basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: ELECTRONICS

NOVEMBER 2023

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: MULTIPLE CHOICE

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

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1
- When any person dies. ✓
- When the health and safety of any person is endangered. ✓
- When a major incident occurs.

NOTE: Only serious injuries are reported to the health and safety inspector. (2)

2.2 Danger means anything that may cause injury to a person ✓ or damage to property. ✓ (2)

2.3 The Emergency Master Switch should be located at a key access point ✓ so that in an emergency, workers could access the switch easily. ✓

2.4 Charring of tissue. ✓
Difficulty in breathing. ✓
Severe symptoms of shock. (2)
Muscle and bone damage.

2.5 Check whether the person is able to breath. ✓
Send a person to call for medical assistance. ✓
Keep the person lying down.
If unconscious, put the person on his/her side. (recovery position)
Don't move the person in case of neck or spine injuries.
Cover the person to maintain body heat.
Keep a close watch on the person's colour, raising the head or legs to manage the blood flow into the paler areas. (2)

[10]

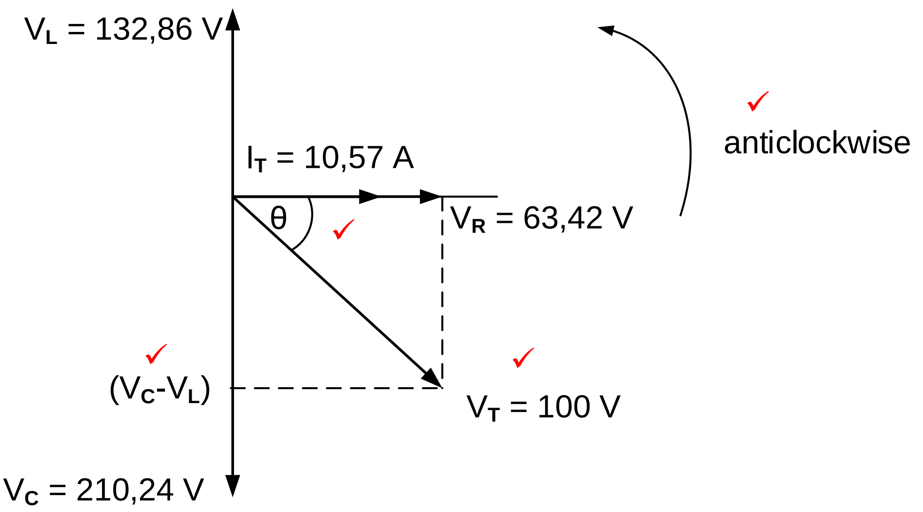
QUESTION 3: RLC CIRCUITS

3.1 Inductive reactance is directly proportional to frequency. ✓ (1)

3.2 The current waveform lags the voltage waveform by 90°. ✓
(voltage waveform leads the current waveform by 90 degrees) (1)

3.3 3.3.1 The supply current is leading ✓ because V_C is greater than V_L. ✓
Alternative motivation:
Because the circuit is more capacitive
The supply current is leading because V_L is smaller than V_C (2)

3.3.2



(4)

3.3.3

$$V_T = \sqrt{V_R^2 + (V_C - V_L)^2} \quad ✓$$
$$= \sqrt{63{,}42^2 + (210{,}24 - 132{,}86)^2} \quad ✓$$
$$= 100{,}05\ V \quad ✓$$

(3)

3.3.4

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad ✓$$
$$= \frac{1}{2\pi\sqrt{(0{,}02)(80 \times 10^{-6})}} \quad ✓$$
$$= 125{,}82\ Hz \quad ✓$$

(3)

3.4 3.4.1

$$I_T = \sqrt{I_R{}^2 + (I_L - I_C)^2} \quad ✓$$
$$= \sqrt{3^3 + (5-5)^2} \quad ✓$$
$$= 3\,A \quad ✓$$

(3)

