Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

O21-A490U10-1

A490U10-1

MONDAY, 4 OCTOBER 2021 – AFTERNOON

ELECTRONICS – A level component 1
Principles of Electronics

2 hours 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**4**	
2.	**12**	
3.	**7**	
4.	**24**	
5.	**14**	
6.	**19**	
7.	**13**	
8.	**14**	
9.	**13**	
10.	**12**	
11.	**8**	
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 **4***(d)*.

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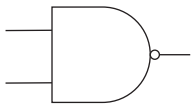
Answer **all** *questions.*

1. *(a)* State the type of logic gate shown below. [1]



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(b) Complete the truth table below for a 3-input XOR 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	

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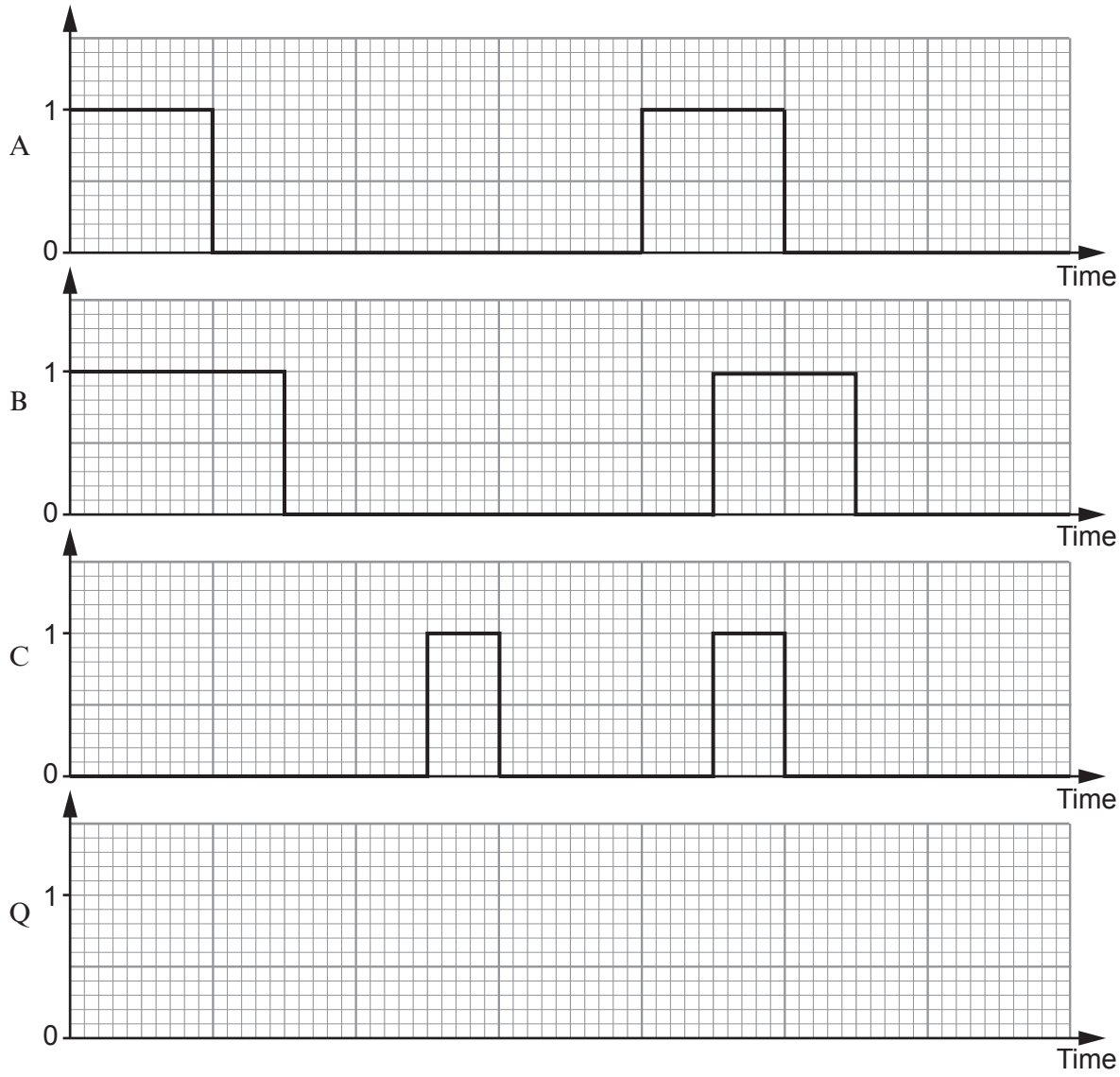
(c) The upper graphs show the signals applied to the inputs A, B and C of the 3-input XOR gate. Use the bottom axes provided to sketch the resulting output Q. [2]



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2. *(a)* Simplify the following expressions, showing appropriate working. [2]

(i) A.(A + B)

.....

