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SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: ELECTRONICS

2023

MARKS: 200

TIME: 3 hours

**This question paper consists of 27 pages, a 1-page formula sheet and
a 5-page answer sheet.**

INSTRUCTIONS AND INFORMATION

1. This question paper consists of SIX questions.
2. Answer ALL the questions.
3. Answer the following questions on the attached ANSWER SHEETS:

QUESTIONS 4.4.3 and 4.5.3
QUESTIONS 5.3.6, 5.4.3 and 5.6.1
QUESTIONS 6.2.2, 6.6.3 and 6.8.3
4. Write your centre number and examination number on every ANSWER SHEET and hand them in with your ANSWER BOOK, whether you have used them or not.
5. Sketches and diagrams must be large, neat and FULLY LABELLED.
6. Show ALL calculations and round off answers correctly to TWO decimal places.
7. Number the answers correctly according to the numbering system used in this question paper.
8. You may use a non-programmable calculator.
9. Calculations must include:
 - 9.1 Formulae and manipulations where needed
 - 9.2 Correct replacement of values
 - 9.3 Correct answer and relevant units where applicable
10. A formula sheet is attached at the end of this question paper.
11. Write neatly and legibly.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (1.1 to 1.15) in the ANSWER BOOK, e.g. 1.16 D.

- 1.1 A critical incident causes ...
- A damage to equipment. External repair services are required.
 - B a person to sustain a sudden and severe physical injury. External medical services are required.
 - C a person to sustain a physical injury. External medical services are not required.
 - D a person to get a mental disturbance. A restful recovery is required. (1)
- 1.2 The ... is the term used for the ratio of the applied voltage to the resulting circuit current where the applied voltage is the resultant of V_R , V_C and V_L in an RLC circuit.
- A reactance
 - B resistance
 - C impedance
 - D phase angle (1)
- 1.3 The current through a capacitor in an RLC parallel circuit will ... when the frequency increases.
- A remain the same
 - B decrease
 - C increase
 - D be zero (1)
- 1.4 The ... of the inductor is the ratio of the inductor's reactance (X_L) to its internal resistance (r_{int}).
- A resonant frequency
 - B Q-factor
 - C power
 - D gain (1)
- 1.5 If the emitter is supplied with sufficient current, the UJT operating point will continue falling until the ... point is reached.
- A zero voltage
 - B saturation
 - C cut-off
 - D valley (1)

- 1.6 ONE of the advantages of a Darlington transistor, when used in common collector mode, is that it has ...
A lower input impedance.
B high voltage distortion.
C higher output impedance.
D lower output impedance. (1)
- 1.7 ONE of the characteristics of an ideal op amp is that the input impedance is ...
A extremely high.
B zero.
C extremely low.
D moderate. (1)
- 1.8 When negative feedback is used in an op-amp circuit, the overall gain is ...
A increased.
B unchanged.
C reduced.
D infinite. (1)
- 1.9 The operation of a Schmitt trigger can best be described by ...
A hysteresis.
B negative feedback.
C open-loop gain.
D attenuation. (1)
- 1.10 The ... is the only op-amp application that uses an 'open loop' connection to bring its full gain of $\pm 100\,000$ into use.
A summing amplifier
B integrator
C comparator
D differentiator (1)
- 1.11 The ... determines the shape of the output in an op-amp integrator circuit.
A input capacitor
B feedback resistor
C input voltage
D RC time constant (1)

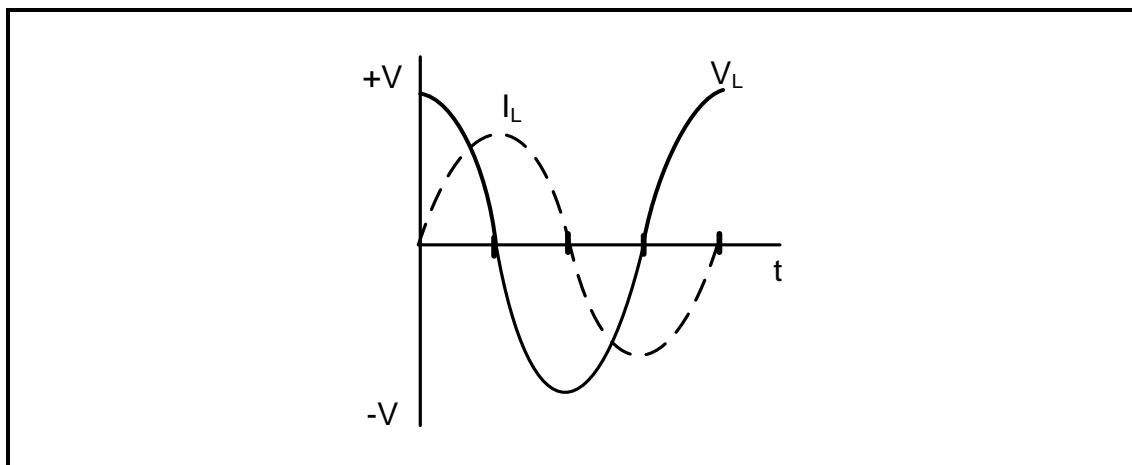
- 1.12 When a square wave is fed to the input of a passive RC differentiator with a short time constant, the output will be a ...
- A sine wave with 90° phase shift.
 - B spike with a fast rise and slow decay.
 - C square wave with 180° phase shift.
 - D a triangular wave.
- (1)
- 1.13 Tuning circuits in RF amplifiers are primarily ...
- A class A amplifiers.
 - B class B amplifiers.
 - C class AB amplifiers.
 - D class C amplifiers.
- (1)
- 1.14 In an amplifier, the gain that occurs between the lower and upper frequency range is called the ...
- A critical gain.
 - B input gain.
 - C midrange gain.
 - D decibel gain.
- (1)
- 1.15 An oscillator differs from an amplifier because the oscillator ...
- A has no gain.
 - B requires no input signal.
 - C requires an input signal.
 - D always has a half-wave output.
- (1)
[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

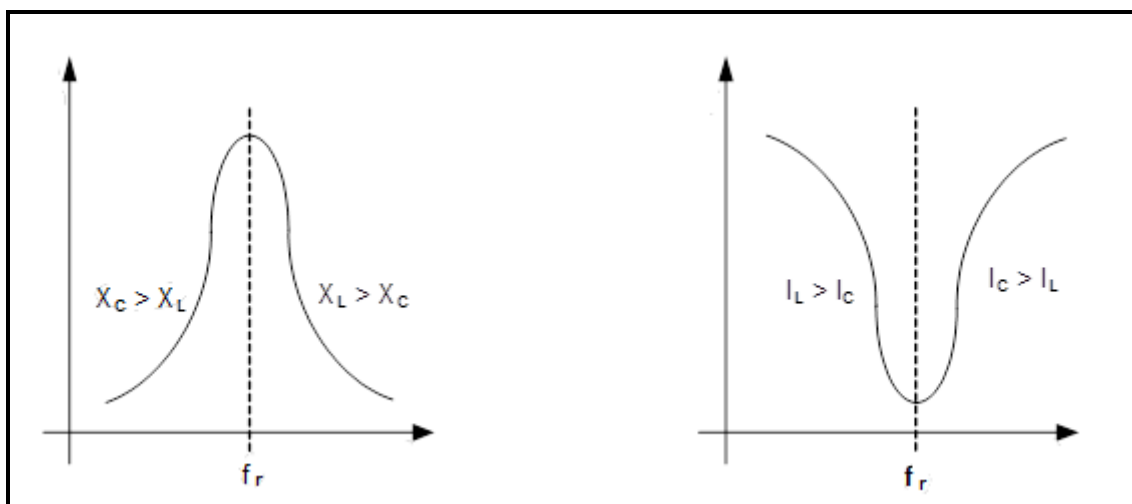
- 2.1 State the purpose of the Occupational Health and Safety Act, 1993 (Act 85 of 1993). (3)
- 2.2 Explain how an *unsafe act* can reduce the rate of production at the work place. (2)
- 2.3 Explain the term *high impact; low probability* with reference to risk analysis. (2)
- 2.4 State TWO recommended procedures to stop bleeding in an emergency. (2)
- 2.5 State ONE procedure to follow for personal protection when administering the procedures mentioned in QUESTION 2.4. (1)
[10]

QUESTION 3: RLC CIRCUITS

- 3.1 Describe what is meant by the term *in phase* with reference to the relationship between the applied voltage and current in an RLC circuit connected to an AC supply. (3)
- 3.2 Refer to the AC waveforms in FIGURE 3.2 below and draw the phasor diagram that represents them.

**FIGURE 3.2: CURRENT AND VOLTAGE WAVEFORMS**

- 3.3 Name TWO applications of resonance as applicable to tuned circuits. (2)
- 3.4 Identify the graphs below.

**FIGURE 3.4(a)****FIGURE 3.4(b)**

- 3.4.1 FIGURE 3.4(a) (1)
- 3.4.2 FIGURE 3.4(b) (1)

3.5 Refer to FIGURE 3.5 below and answer the questions that follow.

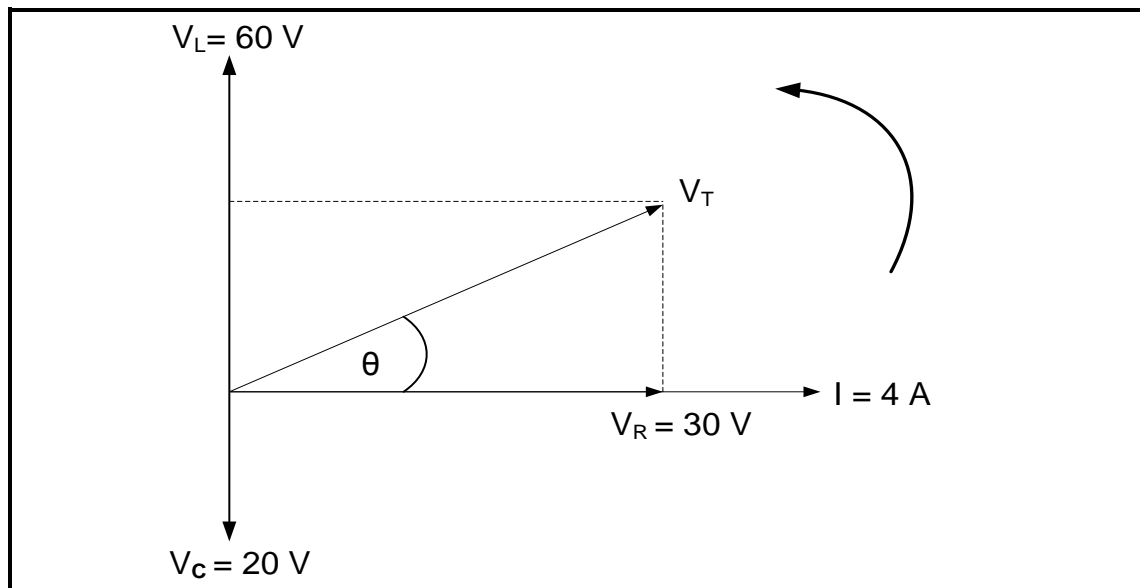


FIGURE 3.5: PHASOR DIAGRAM

Given:

$$\begin{aligned}V_L &= 60 \text{ V} \\V_C &= 20 \text{ V} \\V_R &= 30 \text{ V} \\I &= 4 \text{ A} \\f &= 60 \text{ Hz}\end{aligned}$$

