AQA

Please write clearly in block capitals.

Centre number		Candidate number	

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________
I declare this is my own work.

A-level
PHYSICS

Paper 3
Section B Electronics

Friday 5 June 2020 Afternoon

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.

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.

There are no questions printed on this page

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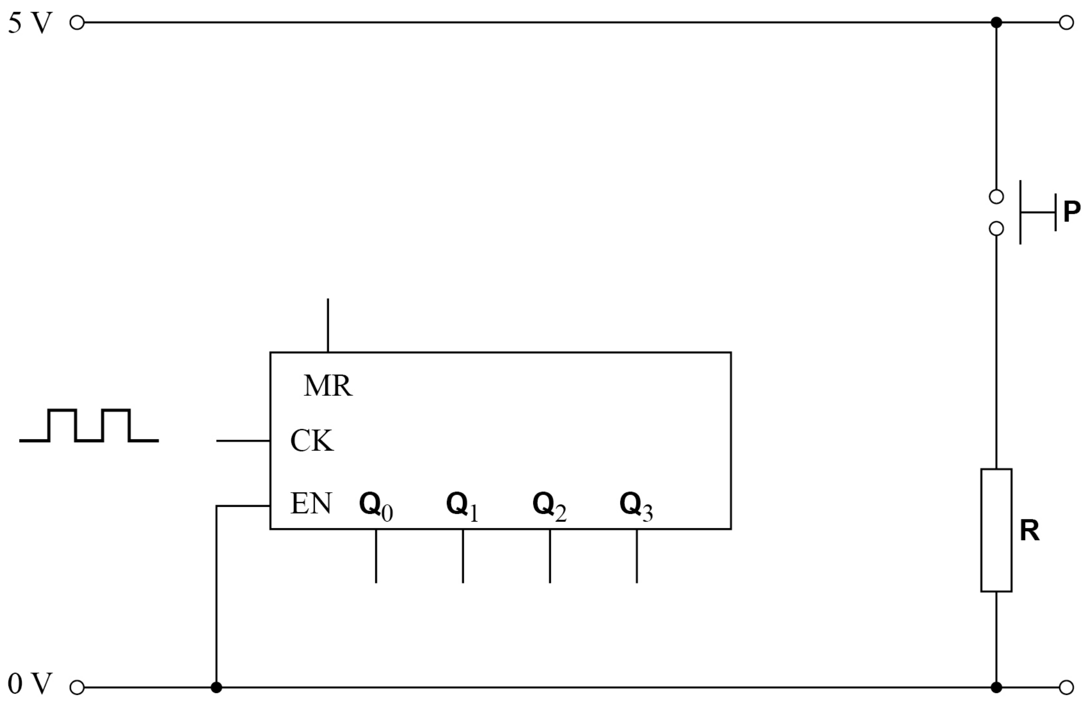
ANSWER IN THE SPACES PROVIDED

Section B

Answer **all** questions in this section.

0 1 **Figure 1** shows part of a circuit that includes a 4-bit binary counter. The main inputs and outputs of the counter are shown.
The counter generates a sequence of binary codes representing the decimal numbers 0 to 7
Output $\mathbf{Q}_0$ is the least significant bit of the binary codes.

Figure 1



The counter resets when the master reset pin MR receives a logic 1

The circuit requires the counter to reset when either one of two conditions is met.

Condition 1 Manual reset using the switch **P** to reset the counter to 0

Condition 2 Automatic reset when an appropriate binary code is produced at the counter outputs. This will cause the counter to continually cycle through the decimal numbers 0 to 7

0 1 . 1 Complete **Figure 1** to show how both reset conditions can be met.

Do **not** show the power line connections to the integrated circuit.

