basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: ELECTRONICS

2021

MARKS: 200

TIME: 3 hours

This question paper consists of 22 pages, a 1-page formula sheet and 4 answer sheets.

INSTRUCTIONS AND INFORMATION

1. This question paper consists of FIVE questions.

2. Answer ALL the questions.

3. Answer the following questions on the attached ANSWER SHEETS:

   QUESTIONS 4.2.4, 4.7.1 and 4.7.2
   QUESTIONS 5.9.3 and 5.10.6

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 answers 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: OCCUPATIONAL HEALTH AND SAFETY

1.1 Define the term *safe* with reference to the Occupational Health and Safety Act, 1993 (Act 85 of 1993). (1)

1.2 State TWO characteristics or moral principles related to work ethics. (2)

1.3 Give ONE category/example of a dangerous practice in a workshop. (1)

1.4 Explain why poor ventilation is an unsafe condition in a workshop. (2)

1.5 Name TWO general duties of employees at the workplace. (2)

1.6 Explain the need for human rights in the workplace. (2)
[10]

QUESTION 2: RLC CIRCUITS

2.1 Define the following terms with reference to RLC circuits:

2.1.1 Phase angle (2)

2.1.2 Capacitance (1)

2.2 Explain the effect Lenz's law has on an inductor in an RLC circuit connected across an alternating supply voltage. (2)

2.3 The series RLC circuit in FIGURE 2.3 below consists of a resistor with a resistance of 30 Ω, an inductor with an inductance of 300 mH and a capacitor with a capacitive reactance of 30,32 Ω. The components are all connected across the supply voltage of 80 V/60 Hz AC with a total current of 2,55 A flowing through the circuit. Answer the questions that follow.

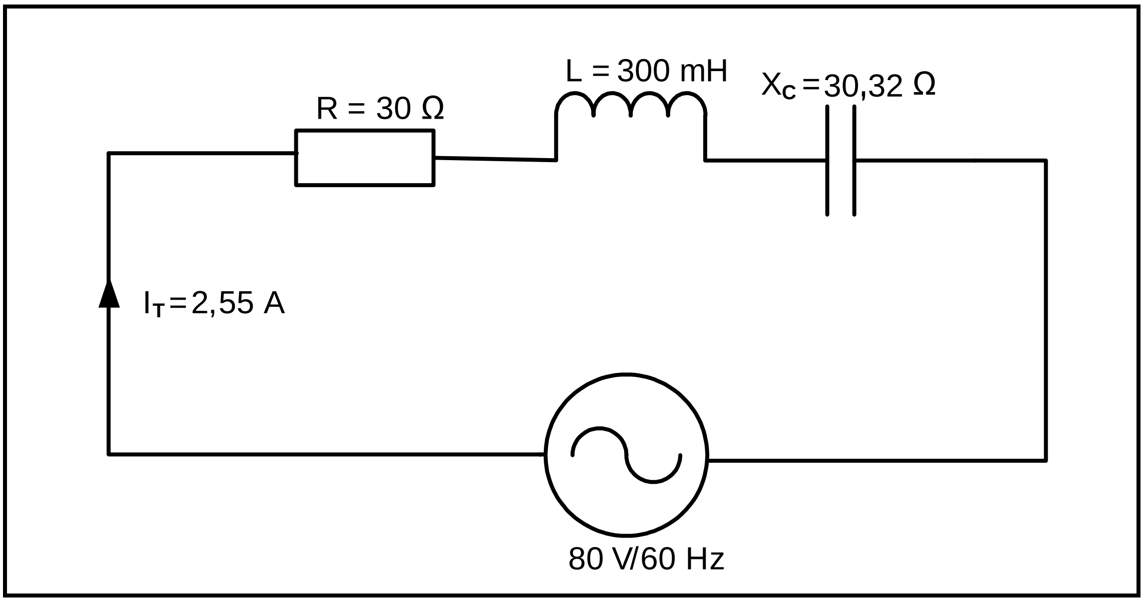


FIGURE 2.3: SERIES RLC CIRCUIT

Given:

R = 30 Ω
L = 300 mH
X_C = 30,32 Ω
I_T = 2,55 A
V_T = 80 V
f = 60 Hz

2.3.1 Calculate the inductive reactance of the circuit. (3)

2.3.2 Calculate the total impedance of the circuit. (3)

2.3.3 State whether the circuit is capacitive or inductive. Give a reason to substantiate your answer. (2)

2.4 FIGURE 2.4 below shows a parallel RLC circuit that consists of a 75 Ω resistor, an inductor with unknown inductance value and a capacitor with a capacitive reactance of 50 Ω, all connected across 300 V AC supply voltage. The current flowing through the resistor is 4 A and the current flowing through the inductor is 3 A. Answer the questions that follow.

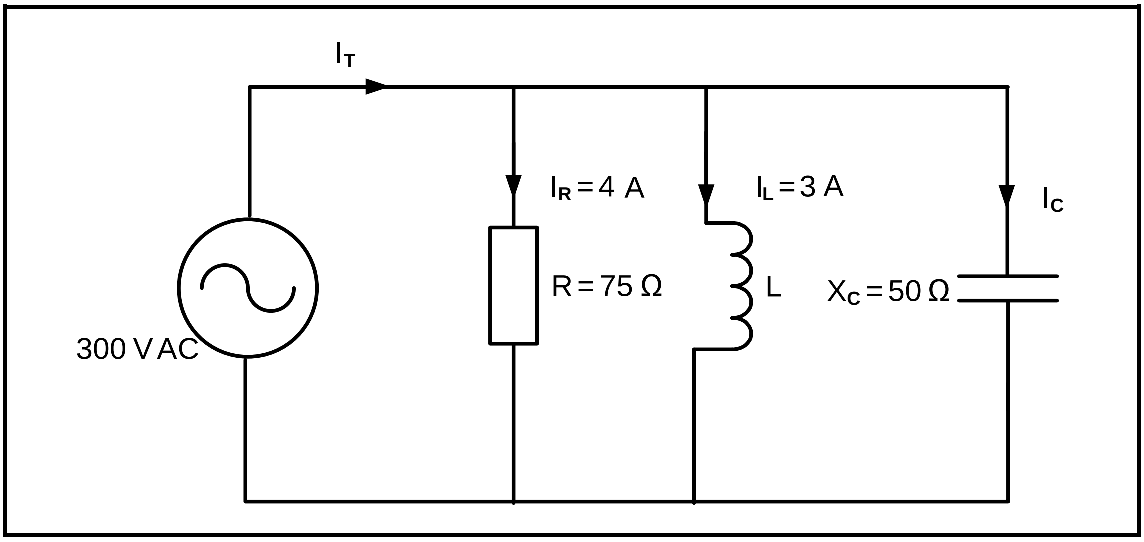


FIGURE 2.4: PARALLEL RLC CIRCUIT

Given:

V_T = 300 V AC
X_C = 50 Ω
R = 75 Ω
I_R = 4 A
I_L = 3 A

2.4.1 Calculate the value of the current through the capacitor. (3)

2.4.2 Calculate the value of the inductive reactance. (3)

2.4.3 Calculate the value of the total current. (3)

2.4.4 Calculate the phase angle. (3)

2.5 Refer to FIGURE 2.5 below and answer the questions that follow.

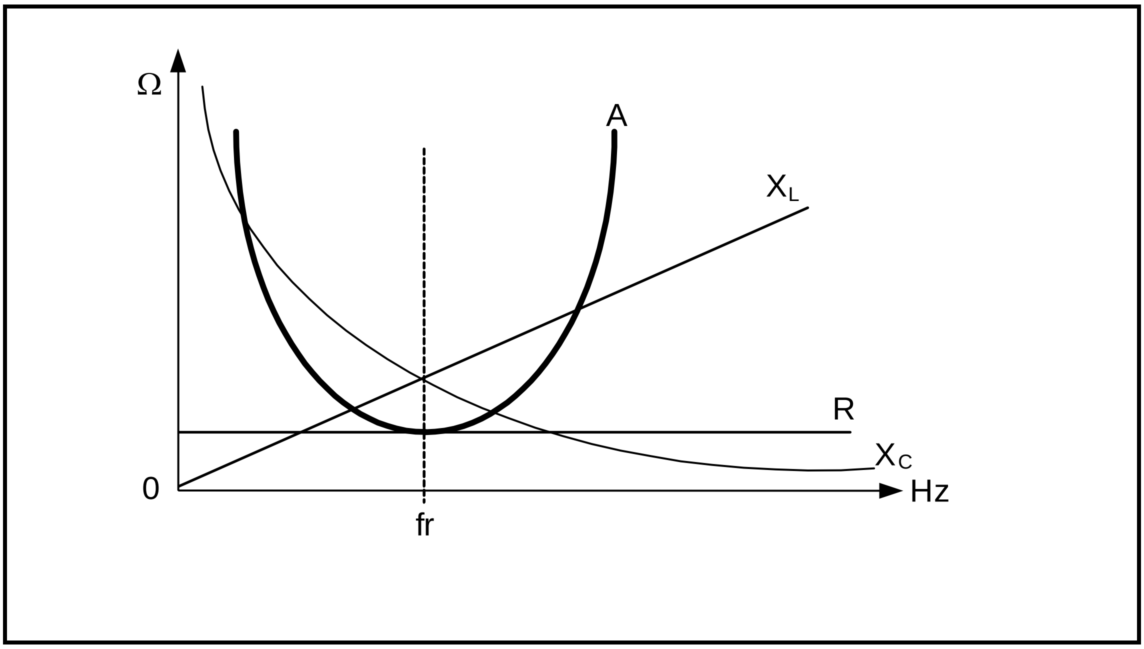


FIGURE 2.5: RESONANCE RESPONSE CURVE

2.5.1 Name the response curve represented by **A**. (1)

2.5.2 Compare the magnitude of the reactance values (X_L and X_C) below the resonant frequency. (2)

2.5.3 Explain why the inductive reactance in FIGURE 2.5 is represented by a straight line and the capacitive reactance is represented by a curved line. (2)

2.5.4 Calculate the resonant frequency of a series RLC circuit with the following component values: a resistor with a resistance of 20 Ω, capacitor with a capacitance of 1,47 µF and an inductor with an inductance of 2,12 H connected across an AC supply.