3.5.1 Calculate the value of the supply voltage. (3)

3.5.2 Calculate the phase angle. (3)

3.5.3 State whether the phase angle is leading or lagging. (1)

3.6 Refer to FIGURE 3.6 below and answer the questions that follow.

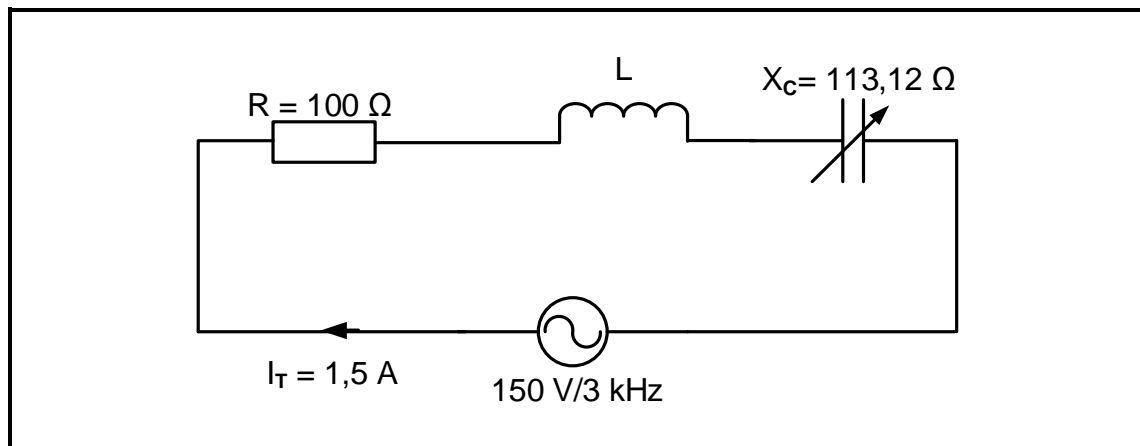


FIGURE 3.6: RLC SERIES CIRCUIT

Given:

$$\begin{aligned} R &= 100 \Omega \\ X_C &= 113,12 \Omega \\ V_T &= 150 \text{ V} \\ I_T &= 1,5 \text{ A} \\ f &= 3 \text{ kHz} \end{aligned}$$

- 3.6.1 Calculate the value of the inductance for the circuit to resonate at 3 kHz. (3)
- 3.6.2 Calculate the Q-factor of the circuit at resonance. (3)
- 3.6.3 Calculate the bandwidth of the circuit. (3)
- 3.6.4 Explain how the value of the total current would be influenced if R is halved when the circuit is at resonance. (1)

3.7 Refer to FIGURE 3.7 below and answer the questions that follow.

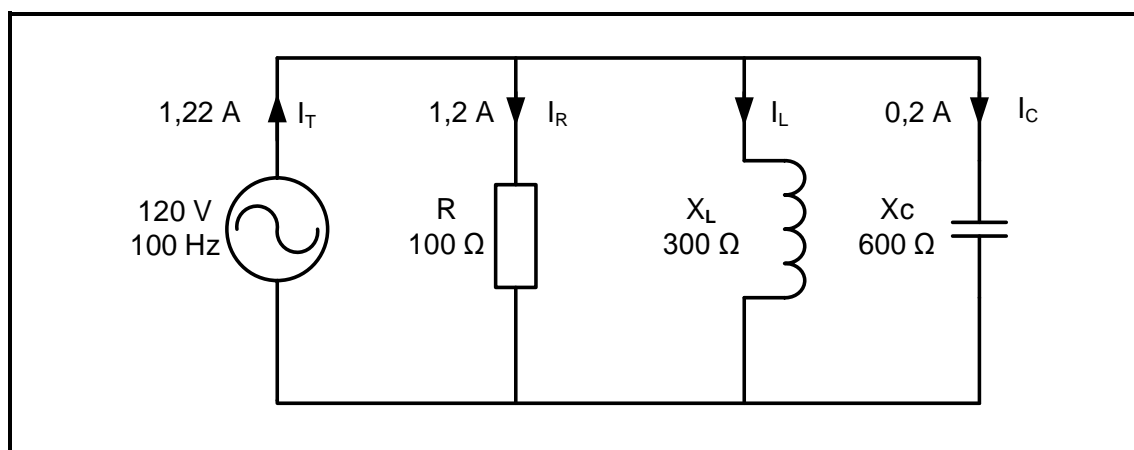


FIGURE 3.7: RLC PARALLEL CIRCUIT DIAGRAM

Given:

$$\begin{aligned}V_T &= 120 \text{ V} \\I_R &= 1,2 \text{ A} \\I_C &= 0,2 \text{ A} \\I_T &= 1,22 \text{ A} \\f &= 100 \text{ Hz} \\R &= 100 \, \Omega \\X_C &= 600 \, \Omega \\X_L &= 300 \, \Omega\end{aligned}$$

3.7.1 Calculate the current through the inductor. (3)

3.7.2 Calculate the value of the active power. (3)

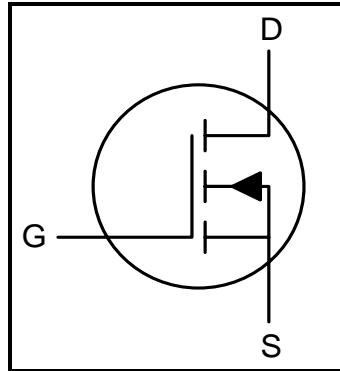
3.7.3 State, with a reason, if the circuit is capacitive or inductive. (2)

[35]

QUESTION 4: SEMICONDUCTOR DEVICES

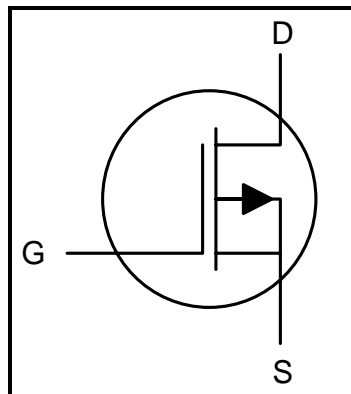
4.1 Identify the semiconductor device symbols in QUESTIONS 4.1.1 and 4.1.2 below.

4.1.1



(2)

4.1.2



(2)

4.2 Describe the construction of the MOSFET in FIGURE 4.2 below.

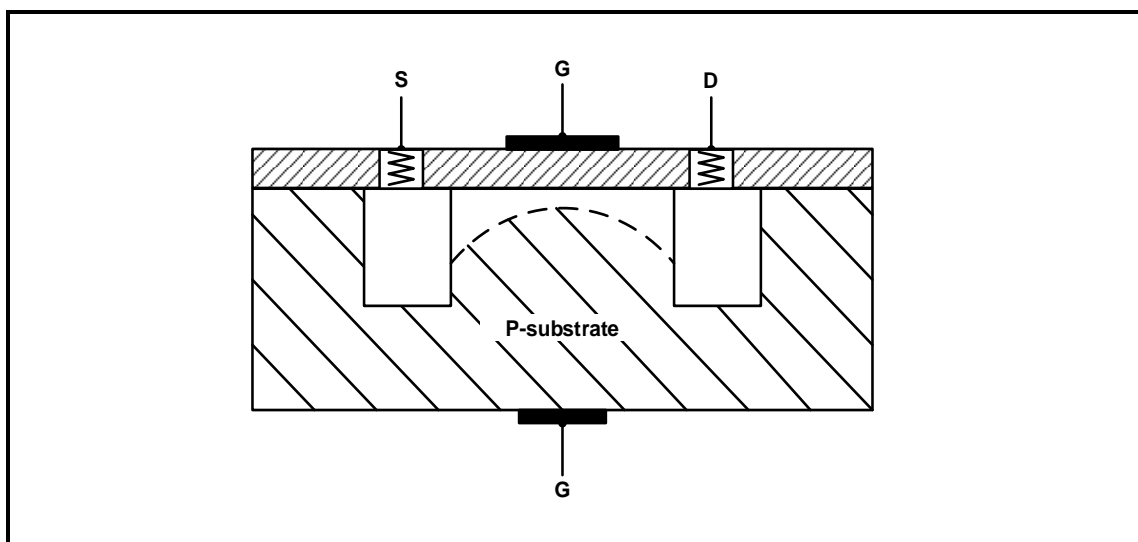


FIGURE 4.2: CROSS-SECTION OF A MOSFET CONSTRUCTION

(4)

4.3 Refer to FIGURE 4.3 below and answer the questions that follow.

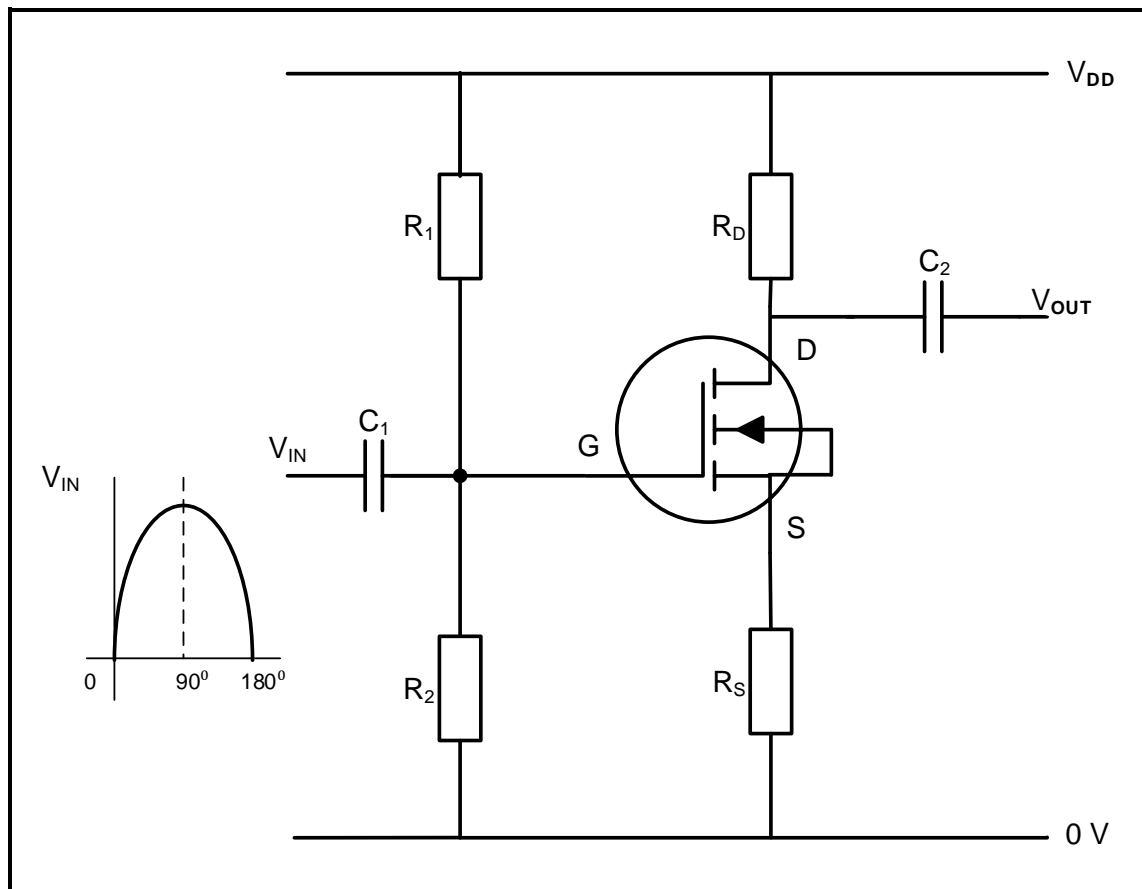


FIGURE 4.3: MOSFET AMPLIFIER

- 4.3.1 State the purpose of R_1 and R_2 . (1)
- 4.3.2 Describe how the MOSFET can be operated as a linear amplifier. (3)
- 4.3.3 Describe the operation of the circuit during the first 90° of the input signal. (3)

