Surname	Centre Number	Candidate Number
First name(s)		2

GCE AS

B490U10-1

S23-B490U10-1

eduqas Part of WJEC

TUESDAY, 23 MAY 2023 – AFTERNOON

ELECTRONICS – AS component 1
Principles of Electronics

2 hours 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**10**	
2.	**11**	
3.	**10**	
4.	**13**	
5.	**10**	
6.	**8**	
7.	**20**	
8.	**17**	
9.	**9**	
10.	**12**	
Total	**120**	

B490U101
01

ADDITIONAL MATERIALS

You will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.
You may use a pencil for graphs and diagrams only.
Write your name, centre number and candidate number in the spaces at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.
The assessment of the quality of extended response (QER) will take place in questions **6**(b) and **10**(a).

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Answer **all** questions.

1. (a) Simplify the following expressions. [2]

(i) $\overline{A}.\overline{B}+A.\overline{B}$ ....

(ii) $\overline{B}.(A+B)$ ....

(b) Use a Karnaugh map to simplify the following equation as much as possible. [4]

$$Q=\overline{D}.C.B.A+D.C.B+D.\overline{B}.\overline{A}+\overline{D}.\overline{C}.\overline{B}.\overline{A}+D.B.\overline{A}$$

DC \ BA	00	01	11	10
00				
01				
11				
10				

Q = ...

(c) Apply de Morgan's theorem to the following equation and simplify it. [4]

$$Q=\overline{\overline{A}.B.(B+C}\,)$$

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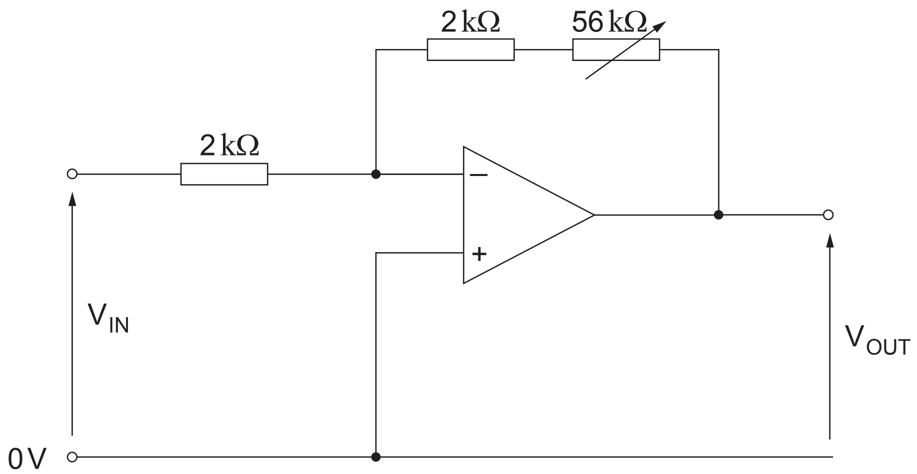
2. The circuit diagram below shows an op-amp set up as a voltage amplifier. The variable resistor allows the user to change the gain of the amplifier.
The output saturates at ±18 V.



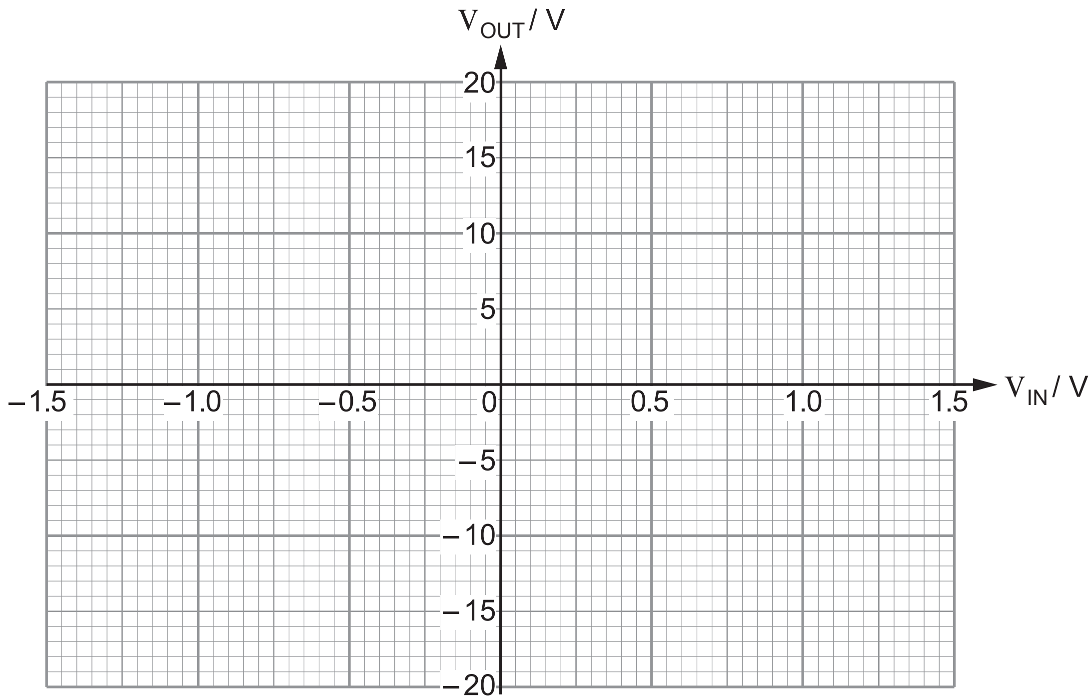
(a) Calculate the maximum and minimum voltage gains of this amplifier. [2]

Maximum gain = ...

Minimum gain = ...

(b) The variable resistor is adjusted to give a voltage gain of –20.

(i) Draw the voltage transfer characteristics of this amplifier for input voltages between ± 1.5 V. [3]



