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

Tuesday 17 June 2025 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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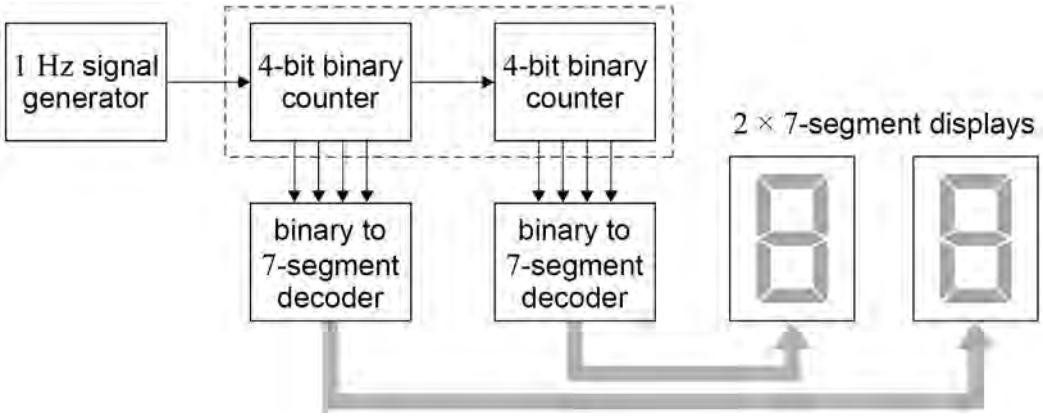
Section B

Answer **all** questions in this section.

0 1 . 1 **Figure 1** shows a system diagram for a timer designed by a student.

