

AQA A-LEVEL PHYSICS • 7408

PHYSICS



EXAM QUESTION PACK

3.13 ELECTRONICS: DEVICES

SCORE

/134

PERCENTAGE

%

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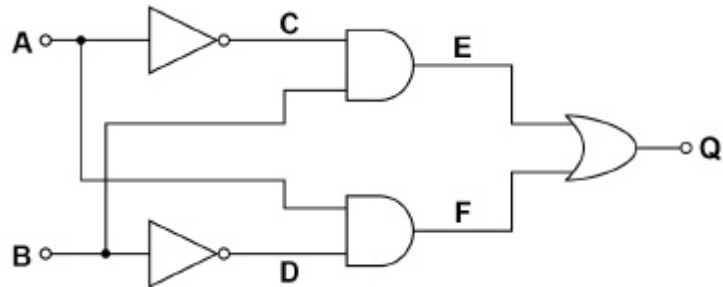
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Q1.

- (a) 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.

Q = _____

(2)

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

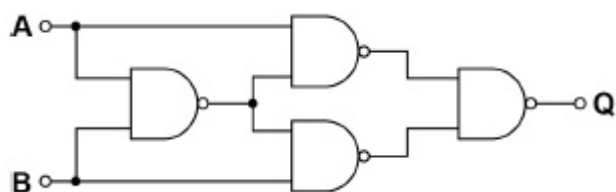
Complete the truth table.

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

(2)

- (c) **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)

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

(1)

(Total 7 marks)

Q2.

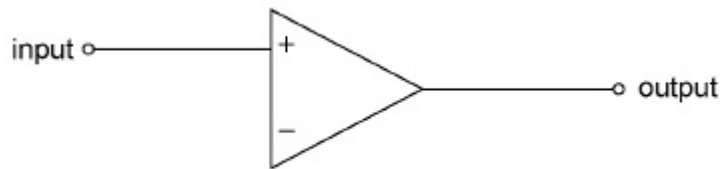
- (a) An ultrasound sensor produces an output that needs to be amplified to 3.0 V
The amplifier used has a voltage gain of 40

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

$$V_{in} = \underline{\hspace{2cm}} \text{ V}$$

(1)

- (b) An operational amplifier in non-inverting mode is used to amplify the output of the sensor. The partially completed circuit diagram is shown below.



0 V

Complete the circuit diagram above 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)

- (c) Determine, using resistors selected from the list below, how the voltage gain of 40 can be achieved by the non-inverting amplifier of the diagram.

1 k Ω 3.6 k Ω 10 k Ω 39 k Ω 150 k Ω

$R_{in} =$ _____ k Ω

$R_f =$ _____ k Ω

(2)

- (d) The ultrasound frequency detected by the sensor is 50 kHz
For this operational amplifier

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

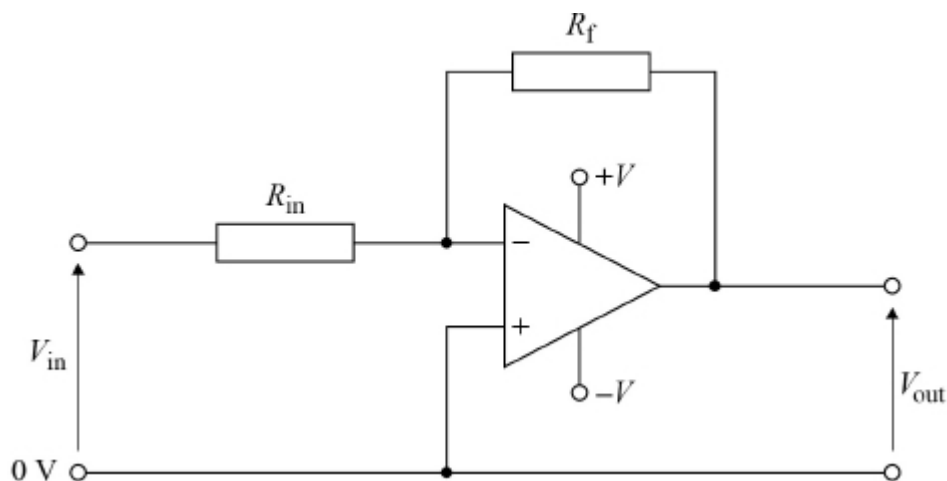
Discuss whether this operational amplifier is suitable for amplifying the sensor's output voltage.

(2)
(Total 7 marks)

Q3.

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

Figure 1



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

(1)

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

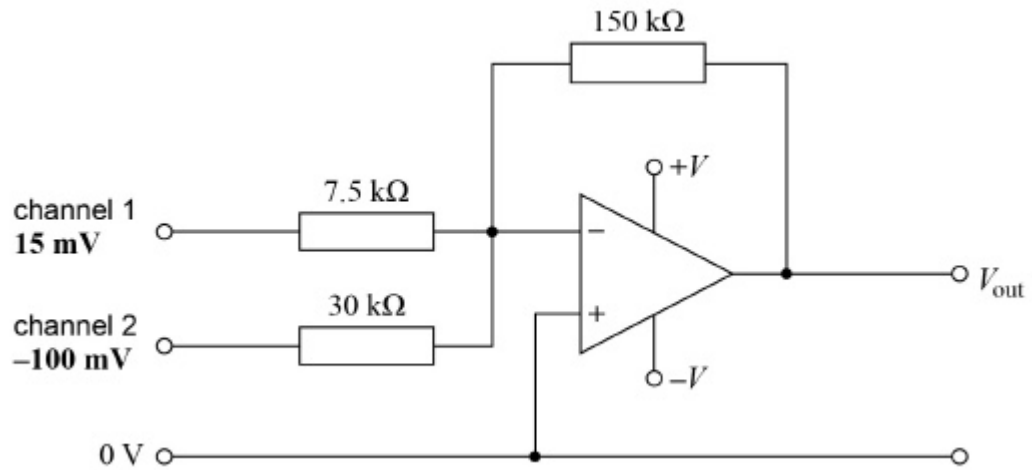
(1)

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

(2)

- (d) **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.

voltage gain (channel 1) = _____ (1)

- (e) 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.

V_{out} = _____ V (2)

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

(1)

(Total 8 marks)

Q4.

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

Figure 1



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 2** can be made to display the numbers 1 to 6 in sequence.

Figure 2

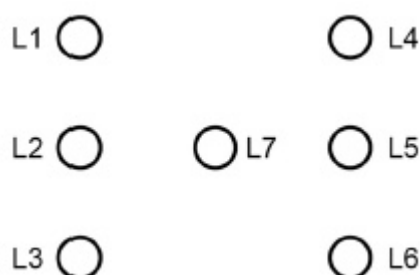
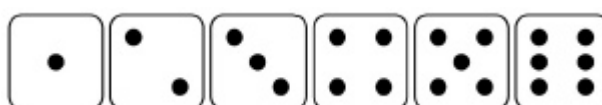


Figure 3 shows the sequence of numbers.