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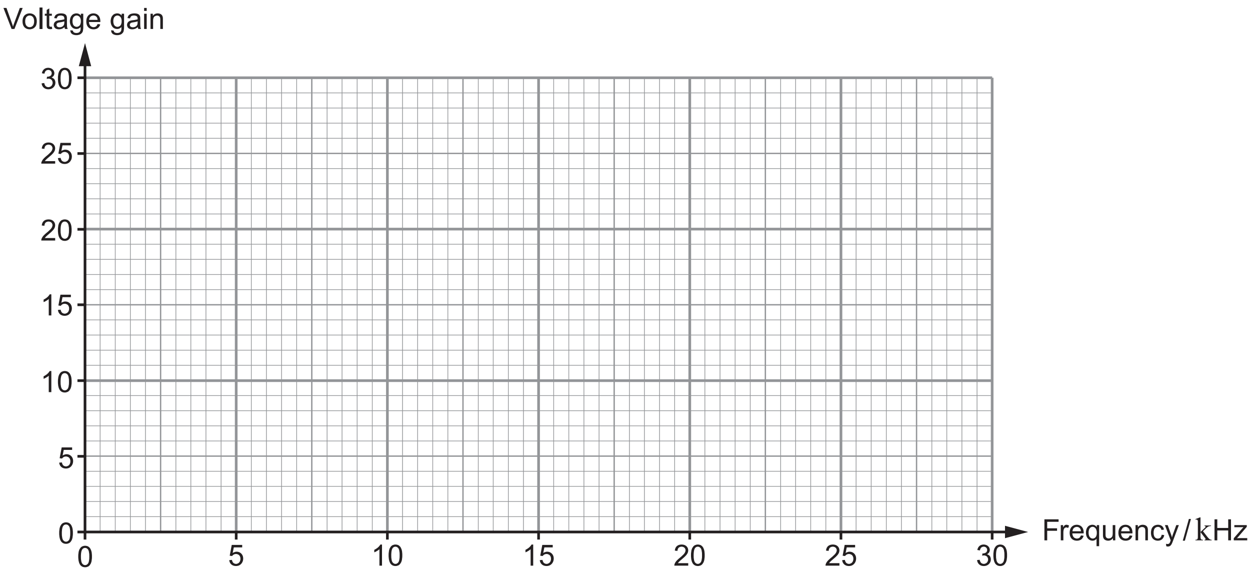
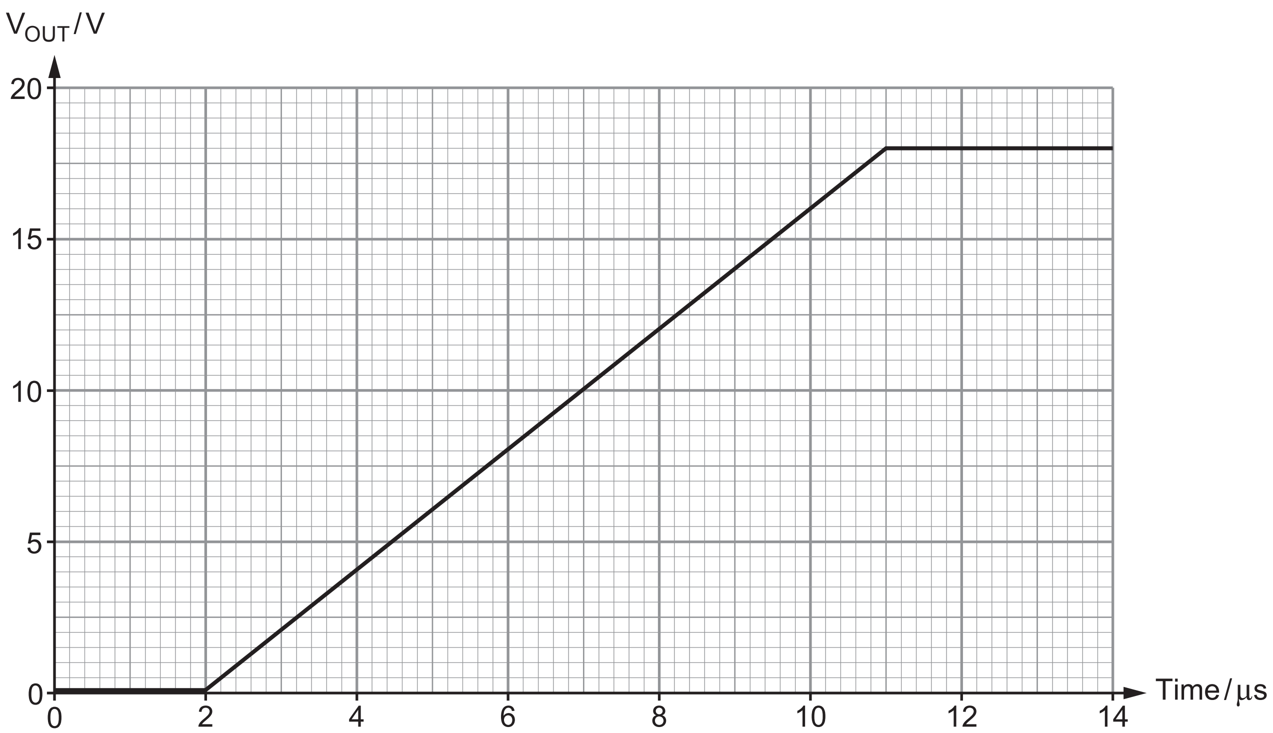
(ii) The amplifier has a bandwidth of 24 kHz.

Draw the frequency response of the amplifier on the grid below. [3]



(c) The following graph shows how the output voltage of the amplifier responds to a large step input voltage.



Calculate the slew rate of this amplifier. [3]

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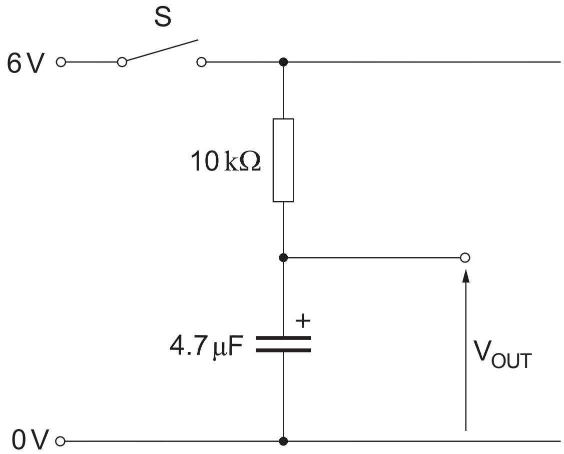
 (B490U10-1) **Turn over.**

3. The capacitor shown in the following circuit is initially discharged.



(a) (i) Calculate the time taken for V_{OUT} to reach 3 V when switch S is closed. [2]

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(ii) Calculate V_{OUT} after 100 ms. [3]

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(iii) Estimate the time for V_{OUT} to reach 6 V. [1]

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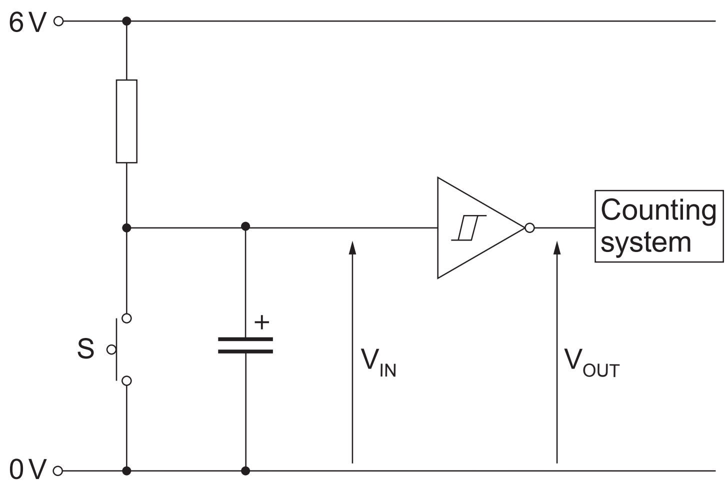
(b) A capacitor-resistor combination is used with a Schmitt inverter to debounce the switch in the following circuit.



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The Schmitt inverter has the following data sheet.

- Supply voltage 6 V.
- The output changes from logic 0 to logic 1 when the **falling** input voltage reaches 2.5 V.
- The output changes from logic 1 to logic 0 when the **rising** input voltage reaches 3.5 V.

