basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: DIGITAL ELECTRONICS

2022

MARKS: 200

TIME: 3 hours

This question paper consists of 17 pages, a 1-page formula sheet and 9 answer sheets.

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 3.3.5, 3.4.6, 3.6.1 and 3.6.2
        QUESTION 4.2.3
        QUESTIONS 5.3.1, 5.4.1, 5.4.2, 5.5, 5.6.1 and 5.8
        QUESTION 6.11

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 (1.1.1 to 1.1.15) in the ANSWER BOOK, e.g. 1.16 D.

1.1   The layer(s) of the skin that is/are affected by a third-degree burn would be …

   A   the outer layer.
   B   the second layer.
   C   all layers of the skin.
   D   None of the above-mentioned.   (1)

1.2   A/An … circuit is used to clean up an input signal which has been distorted.

   A   integrator
   B   differentiator
   C   Schmitt trigger
   D   comparator   (1)

1.3   Open-loop gain with reference to op amps is when …

   A   a feedback resistor is connected from the output to the inverting input.
   B   no feedback resistor is connected from the output to the input.
   C   a capacitor is connected from the output to the inverting input.
   D   a feedback resistor is connected from the output to the non-inverting input.   (1)

1.4   When a triangular waveform is applied to the input of a differentiator, the output waveform will be a/an …

   A   DC level.
   B   inverted triangular waveform.
   C   first harmonic frequency of the triangular waveform.
   D   square waveform.   (1)

1.5   The basic circuit of a passive RC differentiator is a …

   A   capacitor in series with the input and a resistor in parallel with the output.
   B   resistor in series with the input and a capacitor in parallel with the output.
   C   resistor in series with the input and a resistor in parallel with the output.
   D   capacitor in series with the input and a capacitor in parallel with the output.   (1)

1.6   Phase shift through an op amp is caused by the …

A   cut-off frequency.
B   internal RC circuits.
C   notch frequency.
D   unity-gain frequency.   (1)

1.7   Negative feedback in an op amp …

A   increases the input and output impedances.
B   decreases the output impedance and the bandwidth.
C   increases the input impedance and the bandwidth.
D   does not affect impedances or the bandwidth.   (1)

1.8   A … output is the transistor collector connected to the cathode of the LED.

A   sourcing
B   draining
C   distributing
D   sinking   (1)

1.9   The … is designed to accept input data in decimal form and convert this information into its binary form.

A   decoder
B   seven-segment display
C   encoder
D   half-adder   (1)

1.10   A combinational logic circuit combining an AND gate with an exclusive OR gate (XOR) is called the … circuit.

A   half-adder
B   full adder
C   parallel adder
D   arithmetic   (1)

1.11   The … is where the timing signal is delayed by a fraction of time through each flip-flop.

A   ripple counter
B   down counter
C   frequency divider
D   propagation delay   (1)

1.12   A fast temporary memory that allows information to be stored and retrieved by the system as it operates, is called the …

    A   ROM.
    B   RAM.
    C   CPU.
    D   I/O unit.   (1)

1.13   A register that contains the address and status of the next instruction for processing and also tells the processor what the next instruction is, is called the …

    A   program counter.
    B   memory address register.
    C   accumulator.
    D   current instruction register.   (1)

1.14   The bus that is used to transmit the memory address from the memory and input/output ports to the CPU is called the … bus.

    A   system
    B   control
    C   data
    D   address   (1)

1.15   ONE advantage of the serial peripheral interface bus (SPI) is that it …

    A   cannot transmit off the PCB.
    B   is susceptible to noise.
    C   supports high-speed full-duplex communication.
    D   supports only one master device on the bus.   (1)
    [15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1   Explain the term *machinery* with reference to the Occupational Health and Safety Act, 1993 (Act 85 of 1993).   (2)

2.2   Explain the term *critical incident* with regard to emergencies.   (2)

2.3   State TWO steps you should take when you discover a fire in an electrical workshop.   (2)

2.4   State the importance of wearing a face mask in the workshop.   (2)

2.5   Name TWO environmental considerations when working with chemicals during the printed circuit board manufacturing process.   (2)

[10]

QUESTION 3: SWITCHING CIRCUITS

3.1   Name the type of multivibrator that:

3.1.1   Produces one pulse cycle of 'high' and 'low' when a trigger pulse is applied to its input   (1)

3.1.2   Changes state when a trigger pulse is applied and remains in that state   (1)

3.2   Refer to FIGURE 3.2 below and answer the questions that follow.
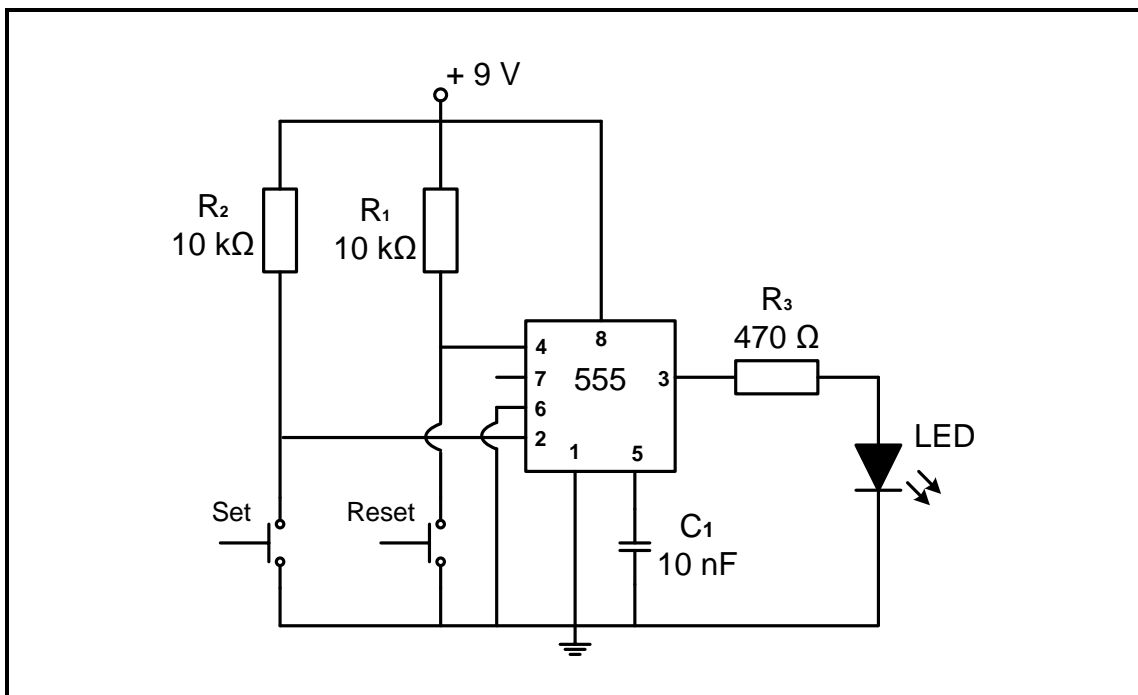
FIGURE 3.2: BI-STABLE MULTIVIBRATOR

