basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY

NOVEMBER 2015

MEMORANDUM

MARKS: 200

This memorandum consists of 15 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 is used in a next calculation, the first answer will be deemed incorrect. However, should the incorrect answer be applied correctly, the marker has to re-calculate the answer using the incorrect values. If the candidate used the initial incorrect answer correctly thereafter, the candidate should receive the full marks for subsequent correct calculations.

3. This memorandum is only a guide with model answers. Alternative interpretations must be considered and marked on merit. This principle should be applied consistently throughout the marking session at ALL marking centres.

QUESTION 1: OCCUPATIONAL HEALTH AND SAFETY

1.1
- Working on a installation with exposed live conductors. ✓
- Working with portable electric equipment that is not insulated correctly.
- Using electrical machines without using the required safety equipment and/or clothing. (1)

1.2 Dangerous practices are defined as processes or activities that have some form of risk or hazard✓ when performed that could lead to serious injury or death. ✓
List the action - 1 Mark
Reference an example – 1 Mark (2)

1.3
- Insufficient ventilation✓
- Insufficient lighting ✓
- Inadequate guards around machinery.
- Loose and dangerous components on moving machinery. (2)

1.4 Human rights are designed to protect a worker in the workplace regardless of their race, religion, etc. ✓ To ensure that the worker is treated with dignity. ✓

It can be explained as the correct and acceptable manner in which all people are entitled to be treated in the workplace.

Human rights are the fundamental rights to which all human beings must have access to. These are amongst others, the right to life without persecution, freedom, education. (2)

1.5 Risk management is important in maintaining safety in a workshop in terms of:
- Employee wellbeing ✓
- Customer wellbeing ✓
- Income and profits ✓
- Assets and property
- Productivity
- Risk management considers risk from the worker to the employer and the company as well as the end user.
- Identification of risk and prevention of loss / alleviation of danger as a preventative measure. (3)

[10]

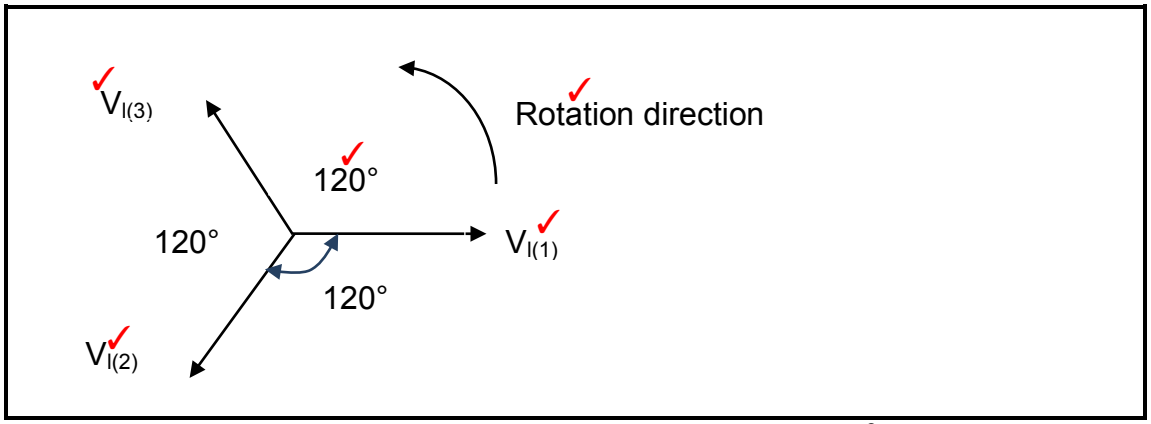
QUESTION 2: THREE-PHASE AC GENERATION

2.1

- Active power refers to the power component✓ (voltage and current values) through which work is done. ✓
- Active power is the power that is effectively being used by the load or the circuit. Active power is the product of the voltage and current values that are in phase with each other.
- Active power is the portion of power that, averaged over a complete cycle of the AC wave form, results in net transfer of energy in one direction.
- Active power is the electrical power component that can be converted into mechanical power or heat.
- $P = \sqrt{3}\ V_l\ I_l\ \text{Cos}\ \alpha$

(2)

2.2



The candidate MUST show the degree symbol for the 120° to be considered as correct.
Colours of the phases are acceptable as labels of the 3 phases.
E for EMF is also acceptable. The phasor diagram must have labels to be marked as correct.

