AQA

Please write clearly in block capitals.

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

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Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Electronics

Monday 17 June 2024 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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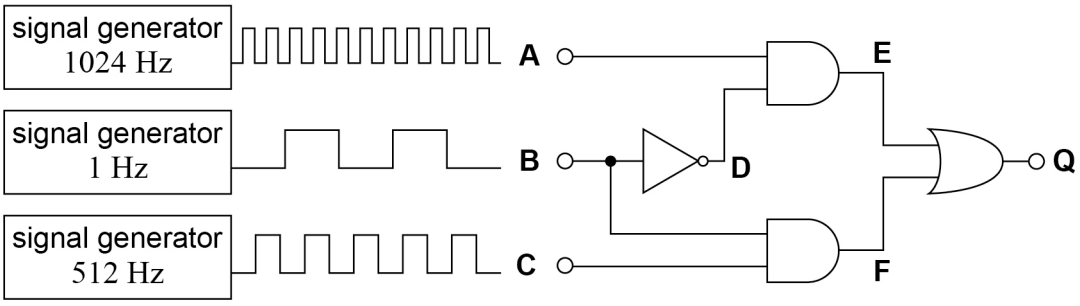
Section B

Answer **all** questions in this section.

0 1 A toy manufacturer is designing a two-tone siren for use in small battery-operated cars.
Figure 1 shows design Option **1**.

Option **1** uses three separate signal generators feeding into a logic sub-system.
The signal generators produce logic-compatible 9 V square waves of frequencies 1024 Hz, 1 Hz and 512 Hz.

Figure 1



The waveforms shown are not to scale.

0 1 . 1 Explain how the logic level applied at **B** in **Figure 1** determines the output frequency at **Q**.

[2 marks]

0 1 . 2 Write the Boolean algebra expression for output **Q** in terms of the inputs **A**, **B** and **C**.
Use only the logic operations shown in **Figure 1**.

[2 marks]

Q = _____

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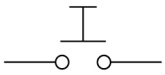
0 1 . 3 Option **1** is tested by replacing the 1 Hz signal generator with a manual input.

The manual input is provided by the combination of a push-to-make switch and a 10 kΩ resistor.

The combination produces the following voltages at its output:
- 0 V when the switch is not pressed
- 9 V when the switch is pressed.

Figure 2 shows the symbol for the push-to-make switch.

Figure 2



Complete **Figure 3** to show how this switch and the 10 kΩ resistor are connected.
Label the output V_{out}.
You do not need to add details taken from **Figure 1**.

[1 mark]

Figure 3

Question 1 continues on the next page

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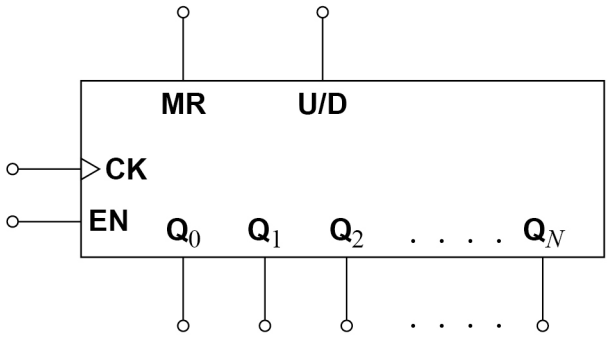
0 1 . 4 **Figure 4** shows a generalised layout of an integrated circuit (IC) for an N-bit binary counter.
$\mathbf{Q}_0$ is the output that provides the least significant bit.

Figure 4



A signal generator feeds a square wave of frequency 1024 Hz into the clock of the IC. The N-bit binary counter generates the 512 Hz signal and the 1 Hz signal from separate outputs.

Deduce which of the outputs $\mathbf{Q}_0$ to $\mathbf{Q}_N$ will provide the 1 Hz signal.