(i) Why is a debounce sub-system required in this circuit? [1]

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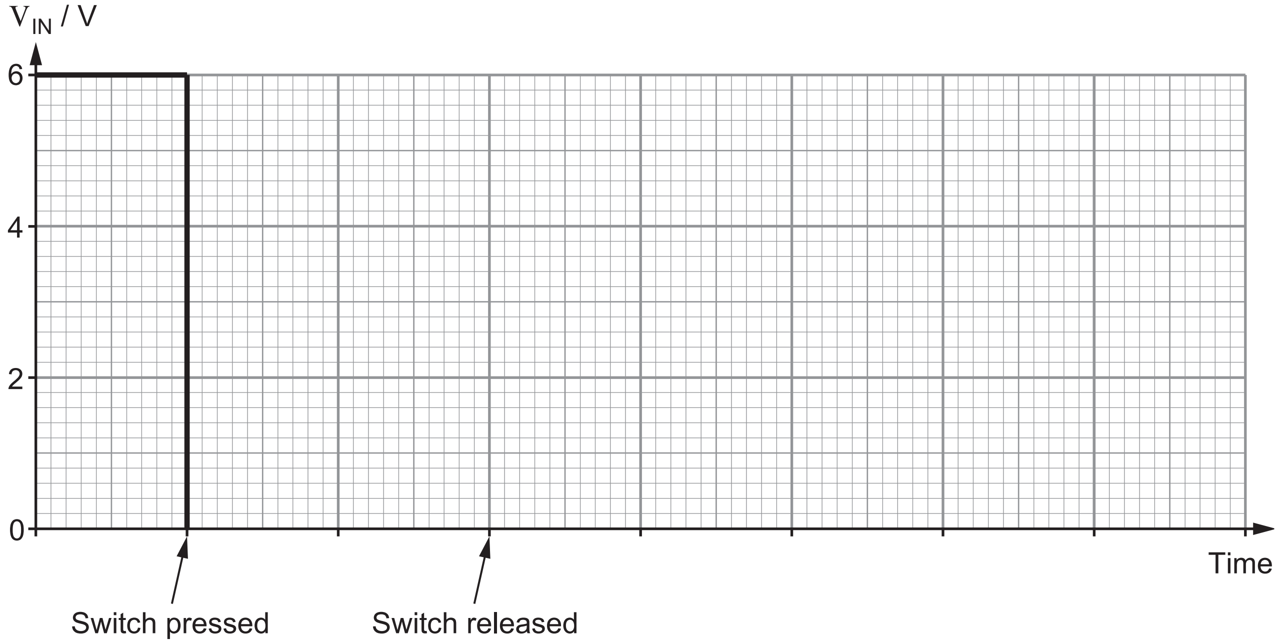
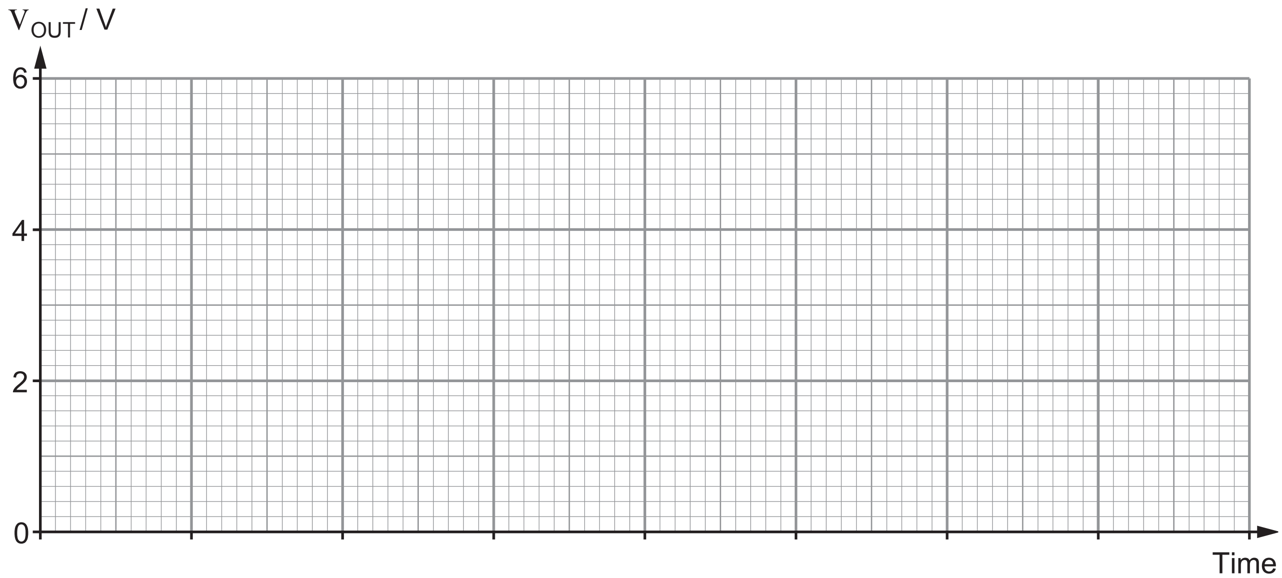
(ii) Complete the graph of V_{IN} against time and then sketch the graph of V_{OUT} against time. The times at which the switch is pressed and released are shown. [3]





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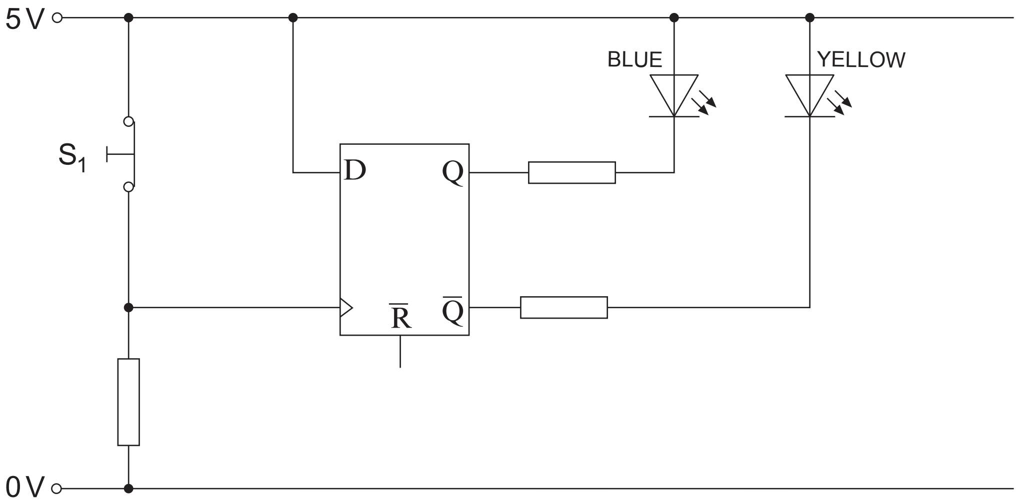
4. A student designs a system to indicate that a fire door has been opened.



(a) (i) The reset is active low. What does this mean? [1]

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(ii) **Add the necessary components** to the diagram such that the D-type flip-flop can be reset with the momentary press of a switch S_2. [2]

(b) The D-type is rising-edge-triggered and is initially reset.

(i) Explain what happens to the blue and yellow LEDs when the switch S_1 is initially open, then closed and opened again. [3]

