Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A490U10-1

Z22-A490U10-1

TUESDAY, 24 MAY 2022 – AFTERNOON

ELECTRONICS – A level component 1

Principles of Electronics

2 hours 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**13**	
2.	**9**	
3.	**6**	
4.	**9**	
5.	**15**	
6.	**15**	
7.	**5**	
8.	**16**	
9.	**20**	
10.	**8**	
11.	**14**	
12.	**10**	
Total	**140**	

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ADDITIONAL MATERIALS

In addition to this examination paper, 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 question **11**(a).

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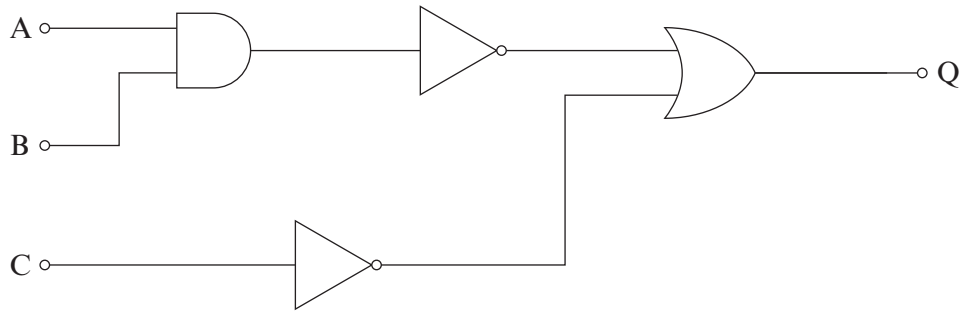
Answer **all** questions.

1. (a) NAND gates are used in combinational logic circuits.

(i) Complete the truth table for a 3-input NAND gate. [1]

C	B	A	Q
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

(ii) Draw the NAND gate equivalent circuit for the circuit shown below using only 2-input NAND gates. [3]



(iii) Cross out all redundant gates. [2]

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(iv) Referring to the circuits opposite, explain the benefit of using the NAND gate equivalent circuit. [2]

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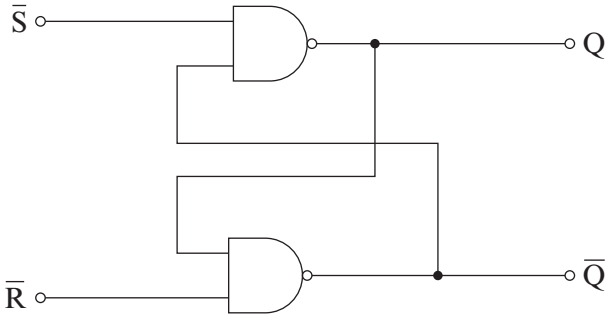
(b) NAND gates are also used in sequential logic.

(i) Complete the table for the outputs of the circuit below. [3]



$\overline{S}$	$\overline{R}$	Q	$\overline{Q}$
1	1	1	0
1	0		
1	1		
0	1		
1	1		
0	0		

(ii) State **one** problem with the circuit above. [1]

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(iii) Give a practical application of the circuit above. [1]

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

(i) $A.1 =$ .....

(ii) $B.\overline{B} =$ .....

(b) Simplify the following Boolean equation using de Morgan's theorem. [4]

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

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$Q =$ .....

(c) A different logic system has the following Karnaugh map. Identify the minimum number of groups to give output Q in its simplest form. [3]

D.C \ B.A	00	01	11	10
00	1	1	0	0
01	0	0	1	0
11	1	1	1	0
10	1	1	0	0

$Q =$ .....

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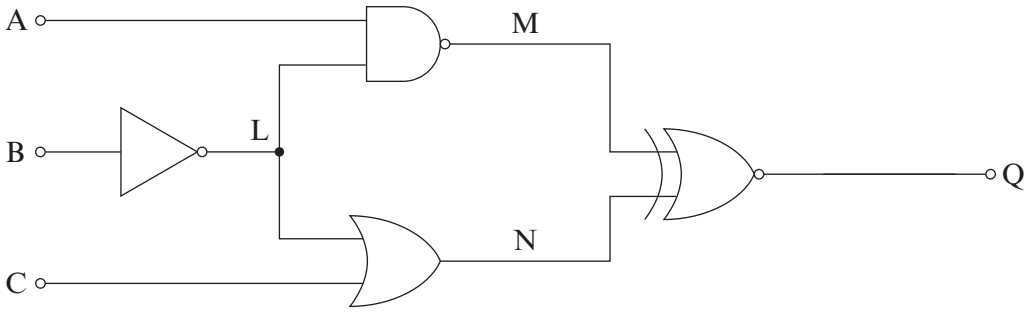
3. (a) Complete the truth table for the circuit below. [4]



C	B	A	L	M	N	Q
0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

(b) Give the Boolean expression for the output Q in terms of A, B and C, without simplification. [2]

Q = ...

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Turn over.

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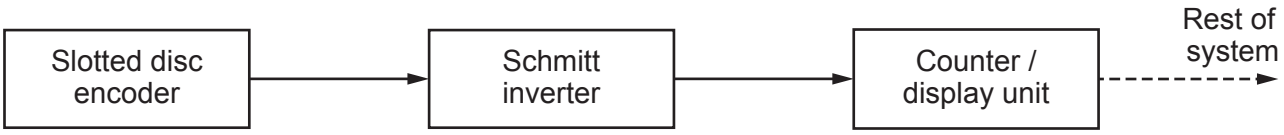
4. To avoid damage a wind turbine has a maximum speed of 20 revolutions per minute (rpm). A block diagram for a part of the system to monitor the speed is shown below.



(a) The encoder uses a slotted disc with 50 slots.

