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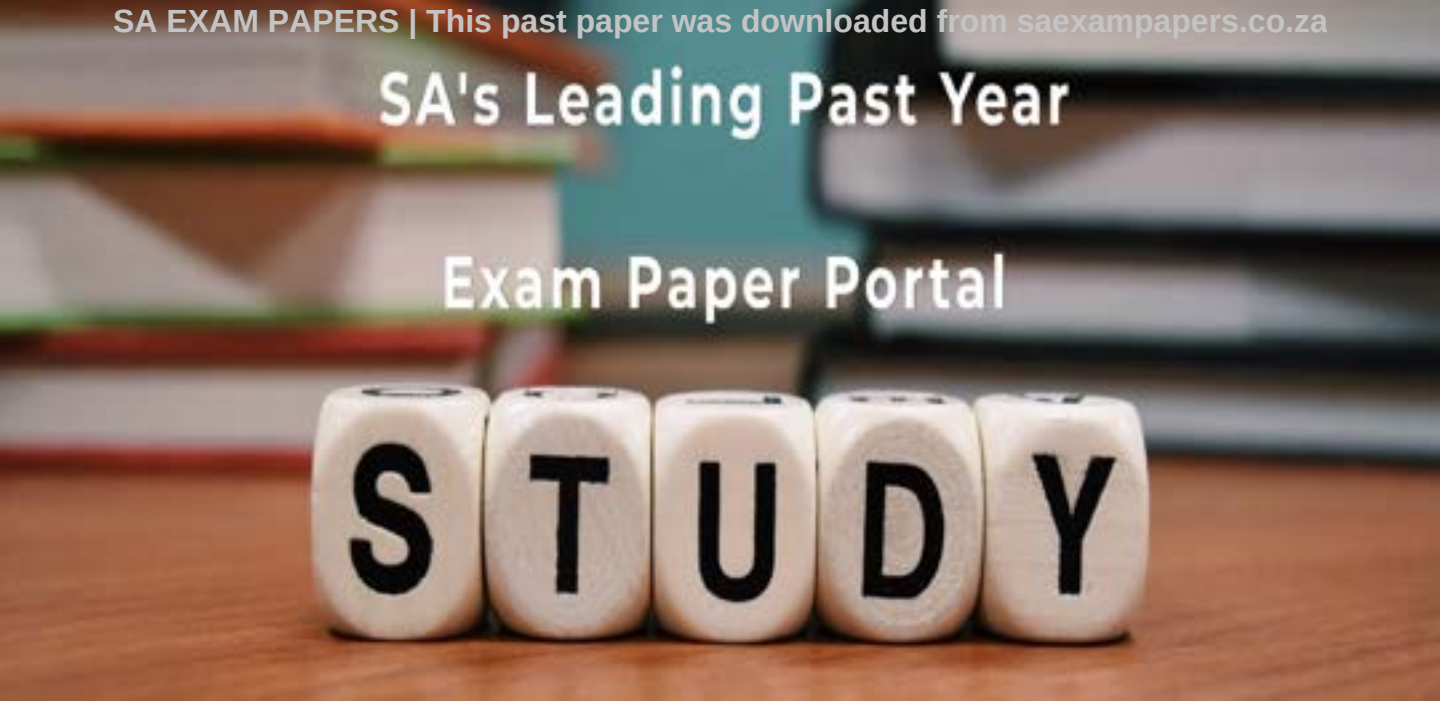

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NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2024

ELECTRICAL TECHNOLOGY: POWER SYSTEMS MARKING GUIDELINE

MARKS: 200

This marking guideline consists of 13 pages.

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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 must 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.

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QUESTION 1: MULTIPLE-CHOICE QUESTIONS

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

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QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

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

2.2
- Direct pressure ✓
- Pressure points ✓ (2)

2.3 **Treatment for shock includes:**
- Keep the person lying down ✓
- If unconscious, put him by his side (recovery position) ✓
- Do not move the person in case of neck or spine injuries
- Cover the person to maintain body heat
- Keep a close watch on the patient's colour, raising the head or legs to 'manage' the blood flow into the paler areas. (2)

2.4 A 'medical emergency' is an event that is considered serious enough as to pose an immediate risk ✓ to a person's life or long-term health. ✓ (2)

2.5
- Poor housekeeping ✓
- Inadequate lighting
- Insufficient ventilation
- Overcrowding (1)