Figure 3



The black dots show which LEDs are lit for each of the numbers 1 to 6.

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

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										

(a) Complete the table to show the logic outputs for the lamps L1 and L6.

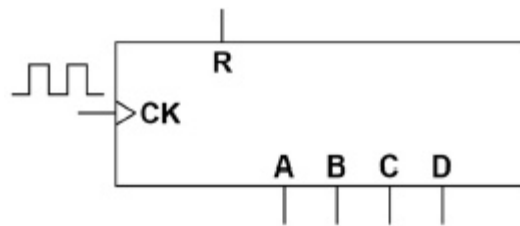
(2)

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

(1)

- (c) **Figure 4** shows some of the input and output pins of the 4-bit binary counter.

Figure 4



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 4** 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.

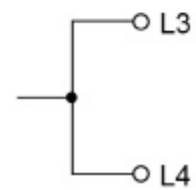
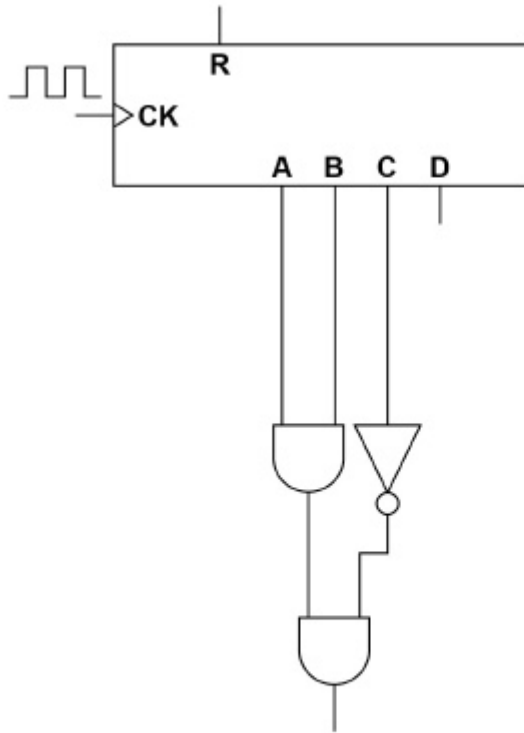
(2)

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

Figure 5 shows part of a logic circuit needed to represent this Boolean expression.

Complete the logic circuit in **Figure 5** by adding AND, OR and NOT gates.

Figure 5



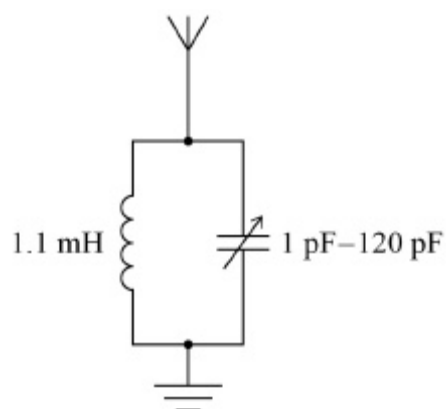
(3)

(Total 8 marks)

Q5.

Figure 1 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 1



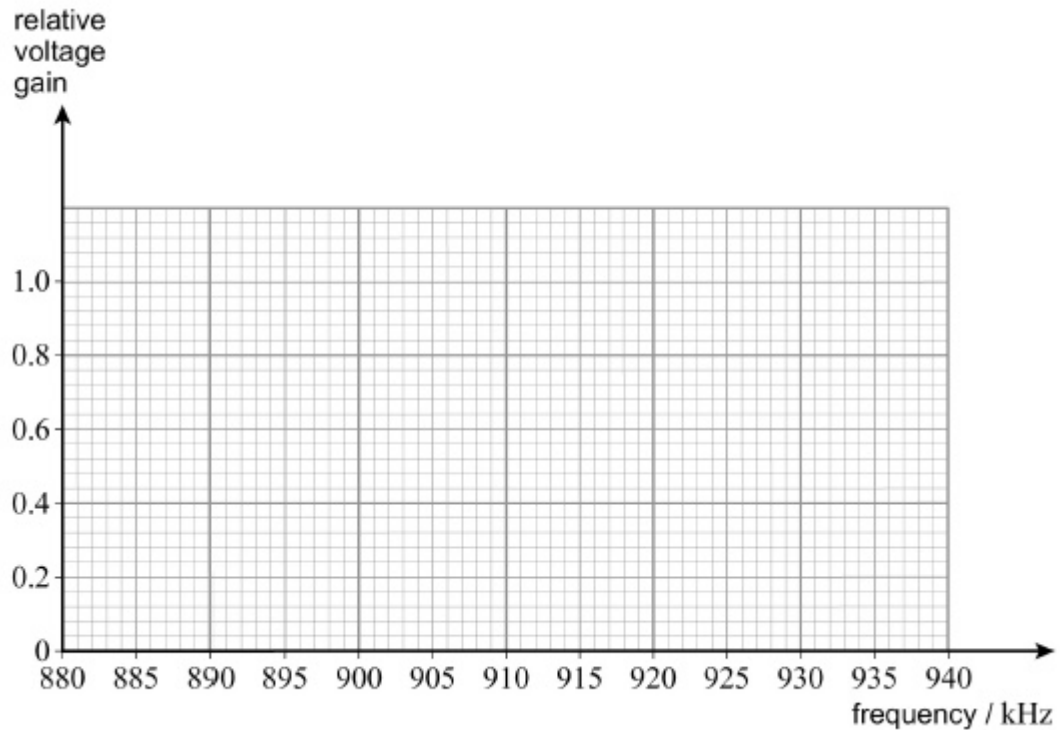
- (a) Calculate the value of the capacitance when the circuit resonates at a frequency of 910 kHz.

capacitance = _____ pF

(2)

- (b) Draw on **Figure 2** an ideal response curve for the resonant circuit, labelling all relevant frequency values based upon a 10 kHz bandwidth.

Figure 2



(3)

- (c) The Q-factor for the practical tuning circuit has a smaller value than the ideal one assumed in question (b).