If $I_L = I_C$ the circuit is at resonance
Therefore $I_R = I_T$
= 3 A

3.4.2

$$Cos\theta = \frac{I_R}{I_T} \checkmark$$

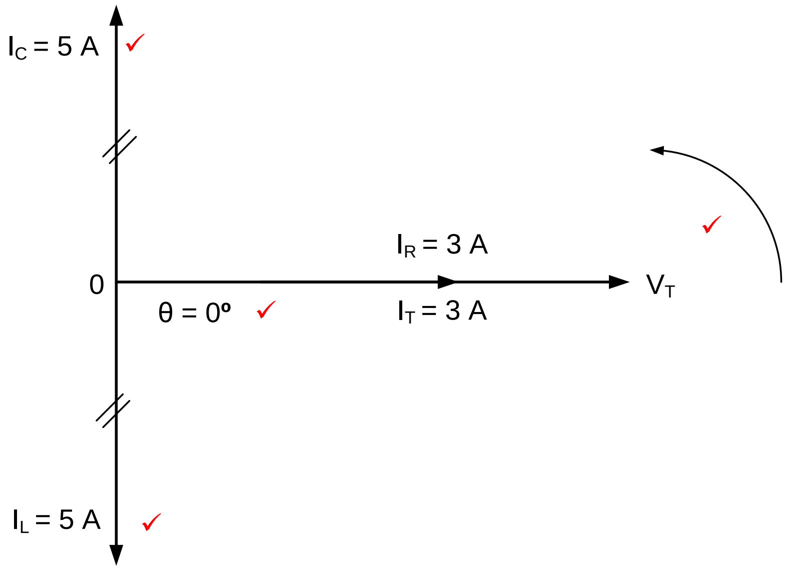
$$\theta = Cos^{-1}\left(\frac{I_R}{I_T}\right) \checkmark$$

$$= Cos^{-1}\left(\frac{3}{3}\right) \checkmark$$

$$= 0^{\circ}$$

(3)

3.4.3



(4)

3.5 3.5.1

$$Q = \frac{X_C}{Z}$$ ✓ (R = Z at resonance)

$$= \frac{300}{30} \checkmark$$

$$= 10 \checkmark$$

(3)

3.5.2

$$BW = \frac{f_r}{Q} \checkmark$$

$$= \frac{4{,}77 \times 10^3}{10} \checkmark$$

$$= 477\ Hz \checkmark$$

(3)

3.5.3

$$V_L = I_T \times X_L \checkmark$$

$$= 1 \times 300$$ ✓ ($X_L = X_C$ at resonance)

$$= 300\ V \checkmark$$

(3)

3.5.4 The voltage across the inductor is greater than the supply voltage due to this being a series resonant circuit ✓ and to the voltage magnification ✓ of the Q-factor.
L and C forms a tank/oscillator which amplifies the voltage and supply each other with out of phase energy where the amplification depends on Q.

(2)
[35]

QUESTION 4: SEMICONDUCTOR DEVICES

4.1 4.1.1 A = Source / Drain ✓
B = Drain / Source ✓ (2)

4.1.2 The N-channel JFET consists of a channel of lightly doped N-type material ✓ sandwiched between two heavily doped P-type regions ✓ that have been formed of diffusion. (2)

4.1.3 The PN junction is reversed baised ✓ causing the depletion region on either side ✓ of the conducting channel to widen, ✓ resulting in the reduction of the drain current through the channel. (3)

4.2 4.2.1 Output characteristic of an n-channel MOSFET. ✓ (1)

4.2.2 A = Enhancement mode ✓
B = Depletion mode ✓ (2)

4.3 4.3.1 Digital wrist watch ✓
Pocket calculator ✓
Audio amplifiers
LED drivers
Inverters (2)

4.3.2 The gate of a MOSFET is insulated from the channel by a silicon dioxide (S_iO_2) layer ✓ whereas the gate of the JFET is in direct contact with the channel. ✓ (2)