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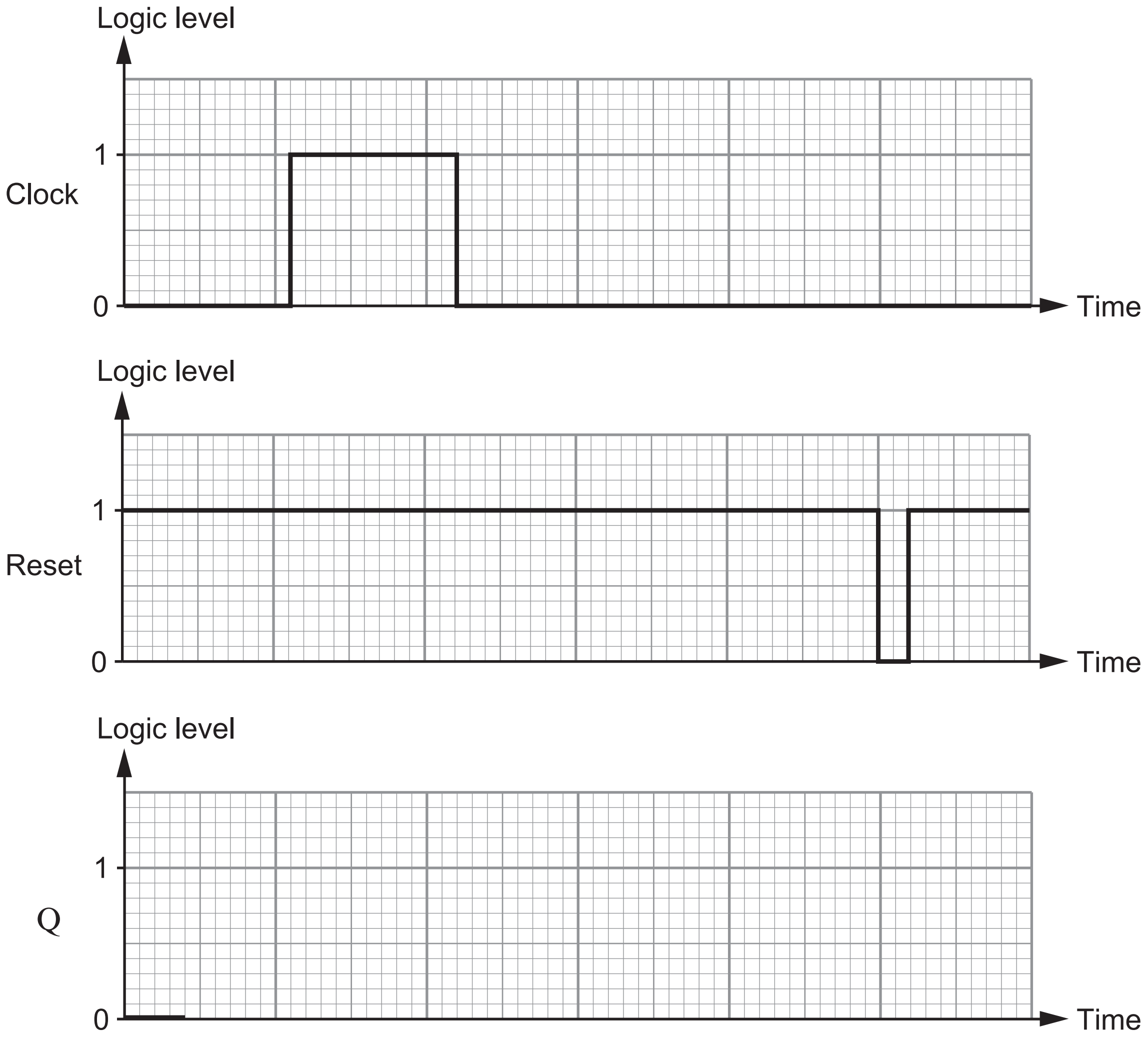
(ii) The signals shown in the timing diagrams below are applied to the D-type. Complete the timing diagram for output Q. [2]



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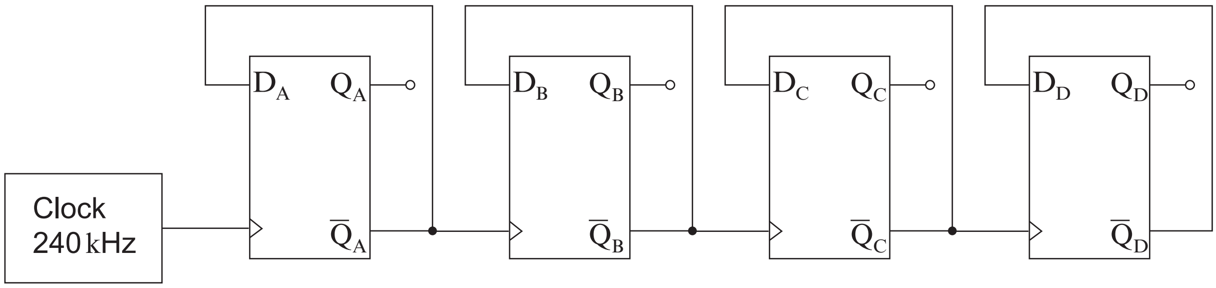
(c) The clock in the following diagram produces a square wave output of 240 kHz. This is fed into the series of 4 D-type flip-flops shown here.



(i) What is the frequency at the output Q_A? [1]

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(ii) Which output will produce a frequency of 30 kHz? [1]

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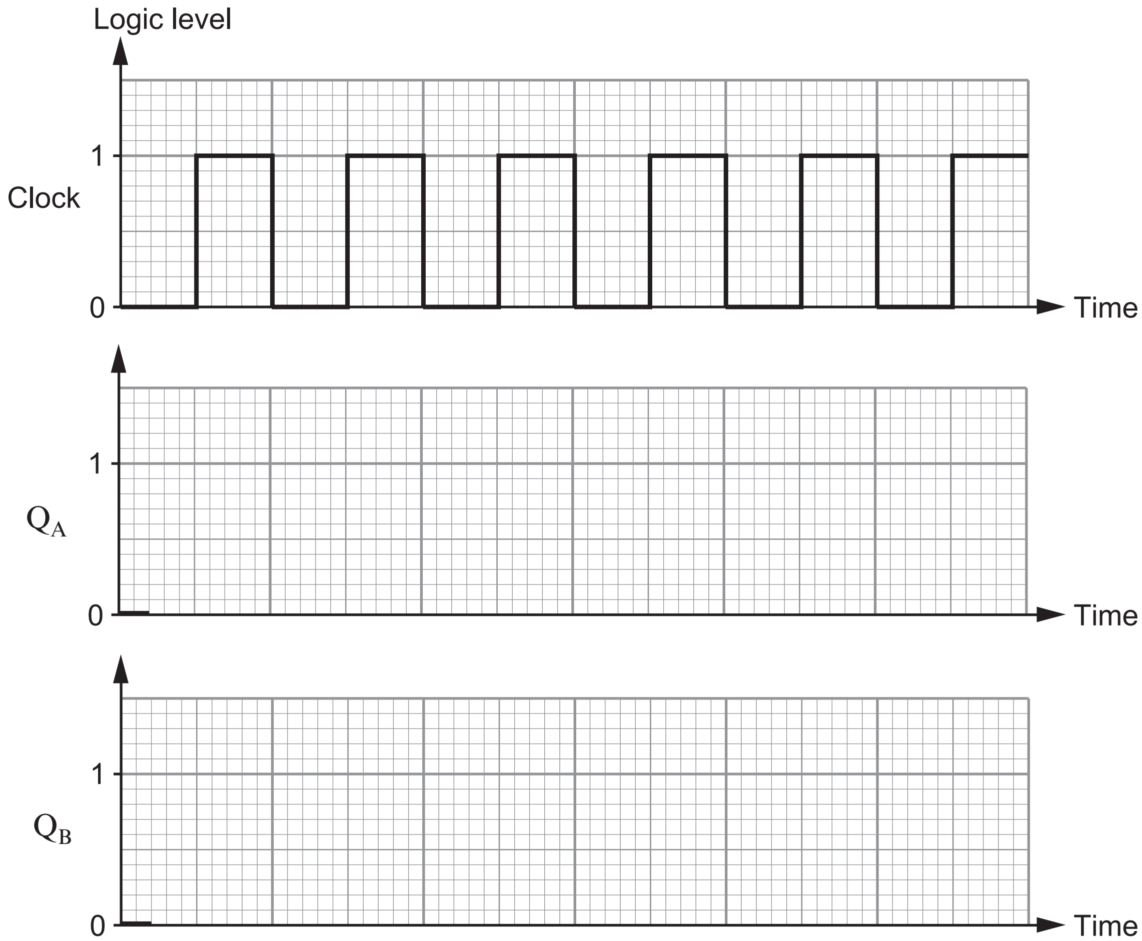
(iii) The timing diagram below shows the output from the clock.
Complete the diagram to show the signal at outputs Q_A and Q_B. [3]



