Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A490U10-1

O20-A490U10-1

MONDAY, 5 OCTOBER 2020 – AFTERNOON

ELECTRONICS – A level component 1
Principles of Electronics

2 hours 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**12**	
2.	**16**	
3.	**10**	
4.	**17**	
5.	**15**	
6.	**16**	
7.	**18**	
8.	**15**	
9.	**15**	
10.	**6**	
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.

Answer **all** questions.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet.

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 **10**.

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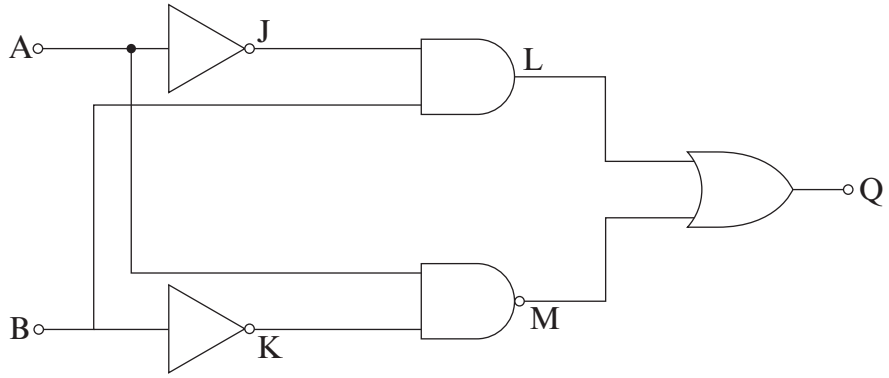
Answer all questions.

1. *(a)* A design for a logic system is shown below:



(i) Redesign the logic system using only 2-input NAND gates.

Draw a diagram showing your design and cross out all redundant gates. [4]

(ii) Complete the truth table for the original logic system. [3]

B	A	J	K	L	M	Q
0	0					
0	1					
1	0					
1	1					

(iii) Write down the Boolean expression for the outputs L, M and Q in terms of inputs B and A. [3]

L = ...

M = ...

Q = ...

(Do not attempt any simplification.)

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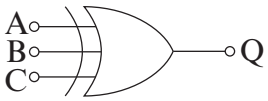
(b) The diagram shows the circuit symbol for a 3-input X-OR gate.



Complete the truth table for this gate. [2]

C	B	A	Q

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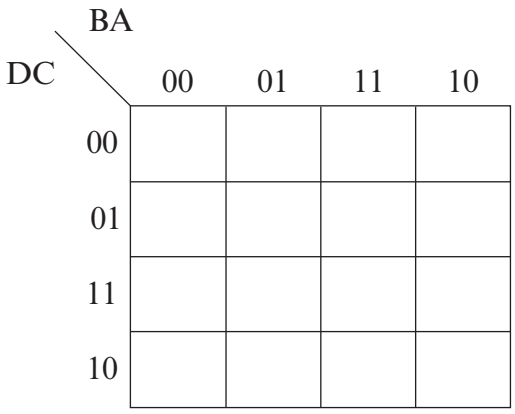
2. *(a)* Simplify the following Boolean expression using a Karnaugh map. [4]

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

Justify your answer by showing and identifying any groups you make.



Q = ...

(b) Use Boolean algebra to simplify the following Boolean expression: [2]

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

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(c) Use de Morgan's theorem to simplify the following Boolean expression. [2]

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

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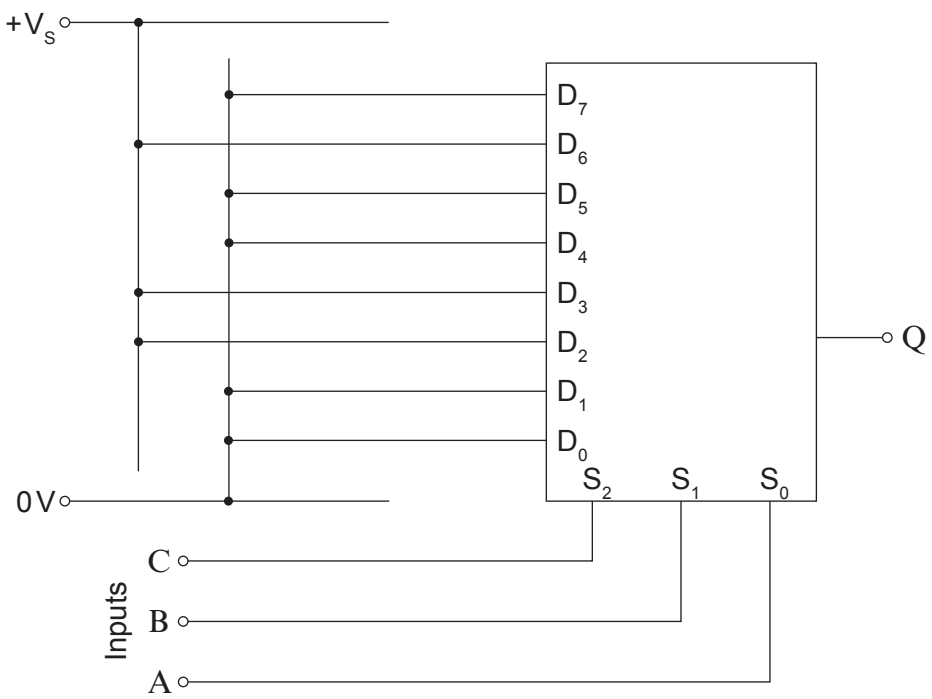
(d) (i) Complete the truth table for the output Q of the multiplexer circuit shown below. [2]



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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(ii) Determine the simplest expression for output Q using a Karnaugh map **or** the rules of Boolean algebra. [3]

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Q = ...

