AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

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I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Electronics

Thursday 15 June 2023 Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

Materials

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

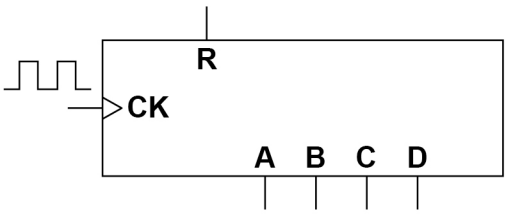
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Section B

Answer **all** questions in this section.

0 1 **Figure 1** shows the input and output pins for a 4-bit binary counter. The output pin for the least significant bit is **A**.

Figure 1

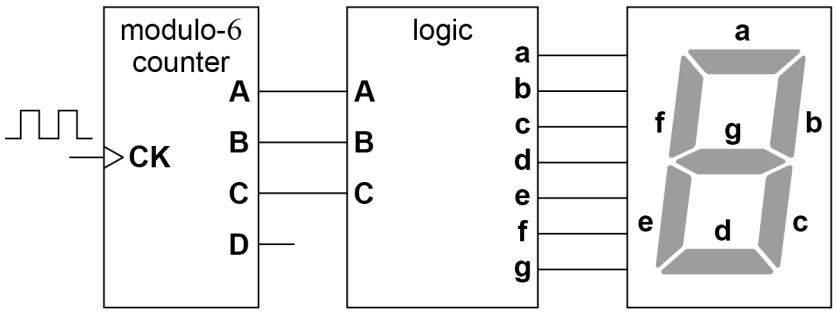


0 1 . 1 Complete **Figure 1** by adding a single logic gate to the binary counter so that the circuit functions as a modulo-6 counter.

[2 marks]

Figure 2 shows three outputs of the modulo-6 counter connected to a logic sub-system that controls a 7-segment display.
The decimal point on the display is not shown.
The whole system shown in **Figure 2** is to be used as an electronic dice.

Figure 2



Segments in the 7-segment display are turned on or off by the logic sub-system to display the decimal numbers 1 to 6 in sequence.
A segment in the display turns on when the logic output with the same letter as the segment is at logic 1.

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Table 1 shows how the values of **CBA** control the logic level applied to each of the segments **a** to **g** during the counting cycle.

Table 1

Logic inputs			Logic outputs						
C	**B**	**A**	**a**	**b**	**c**	**d**	**e**	**f**	**g**
0	0	0	0	1	1	0	0	0	0
0	0	1	1	1	0	1	1	0	1
0	1	0	1	1	1	1	0	0	1
0	1	1	0	1	1	0	0	1	1
1	0	0	1	0	1	1	0	1	1
1	0	1	1	0	1	1	1	1	1

0 1 . 2 One of the logic outputs **a** to **g** is controlled by a single NOT gate. This gate uses one of the inputs **A**, **B** or **C**.

State the input that is used and the segment that this NOT gate controls.

[1 mark]

input = _____

segment = _____

0 1 . 3 **X** represents one of the logic outputs. The Boolean expression for this output is:

$$\mathbf{X} = (\mathbf{A} \cdot \mathbf{B}) + \mathbf{C}$$

State which of the logic outputs **a** to **g** is being controlled by this function.

[1 mark]

logic output = _____

Question 1 continues on the next page

Turn over ►

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0 1 . 4 **Y** represents another of the logic outputs. The Boolean expression for this output is:

$$\mathbf{Y} = \left(\overline{\mathbf{A}} \cdot \overline{\mathbf{B}}\right) + \left(\overline{\overline{\mathbf{B}} \cdot \overline{\mathbf{C}}}\right)$$

Complete **Figure 3** to show the combination of logic gates needed to represent the expression.
You should only use logic gates that represent the individual functions shown in the expression.

[3 marks]

Figure 3

A ○

B ○ ○ **Y**

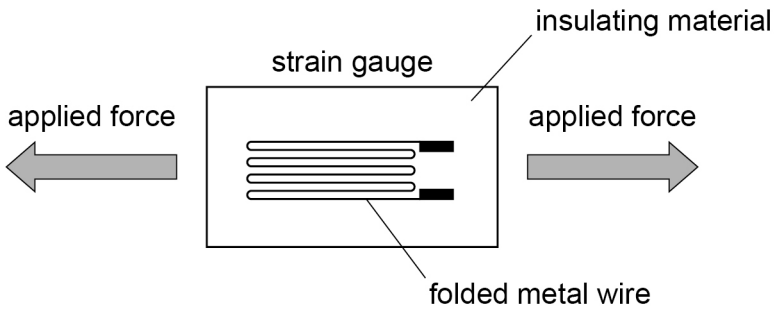
C ○

7

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0 2 **Figure 4** shows a strain gauge that consists of a folded metal wire glued to a piece of insulating material.