4.4 4.4.1 When the value of the R_1 is higher, the capacitor will take a longer time to charge ✓ as the time constant will be longer. ✓ (2)

4.4.2
- The UJT regulates the voltage pulses to the gate of the SCR to control the ON/OFF duration of the SCR. ✓
- When the SCR is ON, it will supply current to the motor. ✓
- The speed of the motor will be controlled by changing the frequency of the saw tooth pulses using the variable resistor. ✓ (3)

4.5 4.5.1 Very high current gain ✓
Very low output impedance.✓
Improved input impedance. (2)

4.5.2 The collector emitter voltage of the Darlington pair is in the region of 0,9 V. ✓ (1)

4.5.3
- When the base current is applied to the base of Transistor (Q_1) it will be amplified ✓and emerge as the emitter current of Transistor (Q_1).
- The emitter current of transistor Q_1 is fed to base of transistor Q_2, ✓ and further be amplified for the second time. ✓ (3)

4.6 4.6.1 The purpose of the feedback resistor is to reduce the gain of the amplifier to the required level. ✓
Provides negative feedback of the output to the inverting input. (1)

4.6.2 Op-amps are seldom used in an open loop mode because of their very high gain ✓ which creates poor stability of the output voltage.✓ (2)

4.6.3

$$A_v = -\frac{R_F}{R_{IN}}$$ ✓ ✓

$$= -\frac{1{,}2 \times 10^3}{1 \times 10^3}$$

$$= -1{,}2$$ ✓

(3)

4.7 4.7.1 It provides the op-amp with dc stability. ✓
It prevents the op-amp from saturating. ✓ (2)

4.7.2

$$A_V = 1 + \frac{R_F}{R_{IN}}$$ ✓

$$= 1 + \frac{120\ 000}{10\ 000}$$ ✓

$$= 13$$ ✓

(3)

OR

$$A_V = -\frac{R_F}{R_{IN}}$$

$$= -\frac{120\ 000}{10\ 000}$$

$$= -12$$

NOTE: With the swopping of the symbols on the diagram provided the calculation of the inverting op-amp gain will also be considered

4.8 4.8.1 Timer ✓
Oscillator ✓
Multi-vibrator
Schmitt trigger
temperature measurements
control servo devices
digital logic probes
create warning lights
produce musical notes (2)

4.8.2
- They cannot cope with high currents, ✓ high voltage ✓ or high power requirements.
- They can be damaged by overloading or by fluctuating power supplies.
- Current limitation of 200 mA
- Voltage limitation of 18 V (2)

4.8.3 Pin 4 is the reset input for the flip-flop and as soon as the reset pin is set to 0 V ✓, the output pin 3 ✓ and the discharge pin 7 will be connected to 0 V ✓ resetting the IC.
(The reset pin 4 is used to reset the IC i.e it causes the output to return to zero volts if it is connected to zero volts). (3)

4.8.4 (a) The NPN transistor provides a low resistance path for discharge current to flow from Pin 7 to ground ✓ only when the flip-flop goes high. (1)

(b) Comparator 2 compares lower voltage (⅓V_{CC}) against the trigger voltage. ✓ (1)

[45]

QUESTION 5: SWITCHING CIRCUITS

5.1 A bistable multivibrator's output has two stable states ✓ keeping its output in either high or low state when a trigger input is applied.
An astable multivibrator's output has no stable state, ✓ it changes between high and low continuously. (2)