C \ BA	00	01	11	10
0				
1				

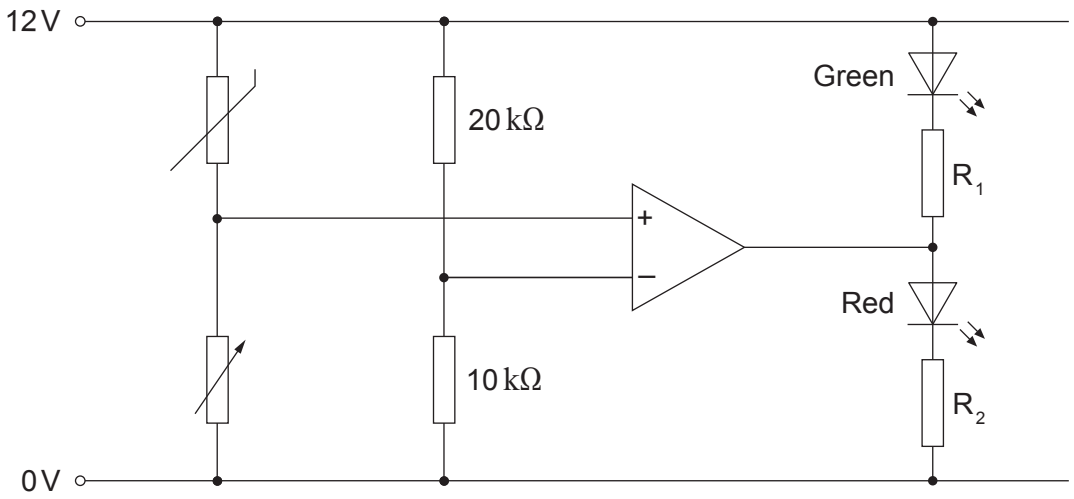
(iii) Design a logic system to generate the same logic function as the multiplexer. [3]

Examiner only

3. *(a)* Add the words 'zero' or 'infinite' to complete the following table of characteristics for an ideal op-amp. [1]

Property	Ideal value
Input impedance	
Output impedance	
Slew-rate	
Common-mode rejection ratio	

(b) The diagram shows the circuit for a temperature alarm for a greenhouse.



The op-amp saturates at +11 V and 0 V.

The variable resistor has a resistance of 5 kΩ.
At 0 °C, the resistance of the thermistor is 7 kΩ

Which LED is lit at 0 °C?

Explain how you arrived at your answer, providing supporting calculations. [4]

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Turn over.

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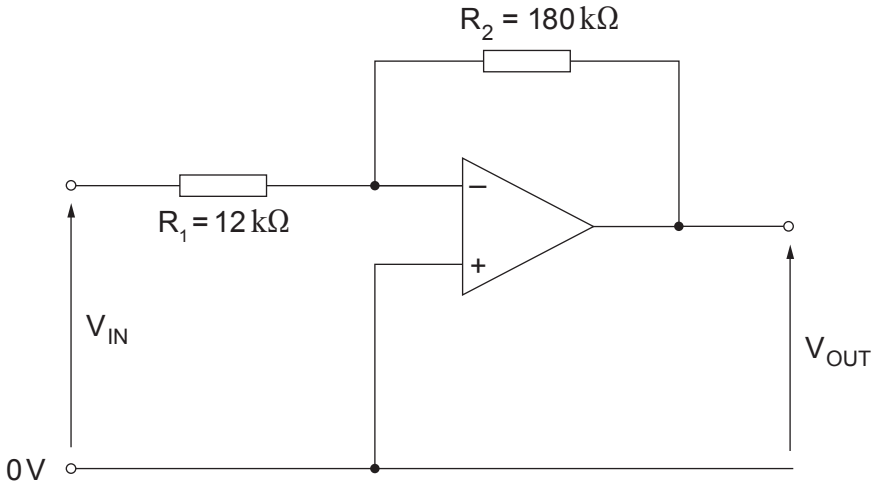
(c) The circuit diagram shows one form of voltage amplifier.



The output of the op-amp saturates at ±12 V.

(i) What is the voltage gain of this amplifier? [1]

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(ii) The signal shown in the top graph opposite is applied to the input of the amplifier. Use the axes provided opposite to draw the resulting signal at the output. [2]

