AQA

Please write clearly in block capitals.

Centre number ☐☐☐☐☐ Candidate number ☐☐☐☐

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Candidate signature ______________________

I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Electronics

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.

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.

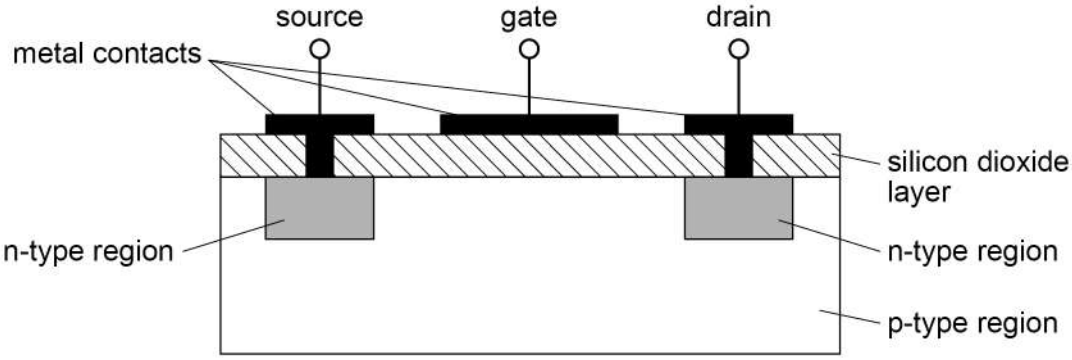
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

Section B

Answer **all** questions in this section.

0 1 **Figure 1** shows a simplified structure of an N-channel enhancement mode MOSFET.

Figure 1



0 1 . 1 State the name of the part shown in this MOSFET structure that causes the input resistance to be very large.

[1 mark]

____

0 1 . 2 Which terminal of the MOSFET is connected directly to 0 V when it is used as a simple switch?

Tick (✓) **one** box.

[1 mark]

drain ☐

gate ☐

source ☐

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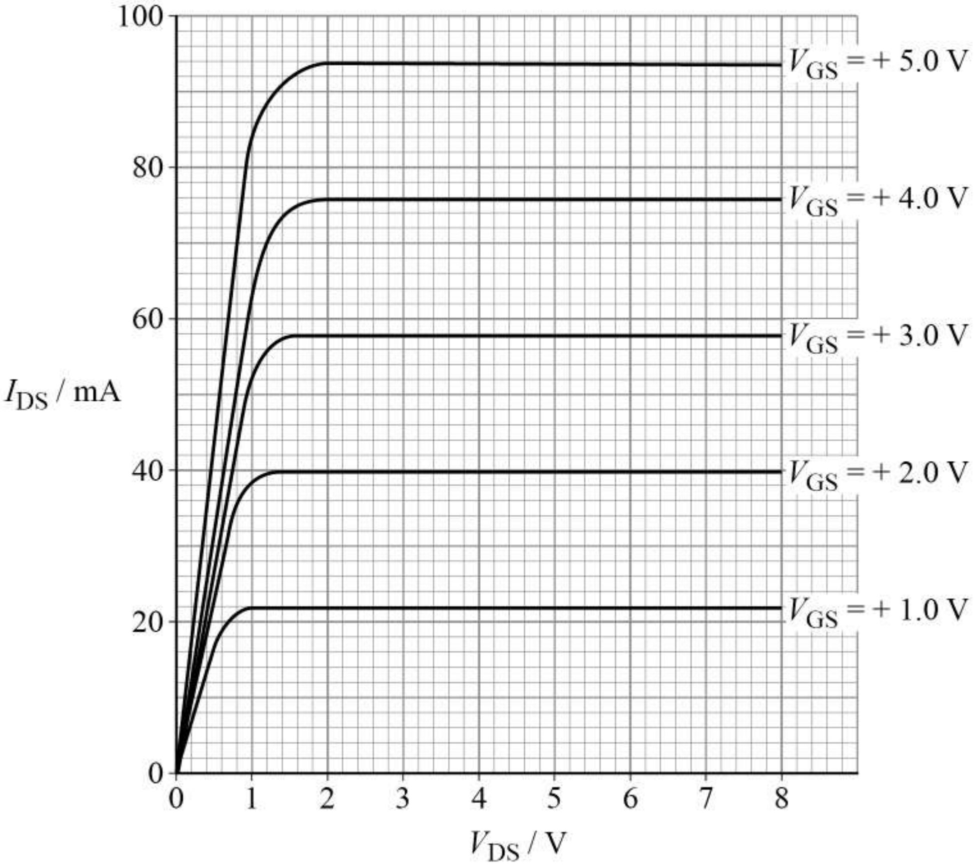
Figure 2 shows how the drain–source current I_{DS} of the MOSFET varies with drain–source voltage V_{DS} for a range of gate–source voltages V_{GS}.