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

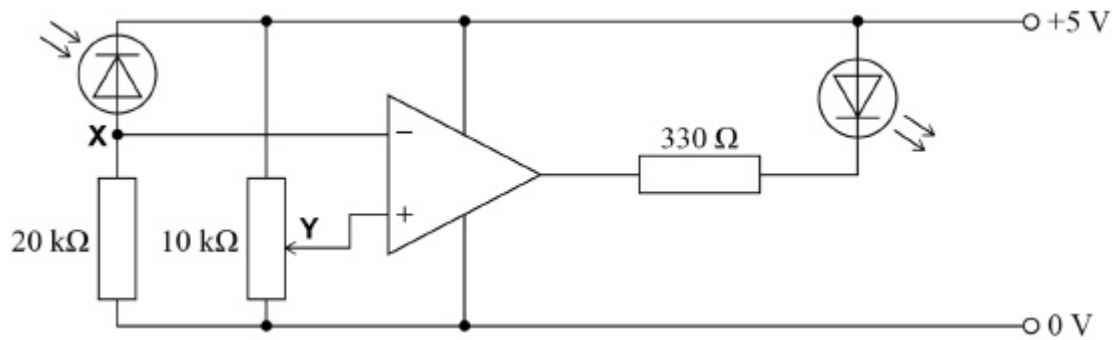
(2)

(Total 7 marks)

Q6.

A photodiode forms part of a light meter used for checking light levels in an office. **Figure 1** shows the circuit diagram for the light meter.

Figure 1



- (a) State the mode in which the photodiode is being used in **Figure 1**.

(1)

- (b) In which mode is the operational amplifier being used in **Figure 1**?

Tick (✓) the correct box.

Non-inverting amplifier

☐

Comparator

☐

Summing amplifier

☐

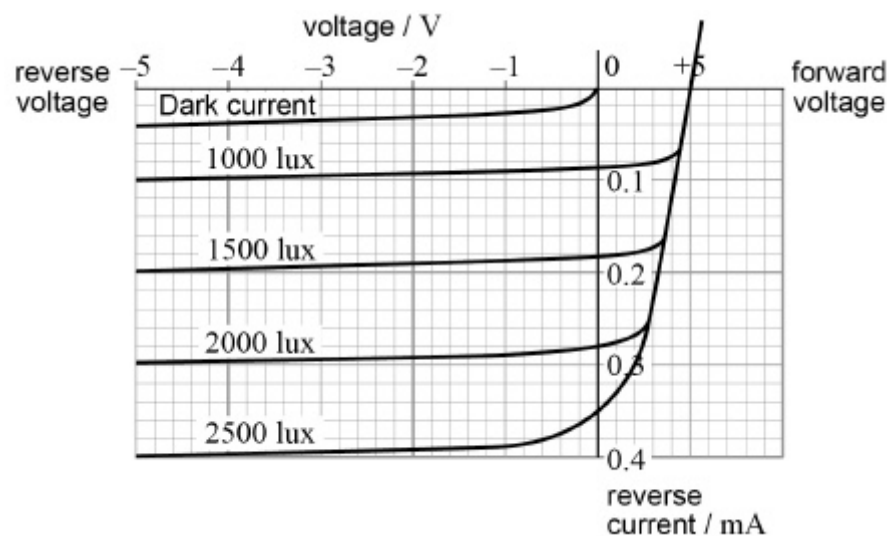
Difference amplifier

☐

(1)

- (c) **Figure 2** shows an extract from a data sheet of the characteristics for a photodiode under different light levels measured in lux.

Figure 2



For a particular lighting condition, the current through the photodiode in **Figure 1** was 0.10 mA.

Estimate, using the information in **Figure 2**, the light level needed to cause this reverse current through the photodiode.

light level = _____ lux

(1)

- (d) Calculate the voltage at point **X** in the circuit shown in **Figure 1** for the light level in question (c).

voltage = _____ V

(1)

- (e) The 10k Ω linear potential divider shown in **Figure 1** is set to give 1.75 V at point **Y**.

Assume that the operational amplifier has ideal characteristics.

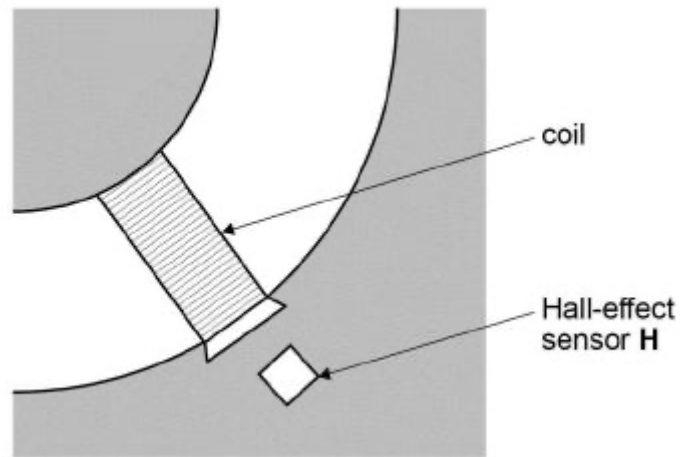
Deduce whether the output LED would be switched ON or OFF when the current through the photodiode is 0.10 mA.

(2)

(Total 6 marks)

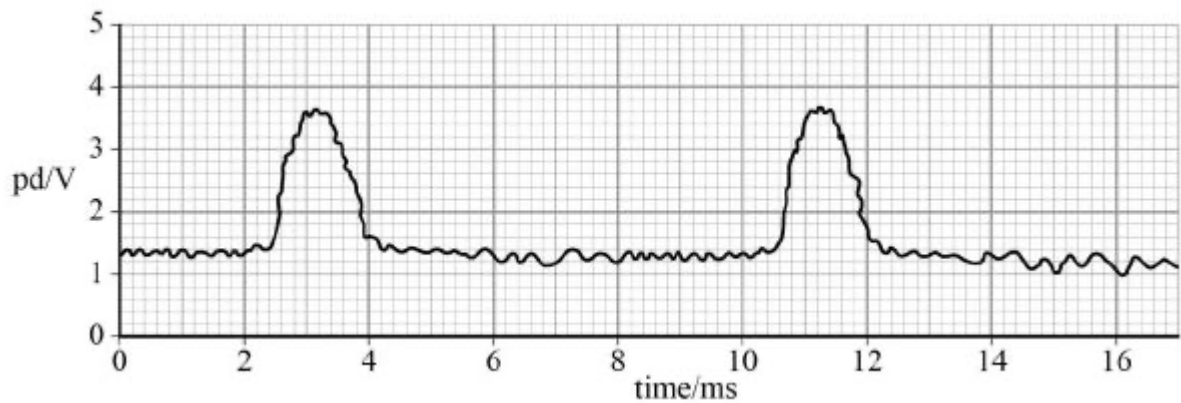
Q7.

The diagram shows part of the motor from a computer disk drive.



On each rotation a small magnet passes a Hall-effect sensor **H** which detects the change in magnetic field and produces an output potential difference (pd) that varies with time as shown in **Figure 1**.