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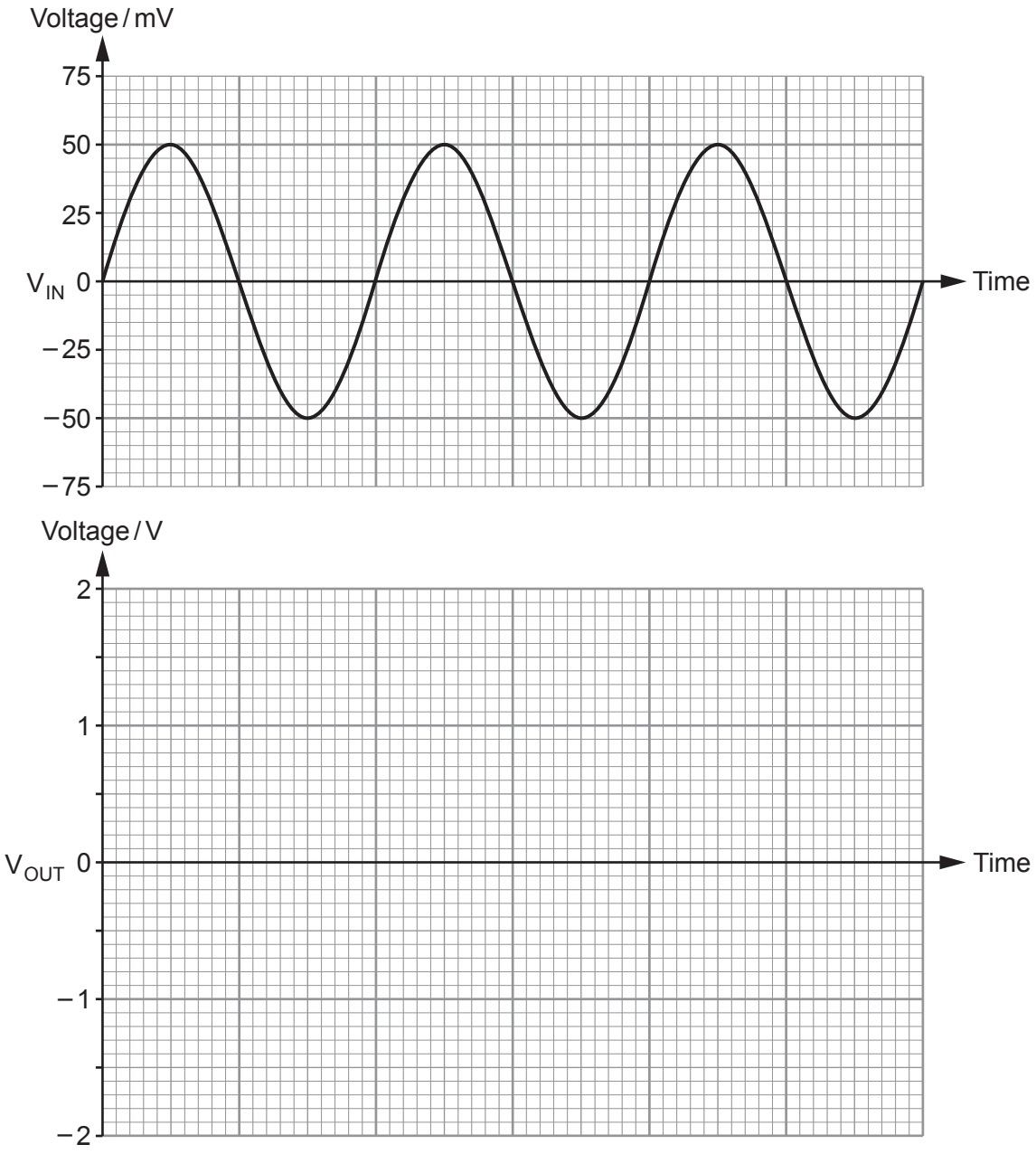

(iii) Describe the relationship between the currents through R_2 and R_1.

Give a reason for your answer. [2]

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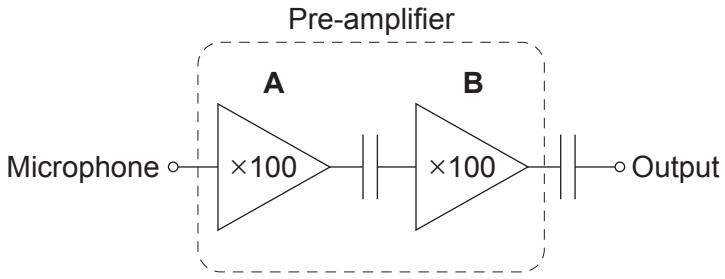
4. A microphone uses a multi-stage preamplifier, made from two non-inverting voltage amplifiers, labelled **A** and **B** in the following diagram.



(a) Calculate the overall gain of the preamplifier. Give a reason why this circuit is better than one using a single non-inverting amplifier having the same overall gain. [2]

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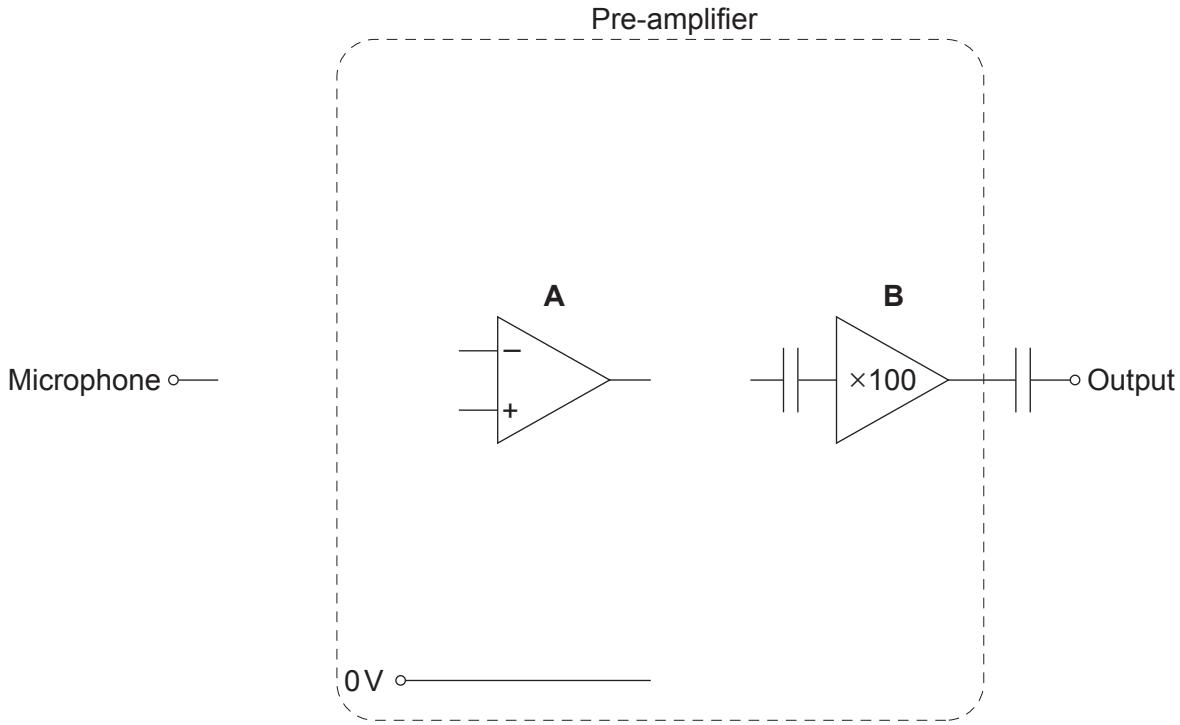
(b) Complete the circuit diagram for amplifier **A**. [3]



