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AQA A LEVEL PHYSICS (7408): QUESTIONS BY TOPIC

Electronics (3.13)

A Level Physics (7408) · Section 3.13

45 questions · 315 marks · Mark schemes included

AQA A Level Physics (7408), June 2017 – June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

45 questions · 315 marks · 6 sub-topics



SUB-TOPIC 3.13.1

DISCRETE SEMICONDUCTOR DEVICES

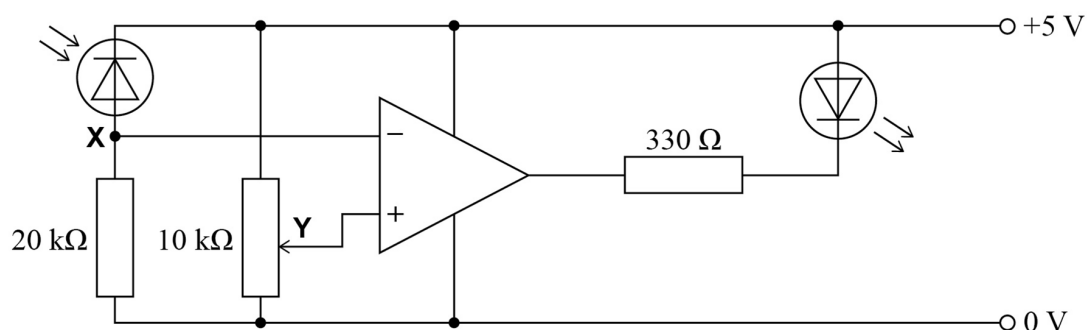
Sub-topic 3.13.1 · 6 questions · 43 marks · lowest tariff first



0 4

A photodiode forms part of a light meter used for checking light levels in an office. **Figure 10** shows the circuit diagram for the light meter.

Figure 10



0 4 . 1

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

[1 mark]

0 4 . 2

In which mode is the operational amplifier being used in **Figure 10**?

Tick (✓) the correct box.

[1 mark]

Non-inverting amplifier

☐

Comparator

☐

Summing amplifier

☐

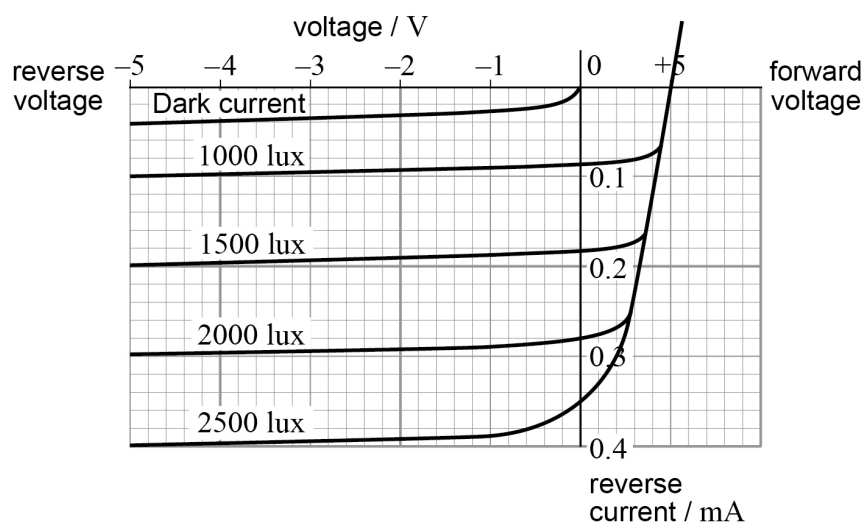
Difference amplifier

☐

0 4 . 3

Figure 11 shows an extract from a data sheet of the characteristics for a photodiode under different light levels measured in lux.

Figure 11



For a particular lighting condition, the current through the photodiode in **Figure 10** was 0.10 mA.

Estimate, using the information in **Figure 11**, the light level needed to cause this reverse current through the photodiode.

[1 mark]

light level = _____ lux

0 4 . 4

Calculate the voltage at point **X** in the circuit shown in **Figure 10** for the light level in question **04.3**.

[1 mark]

voltage = _____ V

Question 4 continues on the next page



0	4	.	5
---	---	---	---

The $10\text{ k}\Omega$ linear potential divider shown in **Figure 10** is set to give 1.75 V at point **Y**.

Assume that the operational amplifier has ideal characteristics.

Deduce whether the output LED would be switched ON or OFF when the current through the photodiode is 0.10 mA .

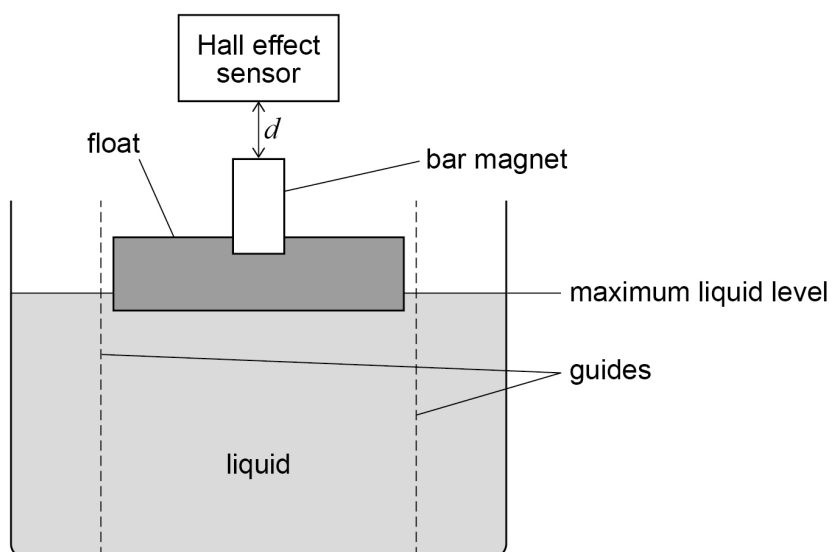
[2 marks]



0	3
---	---

Figure 7 shows a system to monitor a tank filling with liquid in which a magnet is mounted on a float.

Figure 7



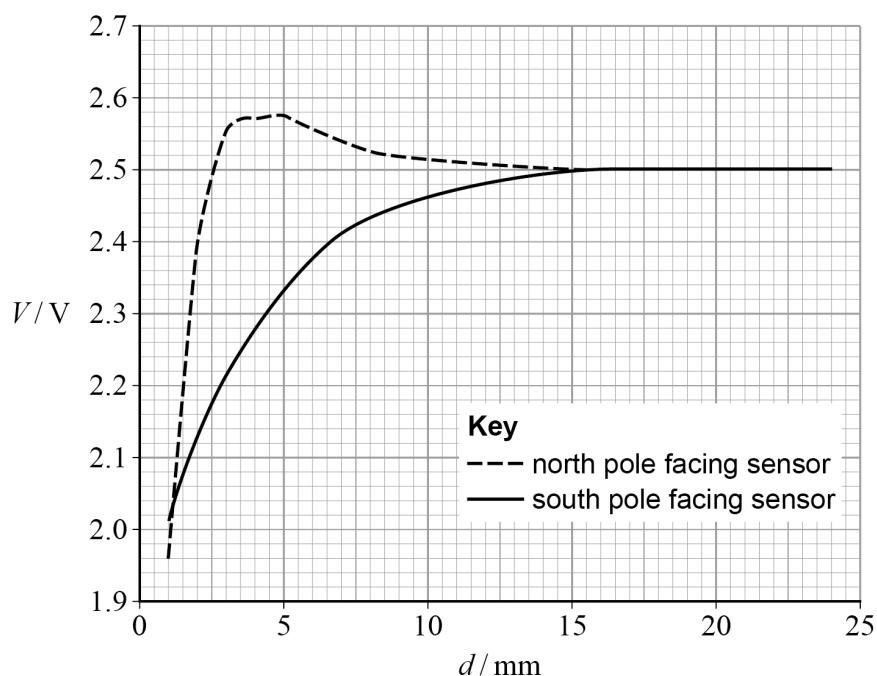
The Hall effect sensor produces an output voltage V . V depends on the distance d between the sensor and the magnet.

When V reaches a certain value, the flow of liquid to the tank is switched off.

The magnet may be arranged with either the north (N) or south (S) pole facing the sensor.

Figure 8 shows how the magnitude of V varies with d for the two possible arrangements of the magnet.

Figure 8



0 3 . 1

Compare the advantages of the two arrangements for monitoring the movement of the magnet towards the Hall effect sensor.

In your answer you should compare:

- the sensitivity of the system
- the range of d over which the system is useful.

You may ignore any effect from the Earth's magnetic field.

[3 marks]

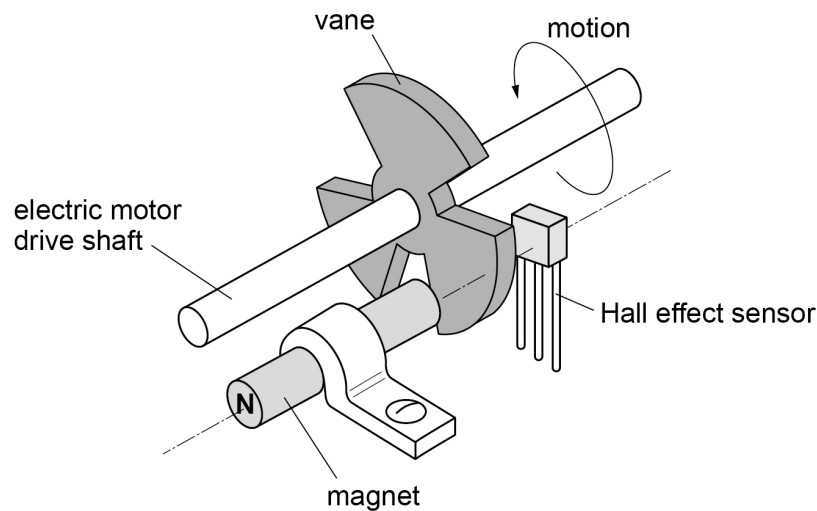
Question 3 continues on the next page



0 3 . 2

Figure 9 shows a Hall effect sensor being used as a tachometer to monitor the rotational speed of the drive shaft of an electric motor.

Figure 9



The output of the Hall effect sensor is connected to an oscilloscope. When the vane is between the magnet and the Hall effect sensor, the output of the Hall effect sensor is low.

The trace produced on the oscilloscope is shown in **Figure 10**.

Figure 10

The time-base on the oscilloscope is set to 5 ms / div.

Calculate the number of complete revolutions of the drive shaft in one second.

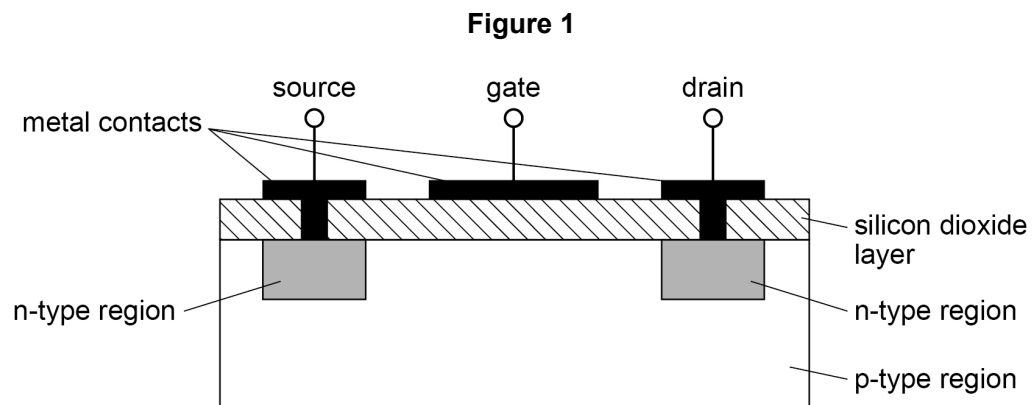
[3 marks]

number of complete revolutions = _____



0 1

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



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

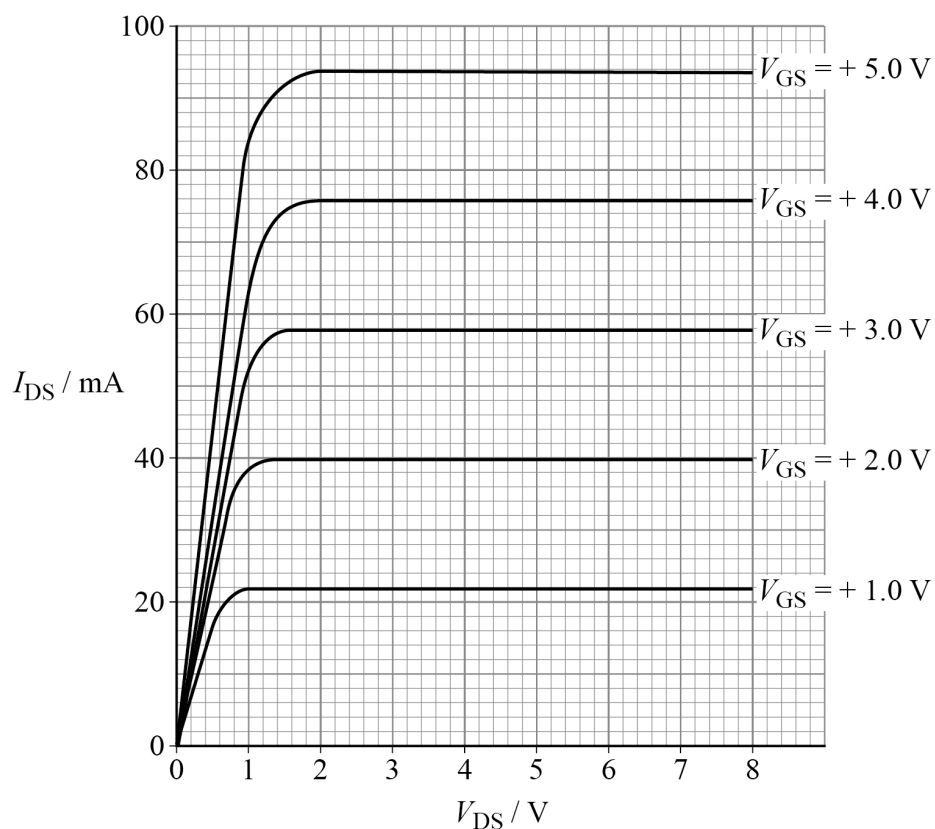
☐

source

☐

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 $154\ \Omega$ 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



0 1 . 4

Figure 3 shows an individual MOSFET. The drain–source leakage current I_{DSS} for this MOSFET is about 10 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

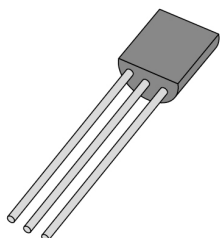
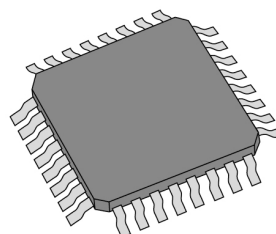


Figure 4



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 mA h
Phone time available on stand-by from one full charge	≈ 12 hours

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

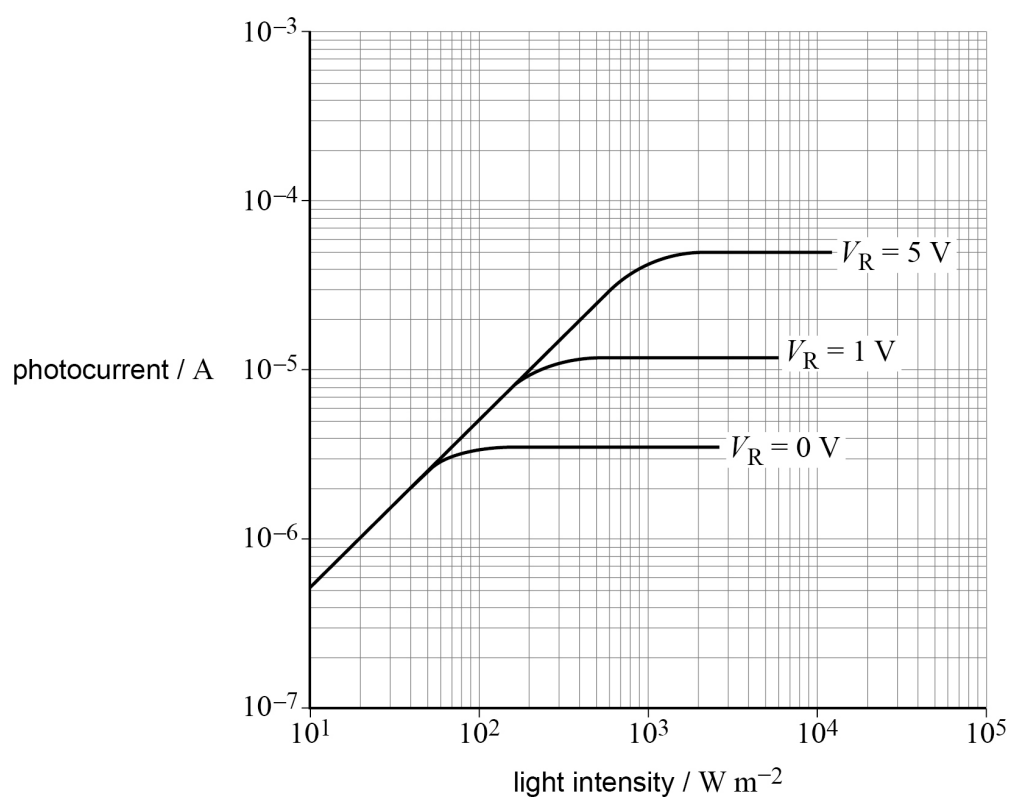
The I_{DSS} value for each MOSFET used in the mobile phone CPU must be different from that measured in the individual MOSFET shown in **Figure 3**.

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

[3 marks]

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



0 4 . 2

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

[2 marks]**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 k Ω to 1 M Ω 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**

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.

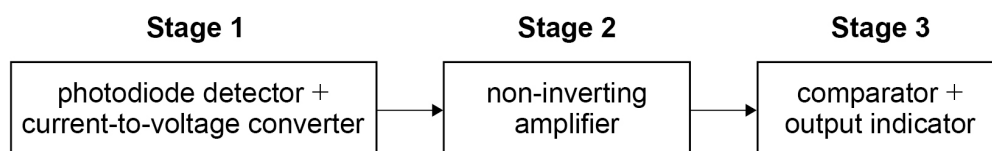
[1 mark]

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 W m^{-2} .

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

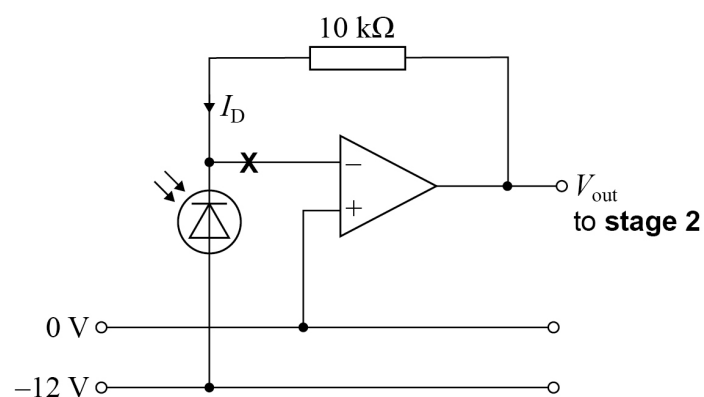
Figure 7



Each stage uses an operational amplifier. The power rails to the operational amplifiers are 0 V and +12 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.

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



0 V ○ ————— ○

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 k Ω to 100 k Ω
- 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



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

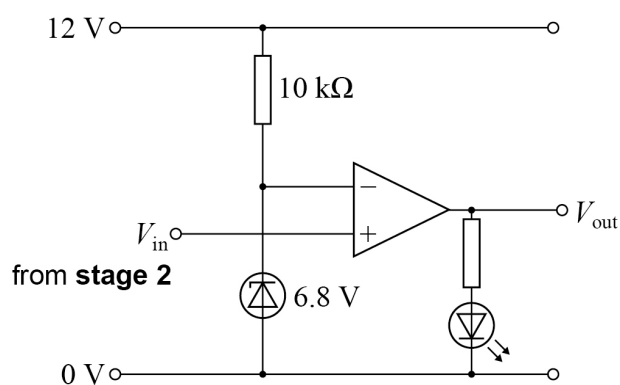


Figure 11 shows part of the data sheet for the photodiode.

Figure 11

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]



0	4
---	---

A silicon-based 5.1 V Zener diode requires a minimum operating current I of 5.0 mA to maintain its Zener voltage V_Z .

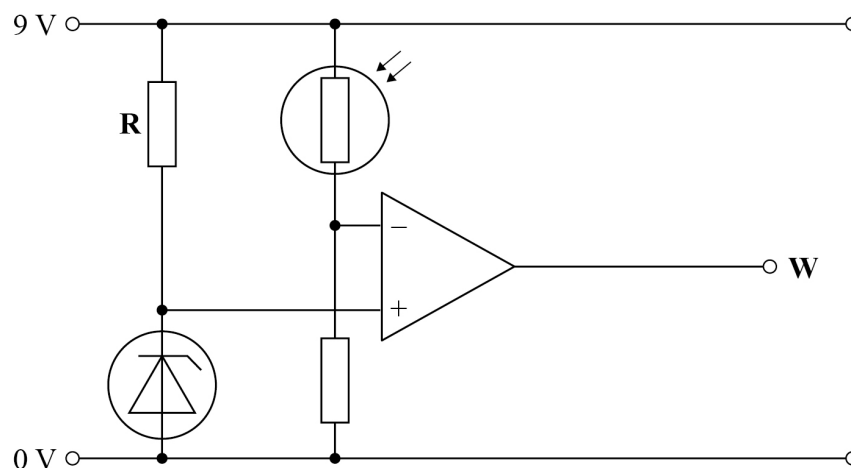
0	4	.	1
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Draw on **Figure 11** the general I – V characteristic for this diode.

[2 marks]

Figure 11



0 4 . 2**Figure 12** shows a circuit that uses a 5.1 V Zener diode.The circuit causes the output **W** of the operational amplifier to change at a particular light intensity.**Figure 12**

State the function of the Zener diode in this circuit.

[1 mark]**0 4 . 3**Deduce whether a 100 Ω , 0.13 W resistor is suitable for **R** in **Figure 12**.**[2 marks]**

Question 4 continues on the next page

0 4 . 4

The circuit in **Figure 12** is rebuilt and the position of **R** is swapped with the position of the Zener diode.

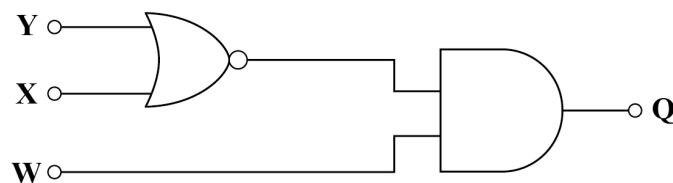
Explain how this affects the light intensity at which **W** changes.

[2 marks]

0 4 . 5

The output **W** from the operational amplifier shown in **Figure 12** becomes one of three inputs to the combinational logic circuit shown in **Figure 13**.

Figure 13



Write the Boolean algebra expression for the output **Q** in terms of **W**, **X** and **Y** based on the logic gates shown in **Figure 13**.

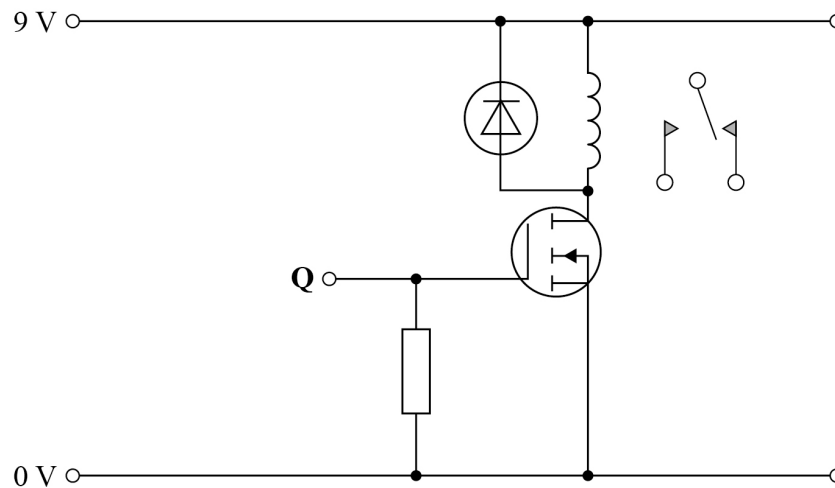
[1 mark]

Q = _____

0 4 . 6

Output **Q** from **Figure 13** becomes the input to the final part of the circuit shown in **Figure 14**.

Figure 14



The circuit uses a MOSFET to activate a relay.

State **one** property that makes the MOSFET suitable for interfacing with logic gates.

[1 mark]

SUB-TOPIC 3.13.2

ANALOGUE AND DIGITAL SIGNALS

Sub-topic 3.13.2 · 4 questions · 26 marks · lowest tariff first



0	5
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In a recording studio the output from a microphone is an analogue signal. The equipment in the studio converts this analogue signal into a digital signal before storing it.

Discuss aspects of the analogue-to-digital conversion in this context.

In your answer you should include:

- what is meant by quantisation
- factors that affect the quality of the digital version of the analogue signal
- the advantages and disadvantages of digitising the analogue signal.

You may use diagrams to help make clear aspects of your answer.