Figure 1



- (a) Determine the speed of the motor in revolutions per second.

speed of motor = _____ rev s^{-1}

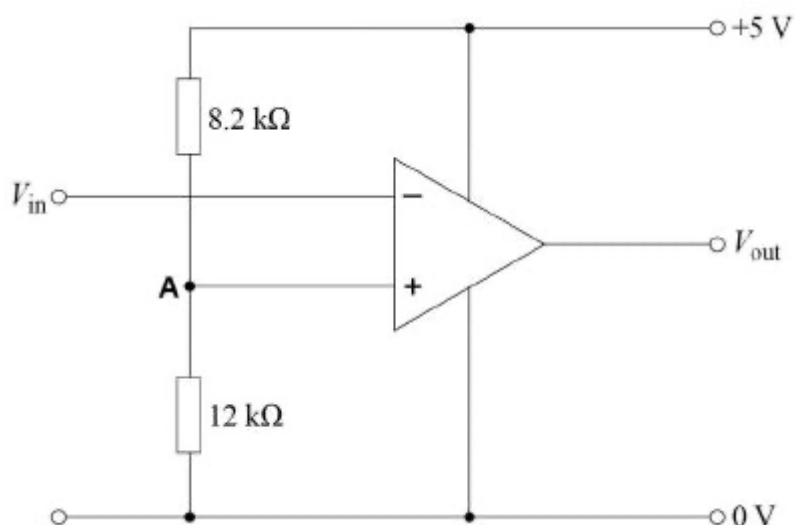
(2)

- (b) Explain why the output from the magnetic field sensor is unsuitable to be applied directly to the logic circuit of the motor controller.

(1)

- (c) The signal from the magnetic field sensor is applied to the circuit shown in **Figure 2**.

Figure 2



Show that the potential of point **A** is about +3 V.

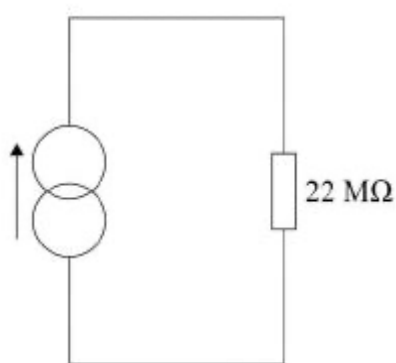
(1)

- (d) Draw on **Figure 1** the waveform showing the variation with time of the output voltage V_{out} of the circuit shown in **Figure 2**.

(2)

Q8.

The diagram shows a constant-current generator connected to a $22 \text{ M}\Omega$ resistor.



- (a) The output from the current generator is $5.0 \times 10^{-10} \text{ A}$.

Show that the magnitude of the pd across the $22 \text{ M}\Omega$ resistor is about 10 mV.

(1)

- (b) A student tries to measure this voltage with a digital voltmeter set on the 200 mV range. The resistance of the meter on this range is $1.0\text{ M}\Omega$.

Explain why the meter does **not** read 10 mV.

(2)

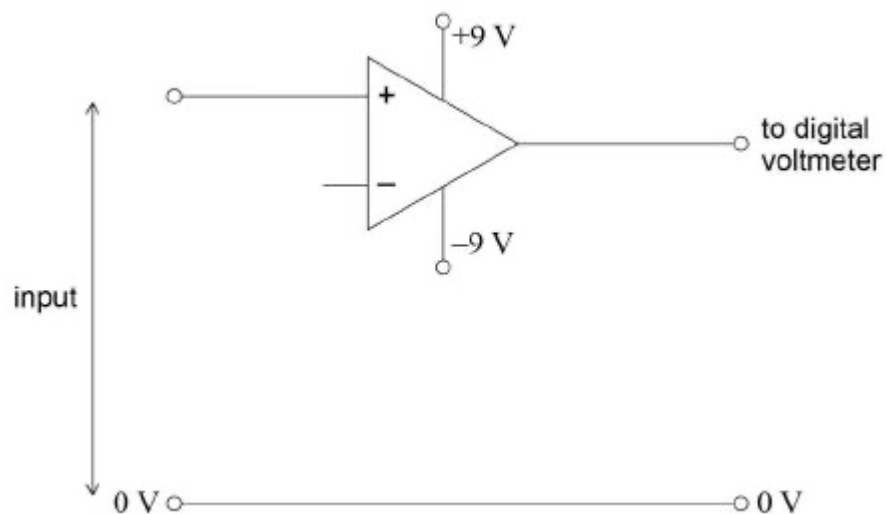
- (c) The student then decides to use a non-inverting operational amplifier to interface to the digital voltmeter.

Discuss the important property that makes this configuration a suitable choice.

(2)

- (d) **Figure 1** shows a partly-drawn circuit diagram for the non-inverting amplifier.

Figure 1



Complete **Figure 1** to form a non-inverting amplifier by adding **two** labelled resistors

and any connections that are needed.

(2)

- (e) The values of the two resistors added to **Figure 1** are to give the non-inverting amplifier a voltage gain of 20. The resistance of the smaller of these two resistors is 500 kΩ.

Which of the following is the correct resistance for the other resistor?
Tick (✓) the correct answer in the right-hand column.

	✓ if correct
1.0 MΩ	
9.5 MΩ	
10.0 MΩ	
10.5 MΩ	

(1)

- (f) Justify your choice of resistance value by calculation.

(1)

Q9.

A student needs to monitor the temperature of a pond using a remote link. To provide the link the student decides to use radio transmitter and receiver modules.

The radio modules available to the student are available with either amplitude modulation (AM) or with frequency modulation (FM).

- (a) Describe what is meant by amplitude-modulated and by frequency-modulated radio waves.

In your answer you should:

- indicate the principal features of each of these two types of modulation
- explain the differences between them
- refer to the advantages and disadvantages of using each type of modulation.

(6)

- (b) The radio modules chosen by the student transmit a signal that is amplitude modulated having a carrier frequency of 434 MHz. The data sheet for the modules specifies quarter-wave aerials for both the transmitter and receiver.

Calculate the length of a quarter-wave aerial.

length of aerial = _____ m

(2)

- (c) The output from the temperature sensor in the pond is connected to an astable oscillator. The frequency f (in Hz) of the astable varies with temperature θ (in °C) according to the equation

$$f = 7.3(6\theta + 273)$$

During the course of the year the temperature of the pond varies between 4°C and 22°C. The highest frequency produced by the astable is 3.0 kHz.