2.6
- Always wear an apron ✓
- Protective glasses to protect against splashing into the eyes
- Wear latex gloves (1)

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QUESTION 3: RLC CIRCUITS

3.1 I_C leads V_C by 90°. ✓ (1)

3.2 3.2.1 A phasor diagram is a graphical representation of a sinusoidal alternating current or voltage ✓ in an RLC circuit. ✓ (2)

3.2.2 The resonant frequency is the frequency at which the inductive reactance ✓ is equal to the capacitive reactance. ✓
NOTE: All characteristics of resonance explained correctly will be accepted. (2)

3.3 3.3.1 $X_L = 2\pi fL$ ✓
$= 2\pi \times 60 \times 100 \times 10^{-3}$ ✓
$= 37{,}7\ \Omega$ ✓ (3)

3.3.2 $X_C = \frac{1}{2\pi fC}$ ✓

$= \frac{1}{2 \times \pi \times 60 \times 4 \times 10^{-6}}$ ✓

$= 663{,}15\ \Omega$ ✓ (3)

3.3.3 $Z = \sqrt{R^2 + (X_C - X_L)^2}$ ✓

$= \sqrt{600^2 + (663{,}15 - 37{,}7)^2}$ ✓

$= 866{,}71\ \Omega$ ✓ (3)

3.3.4 $I_T = \frac{V}{Z}$ ✓

$= \frac{120}{866{,}71}$ ✓

$= 0{,}14\ A$ ✓ (3)

3.5 $f_r = \frac{1}{2\pi\sqrt{LC}}$ ✓
$= \frac{1}{2 \times \pi \times \sqrt{100 \times 10^{-3} \times 0{,}022 \times 10^{-6}}}$ ✓

$= 3\,393{,}19\ Hz = 3{,}39\ kHz$ ✓ (3)

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3.6 3.6.1 $I_T = \sqrt{I_R^2 + (I_L - I_C)^2}$ ✓

$= \sqrt{4^2 + (6-4)^2}$ ✓

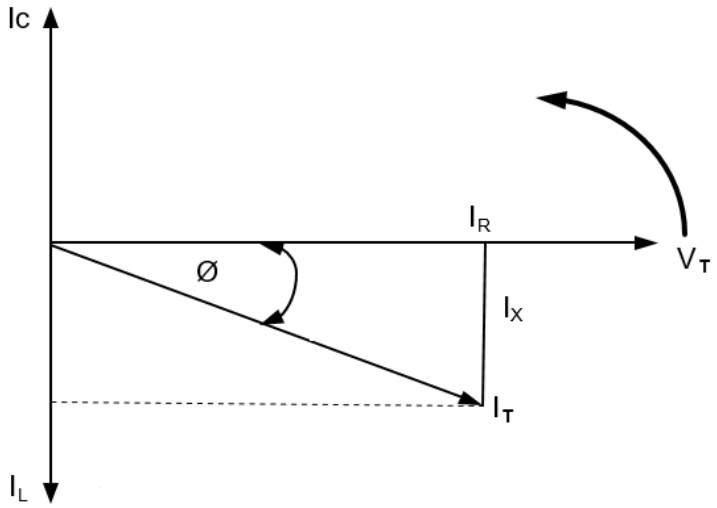
$= 4{,}47\text{A}$ ✓ (3)

3.6.2 $\theta = \cos^{-1}\frac{I_R}{I_T}$ ✓

$= \cos^{-1}\frac{4}{4{,}47}$ ✓

$= 26{,}51°$ ✓ (3)

3.6.3



NOTE: I_C, I_L and the angle is considered the primary marks. If the rotation is omitted a mark will be allocated to V_T being the reference. (3)

3.6.4 The circuit is predominantly inductive, ✓ because the inductive current is greater ✓ than the capacitive current. ✓ (3)

3.7
- The phase angle would be zero ✓
- X_L will be equal to X_c ✓
- V_L will be equal to V_C and out of phase with each other thus cancelling each other ✓
- Power factor will be 1.
- R = Z,
- The circuit will be at resonance.