Figure 4



The resistance of the metal wire:

- increases when the gauge is stretched by forces applied as shown
- changes when there is a change in temperature.

Question 2 continues on the next page

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0 2 . 1 **Figure 5** shows a circuit that contains two identical strain gauges **A** and **B**.
The resistance of each strain gauge is $120.00\ \Omega$ when the strain is zero.

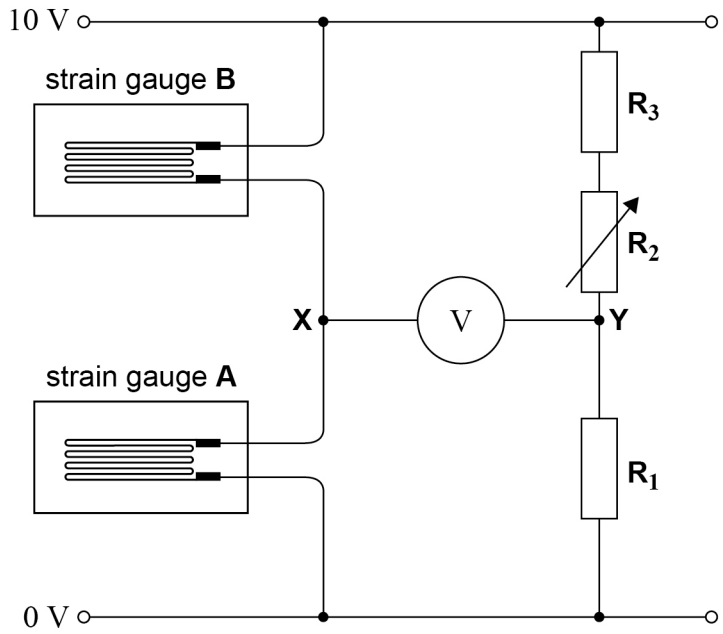
$\mathbf{R_1}$ is a $560\ \Omega$ fixed resistor.

$\mathbf{R_2}$ is a $100\ \Omega$ variable resistor.

$\mathbf{R_3}$ is a $510\ \Omega$ fixed resistor.

Assume that the voltmeter is ideal.

Figure 5



The circuit is used to measure changes in strain in a metal beam.
A is glued firmly to the metal beam.
B is placed on the beam near **A** but is not glued to the beam.

Initially, with the gauges under zero strain, $\mathbf{R_2}$ is adjusted to produce $0\ \text{V}$ on the voltmeter.
When the beam bends, **A** stretches and **B** remains unstretched.
The resistance of **A** increases to $120.06\ \Omega$.

Calculate, in mV, the new reading on the voltmeter.

[3 marks]

reading on the voltmeter = _____ mV

Do not write outside the box

0 2 . 2 Explain the advantage of using strain gauge **B** rather than a $120.00\ \Omega$ resistor in the circuit.

[2 marks]

0 2 . 3 The voltages at **X** and **Y** in **Figure 5** are now used as inputs to an operational amplifier.
The operational amplifier is configured as a difference amplifier with a gain of $+5$

Complete **Figure 6** to show the difference amplifier circuit.
Any resistors used must be labelled with their values. These values must be in the range $10\ \text{k}\Omega$–$10\ \text{M}\Omega$.
Do not show the supply rails.

[3 marks]

Figure 6



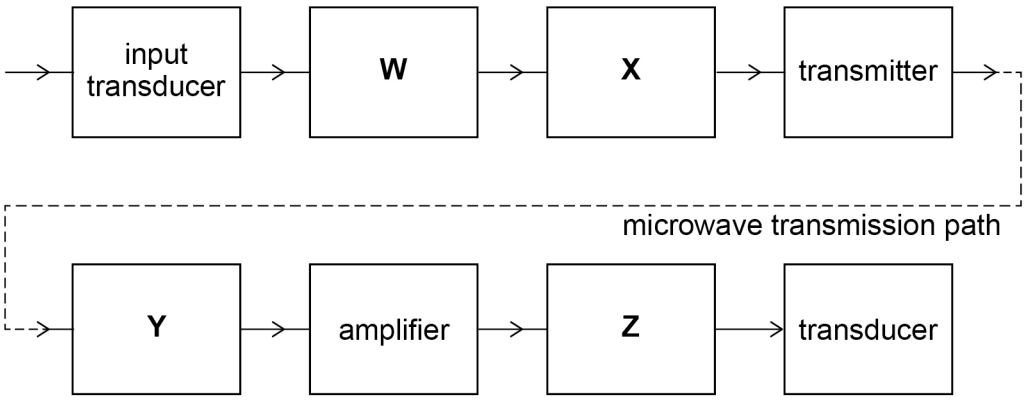
8

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0 3 . 1 **Figure 7** shows a block diagram for part of a communication system that transmits control information from Earth to a satellite.