3.2.1   Name the function of resistors:

(a) **R_1**   (1)

(b) **R_3**   (1)

3.2.2   Identify the state of the LED when trigger pin 2 is high.   (1)

3.2.3   Explain what happens in the circuit when the set switch is pressed.   (2)

3.2.4   Explain the purpose of connecting pin 6 to ground.   (2)

3.3 FIGURE 3.3 below shows an op amp as a comparator. The resistance of the LDR increases as the level of light falls.
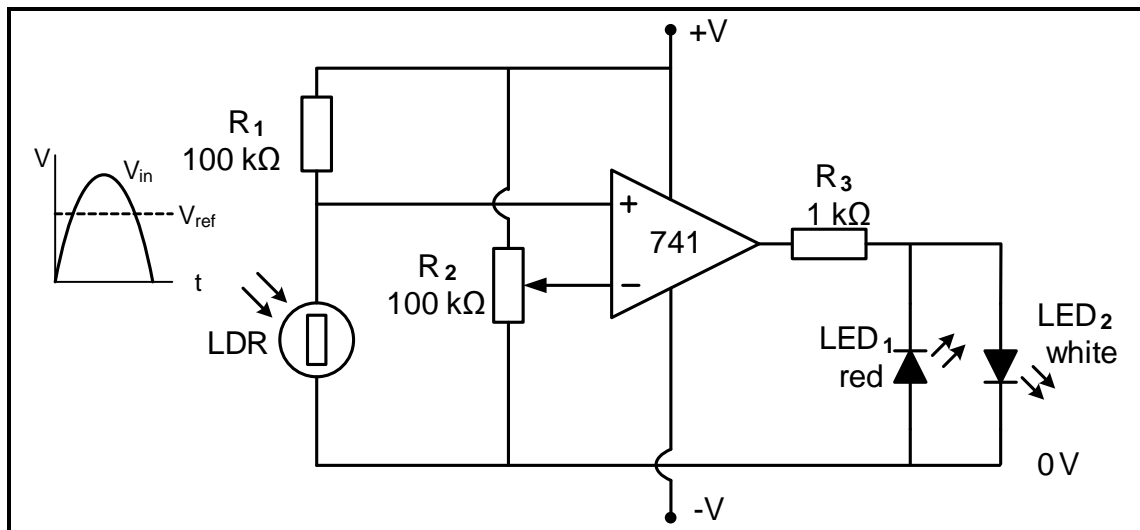
FIGURE 3.3: OP AMP COMPARATOR AS A DARK SENSOR

3.3.1 State the purpose of **R$_2$**. (1)

3.3.2 Explain how an increase in the level of light affects the voltage on the non-inverting input. (2)

3.3.3 Explain the operation of the circuit with reference to the voltages on the input terminals and the output voltage. (3)

3.3.4 Predict the state of **LED$_1$** and **LED$_2$** when the voltage on the inverting terminal is higher than the voltage on the non-inverting terminal. (2)

3.3.5 Draw the output on the ANSWER SHEET for QUESTION 3.3.5. (3)

3.4   Refer to FIGURE 3.4 below and answer the questions that follow.
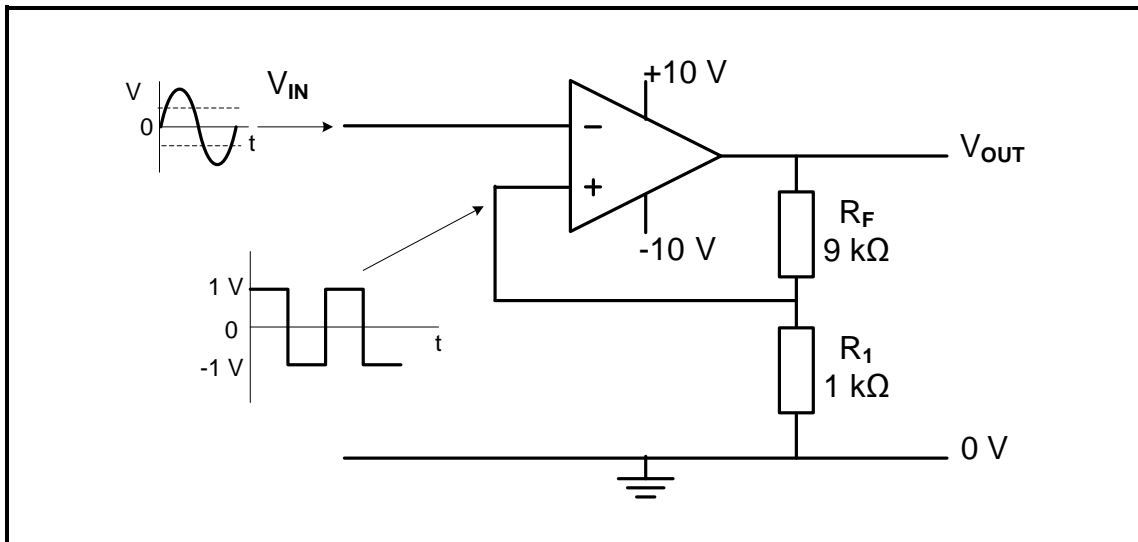
FIGURE 3.4: SCHMITT TRIGGER