[1 mark]

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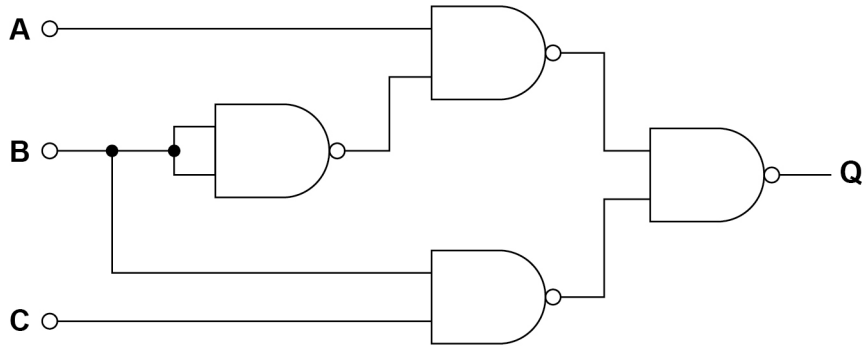
0 1 . 5 To make the two-tone siren, the manufacturer decides to use a new design, Option **2**.

Option **2** contains:

- one 1024 Hz signal generator
- one N-bit binary counter
- a new logic sub-system as shown in **Figure 5**.

Figure 5



Assume that:

- each **type** of logic gate has its own dedicated IC chip
- each separate signal generator is based upon its own IC chip.

Compare the number of ICs used in Option **1** with the number used in Option **2**.
Go on to explain **one** advantage of the manufacturer's decision.

[2 marks]

8

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0 2 The short message service (SMS) on a mobile phone can send a maximum of 160 characters per message. Each character is represented by its own seven-bit binary code as it is converted to digital data.

0 2 . 1 The mobile phone transmits digital data at a rate of 8 kilobytes per second (kB s^{-1}) when using the SMS function.

Determine the minimum time required to send 160 characters.

[2 marks]

time = _____ s

Electrical noise can affect communication systems.

0 2 . 2 Describe **one** origin of electrical noise in a communication system.

[1 mark]

0 2 . 3 Describe the effect that electrical noise can have:

- on the signal and
- on the communication system.

[2 marks]

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Figure 6 shows a noisy digital signal V_{in} which is applied to a circuit.

The circuit output V_{out} switches to:

- 5 V when the input voltage V_{in} falls below 1.8 V
- 0 V when the input voltage V_{in} rises above 3.2 V.