Given:

R = 20 Ω
C = 1,47 µF
L = 2,12 H (3)

2.5.5 Name ONE application of the circuit in QUESTION 2.5.4. (1)

2.6 Refer to FIGURE 2.6 below and answer the questions that follow.

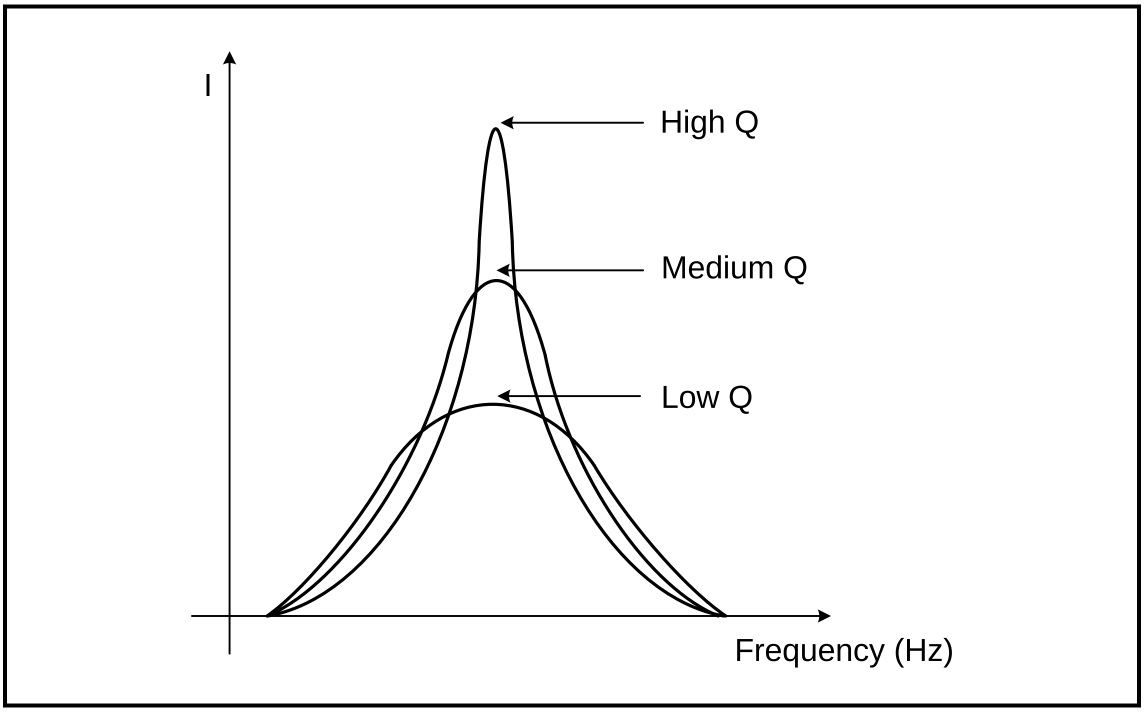


FIGURE 2.6: FREQUENCY RESPONSE CURVE

2.6.1 Explain how the value of the Q-factor affects the value of the current. (1)

2.6.2 Define the term *half power points*. (1)

2.6.3 When choosing a component, name TWO factors that determine the quality factor of the circuit. (2)

2.6.4 Describe what happens to the selectivity and band pass frequencies as the Q-factor in FIGURE 2.6 is lowered. (2)
[40]

QUESTION 3: SEMICONDUCTOR DEVICES

3.1 Name ONE type of field-effect transistor (FET). (1)

3.2 Refer to FIGURE 3.2 below and answer the questions that follow.

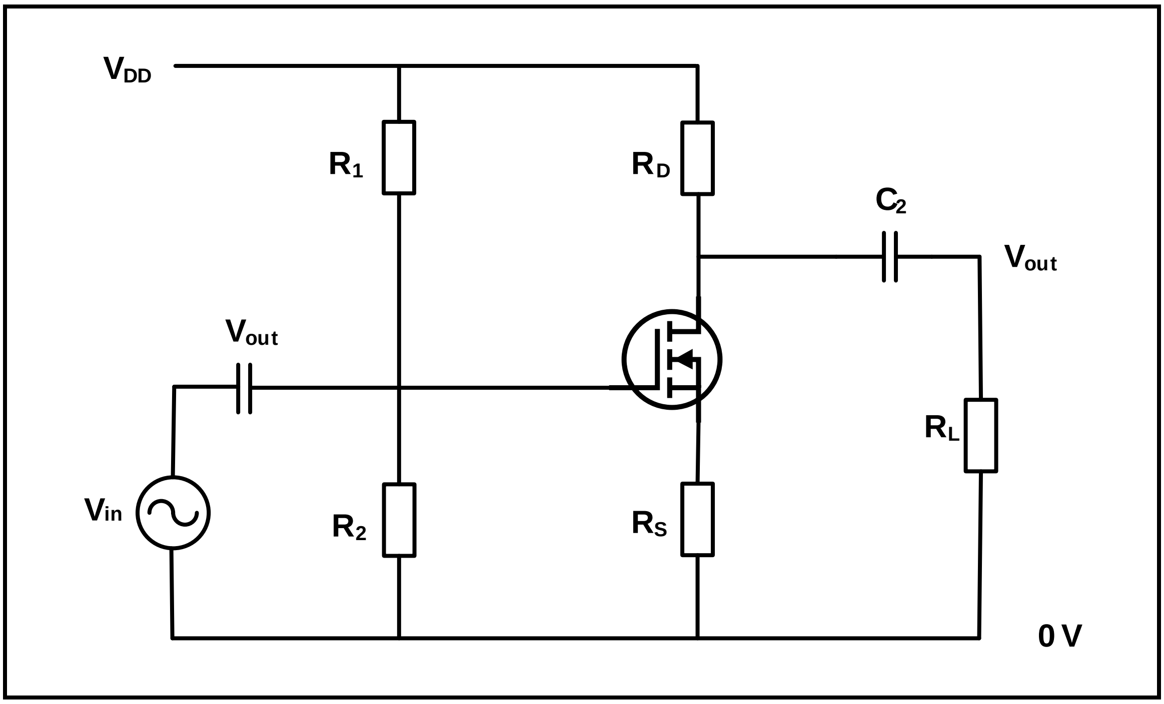


FIGURE 3.2: FET AS AN AMPLIFIER

3.2.1 Identify the type of MOSFET used in this circuit. (2)

3.2.2 Name ONE application of a MOSFET other than an amplifier. (1)

3.3 FIGURE 3.3 below shows the incomplete characteristic curve of a unijunction transistor (UJT). Answer the questions that follow.

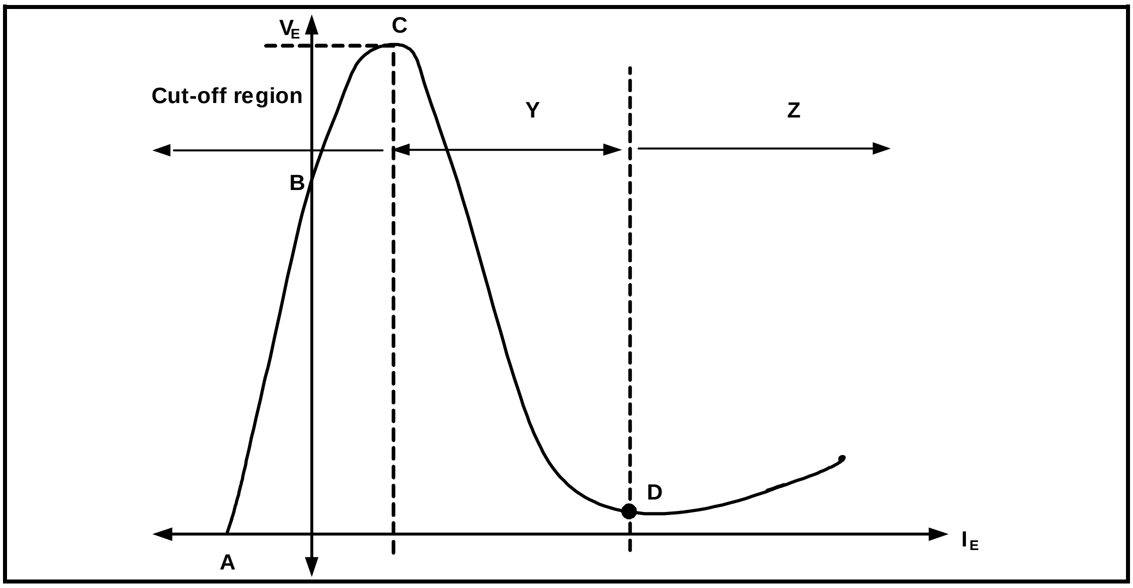


FIGURE 3.3: UJT CHARACTERISTIC CURVE

3.3.1 Label regions **Y** and **Z**. (2)

3.3.2 Label point **D**. (1)

3.3.3 With reference to reverse leakage current, explain what happens at cut-off point **B**. (3)

3.4 Name FOUR characteristics of an ideal operational amplifier. (4)

3.5 FIGURE 3.5 below shows the op amp as a non-inverting amplifier. Answer the questions that follow.

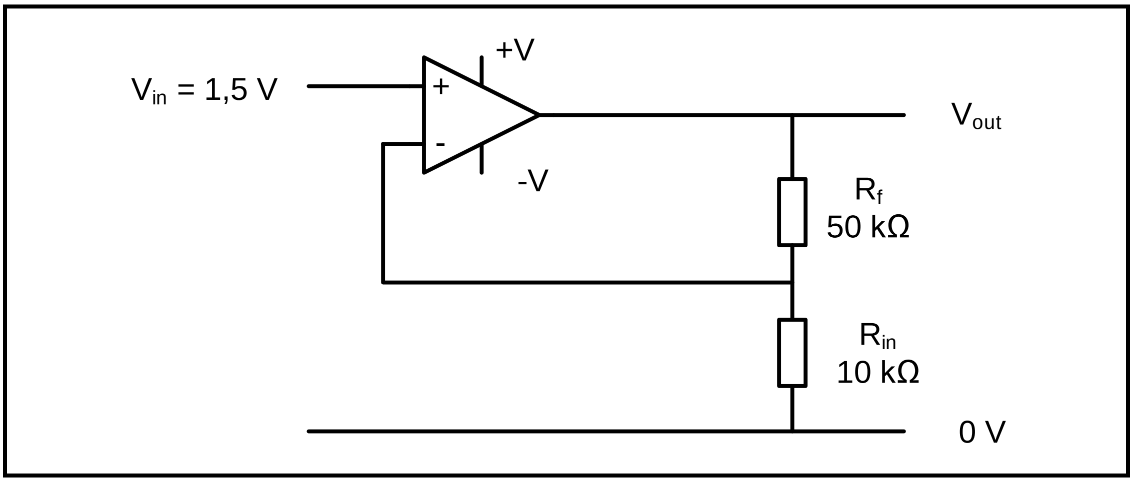


FIGURE 3.5: NON-INVERTING AMPLIFIER

Given:

V_{IN} = 1,5 V
R_F = 50 kΩ
R_{IN} = 10 kΩ

3.5.1 Calculate the voltage gain in FIGURE 3.5. (3)

3.5.2 Calculate the output voltage. (3)

3.5.3 Describe the effects of decreasing the feedback resistor. (2)

3.6 FIGURE 3.6 below shows the 555 timer IC. Answer the questions that follow.

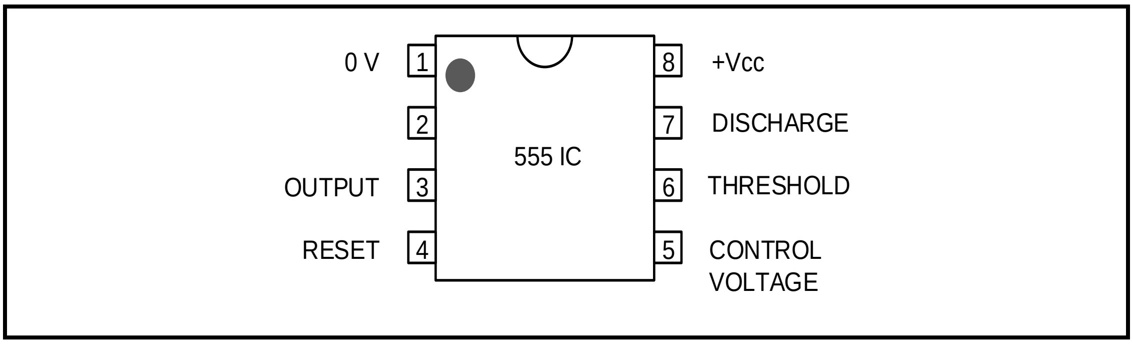


FIGURE 3.6: 555 TIMER IC

3.6.1 Identify pin **2**. (1)

3.6.2 Explain the function of pin 6 (threshold) on a 555 IC. (3)

3.6.3 State the voltage parameters between which a 555 timer can operate. (2)

3.6.4 Explain the astable mode of operation of a 555 timer. (2)
[30]

QUESTION 4: SWITCHING CIRCUITS

4.1 Refer to FIGURE 4.1 below and answer the questions that follow.

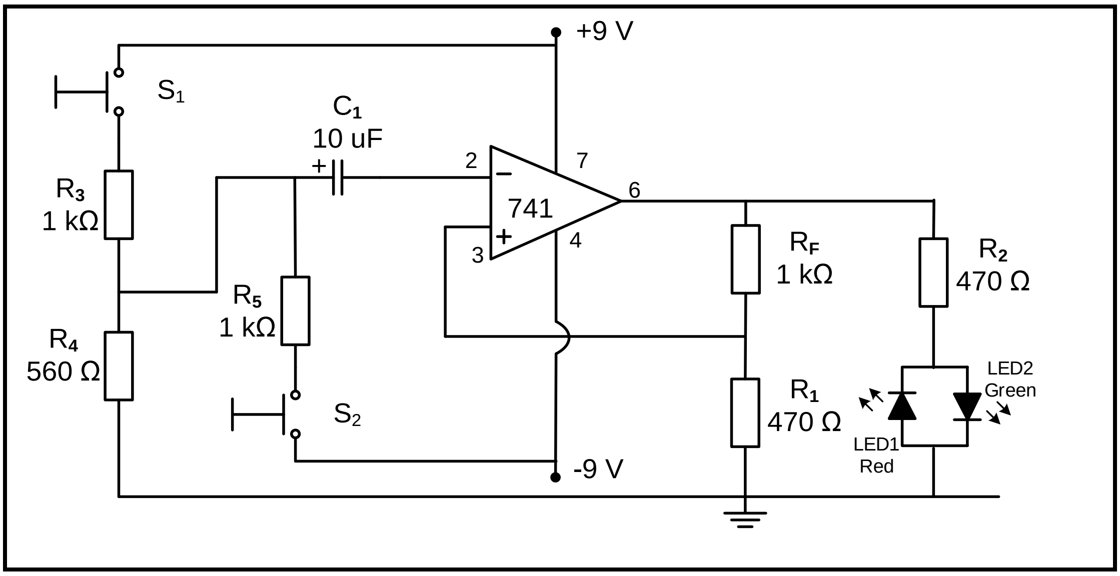


FIGURE 4.1: MULTIVIBRATOR

4.1.1 Identify the multivibrator in FIGURE 4.1. (1)

4.1.2 State the polarity of the pulse provided on the inverting input when switch S_1 is pressed. (1)

4.1.3 State TWO functions of the 741 op amp in the circuit. (2)

4.1.4 Which LED will be forward biased when S_1 is pressed? (1)

4.1.5 State the polarity of the voltage present on pin 3 after switch S_2 is pressed. (1)

4.2 FIGURE 4.2 below shows a 741 op-amp monostable multivibrator. Answer the questions that follow.

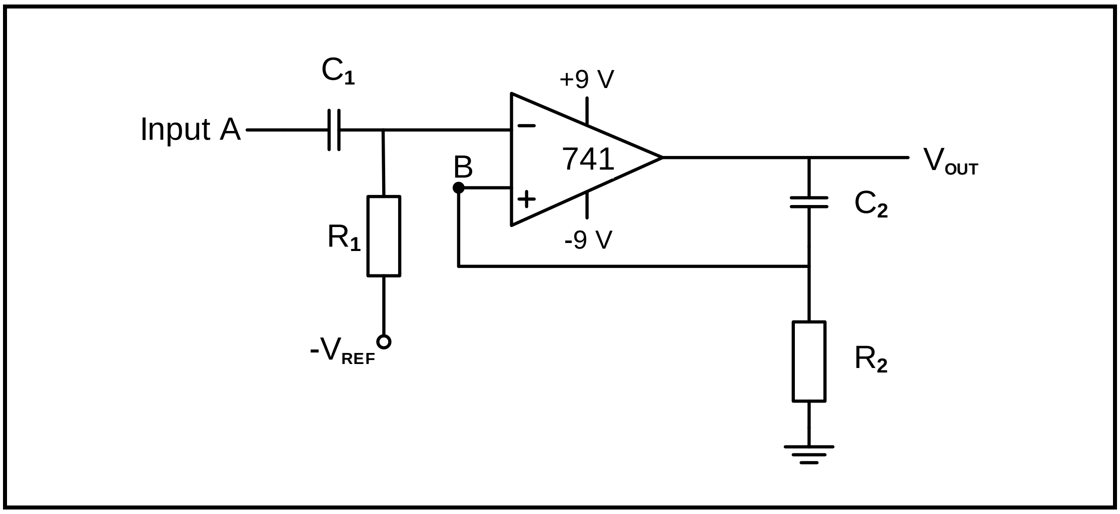


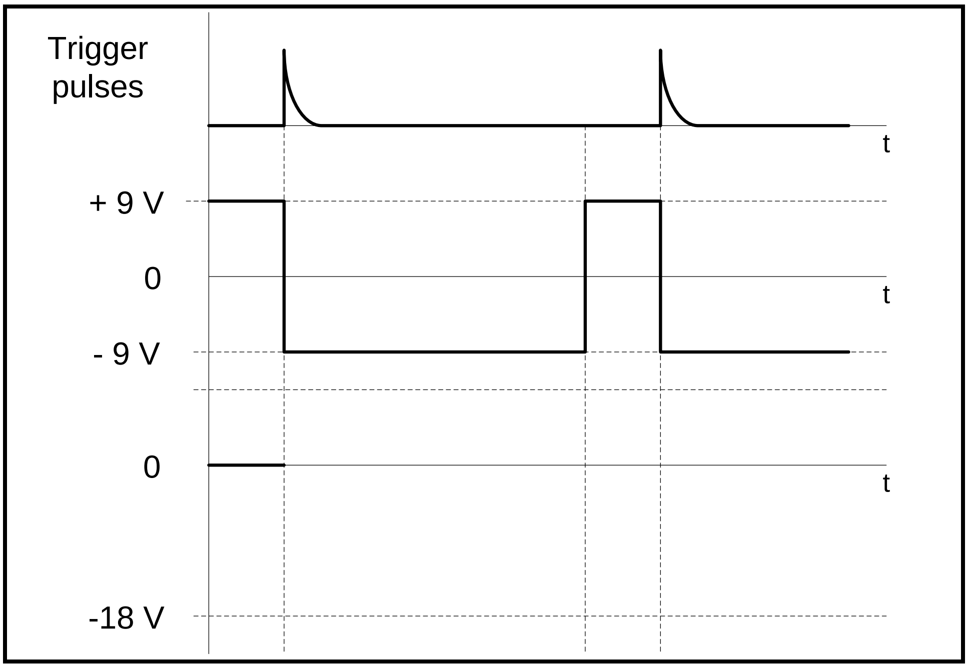
FIGURE 4.2: 741 OP-AMP MONOSTABLE MULTIVIBRATOR

4.2.1 Write down the value of the voltage across capacitor C_2 when the circuit is in its natural resting position. (1)

4.2.2 Write down the voltage at point **B** when the circuit is in its reset state. (1)

4.2.3 Explain when the circuit output will change state. (2)

4.2.4 On the ANSWER SHEET for QUESTION 4.2.4, draw the voltage at point **B** if the input signal below is applied to the input of the circuit.