[3 marks]

Question 1 continues on the next page

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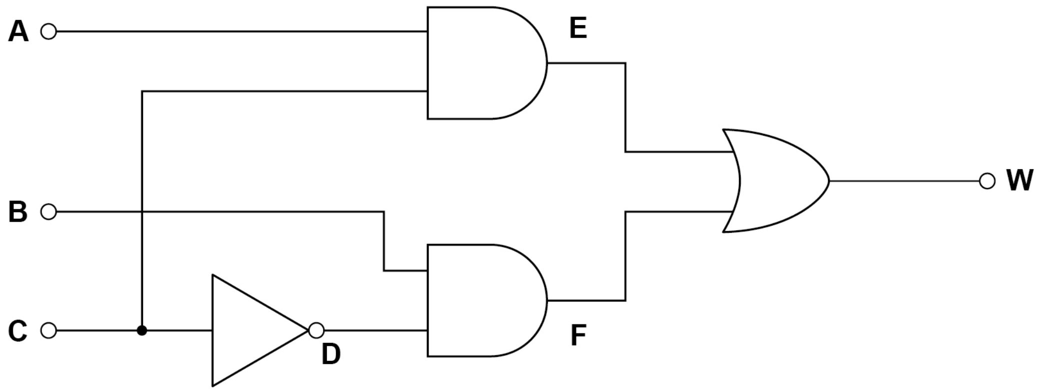
0 1 . 2 A logic system is designed to identify prime numbers.

The binary codes from the counter are now applied to the inputs **ABC** of the logic system shown in **Figure 2**.

Input **A** takes the least significant bit of the binary code from the counter.

Output **W** becomes logic state 1 when a prime number 2, 3, 5 or 7 is detected. Otherwise output **W** is at logic 0

Figure 2



Write the Boolean algebra expression for output **W** in terms of the inputs **A**, **B** and **C**. The expression must contain only the four logic gate operations shown in **Figure 2**.

[2 marks]

W = ______________________________

0 1 . 3 Complete **Table 1**, the truth table for the logic system in **Figure 2**.

[1 mark]

Table 1

Decimal number	C	B	A	D	E	F	W
0	0	0	0	1	0		0
1	0	0	1	1	0		0
2	0	1	0	1	0		1
3	0	1	1	1	0		1
4	1	0	0	0	0		0
5	1	0	1	0	1		1
6	1	1	0	0	0		0
7	1	1	1	0	1		1

0 1 . 4 The logic system in Question **01.2** is replaced with one that gives an output **S** using the same binary input codes **CBA**.

The Boolean algebra equation for output **S** is

$$\mathbf{S} = \overline{\mathbf{A}}\,.\,(\mathbf{B} + \mathbf{C})$$

Deduce which decimal numbers 0 to 7 will cause **S** to become logic 1

[1 mark]

Question 1 continues on the next page

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0 1 . 5 Complete **Figure 3** by drawing the logic system for **S**.

You must use only the logic gate operations given in $\mathbf{S} = \overline{\mathbf{A}}.(\mathbf{B}+\mathbf{C})$

[2 marks]

Figure 3

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Turn over for the next question

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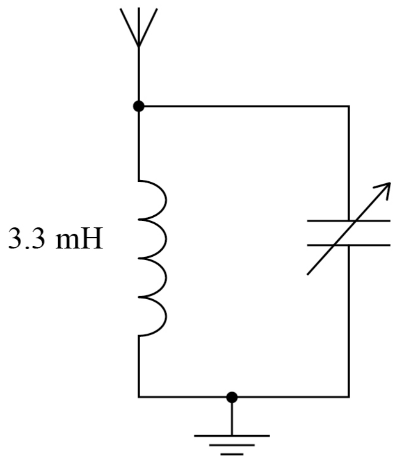
0 2 **Figure 4** shows the filter circuit that forms the first stage in an amplitude modulated (AM) radio receiver.

The circuit contains a 3.3 mH inductor and a variable capacitor.

Figure 4



0 2 . 1 The circuit is tuned to receive a radio station transmitting at a frequency of 1053 kHz.

Calculate the value of the capacitance needed to receive this station.

[1 mark]

capacitance = ____________________ pF

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0 2 . 2 The circuit is retuned to receive a different radio station by setting the variable capacitor to a value of 9.3 pF.