Figure 6

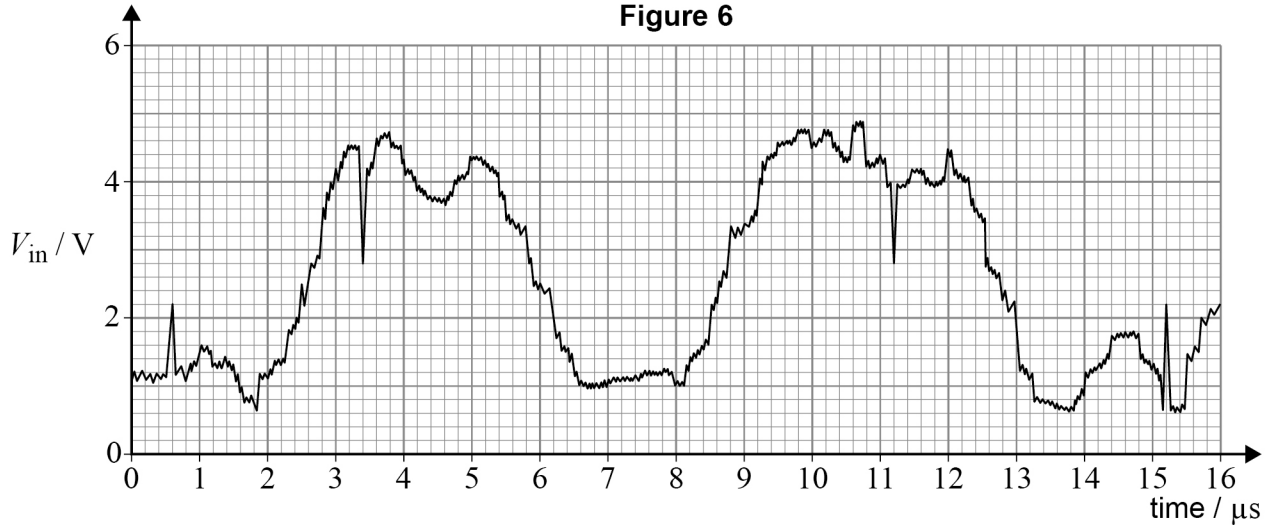
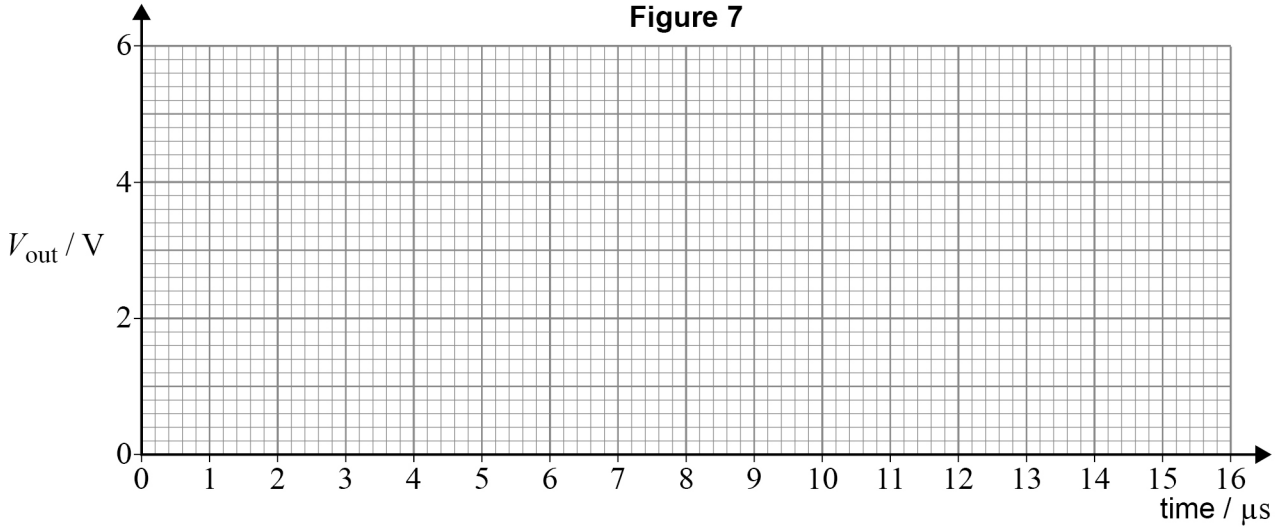


Figure 7



0 2 . 4 Draw, on **Figure 7**, the output signal V_{out} from the circuit.
Assume that V_{out} is initially at 5 V.

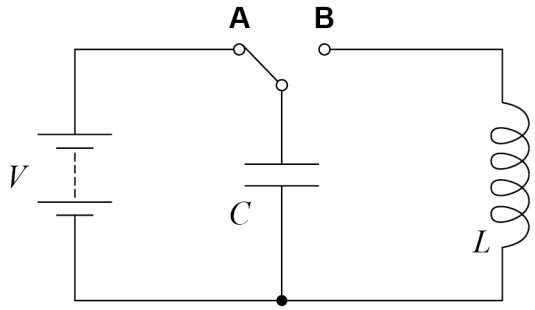
[2 marks]

7

Turn over ►

0 3 **Figure 8** shows an LC circuit that produces electrical oscillations when the switch is moved from position **A** to position **B**.

Figure 8



0 3 . 1 Which quantity in the LC circuit is analogous to the mass in a mass–spring system?

Tick (✓) **one** box.