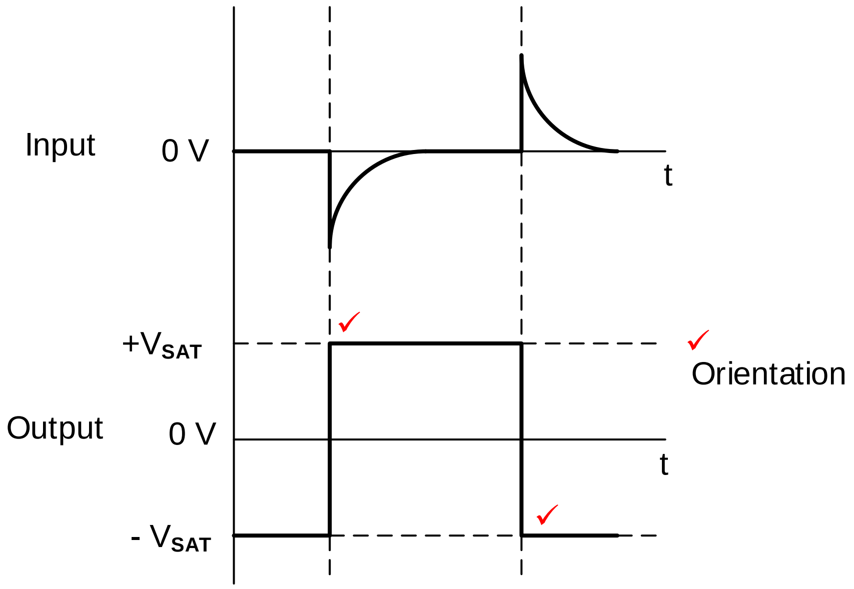
5.2 5.2.1 R_1 + R_2 act as a voltage divider ✓ with R_2 that provides positive feedback. ✓
R_2 acts as a voltage divider with R_1 that provides positive feedback and maintains a voltage with the same polarity as the output on the non-inverting input. (2)

5.2.2 Positive ✓ (1)

5.2.3 When S_1 is pressed the circuit output will be negative where it will remain until S_2 is pressed. ✓
When S_1 is pressed, both plates of the capacitor rise forcing the inverting terminal high. Making this voltage greater than the voltage on the non-inverting terminal; the op-amp immediately saturates forcing its output low ($-V_{SAT}$) where it will remain. (1)

5.2.4 When S_1 is pressed a positive voltage will be applied to inverting input of the op-amp ✓ and the output will be at negative saturation.✓ Because the supply voltage is -9 V the output voltage value will be -9 V. ✓ (3)

5.2.5



(3)

5.3 5.3.1 Active low ✓ (1)

5.3.2 4 V ✓
⅔ of the supply voltage (1)

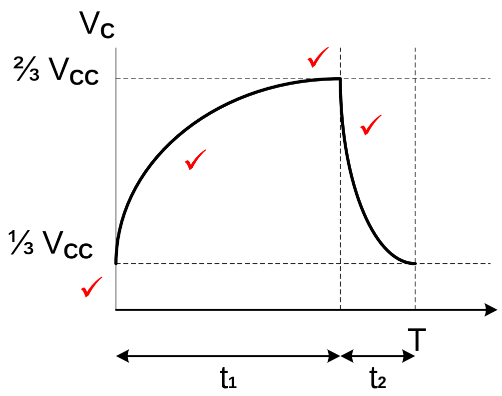
5.3.3 When the trigger is pressed, pin 2 is pulled down to 0 V. ✓ This activates the circuit and the capacitor starts to charge through resistor R_1. ✓ As soon as the voltage across the capacitor reaches ⅔ of the supply voltage, ✓ threshold pin 6 will trip/de-activate the internal timing circuit. At the same time both the output pin 3 and discharge pin 7 is pulled 'low' ✓ ending the timing period of the circuit. Capacitor C_1 then dischargers through pin 7 and pin 1 to ground ✓ where it is held 'low' until it is triggered again. (5)

5.3.4 By connecting a small value capacitor of 0,01 µF ✓ from pin 5 to ground. ✓ (2)

5.4 5.4.1 Duty cycle is the time comparison between the high ✓ and low states of a multivibrator output, ✓ usually expressed in percentage. (The percentage/time of a cycle which the output is high)
Duty cycle is the time comparison between the high state and the period of a multivibrator output. (2)

5.4.2 The charging time of the capacitor is longer ✓ because the capacitor charges through R_1+R_2 ✓ and discharges through R_2 only. ✓ (3)