[6 marks]

END OF QUESTIONS



0	5
---	---

A telephone company transmits 15 speech channels across a single transmission link. The analogue information is first subjected to pulse code modulation (PCM) before transmission using time division multiplexing (TDM). The transmission system incorporates regenerators which remove noise from the signal.

Explain the basic principles of:

- pulse code modulation (PCM)
- time division multiplexing (TDM)
- a regenerator.

[6 marks]

END OF QUESTIONS



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 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]

0 3 . 2

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

[1 mark]

number of quantisation levels = _____



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]



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:

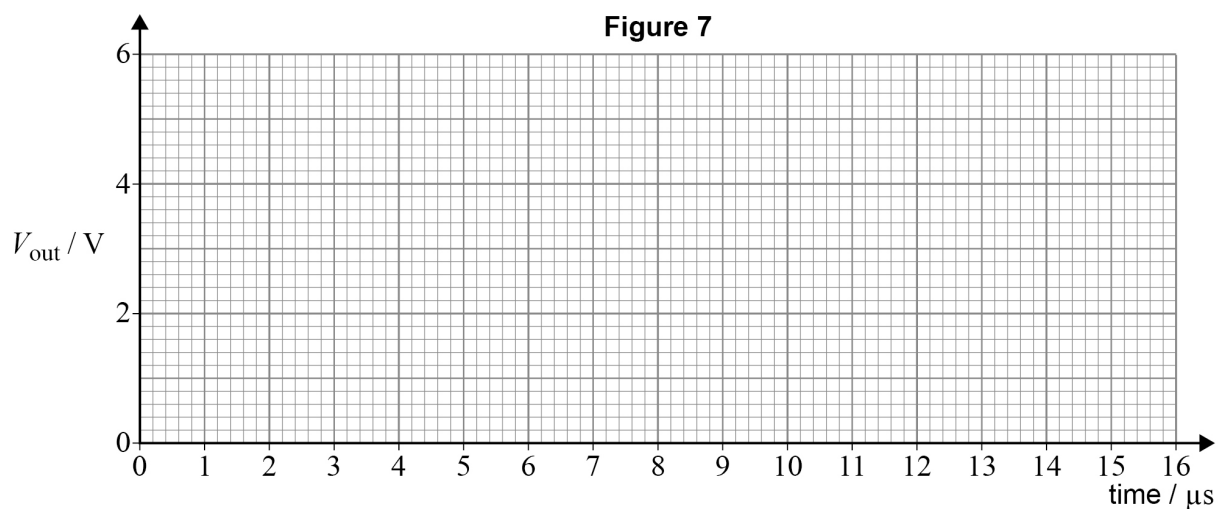
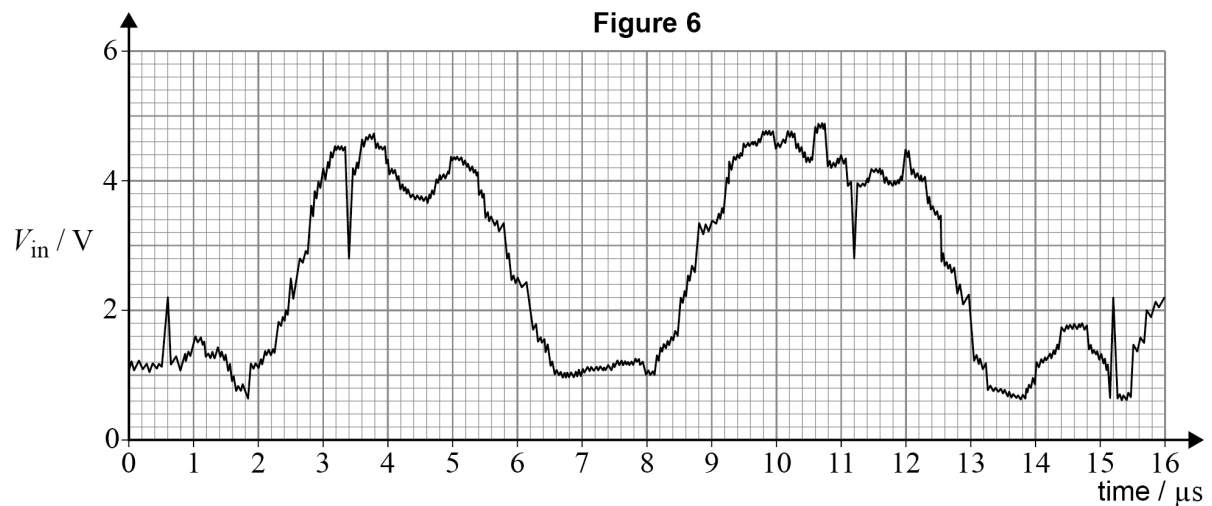
- on the signal and
- on the communication system.

[2 marks]

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.



- 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]

SUB-TOPIC 3.13.3

ANALOGUE SIGNAL PROCESSING

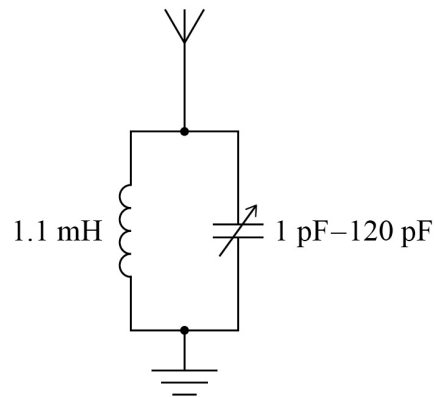
Sub-topic 3.13.3 · 3 questions · 21 marks · lowest tariff first



0	3
---	---

Figure 8 shows the first-stage filter circuit for a simple AM receiver. The circuit can be adjusted to resonate at 910 kHz so that it can receive a particular radio station.

Figure 8



0	3	.	1
---	---	---	---

Calculate the value of the capacitance when the circuit resonates at a frequency of 910 kHz.

[2 marks]

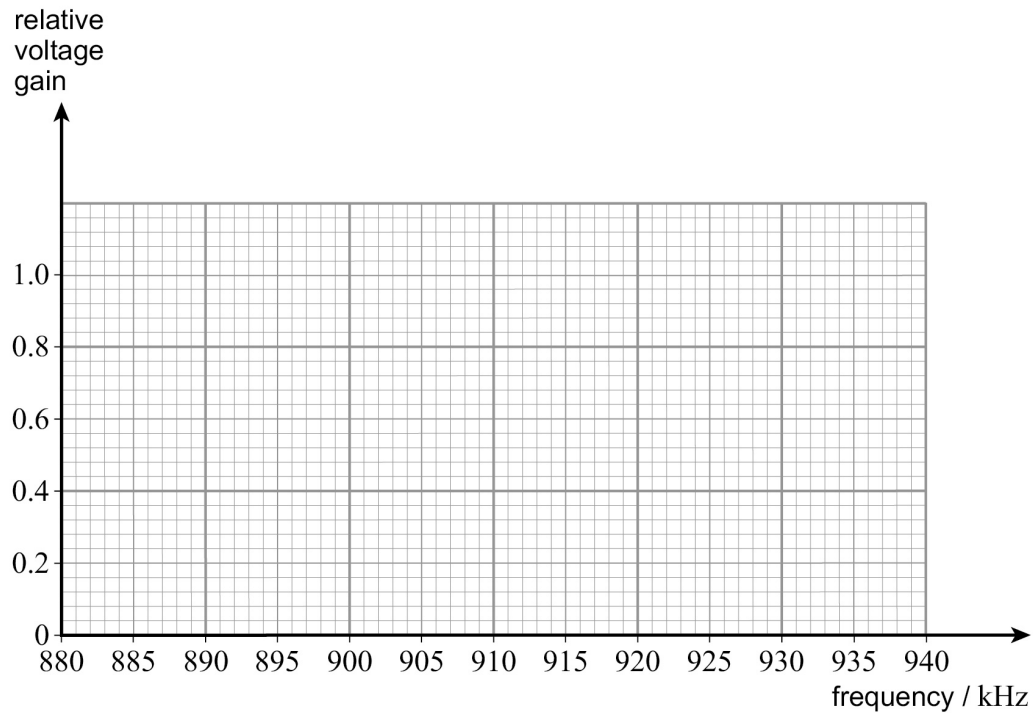
capacitance = _____ pF

03.2

Draw on **Figure 9** an ideal response curve for the resonant circuit, labelling all relevant frequency values based upon a 10 kHz bandwidth.

[3 marks]

Figure 9



03.3

The Q-factor for the practical tuning circuit has a smaller value than the ideal one assumed in question **03.2**.

Discuss the changes the listener might notice when tuning to this station due to the practical Q-factor being smaller.

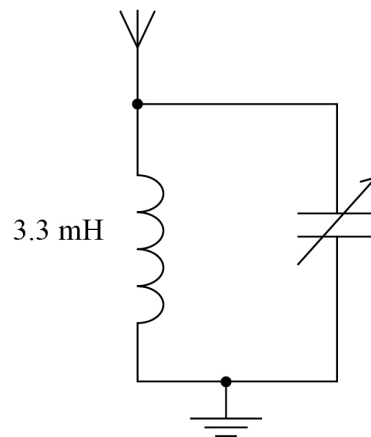
[2 marks]

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

022

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]

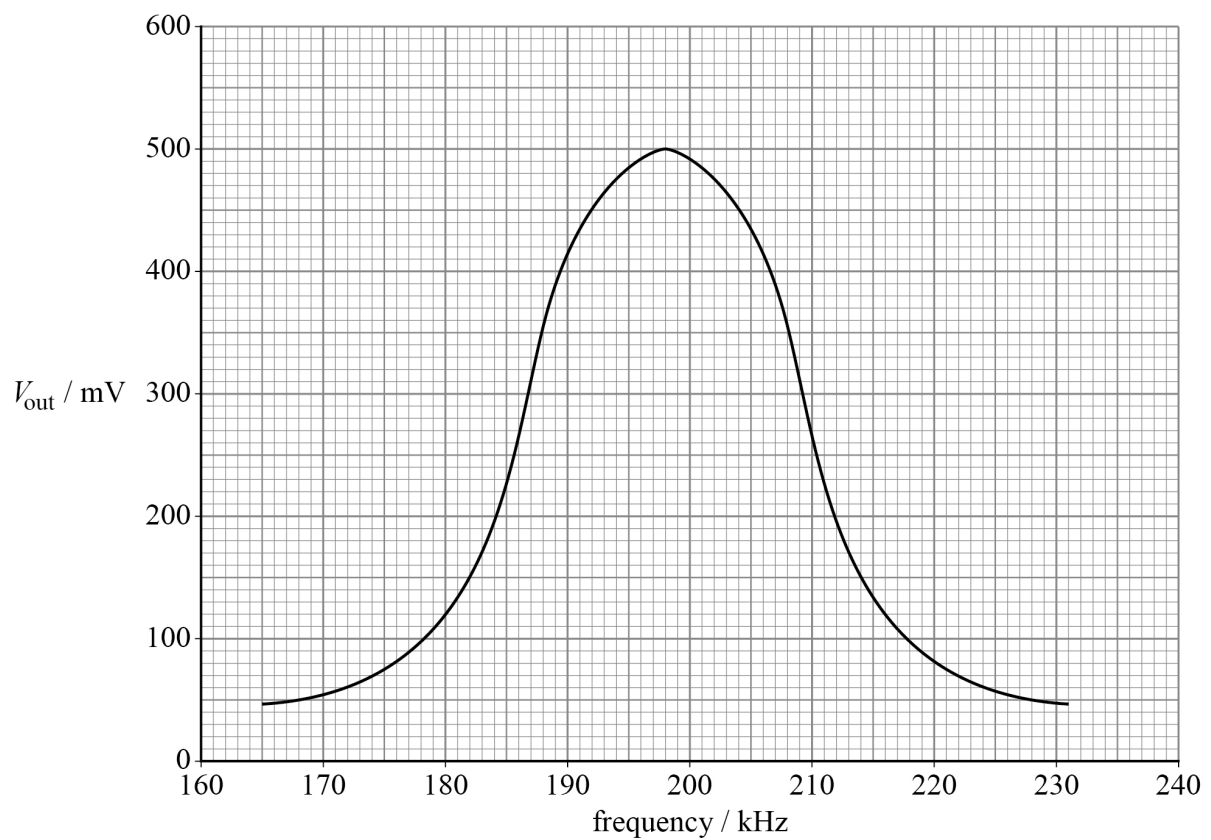
Table 2

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



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.

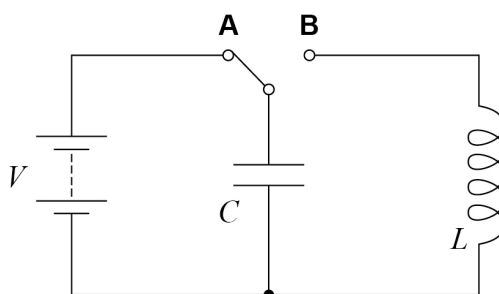
[1 mark]



03

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

Figure 8



03.1

Which quantity in the LC circuit is analogous to the mass in a mass–spring system?

Tick (✓) **one** box.

[1 mark]

C ☐

$\frac{1}{C}$ ☐

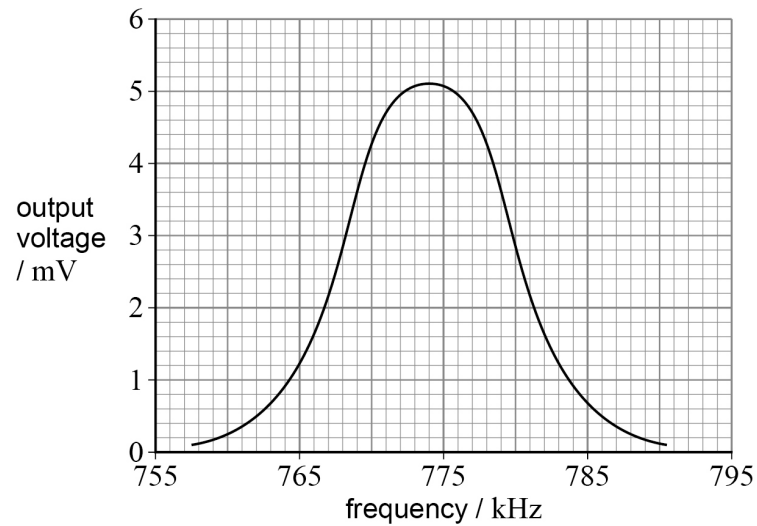
L ☐

$\frac{1}{L}$ ☐

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]

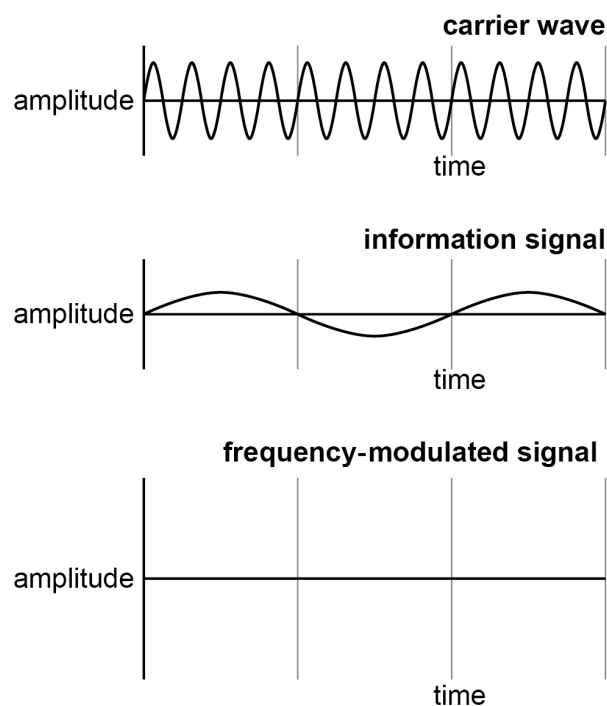
$Q =$ _____

Question 3 continues on the next page

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

SUB-TOPIC 3.13.4

OPERATIONAL AMPLIFIERS

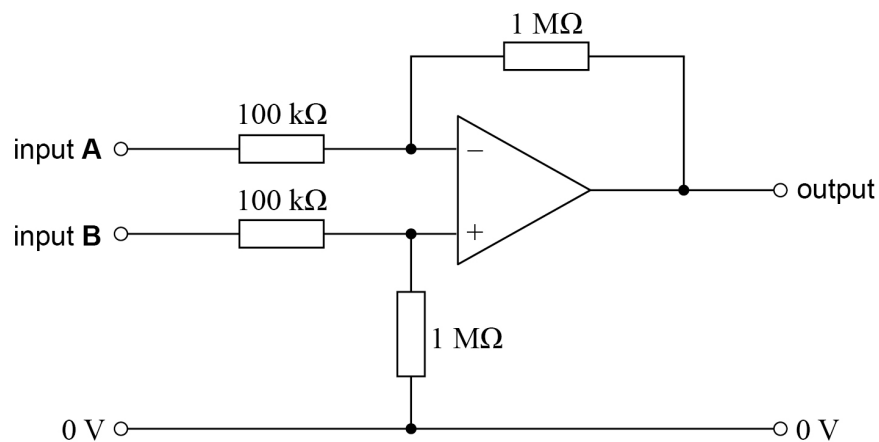
Sub-topic 3.13.4 · 9 questions · 64 marks · lowest tariff first



0 2

Figure 4 shows an operational amplifier circuit used in an audio mixing desk.

Figure 4



The power supply for the amplifier is -12 V and $+12\text{ V}$ but this is not shown in **Figure 4**.

0 2 . 1

What is the operational amplifier configuration shown in **Figure 4**?

Tick (✓) **one** box.

[1 mark]

non-inverting amplifier

☐

comparator

☐

summing amplifier

☐

difference amplifier

☐

0 2 . 2

The circuit shown in **Figure 4** is tested by making the following connections:

- input **A** is connected to an audio signal of amplitude 150 mV
- input **B** is connected to 0 V.

Calculate the amplitude of the output voltage.

[2 marks]

output voltage = _____ V

Question 2 continues on the next page

0 2 . 3

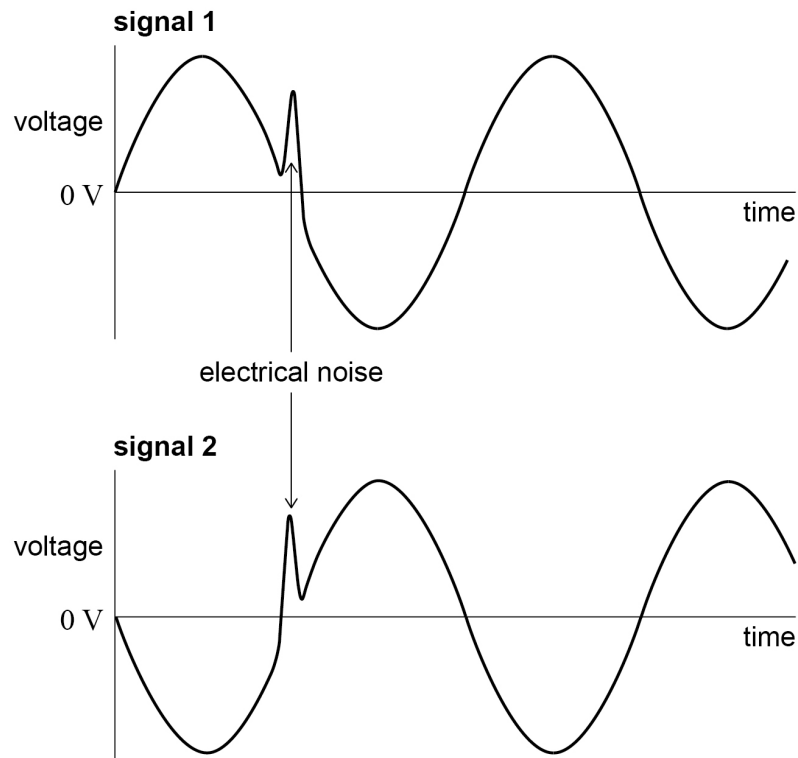
A microphone converts a sound wave into the voltage signal labelled **signal 1** in **Figure 5**. At the same time the microphone produces a second signal, labelled **signal 2**. **Signal 2** is the inversion of **signal 1**. These two signals travel along two separate wires in the same cable.

Figure 5



Figure 6 shows some electrical noise that has been picked up and added to the signals as they travel through the cable from the microphone to the operational amplifier circuit in **Figure 4**.

Figure 6



The connections made in question **02.2** are removed.

Signal 1 is connected to input **A** and **signal 2** is connected to input **B**.

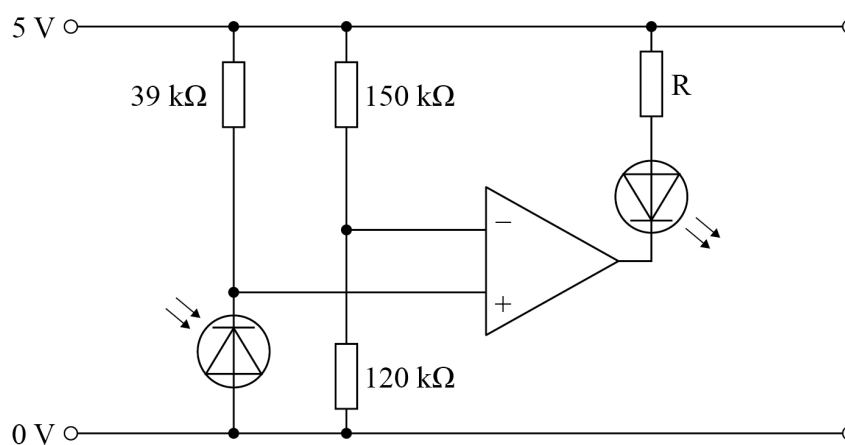
Explain how the operational amplifier circuit affects the noise and strength of the output signal.

[3 marks]

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

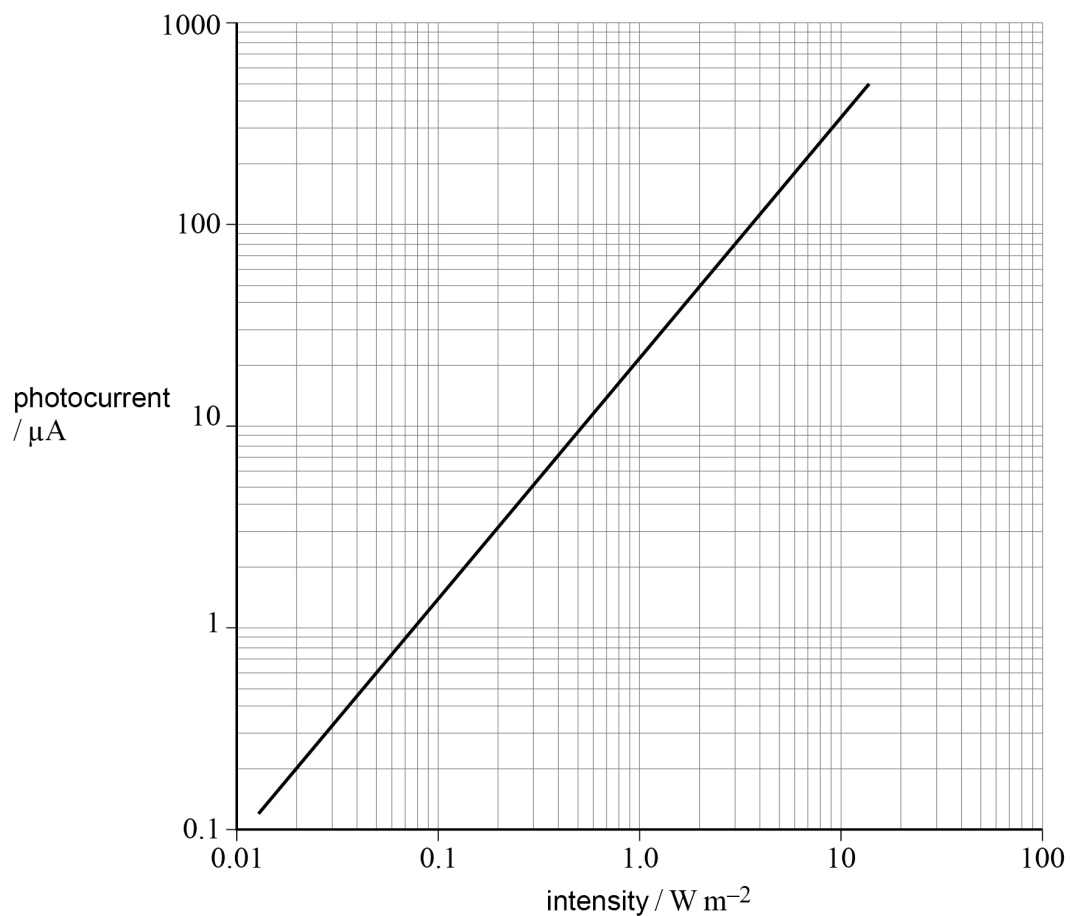
☐

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 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 V.

[3 marks]

Question 4 continues on the next page



0	4
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 .

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]



0 4 . 1

A particular operational amplifier has the following properties:

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

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

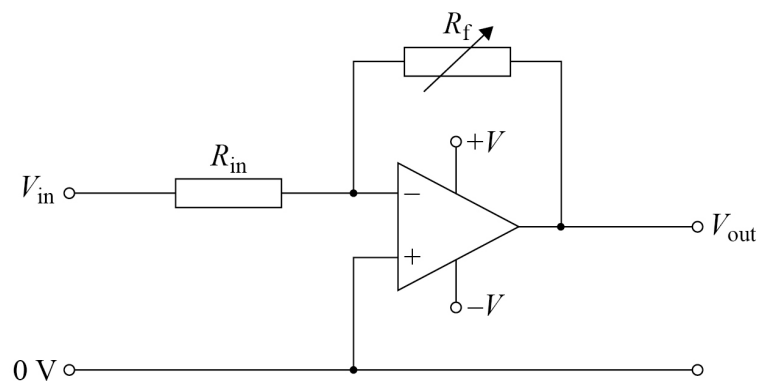
[2 marks]

Figure 8

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]

0 2 . 1

An ultrasound sensor produces an output that needs to be amplified to 3.0 V
The amplifier used has a voltage gain of 40

Calculate the input voltage V_{in} to the amplifier from the sensor.