(i) The counting system records 200 pulses in a thirty second period. Calculate the rotational speed in rpm. [2]

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(ii) Calculate the number of slots that would be counted in one minute at the maximum acceptable speed. [1]

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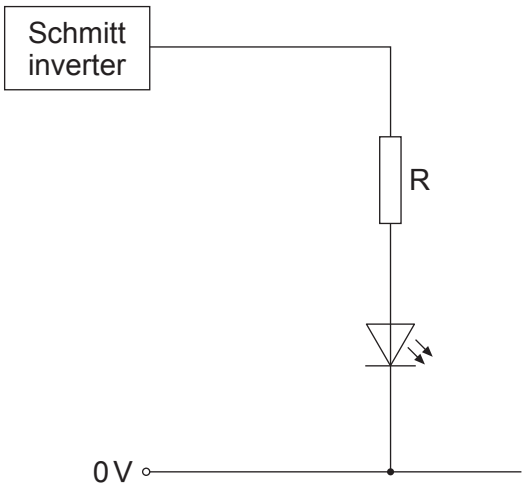
(iii) The output of the Schmitt inverter is connected to an LED for testing as shown below.



The Schmitt inverter outputs 5 V for a logic 1. The LED has a forward voltage drop of 2.1 V. Calculate the ideal value of the resistor required to limit the current through the LED to a maximum of 20 mA. [2]

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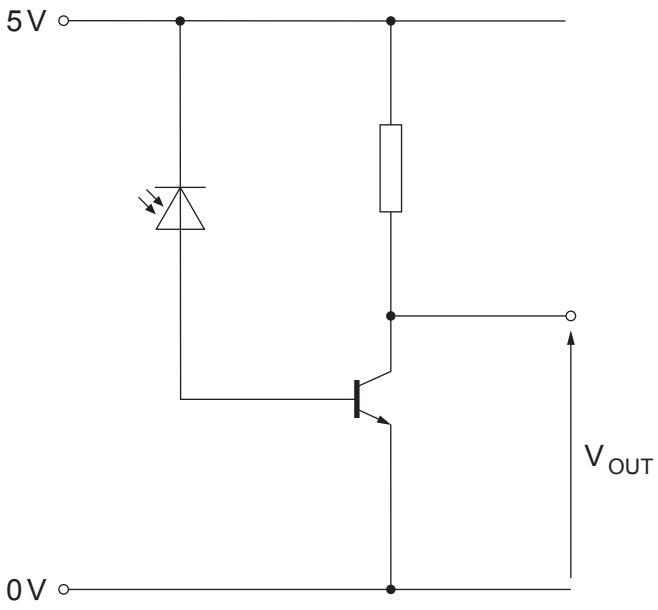
(iv) A photodiode is used as part of the encoder. A circuit for this is shown below.



Describe what happens in the circuit when light falls on the photodiode. [3]

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(b) State the purpose of the Schmitt inverter in the system. [1]

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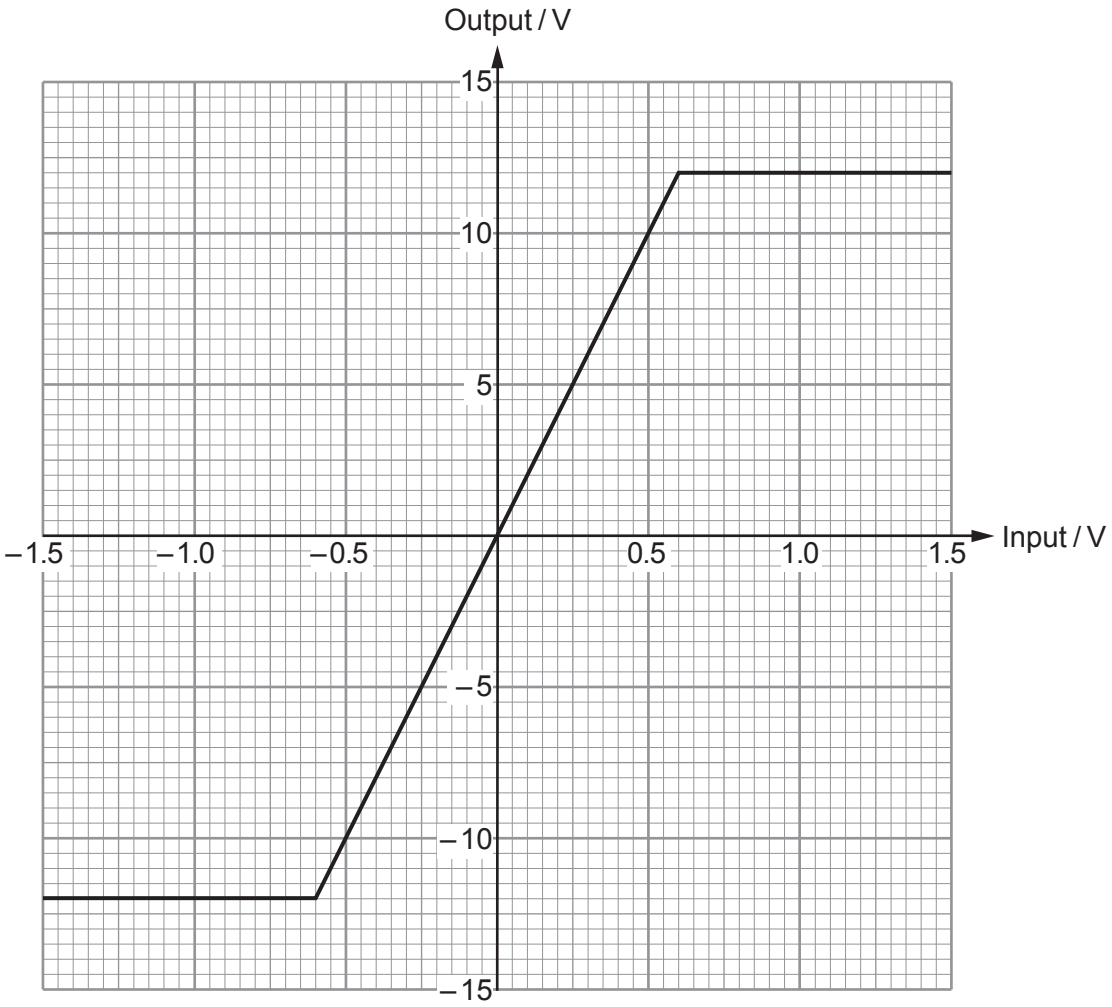
5. The graph below shows the voltage transfer characteristic of an amplifier.