4.4 Refer to FIGURE 4.4 below and answer the questions that follow.

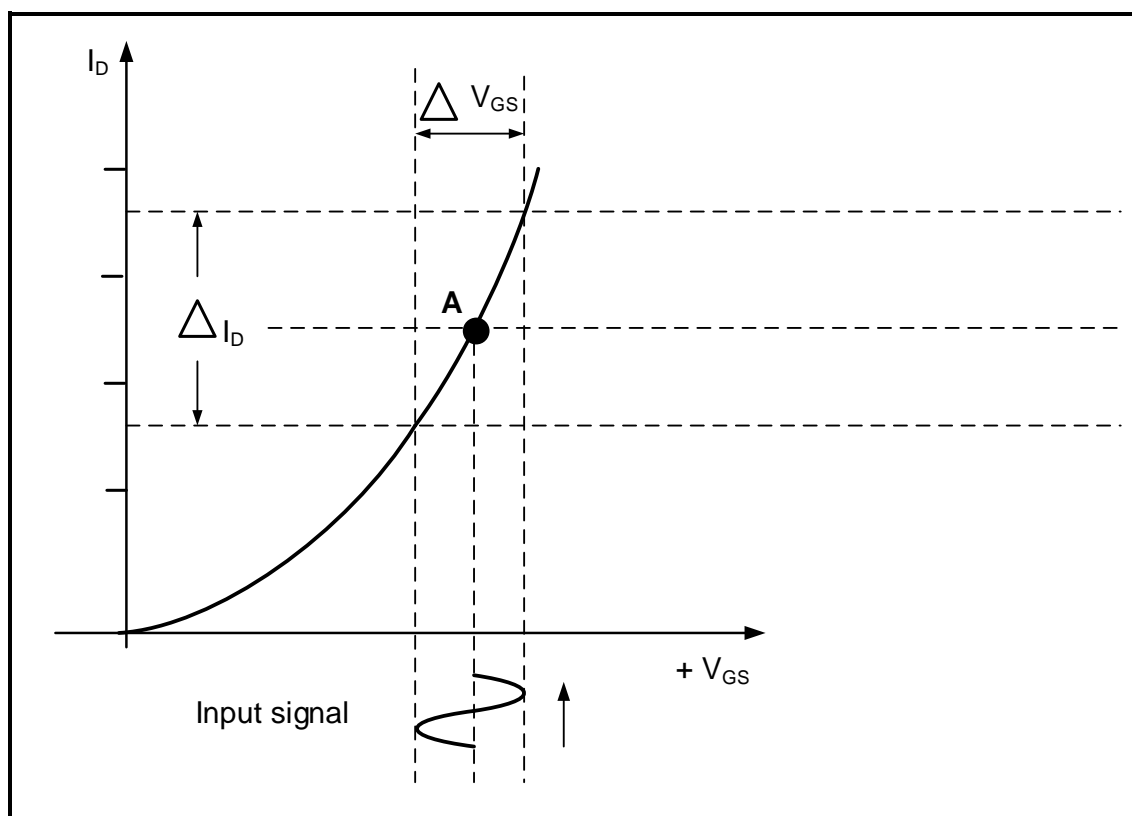


FIGURE 4.4: TRANSFER CHARACTERISTIC CURVE

- 4.4.1 Identify the type of transistor used to produce the characteristic curve in FIGURE 4.4. (1)
- 4.4.2 Name point **A** on the characteristic curve. (1)
- 4.4.3 Draw the output waveform on the ANSWER SHEET for QUESTION 4.4.3. (2)

- 4.5 FIGURE 4.5 below shows a UJT as a saw-tooth generator. Answer the questions that follow.

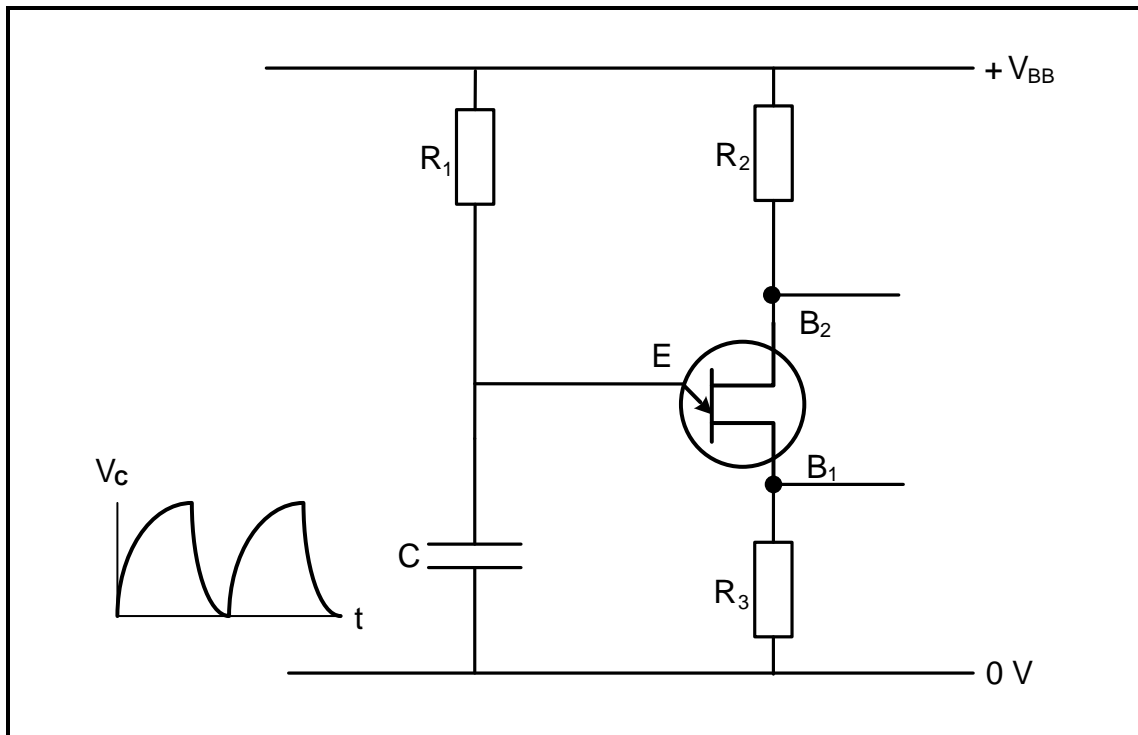


FIGURE 4.5: THE UJT AS A SAW-TOOTH GENERATOR

- 4.5.1 State the mode of switching of the UJT in FIGURE 4.5. (1)
- 4.5.2 Explain the purpose of R_3 . (2)
- 4.5.3 Draw the output waveform that would develop across B_1 on the ANSWER SHEET for QUESTION 4.5.3. (3)

- 4.6 FIGURE 4.6 below shows two identical signals on the input terminals of an op amp. Draw the output waveform of the op amp in the ANSWER BOOK.

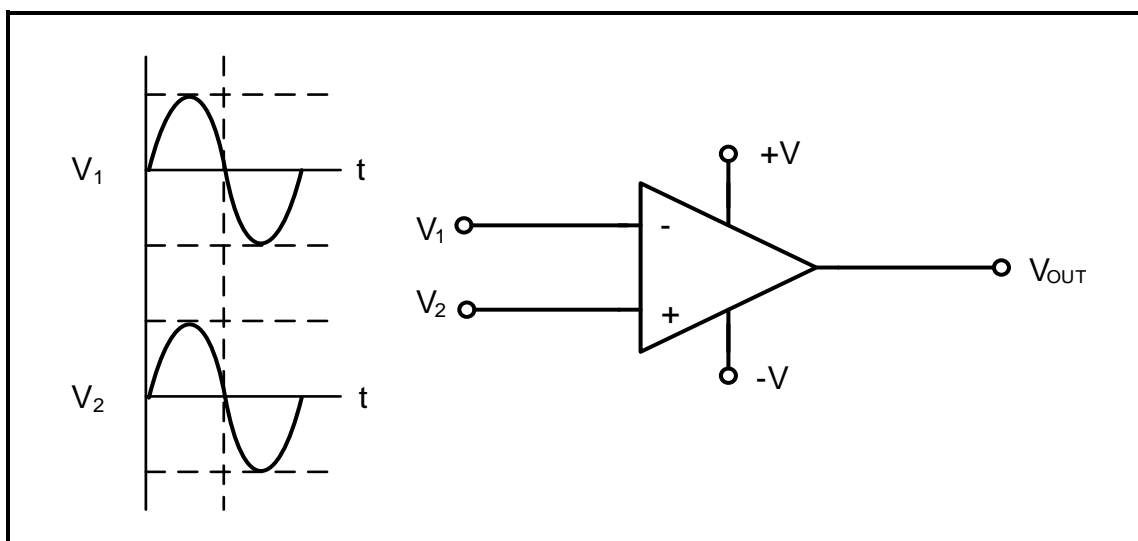


FIGURE 4.6: 741 OP AMP

(2)

4.7 Refer to FIGURE 4.7 below and answer the questions that follow.

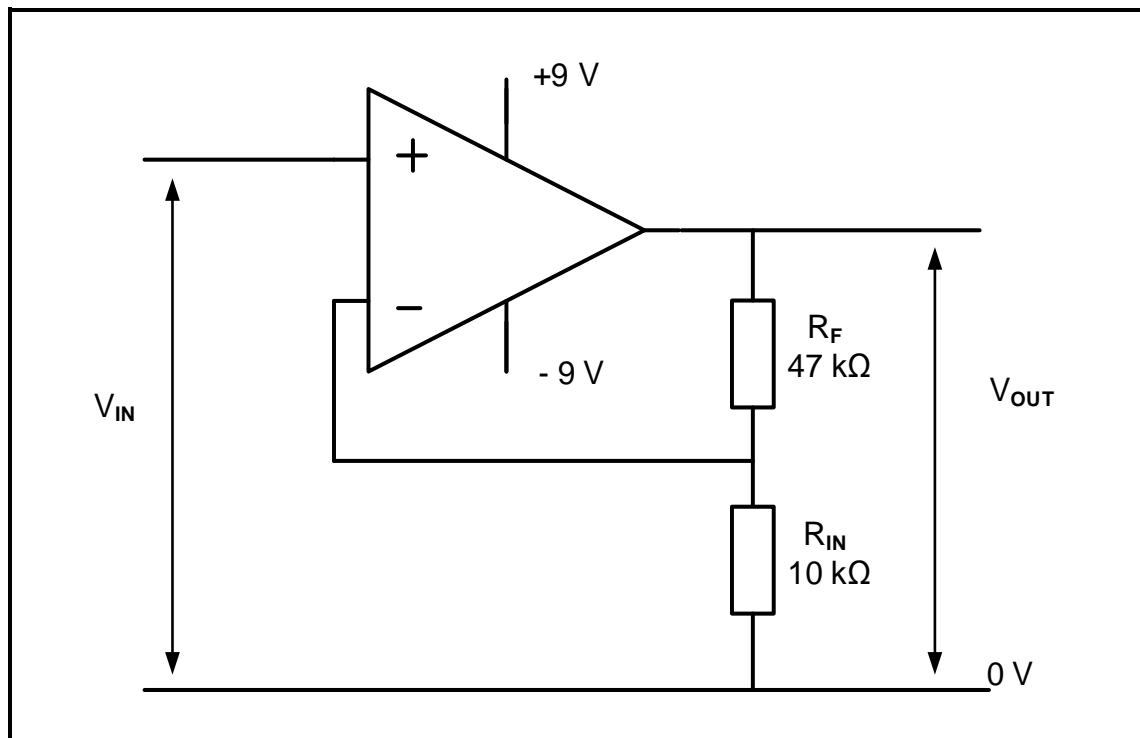


FIGURE 4.7: OPERATIONAL AMPLIFIER CIRCUIT

- | | | |
|-------|--|-----|
| 4.7.1 | Identify the op-amp circuit in FIGURE 4.7. | (1) |
| 4.7.2 | Describe what is meant by <i>infinite bandwidth</i> of an op amp. | (2) |
| 4.7.3 | Calculate the voltage gain. | (3) |
| 4.7.4 | Calculate the output voltage if a 100 mV signal is applied to the input. | (3) |