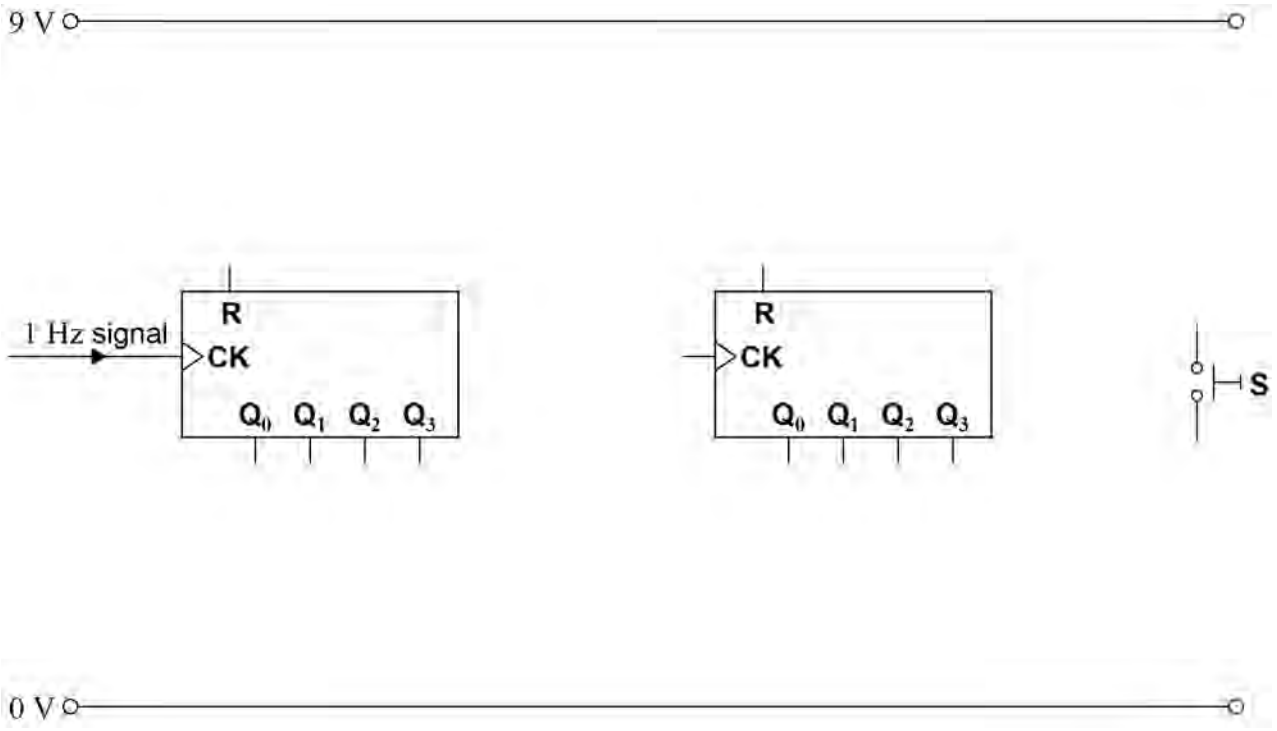
Figure 1



The system displays the numbers from 00 to 59 before resetting.
The timer is designed to count in time intervals of 1 s.

Part of **Figure 1** is enclosed within dashed lines.
Figure 2 shows an incomplete circuit diagram for this part of the system.
Figure 2 also includes a switch **S** that is used to manually reset both counters.

Figure 2



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Each counter in **Figure 2** advances by 1 when **CK** receives the rising edge of a pulse. When **R** on a counter receives a logic 1, that counter resets.

Complete the circuit diagram in **Figure 2** by adding:

- logic gates to select the reset code for each counter
- a link to show how the second counter is triggered from the first counter
- a resistor with switch **S** to form the manual reset
- logic gates for each of the counters to provide the reset conditions at **R**.

[5 marks]

0 1 . 2 Another student designs a logic system to combine judgements from three people. When at least two of the three people input logic 1, the system provides an output of logic 1. Otherwise, the output is logic 0.

The three people are represented by inputs **X**, **Y** and **Z**.

The output **Q** from this logic system is given by the Boolean expression:

$$\mathbf{Q} = (\mathbf{X}.\mathbf{Y}) + \mathbf{Z}.(\overline{\overline{\mathbf{X}}.\overline{\mathbf{Y}}})$$

Complete **Figure 3** to show the combinational logic diagram for this expression.
Use only the logic gates indicated in the expression.
Do not transform the expression.

[2 marks]

Figure 3

Question 1 continues on the next page

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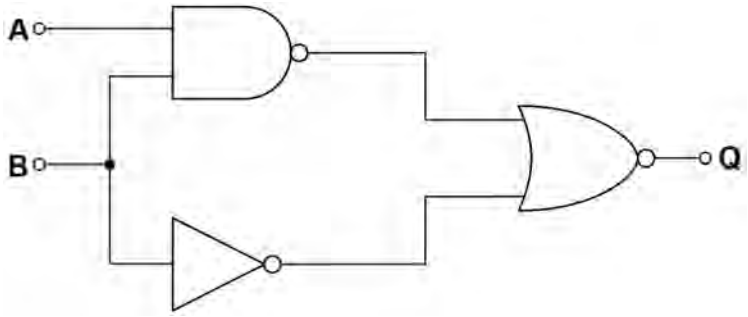
0 1 . 3 A single logic gate can sometimes be used to replace a more complex logic system.

Figure 4 shows a logic system with inputs **A** and **B** and output **Q**.

Figure 4



Which single logic gate could replace this combinational logic system?

Tick (✓) **one** box.

[1 mark]

