{V} = 6{,}35\ \mathrm{kV}$ ✓ (3)

5.5.2 $S = \sqrt{3}V_{LP}I_{LP}$ ✓
$= \sqrt{3} \times 33\,000 \times 9{,}72$ ✓
$= 555\,572{,}62\ \mathrm{VA} = 555{,}57\ \mathrm{kVA}$ ✓ (3)

5.5.3 $P = \sqrt{3}V_{LS}I_{LS}cos\theta$
$I_{LS} = \frac{P}{\sqrt{3}V_{LS}cos\theta}$ ✓
$= \frac{500\,000}{\sqrt{3} \times 11\,000 \times 0{,}9}$ ✓
$= 29{,}16\ A$ ✓ (3)

5.5.4 $I_{LP} = \sqrt{3}I_{PP}$
$I_{PP} = \frac{I_{LP}}{\sqrt{3}}$ ✓
$= \frac{9{,}72}{\sqrt{3}}$ ✓
$= 5{,}61\ A$ ✓ (3)

5.5.5 $\eta = \frac{P_{OUT}}{P_{OUT}+losses} \times 100\%$ ✓
$= \frac{500\,000}{500\,000+1\,800} \times 100\%$ ✓
$= 99{,}64\ \%$ ✓ (3)

[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1
- Robust ✓
- Dependable ✓
- Economical ✓
- Requires less maintenance
- More efficient (3)

6.2
- Lathes ✓
- Drill presses ✓
- Bench grinders (2)

6.3 6.3.1 Continuity test ✓
Insulation resistance between windings and earth ✓ (2)

6.3.2 No. ✓ There is no continuity between V_1 and V_2 ✓ and V_2 of the coil is short circuited to earth. ✓ (3)

6.4 6.4.1 Yes, it is suitable. ✓ (1)

6.4.2 $P = \sqrt{3}V_L I_L \cos\theta$ ✓
$= \sqrt{3} \times 380 \times 24 \times 0{,}8$ ✓
$= 12\ 637{,}04\ \text{W} = 12{,}64\ \text{kW}$ ✓ (3)

6.4.3 $\eta = \frac{P_{OUT}}{P_{IN}} \times 100\%$ ✓
$= \frac{10\ 000}{12\ 637{,}04} \times 100$ ✓
$= 79{,}13\ \%$ ✓ (3)

6.4.4 $\%\text{slip} = \frac{n_s - n_r}{n_s}$
$n_s = \frac{n_r}{1 - \text{sli}}$ ✓
$= \frac{3000}{1 - 0{,}04}$ ✓
$= 3125\ \text{rpm}$ ✓ (3)

6.5 6.5.1 The timer ensures that motor 2 can only be started after a preset time. ✓ (1)

6.5.2 380 V ✓ (1)

6.5.3 MC_2 would de-energise ✓ as soon as the start motor 2 button is released. ✓ (2)

6.5.4 Motor 1 must start first. ✓
Motor 2 can only be started after a preset time has elapsed. ✓
Both motors must have independent overload protection. ✓
The stop button switches the whole circuit off. ✓ (4)

6.6 The star contactor ensures that the motor is connected in star during start-up, ✓ thus reducing the starting current by $\sqrt{3}$ or 58% of full load current. ✓
The delta contactor ensures that the motor is connected in delta after a preset time. ✓ This delivers maximum power to be delivered when the motor is at full speed. ✓ (4)

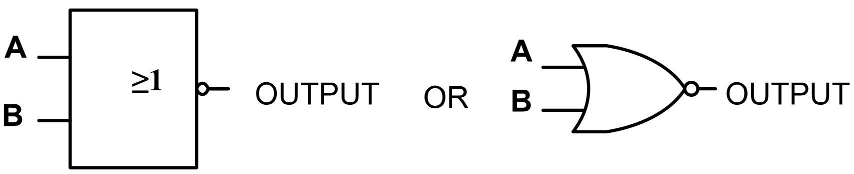
6.7
$$P = \sqrt{3}V_L I_L \cos\theta$$
$$I_L = \frac{P}{\sqrt{3}V_L \cos\theta} \checkmark$$
$$= \frac{6\,000}{\sqrt{3}\times 380\times 0{,}78} \checkmark$$
$$= 11{,}69\ A \checkmark$$
(3)
[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLS's)

7.1
- Input scan ✓
- Process scan ✓
- Output scan ✓

(3)