(5)

2.3 2.3.1

$$P_{in} = \sqrt{3}\ V_l x\ I_l\ x\ \text{Cos}\theta$$

$$I_l = \frac{P_{in}}{\sqrt{3}\ x\ V_l\ x\ \text{Cos}\theta}$$ ✓

$$= \frac{50\,000}{\sqrt{3}\ x\ 380\ x\ 0{,}95}$$ ✓

$$= 79{,}96\ A$$ ✓

(3)

2.3.2

$$S = \sqrt{3}\ V_l\ x\ I_l$$ ✓

$$= \sqrt{3}\ x\ 380\ x\ 79{,}96$$ ✓

$$= 52{,}62\ kVA$$ ✓

(3)

2.4 The advantages of power factor correction are:

- It results in cost savings due to less power being drawn from the supplier due to power factor correction of the load. ✓
- Equipment lasts longer as it experiences less energy wastage due to dissipated heat energy. ✓
- Due to less current drawn from the supply switch gear and cables may be rated at a lower current reducing costs.
- More efficient installation allows for longer periods between services and maintenance due to reduced wear and tear. (2)

2.5 The function of the wattmeter is to measure the active power ✓ consumed in an installation. ✓ (2)

2.6 Power $= P_1 + P_2$ ✓

$= 2\,500 + 500$ ✓

$= 3\,000$ W ✓

$= 3$ kW

(3)
[20]

QUESTION 3: THREE-PHASE TRANSFORMERS

3.1 Protection devices in transformers include:
- Fuses ✓
- Over-current relay
- Differential current relay
- Buchholz relay (electrical or mechanical) (1)

3.2 Losses in transformers lead to:
- Increase in current drawn ✓
- Generation of more heat
- Increase in I^2R losses
- Reduced efficiency (1)

3.3 The methods of cooling transformers include:
- Oil cooling ✓
- Water cooling ✓
- Air cooling ✓
- Gas cooling (3)

3.4 If the load is increased the power output would increase ✓therefore the primary current would increase ✓ as the voltages remain constant. ✓ (3)

3.5 3.5.1

$$I_{l(secondary)} = \frac{P}{\sqrt{3} \times V_{l(secondary)} \times \cos\theta} \quad ✓$$

$$= \frac{60\,000}{\sqrt{3} \times 380 \times 0{,}8} \quad ✓$$

$$= 113{,}95 \text{ A} \quad ✓$$

(3)

3.5.2

$$I_{l(primary)} = \frac{P}{\sqrt{3} \times V_{l(primary)} \times \cos\theta} \quad ✓$$

$$= \frac{60\,000}{\sqrt{3} \times 11\,000 \times 0{,}8} \quad ✓$$

$$= 3{,}94 \text{ A} \quad ✓$$

(3)

3.5.3

$$S = \sqrt{3} \times V_{l\ (primary)} \times I_{l\ (primary)} \quad ✓$$

$$= \sqrt{3} \times 11\,000 \times 3{,}94 \quad ✓$$

$$= 75{,}07 \text{ kVA} \quad ✓$$

(3)

3.5.4

$$Q = \sqrt{3} \times V_{l(primary)} \times I_{l(primary)} \sin 36{,}87 \quad ✓$$

$$= \sqrt{3} \times 11\,000 \times 3{,}94 \times 0{,}6 \quad ✓$$

$$= 45{,}04 \text{ kVA}_R \quad ✓$$

(3)
[20]

Note to marker: Candidates may use the secondary line voltage and line current to do this calculation.

QUESTION 4: THREE-PHASE MOTORS AND STARTERS

4.1
- Stator ✓
- Rotor ✓
- End plates (2)

4.2
- For the same size frame a three-phase motor delivers more power than a single-phase motor. ✓
- A three-phase motor is self-starting. ✓
- A three-phase motor develops a higher torque for the same size than a single-phase motor. (2)

4.3 It is important to carry out electrical inspections before energising a motor to ensure that there are no electrical faults ✓which may lead to electric shock or damage to the motor. ✓ (2)

4.4 4.4.1 If the motor draws a current greater than the setting on the overload, ✓ the overload will open ✓ removing power to the control circuit and the power circuit, switching the motor off. ✓ (3)