(ii) B + (A.B)

.....

(b) A logic system is designed to meet the specification in the following truth table.

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

(i) Write down the Boolean equation for the output Q in terms of its inputs A, B and C. [2]

Q = ...

(ii) Use Boolean algebra to simplify the equation. [2]

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(c) Complete the Karnaugh map for the Boolean equation given below. You **do not** need to find the groups or simplify the equation. [3]

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

DC \ BA	00	01	11	10
00				
01				
11				
10				

(d) The Karnaugh map for a logic system is shown below.
Give the simplest Boolean expression for the output Q of the logic system.
On the Karnaugh map **show** and **identify** the groups that you create. [3]

DC \ BA	00	01	11	10
00	1	0	0	1
01	1	0	1	1
11	0	1	1	1
10	0	1	0	0

Q = ...

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3. A logic system is required to meet the equation below.

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

(a) Show how the system can be made from AND, OR and NOT logic gates. [3]

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(b) Redraw the circuit using only 2-input NAND gates and cross out any redundant gates. [4]

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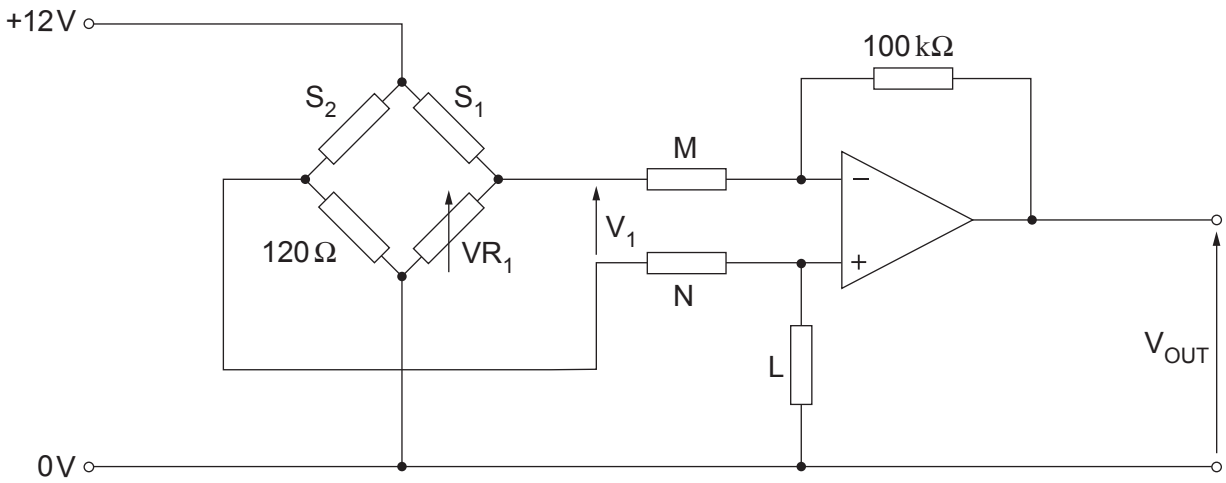
4. Engineers want to monitor the strain in one of the cables of a suspension bridge over a period of six months. The measurements of strain will be stored in a microcontroller to be analysed later.

Below is a block diagram of the system they plan to use.

The strain sensor and difference amplifier circuit is shown below:



(a) The bridge circuit uses a strain gauge S_1 and a dummy strain gauge S_2 which are identical.

(i) Explain why there are two strain gauges and a variable resistor VR_1 in the bridge circuit. [2]

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(ii) Calculate the voltage V_1 correct to 3 decimal places when:

S_1 has a resistance of 120.5 Ω
S_2 has a resistance of 120 Ω
VR_1 has a resistance of 119 Ω [3]

(b) The difference amplifier has a gain of – 20.

(i) Using your answer to *(a)*(ii) calculate the value of V_{OUT}. [2]

(ii) Calculate suitable values for the resistors M, N and L. [3]

M = ... N = ... L = ...