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(c) Determine suitable values for any resistors used in the circuit for amplifier **A** and label each resistor with its value. [3]

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(d) The preamplifier has a bandwidth of 15 kHz.

(i) Calculate the gain-bandwidth product of the op-amp used in amplifier **B**. [2]

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(ii) What is the voltage gain of amplifier **B** at a frequency of 15 kHz? [2]

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(e) Both op-amps saturate at ±12 V.

A 1 kHz test signal is applied to the input of the preamplifier. What is the maximum amplitude that will avoid clipping distortion at the output of the preamplifier? [2]

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(f) What is the **minimum** slew-rate for the op-amp used in amplifier **B** that will avoid slew-rate distortion for a microphone signal with a frequency of 10 kHz and an amplitude of 1 mV? [3]

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Turn over.

Examiner only

5. An optical communication system transmits data as a series of digital pulses from a laser diode.

(a) The laser diode emits 54 mJ of energy in 3 ms. Calculate the power delivered by the laser. [2]

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(b) (i) Give **one** advantage of digital communication over analogue communication. [1]

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(ii) Give **one** advantage of analogue communication over digital communication. [1]

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(c) What is the advantage of multiplexing digital signals onto a communications link? [1]

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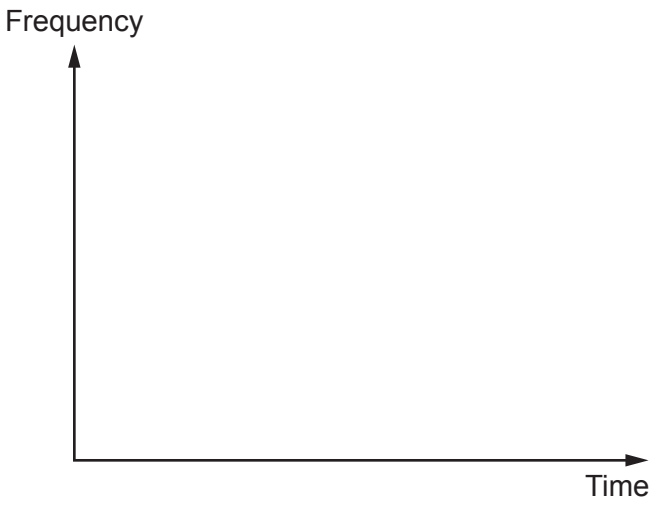
(d) Using FDM, four communication channels, each with a bandwidth of 5 GHz are multiplexed onto an optical fibre.

(i) Use the axes provided to illustrate the meaning of FDM in this situation. [2]



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(ii) Calculate the minimum bandwidth required for this system. [2]

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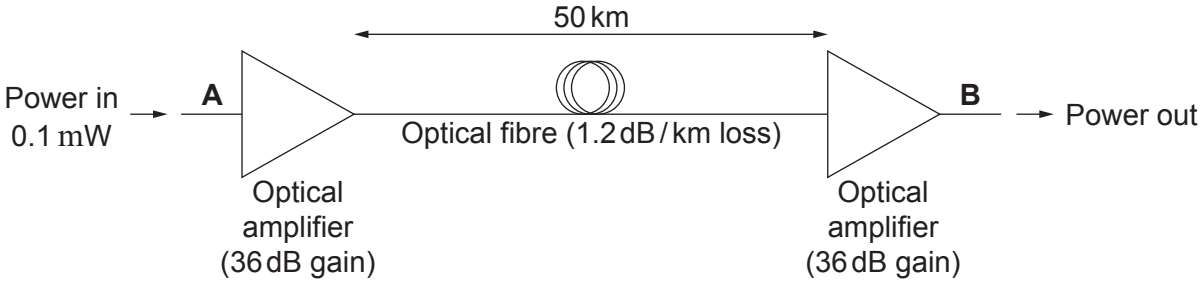
(e) The following diagram shows the power gains and losses taking place in the section, (labelled **A** to **B**,) of the optical fibre communication system.



(i) The signal at **A** has a power level of 0.1 mW.

What is the power level of the signal at **B**? [3]

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(ii) At **A**, the signal, with a power level of 0.1 mW, is distorted by noise with power of 0.001 mW.

What is the signal-to-noise ratio (SNR) in dB at **A**? [2]

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(iii) What happens to the SNR as the signal travels along the fibre? [1]

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Turn over.

Examiner only

6. In a recording studio, the analogue signal from a microphone is converted to a digital signal.

(a) The audio signal is restricted to frequencies between 500 Hz and 15 kHz before being sampled. Each sample is then converted to a digital value, which is stored in memory, ready for further processing.