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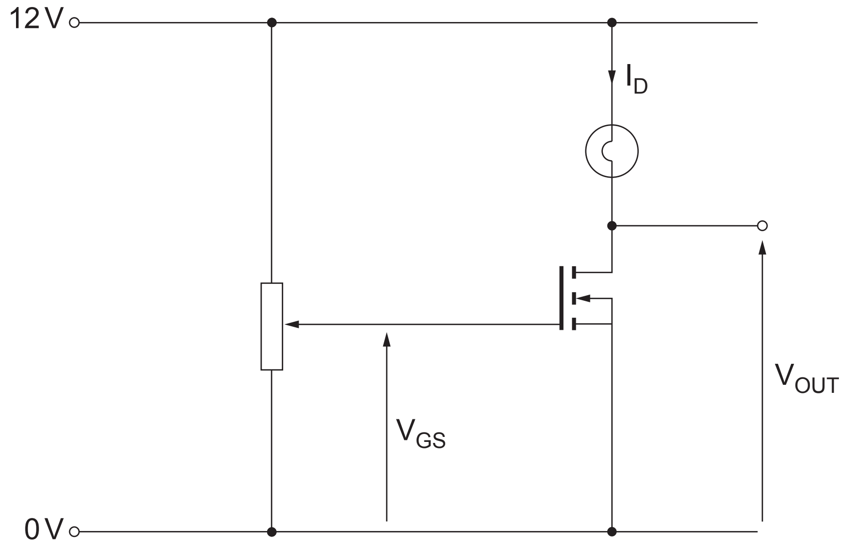
5. The following circuit is set up to check a parameter of a MOSFET.



(a) The table shows the results obtained for I_D as the value of V_{GS} is gradually increased from 0 to 8 V.

V_{GS} / V	I_D / A
0	0
1.0	0.01
2.0	0.02
3.0	0.20
4.0	3.4
5.0	6.6
6.0	9.7
7.0	11.0
8.0	11.0

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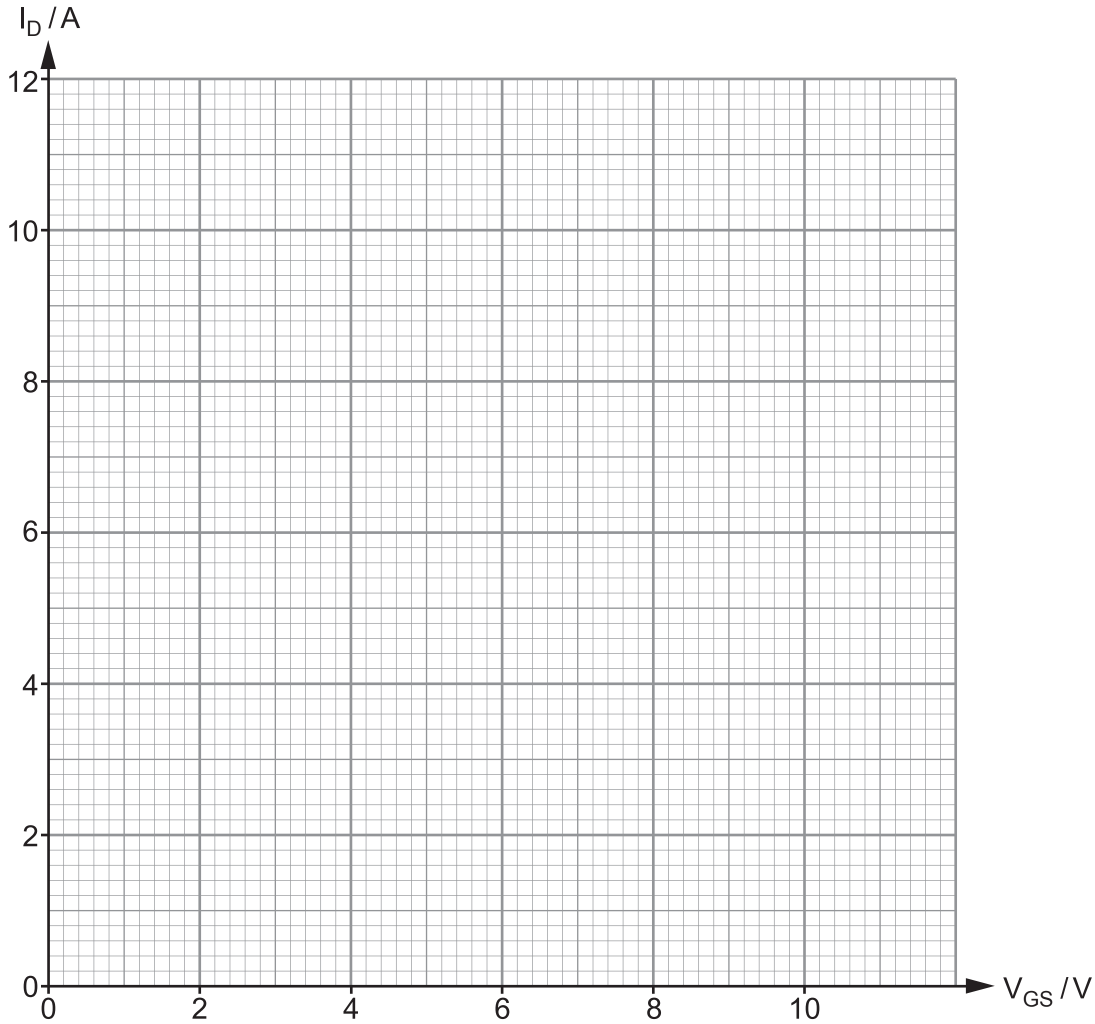
Plot the graph of I_D against V_{GS} on the axes below. [3]



(b) Use the graph to determine:

(i) the value of g_M. [3]

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(ii) the value of V_{GS} at which the MOSFET just saturates. [1]

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(c) V_{OUT} = 1.38 V when the MOSFET just saturates. Calculate the value of r_{DSon}. [3]

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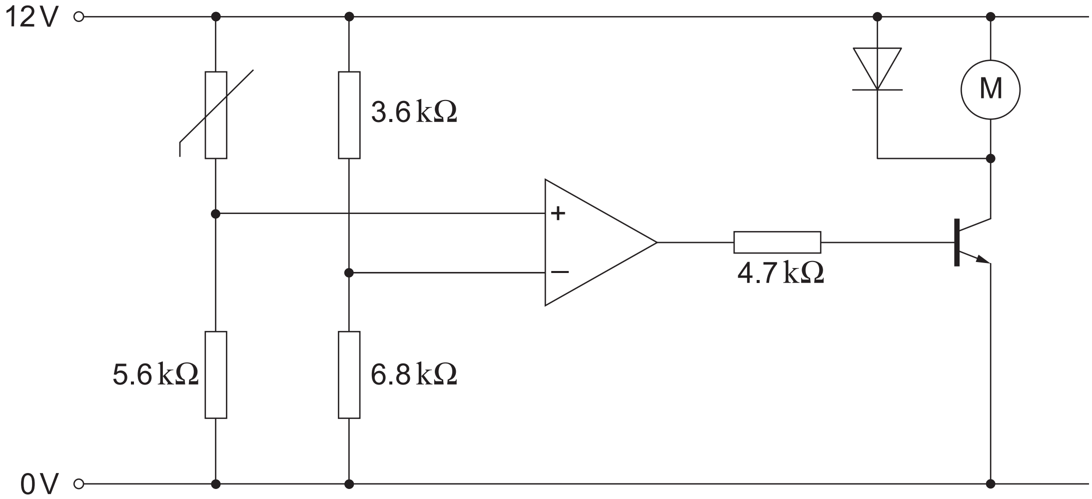
6. A fan is used to prevent overheating in a computer. A design for the system is shown below.