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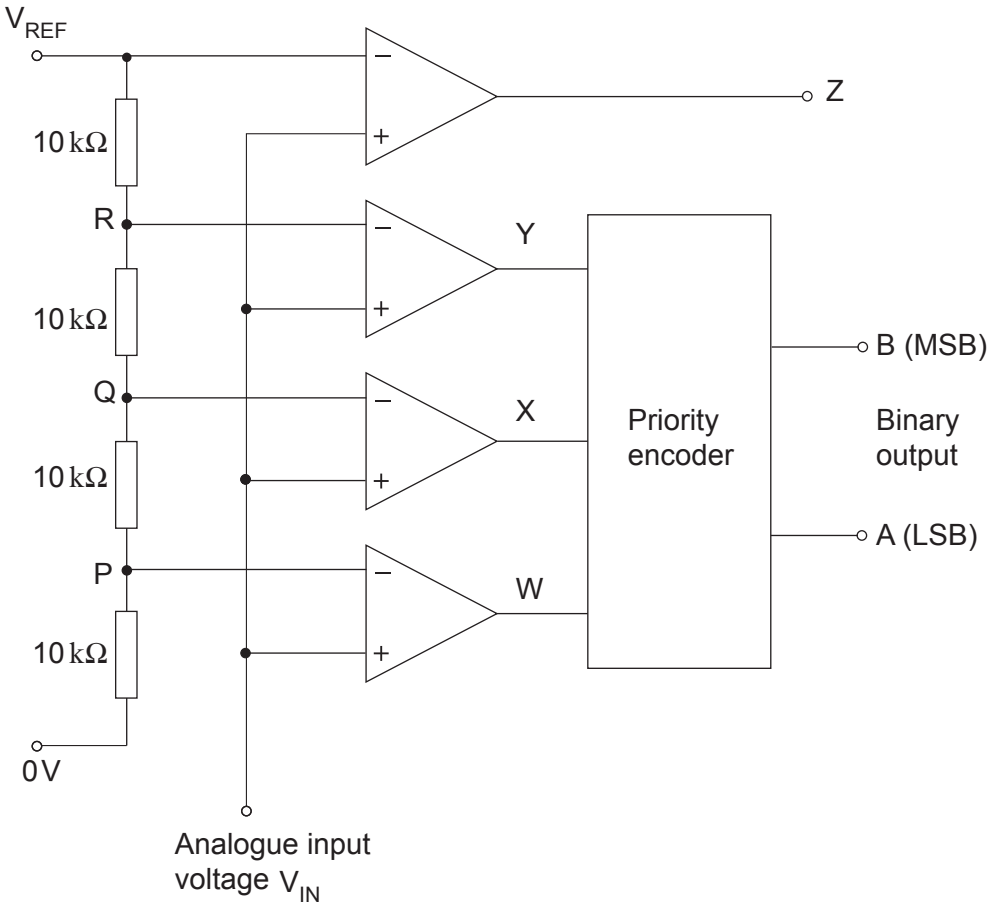
(c) The circuit diagram below shows the ADC. V_{REF} = 5 V and the op-amps saturate at +10 V and 0 V.



(i) Calculate the voltages on the resistor chain at P, Q and R. [2]

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Voltage at P = ... Voltage at Q = ... Voltage at R = ...

(ii) What is the purpose of the output Z? [1]

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(iii) Determine the resolution of the ADC. [2]

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(iv) Complete the table below to show the output voltages for the op-amps at W, X and Y and the binary output BA of the ADC. [3]

Value of V_{IN}/V	Voltage at W/V	Voltage at X/V	Voltage at Y/V	Voltage at Z/V	Binary output	
					B	A
1.40						
3.80						

(d) The engineer now requires results recorded every 10 seconds at a resolution of 0.1 V and voltage range 0 V to 4.5 V. The microcontroller samples the ADC and stores the data to be analysed later.

Discuss the suitability of the ADC in part *(c)* within the monitoring system for this task. Describe any changes that you might make and justify them. [6 QER]

Turn over.

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5. *(a)* *Sunset Radio* broadcasts on a wavelength of 318 m using amplitude modulation.
At certain times a 5 kHz test signal is transmitted.
The speed of light in air is 3×10^8 m s^{-1}.

(i) Calculate the broadcast frequency. [2]

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(ii) **Sketch the waveform** of the modulated carrier signal on the axes below. Indicate the value of time period of the test signal. [3]