OR ☐

NOR ☐

EOR ☐

AND ☐

NAND ☐

8

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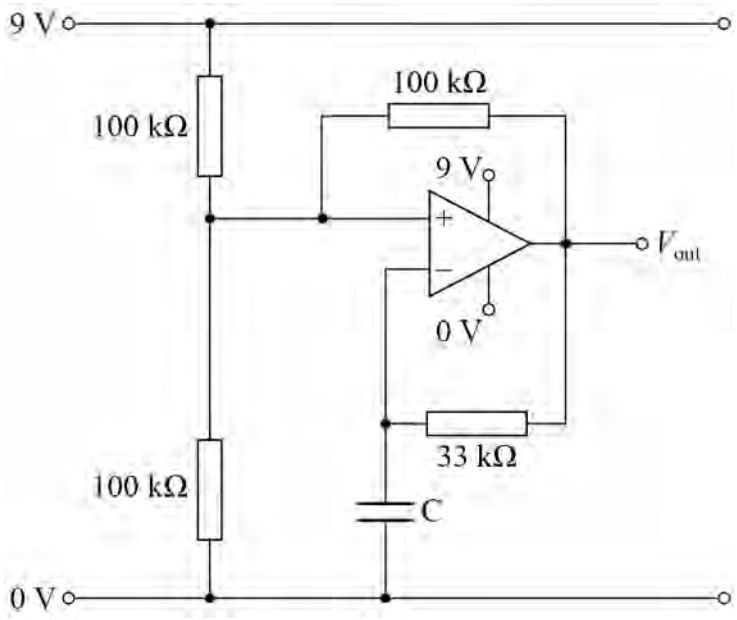
0 2 **Figure 5** shows an operational amplifier circuit designed to function as an oscillator. The circuit produces square waves.

Figure 5



Assume that the operational amplifier is ideal and that it is operating as a comparator in this application.

0 2 . 1 Explain the combined role of the 33 kΩ resistor and C in this circuit.

[1 mark]

0 2 . 2 State the function of the potential divider formed by the three 100 kΩ resistors.

[1 mark]

Question 2 continues on the next page

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0 2 . 3 Deduce the voltage V_+ at the non-inverting input of the operational amplifier when:

- the output voltage V_{out} is $0.0\ \text{V}$
- the output voltage V_{out} is $9.0\ \text{V}$.

[3 marks]

when V_{out} is $0.0\ \text{V}$, V_+ = _____ V

when V_{out} is $9.0\ \text{V}$, V_+ = _____ V

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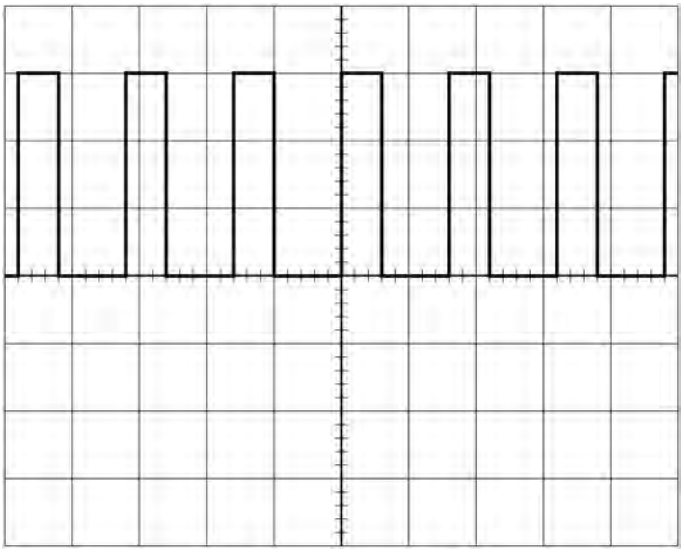
0 2 . 4 **Figure 6** shows the output from a different oscillator displayed on an oscilloscope screen.

Figure 6



The time-base is 10 μs per division.

Deduce the pulse rate frequency, in kHz, and the duty cycle for this signal.

[2 marks]

pulse rate frequency = _____ kHz

duty cycle = _____ %

7

Turn over ►

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0 3 . 1 A photodiode can be used in either photovoltaic mode or photoconductive mode.

State **one** advantage of using a photodiode in photoconductive mode.