4.4.2
- In the forward direction the coil MC_1 is energised✓
- The normally closed contact of MC_1 is now open✓
- The open contact of MC_1 prevents the MC_2 coil from energising. ✓
- Only once the coil MC_1 is de-energised will the contact MC_2 close. ✓
- The closing of normally closed MC_1 contact will allow for the coil of MC_2 to be energised when the reverse button is depressed. ✓
- Similarly the normally closed MC_2 (N/C) contact will prevent the coil of MC_1 to be energised while the direction of rotation of the motor is in reverse. (5)

4.5 The function of the star-delta starter is to start a motor in the star mode ✓ to reduce the current drawn by the motor at start ✓ and to switch the motor into the delta mode once the motor has started. ✓
Note to marker: The purpose of the starter is also acceptable. (3)

4.6 The function of a no-volt coil in a motor starter is to prevent✓ the automatic starting of a motor✓ when the power is restored after a power failure✓. (3)

4.7 By swopping the connections ✓of any two of the three phases. ✓ (2)

4.8
- Power factor ✓
- Frequency ✓
- Power rating ✓
- Phase
- Type of connection (3)

4.9 4.9.1

$$ns = \frac{f}{P} \times 60 \quad ✓$$

$$= \frac{50}{6} \times 60 \quad ✓$$

$$= 500 \text{ r/min} \quad ✓$$

(3)

If Pole Pairs are taken as two per phase then the following calculation will apply:

$$ns = \frac{f}{P} \times 60$$

$$= \frac{50}{2} \times 60$$

$$= 1500 \ r/\min$$

4.9.2 $nr = ns(1 - 0{,}04)$ ✓

$= 500(0{,}96)$ ✓

$= 480 \text{ r/min}$ ✓

(3)

Alternative Answer following previous alternative answer

$nr = ns(1 - 0{,}04)$ P is taken as 2

$= 1500(0{,}96)$

$= 1440 \ r/\min$

4.10 4.10.1

$$P_{100} = \frac{P_{out}}{\eta} \quad ✓$$

$$P_{100} = \frac{29\,700}{0{,}9} \quad ✓$$

$$= 33\,000 \text{ W} \quad ✓$$

$$= 33 \text{ kW}$$

(3)

4.10.2

$$I_l = \frac{P_{100\%}}{\sqrt{3} V_l \cos\theta} \quad ✓$$

$$I_l = \frac{33\,000}{\sqrt{3} \text{ x } 380 \text{ x } 0{,}85} \quad ✓$$

$$= 58{,}98 \text{ A} \quad ✓$$

(3)

4.11 The current drawn from the supply will decrease. ✓ With an improved power factor the motor will still deliver the same power ✓ at the same voltage ✓ but will draw a lower current to do this. (3)

[40]

QUESTION 5: RLC

5.1
$$X_C = \frac{1}{2\pi fC} \quad ✓$$
$$= \frac{1}{2 \times \pi \times 50 \times 120 \times 10^{-6}} \quad ✓$$
$$= 26{,}52\ \Omega \quad ✓$$
(3)

5.2
- The capacitive reactance is equal to the inductive reactance at resonance ✓
- Therefore the resultant reactance is zero. ✓
- The impedance (Z) drops to the resistor value (R) which results in a minimum impedance ✓
- Therefore the current will be maximum. ✓

(4)

5.3 5.3.1
$$I_t = \sqrt{I_r^{\,2} + (I_c - I_l)^2} \quad ✓$$
$$= \sqrt{2{,}5^2 + (6 - 3{,}6)^2} \quad ✓$$ ✓
$$= 3{,}47\ A$$
(3)

5.3.2
$$X_l = \frac{V_{supply}}{I_l} \quad ✓$$
$$= \frac{240}{3{,}6} \quad ✓$$
$$= 66{,}67\ \Omega \quad ✓$$
(3)

5.3.3 If the frequency increases, the inductive reactance of the coil will increase ✓ because the inductive reactance is directly proportional to the frequency ✓ thus reducing the current through the inductor ✓ (3)

5.4 The magnification factor ✓ of the circulating currents in the inductor and capacitor ✓ in relation to the supply current ✓ when the circuit is at resonance ✓
(4)
[20]