Figure 7



Which row gives the functions of the boxes **W**, **X**, **Y** and **Z** in **Figure 7**?
Tick (✓) **one** box.

[1 mark]

W	X	Y	Z	
amplifier	modulator	demodulator	receiver	
modulator	amplifier	receiver	demodulator	
demodulator	amplifier	modulator	receiver	
amplifier	demodulator	receiver	modulator	

0 3 . 2 Syncom 3 was the first geostationary communication satellite.
The satellite was used to broadcast television signals of the 1964 Olympic Games from Tokyo in Japan to Los Angeles in the USA.

State what is required so that de-sensing does not occur in a radio receiver such as that on Syncom 3.

[1 mark]

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Commentators in Los Angeles interviewed athletes in Tokyo using Syncom 3.

The commentators found that there was a significant time delay between the end of each question and the arrival of its reply.

This time delay was made up of:
- the total time that the signals spent travelling
- the total processing time.

0 3 . 3 The distance of the geostationary satellite from both Tokyo and Los Angeles was $40\ 000$ km.

The time delay was 900 ms.

Calculate, in ms, the total processing time.

[2 marks]

total processing time = _____ ms

0 3 . 4 The television signals received in the USA were relayed to the UK using a satellite in low Earth orbit.
The availability of live coverage was different for viewers in the USA and viewers in the UK.

Explain why.

[2 marks]

_____

_____

_____

_____

_____

_____

Question 3 continues on the next page

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0 3 . 5 For the 2020 Olympics, digital TV signals between Tokyo and Los Angeles used a fibre-optic cable. The cable lies on the seabed.

Explain why a fibre-optic cable rather than a satellite link is now preferred for intercontinental communication.

[2 marks]

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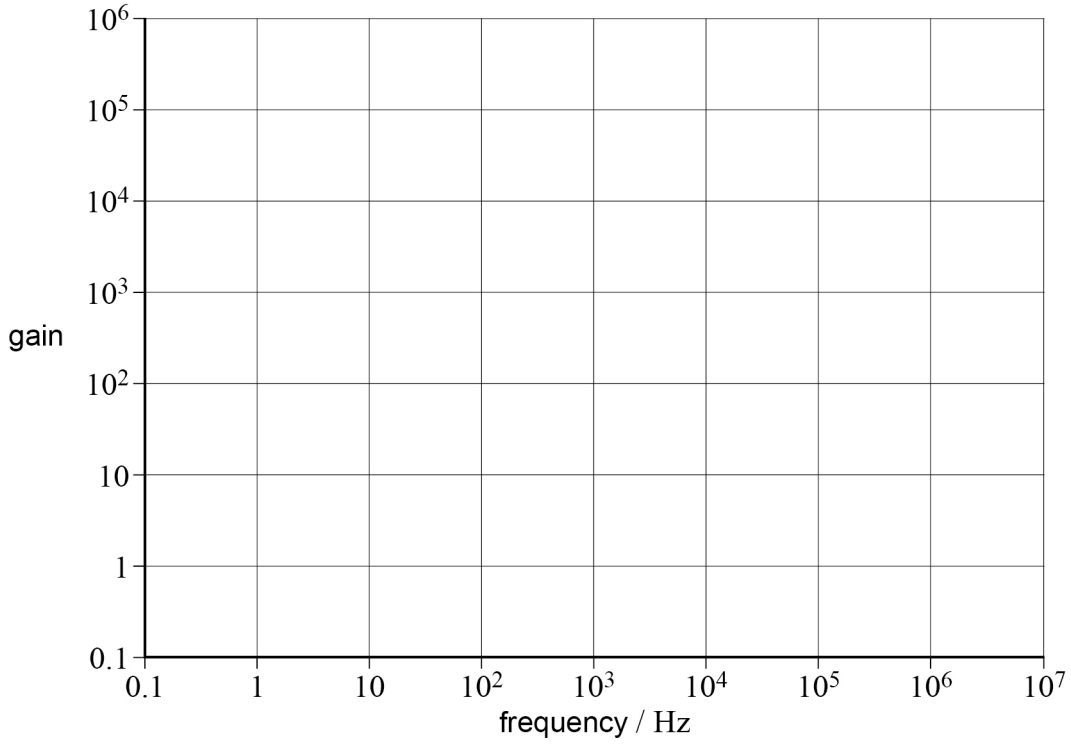
0 4 . 1 A particular operational amplifier has the following properties:

- open-loop gain = 1×10^5
- break frequency (cutoff frequency) = 10 Hz
- gain × bandwidth = 1 MHz.