(i) What is the minimum sampling frequency that allows the original signal to be recreated? [1]

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(ii) What is the implication of using too high a sampling frequency? [1]

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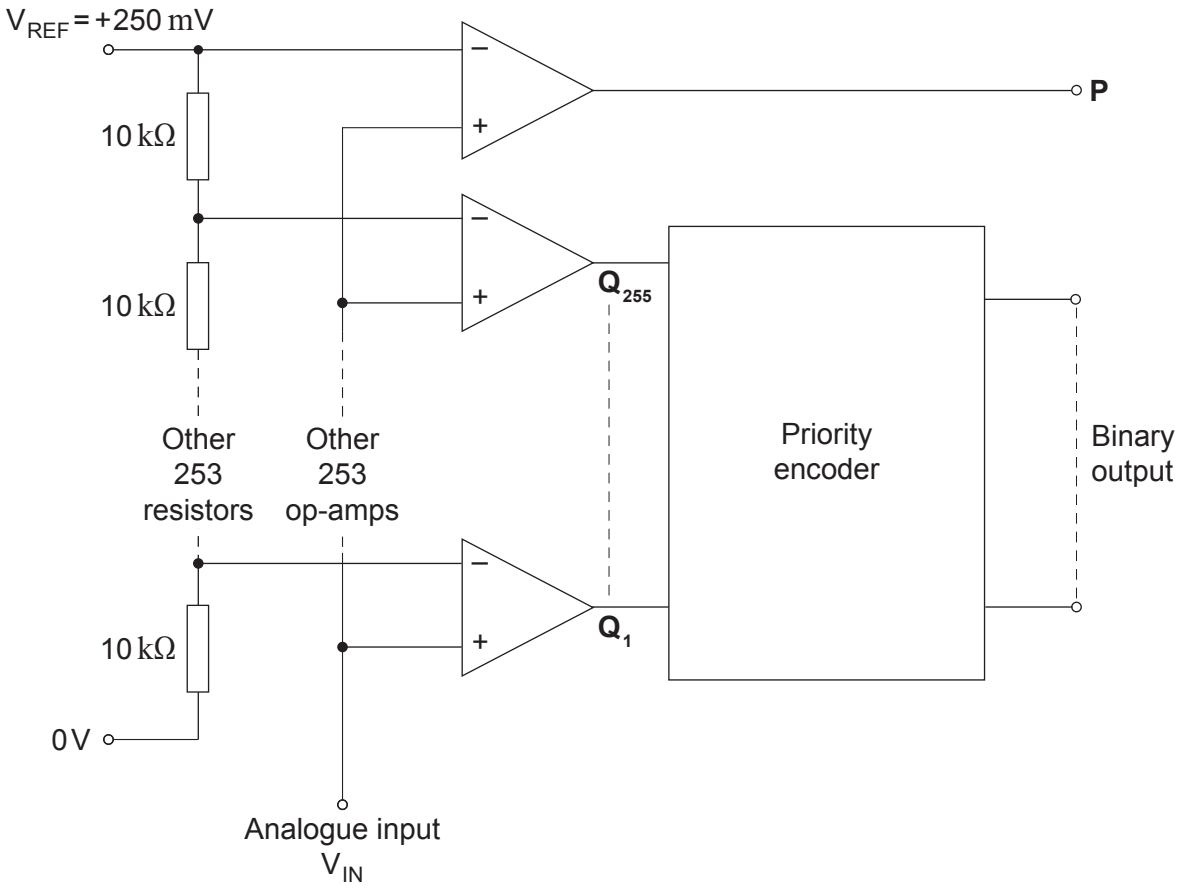
(b) Part of the conversion system is shown in the following circuit diagram:



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(i) What is the resolution of the ADC? [2]

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(ii) How could the sensitivity of the ADC be increased without changing the number of components in the circuit? [1]

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(iii) For this system how many bits does each sample contain? [2]

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(iv) Output **P** goes to logic 1. What does this indicate? [1]

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(c) The audio signal is now sampled at a sampling frequency of 35 kHz.

How many bits are needed to store the data generated in this way from a two minute audio recording? [2]

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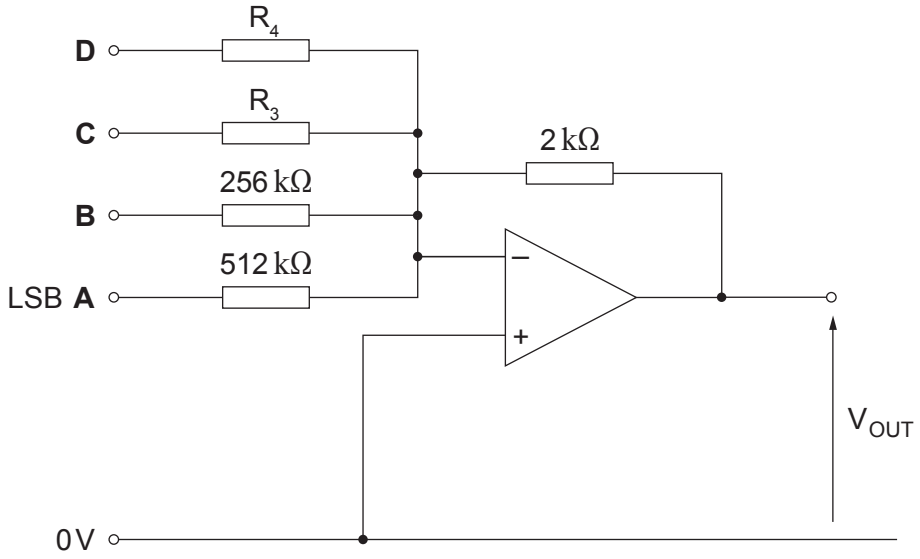
Examiner only

(d) In a different system, digital data is fed into a 4-bit DAC.

The circuit for this is shown in the next diagram:



(i) What is the resistance of resistor R_4? ..... [1]

(ii) The system uses 10 V to represent logic 1 and 0 V to represent logic 0.