Figure 2



The MOSFET is used as a simple switch in a filament lamp circuit.
The circuit uses power rails of 12 V and 0 V.
The resistance of the lamp is 154 Ω when operating at its full power of 0.65 W.

0 1 . 3 Deduce the minimum value of V_{GS} needed for the lamp to operate at full power.

[2 marks]

V_{GS} = ____________________ V

Question 1 continues on the next page

Turn over ►

0 1 . 4 **Figure 3** shows an individual MOSFET. The drain–source leakage current I_{DSS} for this MOSFET is about $10\ \text{nA}$.

Figure 4 shows a microchip where millions of MOSFETs are combined to enable complex processes to be carried out on one chip.

Figure 3

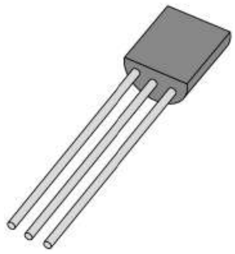
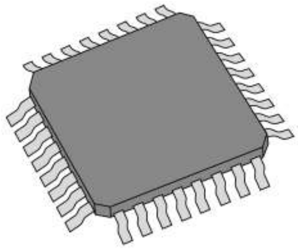


Figure 4



A mobile phone has a central processing unit (CPU) which uses a microchip similar to the one in **Figure 4**.

Table 1 shows the technical specification for the mobile phone.

Table 1

Number of transistors in the CPU	8.5×10^9
Battery capacity	$3110\ \text{mA h}$
Phone time available on stand-by from one full charge	≈ 12 hours

A fully charged battery with a capacity of $1\ \text{A h}$ allows $3600\ \text{C}$ of charge to flow through it before it is fully discharged.

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The I_{DSS} value for each MOSFET used in the mobile phone CPU must be different from that measured in the individual MOSFET shown in **Figure 3**.

Discuss, using the data provided, the reason for this difference.

[3 marks]

7

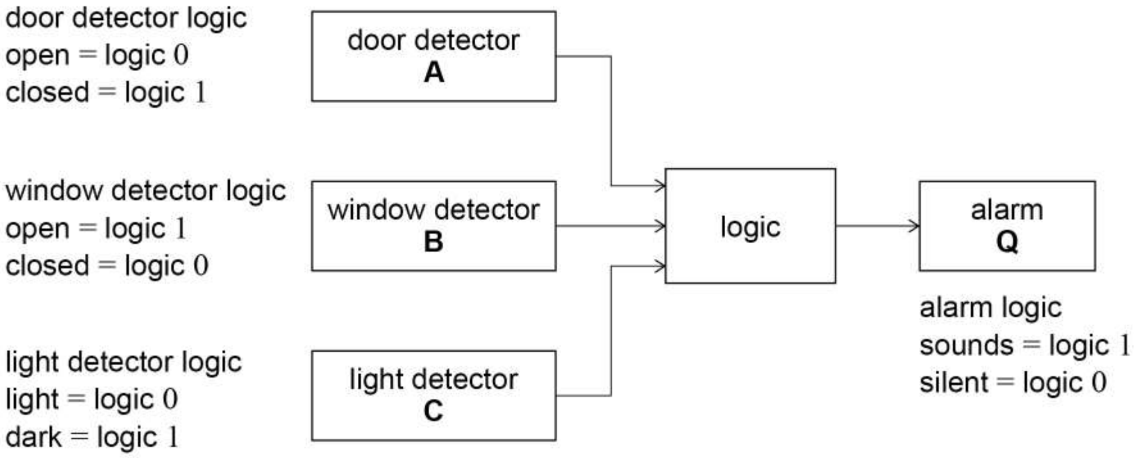
Turn over for the next question

0 2 A burglar-alarm system in a house sounds an alarm during the hours of darkness when **one** of the following conditions is met:

- the door is opened
- the window is opened
- both the door and the window are opened.

Figure 5 shows the main burglar-alarm subsystems and the logic status for the inputs and output.

Figure 5



0 2 . 1 **Table 2** is a partially completed truth table for the logic subsystem.

Table 2

Inputs			**Output**
C	**B**	**A**	**Q**
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	
1	1	0	
1	1	1	

Complete **Table 2**.