3.4.1   Identify the type of Schmitt trigger circuit.   (1)

3.4.2   Determine the value of the output voltage when the voltage on the non-inverting input is -1 V.   (1)

3.4.3   State whether this circuit uses positive or negative feedback.   (1)

3.4.4   Explain the operation of the circuit with reference to the input and trigger voltage levels.   (4)

3.4.5   Predict how an increase in the value of **R₁** will affect the trigger voltage level.   (1)

3.4.6   Draw the output signal on the ANSWER SHEET for QUESTION 3.4.6.   (4)

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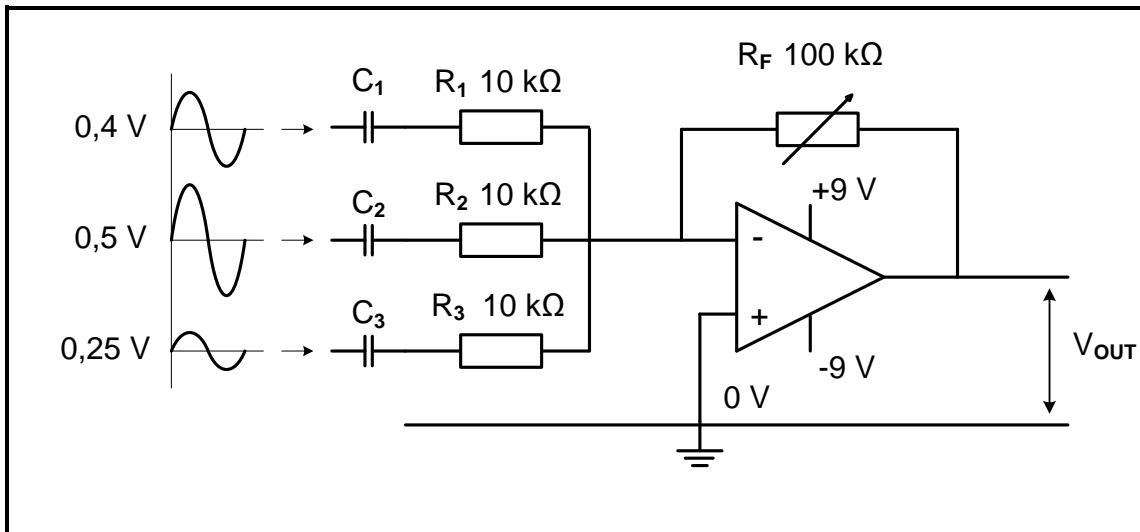
FIGURE 3.5: SUMMING AMPLIFIER

3.5.1   The variable resistor R_F serves a dual purpose. Name both
          purposes.   (2)

3.5.2   Calculate the output voltage when the value of R_F is set to
          78,26 kΩ.   (3)

3.5.3   Explain how an increase in the value of R_F affects the gain of the
          amplifier.   (1)

3.5.4   Describe why it is not recommended to increase the value of R_F
          beyond 78,26 kΩ.   (4)

3.5.5   Explain how this limitation can be overcome without changing the
          value of any of the resistors.   (2)

3.6   Refer to FIGURE 3.6 below and answer the questions that follow.
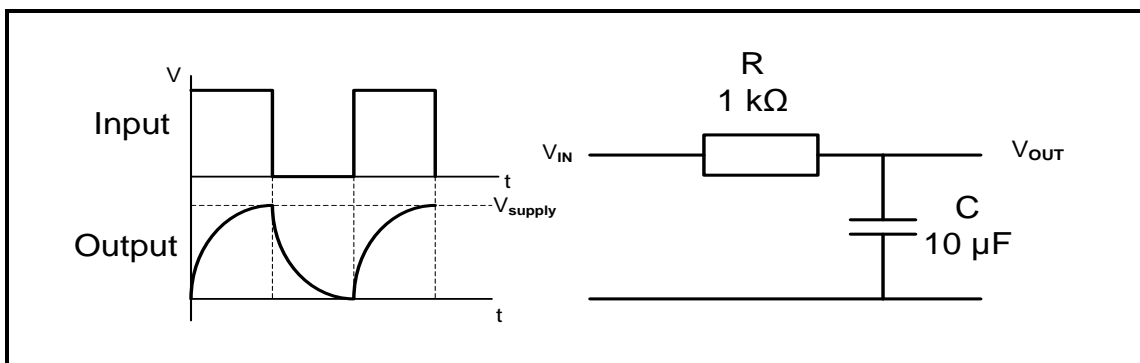
FIGURE 3.6: PASSIVE RC INTEGRATOR

3.6.1   Draw the output when the value of C is changed to 1 µF on the
          ANSWER SHEET for QUESTION 3.6.1.   (3)

3.6.2   Draw the output when the value of C is changed to 100 µF on the
          ANSWER SHEET for QUESTION 3.6.2.   (3)

                                                                          [50]

QUESTION 4: SEMICONDUCTOR DEVICES

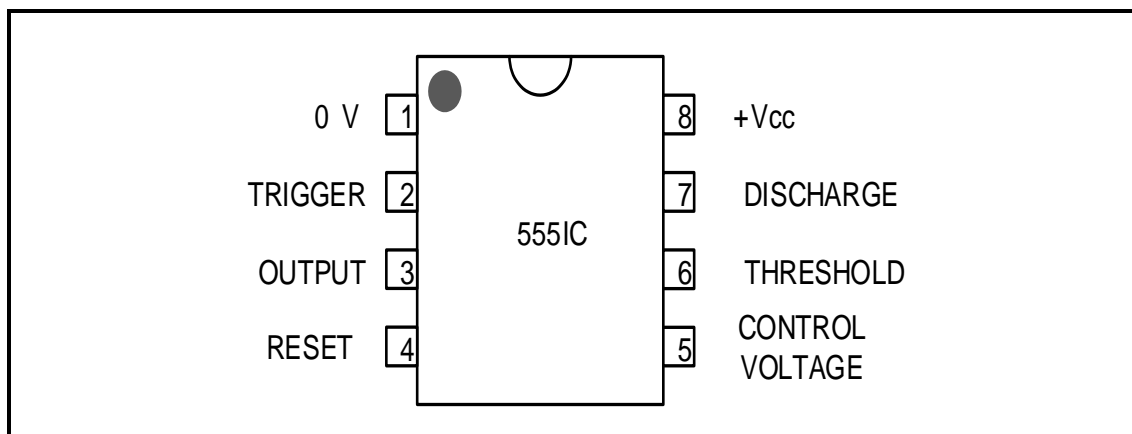4.1 FIGURE 4.1 below shows the 555 IC. Answer the questions that follow.