(a) (i) What is the maximum input voltage before saturation occurs? [1]

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(ii) Calculate the voltage gain of the amplifier. [2]

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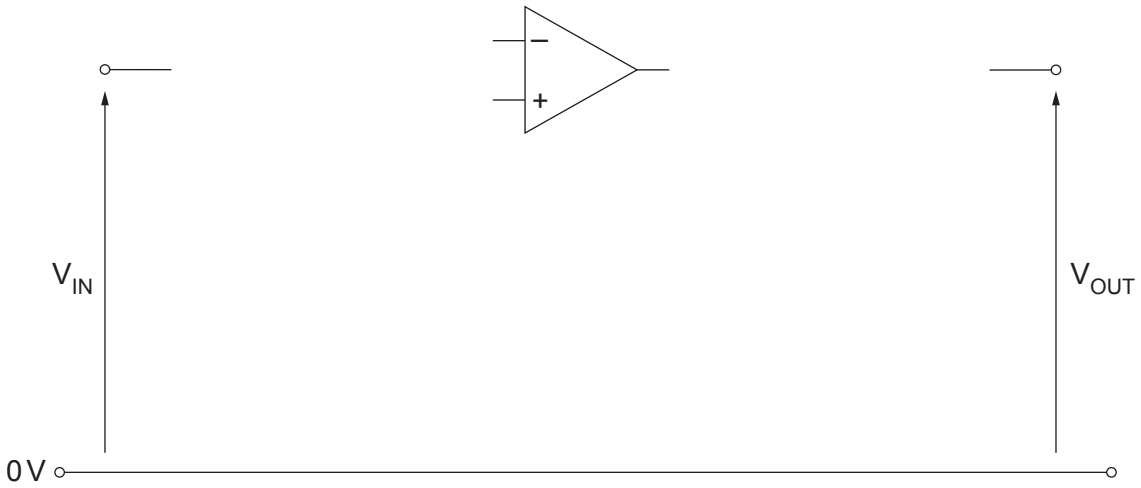
(iii) Design a circuit based on an op-amp for this amplifier. Your circuit should include the value of all components added. [4]



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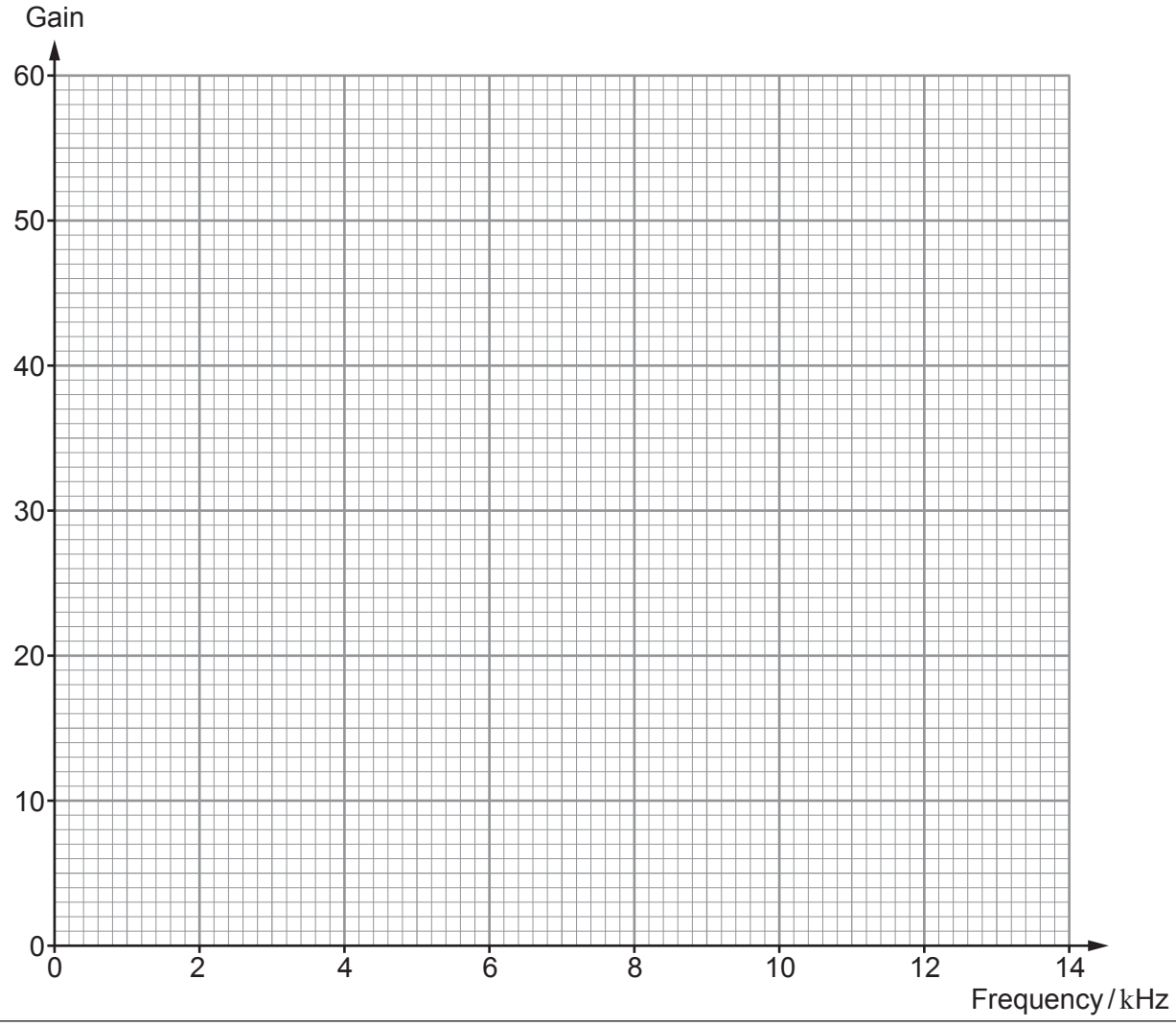
(b) Test results for a different amplifier are shown in the table below.