4.8 Refer to FIGURE 4.8 below and answer the questions that follow.

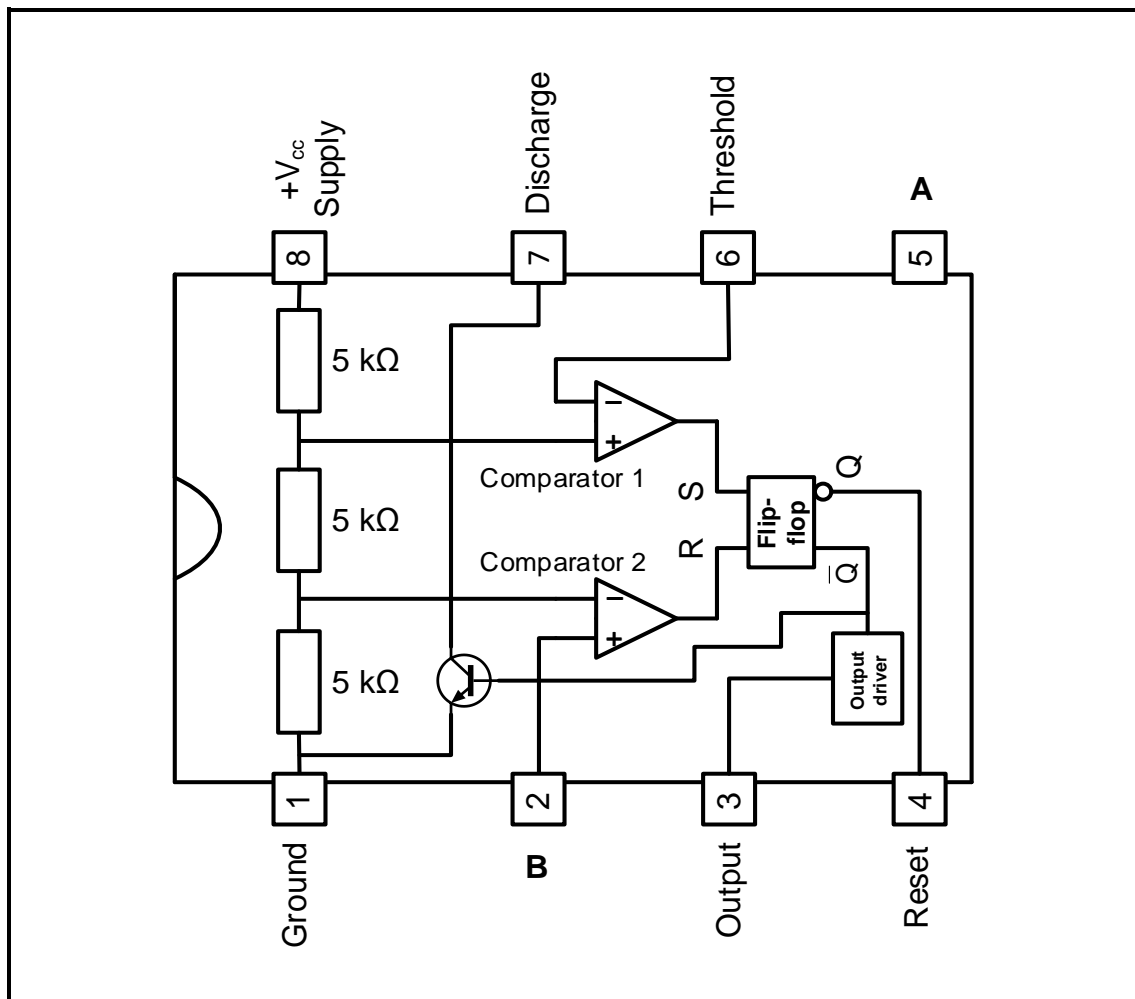
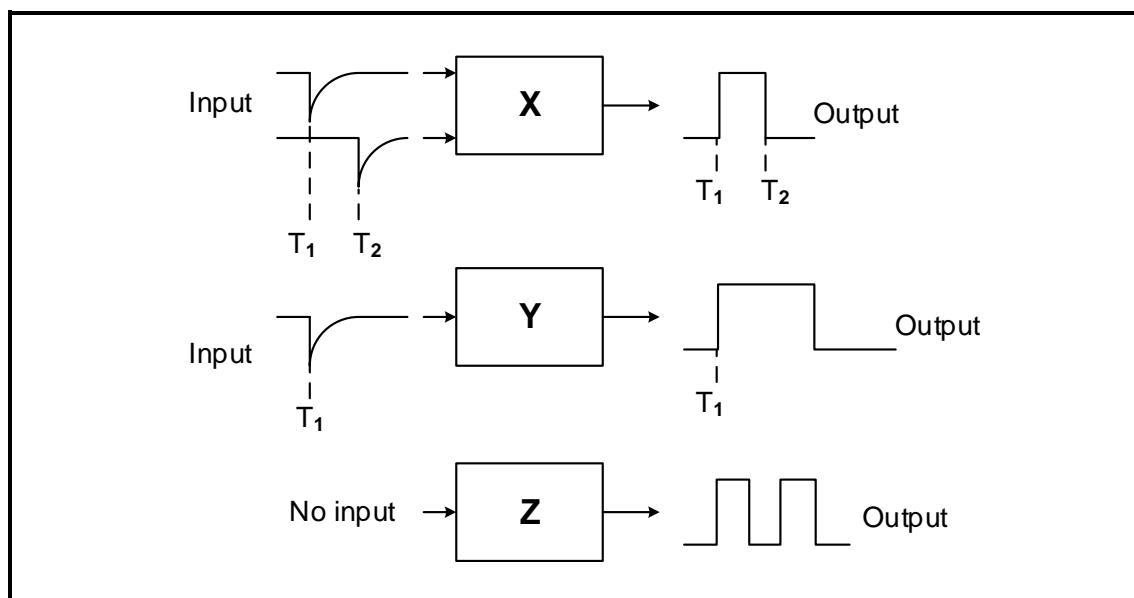


FIGURE 4.8: 555 IC TIMER

- 4.8.1 Label pins **A** and **B**. (2)
- 4.8.2 Explain the function of the discharge input on pin 7. (2)
- 4.8.3 Explain the function of comparator 1. (3)
- 4.8.4 State TWO uses of the 555 IC. (2)
- [45]**

QUESTION 5: SWITCHING CIRCUITS

- 5.1 FIGURE 5.1 below shows block diagrams with different input and output states for three types of multivibrators. Identify the multivibrator in each of the following blocks.

**FIGURE 5.1: BLOCK DIAGRAMS OF MULTIVIBRATORS**

- | | | |
|-------|---------|-----|
| 5.1.1 | Block X | (1) |
| 5.1.2 | Block Y | (1) |
| 5.1.3 | Block Z | (1) |

- 5.2 FIGURE 5.2 below shows the circuit of a multivibrator. Answer the questions that follow.

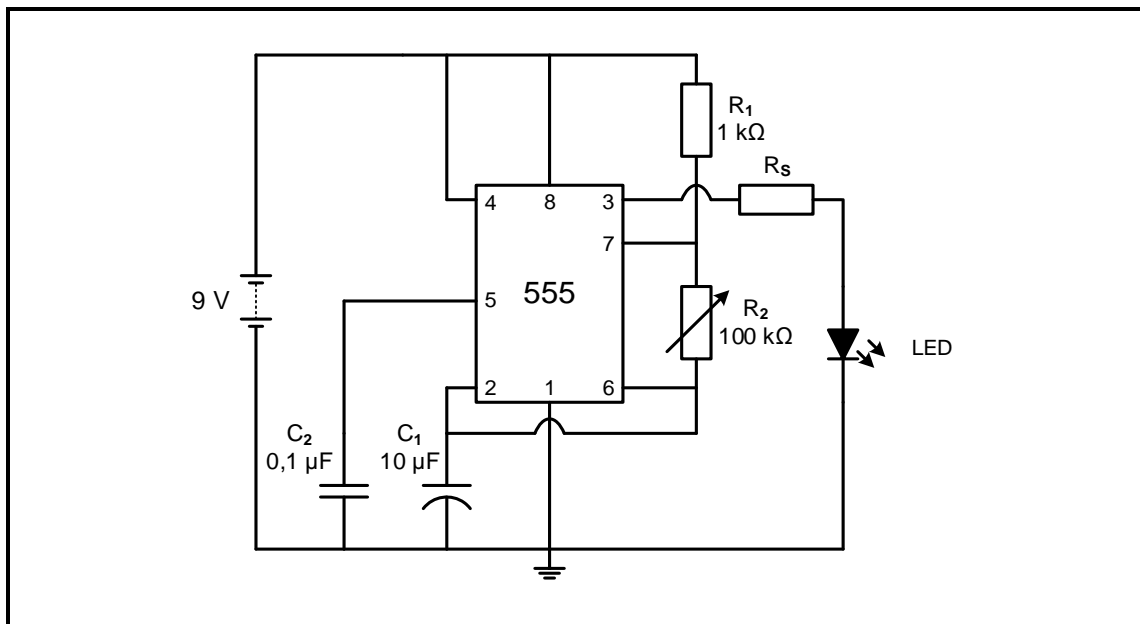


FIGURE 5.2: MULTIVIBRATOR CIRCUIT

- 5.2.1 State the purpose of variable resistor R_2 . (2)
- 5.2.2 Explain how the LED will be affected if it is directly connected to pin 3 without resistor R_S . (3)
- 5.2.3 Explain how this circuit operates. (4)
- 5.2.4 State the discharge path of capacitor C_1 . (1)
- 5.3 FIGURE 5.3 below shows a monostable multivibrator circuit using a 741 op amp. The capacitor is fully charged through resistor R_3 . Answer the questions that follow.

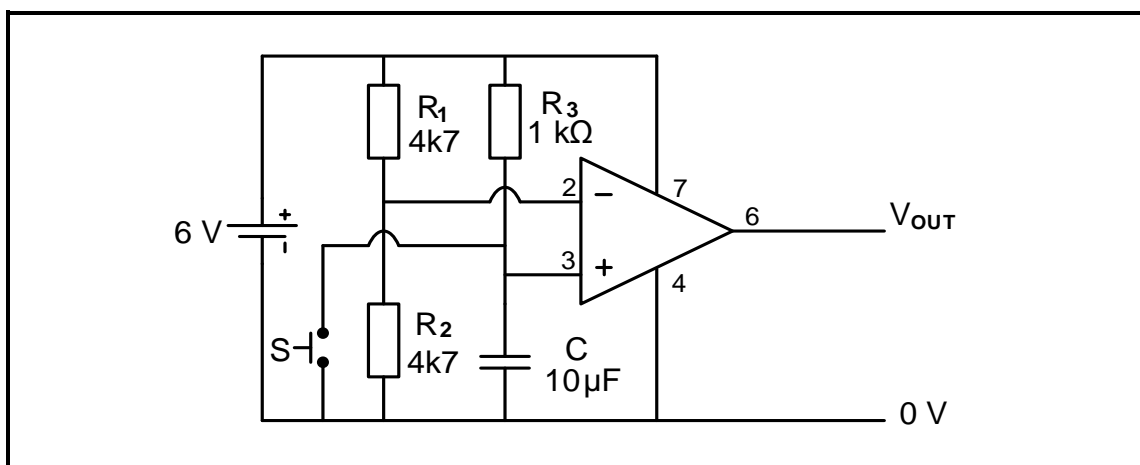
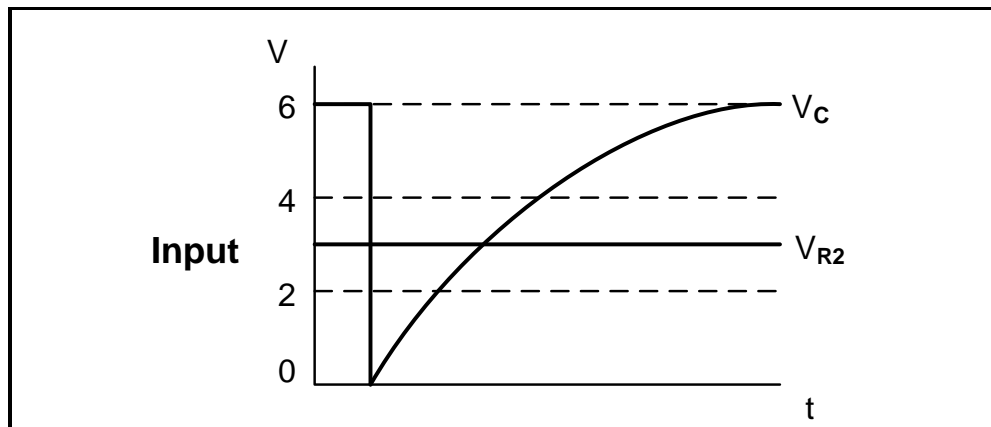