FIGURE 4.1: 555 IC PIN LAYOUT

4.1.1 Briefly describe the functions of pin 6 with reference to the 555 IC. (3)

4.1.2 State the supply voltage range at which the 555 IC operates. (2)

4.1.3 Explain the function of the SR flip-flop in the internal circuit of the 555 timer. (2)

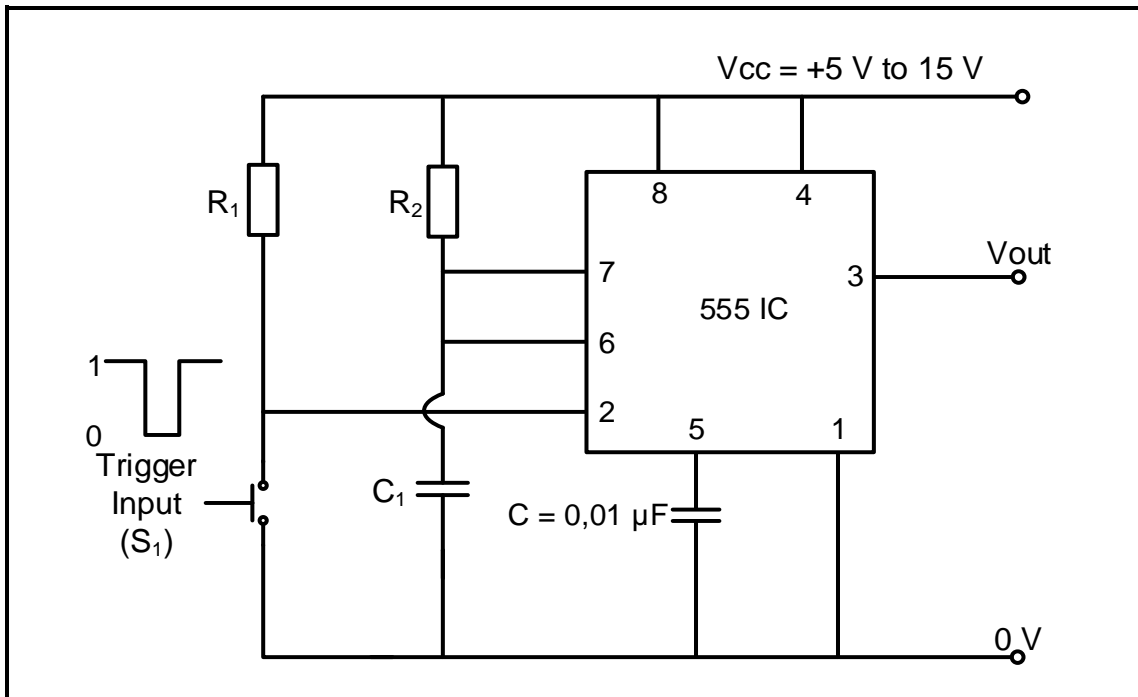4.2   Refer to FIGURE 4.2 below and answer the questions that follow.

FIGURE 4.2: 555 IC MULTIVIBRATOR

4.2.1   Identify the multivibrator in FIGURE 4.2.   (1)

4.2.2   Give a brief description of what happens when the push-to-make switch (S_1) is activated.   (4)

4.2.3   Draw on the ANSWER SHEET for QUESTION 4.2.3 the voltage waveform of the capacitor **C_1** and the output voltage waveform when the trigger input is pressed.   (4)

4.3   Refer to the astable multivibrator in FIGURE 4.3 below which has an output frequency of 1 hertz. Answer the questions that follow.
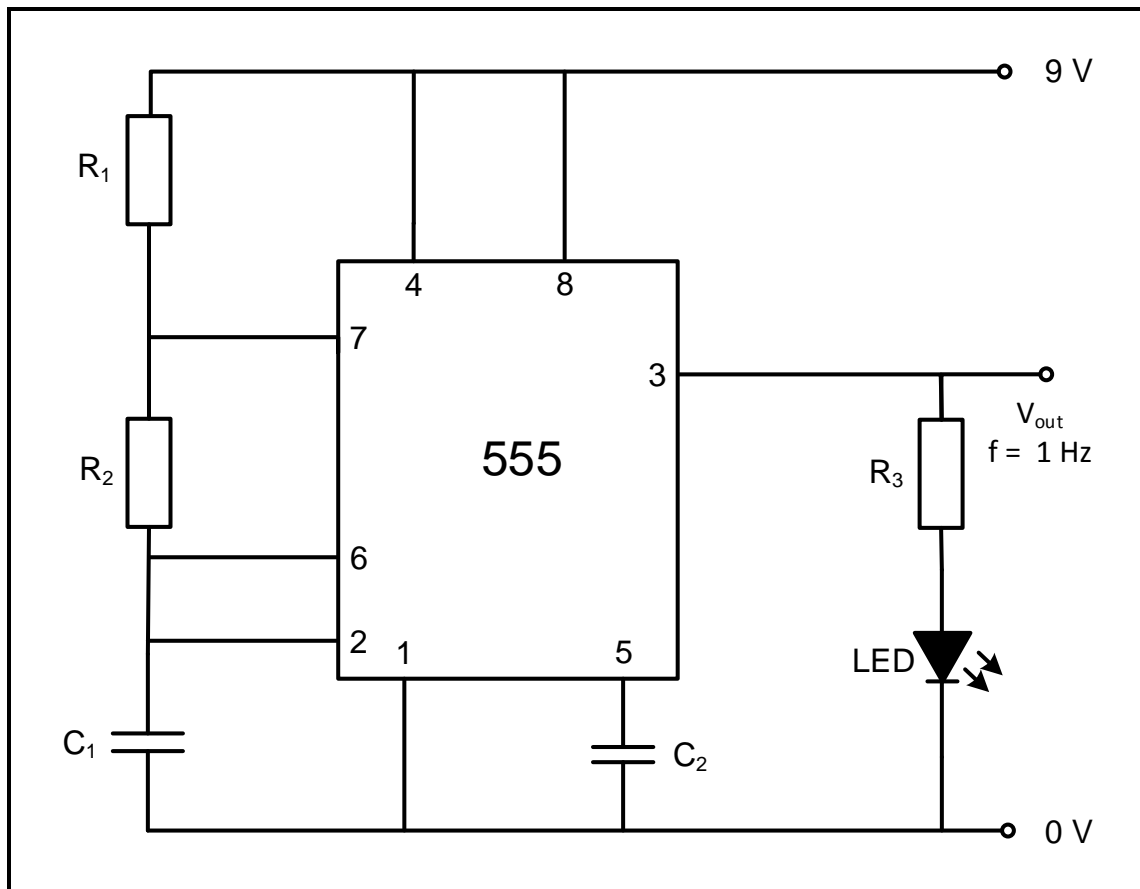
FIGURE 4.3: ASTABLE MULTIVIBRATOR