(i) Complete the table. [1]

Frequency / kHz	V_{IN} / V	V_{OUT} / V	Gain
2.0	0.25	10.25	
4.0	0.25	10.25	
6.0	0.25	9.75	
8.0	0.25	7.10	
10.0	0.25	4.95	
12.0	0.25	3.10	
14.0	0.25	2.60	

(ii) Draw the frequency response graph of the amplifier. [2]



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(iii) This amplifier is required to have a gain of 40 with a tolerance of ±2 and a bandwidth of 10 kHz with a tolerance of ±1 kHz. Use the results to evaluate this amplifier against these requirements. [5]

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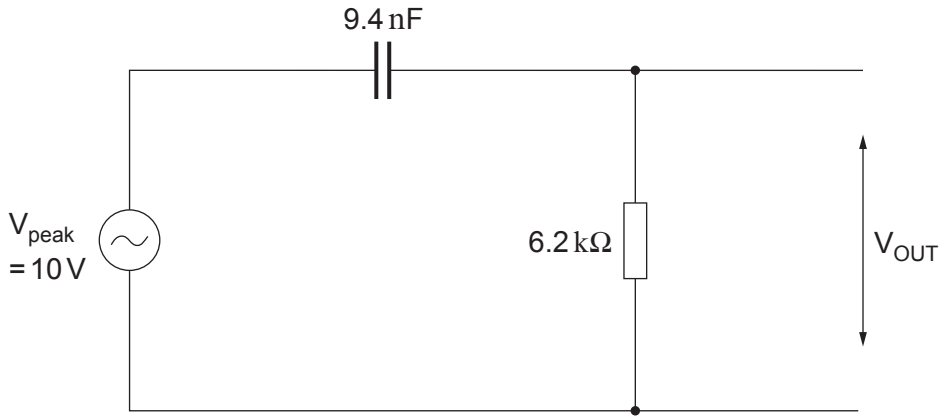
6. Below is the circuit for a passive filter made by a student.



(a) (i) State the type of filter. [1]

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(ii) Calculate the break frequency of the filter. [3]

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(b) (i) Calculate the reactance of the capacitance when the frequency of V_{IN} is 200 Hz and 20 kHz. [3]

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200 Hz ..... 20 kHz .....

(ii) Calculate the peak output voltage at 200 Hz. [3]

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(iii) Calculate the value of V_{OUT} at the break frequency. [2]

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(c) Sketch a graph to show how the output voltage changes with frequency using the axes below. Label significant values of V_{OUT} and frequency. [3]

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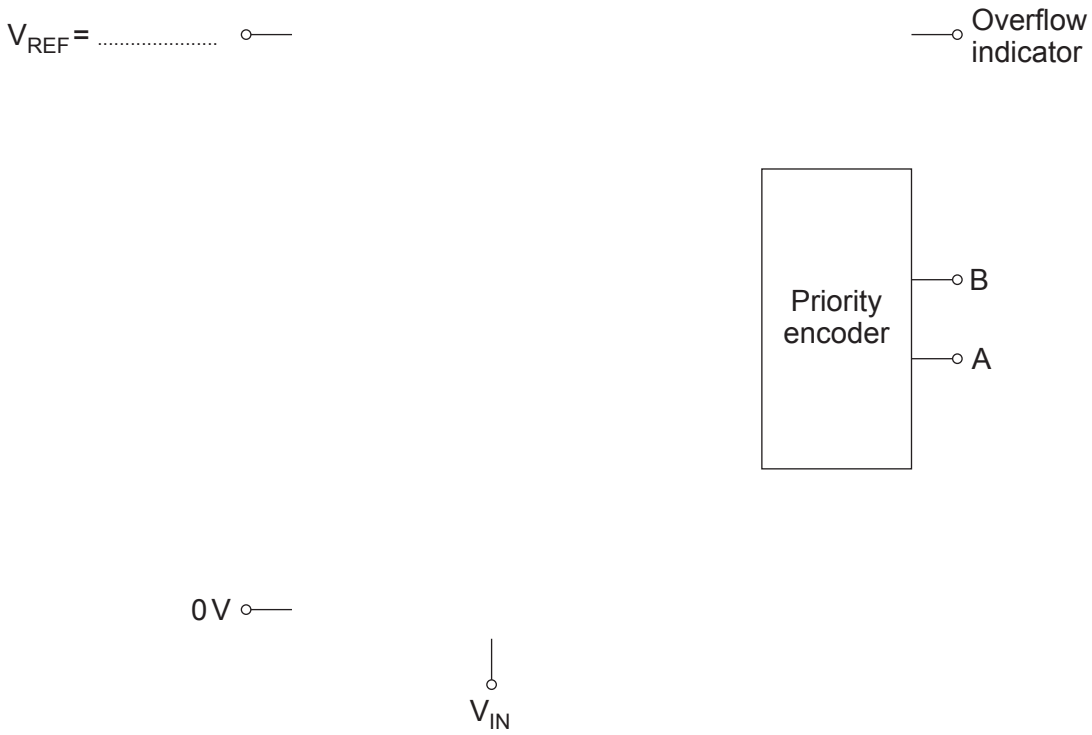
7. Design a flash converter to meet the following specification, including all relevant values:

- Input voltage range of 4 V
- 2-bit binary output
- An overflow to indicate when the input voltage is above the specified range.