(4)

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

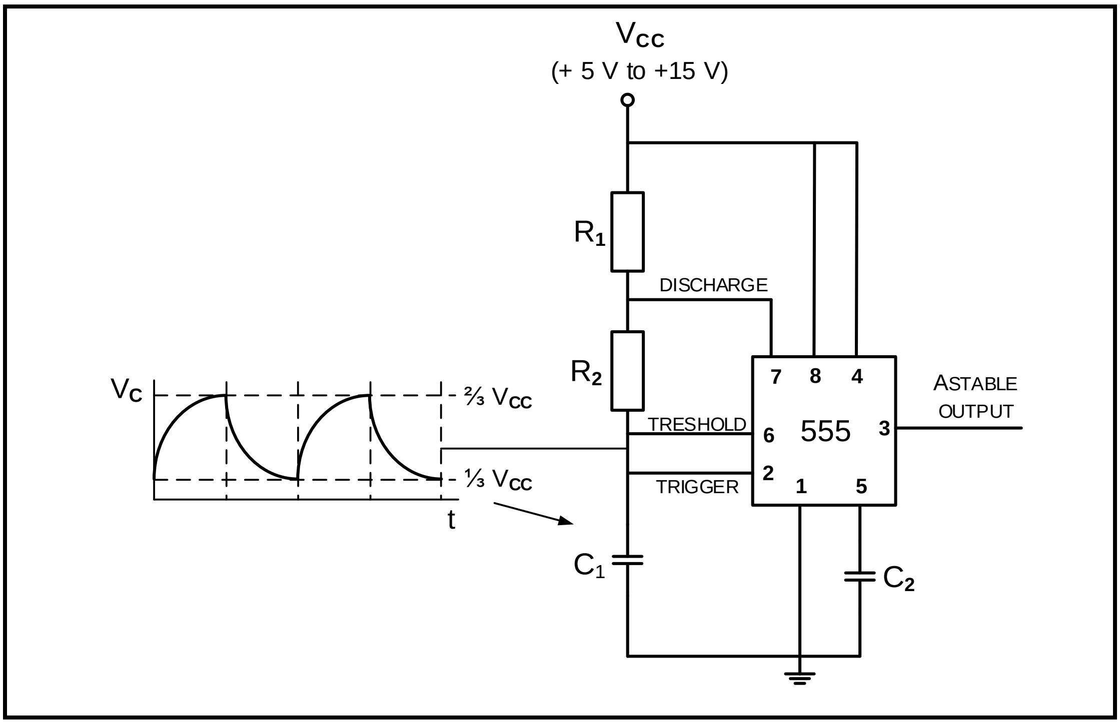


FIGURE 4.3: ASTABLE MULTIVIBRATOR

4.3.1 Identify the components responsible for charging capacitor C_1. (1)

4.3.2 Explain why the output will keep oscillating between high and low states. (2)

4.3.3 Draw a fully labelled 741 IC op-amp equivalent of the circuit in FIGURE 4.3. (6)

4.4 Explain the operation of the circuit in FIGURE 4.4 below.

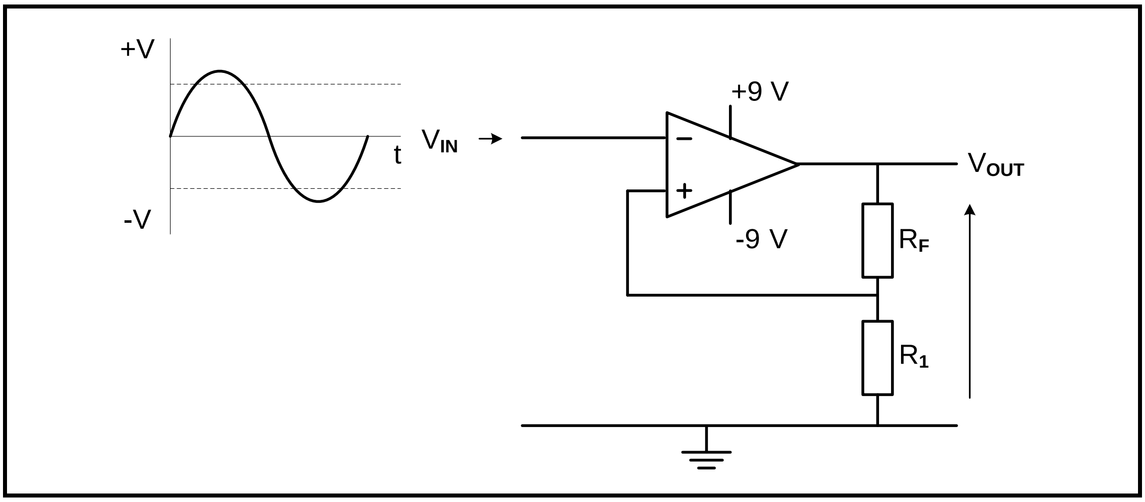


FIGURE 4.4: SCHMITT TRIGGER (6)

4.5 FIGURE 4.5 and TABLE 4.5 below show the resistor values, output voltages and gain of a summing amplifier. Refer to FIGURE 4.5 and study TABLE 4.5 to answer the questions that follow.

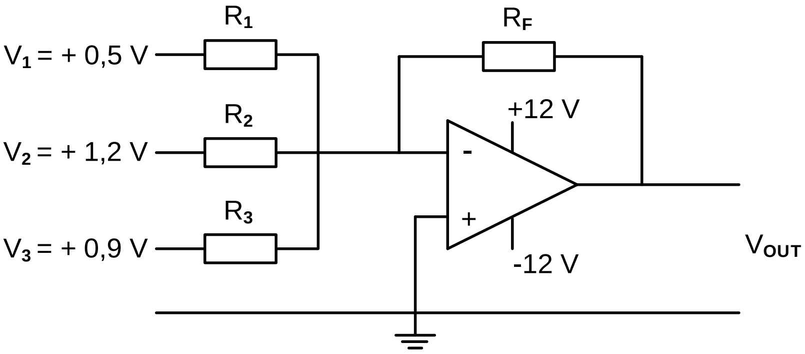


FIGURE 4.5: SUMMING AMPLIFIER

RESISTOR VALUES				**OUTPUT**	**GAIN**
R_1	**R_2**	**R_3**	**R_F**	**V_{OUT}**	**β (A_V)**
20 kΩ	20 kΩ	20 kΩ	20 kΩ	**B**	1
20 kΩ	20 kΩ	20 kΩ	40 kΩ	+ 5,2 V	**D**
5 kΩ	10 kΩ	20 kΩ	40 kΩ	**C**	4,08
20 kΩ	20 kΩ	20 kΩ	**A**	+ 10,4 V	4