(Any 3 x 1) (3)

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QUESTION 4: THREE-PHASE AC GENERATION

4.1
- Installations costs are very high ✓
- Not available everywhere ✓
- Not suitable for most residential applications ✓
- Appliances operating with three-phase supply are expensive. (Any 3 x 1) (3)

4.2 Apparent power is the product of the current and the voltage not considering phase angle in an AC circuit. ✓ Apparent power is the total power drawn from the supply. (1)

4.3
- Generation ✓
- Transmission ✓
- Distribution to consumers ✓ (3 x 1) (3)

4.4 4.4.1 $V_L = \sqrt{3}V_{PH}$ ✓
$= \sqrt{3} \times 230$ ✓
$= 398{,}37\ V$ ✓ (3)

4.4.2 $S = \sqrt{3} \times V_L \times I_L$ ✓
$= \sqrt{3} \times 398{,}37 \times 35$ ✓
$= 24\ 149{,}9\ \text{VA or } 24{,}15\ \text{kVA}$ ✓ (3)

4.4.3 $Q = \sqrt{3}V_L I_L \sin\theta$ ✓
$= \sqrt{3} \times 398{,}37 \times 35 \times \sin 18^\circ$ ✓
$= 7\ 462{,}73\ \text{Var}$ ✓ (3)

4.4.4 $P = \sqrt{3}V_L I_L \cos\theta$ ✓
$= \sqrt{3} \times 398{,}37 \times 35 \times \cos 18^0$ ✓
$= 22967{,}92\ \text{W or } 22{,}97\ \text{kW}$ ✓ (3)

4.5 $P_T = W_1 + W_2$ ✓
$= 10\ 000 + 3\ 000$ ✓
$= 13\ 000\ \text{W} = 13\ \text{kW}$ ✓ (3)

4.6 To measure the power consumed by an application. ✓ (1)

4.7 4.7.1 The meter shows a lagging power factor ✓ (1)

4.7.2 The load is predominantly inductive ✓ (1)

4.7.3
- By connecting capacitors in parallel with the load ✓
- By using synchronous motors
- By using phase advancers (Any 1 x 1) (1)

4.8 The transmission voltage is inversely proportional to the current, ✓ therefore by increasing the transmission voltage, the line current is decreased, and the copper losses are reduced. ✓ (2)

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4.9
- The phase angle ✓
- Power factor ✓ (2 x 1) (2)

4.10 Transmission lines are supplied by a star connection, ✓ so that smaller conductors can be used. ✓ (2)

4.11 The generated electricity is less at the point of distribution because of copper losses occurring, ✓ inside the transmission lines and transformers during power transmission. ✓ (2)

4.12
- To measure power consumed over a certain time. ✓
- To measure energy consumed. (Any 1 x 1) (1)

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QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 5.1.1 When supplying the same loads, single-phase transformers become more expensive than three-phase transformers. ✓ (1)

5.1.2 Three-phase transformers are more efficient than single-phase transformers. ✓ (1)

5.2
- Air Forced (AF) ✓
- Air Natural (AN) ✓ (2 x 1) (2)

5.3 Losses ✓ (1)

5.4
- Assembly or modify the circuit ONLY when the supply is OFF. ✓
- Do not switch the circuit ON before a supervisor or teacher has inspected and is satisfied. ✓
- NEVER touch any bare electric wire or terminal.
- Exercise extreme care during experiments.
- After a practical, wait for the transformer to cool down before returning it back to the storeroom.
- Be very careful of secondary terminals of a live open circuit transformer. Even after switching off, the transformer can store very high (fatal) voltages on the secondary coil.
- Earth the metal parts of a transformer. (Any 2 x 1) (2)

5.5
- The windings or coils are enclosed ✓
- The axis of the shell type can be horizontal or vertical ✓
- The core hides a major part of the windings
- The core has five limbs
- The coils are wound around the central section of the core (Any 2 x 1) (2)

5.6
- Windings failure ✓
- Tap changing failures ✓
- Bushing failures
- Terminal board failures
- Core failures (Any 2 x 1) (2)

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5.7 5.7.1 Delta-star ✓ (1)

5.7.2
- Industry or commercial sites where both single and three-phase power is needed ✓
- Domestic distribution networks where only single-phase power is needed ✓ (2 x 1) (2)

5.7.3 Step-down, ✓ because the turns ratio is 5 : 1 ✓ (2)

5.8 5.8.1 $P = S\cos\theta$

$= 200\,000 \times 0{,}85$ ✓

$= 170\,000\ W$ ✓

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

$= \frac{170\,000}{171\,800} \times 100$ ✓

$= 98{,}95\%$ ✓ (5)