QUESTION 6: LOGIC

6.1 6.1.1
- Sensing device ✓
- Switches ✓
- Push buttons
- Limit switches
- Pressure switches (2)

6.1.2
- Ladder diagrams✓
- Function block diagrams✓
- Sequential function✓
- Flow charts / Flow Diagrams
- Instructional list
- Structured text (3)

6.1.3
- Step 1 (INPUT) – The PLC checks the input parameters✓ via the input interface.✓
- Step 2 (PROCESS) - The PLC will go through its programme from the first instruction✓ and execute it line by line.✓
- Step 3 (OUTPUT) – The PLC will update the outputs ✓after the execution of every instruction ✓ (6)

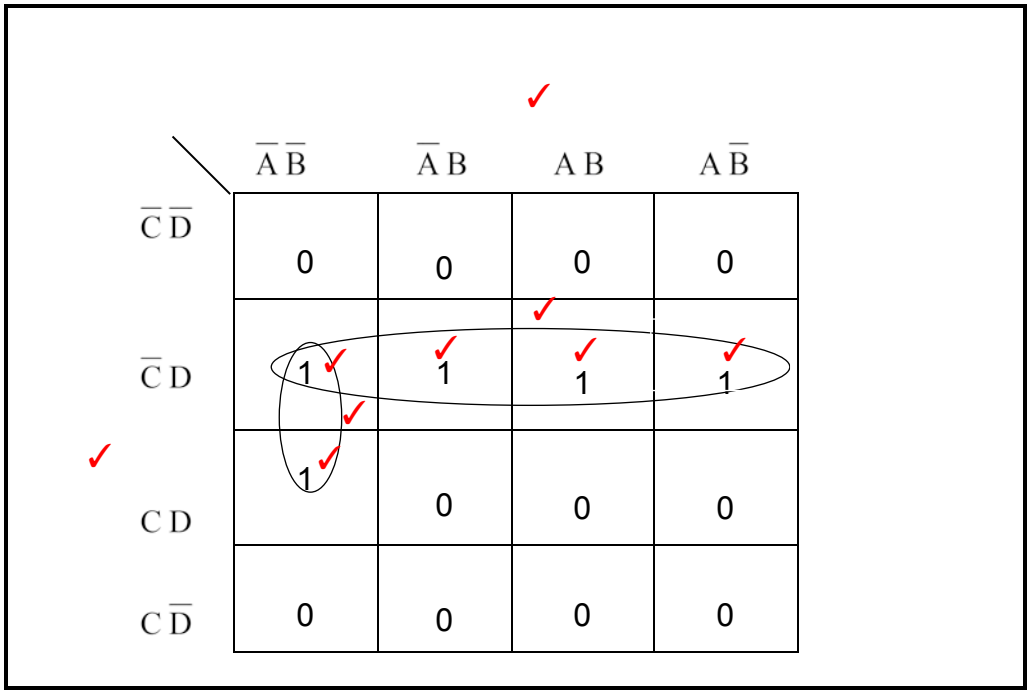
6.1.4 The transistor output PLC operates on low voltage✓ and low currents ✓ which makes it unable to control heavy current devices as the output transistors may be damaged.✓ (3)

6.1.5
- In order to switch on heavy current electrical devices, a transistor output PLC makes use of a relay.✓
- The relay used with the output circuit allows for the electrical separation/isolation between the load and the PLC. ✓
- The relay's output contacts are connected to the load, and not the PLC, thus protecting the PLC.✓ (3)

6.2
- PLC control allows for easy quick change to be made to a system without having to do major rewire. ✓
- PLC programs can be stored electronically. ✓
- PLC control reduces components therefore reducing the size of control panels.
- Reduction in the components used reduces cost.
- Less/No moving parts depending on the type of PLC
- More reliable (2)

6.3 $X = \overline{A}\,\overline{B}\,\overline{C}D + \overline{A}\,\overline{B}CD + \overline{A}B\overline{C}D + AB\overline{C}D + A\overline{B}\,\overline{C}D$