TABLE 4.5

4.5.1 State the function of a summing amplifier. (2)

4.5.2 Calculate the output voltage at **B**. (3)

4.5.3 Calculate the output voltage at **C**. (3)

4.5.4 Calculate the value of the feedback at **A**. (3)

4.5.5 Calculate the total gain at **D**. (3)

4.6 Refer to FIGURE 4.6 below and answer the questions that follow.

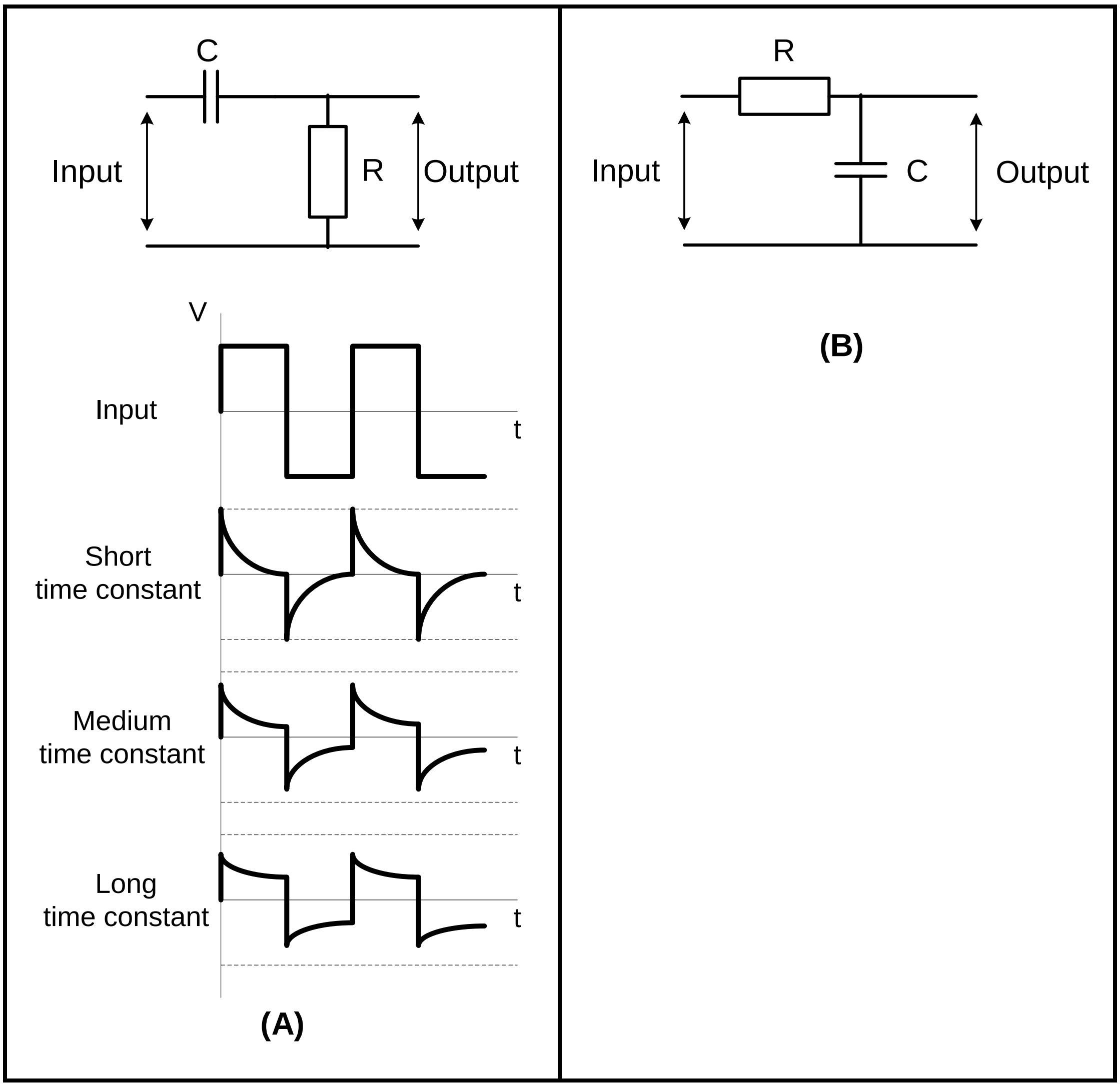


FIGURE 4.6

4.6.1 Identify the circuits in FIGURE 4.6(A) and (B). (2)

4.6.2 Explain the effect that a long time constant has on the operation of the circuit in FIGURE 4.6(A). (3)

4.6.3 Explain the function of the circuit in FIGURE 4.6(B). (2)

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

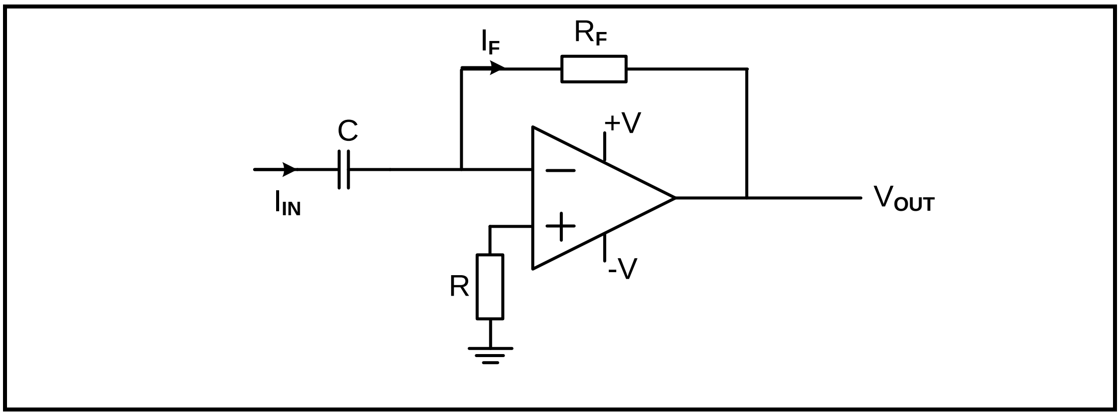
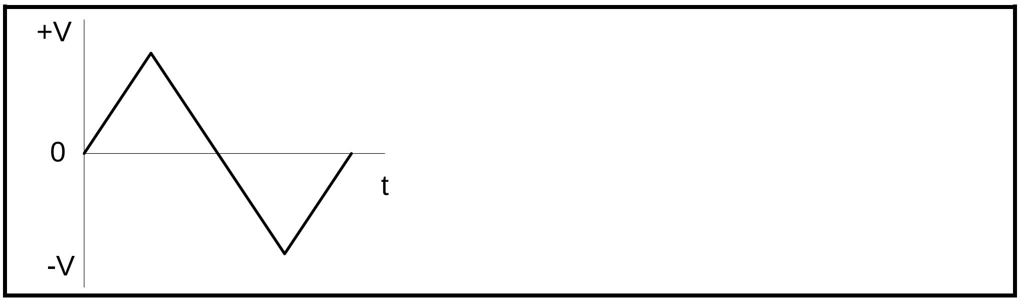


FIGURE 4.7: OP-AMP DIFFERENTIATOR

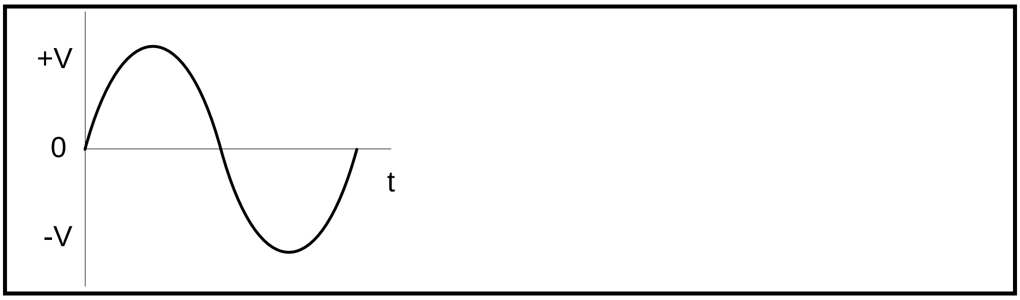
On the ANSWER SHEET for QUESTION 4.7.1 and QUESTION 4.7.2, draw the output waveform if the following inputs are applied to the circuit.

4.7.1



(3)

4.7.2



(5)

4.7.3 State TWO improvements that the op amp brings to the operation of the circuit in FIGURE 4.7. (2)

[60]