Table 2 shows the capacitance range of four variable capacitors **W**, **X**, **Y** and **Z**.

Comment on the suitability of these capacitors for this application and state your preference.

[2 marks]

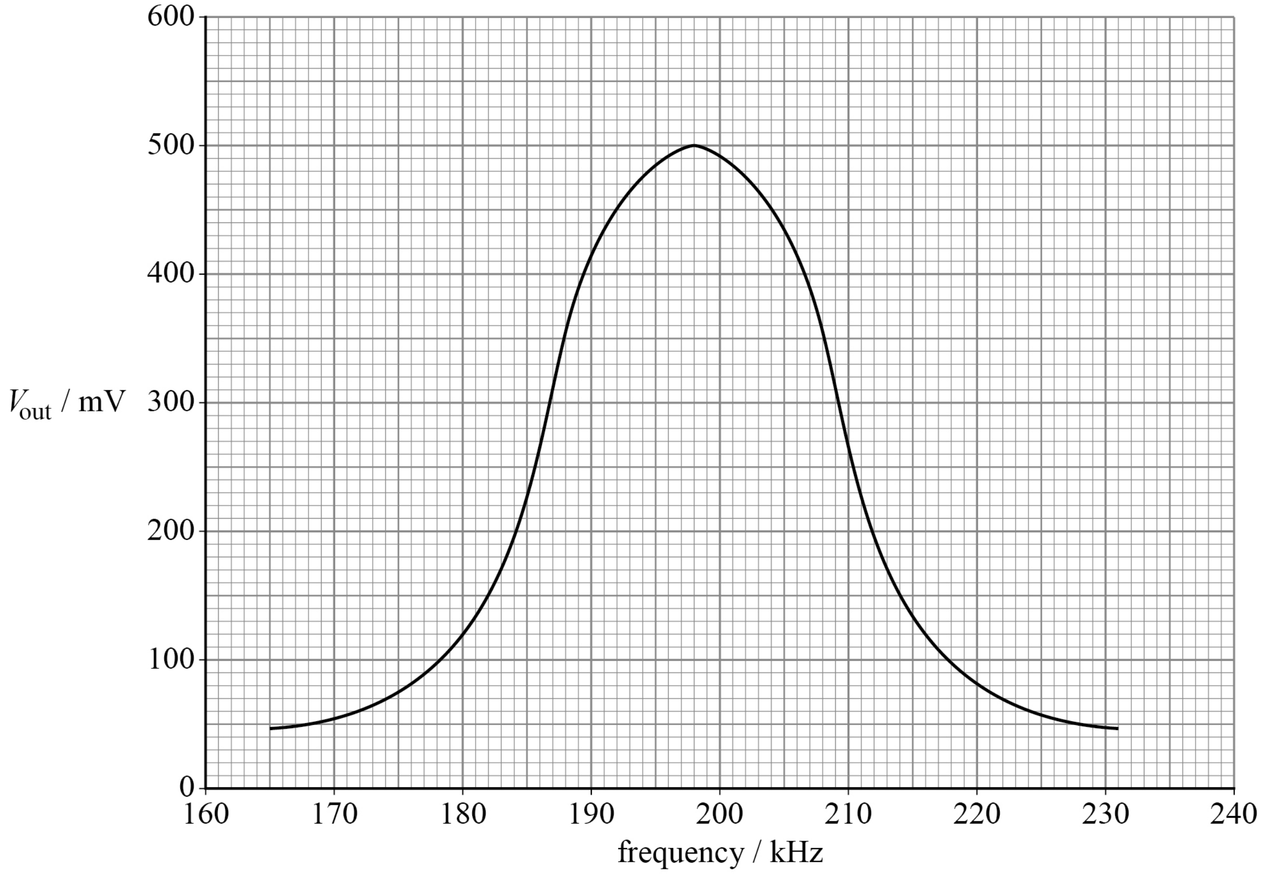
Table 2

Capacitor	Range / pF
W	2–9
X	3–10
Y	4.5–20
Z	10–50

Question 2 continues on the next page

0 2 . 3 **Figure 5** shows part of the frequency response curve for a different filter circuit.