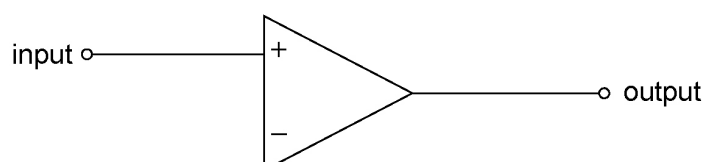
[1 mark]

$V_{\text{in}} =$ _____ V

0 2 . 2

An operational amplifier in non-inverting mode is used to amplify the output of the sensor. The partially completed circuit diagram is shown in **Figure 3**.

Figure 3



0 V ○ ————— ○

Complete the circuit diagram in **Figure 3** by adding and labelling two resistors, R_{in} and R_{f} , so that the operational amplifier is correctly configured in its non-inverting mode.

The power lines should not be shown in the completed diagram.

[2 marks]

0 2 . 3

Determine, using resistors selected from the list below, how the voltage gain of 40 can be achieved by the non-inverting amplifier of **Figure 3**.

1 k Ω 3.6 k Ω 10 k Ω 39 k Ω 150 k Ω **[2 marks]** $R_{in} =$ _____ k Ω $R_f =$ _____ k Ω

0 2 . 4

The ultrasound frequency detected by the sensor is 50 kHz
For this operational amplifier

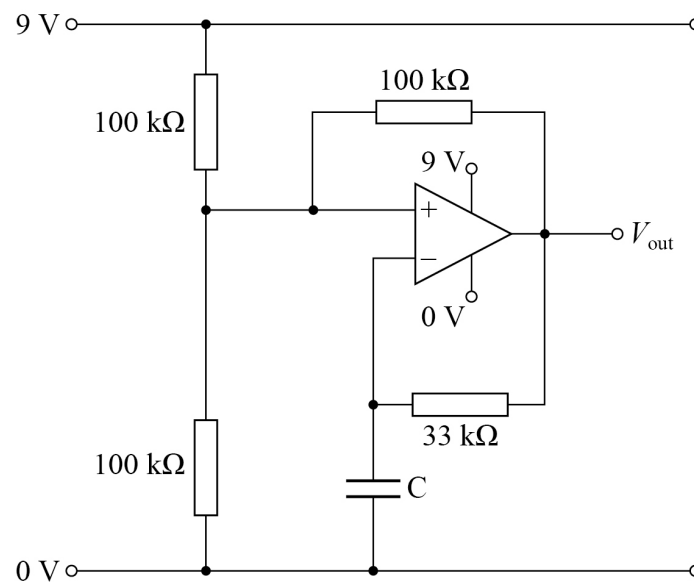
$$\text{gain} \times \text{bandwidth} = 1.0 \text{ MHz}$$

Discuss whether this operational amplifier is suitable for amplifying the sensor's output voltage.

[2 marks]

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

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 V
- the output voltage V_{out} is 9.0 V.

[3 marks]

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

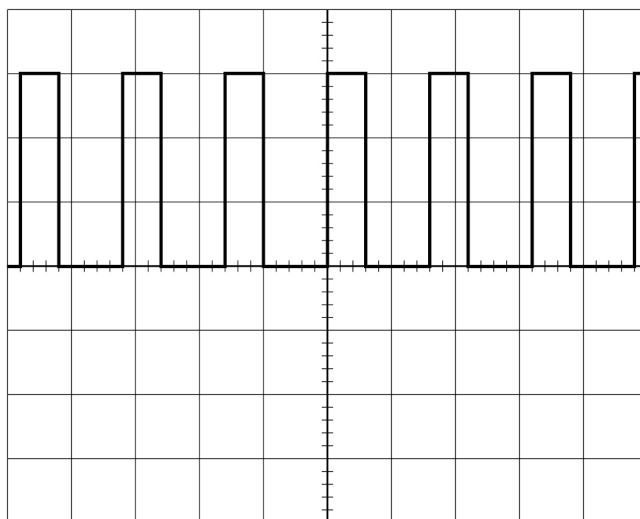
when V_{out} is 9.0 V, $V_+ =$ _____ V



0 2 . 4

Figure 6 shows the output from a different oscillator displayed on an oscilloscope screen.

Figure 6



The time-base is $10\ \mu\text{s}$ per division.

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

[2 marks]

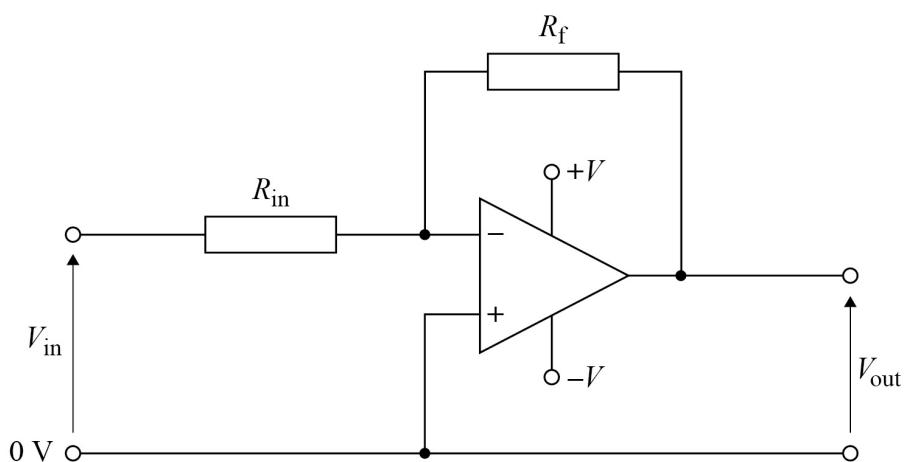
pulse rate frequency = _____ kHz

duty cycle = _____ %

0 1

Figure 1 shows an operational amplifier used as an inverting amplifier.

Figure 1



0 1 . 1

Label **Figure 1** with an **X** to show the point which is a virtual earth.

[1 mark]

0 1 . 2

Name the input pin shown by a (+) on the operational amplifier.

[1 mark]

0 1 . 3

Derive the expression for the inverting amplifier gain $\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_f}{R_{\text{in}}}$

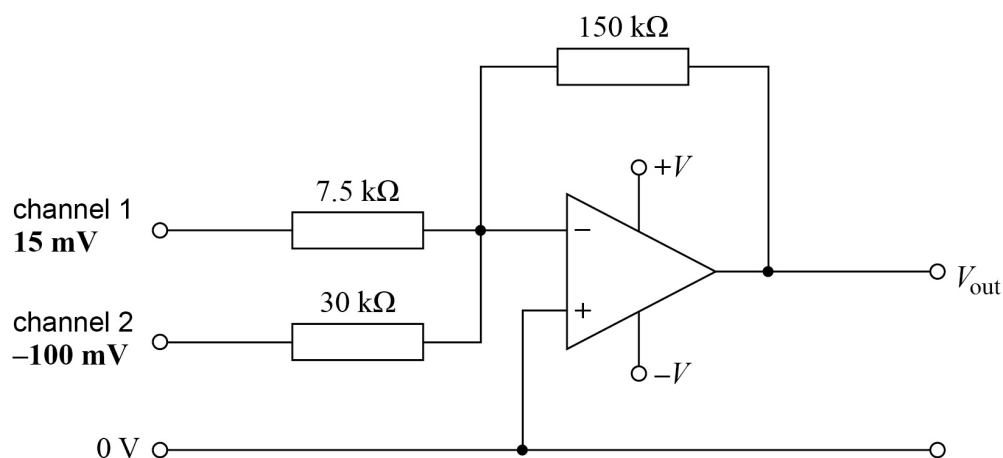
[2 marks]

Question 1 continues on the next page

0 1 . 4

Figure 2 shows the inverting amplifier modified to make a summing amplifier that is to form part of a two-channel audio mixer.

Figure 2



Calculate the voltage gain produced by channel 1.

[1 mark]

voltage gain (channel 1) = _____

0 1 . 5

The mixer is tested using the input signals to channels 1 and 2 with the amplitudes shown in **Figure 2**.

Calculate the amplitude of the output voltage V_{out} produced in the test.

[2 marks]

$V_{\text{out}} =$ _____ V

0 1 . 6

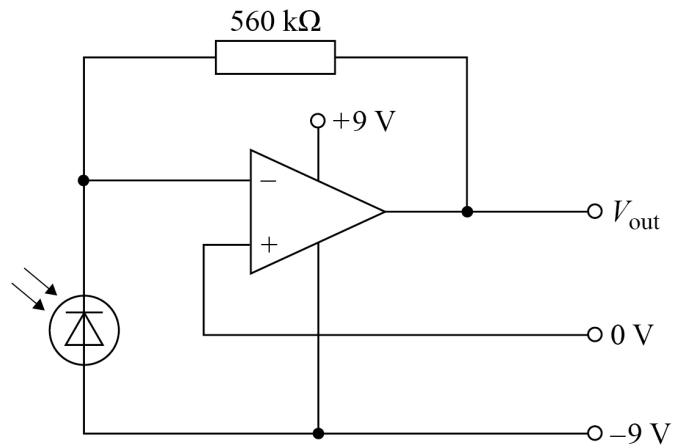
Describe how the function of the audio mixer could be improved by changing the two input resistors from fixed values to variable values.

[1 mark]

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 .

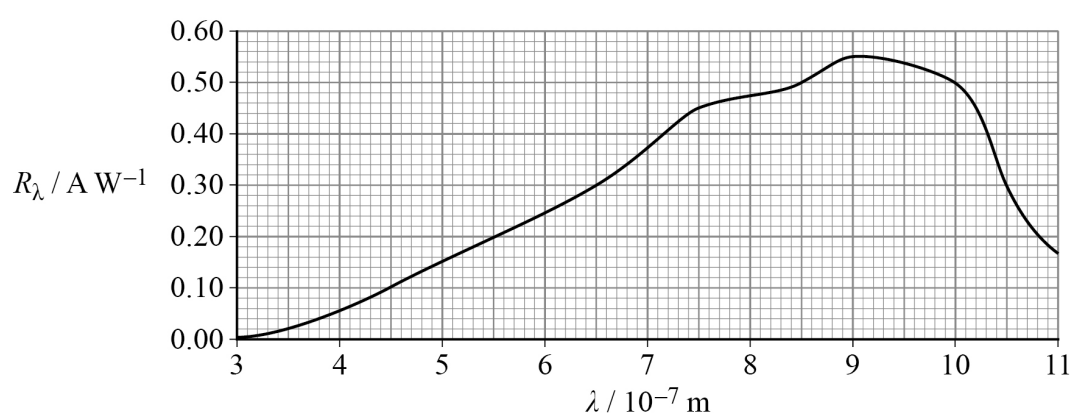
R_λ is defined as:

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

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

0	3	.	4
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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 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 k Ω to 100 k Ω .

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

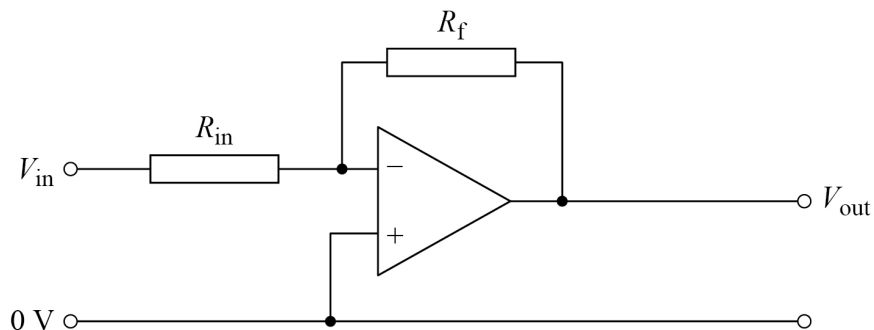
[3 marks]

Figure 12



0 1

Figure 1 shows a circuit containing an ideal operational amplifier. A signal V_{in} is applied to one of the amplifier inputs.

Figure 1

0 1 . 1

Draw an **X** on the circuit in **Figure 1** to indicate a virtual earth point.

[1 mark]

0 1 . 2

Show that the closed loop voltage gain for the amplifier in **Figure 1** is given by:

$$\frac{R_f}{R_{in}} = - \frac{V_{out}}{V_{in}}$$

State any assumptions made in your answer.

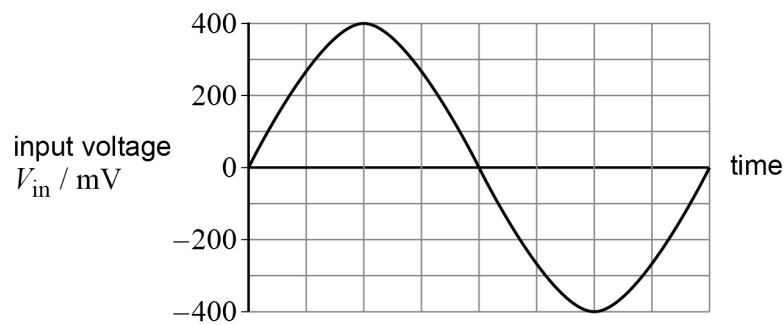
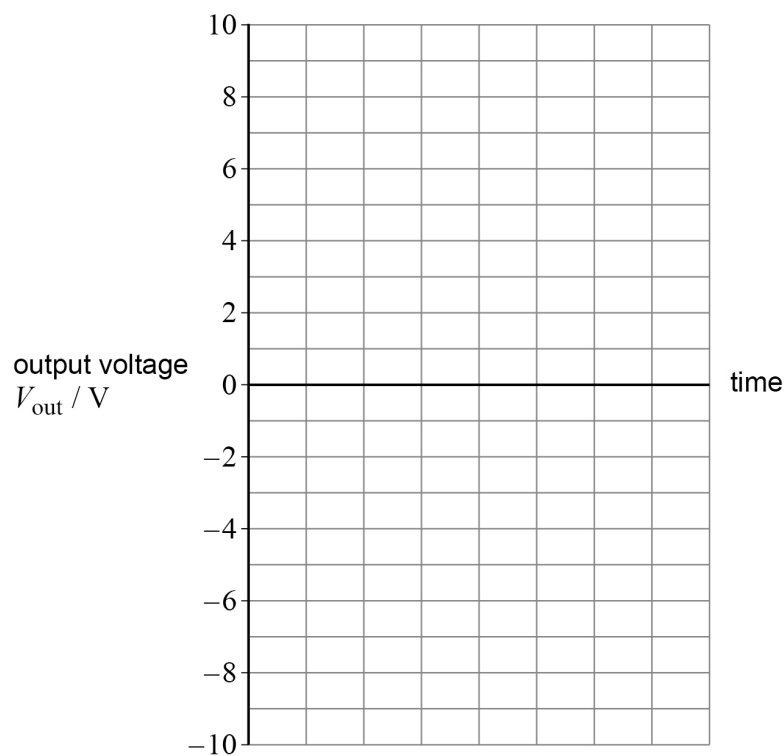
[2 marks]

assumptions _____

Question 1 continues on the next page

0 1 . 3

Figure 2A shows the input signal V_{in} that is applied to the circuit in **Figure 1**.

Figure 2A**Figure 2B**

The circuit in **Figure 1** has a closed loop gain of -20 and has power-supply voltages of ± 6.0 V.

Draw, on **Figure 2B**, the output waveform from the operational amplifier circuit over the same time interval as that shown on **Figure 2A**.

[2 marks]

0	1	.	4
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A student converts the circuit in **Figure 1** into one that will add two input signals V_1 and V_2 .

The new circuit produces an output voltage V_{out} so that:

$$V_{\text{out}} = -(1.5V_1 + 0.75V_2)$$

The circuit is to include a $27\text{ k}\Omega$ feedback resistor.

Complete **Figure 3** to show the circuit that the student constructs.
Annotate your circuit with the values of any additional components.

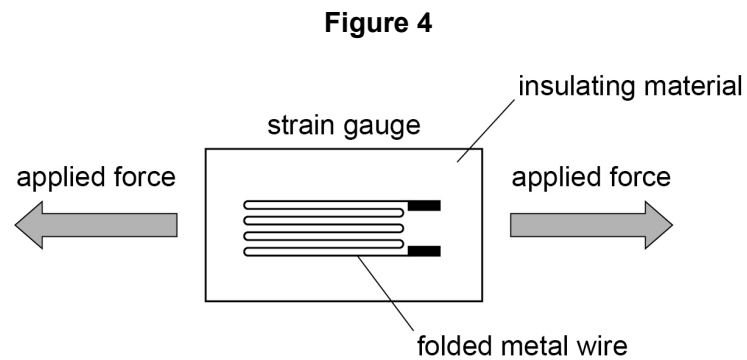
[3 marks]

Figure 3



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



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

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.

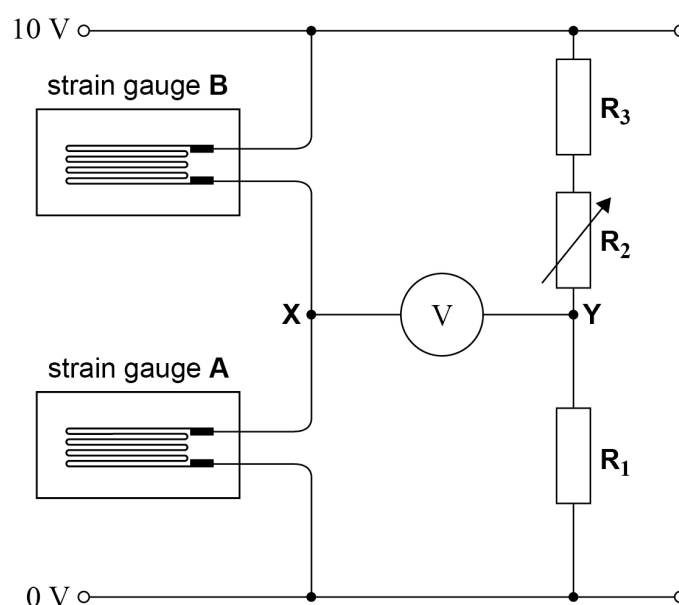
R_1 is a $560\ \Omega$ fixed resistor.

R_2 is a $100\ \Omega$ variable resistor.

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, R_2 is adjusted to produce 0 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

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



SUB-TOPIC 3.13.5

DIGITAL SIGNAL PROCESSING

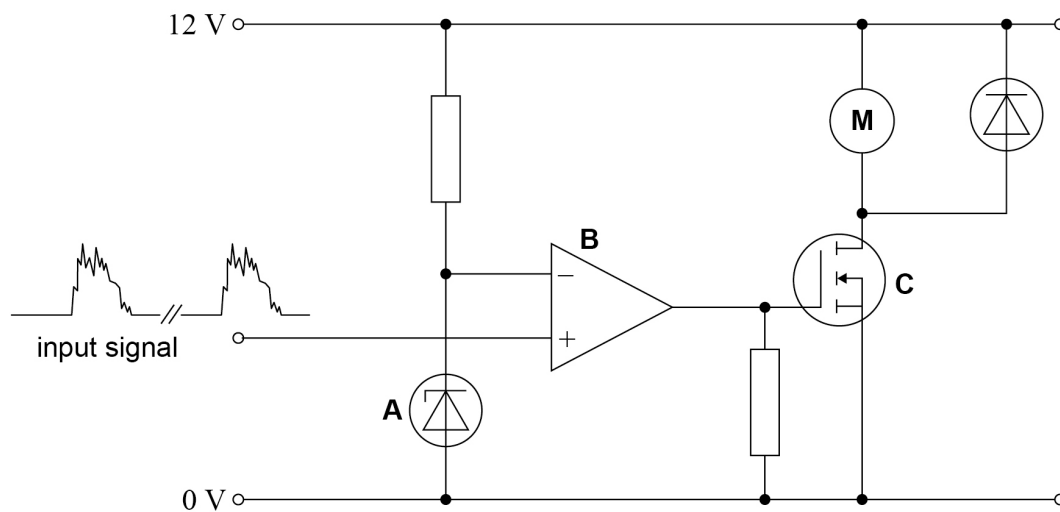
Sub-topic 3.13.5 · 13 questions · 97 marks · lowest tariff first



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:

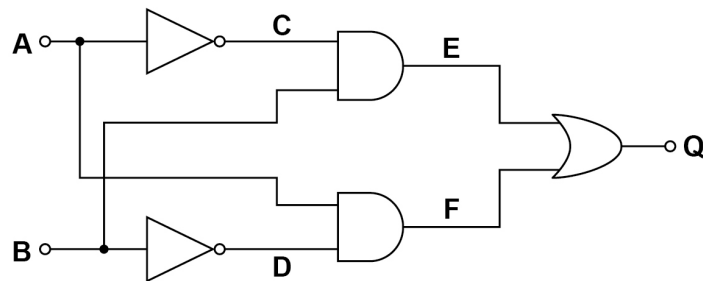
- explain its role in the circuit
 - identify the characteristic properties that make the component suitable for this role.
- [6 marks]**

END OF QUESTIONS

0 1 . 1

Two logic inputs, **A** and **B**, feed into the logic circuit shown in **Figure 1**. The logic output from the circuit is **Q**.

Figure 1



Deduce the Boolean expression for the output of this logic circuit in terms of inputs **A** and **B**.

Include all the logic operations that take place between the inputs and the output.

[2 marks]

Q = _____

0 1 . 2

The truth table shows some of the logic states for the logic gates in **Figure 1**.

Complete the truth table.

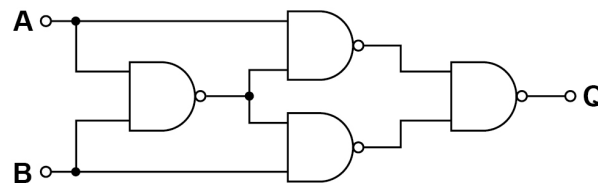
[2 marks]

B	A	C	D	E	F	Q
0	0		1		0	0
0	1		1		1	1
1	0		0		0	1
1	1		0		0	0

0 1 . 3

Figure 2 shows a different logic circuit that produces the same logic output as that of **Figure 1**.

Figure 2



A manufacturer wants to produce a system that uses this logic function, but is undecided as to which circuit to use.

Suggest, giving reasons, **two** benefits of using the logic circuit in **Figure 2** compared to the logic circuit in **Figure 1**.

[2 marks]

0 1 . 4

State the single logic gate that would perform the same logic function as the circuits shown in **Figure 1** and **Figure 2**.

[1 mark]

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**.

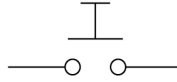
[1 mark]

Question 2 continues on the next page



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 k Ω resistor, can be connected to create the door detector circuit in **Figure 5**.

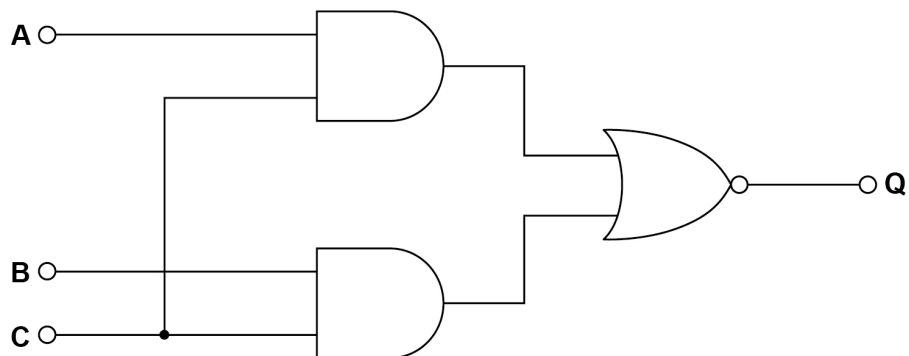
Label the output of the circuit with an **X**.

[2 marks]

Figure 7

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]

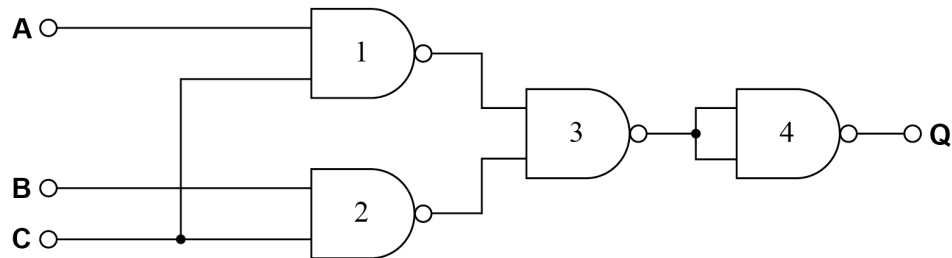
Q = _____

Question 2 continues on the next page

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]

0	4
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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
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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

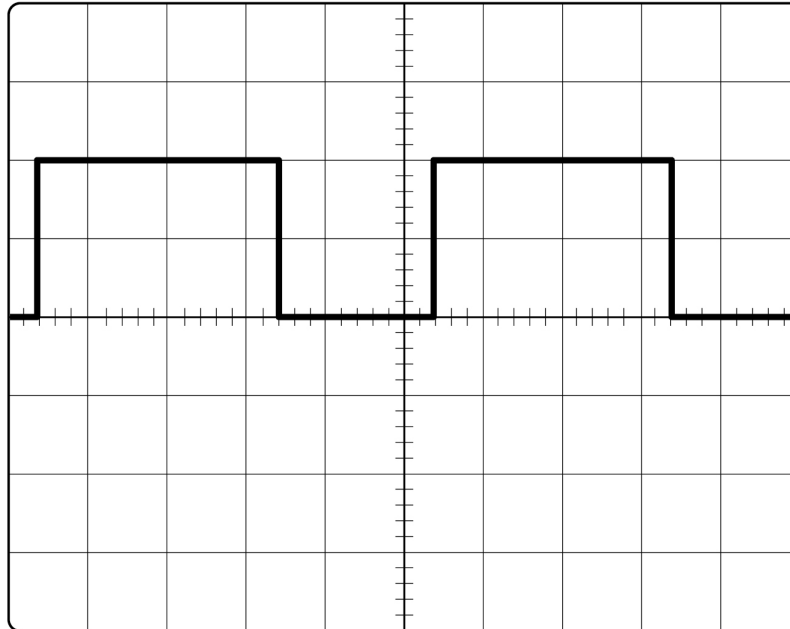


0 4 . 2

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 μ s / division.