What is the output voltage when the input is 0001_2? [2]

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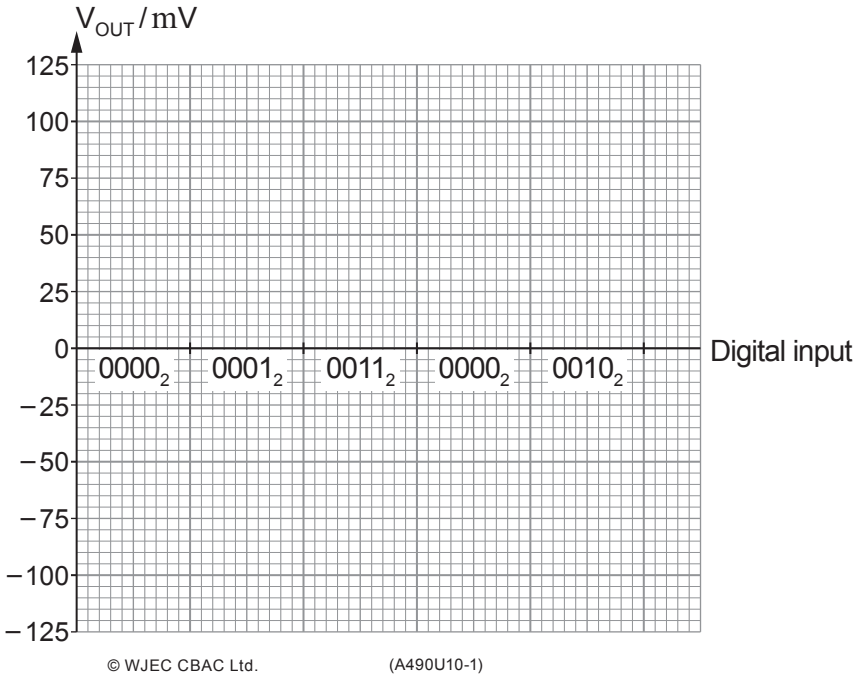
(iii) Complete the graph to show the output voltage, V_{OUT}, of the DAC when the following sequence of **binary** numbers is fed into it:

0000_2, 0001_2, 0011_2, 0000_2, 0010_2 [3]



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7. In an automated sorting system for a warehouse, packages are delivered to the correct storage location by a robot vehicle. The destination is marked as a binary number on a label stuck to the package.

The vehicle moves along a track, following an array coded with Gray code to monitor its position and locate the correct storage location.

The diagram shows a model of the array for eight storage locations **A** to **H** and the corresponding encoded strips. Strip 1 is the LSB.

(a) (i) A package is labelled with the destination address 110.

Which storage segment should the vehicle stop at? ..... [1]

(ii) Complete the shading to show the Gray code for segments **G** and **H**. [2]

(iii) Why is it unwise to code the strip using pure binary code? [1]

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(iv) The actual array of storage locations stretches for a distance of 50 m.

Each location is 1 m long. What is the minimum number of strips needed to encode the addresses for these locations? [2]

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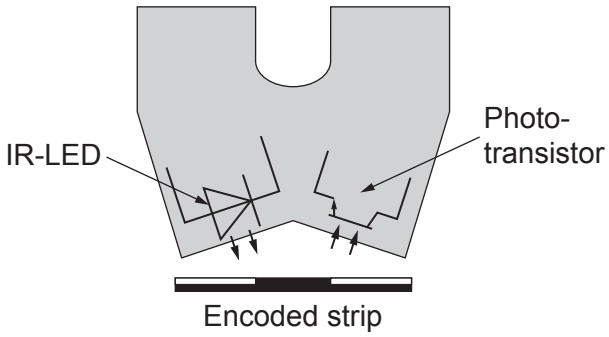
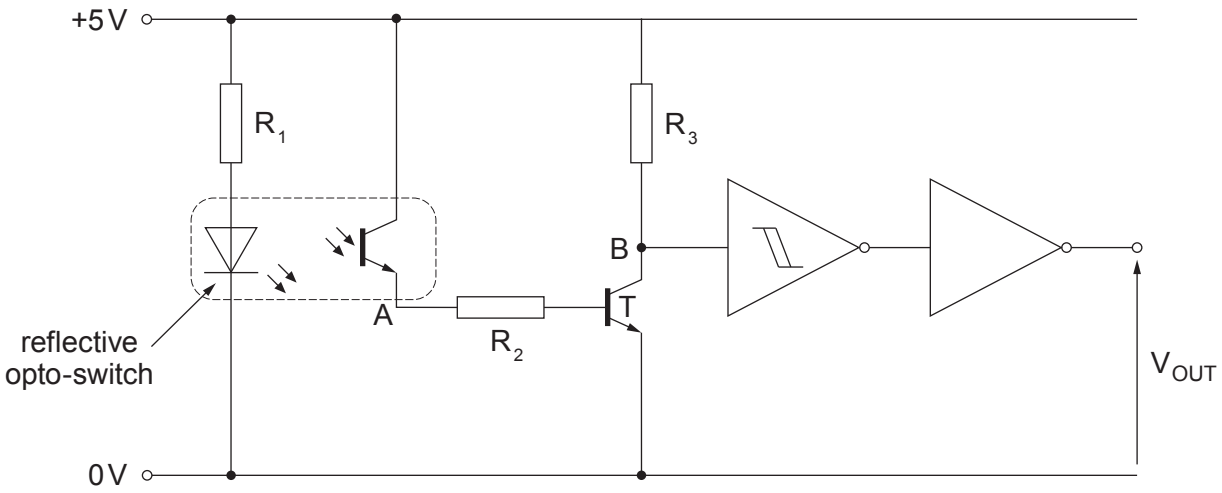
(b) The Gray code is 'read' by reflective opto-switches of the type shown in the following diagram:



The IR-LED emits infra-red light when it is forward biased.
The phototransistor conducts appreciable current only when exposed to IR-light.
This happens only when a white segment appears under the reflective opto-switch.