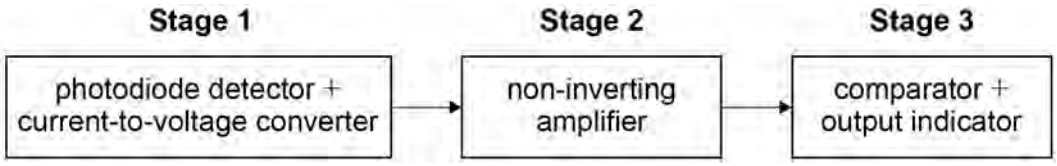
[1 mark]

A light-intensity monitor uses a photodiode in reverse bias. The photodiode responds to the irradiance of light incident on it.

Irradiance is a measure of the power of the light incident on unit surface area and is measured in $\mathrm{W\ m^{-2}}$.

Figure 7 shows the three stages that make up the light-intensity monitor.

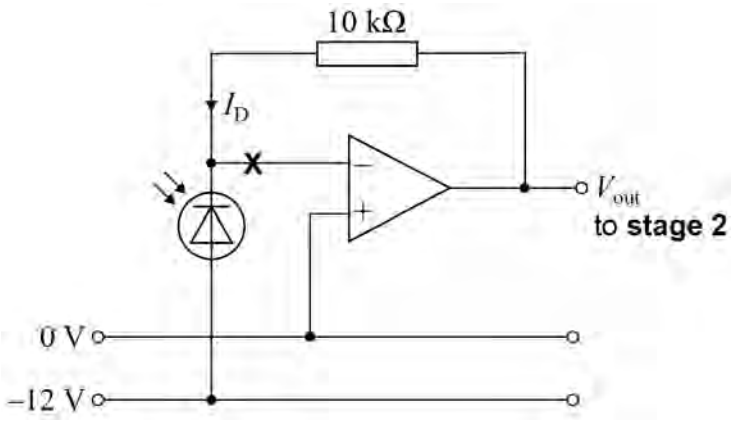
Figure 7



Each stage uses an operational amplifier. The power rails to the operational amplifiers are $0\ \mathrm{V}$ and $+12\ \mathrm{V}$; these are not shown in **Figures 8**, **9** or **10**.

Figure 8 shows the circuit for **stage 1**.

Figure 8



When the photodiode detects light within its sensitive range, there is a reverse photocurrent I_D in the circuit. This current depends on the irradiance of the light.
The output voltage V_{out} of the circuit is proportional to I_D.
Point **X** is a virtual earth.

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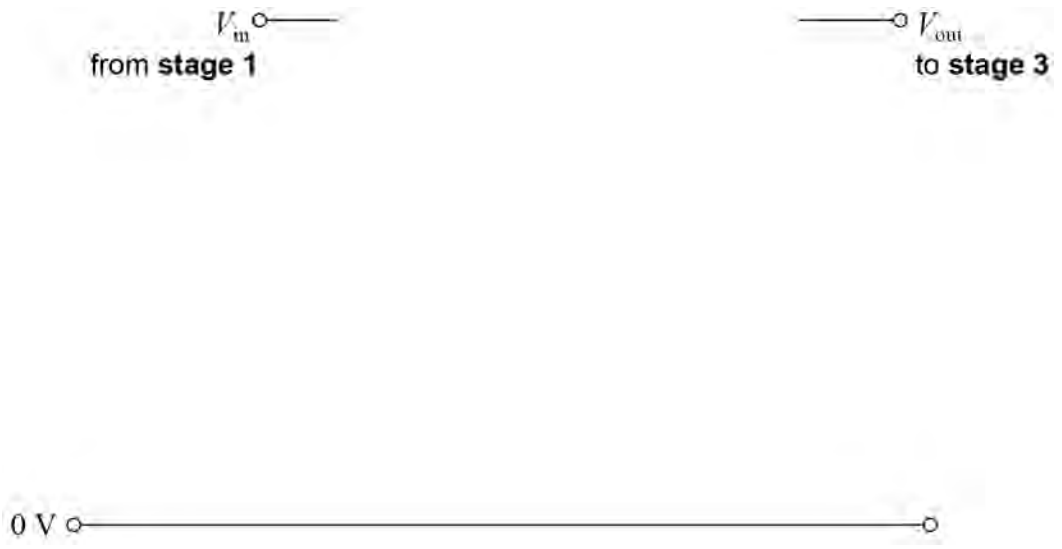
0 3 . 2 Explain what is meant by a virtual earth.