Determine the duty cycle and frequency of the signal.

[3 marks]

duty cycle = _____

frequency = _____ kHz

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 , $Q_2 \dots Q_9$.

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

[2 marks]

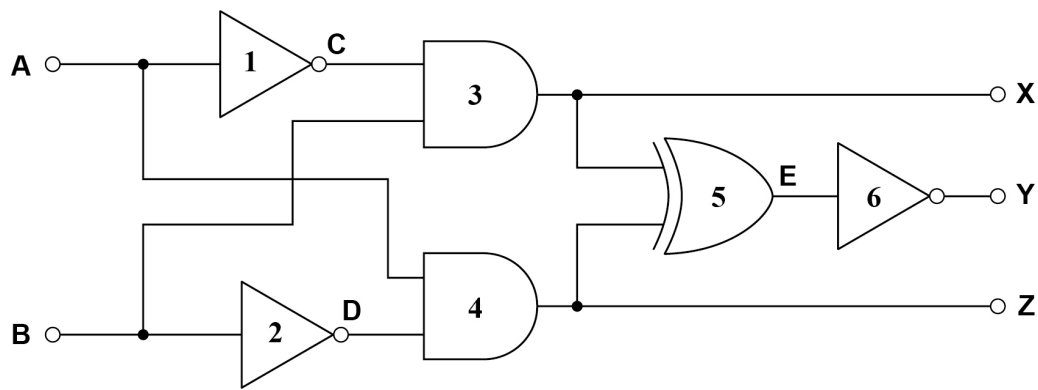
BCD counter: frequency of pulses = _____ Hz

Johnson decade counter: frequency of pulses = _____ Hz

02

Figure 4 shows a logic system made of logic gates labelled **1** to **6**. The logic system has inputs **A** and **B** and outputs **X**, **Y** and **Z**.

Figure 4



02.1

Write the simplest Boolean algebra expression for output **X** in terms of inputs **A** and **B**.

[2 marks]

X = _____

02.2

State the name of logic gate **5** in **Figure 4**.

[1 mark]

02.3

Complete **Table 1**, the truth table for this logic system.

[2 marks]

Table 1

B	A	C	D	E	X	Y	Z
0	0	1	1	0			
0	1	0	1	1			
1	0	1	0	1			
1	1	0	0	0			



0 2 . 4

Suggest a single logic gate that can replace the combination of gates **5** and **6** in this system.

[1 mark]

0 2 . 5

The logic system in **Figure 4** is designed to indicate which of inputs **A** and **B** has the larger binary value, or whether the values are the same. Each decision is indicated by one of the outputs **X**, **Y** or **Z** becoming a logic 1

Which row identifies the outputs **X**, **Y** and **Z**?

Tick (✓) **one** box.

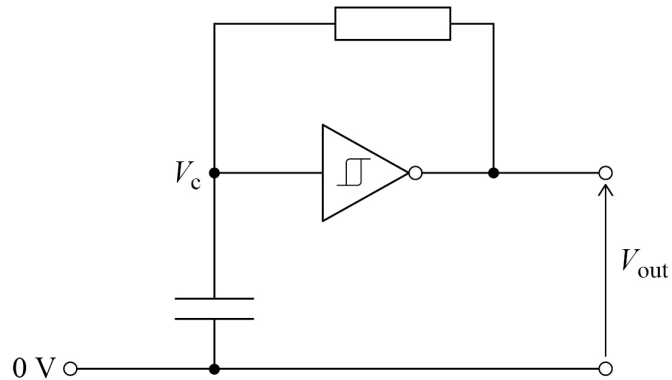
[1 mark]

X	Y	Z	
A = B	A < B	A > B	☐
A < B	A = B	A > B	☐
A < B	A > B	A = B	☐
A > B	A = B	A < B	☐

0 4

Figure 6 shows a type of NOT gate called a Schmitt Trigger. This is connected to a capacitor of capacitance C and a resistor of resistance R to make an oscillator circuit. The circuit is used to produce continuous clock pulses.

Figure 6



V_{out} switches HIGH or LOW when the input voltage V_c passes through one of two trigger voltage values.

The output voltage V_{out} switches to:

- LOW when V_c rises and reaches the upper trigger voltage V_U
- HIGH when V_c falls and reaches the lower trigger voltage V_L .

0 4 . 1 Initially the capacitor is uncharged and V_c is at 0 V.

Explain the sequence of actions of this circuit as the output goes through one full cycle. The first two stages have been done for you.

You should refer to the RC circuit in **Figure 6** and to V_U and V_L in your answer.

[3 marks]

Stage 1: Since V_c is LOW, the output is HIGH.

Stage 2: The capacitor now charges through the resistor, making V_c rise.

Stage 3: _____

Stage 4: _____

Stage 5: _____

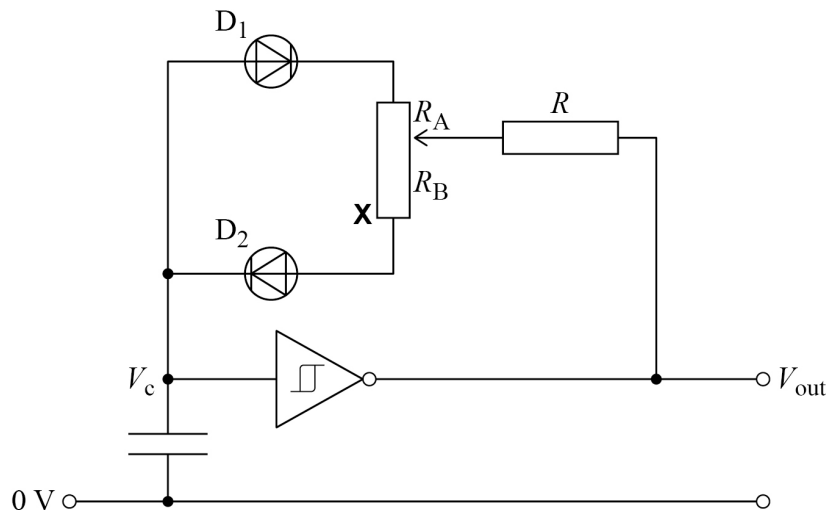
Question 4 continues on the next page

0 4 . 2

Figure 7 shows the oscillator circuit after it has been modified by the addition of:

- two diodes D_1 and D_2
- a potential divider that has a total resistance value of $(R_A + R_B)$.

Figure 7



In this particular circuit:

- the time t_H for the output signal to be HIGH is given by $t_H = 0.7C(R + R_B)$
- the time t_L for the output signal to be LOW is given by $t_L = 0.7C(R + R_A)$.

The slider of the potential divider is moved towards **X**, as shown in **Figure 7**.

State and explain the effect of this change on:

- the mark-to-space ratio ($t_H : t_L$)
- the pulse rate frequency (PRF).

[4 marks]

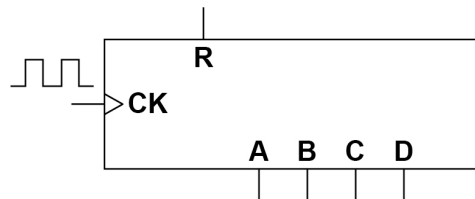
mark-to-space ratio _____

PRF _____

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



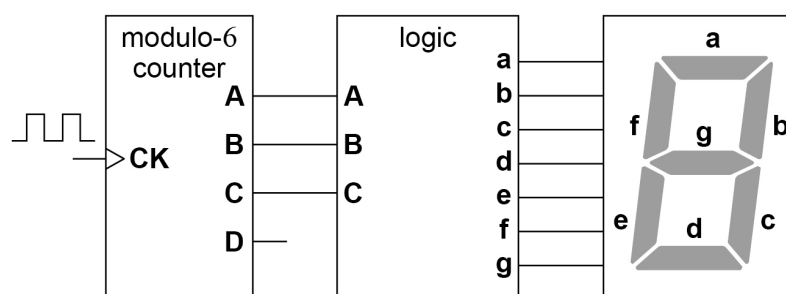
0 1 . 1

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.

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:

$$X = (A \cdot B) + C$$

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



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

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

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]

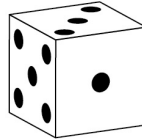
Figure 3



0 2

A die, where dots on the faces of a cube indicate the numbers 1 to 6, is shown in **Figure 3** and is used in many games.

Figure 3



A student makes an electronic version of this by feeding pulses from a pulse generator into a 4-bit binary counter.

The circuit uses the first three outputs of the counter A (least significant bit), B and C.

By feeding the outputs from the counter through logic gates, the seven LEDs shown in **Figure 4** can be made to display the numbers 1 to 6 in sequence.

Figure 4

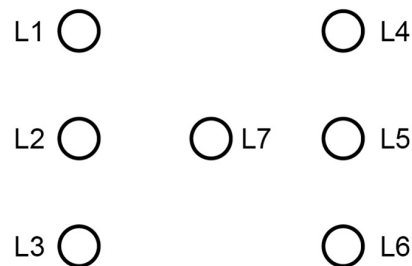


Figure 5 shows the sequence of numbers.

The partially completed truth table in **Table 1** shows which of the LEDs (L1 to L6) are ON (logic 1) and which are OFF (logic 0) during the counting sequence.

Table 1

Number shown on die	Logic inputs			Logic outputs						
	C	B	A	L1	L2	L3	L4	L5	L6	L7
1	0	0	0		0	0	0	0		1
2	0	0	1		0	0	0	0		0
3	0	1	0		0	0	0	0		1
4	0	1	1		0	1	1	0		0
5	1	0	0		0	1	1	0		1
6	1	0	1		1	1	1	1		0
Reset 6 → 1										

0 2 . 1

Complete **Table 1** to show the logic outputs for the lamps L1 and L6.

[2 marks]

0 2 . 2

Deduce the **simplest** Boolean expression that can be used to show how output L7 can be controlled by the logic inputs.

[1 mark]

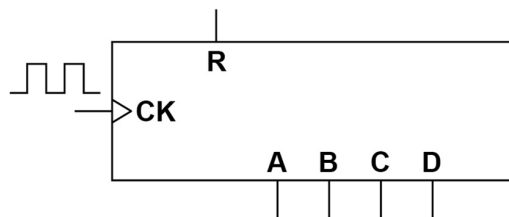
Question 2 continues on the next page



0 2 . 3

Figure 6 shows some of the input and output pins of the 4-bit binary counter.

Figure 6



The data sheet for the counter indicates that the counter resets when the reset pin **R** is taken from logic 0 to logic 1.

Draw on **Figure 6** the logic gate needed and the connections required from the outputs to the reset pin **R** on the counter so that the counter cycles as required.

[2 marks]

0 2 . 4

The output of both L3 and L4 can be written as $(A \cdot B \cdot \bar{C}) + (\bar{B} \cdot C)$

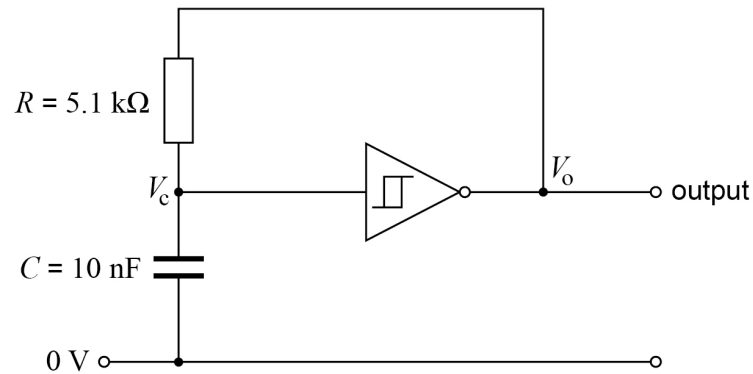
Figure 7 shows part of a logic circuit needed to represent this Boolean expression.

Complete the logic circuit in **Figure 7** by adding AND, OR and NOT gates.

[3 marks]

0 4 . 1

Figure 6 shows an astable circuit based on a NOT logic gate. The symbol in the centre of the logic gate means that the output V_o changes at two different input values of V_c depending on whether the input voltage is rising or falling.

Figure 6

The pulse repetition frequency (PRF) for this particular circuit is given by:

$$\frac{1}{1.4 RC}$$

Calculate the PRF in kHz

[1 mark]

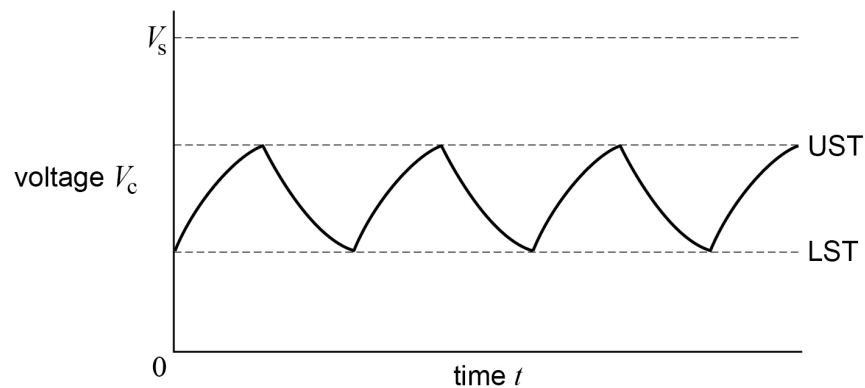
PRF = _____ kHz

0 4 . 2

The supply voltage to the NOT gate is V_s

- When V_c increases and reaches the upper switching threshold (UST), the output of the NOT gate will switch from V_s to 0 V
- When V_c decreases and reaches the lower switching threshold (LST), the output of the NOT gate will switch from 0 V to V_s

The graph in **Figure 7** shows V_c constantly changing as the capacitor charges and discharges.

Figure 7

Draw on **Figure 7** the output voltage V_o for the astable circuit.

[1 mark]

0 4 . 3

The circuit in **Figure 6** can be modified by the addition of a resistor to vary the PRF.

The astable is to be modified so that it produces a frequency 4 times that of the original.

Calculate the value of the resistor that should be added to the circuit and explain where in the circuit this additional resistor should be placed.

[2 marks]

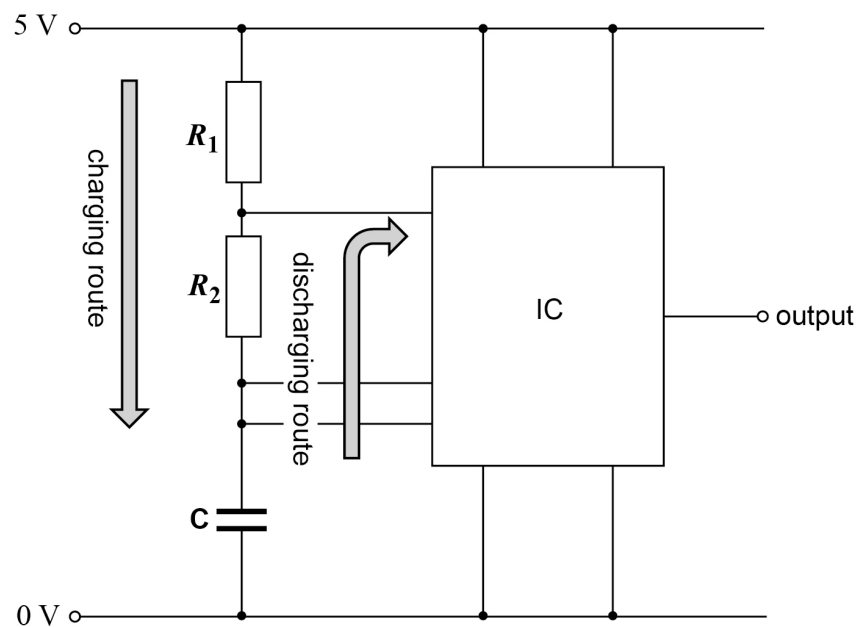
value of resistor = _____ kΩ

Question 4 continues on the next page

0 4 . 4

In another astable, two resistors (R_1 and R_2) and a capacitor C form a timing chain to control the mark and space times for a square wave produced at the output of the integrated circuit (IC) shown in **Figure 8**.

Figure 8



The charging time for the capacitor C is: $t_C = 0.7 \times (R_1 + R_2) \times C$

The discharging time for the capacitor C is: $t_D = 0.7 \times R_2 \times C$

Calculate, in $k\Omega$, values for R_1 and R_2 needed to produce a 5 kHz signal with 75% duty cycle given that the capacitor C has a value of 10 nF

[2 marks]

$R_1 =$ _____ $k\Omega$

$R_2 =$ _____ $k\Omega$

0	4	.	5
---	---	---	---

The output of the IC in **Figure 8** is 5 V during the charging period and 0 V during the discharging period.

Draw on **Figure 9** the wave pattern that represents this signal.

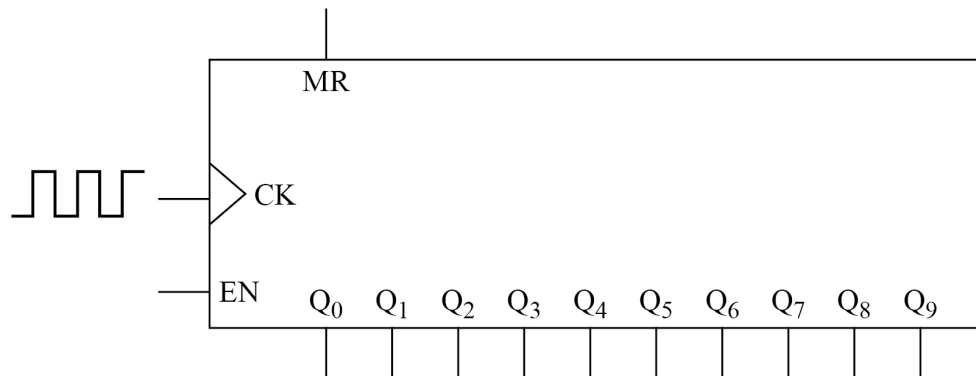
[2 marks]

Figure 9



0 1

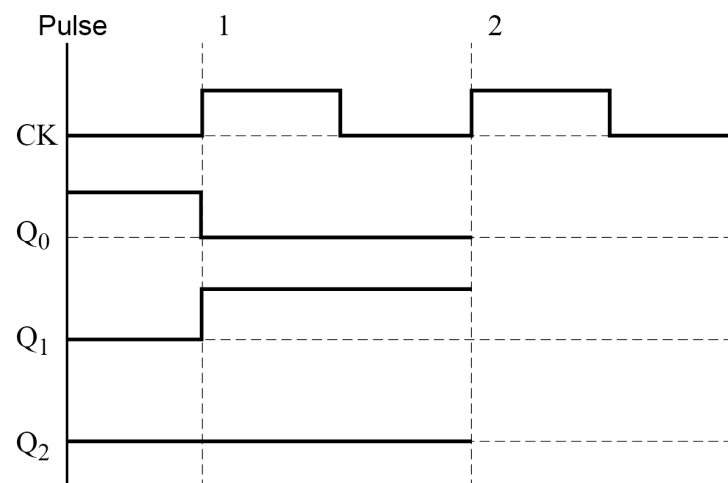
Figure 1 shows the basic layout for a Johnson decade counter. The main input is the clock (CK). The main outputs are shown as Q_0 to Q_9 .

Figure 1

0 1 . 1

Figure 2 shows part of the timing diagram for a Johnson decade counter. This timing diagram shows the output logic states against time. The counter is reset to make $Q_0 = 1$ and then the first two pulses are applied.

Complete **Figure 2** to show the logic states of Q_0 , Q_1 and Q_2 .

[2 marks]**Figure 2**

Question 1 continues on the next page

0 1 . 2 A student sets up the counter to make the traffic light sequence:

red → **red + amber** → **green** → **amber**

The sequence then repeats.

Figure 3 shows a partially completed diagram for producing this sequence.

Draw an OR gate and connections on **Figure 3** so that the LEDs go through the complete sequence.

[1 mark]

Figure 3

0 1 . 3 State **two** factors that determine the ON time for the green LED shown in **Figure 3**.

[2 marks]

1 _____

2 _____

0 1 . 4 The potential difference across the green LED is 2.1 V when it is lit. The current through it should not exceed 9 mA.

All logic gate outputs are:

logic low = 0 V

logic high = 9 V.

The student suggests that a resistor of resistance 720 Ω and a tolerance of $\pm 5\%$ should be used for **R**.

Deduce whether the student's suggestion would be suitable.

[3 marks]



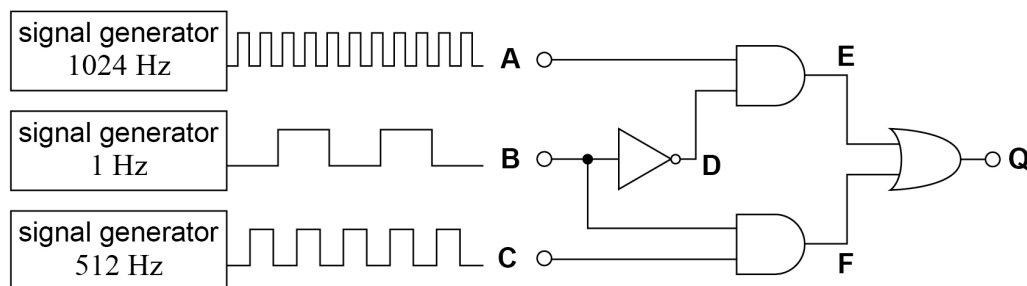
0 1

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 = _____

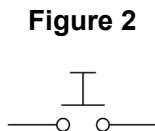
0 1 . 3 Option 1 is tested by replacing the 1 Hz signal generator with a manual input.

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.



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

9 V ○ ————— ○

0 V ○ ————— ○

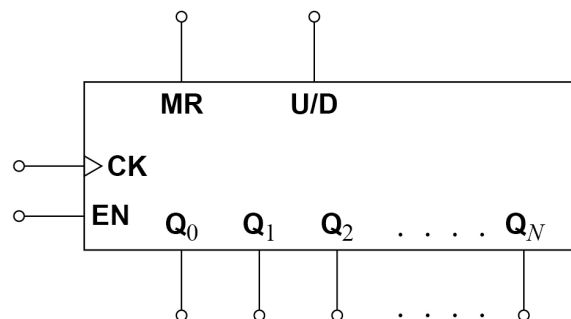
Question 1 continues on the next page

0 1 . 4

Figure 4 shows a generalised layout of an integrated circuit (IC) for an N -bit binary counter.

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 Q_0 to Q_N will provide the 1 Hz signal.

[1 mark]

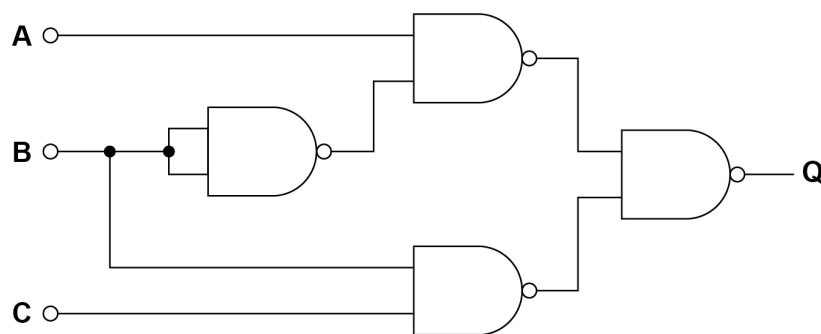
0 1 . 5

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:

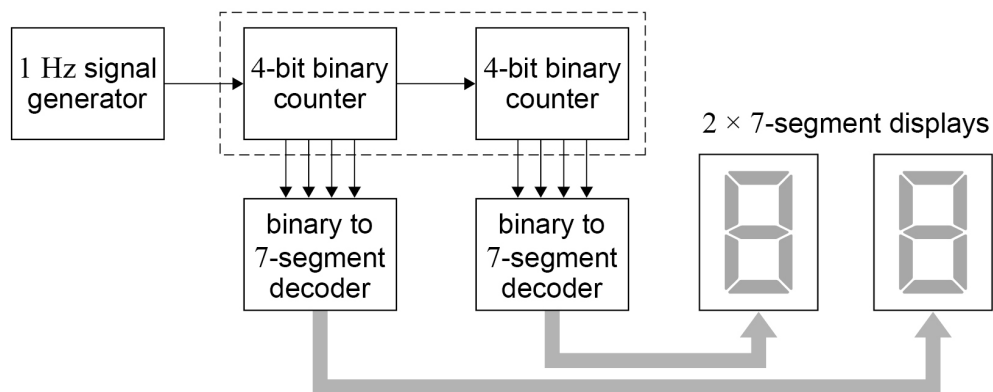
- each **type** of logic gate has its own dedicated IC chip
- each separate signal generator is based upon its own IC chip.