FIGURE 5.3: MONOSTABLE MULTIVIBRATOR CIRCUIT

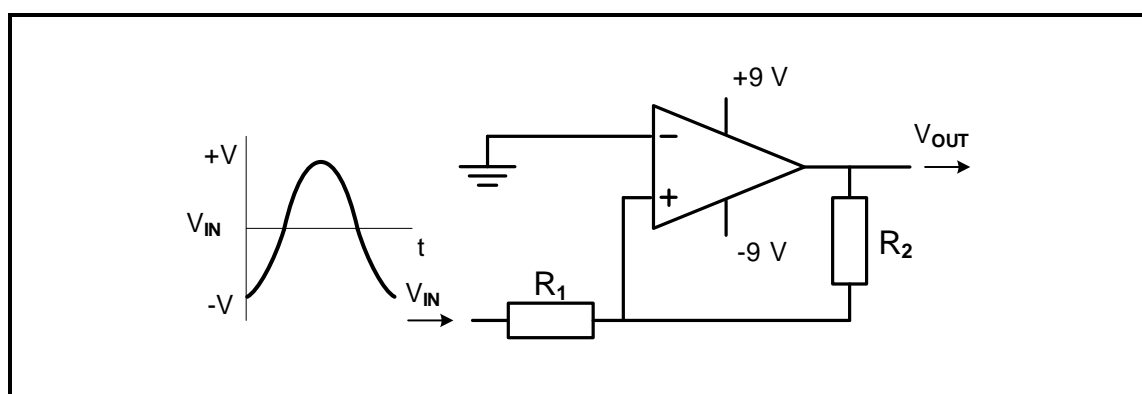
- 5.3.1 Determine the voltage at pin 2 (inverting input) of the op amp. (2)

- 5.3.2 Determine the voltage at pin 3 (non-inverting input) when the switch is open. (1)
- 5.3.3 State whether the output is high (6 V) or low (0 V) when the switch is open. Motivate your answer. (2)
- 5.3.4 Determine the voltage at pin 3 (non-inverting input) when the switch is pressed. Motivate your answer. (2)
- 5.3.5 Describe the operation of the circuit with reference to the voltages on the two input terminals and the output of the op amp when the switch is pressed. (5)
- 5.3.6 Refer to FIGURE 5.3.6 below and draw the output waveform on the ANSWER SHEET for QUESTION 5.3.6.

**FIGURE 5.3.6**

(3)

- 5.4 FIGURE 5.4 below shows a non-inverting Schmitt trigger. Answer the questions that follow.

**FIGURE 5.4: NON-INVERTING SCHMITT TRIGGER**

- 5.4.1 Determine the voltage at which the circuit will trigger. Motivate your answer. (2)
- 5.4.2 Name TWO uses of a Schmitt trigger. (2)
- 5.4.3 Draw the output signal on the ANSWER SHEET for QUESTION 5.4.3. (4)

- 5.5 The information in TABLE 5.5 below was gathered from an inverting summing amplifier with three inputs. The input resistors are all equal and the feedback resistance was adjusted by using a variable resistor. Use the data in the table to answer the questions that follow.

INPUT 1 (V)	INPUT 2 (V)	INPUT 3 (V)	R_{IN} (k Ω)	R_F (k Ω)	V_{OUT} (V)	GAIN
3	1	2	10	X	-6	-1
0,3	0,4	0,3	10	100	-10	Y
1	0,5	0,5	10	20	Z	-2

TABLE 5.5

- 5.5.1 Determine the value of the feedback resistance (R_F) at X. (1)
- 5.5.2 Calculate the gain at Y. (3)
- 5.5.3 Calculate the output voltage (V_{OUT}) at Z. (3)
- 5.5.4 Deduce from TABLE 5.5 the relationship between R_F and the gain. (1)
- 5.6 Refer to FIGURE 5.6 below and answer the questions that follow.

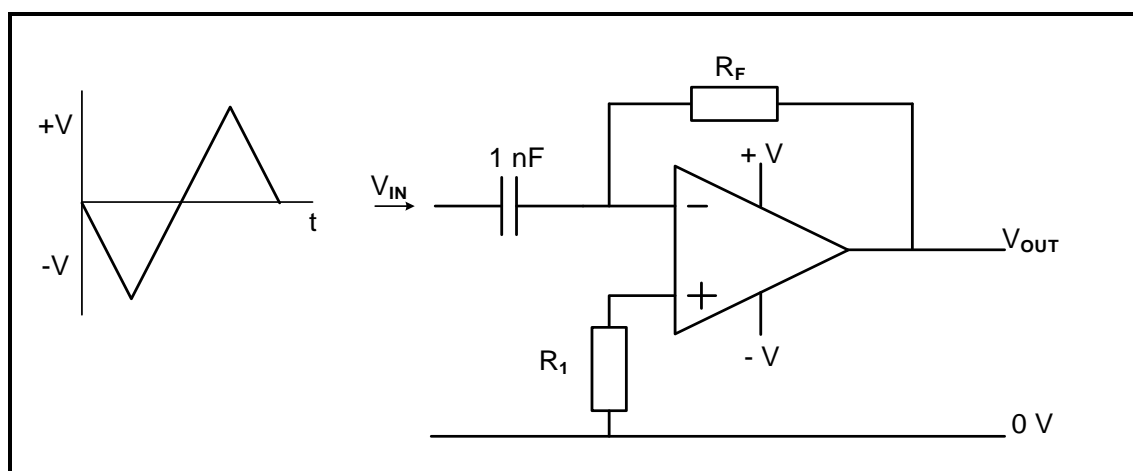


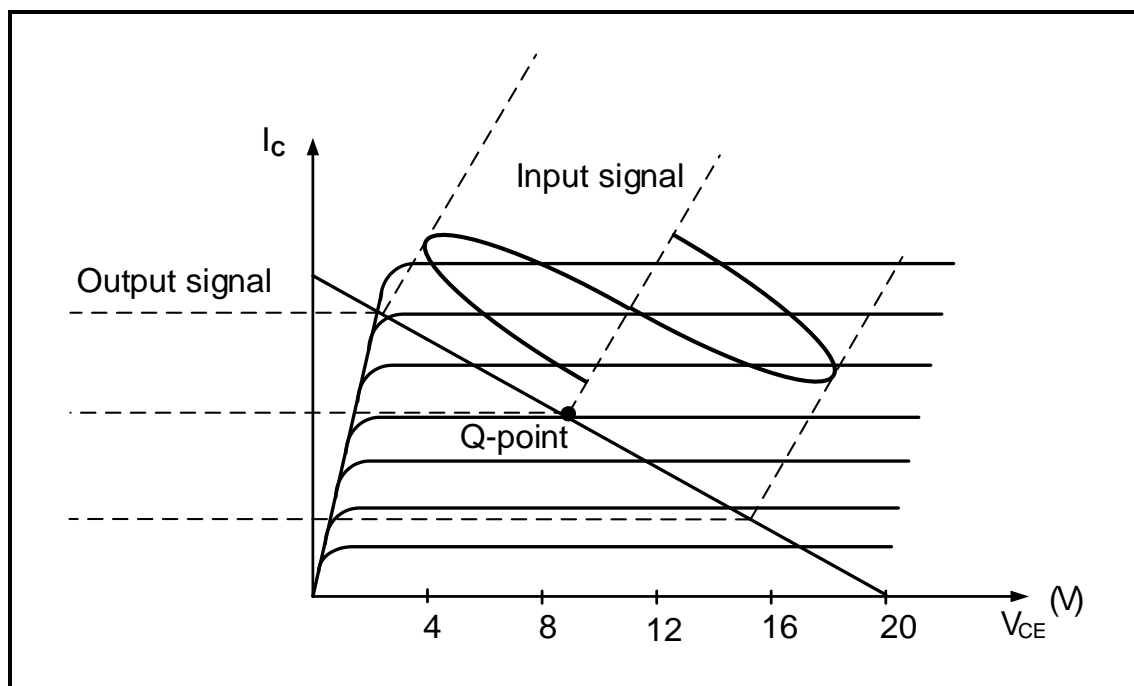
FIGURE 5.6: OP-AMP DIFFERENTIATOR

- 5.6.1 Draw the output on the ANSWER SHEET for QUESTION 5.6.1. (4)
- 5.6.2 Explain what determines the polarity of the output voltage. (2)

[50]

QUESTION 6: AMPLIFIERS

- 6.1 Define the term *stability* with reference to the Q-point of amplifiers. (2)
- 6.2 Refer to FIGURE 6.2 below and answer the questions that follow.

**FIGURE 6.2: CLASSES OF AMPLIFICATION**

- 6.2.1 Identify the class of amplification represented in FIGURE 6.2. (1)
- 6.2.2 Draw the output waveform on the ANSWER SHEET for QUESTION 6.2.2. (2)

6.3 Refer to FIGURE 6.3 below and answer the questions that follow.

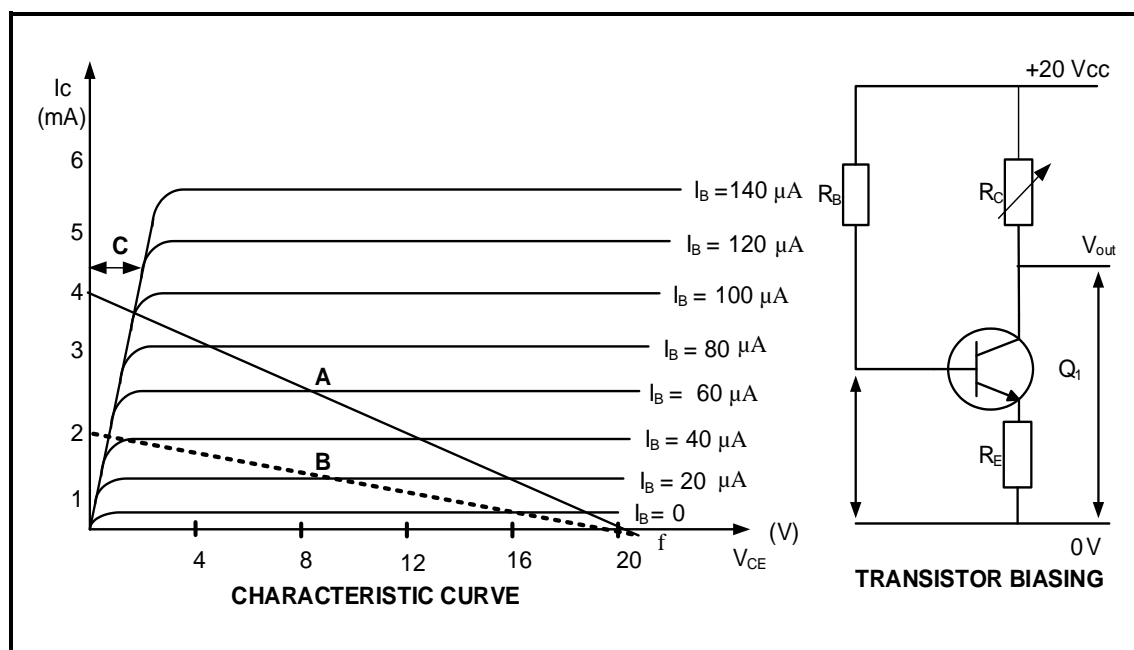


FIGURE 6.3: CHARACTERISTIC CURVE AND TRANSISTOR BIASING

- 6.3.1 Identify region **C** in the characteristic curve. (1)
- 6.3.2 Interpret the data given in FIGURE 6.3 above and calculate the value of the load resistor. (3)
- 6.3.3 Explain why the gradient of the load line decreased from **A** to **B** while the supply voltage remained the same. (2)