[1 mark]

Question 2 continues on the next page

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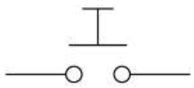
Figure 6 shows the symbol of the push-to-make switch used in the door detector. When the door is closed, the switch button is pushed down onto the contacts. It automatically releases when the door opens.

Figure 6



0 2 . 2 Complete **Figure 7** to show how this switch, together with a $10\ \text{k}\Omega$ resistor, can be connected to create the door detector circuit in **Figure 5**.

Label the output of the circuit with an **X**.

[2 marks]

Figure 7

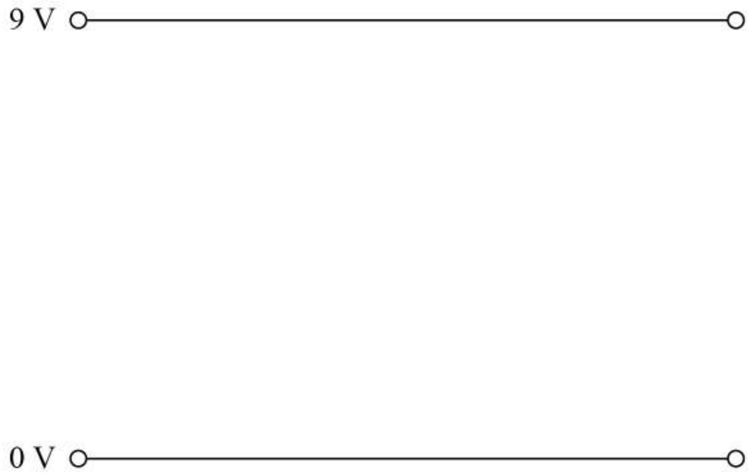


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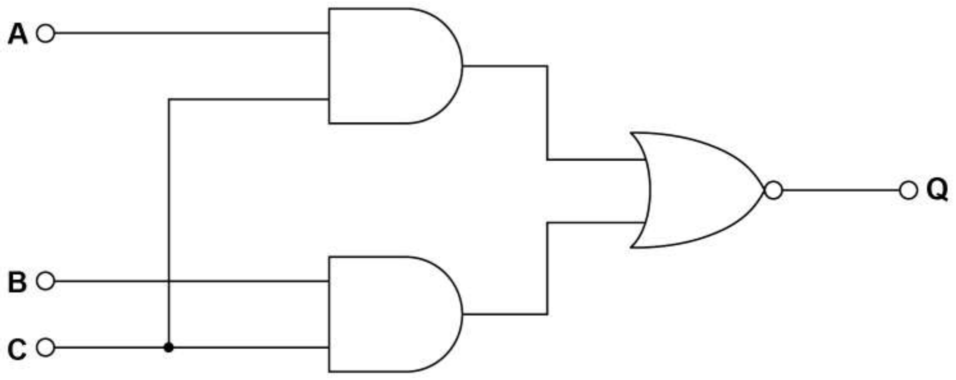
Figure 8 shows a logic circuit for a different alarm system.

Figure 8



0 2 . 3 Write the Boolean algebra expression for **Q** in terms of inputs **A**, **B** and **C**.
In your answer use only AND and NOR operators.

[2 marks]

Q = ______________________________

Question 2 continues on the next page

Turn over ►

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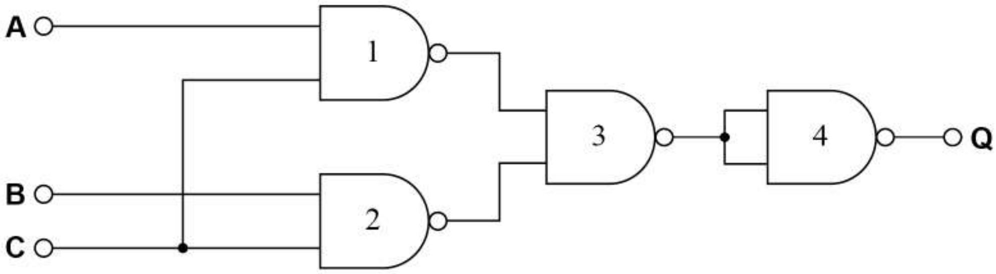
0 2 . 4 **Figure 9** shows a logic circuit that has the same function as the circuit in **Figure 8**. Only one type of gate is used in the circuit in **Figure 9**.

Figure 9



State the logic function performed by gate 4.

[1 mark]

---

0 2 . 5 Microchips containing two-input logic gates are mass-produced. Each microchip contains four identical logic gates.

A manufacturer of the logic circuit used in the burglar alarm chooses to make the circuit in **Figure 9** rather than that in **Figure 8**.

Suggest why.