Calculate the lowest frequency in kHz produced by the astable.

lowest frequency = _____ kHz

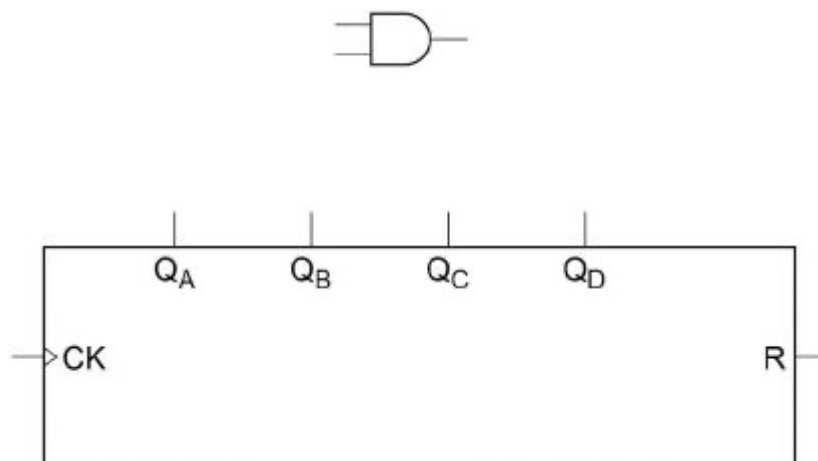
(1)

- (d) Deduce the maximum bandwidth required by the AM carrier wave produced by the radio transmitter as the signal from the astable is transmitted.

Q10.

- (a) Draw connections on **Figure 1** to show how the 4-bit binary counter could be used to form a binary coded decimal (BCD) counter.

Figure 1



(2)

An automatic bread maker has 10 discrete processes. These are shown in the following table. The processes are controlled by the BCD counter.

Process number	Process	Action
0	OFF	add ingredients
1	mix ingredients	motor on
2	warm ingredients	heater on
3	add yeast	add ingredients
4	mix dough	motor on
5	warm ingredients	heater on
6	mix dough	motor on
7	warm ingredients	heater on
8	cook	heater on
9	switch heater OFF	alert that bread is cooked

- (b) Identify and write down the process numbers from the table that correspond to each of the actions when the heater is on. Convert each of these numbers into their binary values.

(1)

- (c) Show, by reference to the labelled terminals on the counter in **Figure 1**, that the Boolean expression for the conditions when the heater is on is

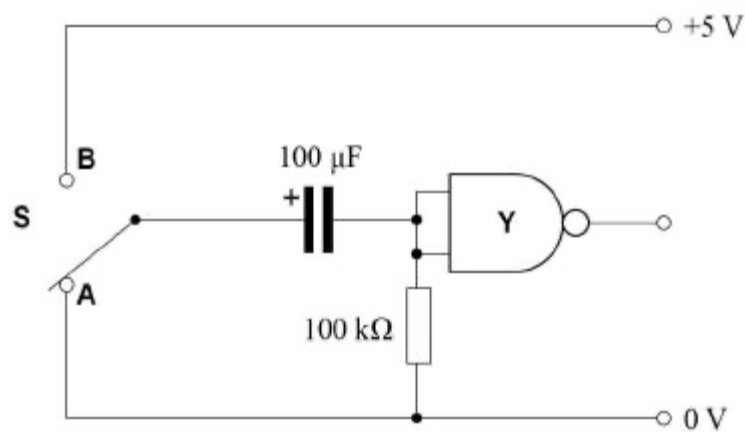
$$= \overline{D}.\overline{C}.B.\overline{A} + \overline{D}.C.\overline{B}.A + \overline{D}.C.B.A + D.\overline{C}.\overline{B}.\overline{A}$$

(2)

Q11.

A student experiments with the circuit shown in **Figure 1**.

Figure 1



Y is a NAND gate for which an input of less than 2.5 V is logic state 0 and input greater than 2.5 V is logic state 1.

Switch **S** is set to position **A** for a long time so that the capacitor is uncharged.

- (a) Explain why the output of **Y** is logic state 1.

(1)

- (b) When **S** is moved to position **B**, the capacitor charges through the 100 kΩ resistor.

Show that the capacitor will be charged to 2.5 V after about 7 s.

(2)

- (c) Suggest an application for a circuit such as that shown in **Figure 1**.

(1)

(Total 4 marks)

Q29.

A fridge is fitted with a temperature-sensing unit to indicate whether the temperature inside the fridge is too high, too low, or at a safe temperature. The system consists of a temperature sensor that produces a 2-bit binary output, a logic circuit and a low current, common cathode 7-segment display. **Figure 1** shows a block diagram of the system.

Figure 1

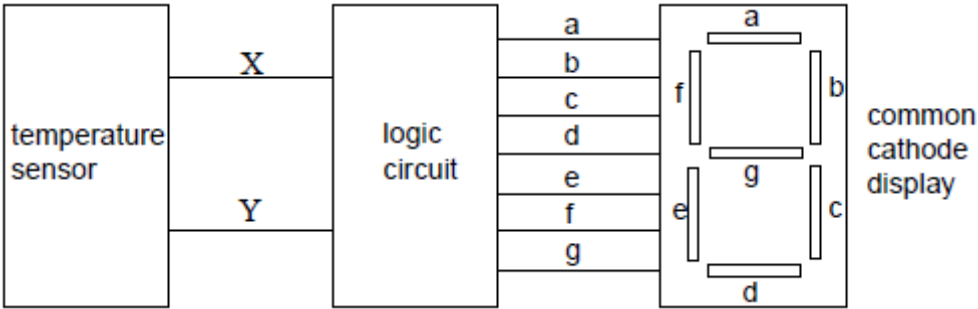


Table 1 shows the operation of the system.

Table 1

Fridge temperature	Temperature sensor output		7-segment display output
	X	Y	
< 3 °C	0	0	L
3 °C to 4 °C	0	1	S
4 °C to 5 °C	1	0	S
> 5 °C	1	1	H

Key

L = low

S = safe

H = high

- (a) Complete **Table 2** to show the logic signals required on lines a to g to display the specified characters.

Table 2

X	Y	a	b	c	d	e	f	g	Display
0	0								L
0	1								S
1	0								S
1	1								H

(3)

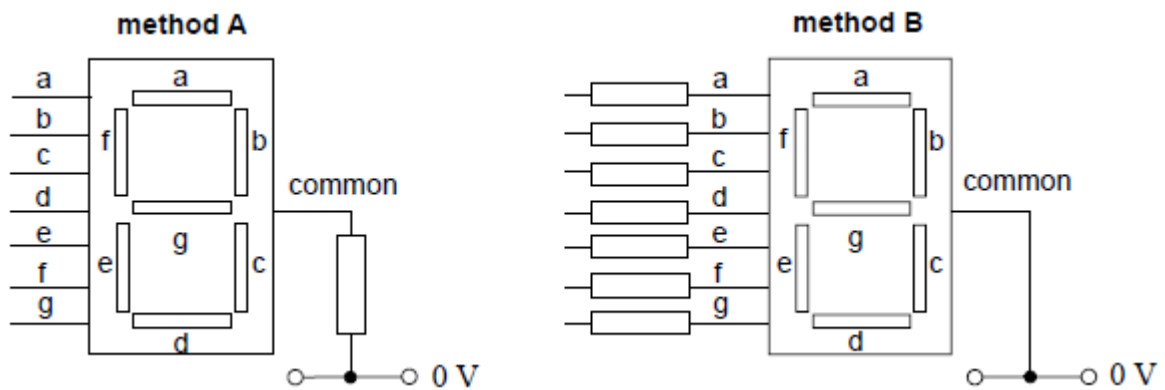
- (b) Circle the single logic gate which would generate the required signal for segment **a**.