7.2 7.2.1

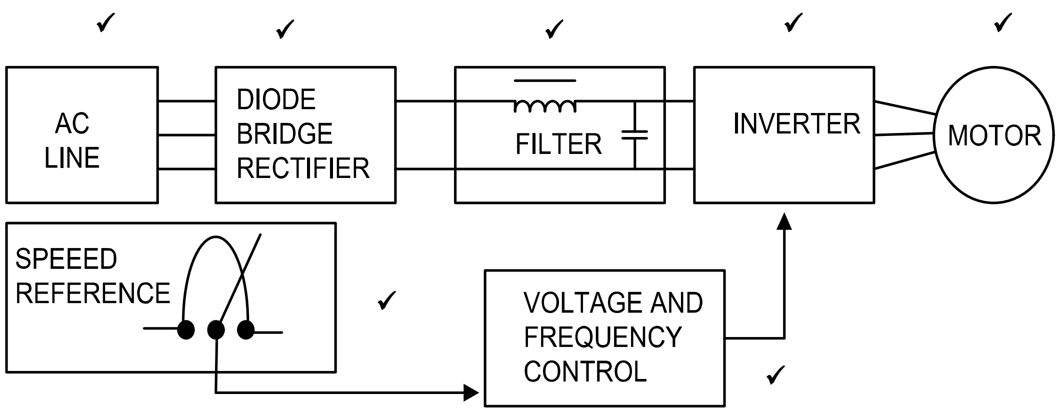


1 mark for symbol correct ✓
2 marks for correct labels ✓✓ (3)

7.2.2 a – 0 ✓
b – 0 ✓ (2)

7.3 They are bits in the storage memory which can be used to hold data ✓ and behave as relays, ✓ being able to be switched on or off ✓ and to switch other devices on or off. ✓ (4)

7.4



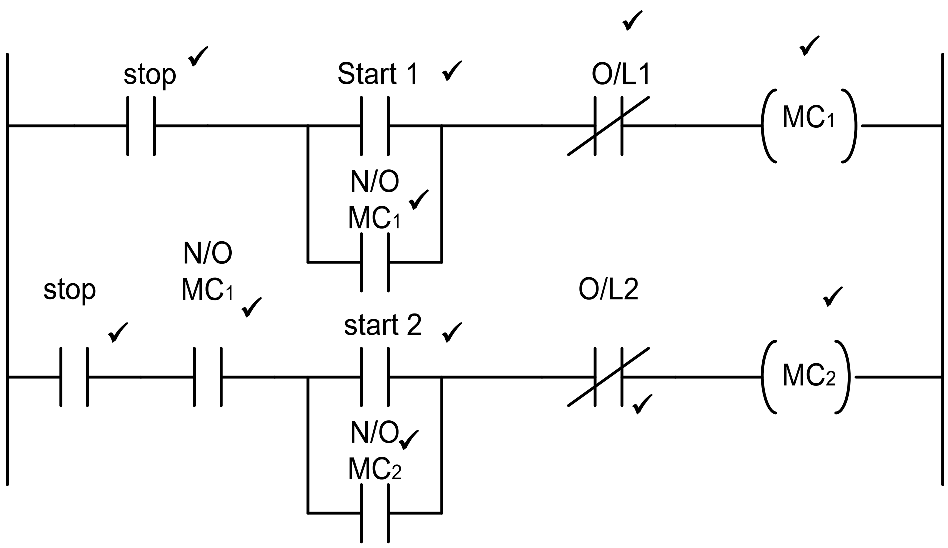
(7)

7.5 PART 1 – converts the AC supply voltage to a DC voltage by rectification. ✓ It consists of three pairs of rectifying diodes, each pair rectifying one of the phases. ✓
PART 2 – smooths the AC ripple out with filter capacitors. ✓ This ensures a true DC voltage on the DC rail. ✓ (4)

7.6
- Variable air volume air conditioning systems ✓
- Water pumping systems
- Exhaust air systems
- Speed control of fan systems
- Heating systems for air and liquid applications (1)

7.7 A switch changes the state of a device from 1 to 0 or vice-versa. ✓
A sensor converts a physical condition into an electrical signal that can be read by a PLC. ✓ (2)

7.8 7.8.1



(11)

7.8.2 The motors may have different rated current values, ✓ so the method offers independent overcurrent prptection to each motor. ✓ (2)

7.8.3 The N/O MC_1 contact is connected to ensure that motor 1 must be energised, before motor 2 can be energised. ✓ (1)
[40]

TOTAL: 200