4.3.1   Explain the mode (state) of the LED.   (2)

4.3.2   Explain the effect on the LED when:

(a) R_2 is halved   (1)

(b)   The value of C_1 is doubled   (1)

[20]

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

5.1   Answer the following questions with reference to the seven-segment LED display.

    5.1.1   Describe the difference between *common-anode* and *common-cathode connections*. (2)

    5.1.2   Draw the circuit of a sourcing digital output using an LED and a transistor. Indicate the direction of current flow at the output. (5)

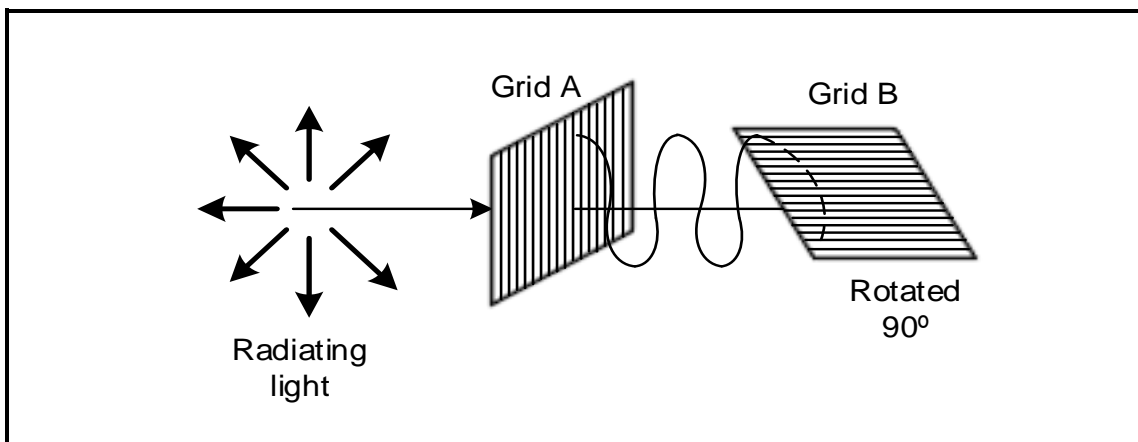5.2   Refer to FIGURE 5.2 below and answer the questions that follow.

FIGURE 5.2: POLARISING GRIDS

    5.2.1   Explain the process when light waves pass through grid A. (2)

    5.2.2   State the effect that grid B has on the light waves. (1)

5.3   Answer the following questions with reference to encoders and decoders.

    5.3.1   Complete the circuit diagram of a three-digit decimal input to two-bit binary output encoder on the ANSWER SHEET for QUESTION 5.3.1. (6)

5.3.2   FIGURE 5.3.2 below shows a circuit diagram of a two-digit binary input to four-digit decimal output decoder. Determine the output at **W**, **X**, **Y** and **Z** when input A is '0_2' and input B is '1_2'.
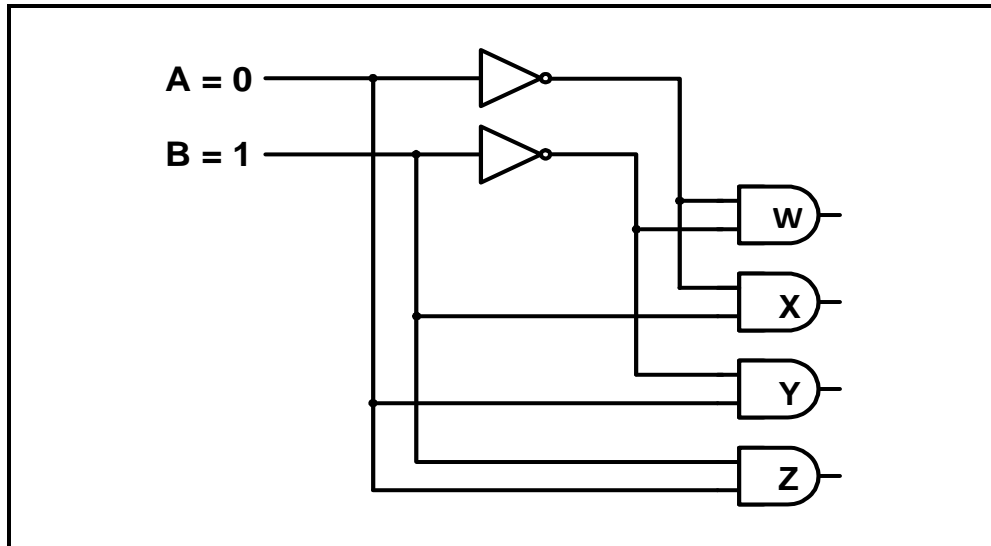

FIGURE 5.3.2   (4)

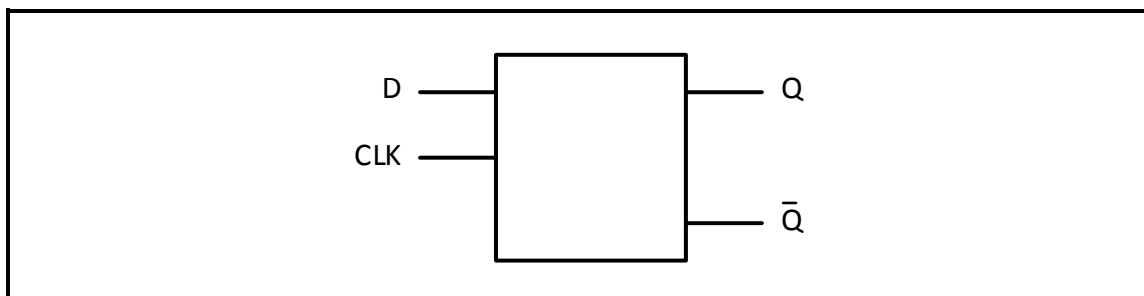5.4   FIGURE 5.4 below represents the logic symbol of a D-type flip-flop.