The sensing circuit for the reflective opto-switch is shown in the next diagram:



(i) The forward current through the IR-LED is 40 mA when emitting infra-red light. It then has a voltage drop of 1.8 V across it.

Use this information to calculate a suitable ideal value for resistor R_1. [2]

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(ii) The sensor is over a white segment.
- The voltage at A is 3.7 V.
- The base resistor, R_2, has a resistance of 1 kΩ.

What is the base current flowing into transistor **T**? [2]

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(iii) Transistor **T** has a current gain, h_{FE} of 60. Resistor R_3 has a resistance of 27 Ω.

What is the voltage at **B** when the opto-switch is over a white segment? [3]

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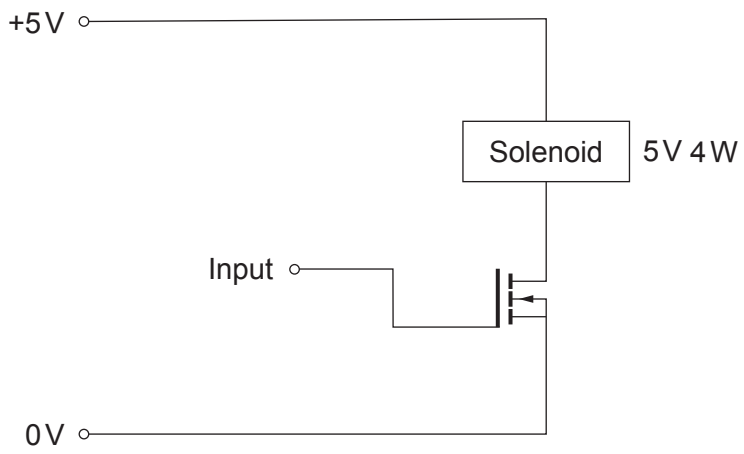
(c) Once the vehicle arrives at its destination, the package is pushed into place by a solenoid-operated actuator. The solenoid dissipates 4 W when energised and is activated by the MOSFET switching circuit shown below:



The table shows data extracted from the datasheet for the MOSFET:

Parameter	Value
Mutual transconductance, g_m	2 S
Drain-source on-state resistance, r_{DSon}	3.5 mΩ
Max power dissipation	60 W

(i) Calculate the value of input voltage needed to turn on the solenoid. [3]

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(ii) Calculate the power dissipated in the MOSFET when the solenoid is energised. [2]

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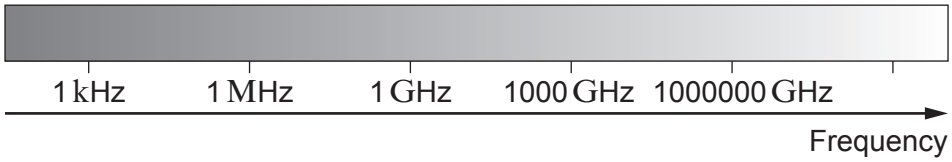
8. *(a)* The diagram represents part of the electromagnetic spectrum.

A microwave signal has a wavelength of 3 cm. Identify its position on the spectrum below. Microwaves travel at $3 \times 10^8\,m\,s^{-1}$. [2]



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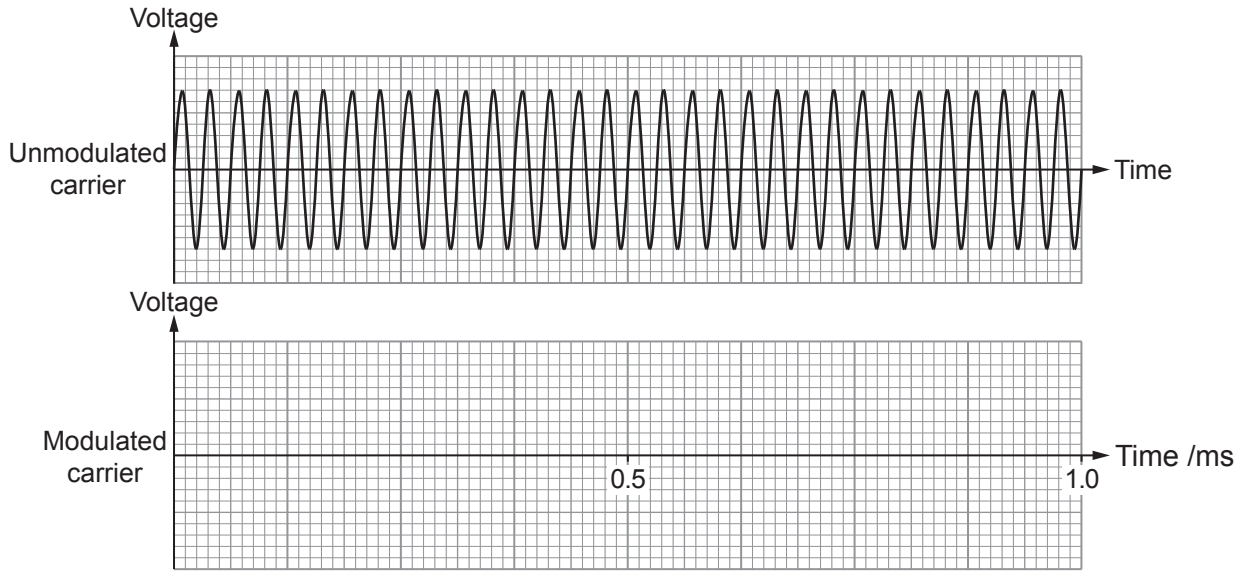
(b) The diagram shows an unmodulated radio carrier wave:



Using AM, a sinusoidal signal with a single frequency of 2 kHz, modulates the carrier. The depth of modulation is 100 %.