5.4.3



NOTE: 1 mark for the correct charging cycle starting from ⅓ V_{cc}.
1 mark for the correct charging signal from ⅓ to ⅔V_{cc}.
1 mark for the correct discharging voltage from ⅔V_{cc} to ⅓V_{cc}.
1 mark for t_1 being longer than t_2.
If the charging starts at 0 and discharges to 0, but everything else is correct 1 mark will be lost. (4)

5.5 5.5.1 By making R_2 variable one can vary the trigger voltage levels. ✓ (1)

5.5.2

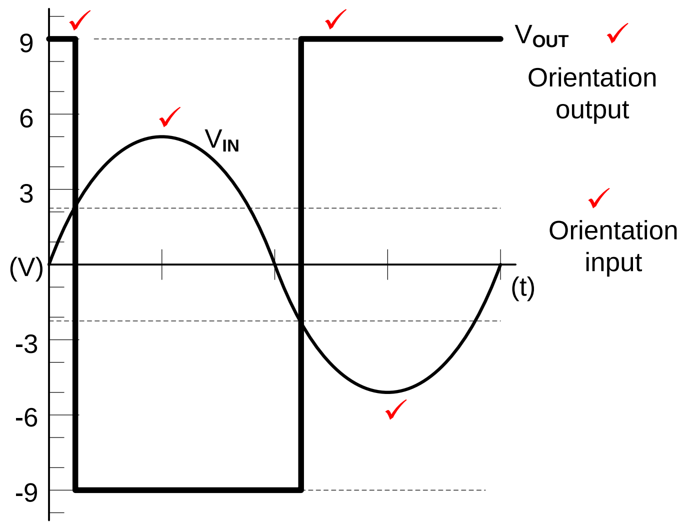
$$V_{FB} = V_{SAT} \times \frac{R_2}{R_1 + R_2} \quad ✓$$

$$= 9 \times \frac{2200}{6800 + 2200} \quad ✓$$

$$= 2{,}2\ V \quad ✓$$

(3)

5.5.3



NOTE: If the learner drew an input voltage of 7 V (5 V x 0,707) it will also be considered.

NOTE: 2 marks for the input
2 marks for the output (2-trigger points)
2 marks for orientation (1 input + 1 output)
If the learner drew an inverted input with the correct output in relation to the inverted input, full marks will be awarded. (6)

5.5.4 The value of the trigger voltage can be decreased by decreasing the value of R_2. ✓ (1)

5.6 5.6.1 The capacitors allow only AC to pass to the input and blocks any DC signals from entering the amplifier. ✓ (1)

5.6.2 The variable resistors allow you to control the gain ✓ of each input independently. ✓ (2)

5.6.3

$$V_{OUT} = -\left(V_1\frac{R_F}{R_1} + V_2\frac{R_F}{R_2} + V_3\frac{R_F}{R_3}\right) \checkmark$$
$$= -\left(0{,}5 \times \frac{10\,000}{2000} + 0{,}2 \times \frac{10\,000}{2000} + 0{,}3 \times \frac{10\,000}{2000}\right) \checkmark$$
$$= -5\,V \checkmark$$

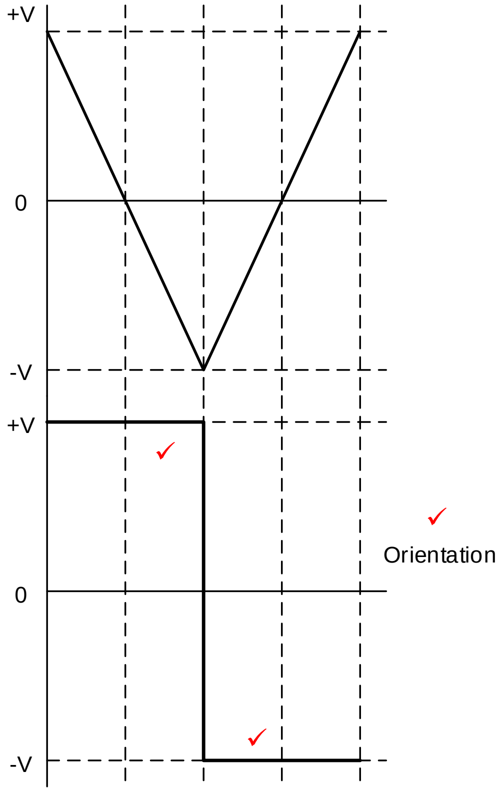
(3)