[1 mark]

C ☐

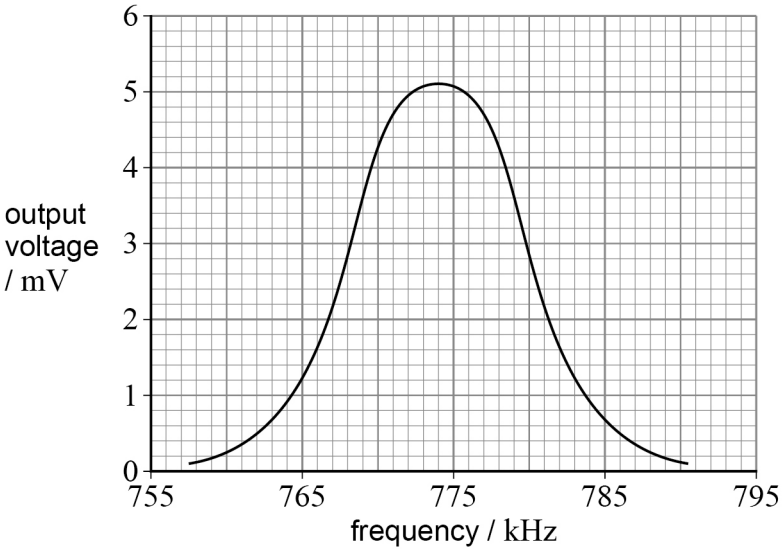
$\frac{1}{C}$ ☐

L ☐

$\frac{1}{L}$ ☐

0 3 . 2 A radio receiver uses a parallel LC tuned circuit to select a radio station. **Figure 9** shows the response of the tuned circuit.

Figure 9



Calculate the quality factor Q of the tuned circuit.

[3 marks]

$Q =$ _____

Question 3 continues on the next page

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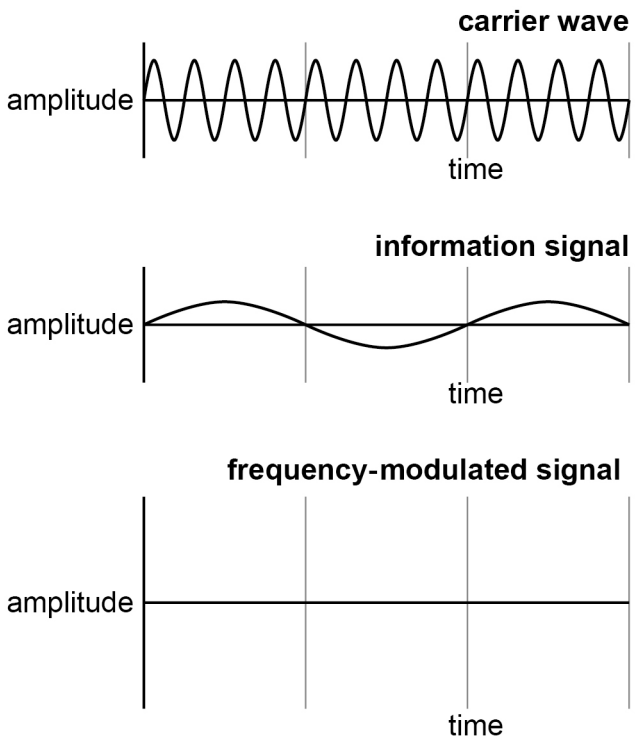
Another radio receiver is used to detect frequency-modulated (FM) radio waves.

Figure 10 shows the variation of amplitude with time for a carrier wave and an information signal.

Figure 10



0 3 . 3 Sketch, on **Figure 10**, the graph that represents the frequency-modulated (FM) signal.

[2 marks]

0 3 . 4 An audio signal is transmitted on an FM music station. The transmission has a bandwidth of 186 kHz. The carrier wave has a maximum frequency deviation of 75 kHz.

Calculate the maximum frequency in the information signal.