AND EXOR OR NAND NOR NOT

(1)

- (c) The LEDs in the 7-segment display must be protected by current limiting resistors. **Figure 2** shows two methods, **A** and **B**, of connecting current limiting resistors.

Figure 2



- (i) State **one** disadvantage of **method A**.

(1)

- (ii) Calculate the value of the current limiting resistors required in **method B** to limit the current in each segment to 20 mA.
 Assume the voltage from the logic circuit is 5 V and the forward voltage drop across each LED in the 7-segment display is 2.2 V.

(2)

- (iii) Circle the appropriate value for these resistors from the following list of E24 resistors.

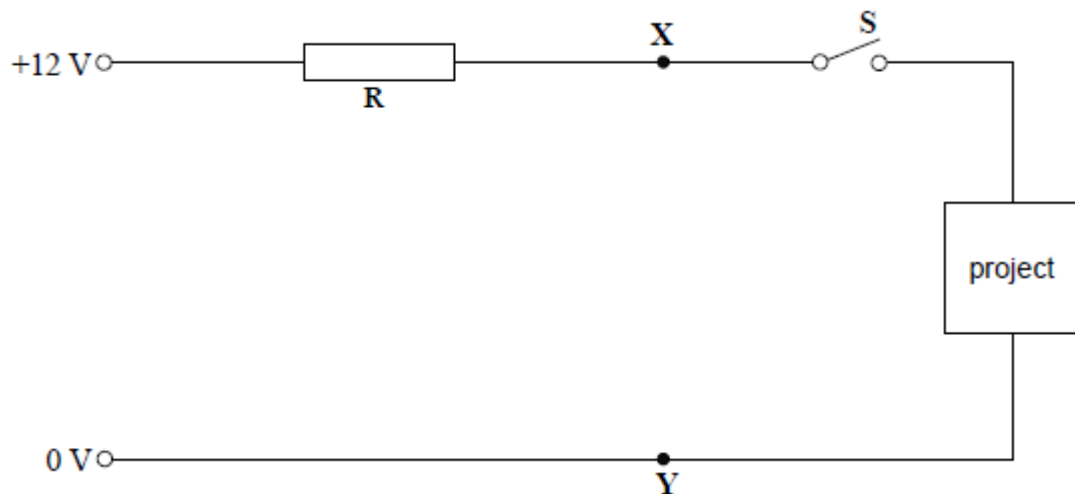
110 Ω 150 Ω 270 Ω 1.1 k Ω 1.5 k Ω

(1)

(Total 8 marks)

Q30.

A Zener diode is used to produce a stabilized 5.1 V from an unregulated 12 V supply to power a project that requires 80 mA.
 Part of the circuit is shown in the diagram.



- (a) Draw on the diagram the Zener diode connected correctly between points **X** and **Y**.

(2)

- (b) The Zener diode requires at least 5 mA to maintain its Zener voltage of 5.1 V.

- (i) Calculate the minimum current flowing through **R** when switch **S** is closed.

(1)

- (ii) Calculate the voltage across resistor **R** under these conditions.

(1)

- (iii) Calculate the value of resistor **R**.

(2)

- (c) The circuit in the diagram above is now constructed using a value of 75 Ω for resistor **R**.

- (i) Show that the power dissipated in the resistor is approximately 0.6 W.

(2)

- (ii) The project is disconnected by turning switch **S** off, but the 12 V supply remains connected.

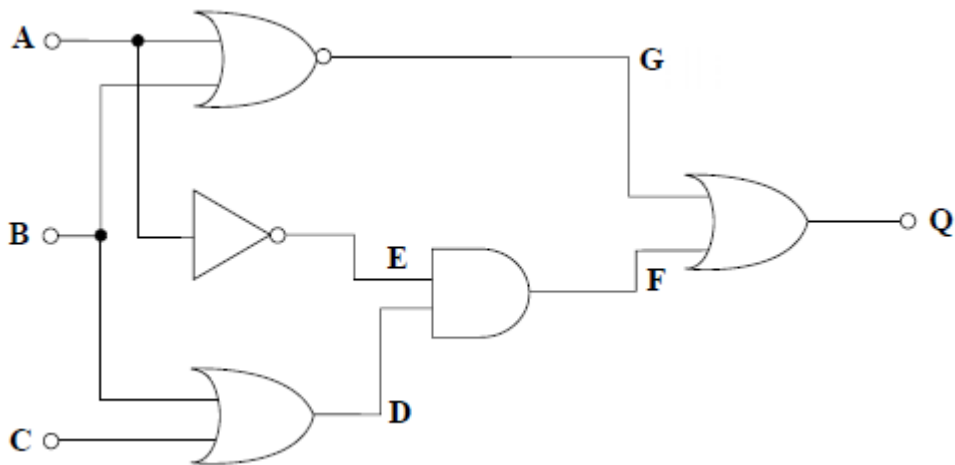
Calculate the current that now flows through the Zener diode.

(2)

(Total 10 marks)

Q31.

The diagram shows a logic circuit with three inputs **A**, **B** and **C**.



- (a) Write the Boolean expressions for the signals at the intermediate points **D**, **E**, and **G** in terms of the inputs **A**, **B** and **C** only.

D

E

G

(3)

- (b) Complete the truth table below for the logic signals at the intermediate points **D**, **E** and **G**.