OR

$$V_{OUT} = -\left(V_1\frac{R_F}{R_1} + V_1\frac{R_F}{R_2} + V_1\frac{R_F}{R_3}\right)$$
$$= -\left(0{,}5 \times \frac{10\,000}{2000} + 0{,}5 \times \frac{10\,000}{2000} + 0{,}5 \times \frac{10\,000}{2000}\right)$$
$$= -7{,}5\,V$$

NOTE: The alternative response must be considered correct if the learners used the formula from the formula sheet. (the formula in the formula sheet included a typographical error)

5.7



(3)
[50]

QUESTION 6: AMPLIFIERS

6.1 Positive feedback is part of the output signal ✓ that is fed back to the input, being in phase with the input signal. ✓
(Positive feedback is where a portion of the output wave is fed back to the input and the feedback signal is in phase with the input signal). (2)

6.2 A Class A amplifier has no crossover distortion therefore less distortion at the output signal. ✓
Class B push-pull amplifiers have more distortion at the output due to cross-over distortion. ✓ (2)

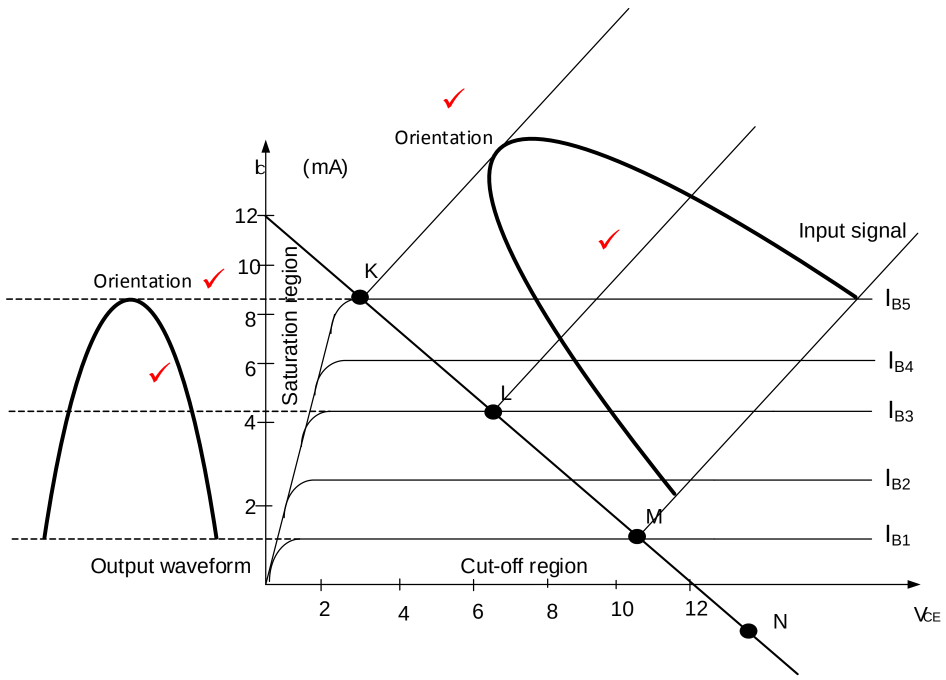
6.3 6.3.1 V_{RL} will be equal to V_{CC}. ✓
12 V
V_{RL} is slightly lower than or equal to 12 V. (1)