You do **not** need to design the priority encoder. [5]



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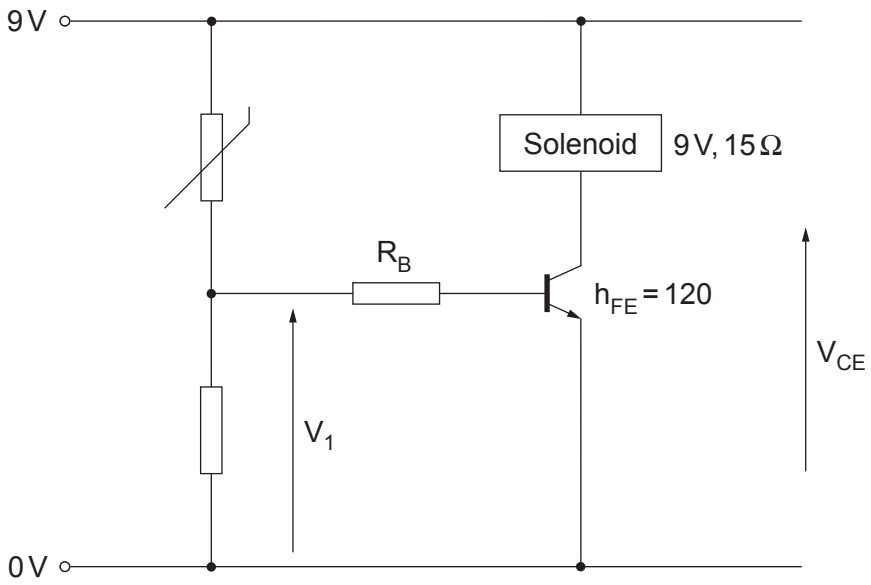
8. A cafe owner wants an automated system to control the windows in the cafe. The owner wants the windows to be opened by a solenoid when the temperature is too high. The circuit below shows a possible solution.



(a) **Add a component** to the diagram to protect the transistor during switching. [1]

(b) The transistor is just saturated when V_1 = 6.4 V. When the transistor is just saturated calculate:

(i) the base current; [3]

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(ii) the ideal value for R_B and select a suitable value from the E24 series. [3]

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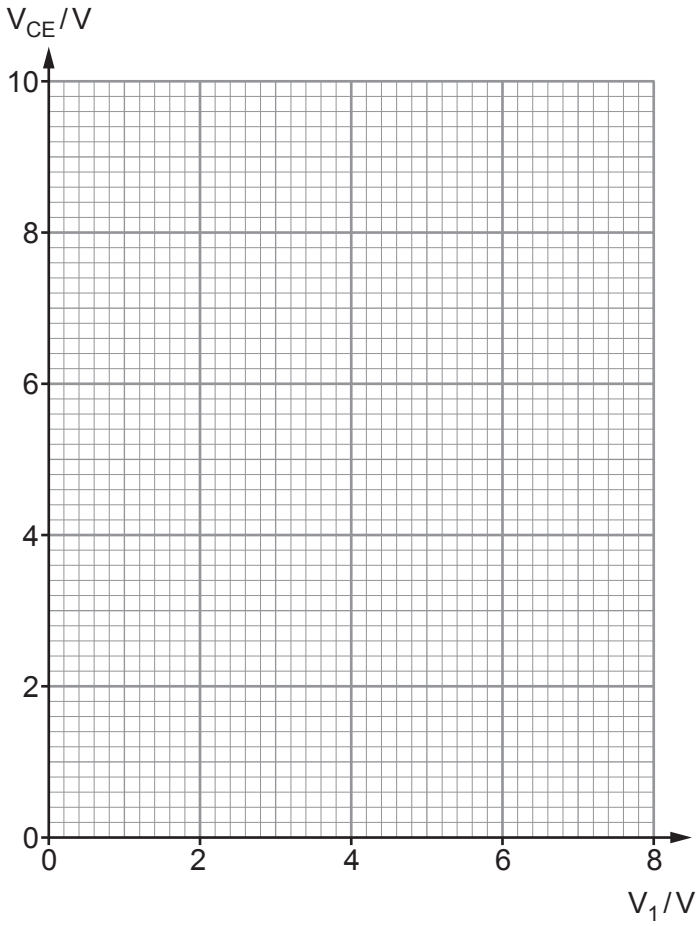
(c) Use the axes below to draw a graph to show how V_{CE} changes when V_1 varies from 0 V to 8 V. [3]



(d) The temperature drops and V_1 changes to 4.5 V.

(i) Use your graph to find V_{CE}. [1]

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(ii) Calculate the collector current at this value of V_1 and the power dissipated in the transistor. [5]