Inputs			Intermediate points		
C	B	A	D	E	G
0	0	0			
0	0	1			
0	1	0			

0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

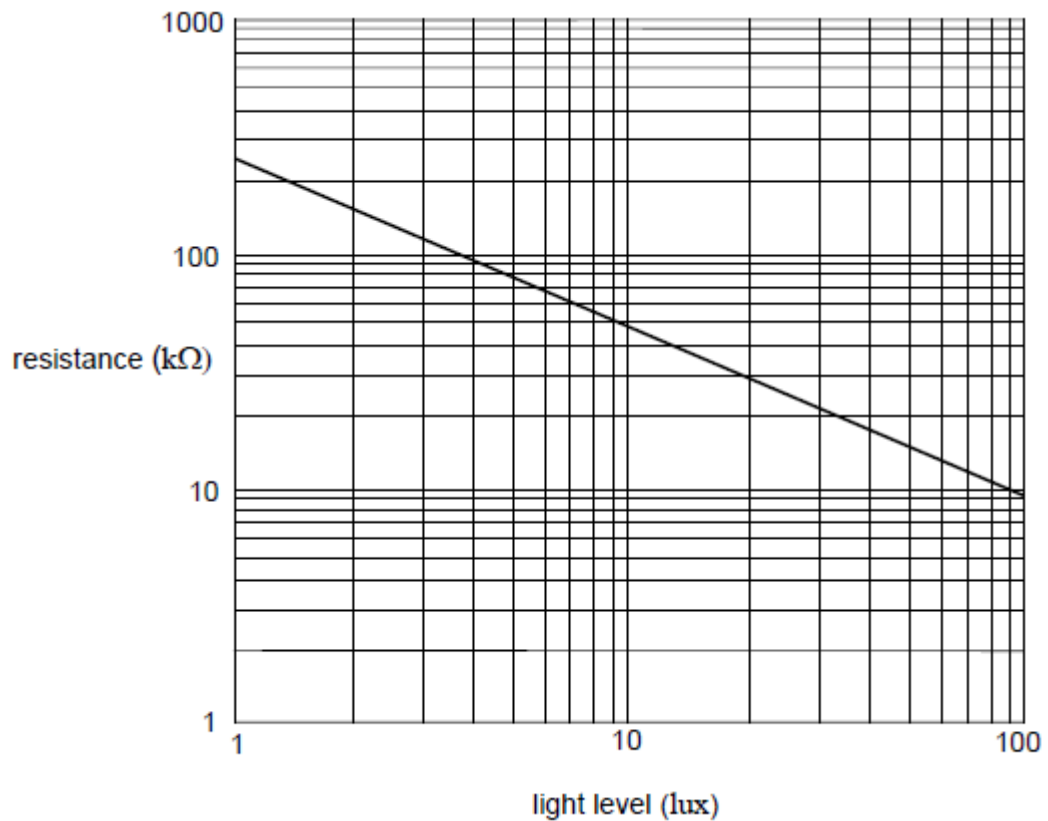
(5)
(Total 8 marks)

Q32.

An LDR is being used as a light sensor in a system that will switch on a porch light when it gets dark.

The characteristic for the LDR is shown in **Figure 1**.

Figure 1



- (a) (i) Explain how the use of the logarithmic scale in **Figure 1** is helpful when displaying this characteristic.

(1)

- (ii) The LDR has a resistance of 60 kΩ when the light level causes the system to switch on the porch light.

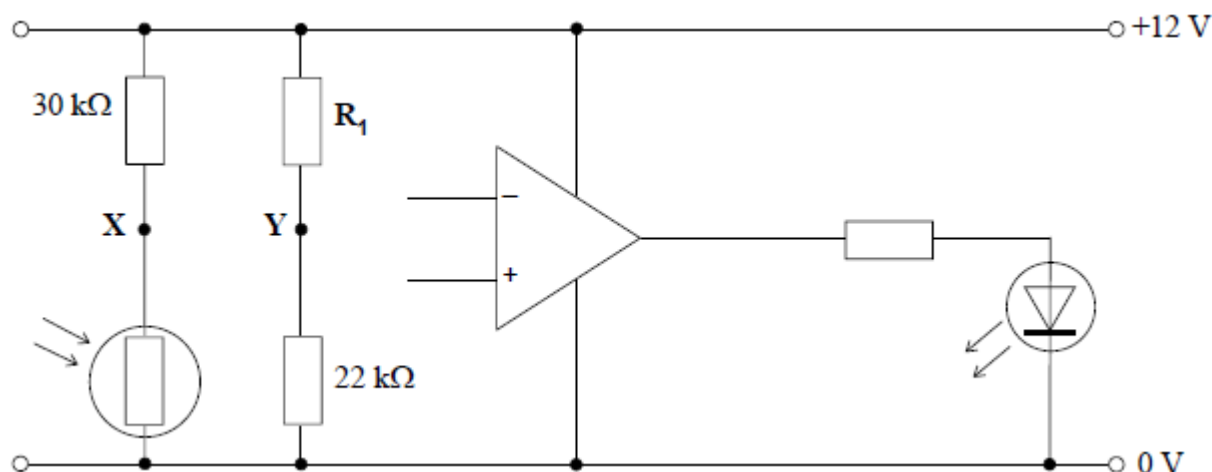
State the value of this light level by reading from the graph in **Figure 1**.

light level _____ lux

(1)

- (b) **Figure 2** shows the circuit for detecting the light level.
The design makes use of an op-amp acting as a comparator.
A red LED acts as an output indicator to aid testing of the detector circuit.

Figure 2



Draw on **Figure 2** the connections from points **X** and **Y** to the op-amp inputs so that the red LED switches on when the light level falls below the required value.

(1)

- (c) (i) Calculate the voltage at point **X** when the red LED switches on.

(2)

- (ii) The reference voltage at **Y** is produced by two fixed-value resistors.

Calculate the value for resistor **R₁** in order to achieve the required circuit operation.

(2)

- (d) The red LED was found to stay on dimly even when the light level was well above the value expected to switch it off.

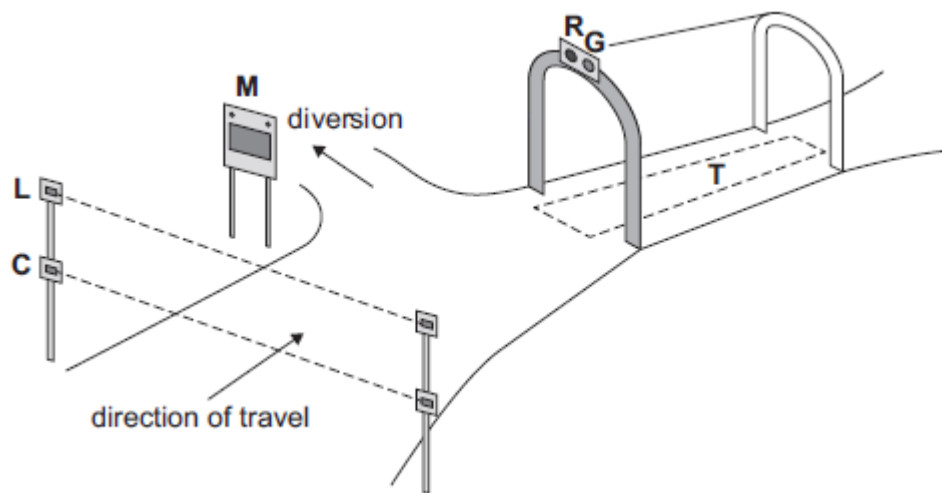
Explain why this might happen and how the problem could be solved.

(3)
(Total 10 marks)

Q33.