5.8.2 $\text{turns ratio} = \frac{V_{PHP}}{V_{PHS}}$ ✓

$= \frac{11\,000}{219{,}39}$ ✓

$= 50 : 1$ ✓ (3)

5.8.3 $S = \sqrt{3}V_{LS}I_{LS}$ ✓

$I_{LS} = \frac{S}{\sqrt{3}V_{LS}}$

$= \frac{200\,000}{\sqrt{3} \times 380}$ ✓

$= 303{,}87\ A$ ✓

OR

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

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

$= \frac{170\,000}{\sqrt{3} \times 380 \times 0{,}85}$ ✓

$= 303{,}87\ A$ ✓ (3)

5.9 A transformer has no moving parts for induction to take place. ✓ Unlike DC, AC produces an alternating flux which expands and collapses ✓ to produce the movement of the magnetic field that is required for induction. ✓ (3)

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QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1
- Check if there is any play on the shaft. ✓
- Check if the shaft turns freely by hand. ✓
- Check if the bearings work smoothly when turned by hand. ✓
- Check for any excessive grease and dust on the bearing brushes.

(Any 3 x 1) (3)

6.2
- Continuity test between ends of each coil. ✓
- Continuity test between the frame of the motor and earth. ✓ (2 x 1) (2)

6.3
- Cranes ✓
- Conveyor belts ✓
- Hoists (Any 2 x 1) (2)

6.4
- Synchronous speed is the speed at which the magnetic field in the stator rotates. ✓
- Rotor speed is the speed at which the rotor rotates in the attempt to reach the synchronous speed. ✓ (2)

6.5 6.5.1 A – End ring ✓
B – Bearing ✓ (2)

6.5.2
- Less maintenance due to no brushes or slip rings. ✓
- They are less prone to explosions because any sparks eliminated due to the absence of brushes and slip rings. (1)

6.5.3
- It helps in reduction of magnetic humming. ✓
- It helps to avoid cogging (locking tendency of the rotor)
- It increases the effective ratio of transformation between stator and rotor.
- It causes an increased rotor resistance due to comparatively lengthier rotor conductor rods.
- Increased slip for a given torque. (Any 1 x 1) (1)

6.6 6.6.1 $n_s = \frac{60f}{p}$ ✓

$= \frac{60 \times 50}{6}$ ✓

$= 500 \text{ rpm}$ ✓ (3)

6.6.2 $n_r = n_s(1 - S)$ ✓

$= 500(1 - 0{,}05)$ ✓

$= 475 \text{ rpm}$ ✓ (3)

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6.7 6.7.1 1,3 A ✓ (1)

6.7.2 The motor can be used in South Africa because it operates with a supply voltage of 380 V ✓ and a frequency of 50 Hz. ✓ (2)

6.7.3 The 7,5 Kw signifies the rated output power ✓ the motor can deliver to drive the load. (1)

6.7.4 $n_s = \frac{60f}{p}$

$p = \frac{60 \times f}{n_s}$ ✓

$= \frac{60 \times 50}{1\,500}$ ✓

$= 2$ pole pairs per phase ✓

$\therefore$ Total number of poles $= 2 \times 2 \times 3$ ✓

$= 12$ poles ✓ (5)

6.7.5 $P_{IN} = P_{out} + P_{losses}$

$= 7\,500 + 1\,200$

$= 8\,700\ W$ ✓

efficiency $= \frac{P_{out}}{P_{in}} \times 100$ ✓

$= \frac{7\,500}{8\,700} \times 100$ ✓

$= 86{,}21\%$ ✓

OR

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

$= \frac{7\,500}{7\,500 + 1\,200} \times 100$ ✓✓

$= 86{,}21\%$ ✓ (4)

6.8 By swopping ✓ any two of the three supply lines. ✓
NOTE: Mentioning the colour of lines are accepted. (2)
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QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS

7.1
- 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. (Any 3 x 1) (3)