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]

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

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:

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

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

X ○—

Y ○—

Z ○—

—○ Q

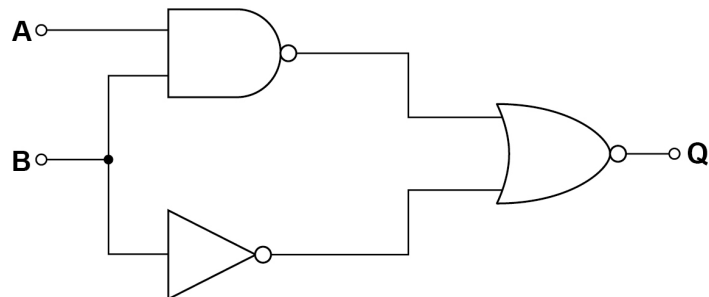
Question 1 continues on the next page



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

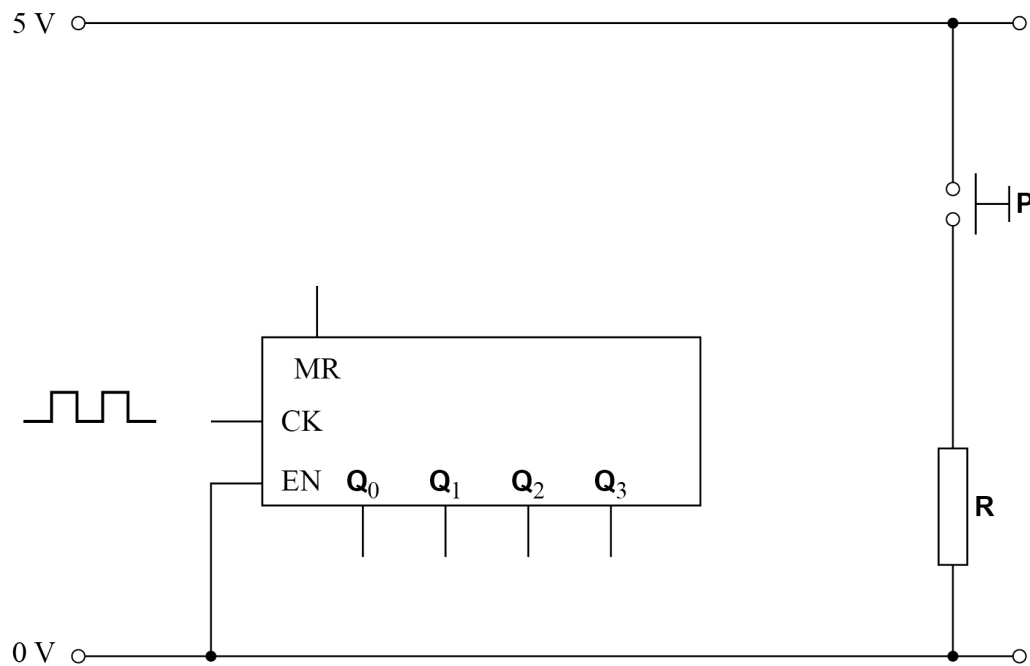
☐

NAND

☐

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 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

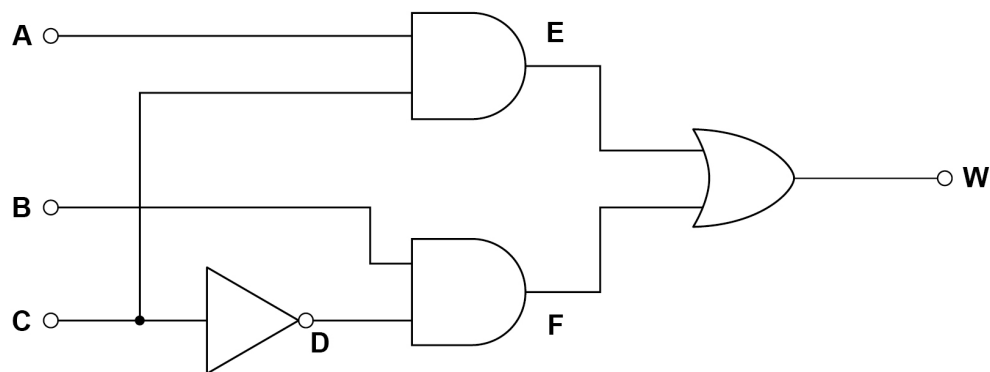
0 1 . 2 A logic system is designed to identify prime numbers.

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

$$S = \bar{A} \cdot (B + C)$$

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

[1 mark]

Question 1 continues on the next page



0	1	.	5
---	---	---	---

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

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

[2 marks]

Figure 3



SUB-TOPIC 3.13.6

DATA COMMUNICATION SYSTEMS

Sub-topic 3.13.6 · 10 questions · 64 marks · lowest tariff first



END OF QUESTIONS

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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]

[illegible]

Question 5 continues on the next page

END OF QUESTIONS



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****END OF QUESTIONS**

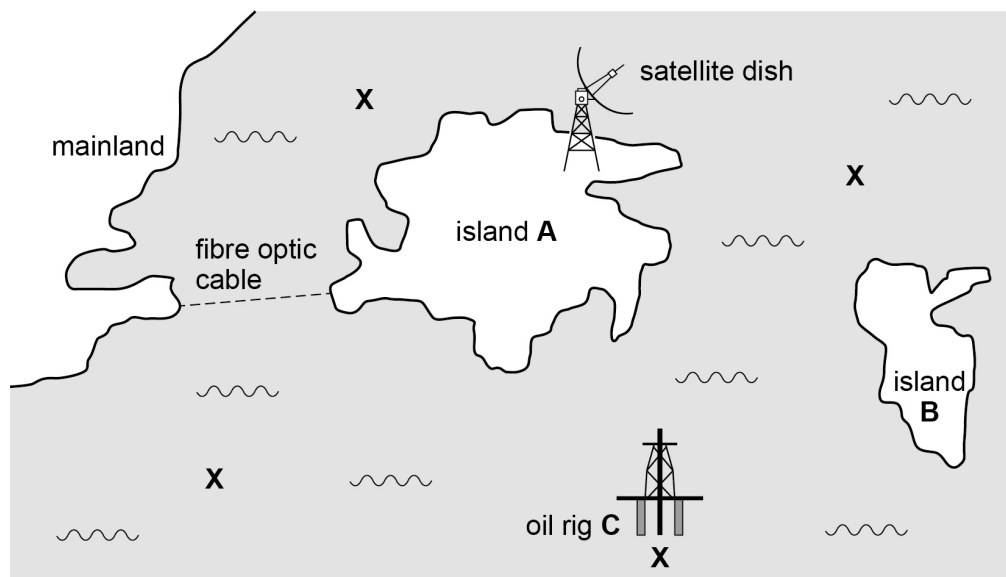
0 5

Figure 8 shows island **A**, a fully developed island off the mainland coast. The island is connected to the mainland by a fibre optic cable lying along the seabed and it also has a satellite link.

Nobody lives on island **B**, but it is due to be developed as a major holiday resort over the next 5 years.

Moveable oil rig **C** is due to explore the four sites marked 'X' for oil and gas over a 9-month period.

Figure 8



A communications company has been asked to provide solutions for island **B** which will allow the development to begin immediately and then later to support a fully developed holiday resort.

A communications solution is also required for oil rig **C** during the 9-month exploration period.

Describe appropriate solutions involving fibre optic cabling and satellite communication systems for each of the two clients, island **B** and oil rig **C**.

In your answer you should:

- outline the way each communications system operates
- suggest, with reasons, your choice of system for each solution.

[6 marks]

END OF QUESTIONS

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]

END OF QUESTIONS



0 4 . 1

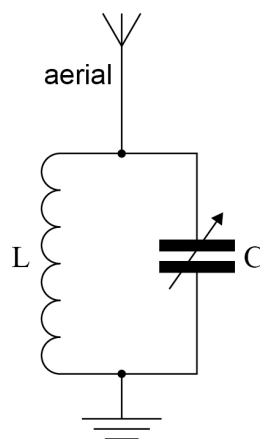
State what is meant by a carrier wave within a radio transmission system.
Go on to explain how the carrier wave is used in this system.

[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

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

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

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

Your answer should include a discussion of:

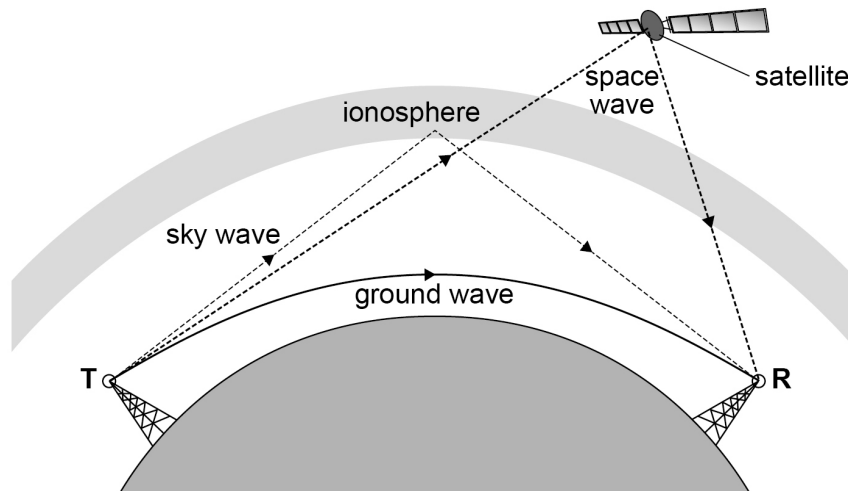
- bandwidth
- the ability of the receiver to reject signals from other radio stations.

[2 marks]

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.

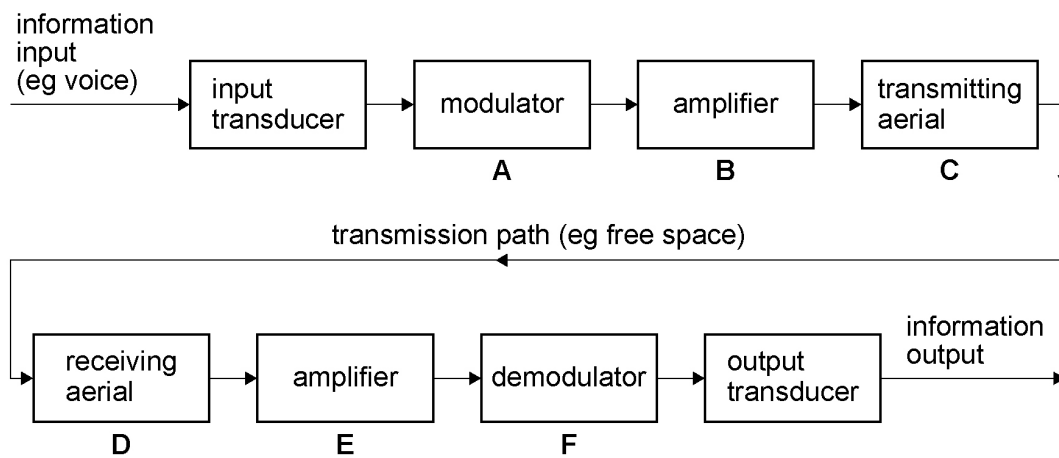
[6 marks]

END OF QUESTIONS

0 3

Figure 4 shows a block (subsystem) diagram for a radio communication system.

Figure 4



0 3 . 1

State the letter representing the subsystem in which you might find an induced emf being generated.

[1 mark]

0 3 . 2

State the letter representing the subsystem where the audio and radio waves are combined.

[1 mark]

0 3 . 3

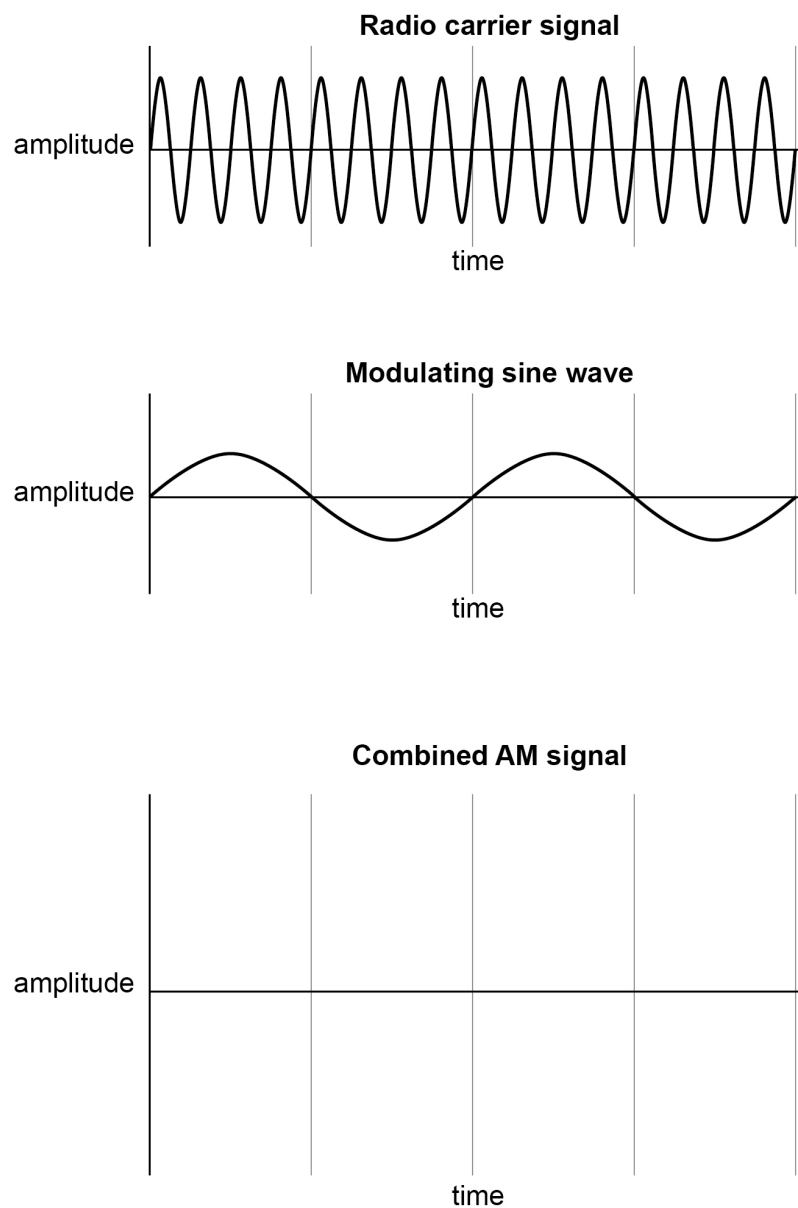
The signal strength at stage **D** must be amplified.

Explain why the signal strength at stage **D** is weak.

[1 mark]

0 3 . 4 Figure 5 shows graphs of a radio carrier signal and a modulating sine wave.

Figure 5



Complete the graph in **Figure 5** to represent the combined amplitude modulated (AM) signal.

[1 mark]

Question 3 continues on the next page

0 3 . 5

Approximately 20 radio stations use amplitude modulation (AM) to broadcast to people living in the London area. Another 35 AM stations broadcast to people outside the London area. However, these broadcasts can still be received in London.

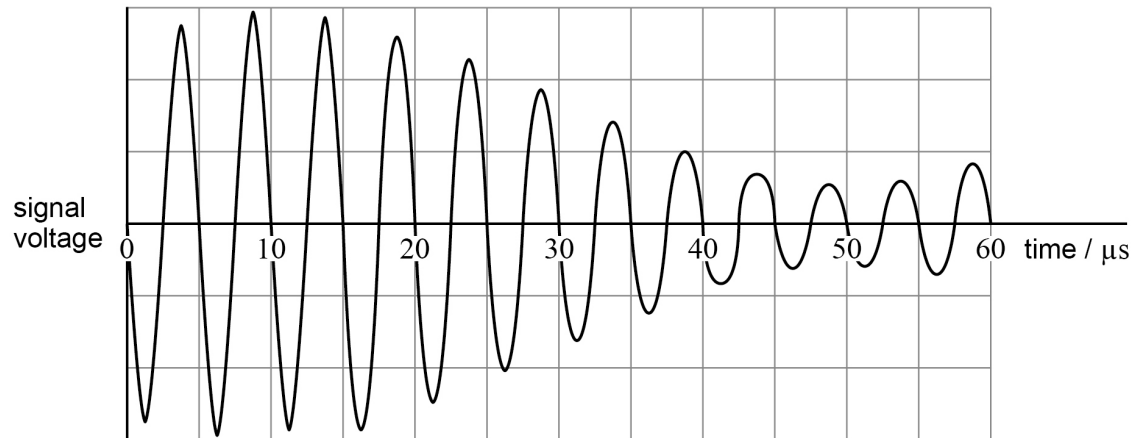
The allocated frequency spectrum for all these broadcasts is in the range 540 kHz to 1600 kHz

Suggest whether all these stations can broadcast hi-fi music using the full audio frequency of 20 kHz

[3 marks]

0 3**Figure 5** shows the output signal from the tuner circuit of a radio receiver.

The radio carrier wave is amplitude modulated by a single-frequency test tone.

Figure 5**0 3 . 1**

Determine the frequency, in kHz, of the carrier wave.

[1 mark]

frequency of carrier wave = _____ kHz

0 3 . 2

Determine the frequency, in kHz, of the test tone.

[2 marks]

frequency of test tone = _____ kHz

0 3 . 3

State **one** advantage of using frequency modulation (FM) rather than amplitude modulation (AM).

[1 mark]

0 3 . 4

The frequency range of the FM radio band in the UK is 88 to 108 MHz.

The FM stations are allocated centre frequencies that start at 88.100 MHz and are separated by 200 kHz.

Calculate the maximum number of stations allowed within the range.

[1 mark]

maximum number of stations = _____

0 3 . 5

A radio station broadcasting on FM transmits a maximum audio frequency of 15 kHz and has a frequency deviation of ± 75 kHz.

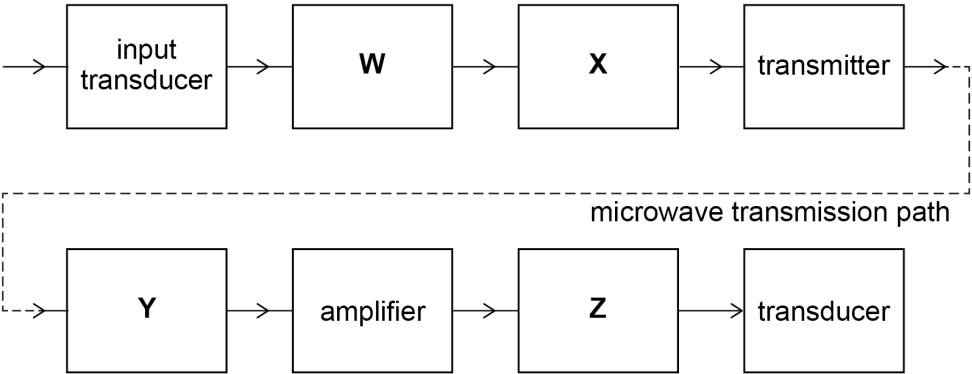
Deduce whether the radio station fits the FM bandwidth allocation in the UK.

[2 marks]

03.1

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	

03.2

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]

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



03.5

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]

MARK SCHEMES

official mark schemes



04.1	Photoconductive (accept reverse bias)		1	
04.2			1	
	Non-inverting amplifier			Tick (✓) if correct
	Comparator			✓
	Summing amplifier			
	Difference amplifier			
04.3	Light level ~ 1000 lux +/- 10%		1	
04.4	$V_x = IR$; $V_x = 100 \mu A \times 20 k\Omega = 2 V$		1	
04.5	Rule that if $V_- > V_+$ then V_{out} is 0 V (low) Voltage drop across LED so LED is ON		1	
		Do not allow LED is ON if supported by incorrect reason	1	
Total			6	

12

Question	Answers	Additional Comments/Guidelines	Mark
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03.1	OR With the south pole facing the sensor: Less sensitivity/smaller gradient ✓ but covers a larger range ✓ No ambiguity in liquid level – (each level produces a discrete output up to saturation) ✓	Mark awarded for each compared point	3	$3 \times \text{AO3 1a}$
03.2	2.4 divisions @ 5 ms / div = 12 ms Periodic time $T = 12 \text{ ms} \times 3 = 36 \text{ ms}$ ✓ Or 7.2 divisions @ 5 ms / div = 36 ms $f = 1 / T$; $f = 1 / 36 \text{ ms}$; 27.8 rev / sec ✓ 27 full revolutions in one second ✓	One mark for appropriate reading from graph to produce periodic time (T). One mark for frequency using their (T). One mark for rounding down	3	AO2 1d
Total			6	

Question	Answers	Additional Comments/Guidance	Mark	ID details
	+ve knee develops at 0.7 V and does not exceed 1.5 V at 30 mA ✓			

01.1	Silicon dioxide layer ✓	Accept Silicon dioxide	1	AO1 1a
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Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	drain ☐ gate ☐ source ☒		1	AO1 1a

Question	Answers	Additional comments/Guidelines	Mark	AO
01.3	For lamp $P = I^2 R$ $I = \sqrt{(P/R)} = \sqrt{(0.65 \text{ W} / 154 \Omega)} = 65 \text{ mA} \checkmark_1$ This leads to a voltage across the lamp of approx 10 V and a V_{DS} of approx 2 V Read from graph to give $V_{GS} = 3.4 \text{ V} \checkmark_2$	Must use $P = I^2 R$ Accept a V_{GS} range of 3.3 V to 3.5 V	2	AO2 1b AO3 1b

Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	Current consumption on stand-by: $8.5 \times 10^9 \times 10 \times 10^{-9} = 85 \text{ A}$ ✓₁ Battery life: $3600 \text{ C} \times 3.110 = 1.12 \times 10^4 \text{ C}$ ✓₂ Use $1.12 \times 10^4 = 85 \times t$ Gives $t = 131.8 \text{ seconds}$ (accept 132 seconds OR just over 2 mins) which is much less than 12 hours ✓₃	Makes a meaningful calculation (one which can lead to a conclusion) using data for the CPU. Makes a meaningful calculation (one which can lead to a conclusion) using data for battery. Uses the value of t to reach a valid conclusion OR Uses the values of the currents from the CPU and battery to reach a valid conclusion	3	AO2 1b AO2 1b AO3 1a
Total			7	

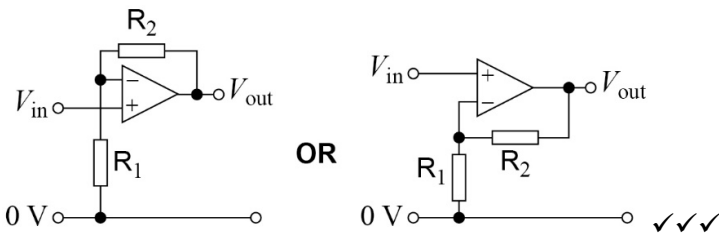
7

Question	Answers	Additional comments/Guidelines	Mark	AO
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04.1	$V_R = 5 \text{ V}$ chosen and idea that the photocurrent increases linearly/ most throughout the light intensity change ✓ $(2 \times 10^{-5} - 5 \times 10^{-6}) \text{ A}$ OR $(20 \times 10^{-6} - 5 \times 10^{-6}) \text{ A}$ Change in photocurrent = $15 \times 10^{-6} \text{ A}$ ✓	MP1 for reason of choice MP2 for answer If no other mark awarded, allow 1 MAX for identification of $V_R = 1 \text{ V}$ and answer in range 5 to $6 \times 10^{-6} \text{ A}$.	2	AO3 AO3
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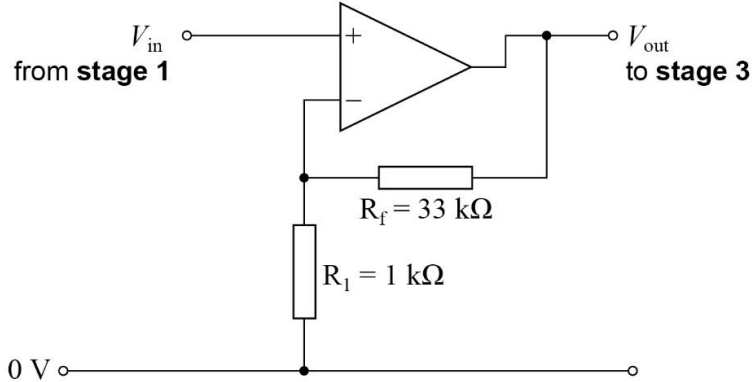
Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	Atomic particles need to interact with scintillation material to produce light ✓ Photodiode is used in photoconductive mode / with reverse bias ✓		2	AO1 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3		1st mark for correct configuration 2nd mark for only two resistors seen, in the ratio 9 : 1 for $R_2:R_1$ 3rd mark: • output labelled • resistor values within suggested range	3	AO1 AO3 AO3
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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03.1	One from: ✓ • shorter response time • current varies linearly with illumination	Accept other correct answers.	1	AO1
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Question	Answers	Additional comments/Guidance	Mark	AO
03.2	A virtual earth is a point that sits at 0 V (due to the configuration of the circuit) even though there is no direct physical connection to ground ✓ OWTTE	Accept the idea that it acts as if grounded.	1	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
03.3		Condone lack of connection blobs on this occasion. Condone the use of an input resistor on the non-inverting input but cannot be used as part of gain calculation. mp1 - general configuration for operational amplifier giving a non-inverting amplification including correctly labelled input terminals ✓ mp2 - use of resistors within the defined range giving $\frac{R_f}{R_1} = +33$ ✓	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
03.4	Identify that the switching voltage in stage 3 is 6.8 V. Output from stage 1 must be $\frac{6.8}{34} = 0.2 \text{ V}$ ✓₁ I_D in stage 1 is $\frac{\text{their MP1 value}}{10 \text{ k}\Omega}$ ✓₂ Uses their mp2 value to calculate an irradiance from the graph. ✓₃	Expect to see $I_D (= 20 \mu\text{A})$ ✓₂ Expect to see an irradiance of (4 W m^{-2}) ✓₃	3	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
03.5	The idea that real op amps may saturate at a value $> 0 \text{ V}$ (This may leave sufficient voltage to activate the LED) ✓		1	AO2
Total			8	



Question	Answers	Additional comments/Guidance	Mark	AO



04.1	33A ✓ –ve knee develops at 5.1 V; 5 mA with near vertical drop. Does not exceed – 5.5 V at –30 mA ✓		2	AO1 1a
04.2	Zener diode provides a reference voltage for non-inverting input ✓ Or Zener diode provides a stabilised voltage for non-inverting input ✓	Accept combination of the two statements	1	AO2 1c
04.3	$I = V/R = 3.9 \text{ V} / 100 \Omega = 39 \text{ mA}$ This is larger than the minimum current to make Zener diode work so the resistor value is fine. ✓ $P = I^2 R = (39 \times 10^{-3})^2 \times 100 = 0.152 \text{ watts}$ This is greater than the power rating for the resistor, so is not a suitable power rating for the resistor ✓	Ecf from value of I	2	AO2 1e
04.4	The reference voltage at the non-inverting input is now smaller ✓ This will cause the output W to switch at a lower light intensity than before ✓		2	AO1 1a

Question	Answers	Additional Comments/Guidance	Mark	ID details
04.5	$Q = (\overline{X} + \overline{Y}) \cdot W$ ✓	Accept transformations eg: $Q = \overline{X} \cdot (\overline{Y} + \overline{W})$ $Q = \overline{X} \cdot \overline{Y} \cdot W$	1	AO2 1b
04.6	MOSFET has large input impedance OR MOSFET causes no loading of the logic gate output. ✓		1	AO1 1a
Total			9	



Question	Answers	Additional Comments/Guidance	Mark	ID details				
	The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist in marking this question. <table><tr><th>Level</th><th>Criteria</th></tr><tr><td>L3</td><td>The candidate shows a good knowledge of PCM, TDM and the process of noise reduction using regenerators in this context.</td></tr></table> 6 marks	Level	Criteria	L3	The candidate shows a good knowledge of PCM , TDM and the process of noise reduction using regenerators in this context.	PCM PCM – the analog signal is sampled and then quantised, converting it into a serial n-bit binary code for transmission. The sampling, which should be done at twice the max frequency contained within the signal and quantisation are responsible for the bit rate which will determine the bandwidth needed for transmission. TDM Without TDM, the 15 channels of speech		3 × AO1 1a
Level	Criteria							
L3	The candidate shows a good knowledge of PCM , TDM and the process of noise reduction using regenerators in this context.							