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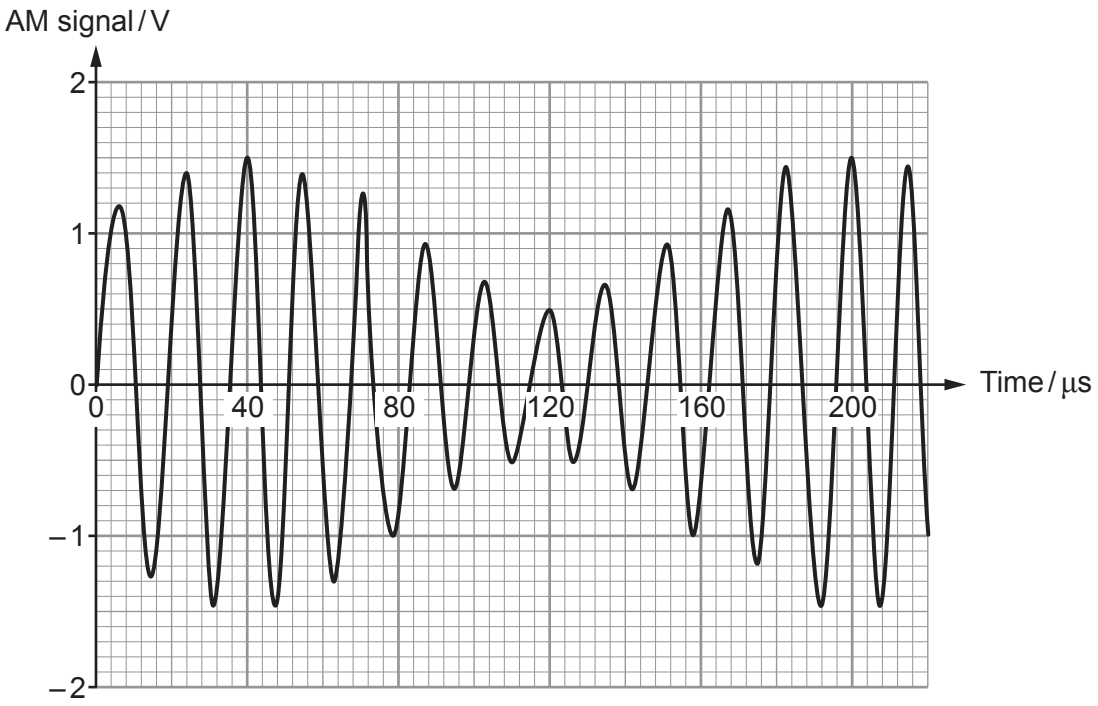
9. Two methods of wireless transmission are AM and FM.

(a) The graph shows an AM signal from a radio station.



(i) Determine the period of the audio signal and calculate its frequency. [3]

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(ii) Calculate the depth of modulation of the AM signal. [3]

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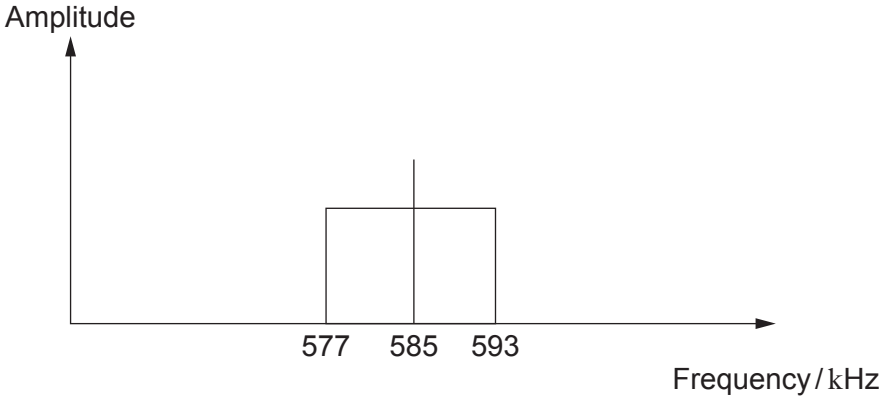
(b) The frequency spectrum of a signal from another station is shown below.



(i) State the carrier frequency of this signal. [1]

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(ii) Calculate the broadcast bandwidth of the transmission. [1]

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(c) (i) Explain what is meant by the term frequency division multiplexing (FDM). [2]

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(ii) If the total range of frequencies available to broadcast is from 535 kHz to 1605 kHz what is the maximum number of signals described in part (b) that can be broadcast using FDM? [2]

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(d) (i) FM is an alternative modulation technique. Describe how an audio signal changes the carrier signal in FM. [2]

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(ii) Describe an advantage of FM over AM. [2]

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(iii) An 8 MHz carrier is modulated using FM by a single frequency of 10 kHz. The frequency deviation is 40 kHz.

Calculate:

I. the modulation index. [2]

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II. the bandwidth of the FM signal. [2]

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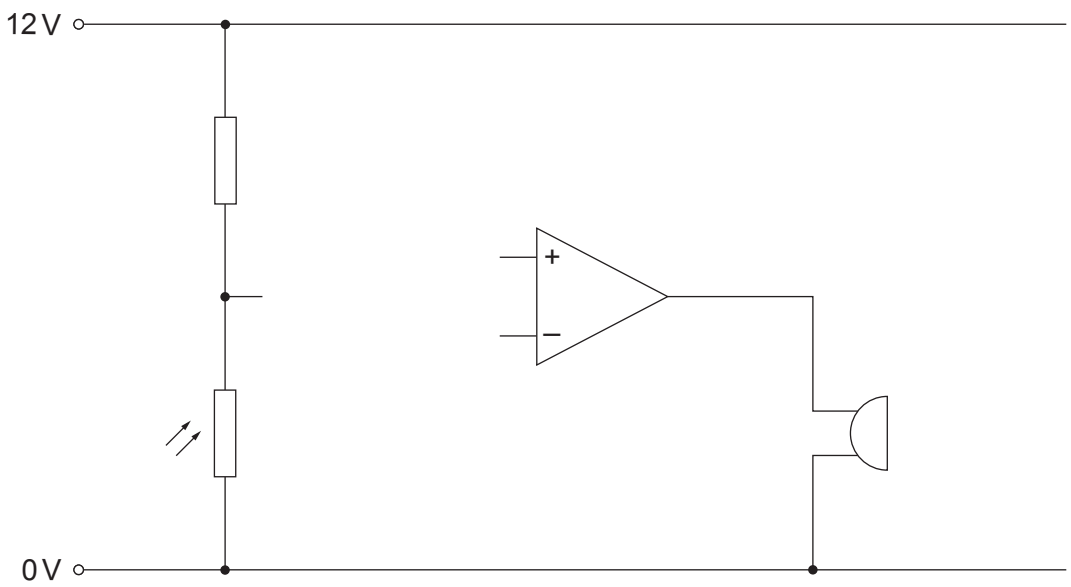
10. A system is required to sound a buzzer when the light level drops below a preset level. Part of the system uses a comparator which is shown below.