[1 mark]

7

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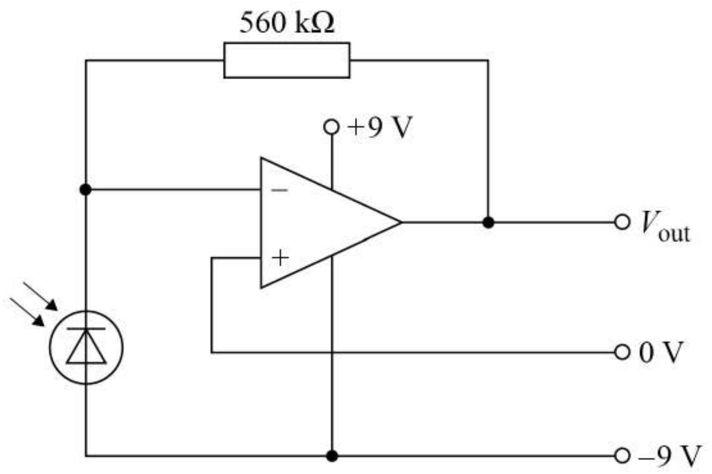
0 3 **Figure 10** shows the circuit for an infrared detector using a photodiode and an operational amplifier. In this application the operational amplifier uses a feedback resistor to give a voltage signal when the current in the photodiode changes.

Figure 10



0 3 . 1 State the mode in which the photodiode is being used in **Figure 10**.

[1 mark]

____

0 3 . 2 In the circuit shown in **Figure 10**, there is a current in the photodiode even when there is no light incident on it. This current is called the dark current.

In an optical communication system, the dark current needs to be very small in comparison to the photodiode current.

Explain why.

[1 mark]

____

____

The responsivity R_λ of a silicon photodiode is a measure of its sensitivity to light at a given wavelength λ.

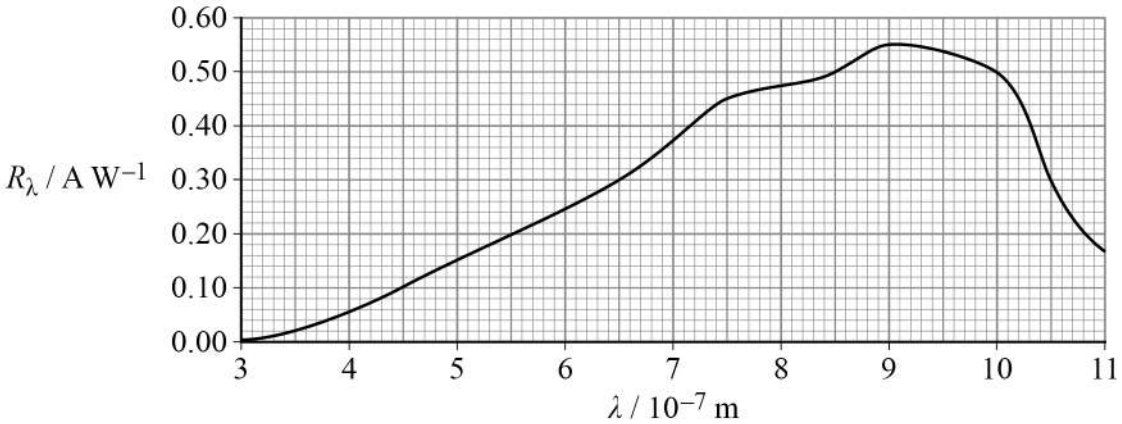
R_λ is defined as:

$$R_\lambda = \frac{I_p}{P}$$

where I_p is the current in the photodiode and P is the incident light power at the given wavelength.

Figure 11 shows the spectral response graph for this photodiode.

Figure 11



0 3 . 3 Monochromatic radiation of wavelength 850 nm and power 4.0 μW is incident on the photodiode in **Figure 10**.

Calculate the output voltage of the detector circuit.

[3 marks]

output voltage = ____________________ V

Question 3 continues on the next page

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0 3 . 4 The output from the detector circuit in **Figure 10** needs to be amplified by a factor of +4

Complete **Figure 12** to show the amplifier circuit required.