FIGURE 5.4

5.4.1   Complete the logic circuit of this flip-flop using the information given on the ANSWER SHEET for QUESTION 5.4.1.   (6)

5.4.2   Complete the truth table of this flip-flop in the table below on the ANSWER SHEET for QUESTION 5.4.2.

INPUTS		OUTPUTS	
CLK	**D**	**Q**	**$\overline{Q}$**
0	0	Latch	
0	1		
1	0		
1	1		

TABLE 5.4.2   (3)

5.5   FIGURE 5.5 below represents the logic symbol of a full adder. Complete the logic circuit of the full adder using the information given on ANSWER SHEET 5.5.
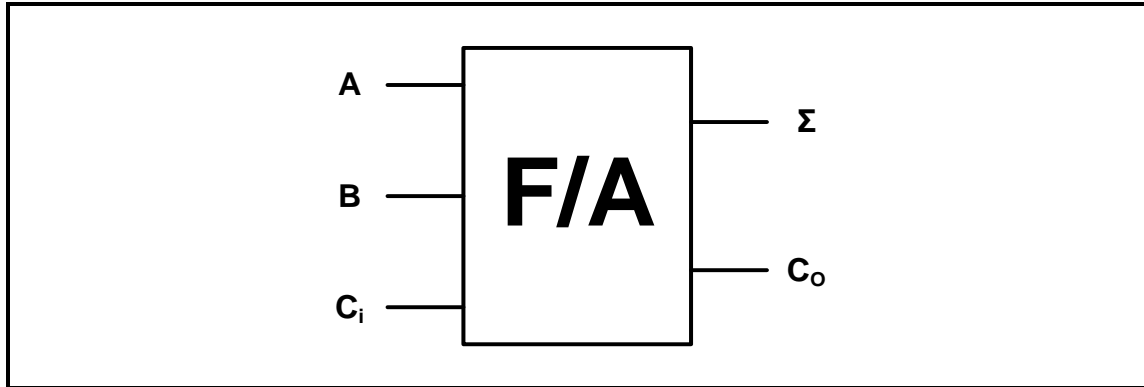

FIGURE 5.5   (8)

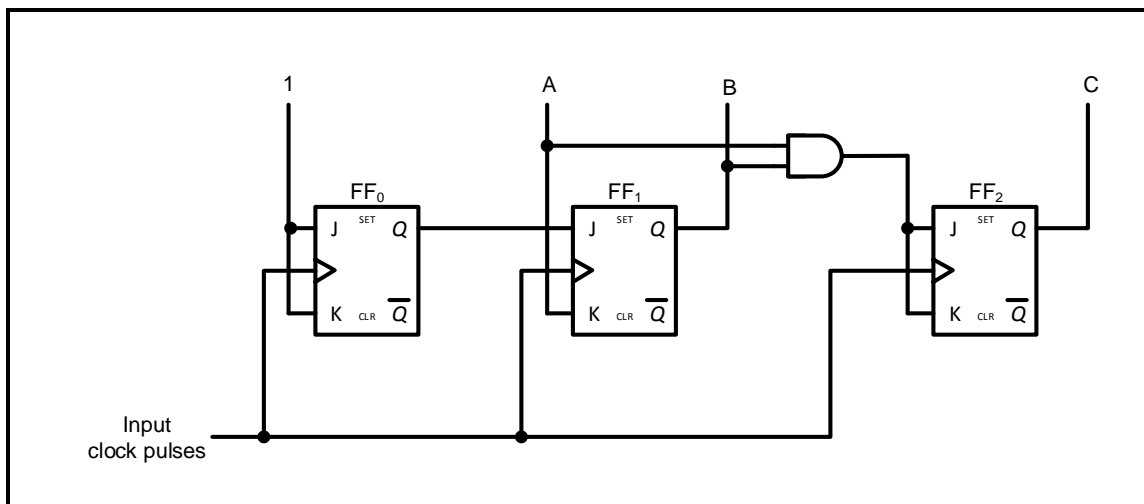5.6   Refer to FIGURE 5.6 below of a three-stage binary counter and answer the questions that follow.

FIGURE 5.6 THREE-STAGE BINARY COUNTER

5.6.1   Complete the timing diagrams for this counter on the ANSWER SHEET for QUESTION 5.6.1.   (8)

5.6.2   State whether the circuit in FIGURE 5.6 is synchronous or asynchronous.   (1)

5.7   State TWO applications of the up/down counter.   (2)

5.8   Complete the sketch of a 4-bit serial-in: serial-out shift register using the information given on the ANSWER SHEET for QUESTION 5.8.   (7)

[55]

QUESTION 6: MICROCONTROLLERS

6.1   Name TWO uses of a microcontroller in industrial control devices.   (2)

6.2   Draw the sequential operating (scan) cycle of the CPU.   (4)

6.3   Explain the difference between a *microprocessor* and a *microcontroller* with reference to the hardware of microcontrollers.   (4)

6.4   Refer to registers within the CPU and answer the questions that follow.

    6.4.1   Explain the function of a memory data register (MDR).   (2)

    6.4.2   Explain the function of a current instruction register (CIR).   (3)

6.5   Refer to communication in a microcontroller and define the term *hardware interface*.   (2)

6.6   Draw a block diagram of full duplex communication.   (4)

6.7   Answer the following questions with reference to serial communication interface.

    6.7.1   Write out the abbreviation *UART* in full.   (1)

    6.7.2   List THREE advantages of the UART.   (3)

    6.7.3   Explain the operation of the UART.   (6)

6.8   Answer the questions that follow with reference to communication protocols.

    6.8.1   Name THREE applications of the RS-485.   (3)

    6.8.2   State the line configuration of the RS-485.   (1)

6.9   State the purpose of an analogue-to-digital-converter (ADC) with reference to the hardware of microcontrollers.   (3)