6.3.1



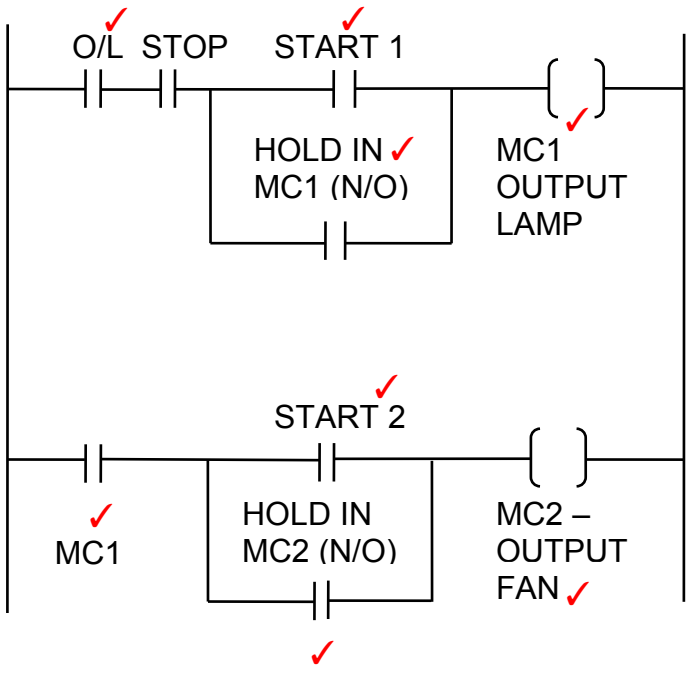
(9)

Alternative labelling methods must be marked on merit.

6.3.2 $X = \overline{A}\,\overline{B}D$ ✓ + ✓ $\overline{C}D$ ✓

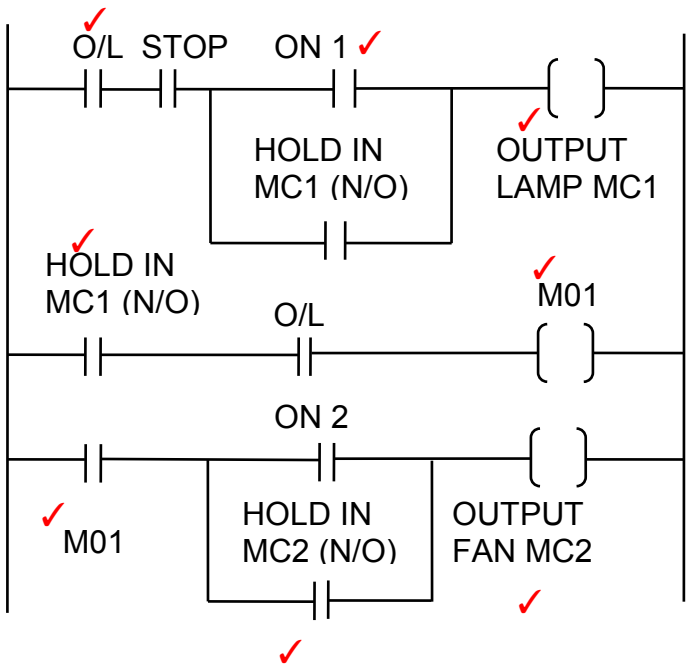
(One tick per term and one tick for OR function) (3)

6.4 6.4.1



(8)

OR



Note: It is important that the circuit must work in sequence.

6.4.2 A timer function ✓ must be included in the diagram after removing the second start function. (1)

[40]

QUESTION 7: AMPLIFIERS

7.1
- Open-loop voltage gain A_v = infinite✓
- Input impedance Z_{in} = infinite✓
- Output impedance Z_o = zero ✓
- Bandwidth = infinite
- Stability/Linearity of operation
- Differential inputs (two inputs)
- Infinite common-mode rejection ratio (3)

7.2 The bandwidth is the range of frequencies ✓ an amplifier can amplify without distorting ✓ the output signal or losing gain.✓ (3)