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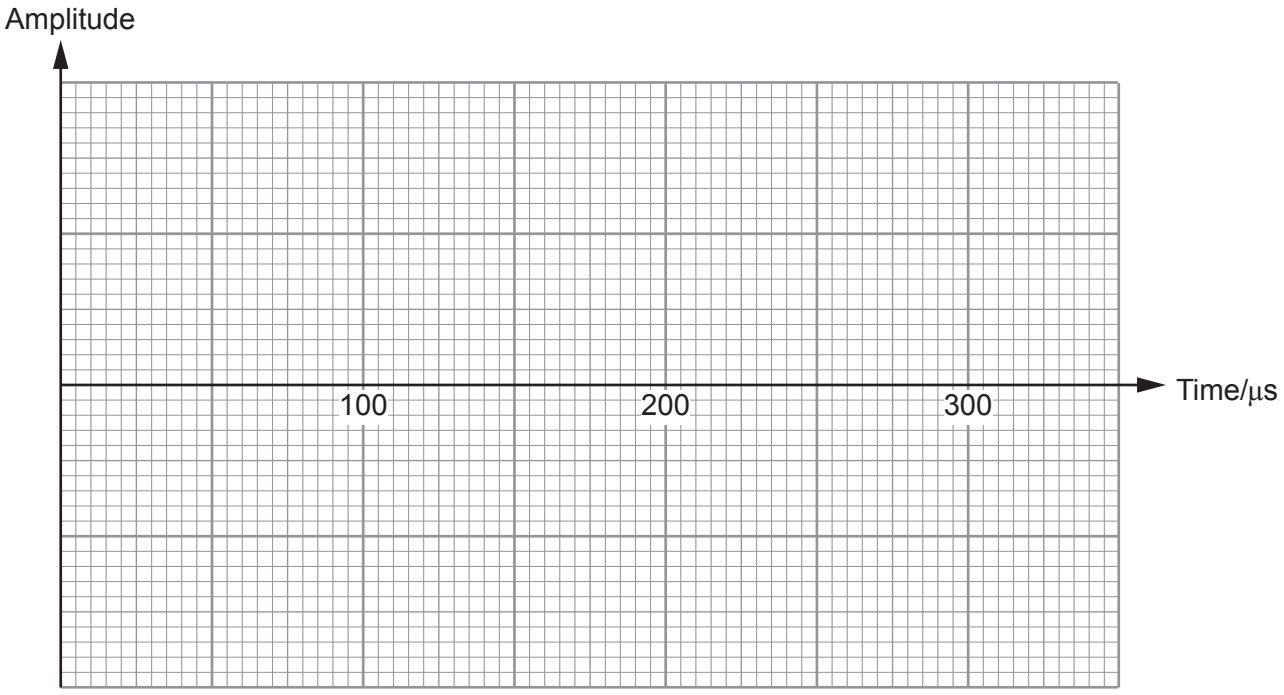

(iii) The modulated carrier is adjusted so that it has a maximum amplitude of 300 mV and a minimum amplitude of 100 mV. Calculate the depth of modulation. [2]

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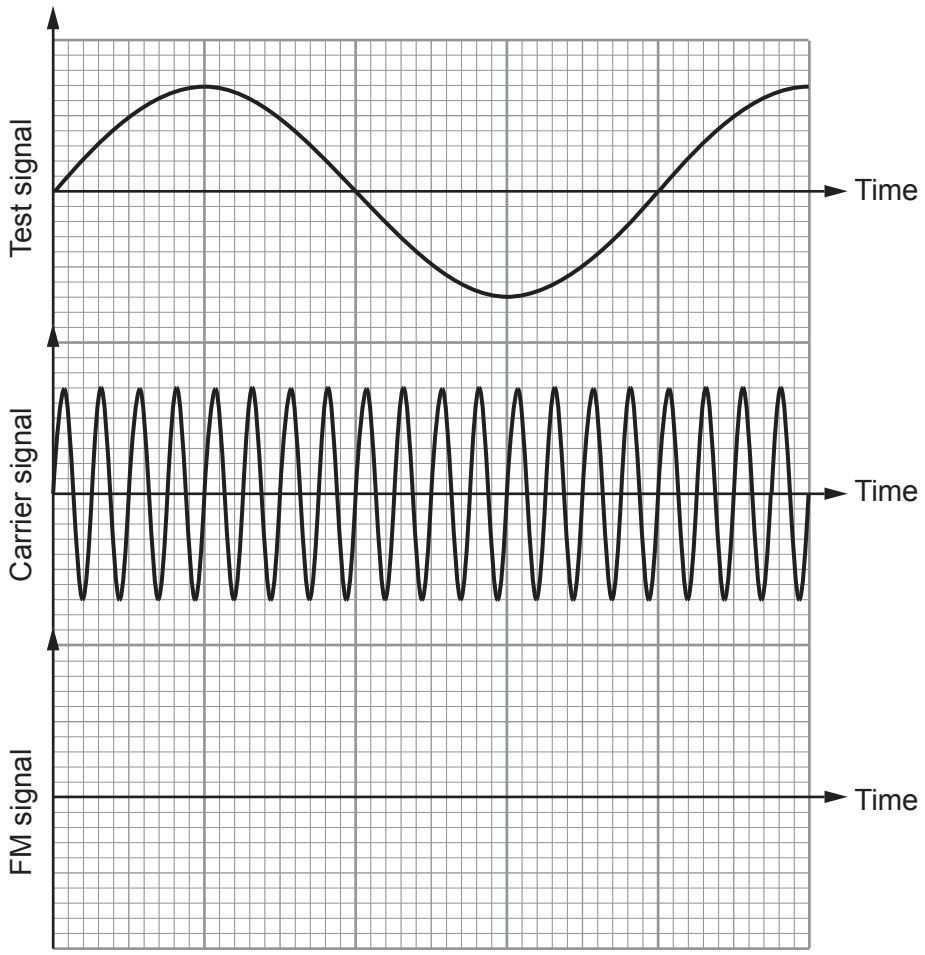
(b) Another radio station uses frequency modulation with a 190 MHz carrier signal modulated by an audio signal with a baseband of 20 Hz to 12 kHz. The frequency deviation is 10 kHz V^{-1} and the maximum audio voltage is 5 V.