QUESTION 5: AMPLIFIERS

5.1 Define the following terms with reference to amplifier circuits:

5.1.1 Attenuation (2)

5.1.2 High-pass filter (2)

5.2 Explain the following categories of transistor amplifiers:

5.2.1 A small-signal amplifier (2)

5.2.2 A power amplifier (2)

5.3 Refer to FIGURE 5.3 below and answer the questions that follow.

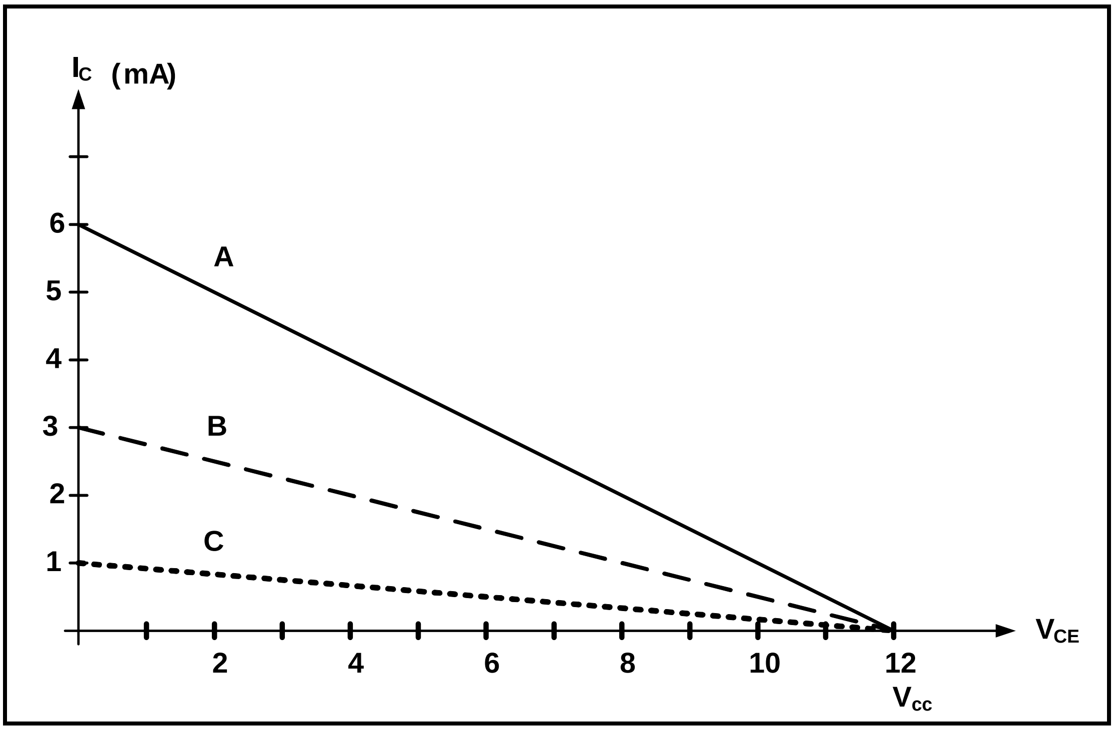


FIGURE 5.3: DC LOADLINES

5.3.1 State ONE purpose of a DC load line. (1)

5.3.2 Explain why there is a difference in the gradients of DC load lines **A**, **B** and **C**. (3)

5.3.3 Calculate the value of the collector resistor of the DC load line represented by line **B**. (3)

5.4 Refer to FIGURE 5.4 below and explain why the amplifier is class A biased.

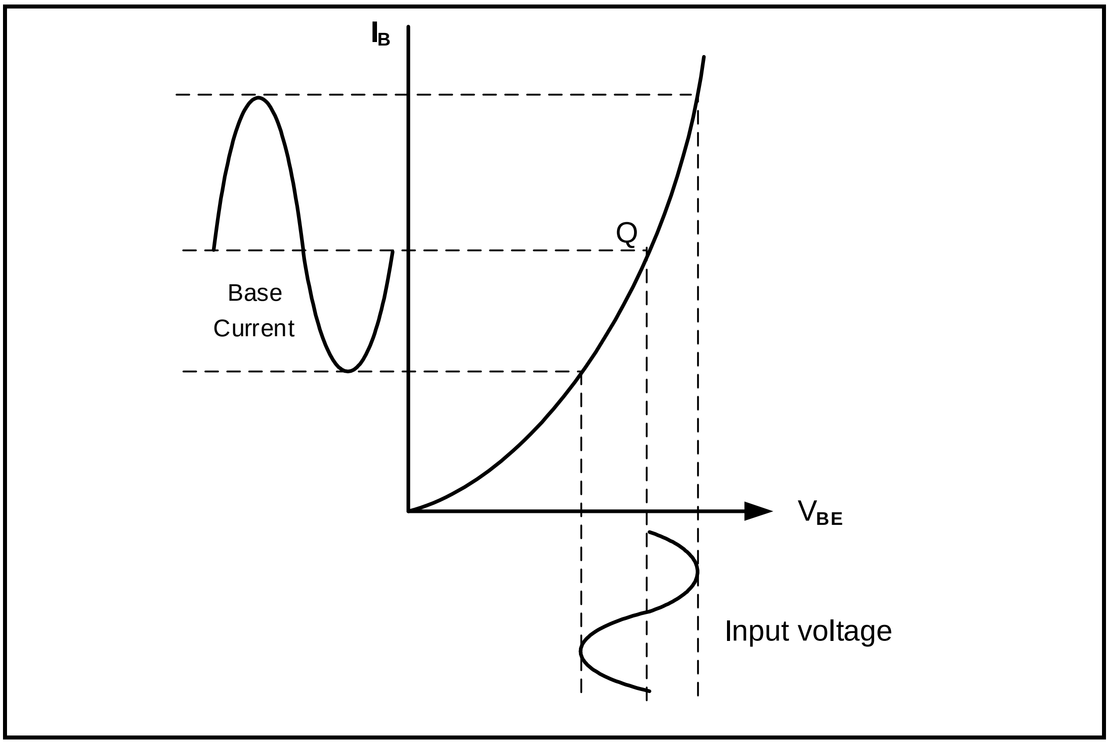


FIGURE 5.4: CHARACTERISTIC CURVE OF A CLASS A AMPLIFIER

5.5 Explain the term *infinite bandwidth* with reference to the frequency response curves of an amplifier circuit. (1)

5.6 Refer to FIGURE 5.6 below and answer the questions that follow.

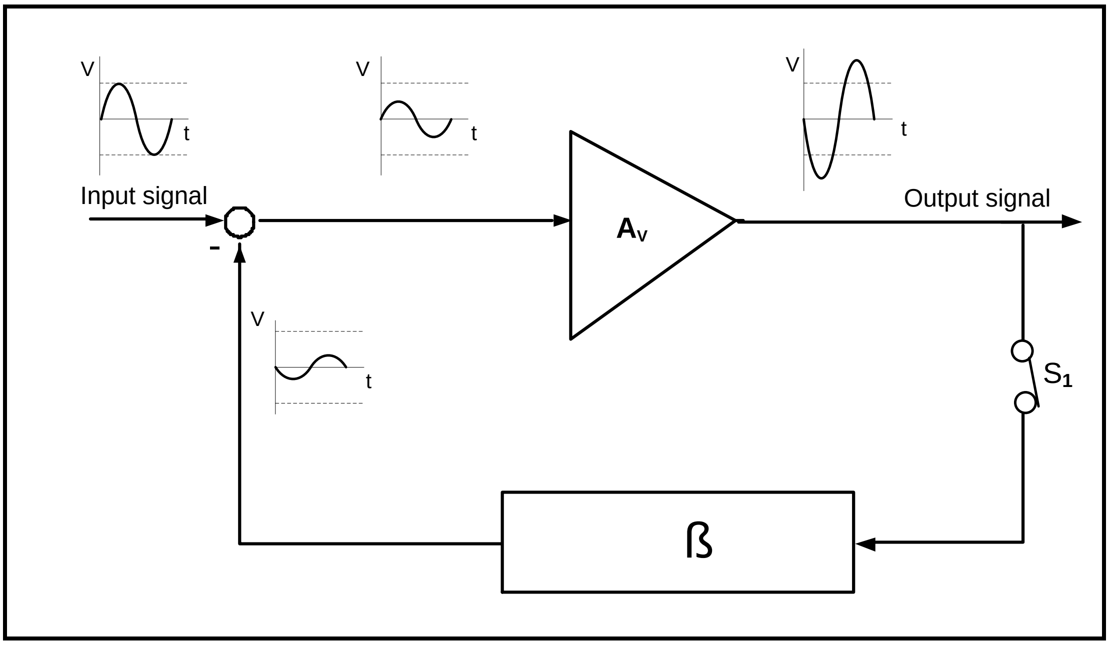


FIGURE 5.6: BLOCK DIAGRAM

5.6.1 Identify the block diagram in FIGURE 5.6. (1)

5.6.2 List THREE conditions that will occur when switch S_1 is opened. (3)

5.7 Refer to FIGURE 5.7 below and answer the questions that follow.

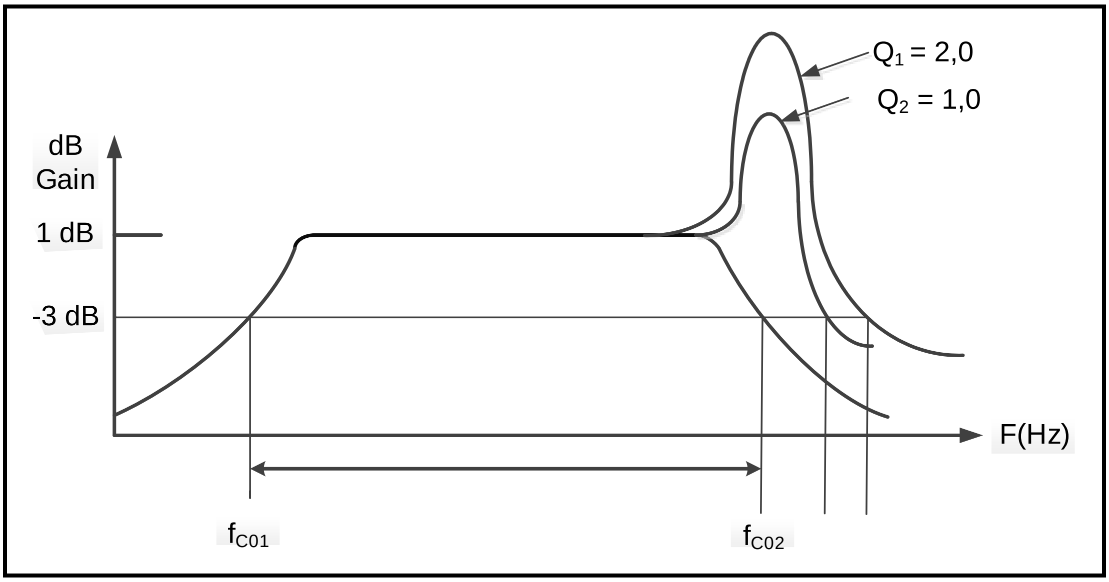


FIGURE 5.7: FREQUENCY RESPONSE CURVE

5.7.1 Identify the amplifier circuit from which the frequency response curve in FIGURE 5.7 is derived. (1)

5.7.2 Describe how the frequency affects the gain. (4)

5.8 Refer to FIGURE 5.8A below and FIGURE 5.8B on the next page and answer the questions that follow.

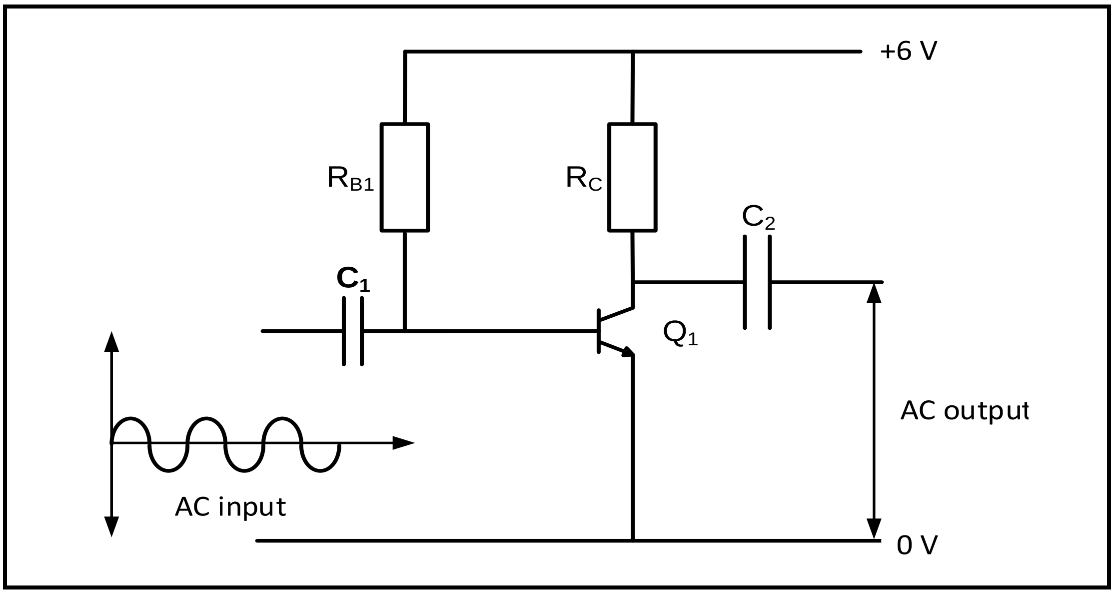


FIGURE 5.8A: COMMON EMITTER AMPLIFIER CIRCUIT

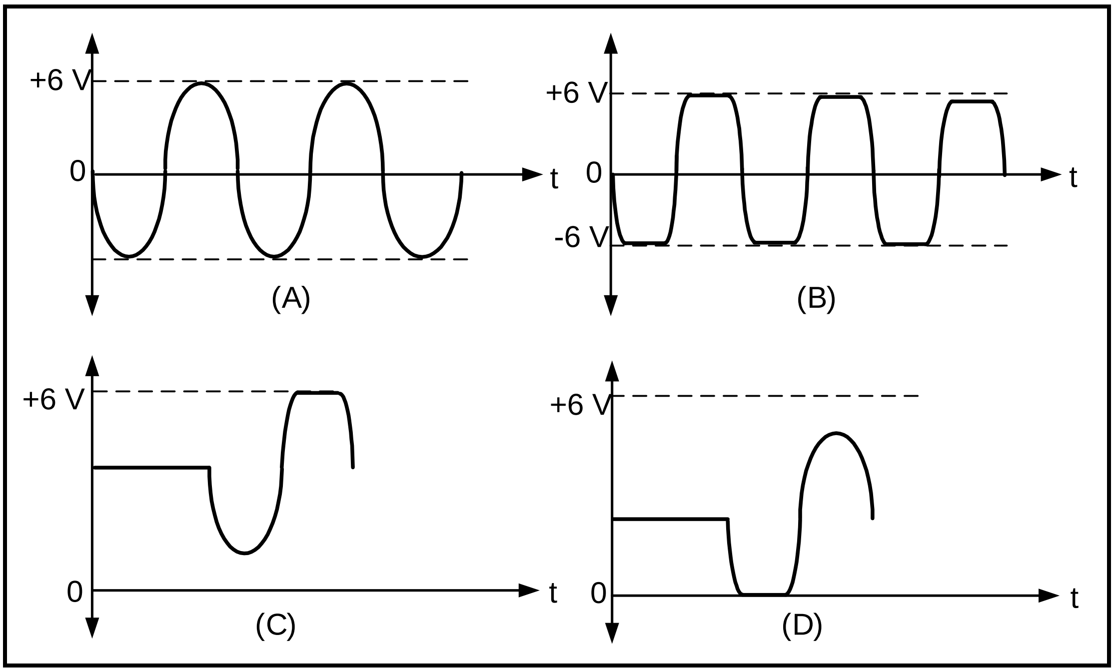


FIGURE 5.8B: OUTPUT WAVEFORMS

Identify the waveform in FIGURE 5.8B that represents the output of the circuit diagram in FIGURE 5.8A for the following conditions:

5.8.1 The transistor is biased at the mid-point of the DC load line (1)

5.8.2 The value of the base R_{B1} is decreased (1)

5.8.3 The base current is decreased (1)

5.8.4 Inputs overload the amplifier (1)

5.9 FIGURE 5.9 below shows a push-pull amplifier using NPN and PNP transistors biased in class B. Answer the questions that follow.