[1 mark]

0 3 . 3 The output signal V_{out} from **stage 1** is used as the input signal V_{in} for **stage 2**.

Figure 9 is an incomplete circuit diagram of **stage 2**.

Figure 9



Complete **Figure 9** to show how an operational amplifier is configured to produce a voltage gain of $+34$

In your answer:

- label resistors with their values within the range $1\ \text{k}\Omega$ to $100\ \text{k}\Omega$
- show the inverting ($-$) and non-inverting ($+$) inputs to the operational amplifier
- do **not** show the power supplies or power rails for the operational amplifier.

[2 marks]

Question 3 continues on the next page

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0 3 . 4 **Stage 3** uses an operational amplifier as a comparator to determine whether the irradiance detected by the photodiode in **stage 1** exceeds a critical value.

Figure 10 shows the **stage 3** circuit diagram.

Figure 10

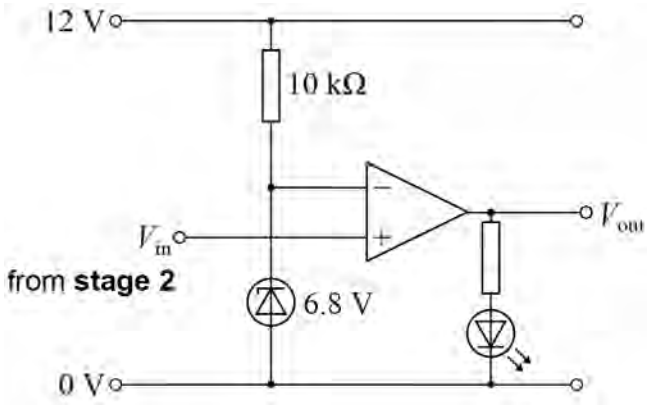
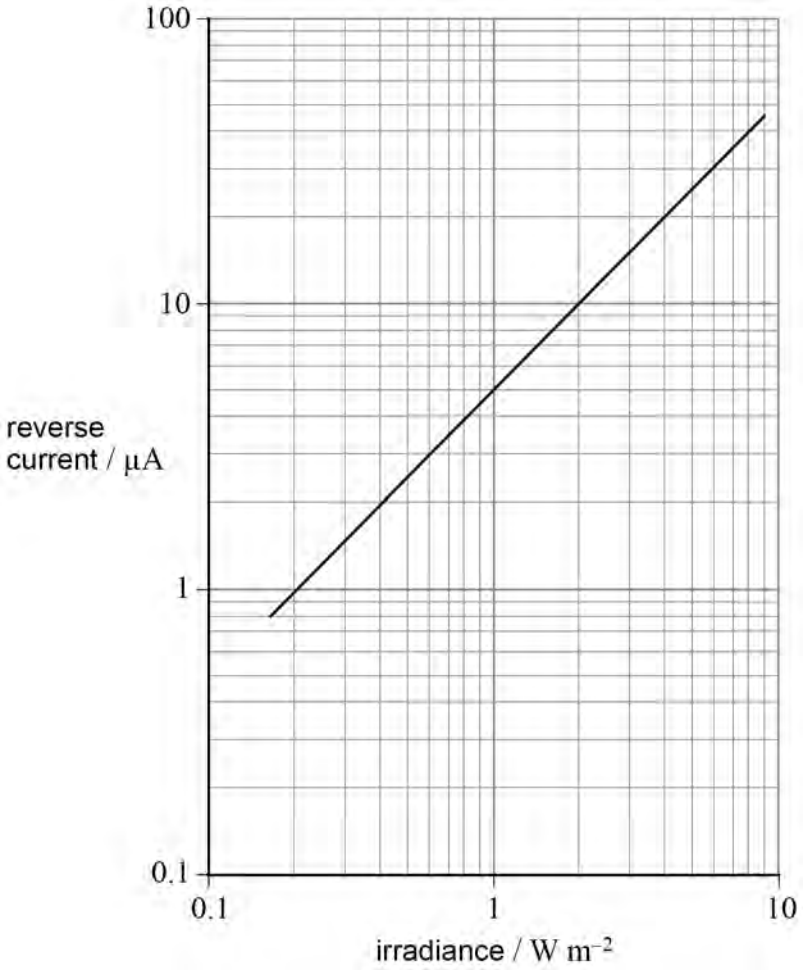