6.4 Refer to FIGURE 6.4 below and answer the questions that follow.

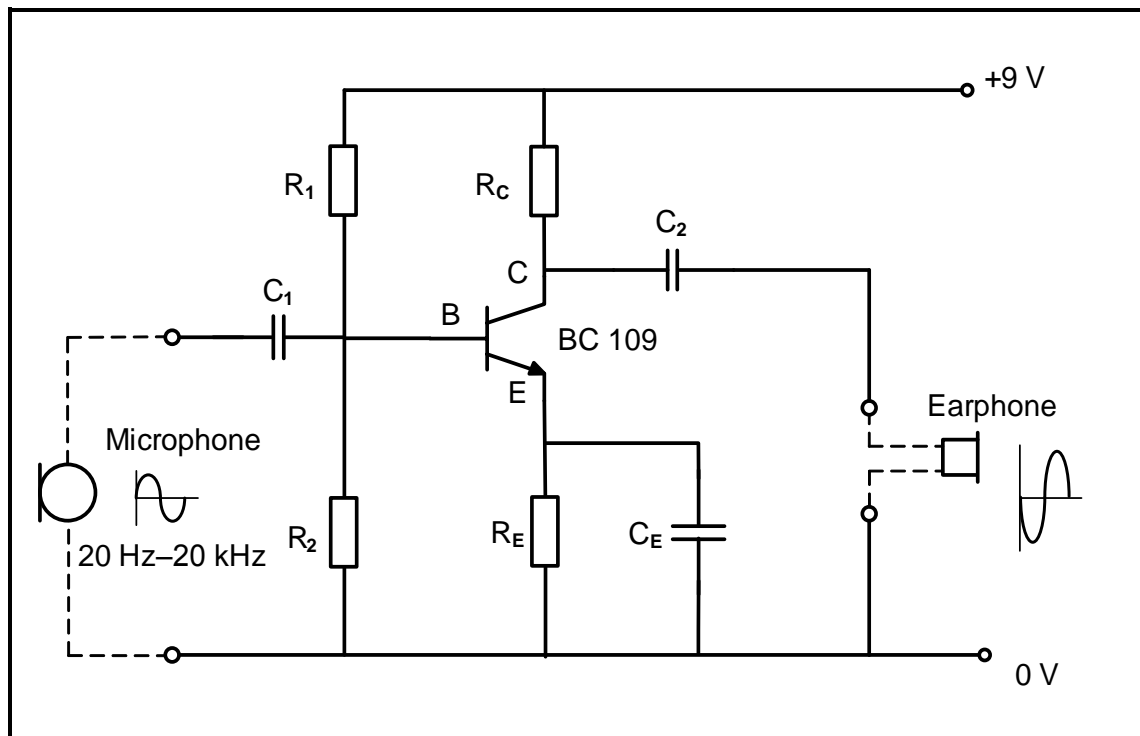


FIGURE 6.4: RC-COUPLED AMPLIFIER

- 6.4.1 Determine the value of the voltage drop across R_C . (1)
- 6.4.2 Explain why the circuit in FIGURE 6.4 must be an audio amplifier. (3)
- 6.4.3 Explain the function of the capacitor C_E in parallel with resistor R_E . (2)

6.5 Refer to FIGURE 6.5 below and answer the questions that follow.

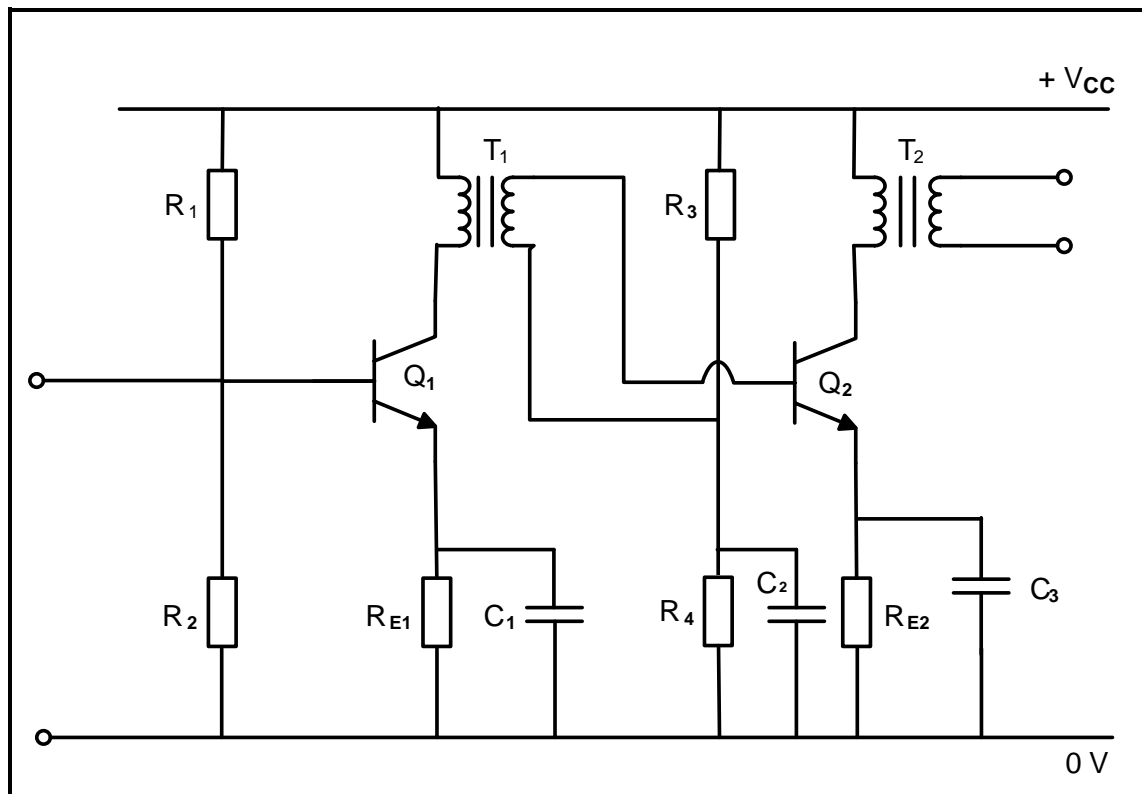


FIGURE 6.5: TWO-STAGE TRANSFORMER-COUPLED AMPLIFIER

- 6.5.1 State TWO functions of capacitors C_1 and C_3 . (2)
- 6.5.2 State ONE advantage of the transformer-coupled amplifier. (1)
- 6.5.3 Describe the uses of T_1 . (3)

6.6 Refer to FIGURE 6.6 below and answer the questions that follow.

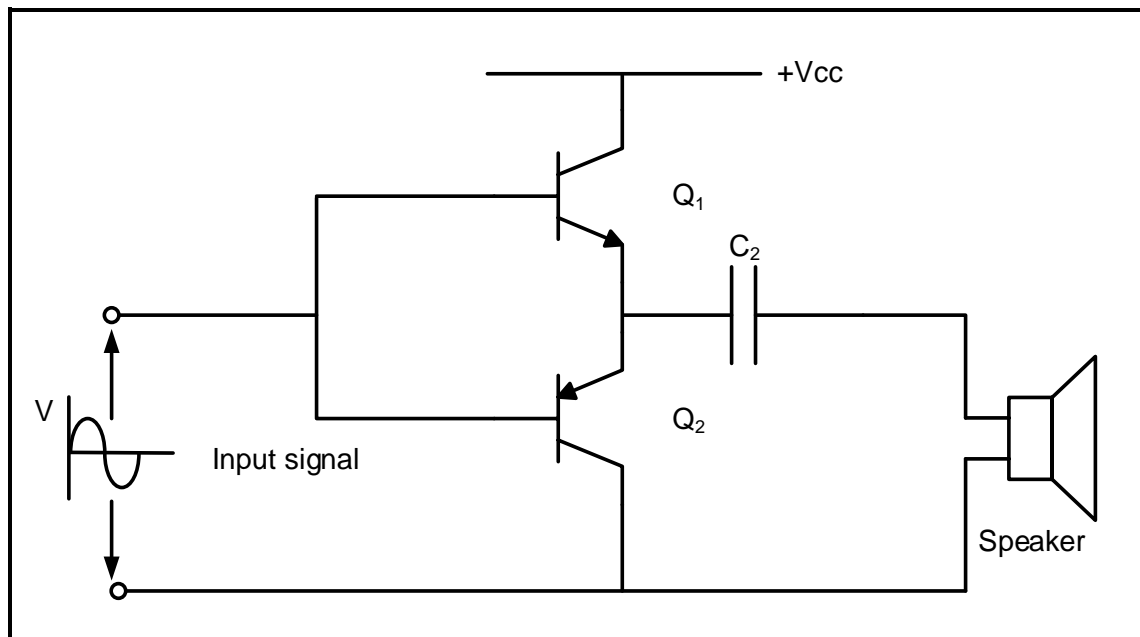


FIGURE 6.6: PUSH-PULL AMPLIFIER CIRCUIT DIAGRAM

- 6.6.1 State the disadvantage of the amplifier in FIGURE 6.6. (1)
- 6.6.2 Describe the function of C_2 . (2)
- 6.6.3 Draw the output waveform across transistor Q_2 on the ANSWER SHEET for QUESTION 6.6.3. (2)

6.7 Refer to FIGURE 6.7 below and answer the questions that follow.

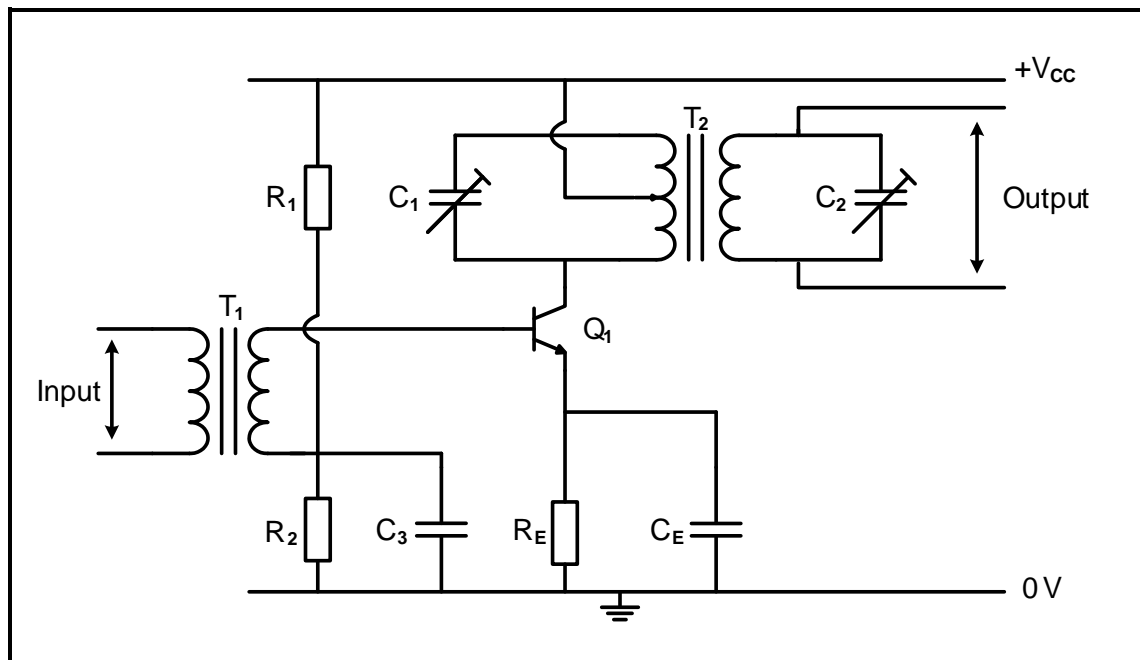


FIGURE 6.7: RADIO-FREQUENCY AMPLIFIER

- 6.7.1 State the use of the radio frequency amplifier. (2)
- 6.7.2 With reference to radio frequency amplifiers, state the term used for unwanted frequencies. (1)
- 6.7.3 Give the reason for using two LC-tuned circuits instead of one LC-tuned circuit. (1)
- 6.7.4 Explain why pre-set capacitors are used in the LC-tuned circuits instead of ordinary capacitors. (1)