[1 mark]

maximum frequency = _____ kHz

7

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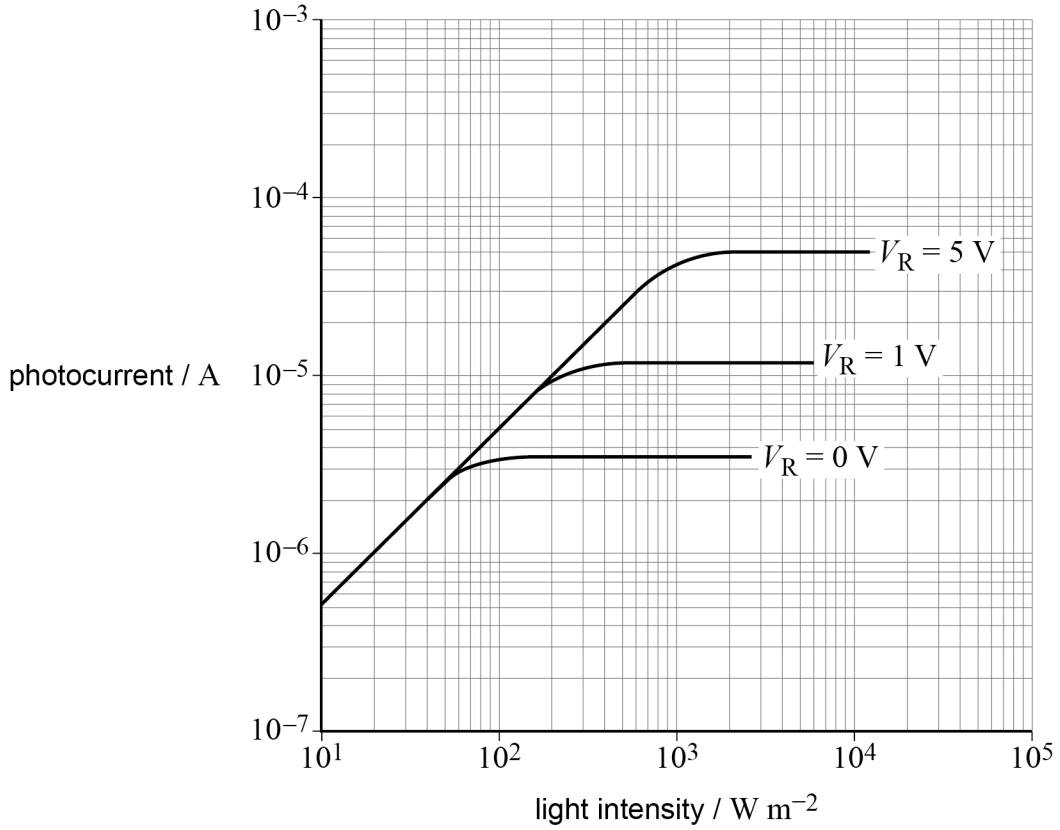
0 4 . 1 **Figure 11** shows the response of a photodiode for different values of reverse-bias voltage V_R.

Figure 11



The photodiode is used as the input for a light-intensity meter.

The light intensity changes from 100 W m^{-2} to 400 W m^{-2}.

Explain which value of V_R in **Figure 11** should be used for this application.
Go on to deduce the change in photocurrent for this change in light intensity.

[2 marks]

change in photocurrent = _____ A

Question 4 continues on the next page

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0 4 . 2 Describe how a photodiode is used in a particle detector to detect sub-atomic particles.

[2 marks]

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0 4 . 3 The particle detector produces an analogue signal that is the input voltage V_{in} to an amplifier circuit.
V_{in} is amplified by a factor of $+10$

Draw, on **Figure 12**, a circuit that uses a single operational amplifier to produce an amplification of $+10$

Use resistors with resistance values in the range $10\ \text{k}\Omega$ to $1\ \text{M}\Omega$ in the circuit.

On your diagram you should label:
- the value of the resistors
- the output of the circuit as V_{out}.

Do **not** show the power supplies for the operational amplifier.

[3 marks]

Figure 12

7

Turn over for the next question

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0 5 Several telephone conversations need to be transmitted simultaneously between two locations.

Describe the process that allows these conversations to be carried by the same optical fibre.

In your answer you should explain:
- the importance of the sampling rate in the analogue-to-digital conversion
- the effect of resolution in this conversion
- the technique that is used to enable several conversations to be transmitted simultaneously.

You may use diagrams to help with your explanation.

[6 marks]

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END OF QUESTIONS

6

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