Figure 11 shows part of the data sheet for the photodiode.

Figure 11



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Determine the minimum irradiance that must be detected by the photodiode in **stage 1** in order to turn on the LED in **stage 3**.

[3 marks]

irradiance = _____ $W\ m^{-2}$

0 3 . 5 When the monitor is tested, the LED turns on fully.
However, the LED does not turn off fully when the irradiance falls below the critical value.

Suggest **one** reason why the LED does not turn off fully.
In your answer, refer to a limitation of real operational amplifiers.

[1 mark]

_____

_____

8

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ANSWER IN THE SPACES PROVIDED

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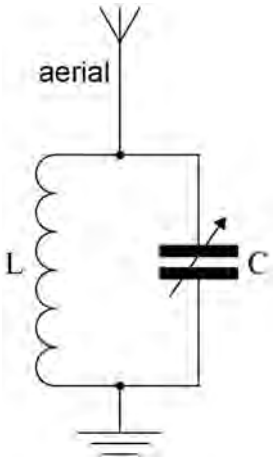
0 4 . 1 State what is meant by a carrier wave within a radio transmission system.
Go on to explain how the carrier wave is used in this system.

[2 marks]

0 4 . 2 **Figure 12** shows the first stage of a radio receiver.

Figure 12



Explain the role of the LC circuit in the first stage of the receiver.

[2 marks]

Question 4 continues on the next page

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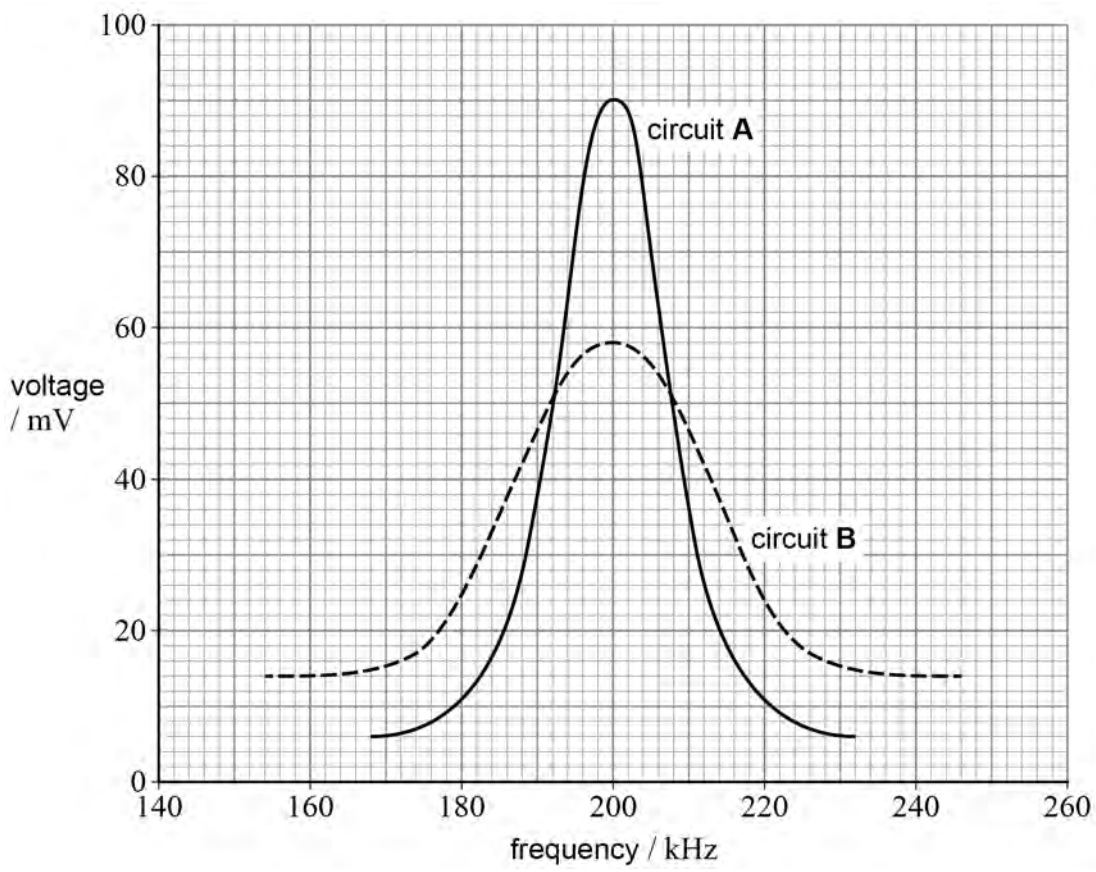
0 4 . 3 Two different LC circuits **A** and **B** are available for the first stage of a radio receiver tuned to a particular radio station.
One of these circuits is to be chosen for the final design of the receiver.