Use the axes to sketch the resulting waveform. [3]

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(c) A communication system uses a LC band-pass filter having a resonant frequency of 225 kHz. It incorporates a 4.3 kΩ series resistor.

The inductor has an inductance of 0.01 mH and a resistance of 0.3 Ω.

(i) Draw a circuit diagram for the LC band-pass filter. [2]

(ii) Calculate the value of capacitor needed to achieve resonance at 225 kHz. [2]

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(iii) Calculate the dynamic resistance of the filter at resonance. [2]

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(iv) Calculate the bandwidth of the filter. [4]

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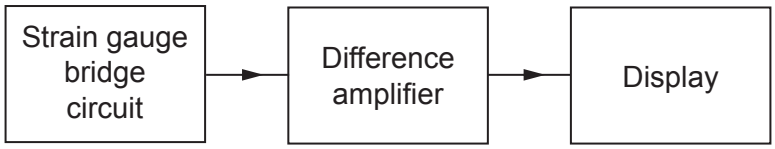
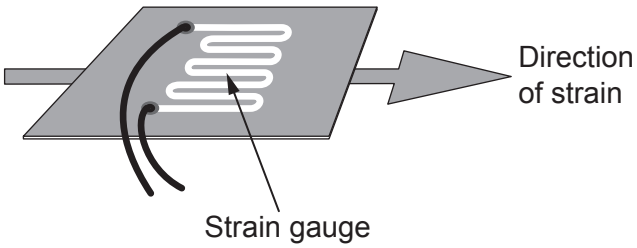
9. A civil engineer has built a model of a proposed structure in order to investigate the effect of stresses within the structure.

The block diagram for the testing system is shown below.

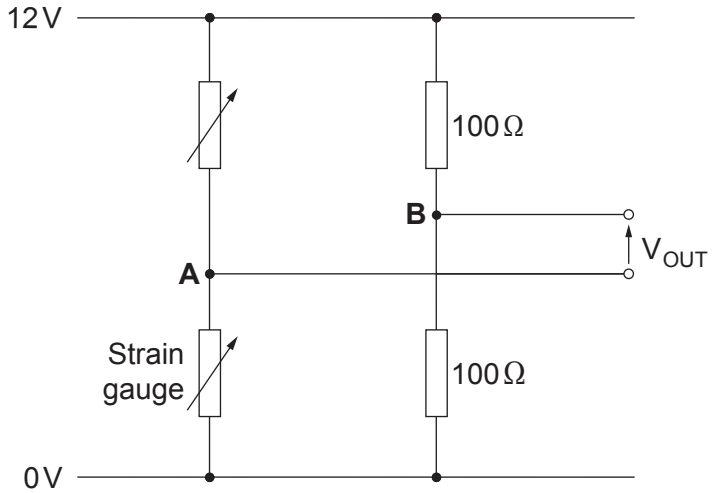


The strain gauge shown in the following diagram, is fixed at the junction between two beams.



It has a resistance of 120 Ω when unstretched. Its resistance increases when it is stretched.

The diagram shows the bridge circuit.



(a) (i) What resistance must the variable resistor be set to in order to balance the bridge circuit when the strain gauge is under no stress? [3]

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(ii) The variable resistor remains at this setting. Under stress, the bridge circuit outputs a voltage of $V_{OUT} = -50\,\text{mV}$.

Calculate the resistance of the strain gauge under these conditions. [4]

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(b) The output of the strain gauge bridge circuit is amplified by connecting points **A** and **B** to the inputs of a difference amplifier.

Design the difference amplifier, based on a single op-amp, so that the difference amplifier obeys the following specification: [5]

Output of bridge circuit	Output of difference amplifier
0 V	0 V
20 mV	10 V

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(c) The model seems to work well, but when the system is installed on the structure, it is found to produce inconsistent results.

Suggest one improvement to the system that might improve its performance.
Give details of the modification and explain why it is needed. [3]

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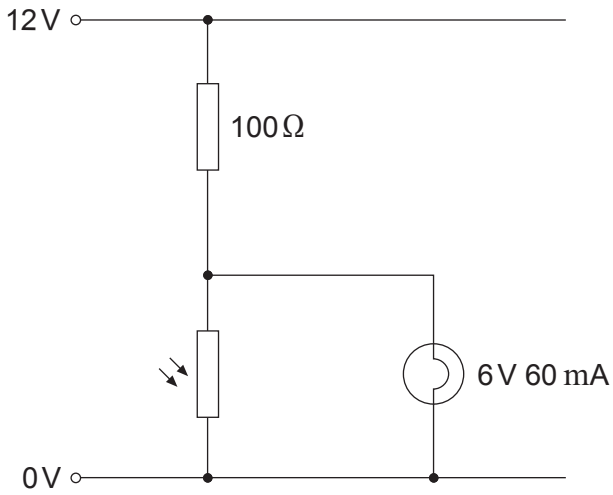
10. A cyclist has designed an automatic light for a cycle.



In daylight, the 6 V 60 mA filament lamp should be turned off.
When it gets dark, the lamp should light up.

The characteristics of the LDR are given in the following table:

Conditions	Resistance
Daylight	400 Ω
Darkness	1 MΩ

Evaluate the circuit and suggest improvements. [6 QER]

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