05		terms correctly. The answer has structure and clearly conveys the information required by the question. The candidate may show a depth of understanding that goes beyond basic recall and will appreciate the impact of the technology on society.	structure, style and sp&g to render meaning clear. The text is legible.	analogue signal is assigned a digital code. • Audio requires a sample rate = $2 \times$ highest frequency component ----- (Nyquist rate) • Under sampling will cause a loss in quality. ----- (Aliasing) • Over sampling results in superfluous data.	6	
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L2 3–4 marks	All of the main processes are addressed and most of the detail is present. There may be an understanding of the impact of the technology on society. There will be some structure, but may be brief or unclear in parts.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
L1 1–2 marks	A limited answer with significant detail missing. The impact on society may be stated basically but not developed. Candidates may be able to recall some technical terms, but these may be used without expansion or understanding. The material may lack organisation.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
0	The work contains no significant analysis of the question asked.	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

ii) Size of digital code:

- Number of bits per sample determines smallest change in analogue signal that can cause a change in digital code – -----**resolution**.
- CD** – standard is 16 bits

The combination of these two factors will determine the amount of data generated in the conversion process. The quantity of data will be very large and will probably require compression techniques to be applied.

Advantages of a digital format :

- Good noise immunity
- Digital recordings don't degrade with frequent use in the same way as analogue recordings (Tape v CD)
- Digital files can be saved and manipulated by computer
- Can be coded for downloading across the Internet

		Disadvantages of a digital format • Can be conceived as being too clinical • Data can become corrupt • Format compatibility issues Further points: Why digital is dominant format in the recording industry • V. good digital system is cheaper than v. good analogue system • Scratch resistant format even on CDs • Development of small personal music devices • Development of downloads using personal computer Development of higher density storage devices (CD to SSD)	
Total			6

05		6 marks regenerators in this context. They use the technical terms correctly, the answer has structure and clearly conveys the information required by the question. The candidate may show a depth of understanding that goes beyond basic recall.	Without TDM, the 15 channels of speech would each need their own cable to create an independent link as the total bandwidth would exceed that of the link. With TDM, the system allocates time slots so that data blocks of code from each speech channel can be transmitted in sequence (multiplexed) across a single link. The full bandwidth of the link is available to each channel.	6	3 × AO3 1b
	L3 5 marks	The candidate shows a good knowledge of PCM, TDM and the process of noise reduction using regenerators in this context. However, there may be minor gaps in knowledge / detail OR the style and structure may lead to a lack of clarity in some of the information being presented.			

Question	Answers		Additional Comments/Guidance	Mark	ID details
	4 marks	The candidate will show a good understanding of two of the processes / subsystems in bold in this context. Technical terms will be used correctly and the information will generally be presented in a structured and coherent manner	Regenerators Regenerators work by using a switching circuit (Schmitt trigger) which has two different switching thresholds . This will usually take out most of the noise sitting on the signal.		
	3 marks	The candidate will show a good basic understanding of two of the processes / subsystems in bold. However, there may be minor gaps in knowledge / detail OR the style and structure may lead to a lack of clarity in some of the information being presented.			
	2 marks	The candidate will show a superficial understanding of two of the processes / subsystems in bold. Overall, this will be a limited answer with significant detail missing. The material may lack clarity / organisation.			
	1 mark	The candidate will show a superficial understanding of one of the processes / subsystems in bold. Overall this will be a limited answer. The material may lack clarity / organisation.			
	0 marks	The work contains no significant analysis of any of the techniques / subsystems in bold.			
Total				6	



03.1	Audio range (bandwidth) is 20 kHz ✓ The sampling frequency should be at least twice the maximum frequency / bandwidth ✓	Reference to Nyquist theorem without reference to numerical data – 1 mark only	2	AO1.1a AO1.1b
03.2	6.5536×10^4	Allow other correct numbers eg 65536	1	AO1.1b
03.3	For one channel: $44.1 \times 10^3 \times 16 \times 3.5 \times 60 = 148.175$ megabits. ✓ For Stereo: $(2 \times 148.175) \div 8 = 37.04$ megabytes ✓ (Accept 37 megabytes)	Two marks for 37 megabytes with no working shown.	2	AO2.1b AO2.1b
03.4	Lower quality music over telephone line due to: telephone call has lower bandwidth than original audio file ✓ loss of high and low frequencies from music ✓	One mark for general comment relating to ratio of bandwidths of the two systems where CD bandwidth has been taken to be in region of 15 kHz – 20 kHz	2	AO3.1b AO3.1b
Total			7	

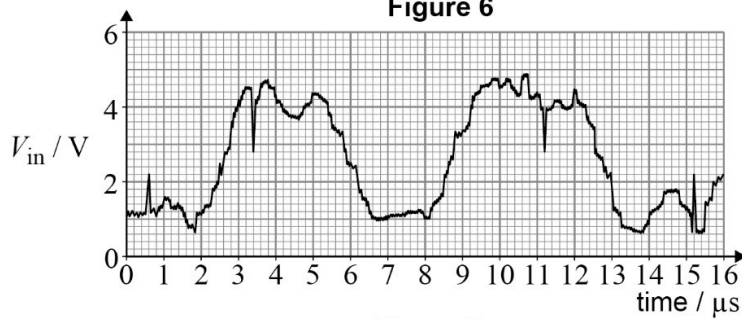
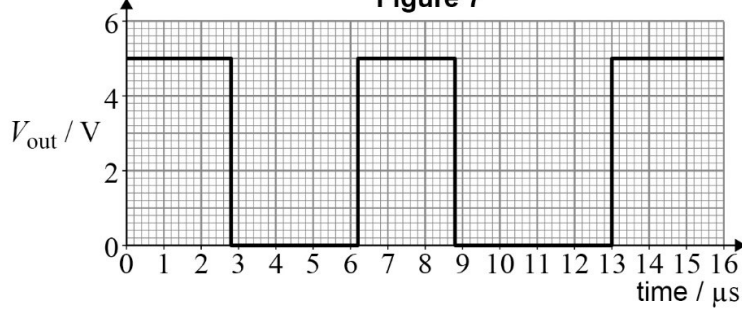
Question	Answers	Additional comments/Guidelines	Mark	AO
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02.1	1 from ✓ • $160 \times 7 = 1120$ bits • 140 bytes seen • their number of bits $\div (64 \times 10^3)$ • their number of bytes $\div (8 \times 10^3)$ $= 17.5 \times 10^{-3} \text{ s}$ ✓	1st mark for correct bits or bytes conversion in message or time calculation 2nd mark for answer Allow 2 sf answer.	2	AO2
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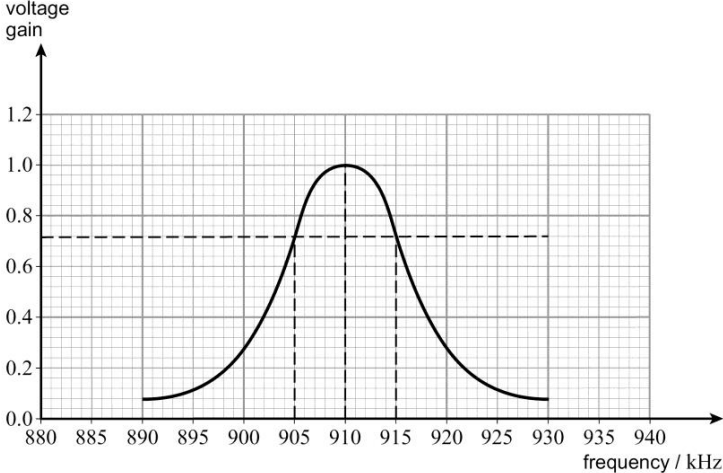
Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	Internal noise: thermal agitation of electrons / charge carriers in a conductor OR External noise: idea of electromagnetic interference (EMI) eg cross-talk / power switching etc. ✓	Accept one example for the mark	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	Effect of electrical noise on the signal: • degrades the quality of the signal ✓ Effect of electrical noise on the communication system: • reduces the efficiency of the transmission e.g. increased latency of the system ✓		2	AO1



Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	Figure 6  Figure 7  ✓✓	1st mark – 0 to 5 V sq wave with 3 marks and two spaces 2nd mark – any three correct transitions.	2	AO2 AO3
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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03.1	$C = 1 / (910 \times 10^3)^2 \times 4 \times \pi^2 \times 1.1 \times 10^{-3}$ $C = 27.8 \text{ pF} \quad (\text{accept } 28\text{pF})$	Answer:	1
03.2		General shape around f_0 and to max of 1.0 on relative voltage gain axis 10 kHz bandwidth at 0.71 gain Frequencies (905 – 910 – 915) kHz (identified / used)	1 1 1
03.3	Smaller Q factor leads to: (Any two from) (i) Broader bandwidth (ii) More noise / (hiss) detected (iii) Less selectivity (iv) More susceptible to crosstalk from neighbouring stations on the frequency spectrum. (v) Less gain due to energy loss / loss of signal detail		2

Total			7
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Question	Answers	Additional Comments/Guidelines	Mark
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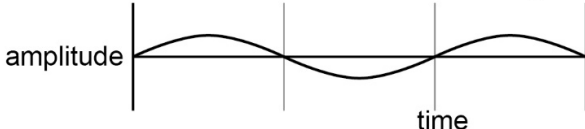
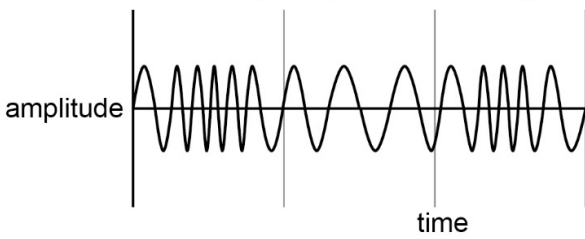


02.1	Numerical value for capacitor = 6.9 pF ✓	Substitution of values into formula alone – not sufficient for mark.	1	AO1.1b
02.2	Y and X most suitable / (W and Z out of range) ✓ Y better than X as value falls within centre of range. ✓	implied choice – 1 mark reason – 1 mark	2	AO3.1a AO3.1a
02.3	Evidence of reading at 0.7 V _{max} (350 mV) ✓ Bandwidth 20 kHz ✓ Allow range (19–21 kHz)	1 mark only for: Evidence of reading at 0.5 V _{max} (250 mV) Bandwidth 25 kHz ✓ Allow range (24–26 kHz)	2	AO2.1b AO2.1b
02.4	$Q = f_0 / f_B = 198 \text{ kHz} / 20 \text{ kHz} = 9.9$ ✓ 1 mark	Allow ecf from 02.3	1	AO1.1b
02.5	Either: Listener hears overlapping stations - due to increase in bandwidth. ✓ Or Listener hears station more faintly - due to energy loss / wider energy distribution ✓	Accept S/N argument as weaker stations become more prominent and can be considered as noise.	1	AO1.1a
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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03.1	L ✓		1	AO1
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Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Evidence of 0.707 OR 0.71 OR 0.7 used ✓ ($V_{\text{out}} = 3.6 \text{ mV}$) use of $Q = \text{their } f_0 \div \text{their } f_B$ ✓ $Q = 774 \div 10 = 77.4$ ✓ Accept range ($Q = 70 - 86$)	Expect to see $f_0 = (779 - 769) \text{ kHz};$ $f_B = 10 \text{ kHz } (\pm 1 \text{ kHz})$ Alternative for 2 marks max if ~50% point is used ($V_{\text{out}} \approx 2.6 \text{ mV}$) leading to $f_B = 12 \text{ kHz } (\pm 1 \text{ kHz})$ ✓ $Q = 65$ ✓ Accept that rounds in range ($Q = 60 - 70$)	3	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	carrier wave  information signal  frequency-modulated signal  ✓✓	1st mark – constant amplitude 2nd mark – correct frequency variation	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	$f_m = 18 \checkmark$ (kHz)	Expect to see bandwidth = $2(\Delta f + f_m)$	1	AO1
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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02.1	difference amplifier ✓		1	AO1 1a
02.2	$V_{\text{out}} = (V_+ - V_-) \times (R_f / R_{\text{in}})$ $V_{\text{out}} = (0 \text{ V} - 150 \text{ mV}) \times (1 \text{ M}\Omega / 100 \text{ k}\Omega)$ ✓ $V_{\text{out}} = -1.5 \text{ V}$ ✓	1 mark for the correct resistor substitution / resistor ratio (10) 1 mark for -1.5 V (must have correct sign)	2	AO1 1b
02.3	Signal 2 is subtracted from signal 1 by the difference amplifier ✓ Noise is common to both so will be reduced / eliminated when subtracted ✓ Signals will also be subtracted resulting in an addition (re-enforcement) of the signal. ✓	Accept arguments based on the 'phase' relationship	3	AO2 1c
Total			6	

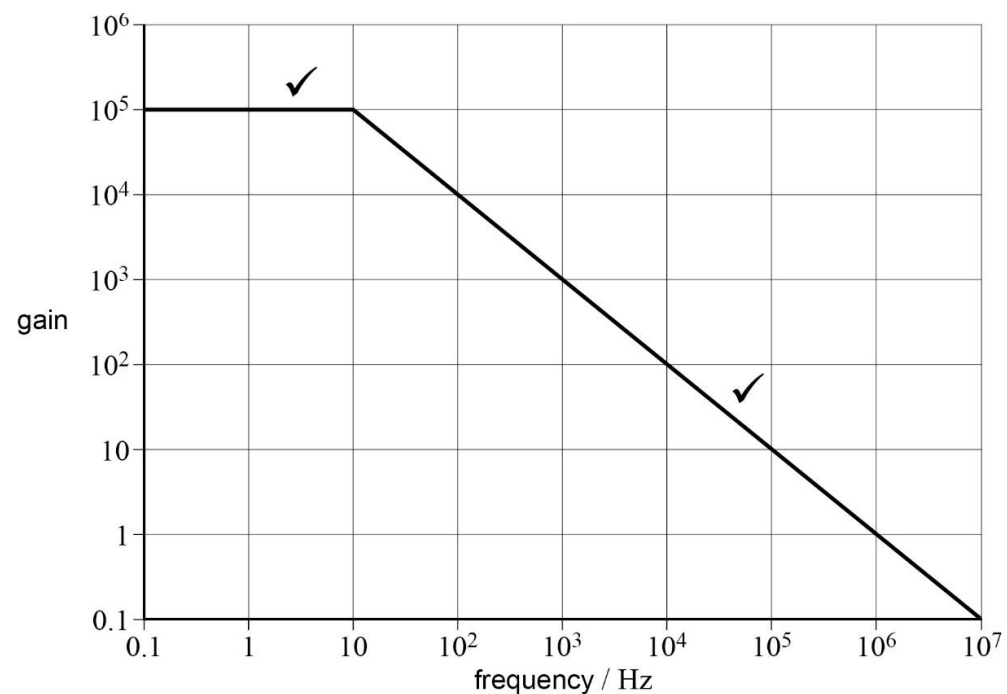
Question	Answers	Additional Comments/Guidance	Mark	ID details
	With the north pole facing the sensor: Higher sensitivity/larger gradient ✓ over very short range ✓ Some ambiguity in liquid level due to peak in graph – (more than one level referenced to a single output reading) ✓ OR			3 x 403



04.1	comparator differential amplifier inverting amplifier non-inverting amplifier	☒ ☐ ☐ ☐		1	AO1.1a
04.2	Photodiode current from graph = 80 μA ✓ Voltage across resistor V_R $V_R = I \times R = 80 \times 10^{-6} \times 39 \times 10^3$ $V_R = 3.12 \text{ V}$ ✓ Voltage at non-inverting pin (V_+) = $(5 - 3.12) = 1.88 \text{ V}$ ✓	Allow $\pm 5 \mu\text{A}$ in reading from the graph Allow a $V_R = 2.93 \text{ V}$ to 3.32 V Allow a V_+ value of 2.07 V to 1.68 V		3	AO3.1a AO2.1d AO2.1d
04.3	Voltage at inverting pin (V_-) is 2.2 V ✓ $V_- > V_+$ so output is low / 0 V so LED will light / on ✓	First mark is for correct value of (V_-) Second mark is for correct application / conclusion using $V_+ = 1.9 \text{ V}$ together with their value for (V_-)		2	AO3.1a AO3.1a
Total				6	

Question	Answers	Additional comments/Guidelines	Mark	AO
		Conner Optic fibre		

04.1

**MP1:**

Flat top at gain = 10^5 from 0.1–10 Hz

Accept either sharp or rounded break frequency roll-off

MP2:

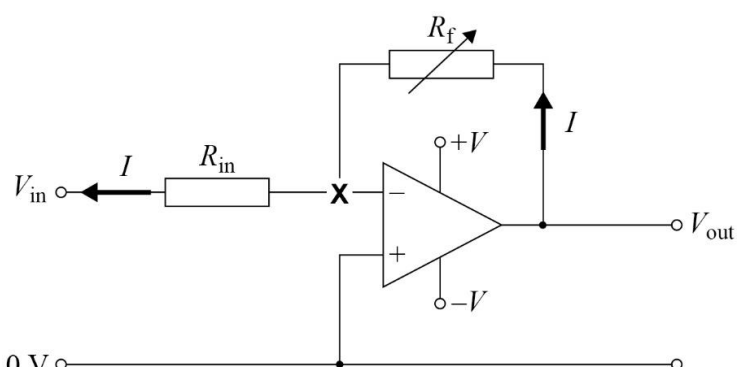
Slope from end of flat down through unity gain and 10^6 Hz

Do not penalise if line not taken beyond unity gain and 10^6 Hz

2

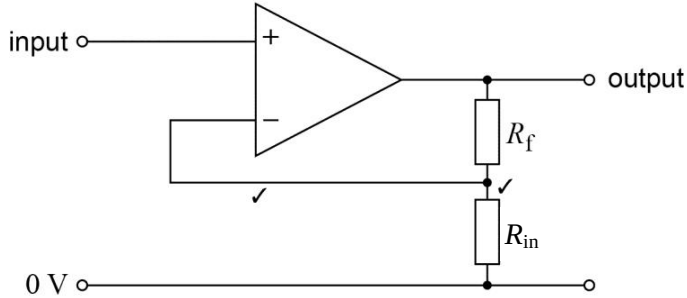
1×
AO1.1b

1×
AO2.1d

Question	Answers	Additional comments/Guidelines	Mark	AO
04.2		MP1: for placing X on a wire somewhere between R_{in} and R_f and the inverting input. MP2: for showing I in the correct direction through both R_f and R_{in}	2	1× AO1 1× AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3	(Since the gain of the amplifier in this mode is $\frac{-R_f}{R_{in}}$) (As R_f increases) the (closed loop voltage) gain increases ✓ (As gain increases then) bandwidth decreases ✓	If no other mark given, allow 1 mark for decrease in gain giving increase in bandwidth	2	1× AO2 1× AO3
Total			6	

Question	Answers	Additional comments/Guidelines	Mark	AO
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02.1	$= 3 \text{ V} / 40$ $= 75 \times 10^{-3} \text{ V} \checkmark$		1	
02.2	 Two resistor chain, correctly labelled connected between output and ground. Inverting input connected to mid-point of resistor chain		2	
02.3	$\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_{in}}$ $40 = 1 + \frac{R_f}{R_{in}} \text{ calculation to give resistor ratio of } 39 \checkmark$ $R_{in} = 1 \text{ k}\Omega ; R_f = 39 \text{ k}\Omega \checkmark$		2	

Question	Answers	Additional Comments/Guidance	Mark	ID details
02.4	Desired gain $\times$ bandwidth is $40 \times 50 \text{ kHz} = 2 \text{ MHz}$ ✓ The Op Amp can only provide $\frac{1}{2}$ the amplification needed. Not suitable. ✓	1 mark - relevant calculation 1 mark - reference to only providing $\frac{1}{2}$ require amplification / gain so not suitable	2	
Total			7	

Question	Answers	Additional Comments/Guidance	Mark	ID details
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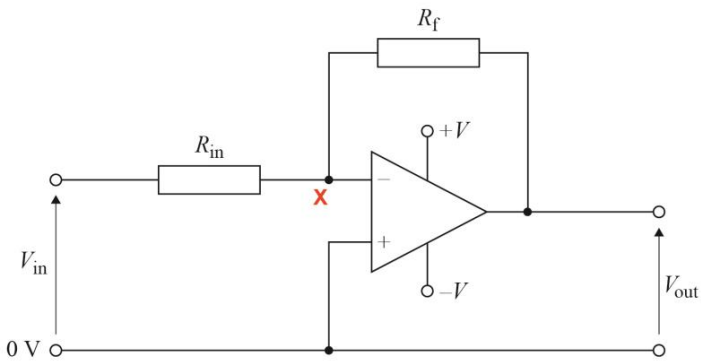
02.1	Accept either: ✓ - determines the charging / discharging rate of the capacitor - determines the oscillation frequency	Condone reference to charging/discharging of the capacitor.	1	AO1
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Question	Answers	Additional comments/Guidance	Mark	AO
02.2	(The three 100 kΩ resistors together) set the reference voltage(s) (at the non-inverting terminal) ✓		1	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.3	Evidence of a parallel resistor calculation or a potential divider calculation ✓ when V_{out} is 0.0 V, $V_+ = 3.0 \text{ V}$ ✓ when V_{out} is 9.0 V, $V_+ = 6.0 \text{ V}$ ✓		3	2 × AO2 1 × AO3

Question	Answers	Additional comments/Guidance	Mark	AO
02.4	PRF = 62.5 kHz ✓ (accept 63 kHz) Duty cycle = 37.5% ✓ (accept 38%)	$\left(PRF = \frac{1}{t_H + t_L} = \frac{1.0 \times 10^6}{(6 + 10)} \right)$ $duty\ cycle = \frac{t_H}{t_H + t_L} \times 100\%$ $= \frac{6}{6 + 10} \times 100\%$	2	AO3
Total			7	

Question	Answers	Additional comments/Guidance	Mark	AO
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01.1		Correct position of X:	1
01.2	The non-inverting input	(non-inverting):	1
01.3	$I = (V_{in} - V_x) / R_{in} = (V_x - V_{out}) / R_f$ But $V_x = 0$ V (a virtual earth) $I = V_{in} / R_{in} = -V_{out} / R_f$ $\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$	Making use of: $I_{in} = -I_f$ Making use of virtual earth concept:	1 1
01.4	Voltage gain (Channel 1) = $-\frac{R_f}{R_{in1}}$ $-(150 \text{ k}\Omega / 7.5 \text{ k}\Omega)$ -20	Both number and sign must be correct:	1
01.5	$V_{out} = -R_f (V_{in \text{ Ch1}} / R_1 + V_{in \text{ Ch2}} / R_2)$ $= -150 \text{ k}\Omega ((15 \text{ mV} / 7.5 \text{ k}\Omega) + (-100 \text{ mV} / 30 \text{ k}\Omega))$ $= -((0.3) + (-0.5)) = 0.2 \text{ Volts}$	Evidence of correct method: Answer and correct sign:	1 1