(i) The test signal below is used to modulate the carrier signal. Use the axes below to sketch the FM signal output. No values on the axes are necessary. [2]



(ii) Calculate the modulation index. [3]

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(iii) Calculate the signal bandwidth. [2]

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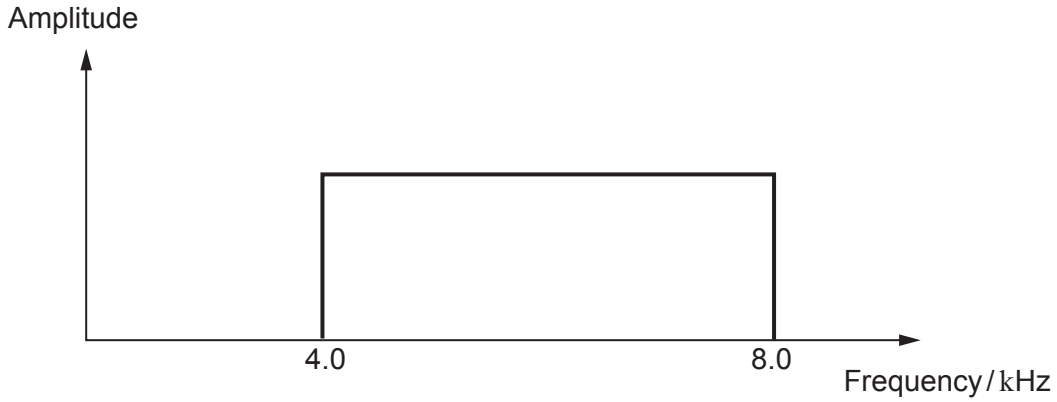
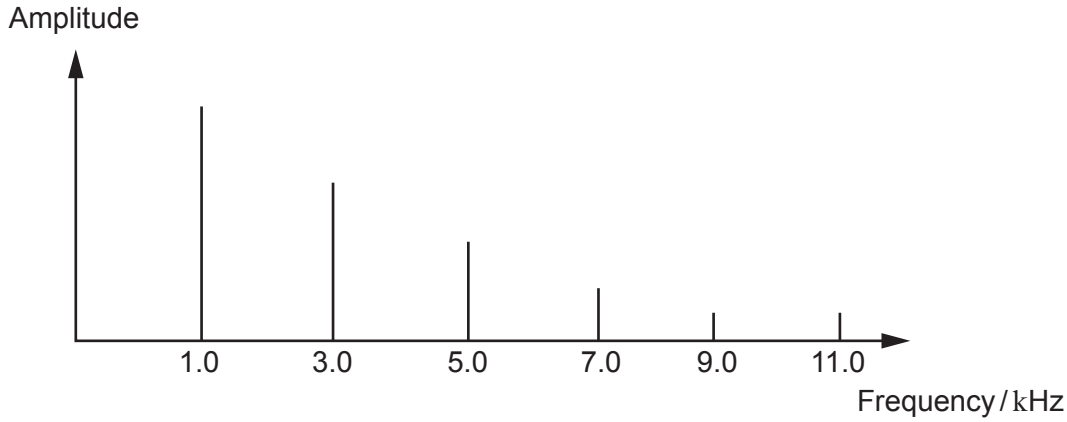
6. A filter with the following ideal response is required for an audio system.



(a) For each of the complex signals below sketch the resulting output signal from the filter. [2]



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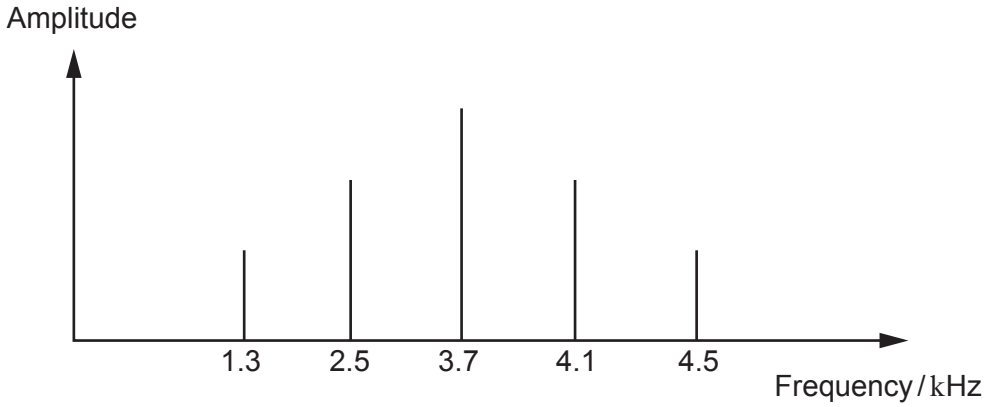