6.3.2 The supply voltage was reduced to 6 Volts, ✓ which resulted in the collector current of 3 mA. ✓ (2)

6.4 6.4.1 Active region ✓
Operating region (1)

6.4.2 Temperature ✓
Power supply variations
Transistor parameter tolerances (1)

6.4.3

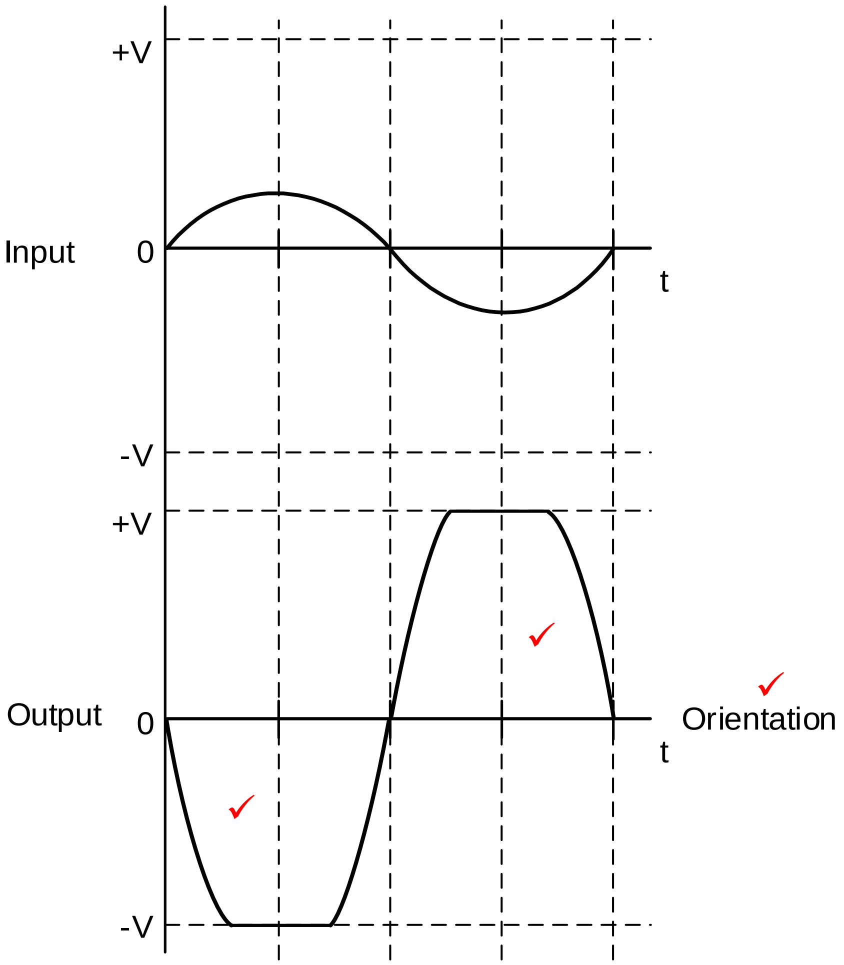


NOTE: Because the input signal is not given, the output must be marked according to what the learner drew on the input. (4)

6.5 6.5.1

- The AC voltage from the base to the emitter will decrease
- The base current will also decrease.✓
- Both the collector current and the voltage across the load will decrease.✓
- The collector emitter voltage (V_{CE}) will increase relative to ground.✓ (3)

6.5.2



NOTE: 1 mark for positive half-cycle
1 mark for negative half cycle
1 mark for orientation. (3)

6.6 6.6.1 Transformer T_2 is used to match the input impedance of the load so that a maximum power can be transferred. ✓ (1)