Question	Answers	Additional Comments/Guidelines	Mark
01.6	By using variable resistors: The gain can easily be changed or the relative levels of the two channels can be set or the required balance between the two signals can be made	One relevant point made:	1
Total			8

7

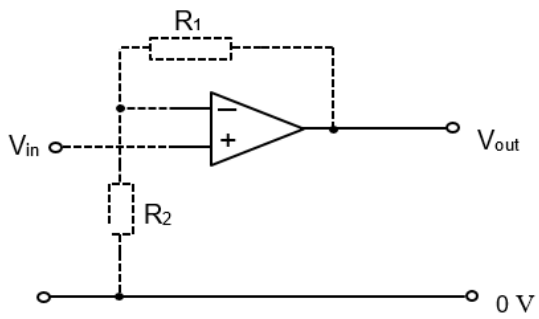
Question	Answers	Additional Comments/Guidelines	Mark
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03.1	Photoconductive mode	Accept 'reverse bias'	1	AO1 1a
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Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Dark currents will become a source of noise – need to keep S:N as high as possible OWTTE OR Need to have a large difference in signal when detector is in light and dark ✓	Must include idea of 'noise' OR Must include concept of large signal change to represent digital signal	1	AO2 1c

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	At 850 nm, $R_\lambda = 0.50 \text{ A/W}$ ✓ Using $R_\lambda = \frac{I_p}{P}$ $I_p = R_\lambda \times P$ $0.50 \times 4 \times 10^{-6} = 2 \text{ } \mu\text{A}$ ✓ ecf $V_{\text{out}} = I_p \times R$ $2 \text{ } \mu\text{A} \times 560 \text{ k}\Omega = +1.12 \text{ V}$ ✓	Reading from graph Allow 0.49 A/W to 0.51 A/W Accept voltage in range of 1.10 V to 1.14 V Accept value without + sign	3	AO3 1b AO3 1b AO3 1b

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4		Correct configuration of R_1 and R_2 ✓ $R_1 : R_2$ ratio 3 : 1 in suggested range ✓ Label the input point which must have a direct connection to the non-inverting input ✓ One mark only An inverting op amp configuration with a voltage gain -4.	3	AO1 1a AO2 1d AO1 1a
Total			8	

Question	Answers	Additional comments/Guidelines	Mark	AO
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01.1	Label the virtual earth point eg X, on the junction between the two resistors ✓	Allow the centre of the 'X' to be placed on any of the three lines leading to the op amp inverting input junction. Do not allow an 'X' in space unless accompanied by unambiguous arrow.	1	AO1
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Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	Set up equation for $I = V_{in} / R_{in} = -V_{out} / R_f$ then rearrange ✓ Reason to support setting up of equation ✓	Second mark given only if reason provided for one of: I through $R_{in} = I$ through R_f (Infinite input impedance) –ve sign (Virtual earth point used)	2	2 x AO1

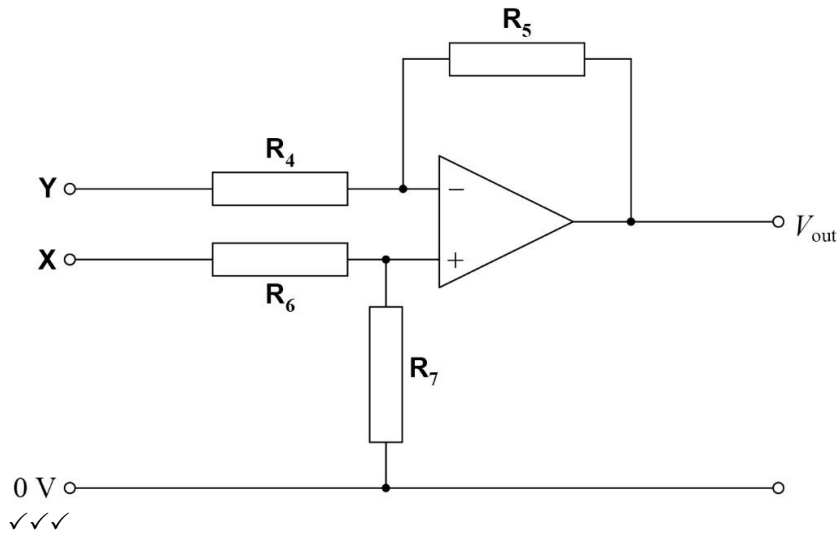
Question	Answers	Additional comments/Guidelines	Mark	AO
01.3	Inverted sine wave of same period as signal shown in Fig 2A ✓ Attempt to use a gain of 20 and show a Cut-off/plateau at $\pm 6\text{ V}$ ✓		2	2 x AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	1 mark for correct connection of resistor R_1 and R_2 ✓ 1 mark for correct values of R_1 and R_2 ✓ 1 mark for values correct way round – referenced to V_1 and V_2 ✓		3	1 x AO1 1 x AO2 1 x AO3
Total			8	

Question	Answers	Additional comments/Guidelines	Mark	AO
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02.1	Method indicated for calculation of potential at X ✓ Correct calculation to give voltage at X = 5.00(125) V ✓ Reading = their value for potential at X – 5 V ✓	MP1: expect to see use of potential divider formula / other method (e.g $V=IR$) explained MP2: Correct calculation for potential at X MP3: Expect to see 1.25 mV Allow 1.2 mV or 1.3 mV to 2 sf.	3	1 × AO2 2 × AO3
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Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	A resistor (used instead of strain gauge B) would not have same response to temperature changes as strain gauge A OR Using strain gauge B will have same response to temperature as strain gauge A ✓ By using two strain gauges the (voltmeter) reading will only be affected by changes in strain (as temperature effects will cancel) OR use of a resistor will cause the (voltmeter) reading to change due to strain and temperature changes ✓	Do not allow just the phrase: 'for temperature compensation'	2	2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	 0 V ✓✓✓	MP1: for correct configuration Condone incorrect op amp terminal signs in MP1. MP2: for X and Y leading to correct op amp terminals. MP3: for $R_5/R_4 = R_7/R_6 = 5$ Do not award MP3 if any resistance value is outside the range (10 kΩ–10 MΩ)	3	1× AO1 1× AO2 1× AO3
Total			8	

Question	Answers	Additional comments/Guidelines	Mark	AO
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05

The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in section 3.10 of the *Mark Scheme Instructions* document should be used to assist in marking this question.

Level	Criteria
L3 6 marks	All three areas covered with at least two aspects covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
L3 5 marks	A fair attempt to analyse all three areas. If there are several errors or missing parts, then 5 marks should be awarded.
L2 4 marks	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
L2 3 marks	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.

The following information is likely to appear in the answer statements.

Component A - Zener diode

Role in circuit

- Used to provide a reference voltage for component B.
- Reference voltage set at a value below the noise level / to exclude the noise on the signal.

Useful characteristic properties

- Used in reverse bias mode.
- Produces a fixed reverse breakdown voltage.

Component B - operational amplifier

Role in circuit

- Used as a comparator.
- Output will saturate high when the input signal is larger than the reference voltage ($V_+ > V_-$).
- Output will drop to zero volts when the signal voltage is below the level of the reference voltage ($V_+ < V_-$).

Useful characteristic properties

- Very high open loop gain which provides saturation for very small voltage difference at the inputs.
- Very high input resistance - negligible load on input signals.
- Produces a clean switching pulse at the output when signal voltage transits the reference voltage.

6

2×
AO1.1a

2×
AO1.1b

1×
AO2.1a

1×
AO3.1b

Question	Answers		Additional comments/Guidelines	Mark	AO
05	Level	Criteria	Component C - MOSFET Role in circuit - Acts as a voltage-controlled switch. Useful characteristic properties - The MOSFET is a voltage-controlled device. - Has a very high input resistance to interface with comparator (draws negligible current from the comparator). - Low drain-source resistance when ON leads to very little power dissipated in the MOSFET. - Can be considered as a current amplifier		
	L1 2 marks	Only one area discussed or makes a partial attempt at two areas.			
	L1 1 mark	None of the three areas covered without significant error. Response is likely to show weakness in technical detail.			
	L1 0 marks	No relevant analysis.			
Total				6	



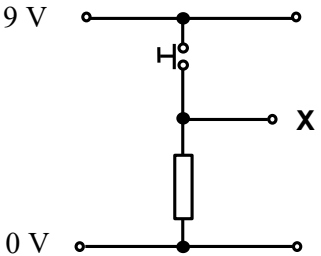
01.1	$Q = (A.B) + (A.B)$ ✓ ✓ (allow written format) do not allow $(A \oplus B)$	- Correct two terms ✓ - Correct operator for OR gate ✓	2																																				
01.2	<table><tr><th>B</th><th>A</th><th>C</th><th>D</th><th>E</th><th>F</th><th>Q</th></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> ✓ ✓	B	A	C	D	E	F	Q	0	0	1	1	0	0	0	0	1	0	1	0	1	1	1	0	1	0	1	0	1	1	1	0	0	0	0	0	Correct column C Correct column E	2	
B	A	C	D	E	F	Q																																	
0	0	1	1	0	0	0																																	
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1	0	1	0	1	0	1																																	
1	1	0	0	0	0	0																																	
01.3	Any two criteria ✓✓ Less complex circuit – easier to manufacture Only uses one type of chip – more economical to buy Uses fewer ICs so saves space Uses fewer ICs so saves on power consumption	Accept any other valid reason	2																																				
01.4	EOR ✓	Also allow EXOR, XOR	1																																				
Total			7																																				

6

Question	Answers	Additional Comments/Guidance	Mark	ID details
	Voltage in = Voltage out / Voltage gain			



02.1	<table><tr><th colspan="3">Inputs</th><th>Output</th></tr><tr><th>C</th><th>B</th><th>A</th><th>Q</th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td><td>1</td></tr></table>			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	0	1	1	0	1	1	1	1	1	All Q states correct for 1 mark	1	AO3 1a
	Inputs			Output																																										
	C	B	A	Q																																										
	0	0	0	0																																										
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Question	Answers	Additional comments/Guidelines	Mark	AO
02.2		Correct orientation for resistor & switch ✓ Correct tap-off point for X ✓	2	AO3 2a AO3 2a

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	$Q = \overline{(C \cdot A)} + (C \cdot B)$ Two correct brackets ✓ + with full bar ✓	Allow for 1 mark: $Q = \overline{C} \cdot (A + B)$	2	AO2 1b AO2 1b

Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	The gate acts as an inverter ✓	Accept 'NOT' as the function	1	AO1 1a

Question	Answers	Additional comments/Guidelines	Mark	AO
02.5	Must be a reason and a consequence for the mark. ✓	eg Uses only one type of logic gate so need to hold less stock OR Uses only one chip rather than two so circuit board can be smaller / less power needed / cheaper Do not allow: Less complex circuit	1	AO2 1c
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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04.1	Difference: BCD counter outputs binary codes. A Johnson decade counter outputs a single output sequentially ✓ Similarity: Both counters recycle at the 10th pulse ✓	Both outputs described. Condone – max counter value for 10th pulse. Accept: both counters count from 0–9 OR both counters count to 10	2	AO1 1a AO1 1a
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Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	Duty cycle: From oscilloscope $t_{on} = 3 \text{ div @ } 50 \mu\text{s / div} = 150 \mu\text{s}$ OR $t_{off} = 2 \text{ div @ } 50 \mu\text{s / div} = 100 \mu\text{s}$ ✓ $\frac{t_{on}}{(t_{on} + t_{off})} \times 100 = 60\%$ OR 0.6 ✓ (accept 'divisions' to signify the values of t_{on} and t_{off}) Frequency: From CRO $t_p = 5 \text{ div @ } 50 \mu\text{s / div}$ $t_p = 250 \mu\text{s}$ $f = 1/t_p = 4 \text{ kHz}$ ✓	Only 1 mark for: either of t_{on} or t_{off} correct but duty cycle wrong OR correct use of both wrong t_{on} and t_{off} One mark for: correct use of their $t_{on} + t_{off}$	3	AO2 1h AO2 1h AO3 1b

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3	BCD: $Q_2 = 600 / 10 = 60 \text{ Hz}$ ✓ (only one pulse is produced in 10 clock pulses at Q_2) Johnson: $Q_2 = 600 / 10 = 60 \text{ Hz}$ ✓		2	AO2 1d AO2 1d
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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02.1	$\bar{A}$ ✓ $.B$ ✓ $\bar{A}.B$	Do not allow $\overline{A+B}$	2	1 x AO1 1 x AO2
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Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	EOR ✓	Accept: XOR ; EXOR; Exclusive OR gate	1	AO1

Question	Answers								Additional comments/Guidelines	Mark	AO																																								
02.3	<table><tr><td>B</td><td>A</td><td>C</td><td>D</td><td>E</td><td>X</td><td>Y</td><td>Z</td></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td></tr></table>								B	A	C	D	E	X	Y	Z	0	0	1	1	0	0	1	0	0	1	0	1	1	0	0	1	1	0	1	0	1	1	0	0	1	1	0	0	0	0	1	0		2	2 x AO2
	B	A	C	D	E	X	Y	Z																																											
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	1	1	0	0	0	0	1	0																																											
X and Z correct ✓																																																			
Y correct ✓																																																			

Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	NOR gate ✓	Also accept any of: EXNOR; ENOR; XNOR; Exclusive NOR gate	1	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO																				
02.5	<table><tr><td>X</td><td>Y</td><td>Z</td><td></td></tr><tr><td>A = B</td><td>A < B</td><td>A > B</td><td>☐</td></tr><tr><td>A < B</td><td>A = B</td><td>A > B</td><td>☒</td></tr><tr><td>A < B</td><td>A > B</td><td>A = B</td><td>☐</td></tr><tr><td>A > B</td><td>A = B</td><td>A < B</td><td>☐</td></tr></table>	X	Y	Z		A = B	A < B	A > B	☐	A < B	A = B	A > B	☒	A < B	A > B	A = B	☐	A > B	A = B	A < B	☐		1	AO2
X	Y	Z																						
A = B	A < B	A > B	☐																					
A < B	A = B	A > B	☒																					
A < B	A > B	A = B	☐																					
A > B	A = B	A < B	☐																					
Total			7																					

Question	Answers	Additional comments/Guidelines	Mark	AO
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04.1	- When V_c reaches a value of V_U, the output voltage V_{out} drops LOW. ✓ - The capacitor now discharges through the resistor causing the value of V_c to fall. ✓ - When V_c reaches a value of V_L, the output voltage V_{out} jumps HIGH. ✓		3	3 x AO2
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Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	Mark-to-space ratio R_B gets smaller and hence (t_H) is reduced OR R_A gets bigger and hence (t_L) is increased ✓ Hence mark:space ratio is reduced / smaller ✓ $PRF = \frac{1}{T} = \frac{1}{(t_H + t_L)} = \frac{1}{0.7C(2R + R_A + R_B)}$ The total resistance ($2R + R_A + R_B$) is constant ✓ As a result of a constant resistance in the circuit, PRF does not change ✓	First mark: Either statement or equivalent labelled diagram(s). Second mark: Conclusion First mark: explanation of how total resistance in the circuit affects the periodic time. Second mark: Conclusion	4	4 x AO3
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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01.1		1 mark for use of the correct counter outputs 1 mark for the correct logic gate connected to reset R	2	1 × AO2 1 × AO3
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Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	input C segment b ✓	Both input and segment needed for the mark Do not allow B for b	1	1 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.3	f ✓	Allow F for f	1	1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
01.4		MP1: all inputs inverted (accept a shorted-out NAND or NOR gates for the inverters) MP2: for correct use of AND and NAND Condone a NOT following an AND for the NAND gate. MP3: for final gate being OR	3	3 × AO3
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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02.1

Number shown on die	Logic inputs			Logic outputs						
	C	B	A	L1	L2	L3	L4	L5	L6	L7
1	0	0	0	0	0	0	0	0	0	1
2	0	0	1	1	0	0	0	0	1	0
3	0	1	0	1	0	0	0	0	1	1
4	0	1	1	1	0	1	1	0	1	0
5	1	0	0	1	0	1	1	0	1	1
6	1	0	1	1	1	1	1	1	1	0
Reset 6 1										

One mark for each full pattern of **L1** and **L6**:

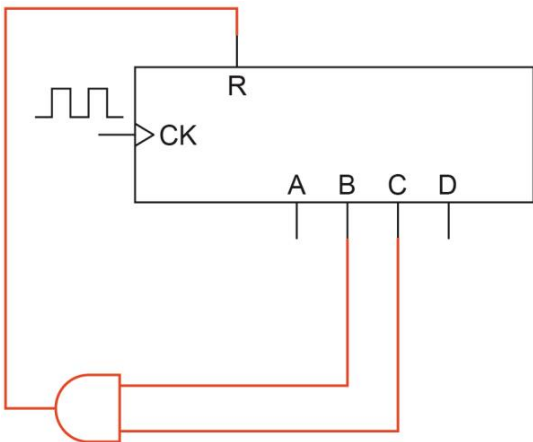
2

02.2

L7 = NOT A; Accept: $L7 = \bar{A}$

Delete previous comment

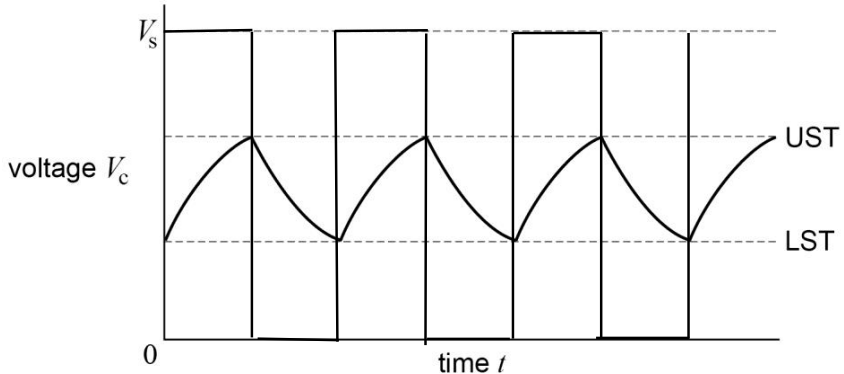
1

Question	Answers	Additional Comments/Guidelines	Mark
02.3	 The diagram shows a 4-bit shift register with inputs A, B, C, and D. A clock input CK is connected to a square wave. A reset input R is connected to the output of a 2-input AND gate. The inputs of the AND gate are B and C. The output of the AND gate is connected to R, which is also connected to the top of the shift register block.	1 mark for reset condition from B and C: 1 mark for use of a single 2-input AND gate: (accept correct implementation of the full reset code $\bar{A}.B.C$ for 1 mark)	2

Question	Answers	Additional Comments/Guidelines	Mark
02.4		1 mark - NOT gate from B: 1 mark - AND gate from $\bar{B}$ and C: 1 mark - OR gate connecting the two conditions:	3
Total			8

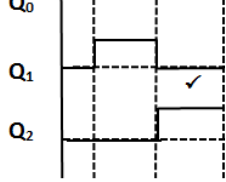
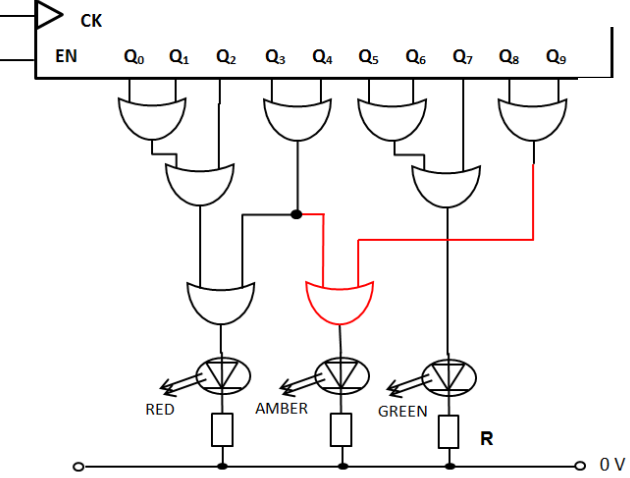
Question	Answers	Additional Comments/Guidelines	Mark
	$f = 1 / (2\pi \sqrt{LC})$ $C = 1 / f^2 4\pi^2 L$	Formula with correct substitution / evidence of correct working:	1



04.1	$= 1 / (1.4 \times 5.1 \times 10^3 \times 10 \times 10^{-9})$ 14 kHz ✓		1	
04.2	Square wave with correct phase and amplitude ✓ 		1	
04.3	New resistor calculated and stated to be 1.7 kΩ ✓ New resistor placed in parallel with original resistor ✓	ecf from 04.1	2	

Question	Answers	Additional Comments/Guidance	Mark	ID details
04.4	$T = \frac{1}{f} = \frac{1}{5 \times 10^3} = 0.2 \text{ ms (200 } \mu\text{s)}$ $t_C = 0.2 \times 10^{-3} \times \frac{3}{4} = 150 \mu\text{s}$ $t_D = 0.2 \times 10^{-3} \times \frac{1}{4} = 50 \mu\text{s}$ $R_2 = \frac{t_D}{0.7 \times C} = \frac{50 \times 10^{-6}}{0.7 \times 10 \times 10^{-9}} = 7.1 \text{ k}\Omega \text{ (Accept 7k}\Omega\text{)}$ $R_1 = \frac{t_C}{0.7 \times C} - R_2 = 14.3 \text{ k}\Omega \text{ (Accept 14k}\Omega\text{)}$	1 mark for significant calculation. eg showing $R_1 = 2R_2$ OR calculation for t_C OR t_D 1 mark for values of R_1 and R_2	2	
04.5	Two properties per mark – (max mark 2)✓✓ • A square wave • Amplitude of 0 V to 5 V • Periodic time of 0.2 ms • High for 0.15 ms – Low for 0.05 ms		2	
Total			8	

Question	Answers	Additional Comments/Guidance	Mark	ID details						
	The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the ‘<i>Mark Scheme Instructions</i>’ document should be used to assist in marking this question. <table><tr><th>Level</th><th>Criteria</th><th>QoWC</th></tr><tr><td>L3 5–6 marks</td><td>All bullet points in the question are covered in detail. The candidate shows good knowledge and uses the technical</td><td>The student presents relevant information coherently, employing</td></tr></table>	Level	Criteria	QoWC	L3 5–6 marks	All bullet points in the question are covered in detail. The candidate shows good knowledge and uses the technical	The student presents relevant information coherently, employing	Expected information: Quantisation – the conversion of a continuously varying voltage level by sampling into one that contains discrete (stepped) voltage levels. Factors affecting quality of conversion i) Sampling rate: • The number of times/second that the analogue signal is		
Level	Criteria	QoWC								
L3 5–6 marks	All bullet points in the question are covered in detail. The candidate shows good knowledge and uses the technical	The student presents relevant information coherently, employing								

01.1		Correct fall of Q_1 and rise of Q_2 - 1 mark	2	AO2 1c
01.2		Logic OR gate correctly connected in position for 1 mark	1	AO3 2a

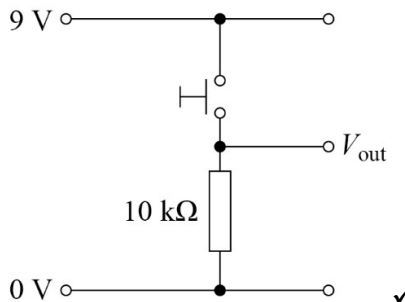
Question	Answers	Additional Comments/Guidance	Mark	ID details
01.3	The ON time for the green LED is determined by: the frequency of the clock ✓ the number of adjacent outputs that are OR'ed ✓	Accept reference to the period of the clock pulse.	2	AO2 1c
01.4	$R = V_R / I$; $R = (9 - 2.1) \text{ V} \checkmark / 9 \text{ mA}$ $R = 6.9 \text{ V} / 9 \text{ mA}$; $R = 767 \Omega \checkmark$ Minimum resistor value that can be used in order not to exceed 9 mA is 767Ω. The 720Ω resistor range is (684 to 756) Ω and falls below this value so should not be used. ✓ OR Calculation using $720 \Omega \pm 5\%$ Resistor range = (684 to 756) $\Omega \checkmark$ leading to smallest current of 9.1 mA ✓ This current will exceed the permitted value of 9 mA. Don't use. ✓	₁One mark for voltage across the resistor ₂One mark for a suitable I-V-R calculation ₃One mark for conclusion with reason. Use of error range to give max resistance must be seen in either ₂ or ₃ for that mark to be awarded.	3	AO3 1a AO3 1b
Total			8	

Question	Answers	Additional Comments/Guidance	Mark	ID details
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01.1	When B = logic 0, (point D is logic 1.) (Result: closes the lower AND gate and opens the upper AND gate.) Only the 1024 Hz signal is allowed to (pass through to the OR gate) output Q. ✓ When B = logic 1,(point D is logic 0). (Result: closes the upper AND gate and opens the lower AND gate.) Only the 512 Hz signal is allowed to (pass through to the OR gate) output Q. ✓	1st mark: • explanation for either logic 1 or logic 0 input • reference as to which frequency passes through OR gate. 2nd mark: reference to other half of the cycle and output frequency. 1 Max if there is no reference to the action of at least 1 gate.	2	AO2
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Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	$Q = (A \cdot \bar{B}) + (B \cdot C)$ ✓ ✓	1st mark for: contents of either bracket 2nd mark for: contents of other bracket and the '+'	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.3		Mark awarded if all the following are present: - resistor and push-to-make switch are in correct position - output point in correct position and labelled.	1	AO3

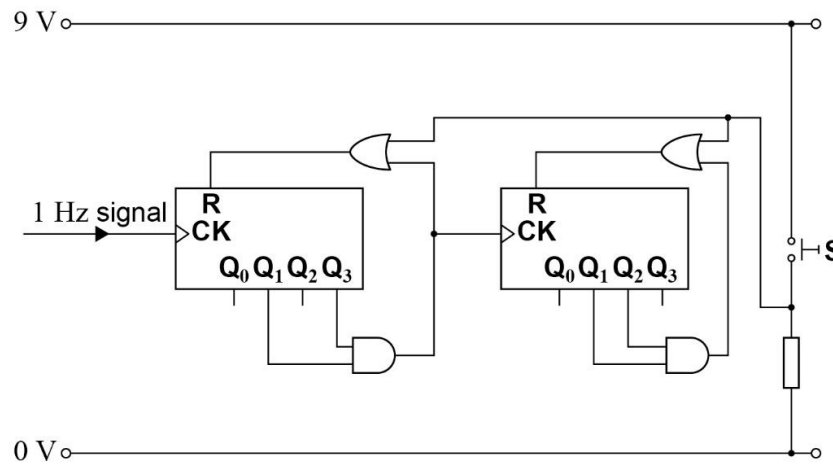
Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	Q_9 ✓	$2^{(n+1)} = 1024$ Condone $n = 9$	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.5	Option 1 requires a total of 6 ICs whereas Option 2 requires a total of 3 ICs ✓ Advantage: One from: ✓ • smaller circuit to fit toys • less power consumed / extended battery life • less complex circuits / lower production costs	1st mark: identifies the main advantage (must be numerical) 2nd mark: gives one advantage from the list /or other valid explanation Allow one mark for answers that only consider number of logic gates in the two systems leading to the correct conclusion.	2	AO3
Total			8	

Question	Answers	Additional comments/Guidelines	Mark	AO
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01.1



Condone lack of connection blobs.