Figure 13 shows the variation of voltage with frequency for both **A** and **B**.

Figure 13



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The receiver is to detect an AM signal transmitted with a carrier frequency of $200\ \text{kHz}$ over a bandwidth of $10\ \text{kHz}$.

Explain whether circuit **A** or circuit **B** is more appropriate for this radio receiver.

Your answer should include a discussion of:

- bandwidth
- the ability of the receiver to reject signals from other radio stations.

[2 marks]

6

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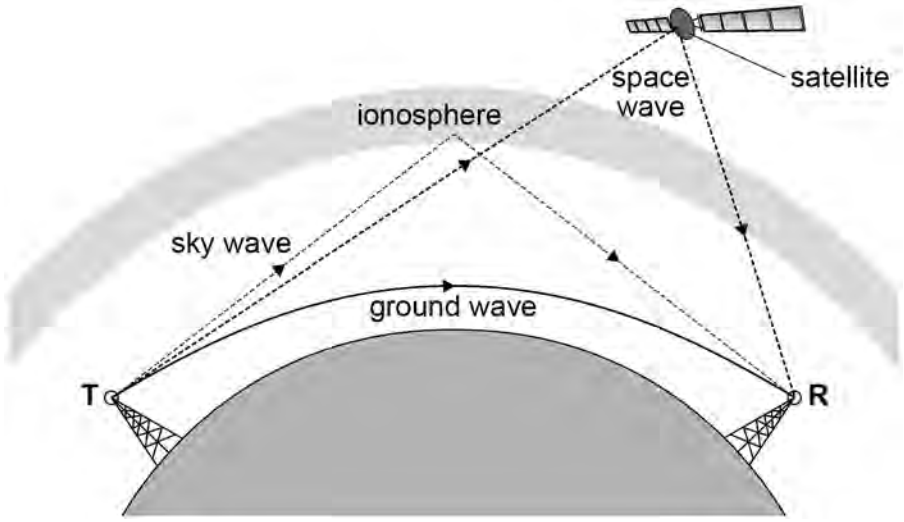
0 5 **Figure 14** shows a transmitter **T** and a receiver **R** which are not in line of sight. Three transmission pathways from **T** to **R** are shown.

Figure 14



Explain, for each of the ground wave, sky wave and space wave:

- the conditions necessary for the pathway to operate
- **one** advantage and **one** disadvantage of using that pathway.

[6 marks]

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END OF QUESTIONS

6

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ANSWER IN THE SPACES PROVIDED

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