(a) The buzzer should sound when the output of the light sensing sub-system increases to 4 V. Complete the circuit for this system on the diagram above, including a fixed voltage reference of 4 V, labelling all values for the components you add. [3]

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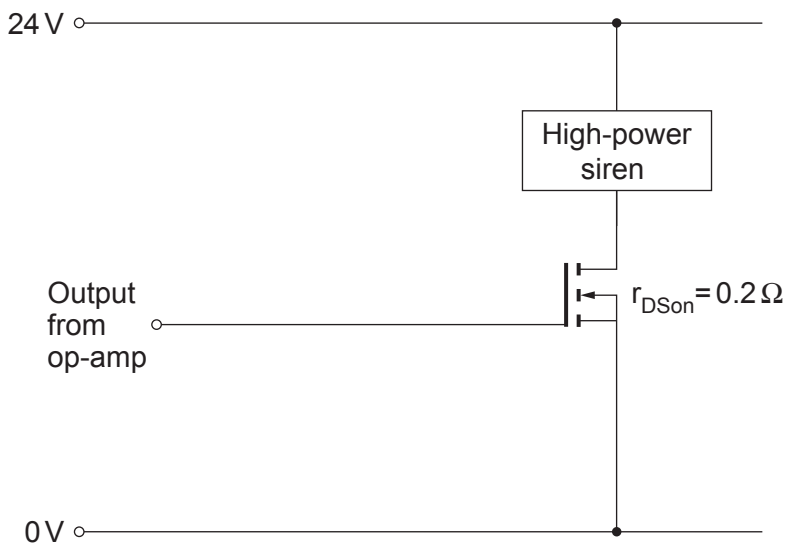
(b) The system is modified to operate a high-power siren rated at 24 V, 5 A using the MOSFET driver circuit shown below. The output of the op-amp saturates at 11 V.



(i) Calculate the minimum value of transconductance g_M required for the MOSFET. [3]

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(ii) Calculate the power dissipated in the MOSFET. [2]

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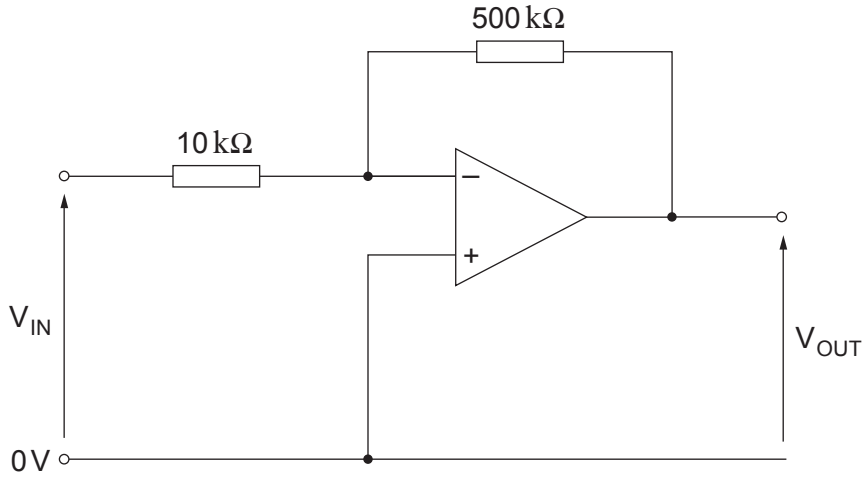
11. A voltage amplifier which meets the following specification is required:

- A gain of –50
- An input impedance of 12 kΩ
- A bandwidth of at least 15 kHz
- An undistorted output for input signals with amplitude up to 250 mV

A student designs the circuit below to meet the specification using an op-amp with the properties shown in the table. The op-amp has a power supply of ±12 V and saturates at ±10 V.



Op-amp properties	
Slew rate	$0.5\,V\,\mu s^{-1}$
Open loop gain	10^5
Input impedance	2 MΩ
Output impedance	70 Ω
Gain bandwidth product	1 MHz

(a) Evaluate the circuit against the specification supported with relevant calculations. Describe any changes you would make to the circuit to improve its performance.

[6 QER]