6.8 Refer to FIGURE 6.8 below and answer the questions that follow.

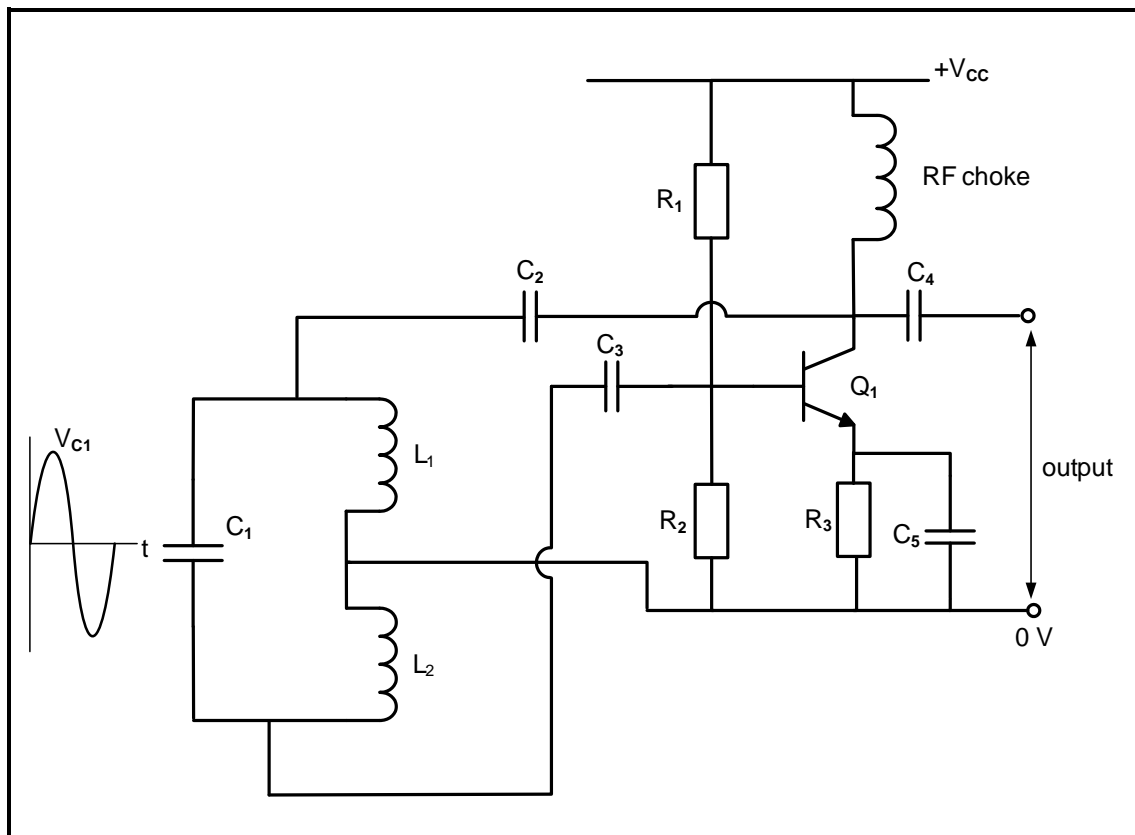


FIGURE 6.8: HARTLEY OSCILLATOR

- 6.8.1 State ONE application of the Hartley oscillator. (1)
- 6.8.2 State the purpose of transistor Q_1 . (2)
- 6.8.3 Draw the output waveform of the circuit on the ANSWER SHEET for QUESTION 6.8.3 when an AC signal is developed across the capacitor (C_1) of the tank circuit. (2)

6.9 Refer to FIGURE 6.9 below and answer the questions that follow.

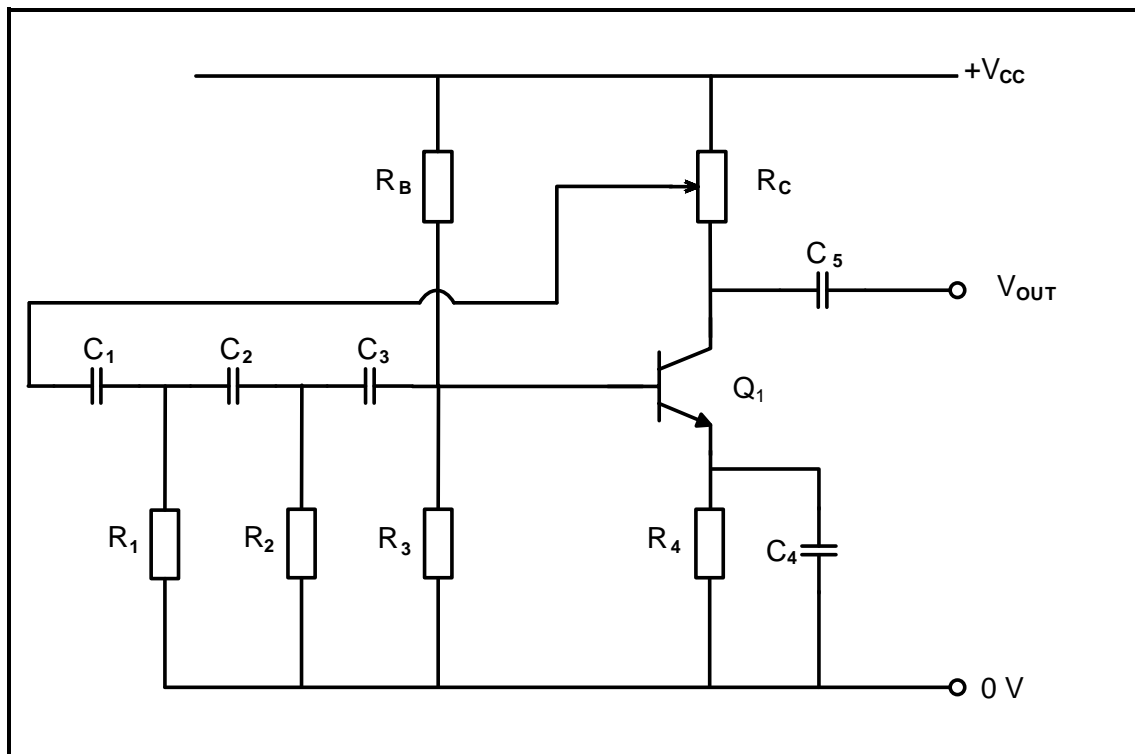


FIGURE 6.9: RC PHASE-SHIFT OSCILLATOR

- 6.9.1 State the function of R_C . (2)
- 6.9.2 Calculate the value of the capacitor when the oscillation frequency of the RC phase-shift oscillator is 64,98 Hz with a resistor value of 10 k Ω . (3)
- 6.9.3 Will the oscillation frequency of the circuit decrease or increase when the values of the capacitors in the phase-shift network decrease? Motivate your answer. (2)

[45]

TOTAL: 200

FORMULA SHEET	
RLC CIRCUITS	SEMICONDUCTOR DEVICES
$P = V I \cos \theta$ $X_L = 2\pi fL$ $X_C = \frac{1}{2\pi fC}$ $f_r = \frac{1}{2\pi\sqrt{LC}}$ OR $f_r = \frac{f_2 + f_1}{2}$ $BW = \frac{f_r}{Q}$ OR $BW = f_2 - f_1$ Series $V_R = IR$ $V_L = I X_L$ $V_C = I X_C$ $I_T = \frac{V_T}{Z}$ OR $I_T = I_R = I_C = I_L$ $Z = \sqrt{R^2 + (X_L - X_C)^2}$ $V_T = \sqrt{V_R^2 + (V_L - V_C)^2}$ OR $V_T = IZ$ $\cos \theta = \frac{R}{Z}$ OR $\cos \theta = \frac{V_R}{V_T}$ OR $\tan \theta = \frac{V_L - V_C}{V_R}$ $Q = \frac{X_L}{R} = \frac{X_C}{R} = \frac{V_L}{V_T} = \frac{V_C}{V_T} = \frac{1}{R} \sqrt{\frac{L}{C}}$ Parallel $V_T = V_R = V_L = V_C$ $I_R = \frac{V_T}{R}$ $I_C = \frac{V_T}{X_C}$ $I_L = \frac{V_T}{X_L}$ $I_T = \sqrt{I_R^2 + (I_L - I_C)^2}$ $Z = \frac{V_T}{I_T}$ $\cos \theta = \frac{I_R}{I_T}$ $Q = \frac{R}{X_L} = \frac{R}{X_C}$	$\text{Gain } A_V = \frac{V_{OUT}}{V_{IN}} = -\frac{R_F}{R_{IN}} \quad A_V = 1 + \frac{R_F}{R_{IN}}$ $V_{OUT} = V_{IN} \left(-\frac{R_F}{R_{IN}} \right)$ $V_{OUT} = V_{IN} \left(1 + \frac{R_F}{R_{IN}} \right)$ SWITCHING CIRCUITS $V_{OUT} = - \left(V_1 \frac{R_F}{R_1} + V_2 \frac{R_F}{R_2} + \dots V_N \frac{R_F}{R_N} \right)$ $\text{Gain } A_V = \frac{V_{OUT}}{V_{IN}} = \frac{V_{OUT}}{(V_1 + V_2 + \dots V_N)}$ $V_{OUT} = - (V_1 + V_2 + \dots V_N)$ AMPLIFIERS $I_C = \frac{V_C}{R_C} \quad V_{CC} = V_{CE} + I_C R_C$ $V_B = V_{BE} + V_{RE}$ $A_V = \frac{V_{OUT}}{V_{IN}}$ $A_I = \frac{I_{OUT}}{I_{IN}}$ $A_P = \frac{P_{OUT}}{P_{IN}}$ OR $A_P = A_V \times A_I$ $\beta_T = \beta_1 \times \beta_2$ OR $A_{VT} = A_{V1} \times A_{V2} \times A_{V3} \times \dots A_{Vn}$ $P_{IN} = I^2 \times Z_{IN}$ AND $P_{OUT} = I^2 \times Z_{OUT}$ Oscillation frequency $f_o = \frac{1}{2\pi\sqrt{LC}}$ OR $f_o = \frac{1}{2\pi\sqrt{6RC}}$ GAIN IN DECIBELS $A_I = 20 \log_{10} \frac{I_{OUT}}{I_{IN}}$ $A_V = 20 \log_{10} \frac{V_{OUT}}{V_{IN}}$ OR $A_V = 20 \log_{10} A_{VT}$ $A_P = 10 \log_{10} \frac{P_{OUT}}{P_{IN}}$ OR $A_P = 10 \log_{10} \frac{P_2}{P_1}$