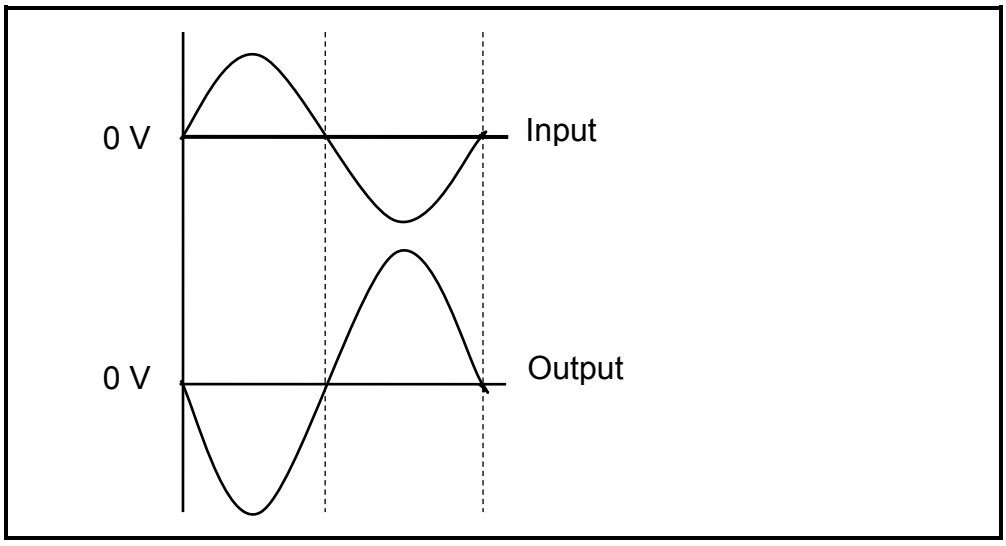
7.3
- The bandwidth is increased. ✓
- The level of noise (hiss) is decreased. ✓
- The deformation of the input signal is reduced.
- The gain is more predictable (2)

7.4 Positive feedback is when part of the output signal is fed back into the input signal✓ in phase with the input✓ therefore increasing the output.✓ (3)

7.5 Stability in op amps means that the operation/linearity of the op amp is not affected ✓ despite changes to the conditions under which the amplifier operates ✓ (2)

7.6 7.6.1 Inverting op amp. ✓ (1)

7.6.2



(3)

- Inversion✓
- Amplification✓
- Frequency must be the same✓

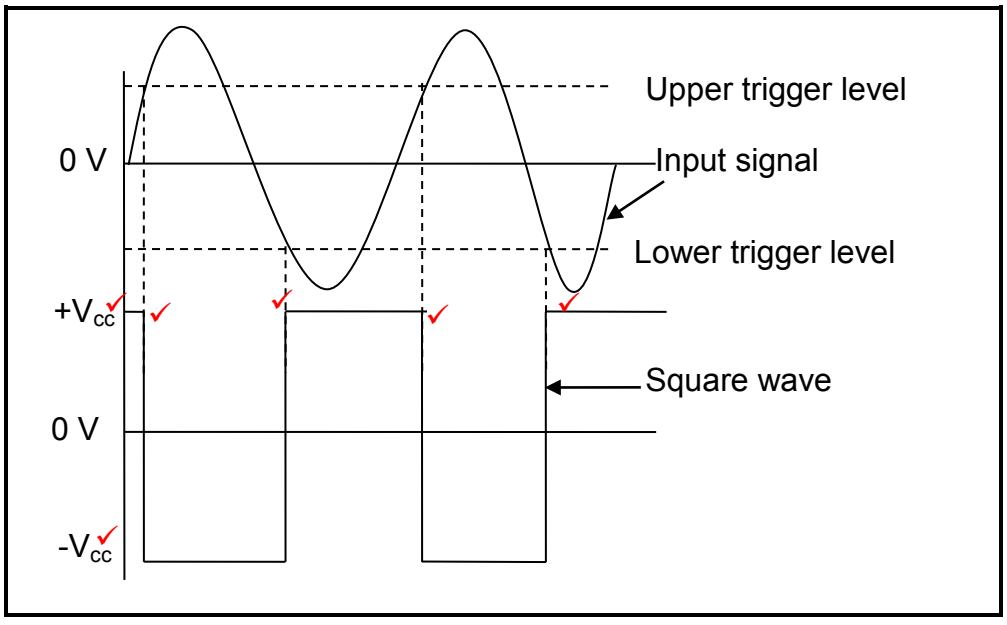
7.6.3
$$A_v = -\frac{R_f}{R_{in}} \quad \checkmark$$
$$= -\frac{15}{5} \quad \checkmark$$
$$= -3 \quad \checkmark$$
(3)

7.6.4
$$A_v = -\frac{V_{out}}{V_{in}}$$
$$V_{out} = -A_v V_{in} \quad \checkmark$$
$$= -3 \times 1,5 \quad \checkmark$$
$$= -4,5 \text{ V} \quad \checkmark$$
(3)

7.7 7.7.1 The Schmitt trigger is used to/as a:
- Voltage sensitive switch ✓
- Supplies a digital output ✓
- Used to measure the frequency of an AC signal
- Day night switches
- Wave form recovery circuit.