(a) The thermistor has a resistance of 2.9kΩ at 38°C. What is the voltage at the non-inverting input at 38°C? [2]

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(b) The circuit specification includes:

- To operate from a 12V power supply
- The fan comes on at a temperature of 38°C

In the proposed solution:

- The fan motor requires a current of 120mA
- The current gain of the transistor is 40
- The output of the comparator saturates at 0.4V below the supply voltage.

Evaluate the proposed design against the circuit specification and suggest any improvements required to meet the specification fully. [6 QER]

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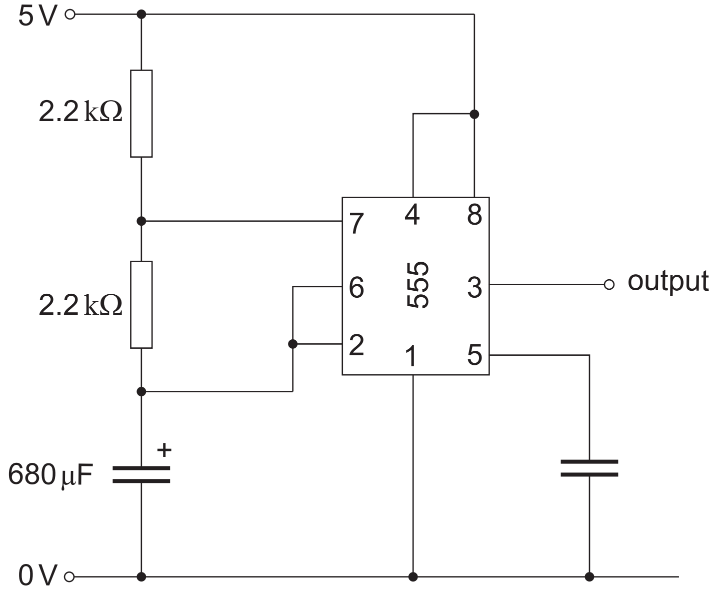
7. (a) The diagram shows an astable circuit.



(i) Calculate the value of the mark-space ratio for the astable. [2]

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(ii) Calculate the duration of the space and hence sketch one complete cycle of the output waveform. Add a suitable scale on the time axis. [4]

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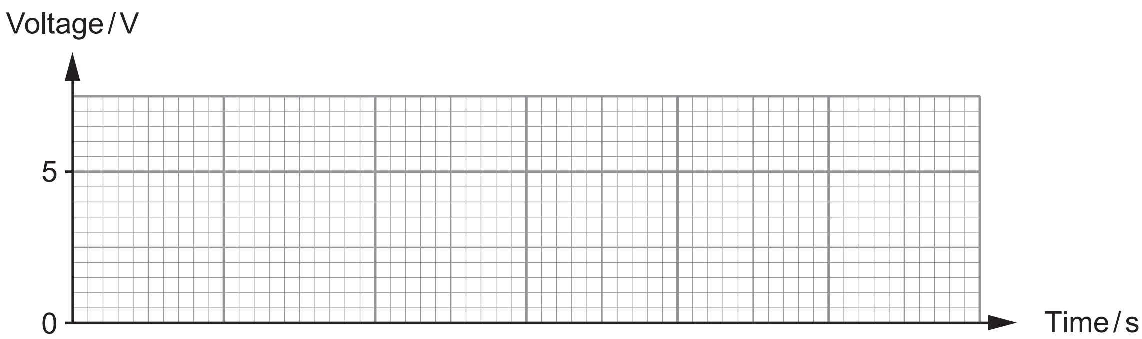

(iii) Calculate the frequency of the output. [2]

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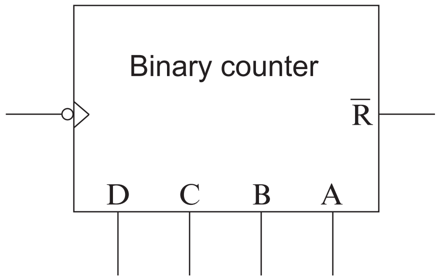
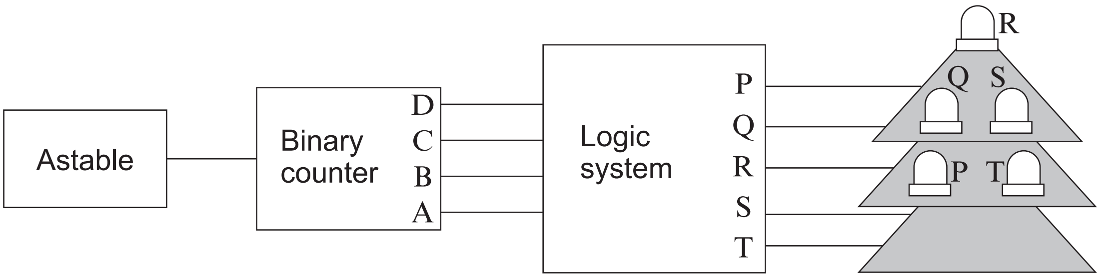
(b) A binary counter is shown below. Add a logic gate and the connections necessary to make the counter reset on the fifth clock pulse. [2]



(c) The astable and counter are used as part of a Christmas decoration.



An LED is on when the corresponding output is high.

The LEDs flash in the sequence specified by the following Boolean equations:

$$P = T = \overline{B.A}$$

$$Q = S = A + C$$

$$R = B.\overline{A} + C$$

Complete the truth table to show the sequence of outputs produced. [3]

Clock pulse	C	B	A	P	Q	R	S	T
0	0	0	0					
1	0	0	1					
2	0	1	0					
3	0	1	1					
4	1	0	0					
5	Counter resets here							

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(d) Design a suitable logic system by using logic gates. Complete the following diagram with your design. [3]

(e) Show how the circuit can be constructed using NAND gates only and cross out all redundant gates. [4]