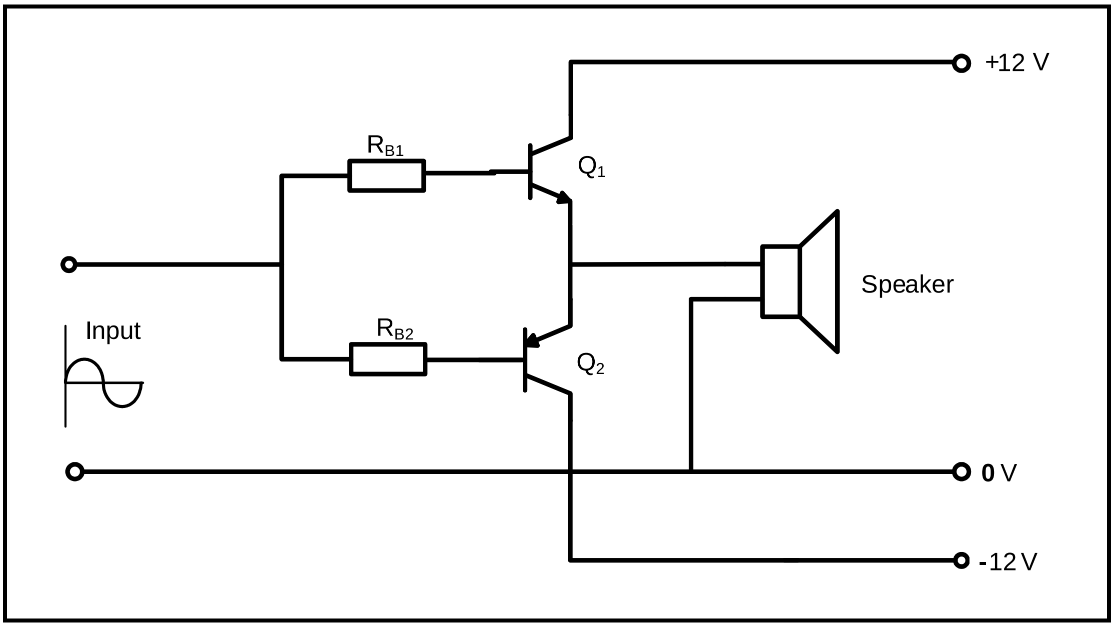


FIGURE 5.9: AMPLIFIER USING COMPLEMENTARY TRANSISTORS

5.9.1 Explain why the circuit in FIGURE 5.9 uses a DC power supply and an AC signal at the input. (2)

5.9.2 Name the type of distortion that can be found in this circuit. (1)

5.9.3 On the ANSWER SHEET for QUESTION 5.9.3, draw the output waveform that would be produced at the speaker if there is distortion. (4)

5.9.4 Explain the operation of the circuit in FIGURE 5.9. (5)

5.10 Refer to FIGURE 5.10 below and answer the questions that follow.

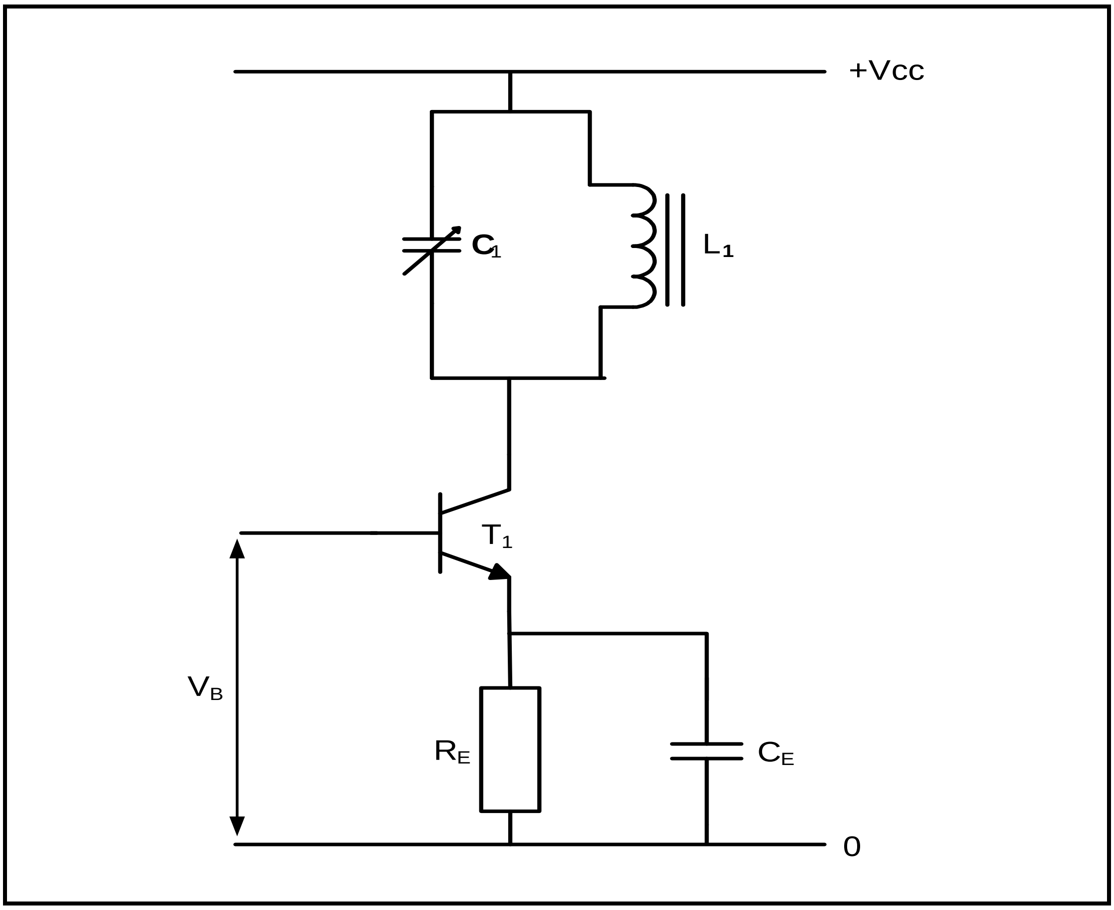


FIGURE 5.10: LC RESONANT CIRCUIT LOAD

5.10.1 Name the class of amplification used in FIGURE 5.10. (1)

5.10.2 Describe a radio-frequency amplifier. (3)

5.10.3 Explain the term *unwanted frequencies* with reference to the operation of radio-frequency amplifiers. (1)

5.10.4 Explain the purpose of the LC-tuned circuit. (2)

5.10.5 Describe how the resonating frequency of the circuit can be varied. (2)

5.10.6 Draw a labelled frequency response curve of the radio-frequency amplifier. (4)

5.11 Refer to FIGURE 5.11 below and explain the operation of the Hartley oscillator tank circuit, as shown in block **A**.

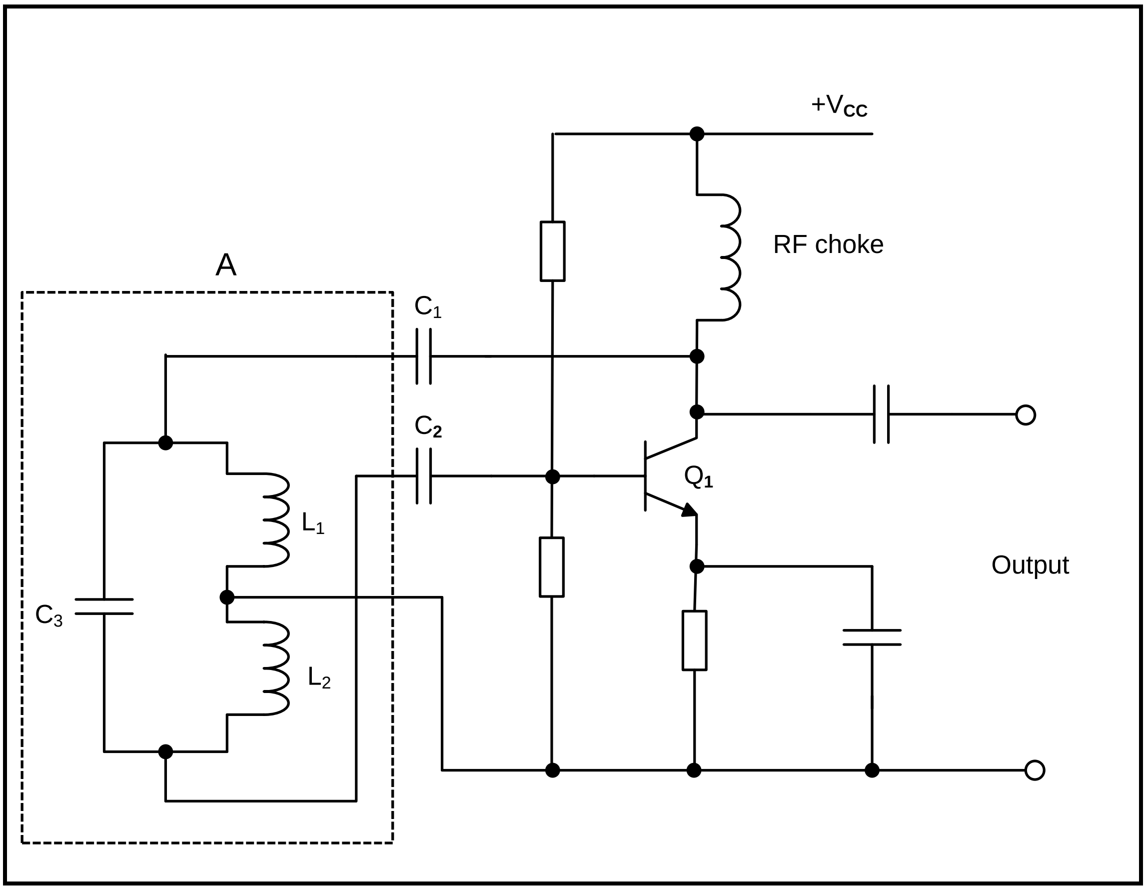


FIGURE 5.11: HARTLEY OSCILLATOR CIRCUIT (4)
[60]