6.10   Explain the relationship between *algorithms* and *flowcharts* with reference to the software of microcontrollers.   (4)

6.11   Complete the flow chart of a monitoring system at a fuel station on the ANSWER SHEET for QUESTION 6.11.

A fuel station has three tanks, each with a level-monitoring sensor. The sensors will be activated when the fuel level reaches the bottom of each tank. The alarm will sound if any of the sensors is activated. The system must include a reset function. NO time delay is needed.   (8)

[50]

TOTAL: 200

FORMULA SHEET

SEMICONDUCTOR DEVICES

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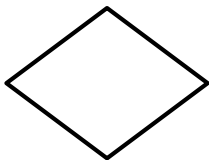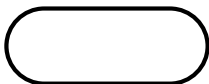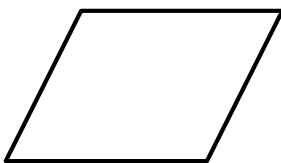
$V_{OUT} = V_{IN} \times \left(-\dfrac{R_F}{R_{IN}}\right)$

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

SWITCHING CIRCUITS

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

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

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

FLOW CHART SYMBOLS

Process

Decision

Terminator

Data

CENTRE NUMBER:							

EXAMINATION NUMBER:													

ANSWER SHEET

QUESTION 3: SWITCHING CIRCUITS

3.3.5

FIGURE 3.3.5 (3)

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3.4.6

FIGURE 3.4.6 (4)

Transfer mark to answer book

MOD

CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET

3.6.1

V

Input

t

V**supply**

Output

Transfer mark to
answer book

MOD

FIGURE 3.6.1 (3)

3.6.2

V

Input

t

V**supply**

Output

Transfer mark to
answer book

MOD

FIGURE 3.6.2 (3)

CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET

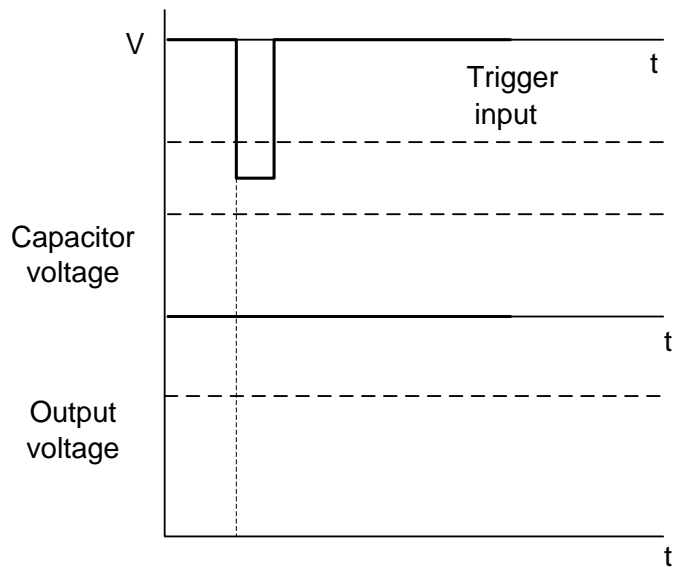**QUESTION 4: SEMICONDUCTORS**

4.2.3

FIGURE 4.2.3

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MOD

(4)

CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET

QUESTION 5: DIGITAL AND SEQUENTIAL DEVICES

5.3.1

FIGURE 5.3.1   (6)

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CENTRE NUMBER: | | | | | | |

EXAMINATION NUMBER: | | | | | | | | | | | |

ANSWER SHEET

5.4.1

D

CLK

Q

Q̅

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answer book

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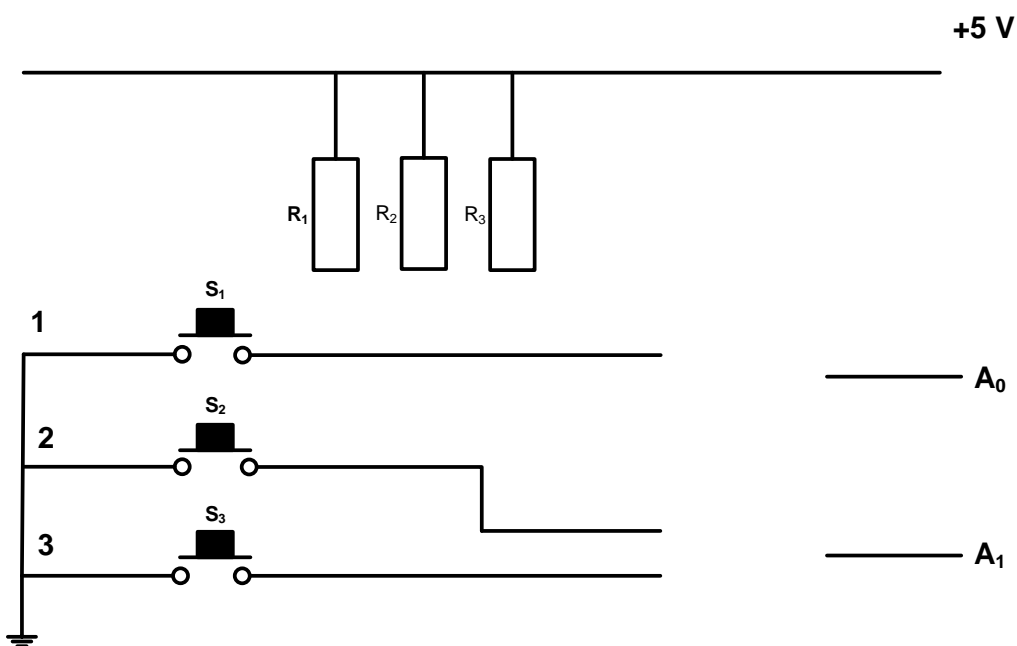
FIGURE 5.4.1 (6)

CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET

5.4.2

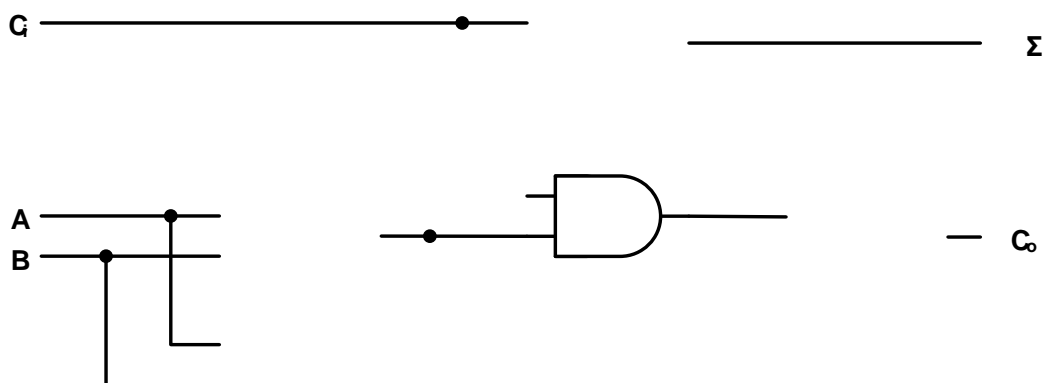| INPUTS		OUTPUTS	
CLK	**D**	**Q**	**$\overline{Q}$**
0	0	Latch	
0	1		
1	0		
1	1		

Transfer mark to answer book

MOD

TABLE 5.4.2   (3)

5.5

Transfer mark to answer book
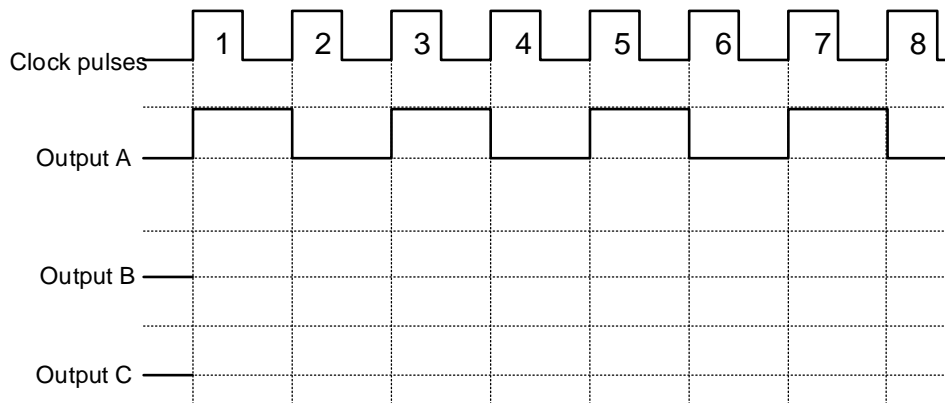
MOD

FIGURE 5.5   (8)
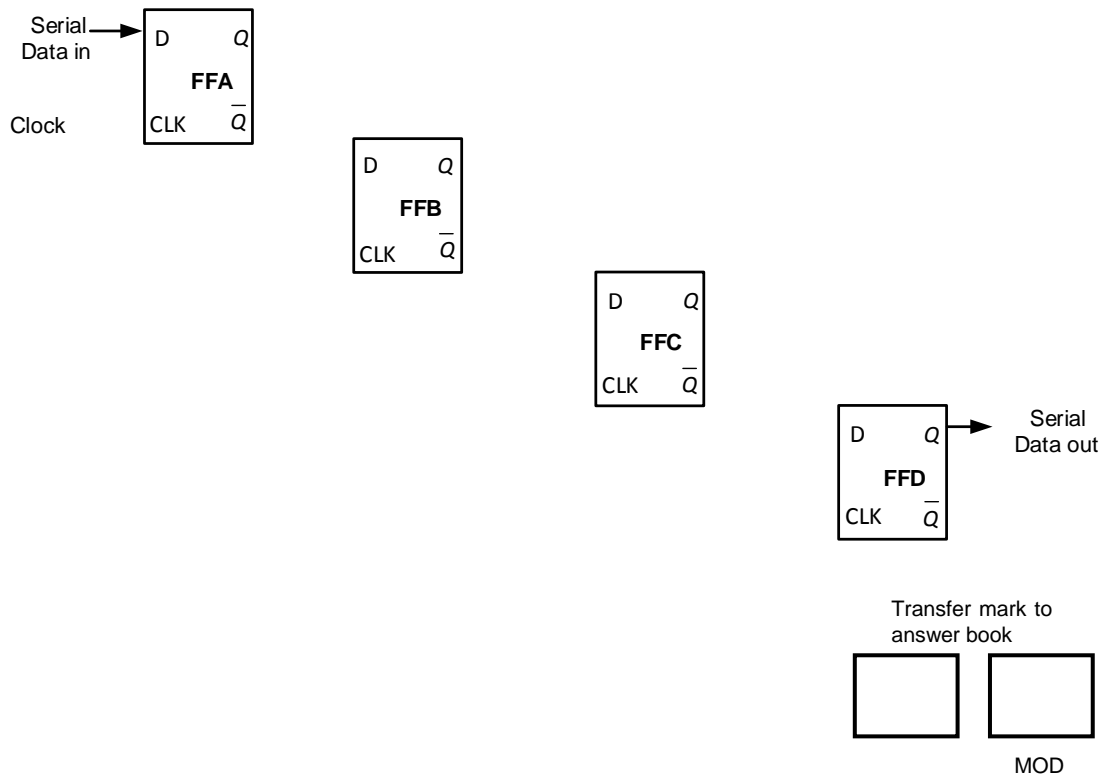
CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET

5.6.1

Clock pulses — | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

Output A

Output B

Output C

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answer book

MOD

FIGURE 5.6.1 (8)

CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET

5.8

Serial Data in →	D Q
	FFA
Clock	CLK $\overline{Q}$

| D   Q |
| **FFB** |
| CLK $\overline{Q}$ |

| D   Q |
| **FFC** |
| CLK $\overline{Q}$ |

| D   Q | → Serial Data out |
| **FFD** |
| CLK $\overline{Q}$ |

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FIGURE 5.8   (7)

CENTRE NUMBER:

EXAMINATION NUMBER:

ANSWER SHEET

QUESTION 6: MICROCONTROLLERS

6.11

Start

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answer book

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FIGUUR 6.11 (8)