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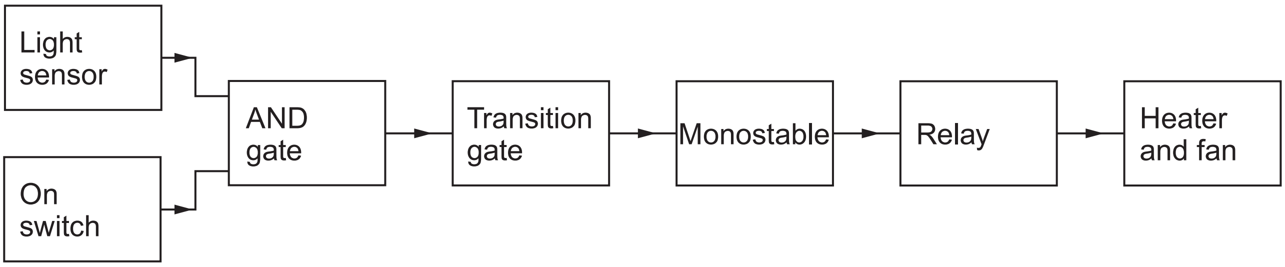
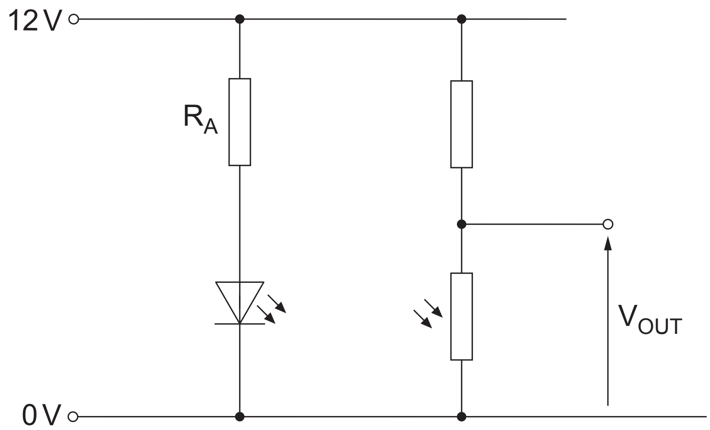
8. The block diagram shows the control system for a hand dryer. The light-sensing circuit detects the presence of hands in the dryer.



(a) The circuit diagram for the light-sensing sub-system is shown below.



(i) The light-sensing sub-system uses a high intensity blue LED with a forward voltage of 4.2V. Calculate the value of R_A required to limit the current through the LED to a maximum of 40mA. [3]

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(ii) Select the preferred value for R_A from the E24 series. [1]

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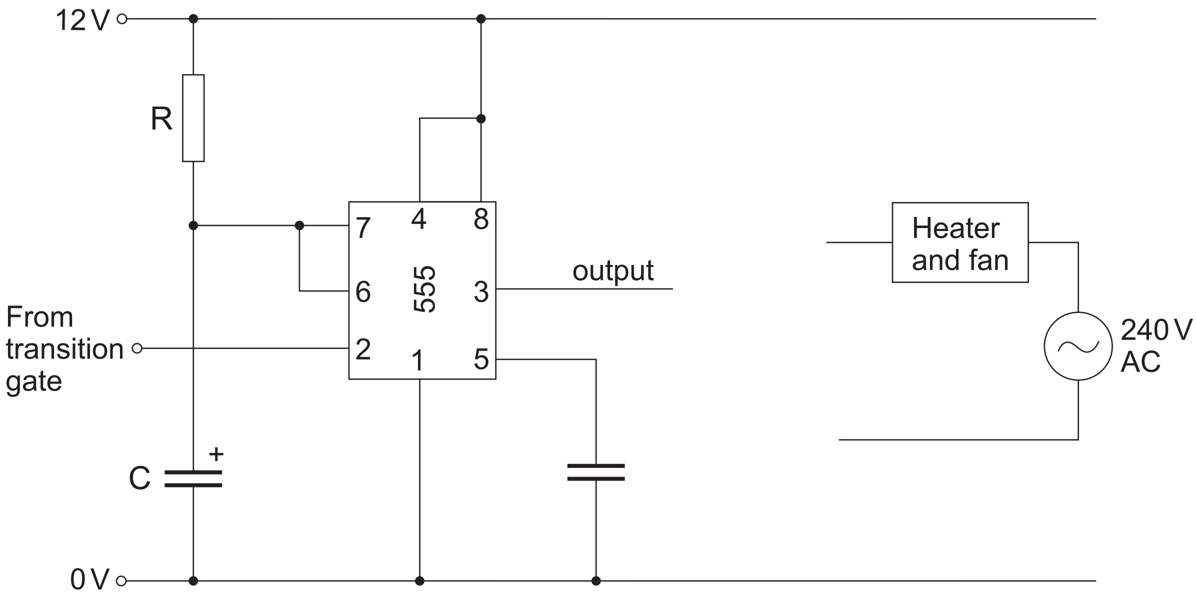
(b) The following circuit diagram shows the monostable used to control the heater and fan.



(i) R is a 16 kΩ resistor. Calculate the value of capacitor C, so that the output of the 555 timer will go high for 12 seconds when pin 2 is momentarily taken to logic 0. [2]

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(ii) Explain why a transition gate is needed between the AND gate and this monostable. [1]

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(c) (i) **Add a relay and connections** to the circuit diagram to show how the monostable output is interfaced to the mains heater and fan. [2]

(ii) The heater has a power rating of 1.2 kW. Calculate the energy used by the heater in 12 s. [2]

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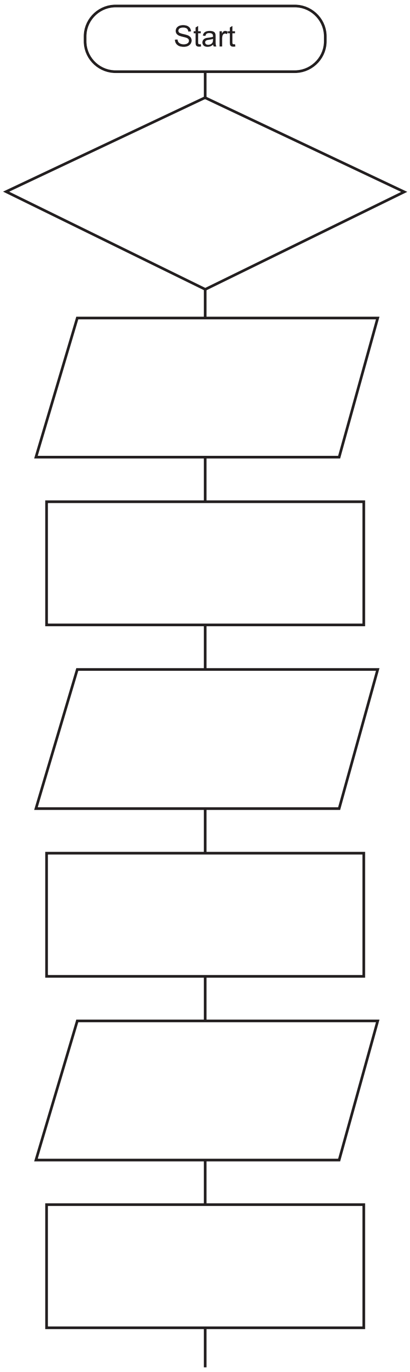
(d) The system is replaced by a microcontroller, with separate heater and fan sub-systems. To save energy, the system detects if hands are in the dryer. It then blows hot air for 5 s and cooler air for a further 7 s. It then delays for 4 s before re-activation. Use the outline below to complete the flowchart for this system. [6]



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9. An extract from the data sheet for an op-amp is given below. The op-amp is used to build a voltage amplifier. The amplifier is powered from a ±12 V supply.

Input impedance / Ω	2×10^{12}
Open loop gain	2×10^{5}
Gain bandwidth product / MHz	3.08
Output impedance / Ω	25

(a) Design the circuit for a non-inverting voltage amplifier with a gain of 70. Include suitable component values on the diagram. [5]

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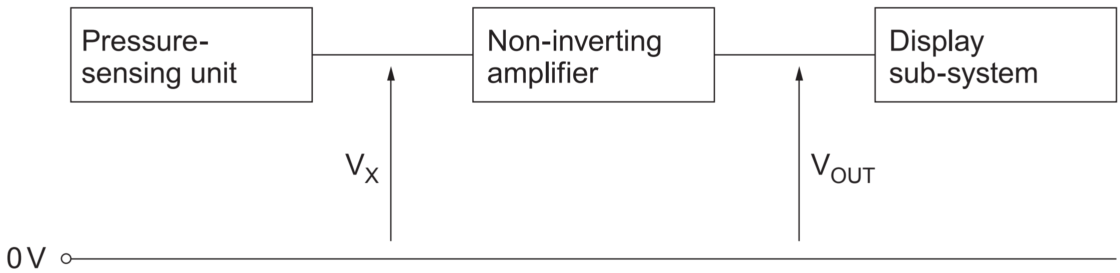
(b) The diagram shows part of a diver's pressure gauge system. The output of the pressure-sensing unit is amplified using the voltage amplifier from part (a).