Draw, on **Figure 8**, the variation of gain with frequency for this operational amplifier in open-loop mode.

[2 marks]

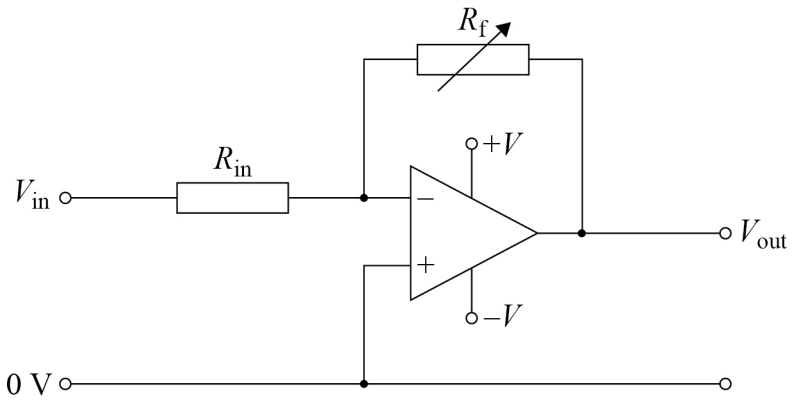
Figure 8



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0 4 . 2 **Figure 9** shows the operational amplifier being used in an inverting amplifier circuit.

Figure 9



Annotate **Figure 9** with:

- an **X** to indicate a point that acts as a virtual earth
- arrows to show the direction of current I in both resistors when the input voltage V_{in} is negative.

[2 marks]

0 4 . 3 The value of R_f in the feedback loop in **Figure 9** is increased.

State and explain the effect of this change on the bandwidth of the inverting amplifier.

[2 marks]

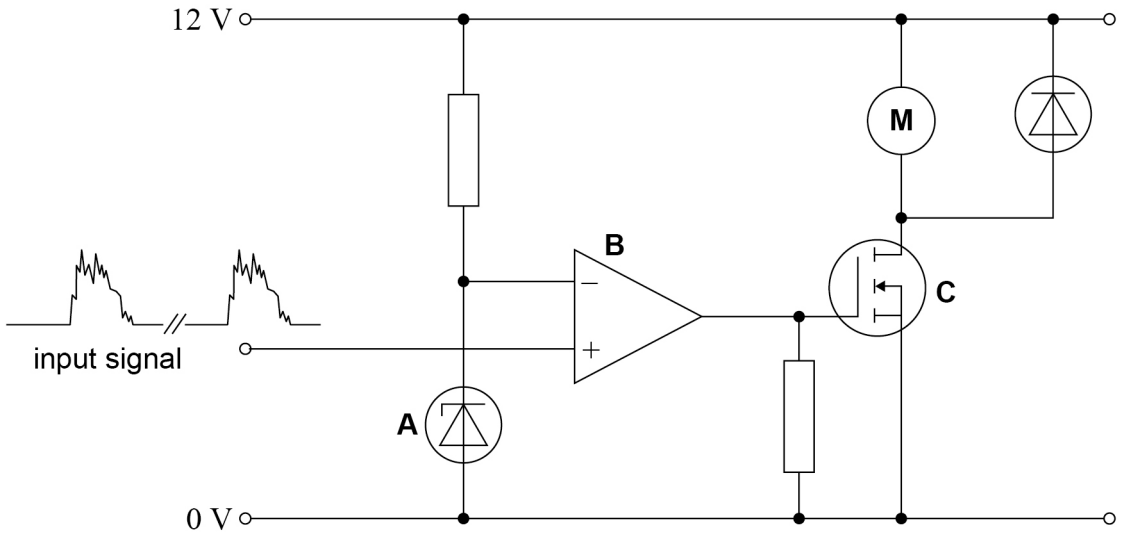
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0 5 **Figure 10** shows a circuit that has an input signal which is a noisy square wave. The circuit is used to remove the noise and switch a motor **M** on and off.

Figure 10



Explain the functions of components **A**, **B** and **C**.

For each of these components you should:

- explain its role in the circuit
- identify the characteristic properties that make the component suitable for this role.

[6 marks]

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