(2)

7.7.2



(6)

7.8
$$f_r = \frac{1}{2\pi\sqrt{L_t C}} \quad \checkmark$$
$$= \frac{1}{2\pi\sqrt{80 \times 10^{-3} \times 0,65 \times 10^{-6}}} \quad \checkmark$$
$$= 697,94 \text{ Hz} \quad \checkmark$$
(3)

7.9 7.9.1 Mono-stable multivibrator. ✓ (1)

7.9.2 Timing circuit ✓ (1)

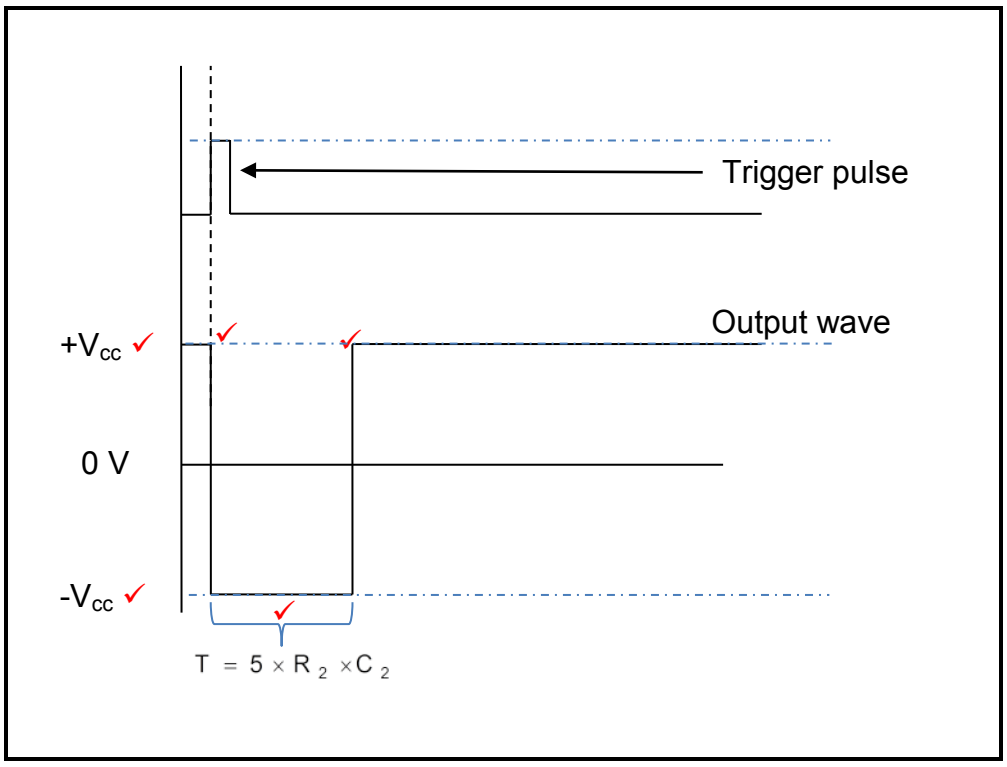
7.9.3 $T = 5 \times R_2 \times C_2$ ✓

$= 5 \times 550\ 000 \times 22 \times 10^{-9}$

$= 0{,}0605\,s$ ✓

$= 60{,}5\,ms$ ✓ (3)

7.9.4



(5)

Note: The output may also start from 0 volts

7.10 7.10.1
- Set and reset switch. ✓
- Electronic on-off switch
- Memory element (1)

7.10.2 The output would change to match $+V_{cc}$ ✓as the input is connected to the inverting input. ✓ (2)

7.11 The dual DC supply supplies energy to the op amp✓ to amplify an input signal. The dual power supply allows the op amp to operate with a positive and negative supply ($+V_{cc}$ and $-V_{cc}$) thus allowing negative and positive amplification ✓with reference to zero volts✓. (3)

[50]

TOTAL: 200