TOTAL: 200

FORMULA SHEET

RLC CIRCUITS

$P = V \times I \times \cos\theta$

$X_L = 2\pi fL$

$X_C = \dfrac{1}{2\pi fC}$

$f_r = \dfrac{1}{2\pi\sqrt{LC}}$ OR $f_r = \dfrac{f_2 + f_1}{2}$

$BW = \dfrac{f_r}{Q}$ OR $BW = f_2 - f_1$

Series

$V_R = IR$

$V_L = IX_L$

$V_C = IX_C$

$I_T = \dfrac{V_T}{Z}$ 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 $V_T = IZ$

$\text{Cos}\,\theta = \dfrac{R}{Z}$ OR $\text{Cos}\,\theta = \dfrac{V_R}{V_T}$

$Q = \dfrac{X_L}{R} = \dfrac{X_C}{R} = \dfrac{V_L}{V_T} = \dfrac{V_C}{V_T} = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$

Parallel

$V_T = V_R = V_L = V_C$

$I_R = \dfrac{V_T}{R}$

$I_C = \dfrac{V_T}{X_C}$

$I_L = \dfrac{V_T}{X_L}$

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

$Z = \dfrac{V_T}{I_T}$

$\text{Cos}\,\theta = \dfrac{I_R}{I_T}$

$Q = \dfrac{R}{X_L} = \dfrac{R}{X_C} = \dfrac{I_L}{I_T} = \dfrac{I_C}{I_T} = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$

SEMICONDUCTOR DEVICES

$\text{Gain } A_V = \dfrac{V_{OUT}}{V_{IN}} = -\dfrac{R_F}{R_{IN}}$ $A_V = 1 + \dfrac{R_F}{R_{IN}}$

$V_{OUT} = V_{IN} \times \left(-\dfrac{R_F}{R_{IN}}\right)$

$V_{OUT} = V_{IN} \times \left(1 + \dfrac{R_F}{R_{IN}}\right)$

SWITCHING CIRCUITS

$V_{OUT} = -\left(V_1\dfrac{R_F}{R_1} + V_2\dfrac{R_F}{R_2} + \ldots V_N\dfrac{R_F}{R_N}\right)$

$\text{Gain } A_V = \dfrac{V_{OUT}}{V_{IN}} = \dfrac{V_{OUT}}{(V_1 + V_2 + \ldots V_N)}$

$V_{OUT} = -(V_1 + V_2 + \ldots V_N)$

AMPLIFIERS

$I_C = \dfrac{V_C}{R_C}$

$V_{CC} = V_{CE} + I_C R_C$

$V_B = V_{BE} + V_{RE}$

$A_V = \dfrac{V_{OUT}}{V_{IN}}$

$A_I = \dfrac{I_{OUT}}{I_{IN}}$

$A_P = \dfrac{P_{OUT}}{P_{IN}}$ OR $A_P = A_V \times A_I$

$A = \beta_1 \times \beta_2$ OR $A_V = A_{V1} \times A_{V2} \times A_{V3}$

$P_{IN} = I^2 \times Z_{IN}$ AND $P_{OUT} = I^2 \times Z_{OUT}$

GAIN IN DECIBELS

$A_I = 20\log_{10}\dfrac{I_{OUT}}{I_{IN}}$

$A_V = 20\log_{10}\dfrac{V_{OUT}}{V_{IN}}$

$A_P = 10\log_{10}\dfrac{P_{OUT}}{P_{IN}}$

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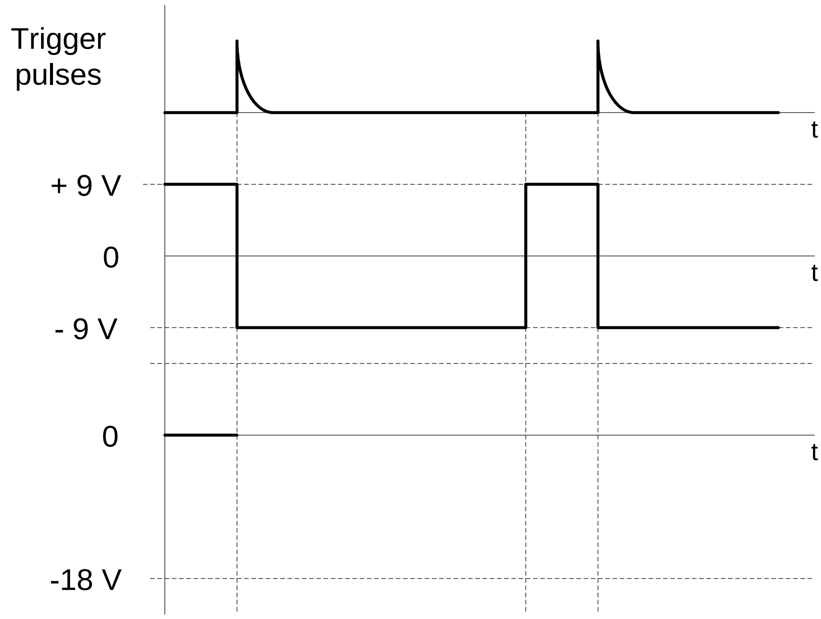
ANSWER SHEET

QUESTION 4: SWITCHING CIRCUITS

4.2.4



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(4)

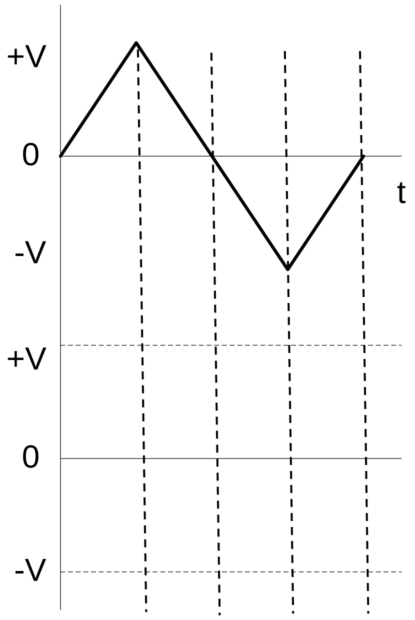
FIGURE 4.2.4

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

4.7.1



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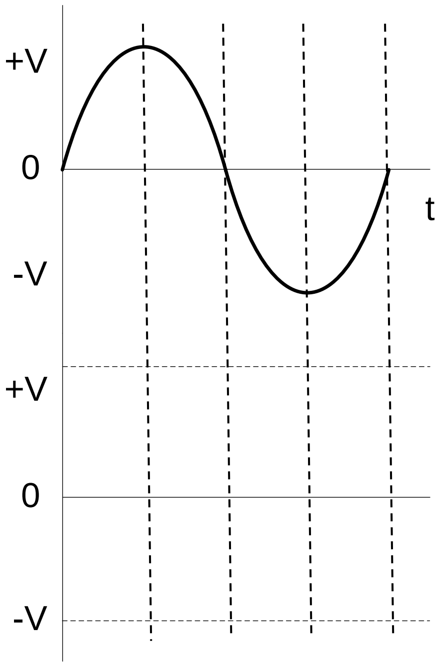
MOD

(3)

FIGURE 4.7.1

4.7.2



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(5)

FIGURE 4.7.2

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 5: AMPLIFIERS

5.9.3

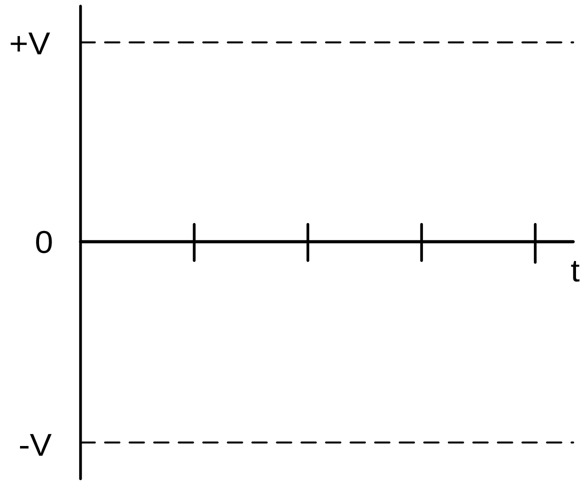

FIGURE 5.9.3

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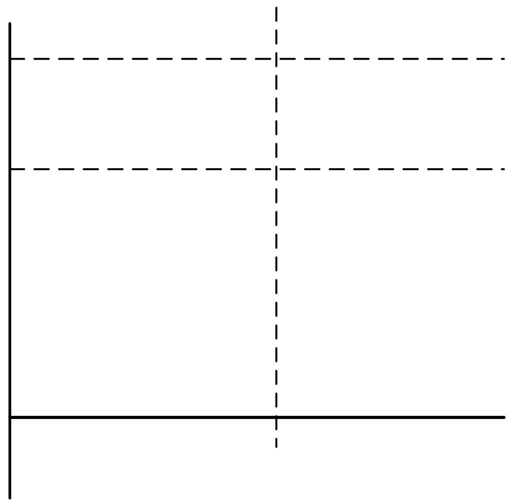
CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

5.10.6



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(4)

FIGURE 5.10.6