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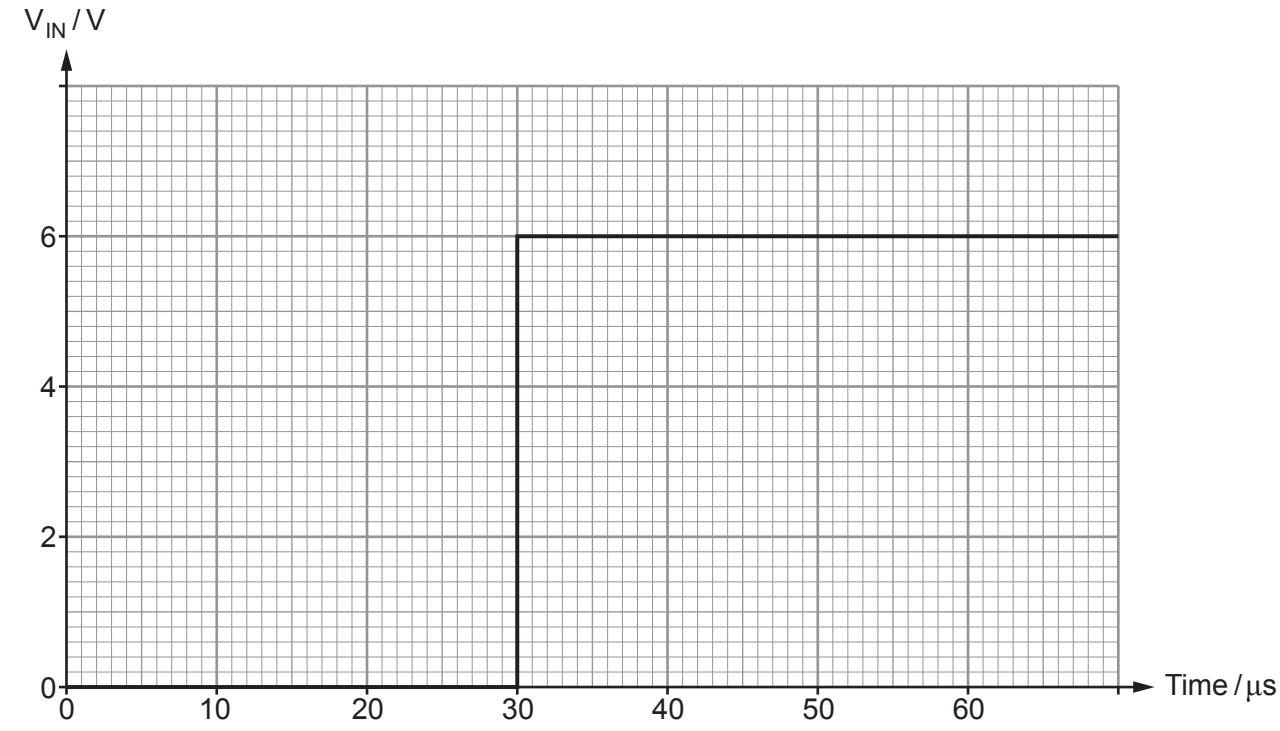
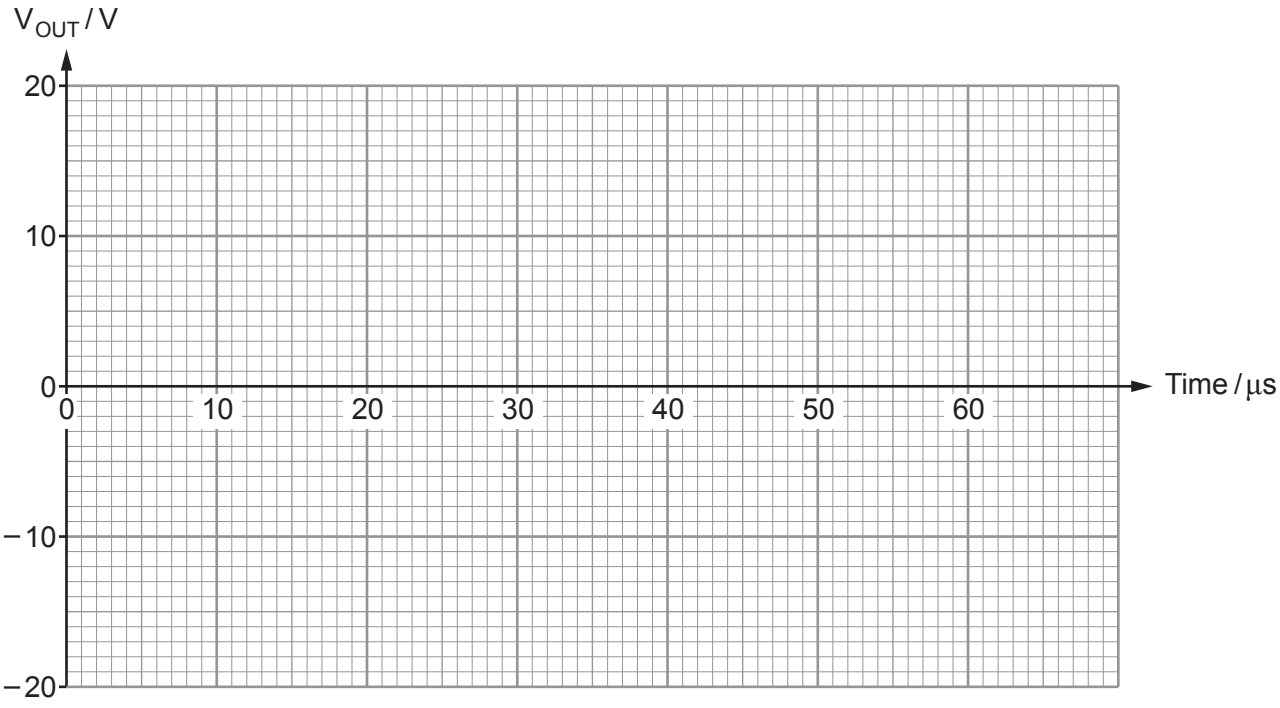
(b) The signal shown below is applied to the input of the amplifier.





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(i) Calculate the time taken for the output to reach saturation and sketch the output using the axis opposite. [4]

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(ii) The 6 V signal is now removed and a sine wave with a peak voltage of 200 mV is now applied to the input of the amplifier. Calculate the maximum frequency before slew rate distortion occurs. [4]

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12. A signal is attenuated as it travels along a communication link.

(a) Explain what is meant by attenuation in this context. [2]

(b) The communication link is 12 km long with a power loss of 1.8 dB/km. Two amplifiers each with a gain of 10 dB are placed along the link. Calculate the input power required to give an output power of 5 nW. [5]

(c) When a signal is connected to the input of the communication link the combined output amplitude of the signal and noise is 32.8 mV. The amplitude of the noise present at the output with no input signal present is 0.42 mV. Calculate the signal to noise ratio (SNR). [3]

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