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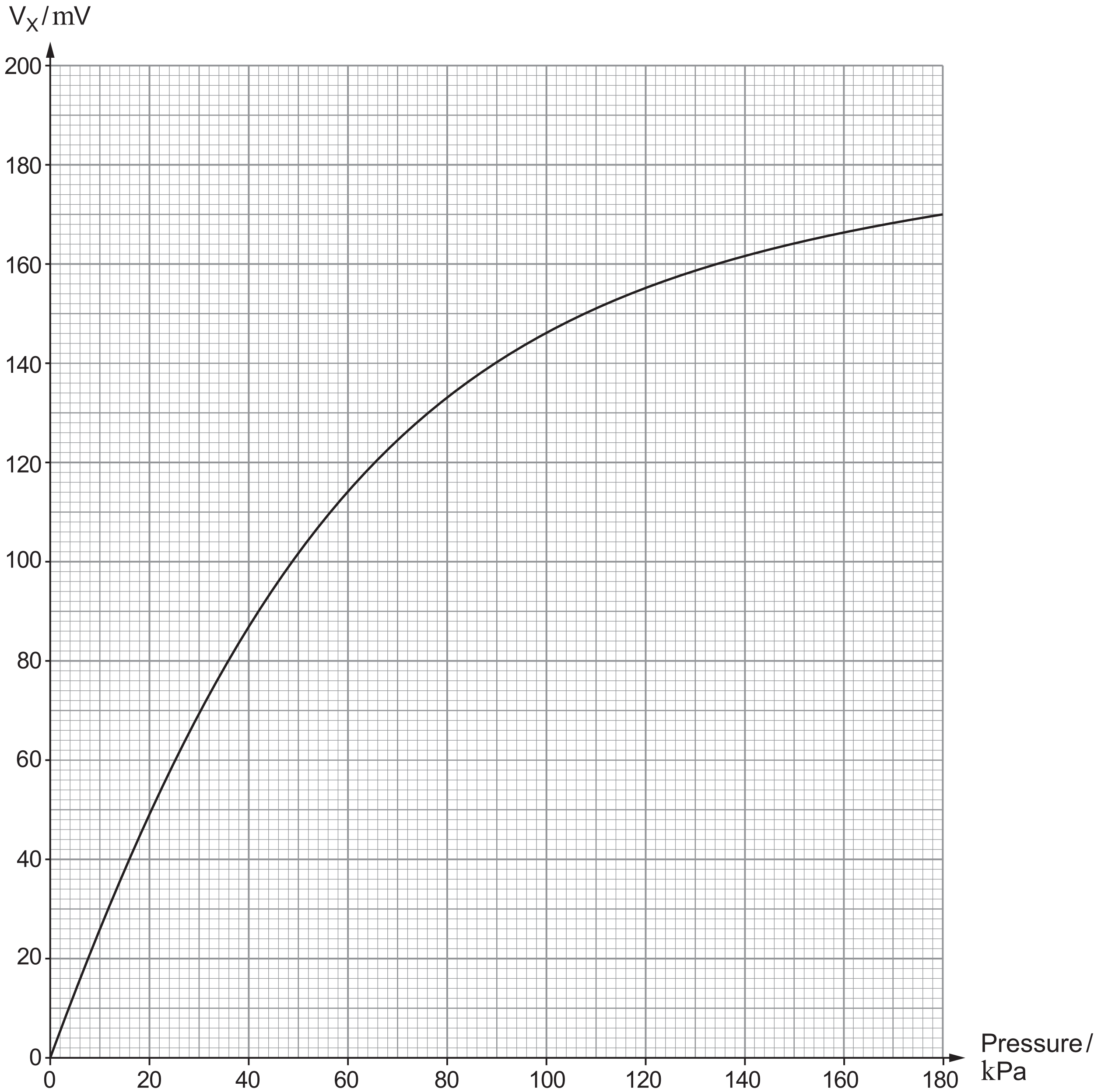
The calibration graph for the pressure-sensing unit is shown below. Pressure is measured in units called kPa.



Use the calibration graph to determine:

(i) the voltage V_X when the pressure is 90 kPa. [1]

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(ii) the **maximum** pressure that this system can reliably measure. The op-amp saturates at ±11.5 V. [3]

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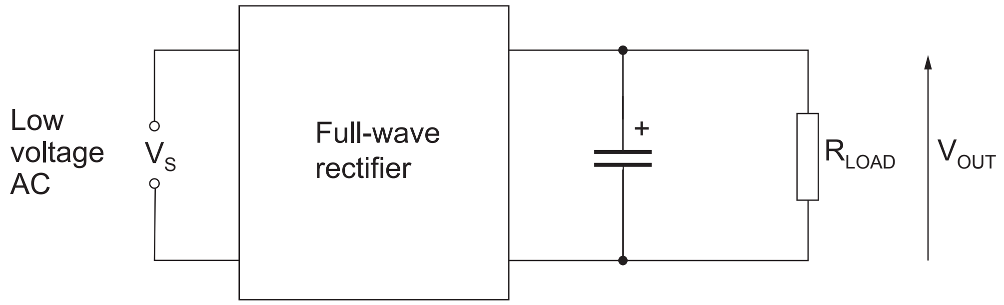
10. (a) The diagram shows the circuit for a power supply.



Explain the action of the whole power supply when connected to R_{LOAD} by comparing the input and output voltages and currents. Describe what happens when an identical resistor is connected in parallel with R_{LOAD}. [6 QER]

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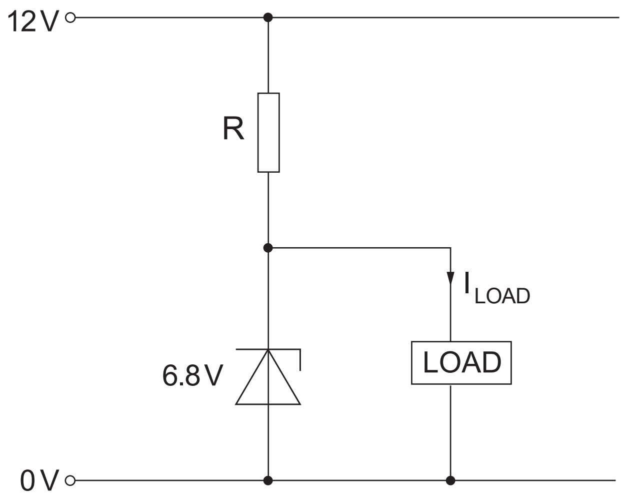
(b) A zener diode regulator is then added to the power supply with a different load. The zener diode requires a current of at least 10 mA to maintain the zener voltage.



The power supply must be able to supply a load current, I_{LOAD}, of 250 mA. Calculate the ideal value for resistor R to allow this load current. [3]

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(c) The load is now disconnected from the power supply. Calculate the power dissipated in the zener diode. [3]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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