Figure 5



Determine the bandwidth of the filter circuit.

[2 marks]

bandwidth = ____________________ kHz

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0 2 . 4 Calculate the Q factor of the filter circuit in Question **02.3**.

[1 mark]

Q factor = ____________________

0 2 . 5 The radio station is tuned using a different filter circuit with a very low Q factor.

State and explain **one** effect of this change on the sound heard by a listener.

[1 mark]

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7

Turn over for the next question

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0 3 Pulse code modulation (PCM) is used to encode live music as an uncompressed digital audio file.
Sampling of the analogue signal is carried out at $44.1\ \text{kHz}$.
A 16-bit system is used to encode each of the two channels that make up the stereo signal.

0 3 . 1 Explain why the sampling frequency used is suitable for this task.

[2 marks]

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0 3 . 2 Calculate the number of quantisation levels available on a 16-bit encoding system.

[1 mark]

number of quantisation levels $=$ ____________________

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0 3 . 3 A recorded piece of stereo music lasts for 3.5 minutes.

Calculate the size, in megabytes, of the digital file needed to store this recording.

[2 marks]

file size = ______________________ megabytes

0 3 . 4 The music file is used by a call centre to play as background music while a phone call is on hold. However, the telephone network is designed to use a bandwidth of 0.3 kHz – 3.4 kHz.

Compare the quality of the music heard by the telephone caller with that of the original file heard when played directly from a compact disc.

[2 marks]

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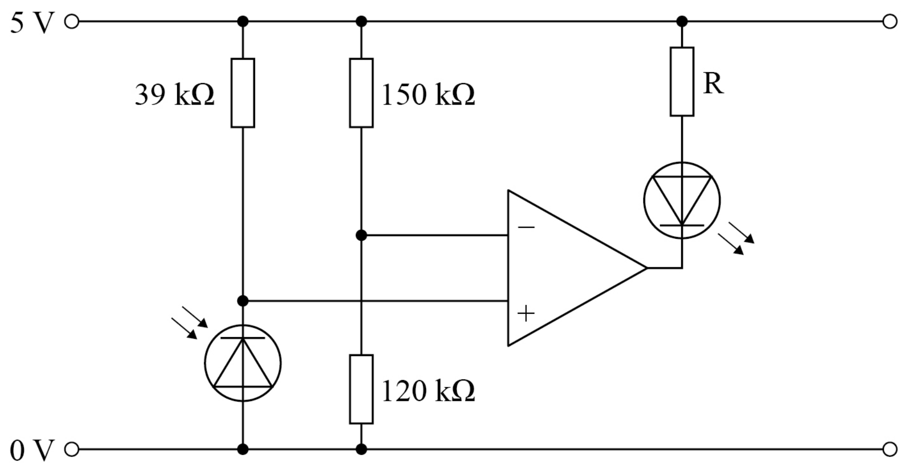
7

Turn over ►

0 4 **Figure 6** shows a circuit containing a photodiode and an ideal operational amplifier. This circuit is used to monitor the intensity of monochromatic radiation.

Figure 6



0 4 . 1 What is the configuration of the operational amplifier circuit shown in **Figure 6**?
Tick (✓) **one** box.

[1 mark]