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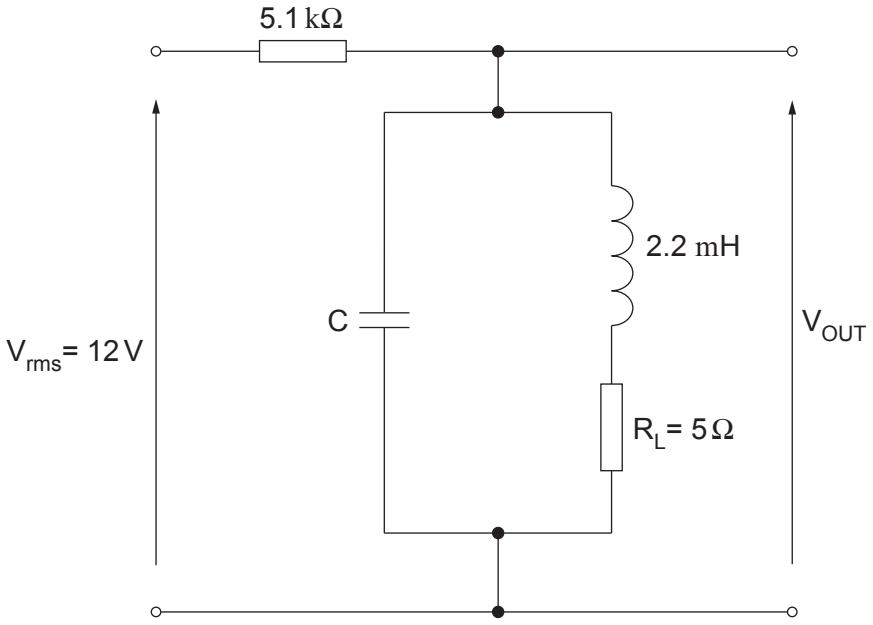
(b) A circuit designed as a solution to the filter in part *(a)* is shown below. The filter should have a resonant frequency of 6 kHz.



(i) Show by calculation the ideal value of capacitor C is 320 nF for this resonant frequency. [2]

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(ii) Calculate the dynamic resistance of the filter. [2]

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(iii) Calculate the peak value of V_{OUT}. [3]

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(iv) Determine the Q factor and the bandwidth of the filter. [3]

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(v) Sketch the frequency response of the filter using the axes below.
Label with numerical values the peak output voltage, resonant frequency and bandwidth. [4]

(vi) Evaluate how well this filter performs in the audio system. [3]

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7. *(a)* State **two** characteristics of an ideal operational amplifier. [2]