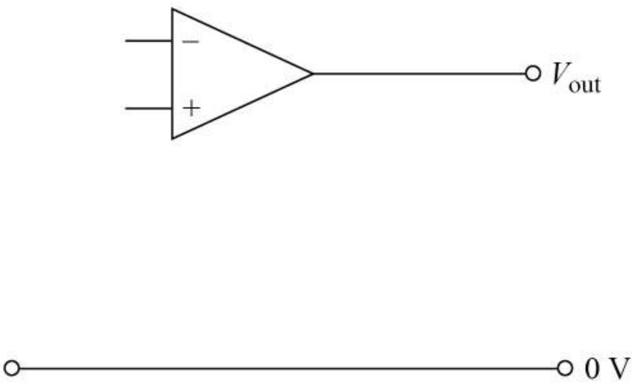
In your completed circuit you should:

- label the input point as $\mathbf{V_{in}}$
- label your diagram with the values of resistance for any resistors used in your circuit. Any resistance values must lie within the range $1\ \text{k}\Omega$ to $100\ \text{k}\Omega$.

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

[3 marks]

Figure 12



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0 4 A Johnson decade counter uses a Johnson counter together with decoding logic. This arrangement produces a single logic 1 at a series of outputs Q_0–Q_9 in a continuous sequence.

0 4 . 1 Describe **one** functional difference and **one** functional similarity between how a Johnson decade counter and a BCD counter output their counts.

[2 marks]

functional difference ______________________________

____

____

____

functional similarity ______________________________

____

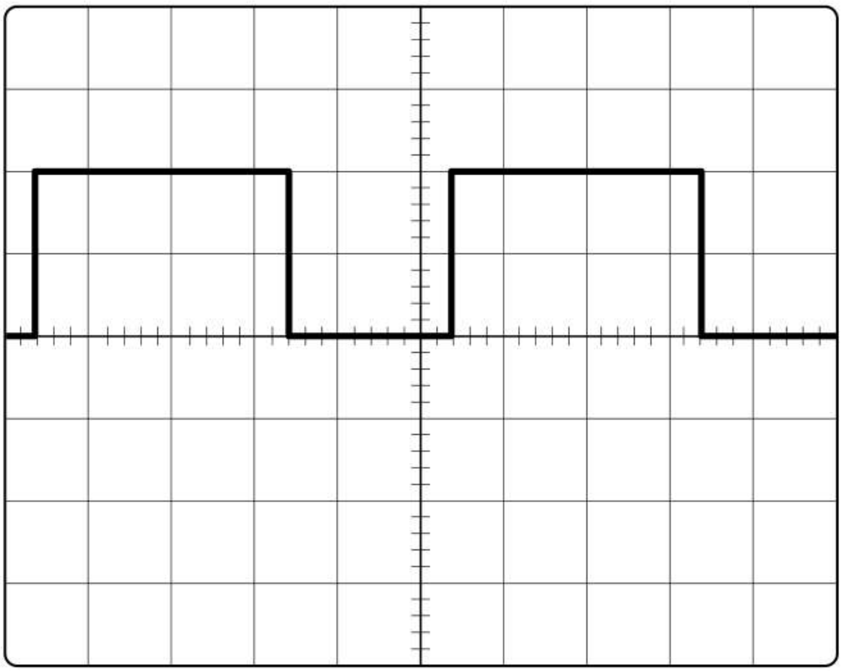
____

____

Question 4 continues on the next page

0 4 . 2 An astable oscillator produces a continuous train of pulses.
Figure 13 shows the display of the pulses on an oscilloscope.

Figure 13



The oscilloscope settings are:

voltage gain = 2 V / division
time-base = 50 μs / division.

Determine the duty cycle and frequency of the signal.

[3 marks]

duty cycle = ____________________

frequency = ____________________ kHz

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0 4 . 3 The astable is adjusted to produce a 600 Hz test signal.

This signal is applied to the clock input of the BCD counter and to the clock input of the Johnson decade counter.

The outputs of the BCD counter are Q_0, Q_1, Q_2 and Q_3 where Q_0 is the least significant part of the output.
The outputs of the Johnson decade counter are Q_0, Q_1, $Q_2 \ldots Q_9$.

Determine the frequency of the pulses available at Q_2 for each counter.

[2 marks]

BCD counter: frequency of pulses = ____________________ Hz

Johnson decade counter: frequency of pulses = ____________________ Hz

7

Turn over for the next question

0 5 **Table 3** shows some communication applications that transmit using different regions of the electromagnetic spectrum.

Table 3

Application	Spectrum region	Typical transmission frequency / MHz
national radio station	longwave	0.198
amateur radio	shortwave	28.2
satellite TV link	microwave	10 700

Explain why each transmission takes the pathway it does from the transmitter to the receiver.

For each of the spectrum regions, you should:

- indicate a frequency range
- refer to the properties of the wave
- name the pathway and outline its properties.

You may use diagrams to help explain your answer.

[6 marks]

Space for diagrams

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6

END OF QUESTIONS

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