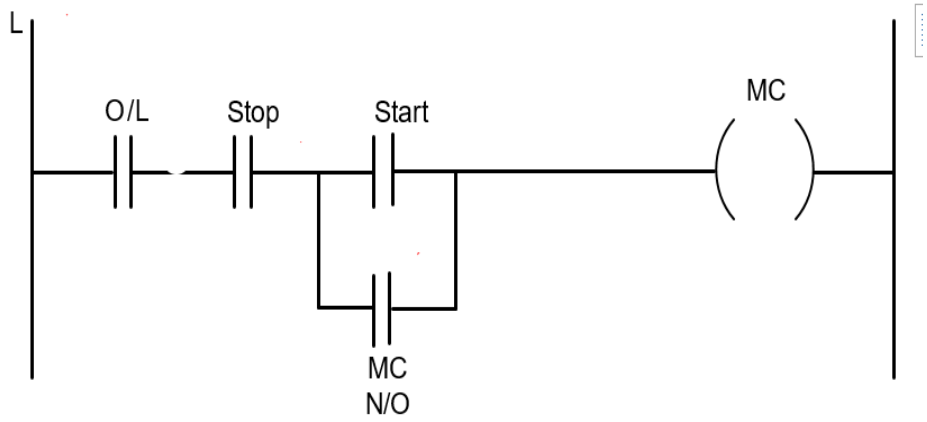
7.2
- Input module ✓
- Output module ✓
- Power supply ✓
- Central processing unit (microprocessor) (Any 3 x 1) (3)

7.3 7.3.1 Hardware refers to all the physical parts and components that combine, ✓ to form the device. ✓ (2)

7.3.2 Software refers to machine or graphical language that is installed ✓ on a computer or written into the PLC that instructs it to interact ✓ with its input and output hardware. ✓ (3)

7.3.3 An Opto-coupler is a semiconductor device that uses light to transmit a signal ✓ between two circuits ✓ that are electrically isolated. ✓ (3)

7.4



NOTE: 1 mark for indicating the power rail or power supply
1 mark for each correctly labelled symbol provided it makes logic sense towards the operation of the circuit. (6)

7.5
- Transistor ✓
- Relay ✓ (2 x 1) (2)

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7.6 7.6.1 DC-to-AC Inverter ✓ (1)

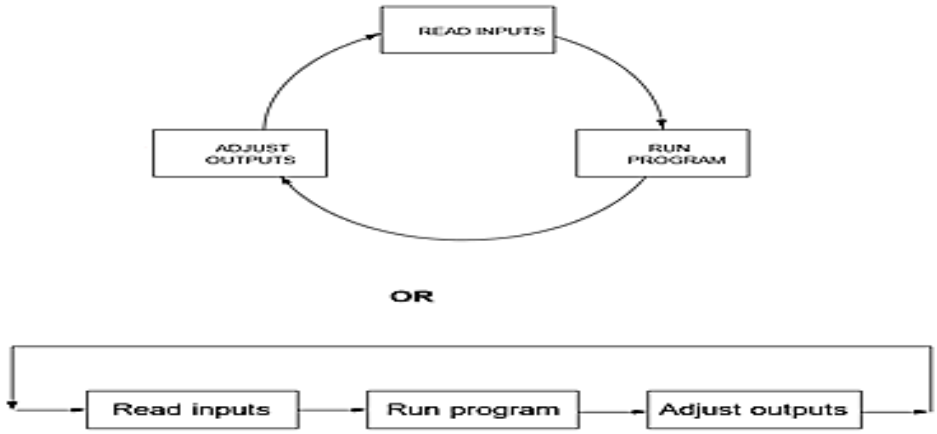
7.6.2
- Insulated Gate Bipolar Transistor (IGBT) ✓
- Metal Oxide Semi-Conductor Field Effect Transistor (MOSFET) (1)

7.6.3
- Improves energy usage. ✓
- Reduces motor wear. ✓
- Achieves variable motor speed control. (Any 2 x 1) (2)

7.6.4
- Vector drives use a mathematical model of the drive-in software. ✓
- By measuring the current vectors in relation to the applied voltage. ✓
- They are able to maintain a constant field at all frequencies below the line frequency. ✓ (3 x 1) (3)

7.7
- An analagoue signal is a continously changing signal. ✓
- A digital signal is a signal with a number of discrete steps. ✓ (2 x 1) (2)

7.8



One mark per labelled block. (3)

7.9 7.9.1 A sensor is a device that detects and converts an enviromental condition into an electrical signal, ✓ that can be used by another device for a particular purpose. ✓ (2)

7.9.2
- Temperature sensor ✓
- Llight sensor ✓
- Overload sensor
- Level sensor (Any 2 x 1) (2)

7.9.3
- To detect the proximity of an object in relation to its distance ✓
- Used to measure rotating speed. ✓ (2 x 1) (2)

[40]

TOTAL: 200

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