comparator ☐

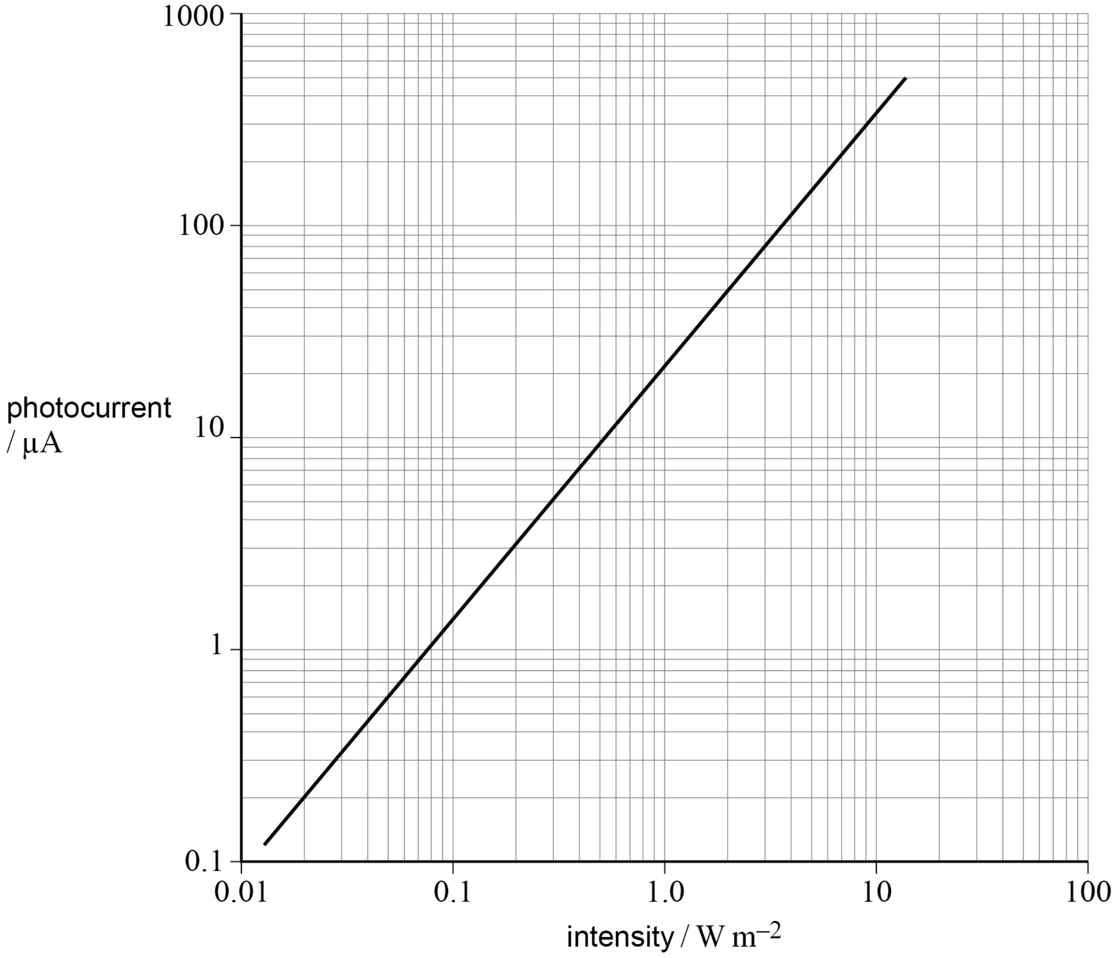
differential amplifier ☐

inverting amplifier ☐

non-inverting amplifier ☐

0 4 . 2 **Figure 7** shows the variation of photocurrent with intensity for the monochromatic radiation incident on the photodiode.

Figure 7



Radiation of intensity $3.0\ \text{W m}^{-2}$ is incident on the photodiode.

Show that the voltage at the non-inverting terminal (V_+) of the operational amplifier is $1.9\ \text{V}$.

[3 marks]

Question 4 continues on the next page

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0 4 . 3 The intensity of radiation incident on the photodiode remains at 3.0 W m^{-2}.

Deduce whether the light-emitting diode (LED) in **Figure 6** is on or off.

[2 marks]

6

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0 5 British embassies in Europe are to be connected to a new long-distance communication link. The link, in the form of a land-based cable, will support multiple simultaneous video conferencing as well as the transmission of sensitive government data.

The company installing the link has to consider the choice between using optic fibre or copper wire in the cables.

Compare the advantages and disadvantages of the two options for use in these cables.
State which option you would advise the company to use.

For both types of cable refer to their:

- physical properties
- ability to reject external interference
- signal-carrying properties.

[6 marks]

Question 5 continues on the next page

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END OF QUESTIONS

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