1 mark for correct reset codes for each counter ✓ (Q₁ and Q₃ for LH counter, Q₁ and Q₂ for RH counter)

1 mark for AND gates used with reset codes ✓

1 mark for correct link between counters ✓

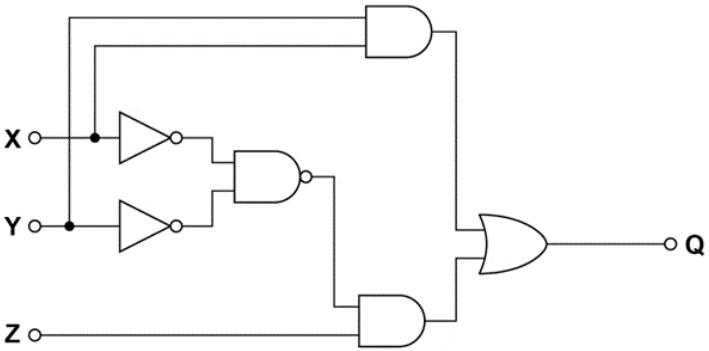
1 mark for correct resistor - switch arrangement used for manual reset ✓

1 mark for OR gates used to provide all reset conditions for each counter ✓

5

2 × AO2

3 × AO3

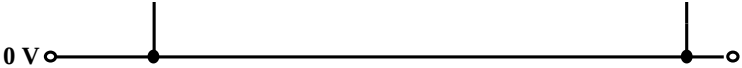
Question	Answers	Additional comments/Guidance	Mark	AO
01.2		Condone no connection blobs on this occasion. mp1 for (X AND Y) OR ✓ mp2 for Z AND ((NOT X) NAND (NOT Y)) ✓ No penalty after final AND gate in mp2	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.3	AND ✓		1	AO2
Total			8	

7

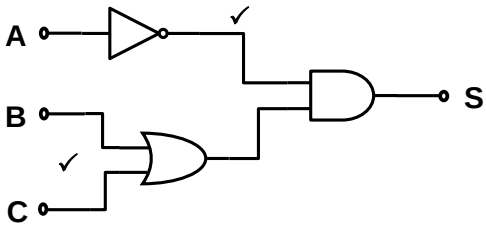
Question	Answers	Additional comments/Guidance	Mark	AO
		Condone reference to charging/discharging		



01.1	 Correct logic gate to MR ✓ Q_3 to logic gate input ✓ Midpoint of switch chain to logic gate input ✓ OR Accept 2 diodes in correct position ✓✓ Correct orientation ✓	2 marks only for both resets in correct positions but no logic gate. 1 mark only for any correct single reset circuit.		
01.2	$(A \cdot C) \checkmark + (B \cdot \bar{C}) \checkmark$	Second mark includes the (+)	2	AO2.1h AO2.1h

		Also allow commutative equivalents such as $(B. \overline{C}) + (A.C)$		
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Question	Answers								Additional comments/Guidelines	Mark	AO	
01.3	Decimal number	C	B	A	D	E	F	W		1	AO2.1f	
	0	0	0	0	1	0	0	0				
	1	0	0	1	1	0	0	0				
	2	0	1	0	1	0	1	1				
	3	0	1	1	1	0	1	1				
	4	1	0	0	0	0	0	0				
	5	1	0	1	0	1	0	1				
	6	1	1	0	0	0	0	0				
	7	1	1	1	0	1	0	1				
01.4	numbers 2, 4 and 6 ✓								accept even numbers	1	AO2.1h	
01.5									NOT A into the AND gate ✓ (B OR C) into the AND gate ✓ Only 1 mark if AND gate is incorrect Do not accept use of NAND, NOR, EXOR / EXNOR gates to generate equivalent functions.		2	AO2.1b AO2.1b
Total										9		

Question	Answers	Additional comments/Guidelines	Mark	AO
	Numerical value for capacitor = 6.9 nF ✓	Substitution of values into formula alone – not	1	AO1.1h

05	Expected information: Longwave f ~ 150 kHz - 300 kHz λ ~ 2 km – 1 km Aerial Very long Mode Ground (surface) wave – diffracted Application Some national radio – large coverage National time signal Shortwave f ~ 3 Mhz - 30 MHz λ ~ 100 m – 10 m Aerial medium Mode Sky wave – reflected from ionosphere (above ~ 500 kHz) Application Some national radio – large coverage Long distance comms. for ships and planes Amateur radio enthusiasts Microwave f ~ 100 GHz - 2 GHz λ ~ 3 mm – 150 mm Aerial Very short Mode Direct (space) wave -terrestrial line of sight hops OR space satellite Application 3G telephone network	1–2 marks: A limited answer with significant detail missing. Candidates may be able to recall terms such as ‘sky waves’ & ‘ground waves’, but there may be confusion as to the spectral frequencies or application. The material may lack organisation and technical terms may not be fully understood or used incorrectly. 3–4 marks: The roles of at least two links are covered and most of the detail is present. There will be some structure, but it may be either brief or unclear in parts. 5–6 marks: All three links are covered in detail. The candidate shows good knowledge and uses technical terms correctly. The answer has structure and clearly conveys the information required by the question. The candidate may show a depth of understanding that goes beyond basic recall.	6
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	Satellite TV Data transfer to remote locations eg (Falkland Islands)		
Total			6



05

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Level	Criteria
L3 6 marks	The candidate shows a good knowledge of the three general properties of copper wire and optic fibre. They use technical terms correctly, the answer has structure and clearly conveys the information required. They reach a conclusion based on the supporting evidence.
L3 5 marks	The candidate shows a good knowledge of the three general properties of copper wire and optic fibre. However, there may be minor gaps in knowledge OR the style / structure may lead to a lack of clarity in some of the information being presented. There is a supported conclusion.
L2 4 marks	The candidate shows a good understanding of two general properties of copper wire and optic fibre. Technical terms will be used correctly and the information will generally be presented in a structured and coherent manner. A conclusion will be drawn from the information presented.

Physical	Corrosion	Copper	Optic fibre
	Weight / connectivity	Will corrode unless well protected	Glass doesn't corrode
External interference	Security	Heavier, easier to join	Lightweight, more difficult to join sections
	External access	Can be tapped without breaking cable	Cannot be tapped unless broken into sections
Signal-carrying properties	Signal degradation / attenuation	Can pick up noise / cross talk	Immune from noise – can be used in noisy environments
	Bandwidth / info carrying capacity	High attenuation	Low attenuation / Possible pulse smearing
		Relatively low bandwidth / fewer channels	Greater bandwidth / capacity / more channels / possibility of sending multiple types of signal eg data + talk

6

AO1.1a
×5AO3.1b
×1

Question	Answers		Additional comments/Guidelines	Mark	AO
05	Level	Criteria			
	L2 3 marks	The candidate shows a good knowledge of two general properties of copper wire and optic fibre. There may be minor gaps in knowledge / detail which may lead to a lack of clarity. There will be a conclusion which draws some support from the information presented.			
	L1 2 marks	The candidate shows some knowledge of two general properties of copper wire and optic fibre. There may be significant gaps in knowledge / detail which may lead to a lack of clarity. There may be no supported conclusion.			
	L1 1 mark	The candidate shows some understanding of one of the general properties of copper wire and optic fibre. Overall, this will be a limited answer with significant detail missing. There may be a lack of structure and clarity. There may be no supported conclusion.			
	L1 0 marks	The work contains no significant analysis of the question asked.			
Total				6	

05

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2-mark (L1), 3 or 4-mark (L2) and 5 or 6-mark (L3) answer. Guidance provided in section 3.10 of the *Mark Scheme Instructions* document should be used to assist in marking this question.

Level	Criteria
L3 6 marks	Candidate matches the three areas of the communications spectrum with the correct pathway. They provide a coherent and comprehensive explanation of the properties of each pathway. The answer has structure and detail.
L3 5 marks	Candidate matches the three areas of the communications spectrum with the correct pathway. They provide a comprehensive explanation of the properties of each pathway, but the answer may lack structure / detail.
L2 4 marks	Candidate matches two areas of the communications spectrum with the correct pathway. They provide a coherent and comprehensive explanation of the properties of each pathway. The answer has structure and detail.

Longwave**Typical frequency range**

Broadcasts between 150 kHz – 300 kHz which fits into the LF band.

Also accept extended (3 kHz – 500 kHz) range to allow for special applications.

Pathway – Ground (surface waves)

- Generally, line of sight.
- Beyond the horizon communication by following earth's curvature.
- Diffraction in the atmosphere due to different refractive index.
- Diffraction due to interaction of the wave with conductive surface (earth).
- Diffraction due to interaction with geographical topography – hills / buildings.
- Long distance propagation due to low attenuation of low frequency waves.
- Transmission severely attenuated by ionosphere so little reflection

Shortwave**Typical frequency range**

Normally taken as 3 MHz – 30 MHz which includes the full HF band. (Accept lower limit of 1.7 MHz)

Pathway – Sky waves

- Ionosphere acts to refract and hence reflect waves back to the earth.
- This allows beyond the horizon reception due to single/multiple reflections (skips).
- Below this frequency, ionosphere will absorb waves.
- Above this frequency, the wave will pass through the ionosphere.
- Can suffer disruption due to the state of the ionosphere day/night effects or sunspot cycle.

6

AO1 1a
AO1 1a
AO1 1a

AO3 1b
AO3 1b
AO3 1b

Question	Answers		Additional comments/Guidelines	Mark	AO
05	Level	Criteria	Microwaves Typical frequency range Normally taken as 2 GHz – 100 GHz Accept 1.7 GHz – 300 GHz Pathway – Space wave - Due to high frequency, microwaves do not diffract around terrestrial objects, so line of sight required. - Microwaves travel straight through atmosphere and ionosphere. - Significant attenuation of transmission by atmosphere and ionosphere. - Different frequencies used for up-link and down-link so that satellite receiver is not desensitized. - Up-link normally at higher frequency (17 – 18 GHz) than down-link (10 – 13 GHz) since higher frequency gives narrower beam and can be given more power to overcome attenuation. (Converse argument for down-link based on wider target area and low power available from satellite). - Microwave communication allows for greater bandwidth to carry complex information.		
	L2 3 marks	Candidate matches the two areas of the communications spectrum with the correct pathway. They provide a comprehensive explanation of the properties of each pathway, but the answer may lack structure / detail.			
	L1 2 marks	Candidate matches one area of the communications spectrum with the correct pathway. They provide a coherent and comprehensive explanation of the properties of that pathway. The answer has some structure and detail.			
	L1 1 mark	Candidate matches one area of the communications spectrum with the correct pathway. They provide some explanation of the properties of the pathway. The answer may lack structure / detail.			
	L1 0 marks	The work contains no significant analysis of the question asked.			
Total				6	

05

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Level	Criteria
L3 6 marks	The candidate shows a good understanding of the way both systems operate. They propose a valid and reasoned solution for both Island B and Oil rig C . They use technical terms correctly; the answer has structure and clearly conveys the information required.
L3 5 marks	The candidate shows a good understanding of the way both systems operate. They propose a valid and reasoned solution for both Island B and Oil rig C . However, there may be minor gaps in knowledge OR the style / structure may lead to a lack of clarity in some of the information being presented.
L2 4 marks	The candidate shows a general understanding of the material but one of the systems or supported solutions will be treated superficially. Structure and technical language used is generally good.

Supporting points that may be made.

General system operation:

a)

Fibre optic cable

- Digital data placed on transmission line using high power IR diode.
- The light ray travels by TIR through the fibre.
- Opto / Electronic repeater / regenerators used - (more recently only opto amplifiers required).
- Data received by a photodiode – converts opto data to electrical.

b)

Satellite

- Typical frequency 12 to 18 GHz
- Digital data sent through free space using a high directional/focused microwave dish (uplink).
- Microwaves used to penetrate atmosphere.
- Satellite likely to be in geostationary orbit.
- Satellite receives data and re-transmits on a different microwave frequency.
- Same dish or dish in another location receives the information (down link).

6

4 ×
AO1

2×
AO3

Question	Answers		Additional comments/Guidelines	Mark	AO
05	Level	Criteria	Proposed solution: Island B Initial phase – use of satellite link • Quick and easy to set up mobile sat unit(s). • Initial usage and platform range likely to be low, hence lower bandwidth / data rates not an issue. • Some difficulties with two-way conversations due to signal delay. • Higher maintenance costs and possible interference problems due to EM noise and security issues. Later phase – install submarine cable • More forward planning / expense needed to put this in – cable ship / terminations / internal network • Heavier usage as development proceeds and wider platform support – hence more bandwidth / larger data rate required. • More reliable link • Low security issues and immune to EM interference. Oil rig C Satellite link • Fibre optic cable not an option due to mobile nature of the rig. • Satellite link is a low-cost short-term solution. • Light use and limited platform requirement so reduced bandwidth / lower data rate not critical. • Some difficulties with two-way conversations due to signal delay. • Reliability issues.		
	L2 3 marks	The candidate shows a general understanding of the material but one of the systems or supported solutions will be treated superficially. There may be some lack of clarity either through the structure or in use of technical terms.			
	L1 2 marks	The candidate shows a basic understanding of the way one system operates. They propose a supported valid solution for either Island B or Oil rig C. There may be some lack of clarity in structure, but there is good use of technical terms.			
	L1 1 mark	The candidate shows a basic understanding of the way one system operates. They propose an unsupported but valid solution for either Island B or Oil rig C. There may be some lack of clarity either through the structure or in use of technical terms.			
	L1 0 marks	The work contains no significant analysis of the question asked.			
Total				6	



05

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2-mark (L1), 3 or 4-mark (L2) and 5 or 6-mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria
6	All three areas covered with at least two aspects covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all three areas. If there are several errors or missing parts, then 5 marks should be awarded.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed or makes a partial attempt at two areas.
1	None of the three areas covered without significant error.
0	No relevant analysis.

The following statements are likely to be present.

Analogue to Digital conversion

Sample rate

- Appreciation of speech being at lower end of audio spectrum (eg 3-4 kHz bandwidth)
- Minimum is $2 \times$ highest frequency
- If too low, then aliasing can occur
- If too high, then forces redundant data to be generated

Resolution

- Determined by number of bits (n) used to code each sample
- Number of levels available is 2^n
- If too low – leads to poor quality signal retrieval
- If too high – may exceed data rate capability of system

Transmission technique

- Name the technique 'Time Division Multiplexing'
- Data from each source transmitted in successive time slots using synchronized switches
- Time slots are of equal length
- Time slots present to each source in a cyclical way giving availability to each source at regular intervals
- Efficient / low-cost solution for heavy use transmission channel

6

AO1

Total

6



04.1	A carrier wave is a fixed frequency (radio wave assigned to a radio station and used to transmit information/signal) ✓ Some aspect of the carrier wave characteristic (eg amplitude / frequency) must be varied / modulated (to represent the information / signal being transmitted) OWTTE ✓		2	AO1
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Question	Answers	Additional comments/Guidance	Mark	AO
04.2	The circuit will resonate at a particular frequency (based upon the values of L and C) ✓₁ The idea that the circuit acts as a filter. (The signal with this frequency will have a large amplitude across the LC circuit compared with other signals received by the aerial. OWTTE OR Varying (L or) C will change the resonant frequency of the circuit and hence the station selected (from those received by the aerial) ✓₂	If filter is not mentioned, accept explanation.	2	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
04.3	Both circuits can accommodate the required bandwidth. (Some evidence that this has been calculated for at least one circuit) ✓₁ Circuit A chosen Consistent explanation ✓₂ .	May be inferred from the calculations and values Expect to see: Bandwidth A = 12 kHz ± 2 kHz Bandwidth B = 24 kHz ± 2 kHz Expect to see: Sharper peak indicates high Q factor hence less interference from other stations Do not accept reference to Q factor alone	2	AO3
Total			6	

Question	Answers	Additional comments/Guidance	Mark	AO
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05

The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in section 3.10 of the *Mark Scheme Instructions* document should be used to assist in marking this question.

Mark	Criteria
6	All three pathways covered in some detail. 6 marks can be awarded even if there is an error and /or parts of one aspect missing.
5	All three pathways covered, at least two in detail. Whilst there will be gaps, there should only be an occasional error.

Ground waves (surface waves)

- use long waves (LW) 150 kHz to 300 kHz (wavelength 1 km to 2 km)
- waves are diffracted by Earth's surface – travel along curvature.

Advantages

- large area of coverage for given power
- absorption of E-M wave is less at low frequency

Disadvantages

- may still be receivers in geographical shadows
- attenuation with distance
- LW - only able to carry limited information due to restricted bandwidth

Accept

medium wave (MW) 300 kHz to 3 MHz (0.1 to 1 km)

Disadvantage

- attenuation in this band increases with increase in frequency
- diffraction may be less prominent hence more shadows in the higher end of this band

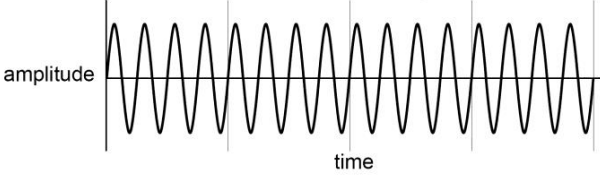
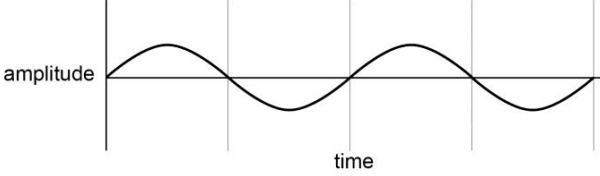
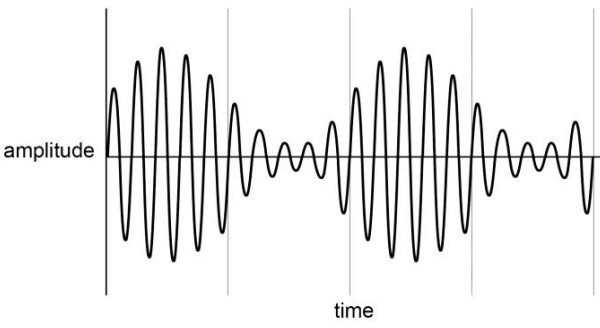
6

AO1

	<table><tr><th>Mark</th><th>Criteria</th></tr><tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.</td></tr><tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr><tr><td>2</td><td>Only one pathway discussed or makes a partial attempt at two pathways.</td></tr><tr><td>1</td><td>None of the three pathways covered without significant error.</td></tr><tr><td>0</td><td>The answer contains no creditable analysis of the question.</td></tr></table>	Mark	Criteria	4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.	3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.	2	Only one pathway discussed or makes a partial attempt at two pathways.	1	None of the three pathways covered without significant error.	0	The answer contains no creditable analysis of the question.	Sky waves • use short wave (SW) 3 MHz to 30 MHz (wavelength 10 m to 100 m) • for $f > 0.5$ MHz, ionosphere reflects radio waves • radio wave is refracted by ionosphere sufficiently to be returned as if reflected Advantages • wavelength too short to suffer diffraction • attenuation is low due to the use of high frequencies Disadvantages • ionosphere susceptible to Sun activity • signal reception fade due to unstable ionosphere Space waves • use microwaves 2 GHz to 100 GHz (wavelength 3 mm to 150 mm) • microwave connects with satellite (uplink) using line of sight • signal transmitted down to Earth station using different frequency (down link) Advantages • wavelength too short to suffer diffraction • short wavelength penetrates atmosphere and the ionosphere • large bandwidth available • satellite able to transmit to multiple receivers over large geographical area Disadvantages • damp atmosphere can cause microwave attenuation • initial capital cost is higher than for other pathways	
	Mark	Criteria													
	4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.													
	3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.													
	2	Only one pathway discussed or makes a partial attempt at two pathways.													
	1	None of the three pathways covered without significant error.													
	0	The answer contains no creditable analysis of the question.													
Total		6													



03.1	D ✓		1	
03.2	A ✓		1	
03.3	One of: ✓ Attenuation of e-m wave across transmission path Small fraction of radiated energy in direction of receiver Energy loss due to reflection from ground / natural topography / absorption in atmosphere	Accept any other reasonable response.	1	

Question	Answers	Additional Comments/Guidance	Mark	ID details
03.4	Radio carrier signal  Modulating sine wave  Combined AM signal  Correct relative positions of envelope max – min on AM and an attempt made to keep carrier frequency constant ✓	Modulating signal forms envelope around carrier.	1	

03.5	About 55 stations can be picked up in London. • A full audio frequency of 20 kHz would require a bandwidth of 40 kHz for each station ✓ • $55 \times 40 \text{ kHz} = 2200 \text{ kHz}$. This is twice as much as waveband available ✓ so stations would have to overlap leading to crosstalk / interference ✓	Accept equivalent arguments / calculations	3		
Total			7		

Question	Answers	Additional Comments/Guidance	Mark	ID details
	PRF = $1 / (1.4 RC)$			



03.1	$(f = 1 / T ; f = 1 / 5 \mu\text{s})$ 200 ✓ (kHz)		1	AO3
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Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Measurement from the graph of the half wavelength of signal $T = 2 \times 42 \mu\text{s}$ ✓ Calculation of frequency ($f = 1 / T$) using their T 11.9 kHz (± 0.6 kHz) ✓	First mark for factor 2 in calculation Allow range $2 \times (40 - 44) \mu\text{s}$ Second mark – allow ecf only if their T is clearly derived from analysis of the graph	2	1 x AO3 1 x AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	Any one from: ✓ • Immune to any noise in amplitude. (since information stored in the frequency variation) • Quality of an FM signal remains high even when the transmitter power is low. (since most of power is in sidebands / information). • Carries more information (since the FM bandwidth is much wider than that of AM)	Max 1 mark	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	=100 stations ✓	$\frac{(108 \text{ MHz} - 88 \text{ MHz})}{200 \text{ kHz}}$	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	Bandwidth = $2(\Delta f + f_m) = 2 \times (75 \text{ kHz} + 15 \text{ kHz}) = 180 \text{ kHz}$ ✓ This fits in allocated 200 kHz band ✓	Second mark – allow ecf if conclusion is consistent with their calc.	2	1 x AO1 1 x AO3
Total			7	

Question	Answers	Additional comments/Guidelines	Mark	AO
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03.1	modulator amplifier receiver demodulator ✓		1	1× AO1
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Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	The up-link and down-link frequencies were made different. ✓		1	1× AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	Evidence of travel time calculation using: distance travelled in single/return journey ÷ speed of e-m wave (in free space) ✓ Processing time = time delay – travel time ✓	Single journey time $= 80 \times 10^6 \text{ m} \div 3 \times 10^8 \text{ m s}^{-1} = 267 \text{ ms}$ OR Return journey time $= 160 \times 10^6 \text{ m} \div 3 \times 10^8 \text{ m s}^{-1} = 533 \text{ ms}$ (accept 534 ms) Do not allow use of $40 \times 10^6 \text{ m}$ Must be a round-trip calculation for second mark. E.g. Processing time = $900 \text{ ms} - 533 \text{ ms}$ = 367 ms Accept their return journey travel time as ecf in MP2	2	2× AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	USA - Geostationary satellite provides permanent link ✓ UK – idea that the satellite is in communication with UK and USA (only) for (short) periods of time. ✓	Accept reference to additional time delay for live events in UK due to extra distance travelled by e-m wave.	2	1× AO1 1× AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	any two from ✓✓ • more secure - need to break into the cable to read data in transition. • continuous communication as link is always connected. • larger bandwidth. • reduced time delay between signal transmission and reception due to shorter distance travelled (even allowing for slower signal speed in cable). • reduced interference - e-m noise will not interfere with optical transmission.	Allow other correct answers.	2	1× AO1 1× AO2
Total			8	

Question	Answers	Additional comments/Guidelines	Mark	AO
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