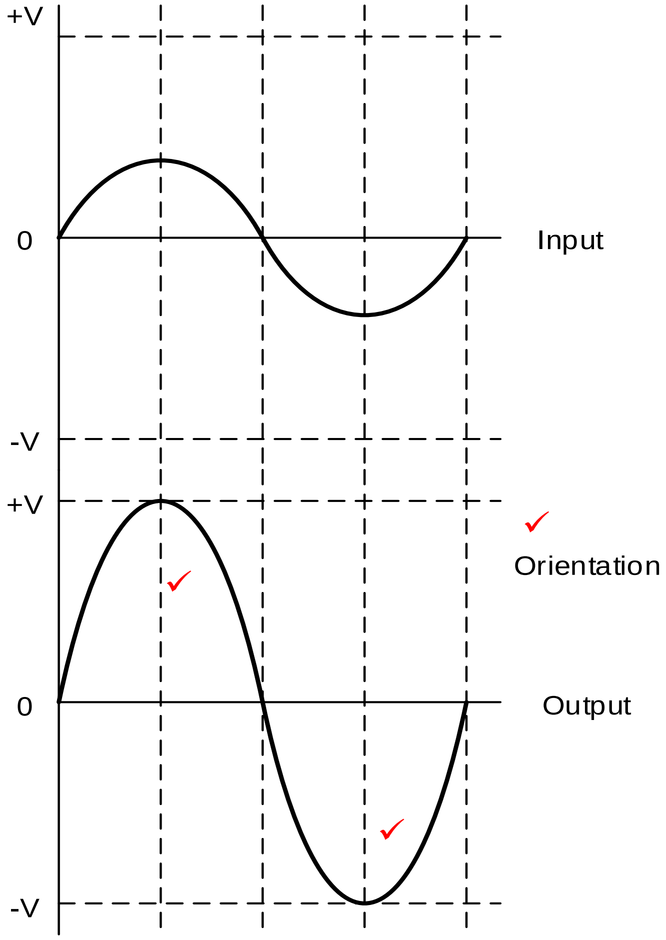
6.6.2 The transformer coupled amplifier is more efficient than RC coupled amplifier because of the primary coil's resistance has much lower value ✓ and causes less dc power loss. ✓
Transformer coupled amplifiers are more efficient than RC coupled amplifiers because the impedance of one stage can be matched to the next stage, resulting in maximum power transfer across the stages. (2)

6.6.3 The number of turns on the secondary and primary coils ✓ can be varied ✓ to correctly match the output impedance of one stage to the input impedance of the next stage. (2)

6.7 6.7.1 Class AB ✓ (1)

6.7.2 Class AB operates more than 180 and less than 360 degrees, ✓ allowing the second transistor to switch on before the first transistor switches off ✓ overcoming crossover distortion.
The circuit overcomes cross-over distortion by making use of biasing resistors R_1 to R_4 to bias the transistors slightly above cut-off.
The class AB biasing does not allow a transistor to operate in the cut-off region, so eliminating cross-over distortion. (2)

6.7.3



(3)

6.8 6.8.1 It stabilises the voltage drop across R_E ✓
It allows the ac current to pass through and blocks the dc current (1)

6.8.2 The LC circuit operates by resonating at the required frequency ✓ and suppressing all other frequencies, ✓ making it extremely selective. ✓ (3)

6.8.3 The amplifier resonates at the required signal frequency ✓ amplifying only the resonant frequency ✓ which is passed on to the mixer stage. ✓ (3)

6.9	6.9.1	C_2 and C_3 allow RF signals to pass from the amplifier to the tank circuit. ✓ C_2 and C_3 together block DC from entering the tank circuit.	(1)
	6.9.2	• Variation in the tuned circuit or transistor parameters.✓ • Change in the load conditions .✓ • Temperature • Fluctuations in the supply voltage	(2)
6.10	6.10.1	The reactance of capacitors C_1 to C_3 ✓ and the value of resistors R_1 to R_3 ✓ determine the phase difference between the current and the applied voltage.	(2)
	6.10.2	The transistor chosen must have a large current gain ✓ to initiate the oscillation start up. ✓	(2)
	6.10.3	The RC phase-shift oscillator is used in lower audio frequency (AF) range up to 10 kHz. ✓	(1) **[45]**

TOTAL: 200