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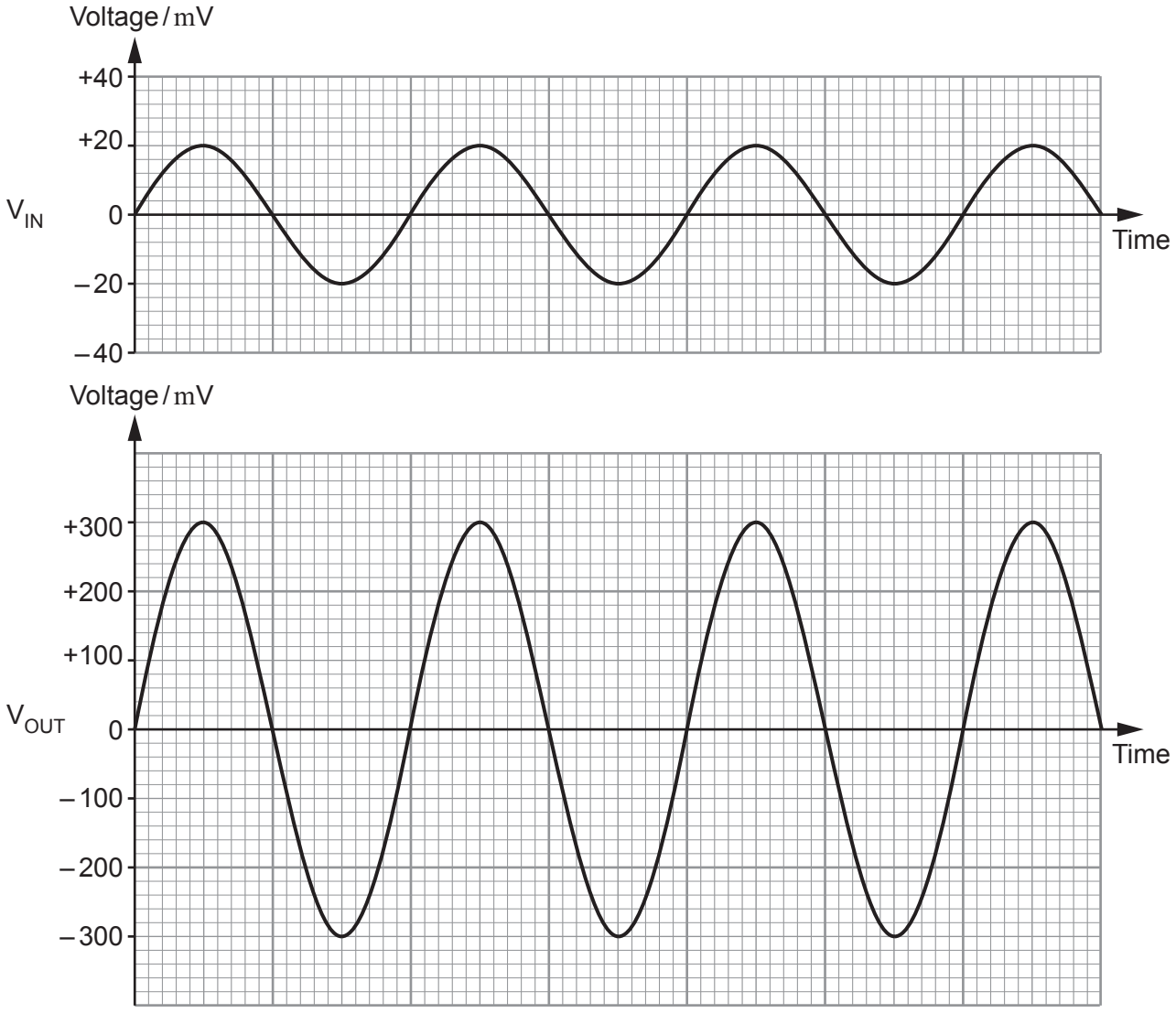
(b) An amplifier has the following input and output signals.



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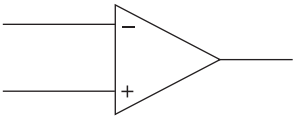
(i) Design an amplifier that will produce this output. Your design should include the circuit diagram labelled with suitable resistor values. [6]



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(ii) The gain-bandwidth product for this op-amp is 1.5 MHz.
State what is meant by bandwidth and calculate the bandwidth for this amplifier.[3]

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(iii) Explain the cause of clipping distortion and give a possible solution to it. [2]

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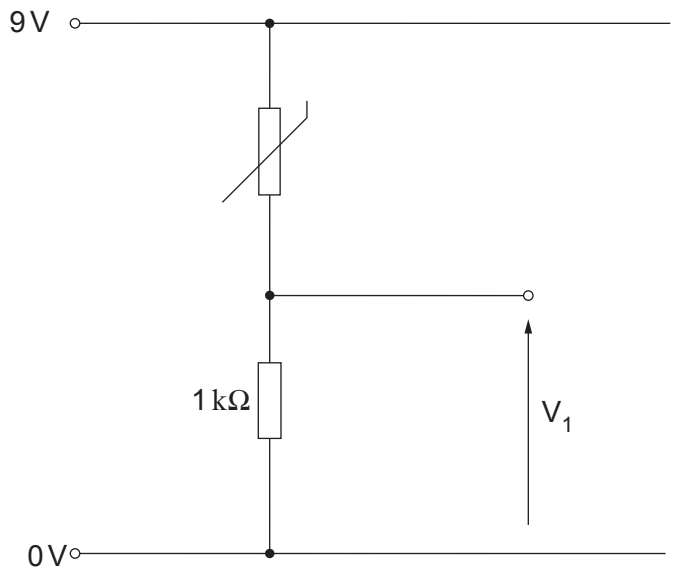
8. A student designs a cooling system. A fan motor should come on when the temperature is above 30 °C.

(a) The temperature sensing sub-system is shown below.