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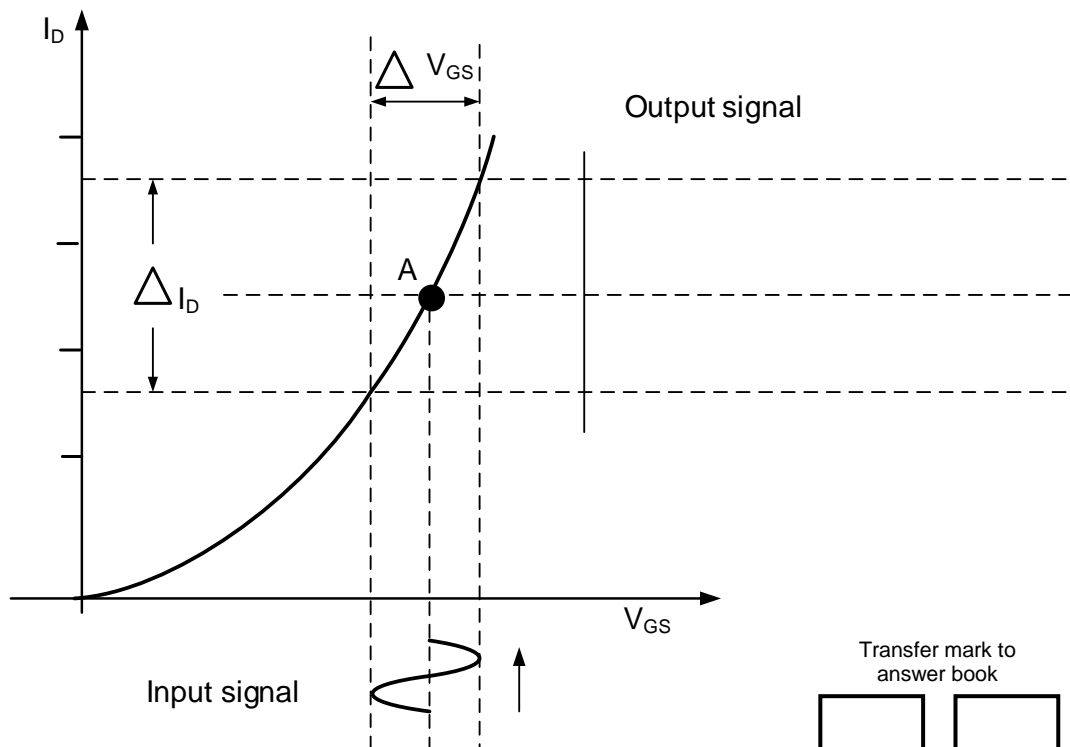
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EXAMINATION NUMBER:

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ANSWER SHEET**QUESTION 4: SEMICONDUCTOR DEVICES**

4.4.3

**FIGURE 4.4.3**Transfer mark to
answer book

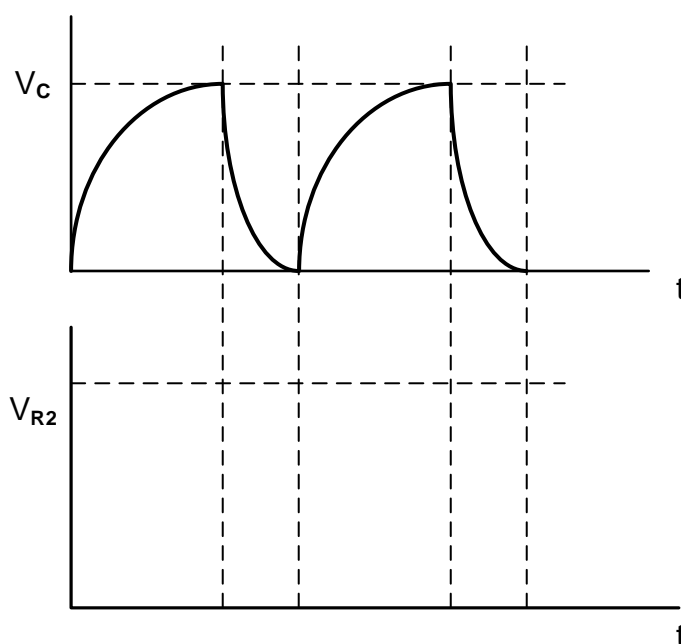
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MOD

(2)

4.5.3

**FIGURE 4.5.3**Transfer mark to
answer book

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MOD

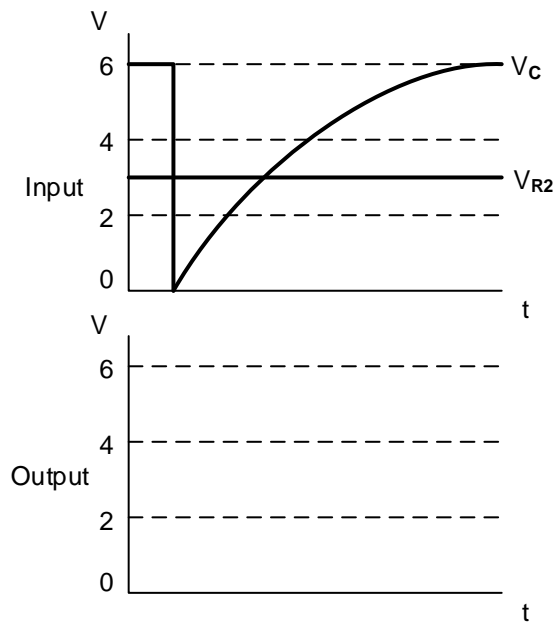
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CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET**QUESTION 5: SWITCHING CIRCUITS**

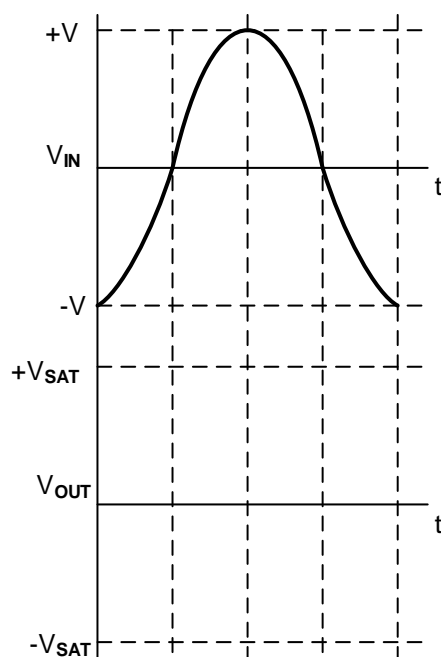
5.3.6

**FIGURE 5.3.6**Transfer mark to
answer book

MOD

(3)

5.4.3

**FIGURE 5.4.3**Transfer mark to
answer book

MOD

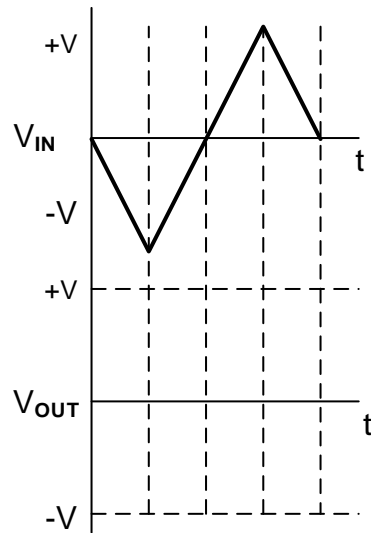
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EXAMINATION NUMBER:													
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ANSWER SHEET

5.6.1

**FIGURE 5.6.1**Transfer mark to
answer book

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(4)

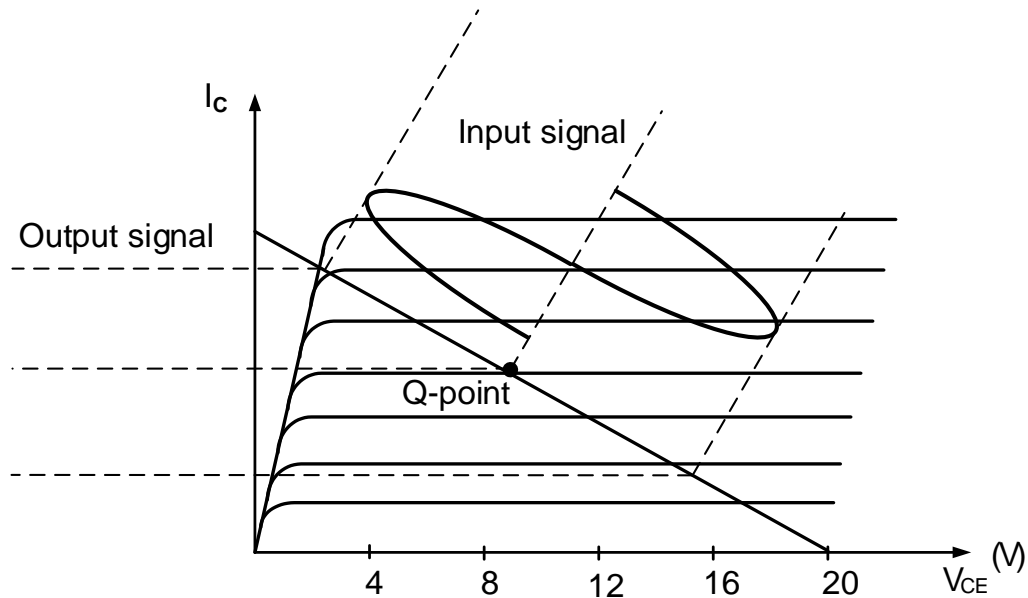
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ANSWER SHEET

QUESTION 6: AMPLIFIERS

6.2.2

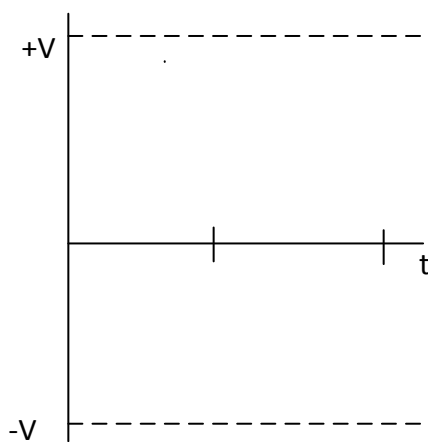
Transfer mark to
answer book

MOD

FIGURE 6.2.2

(2)

6.6.3

Transfer mark to
answer book

MOD

FIGURE 6.6.3

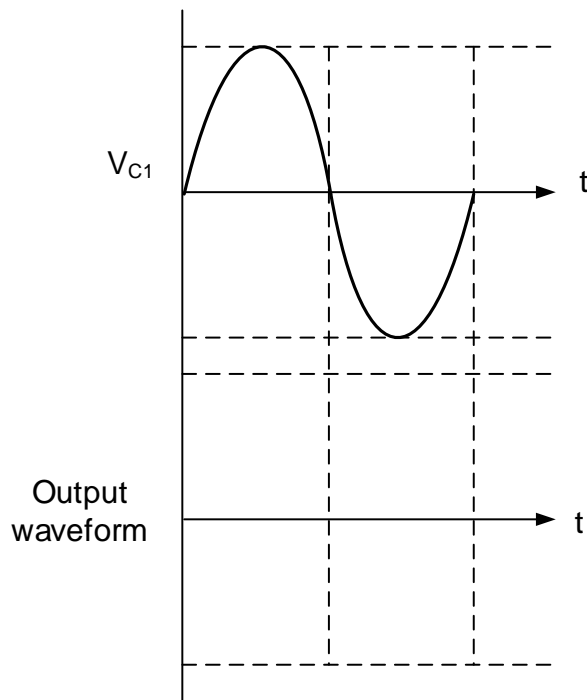
(2)

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EXAMINATION NUMBER:													
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ANSWER SHEET

6.8.3

**FIGURE 6.8.3**Transfer mark to
answer book

MOD

(2)