The thermistor in the temperature sensor has a resistance of 3.2 kΩ at 30 °C. Use Thevenin's theorem to produce the equivalent circuit for the sub-system at 30 °C. Draw the equivalent circuit below and label with appropriate values. [4]

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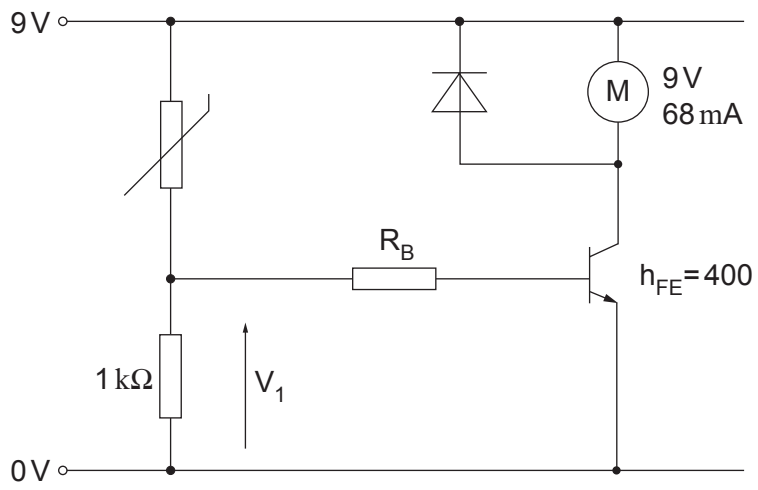
(b) The full system circuit diagram is shown below.



(i) What is the value of I_B required to just saturate the transistor? [2]

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(ii) Use the equivalent circuit from part *(a)* to calculate the value of V_1 required to just saturate the transistor. [3]

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(iii) Calculate the value of R_B required to just saturate the transistor. [3]

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(iv) Explain the purpose of the diode in the circuit diagram on page 23 and give **one** *other* application for a silicon diode. [2]

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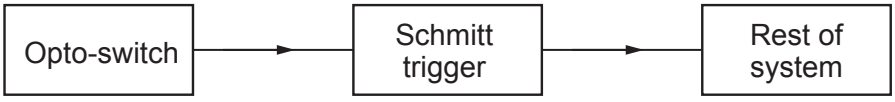
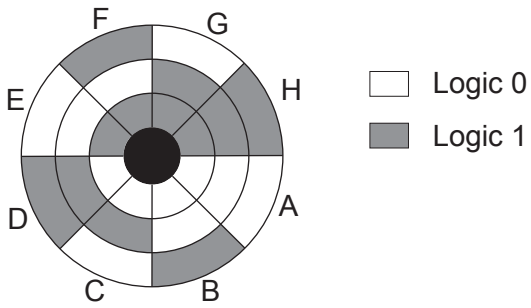
9. A team of engineers are designing a robotic arm for a production line and need a system that can identify the position of the arm. The team plans to use an encoded disc with reflective opto-switches. Each opto-switch is connected to a Schmitt trigger as shown.



(a) One solution uses the binary encoded disc shown below.



The outer ring is the least significant bit (LSB).

(i) Write down the binary number for each of the following segments. [2]

B ..... D ..... G .....

(ii) Such discs can cause false readings. Explain the cause of the false readings and give **one** example of when a false reading might happen. [2]

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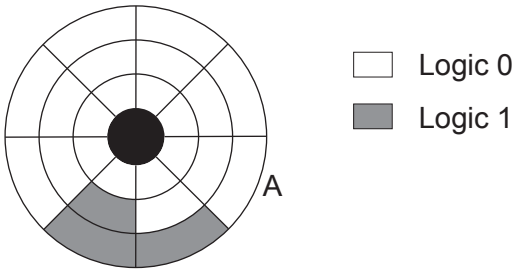
(b) Gray code solves the problem of false readings.

(i) Complete the disc below for Gray code and explain with **one** example how it overcomes the problem of false readings. [4]



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(ii) Calculate the resolution of this 3-bit disc. [2]

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(iii) An improved system requires a resolution of 3°. How many bits would a disc need to achieve this resolution? [3]

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10. Communications signals can be transmitted using a copper cable or a fibre optic cable.

(a) (i) What do the following terms stand for? [2]

TDM .....

FDM .....

(ii) Explain why noise is less of a concern in a digital communication system. [1]

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(iii) Calculate the bandwidth available between the wavelengths 880 nm and 940 nm when the speed of light in the fibre is 2.2×10^8 m s^{-1}. Hence calculate the maximum number of channels when the channel bandwidth is 110 GHz. [6]

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(b) A copper cable communication link is 15 km long. The input signal power is 1.2 W and the output signal power is 80 mW.
Calculate the power loss in dB km^{-1} for the link. [3]

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11. Use op-amps to design a 2-input summing amplifier that will give an output of 5 V for input signals of 0.1 V and 0.2 V. Draw and label your circuit diagram with relevant voltages and component values and show how you calculated any component values used. [8]

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