Figure 1 shows a simplified diagram of a road safety system for traffic travelling towards a road tunnel. The tunnel is too narrow for two-way traffic and too low for lorries.

Figure 1



C and **L** are laser beam sensors placed at different heights on the road just before the tunnel. When a beam is broken, the sensor produces a logic 1.

Cars will break the beam at sensor **C only**. Lorries will break the beams at both sensor **L** and sensor **C**.

M is an electronic message display that tells lorries to take a diversion. The message display lights up when it receives a logic 1.

T is a sensor buried in the road inside the tunnel. It produces a logic 1 when an oncoming car is in the tunnel.

The red stop light **R** comes on when a lorry is detected or when there is an oncoming car in the tunnel. **R** will light up when it receives a logic 1.

The green go light **G** comes on when a car is detected and there are no oncoming cars in the tunnel. **G** will light up when it receives a logic 1.

- (a) Complete the truth table.
Some of the data has already been entered for you.

Input			Output		
Sensor T	Sensor C	Sensor L	Message display M	Red stop light R	Green go light G
0	0	0	0	0	1
0	0	1	0	0	1
0	1	0		0	
0	1	1		1	
1	0	0		1	
1	0	1	0	1	0
1	1	0		1	
1	1	1		1	

(4)

- (b) Write the simplest Boolean expression for the red stop light **R** in terms of **T**, **C** and **L**.

(2)

- (c) The expression for the green go light **G** could be written as $G = \overline{T} \cdot (\overline{C} + \overline{L})$

Draw on **Figure 2** the logic diagram for this expression using only NOT, AND and OR gates.

Figure 2

T 

C 

L 



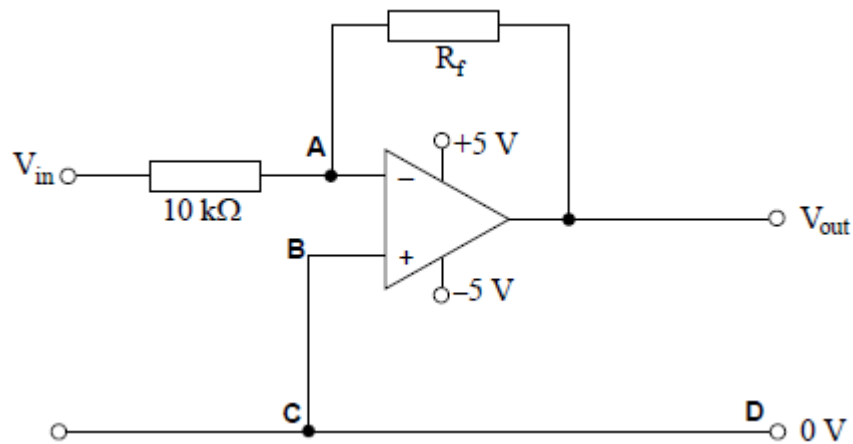
(3)

(Total 9 marks)

Q34.

Figure 1 shows an inverting op-amp amplifier subsystem.

Figure 1



- (a) (i) Write in the box the letter that corresponds to the virtual earth point in **Figure 1**.

(1)

- (ii) Explain the meaning of the term **virtual earth point**.

(2)

- (iii) State the input resistance of this amplifier subsystem.

(1)

- (b) Calculate the value of R_f needed to give the amplifier subsystem a voltage gain of -47 .

(3)

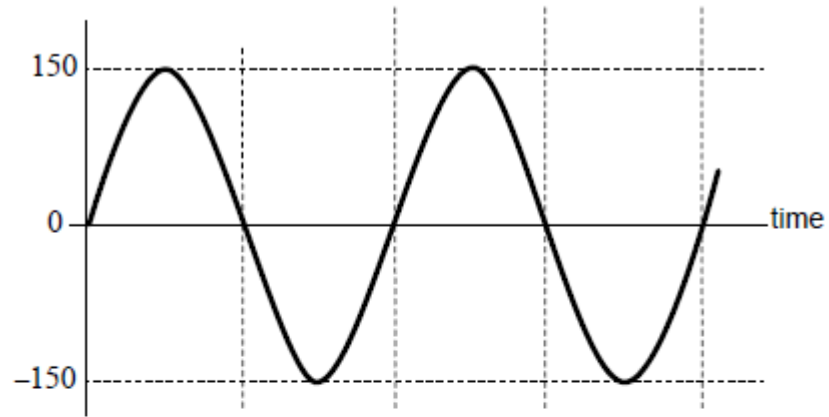
- (c) The amplifier subsystem in part (b) is used to increase the signal voltage from an electric guitar.

The voltage from the guitar to the amplifier input is shown in **Figure 2**.

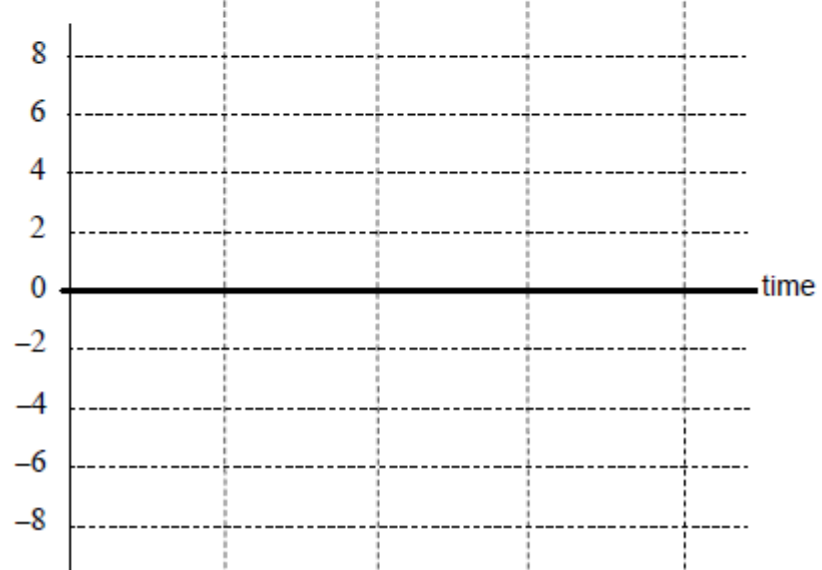
Draw onto the lower part of **Figure 2** the output signal from the amplifier subsystem.

Figure 2

input
voltage (mV)



output
voltage (V)



(4)
(Total 11 marks)

Mark schemes

Q1.

- (a) $Q = (\bar{A}.B) + (A.\bar{B})$ ✓✓ (allow written format)
Do not allow $(A \oplus B)$

- Correct two terms ✓
- Correct operator for OR gate ✓

2

- (b)

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

- (c) 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

- (d) EOR ✓

Also allow EXOR, XOR

1

[7]

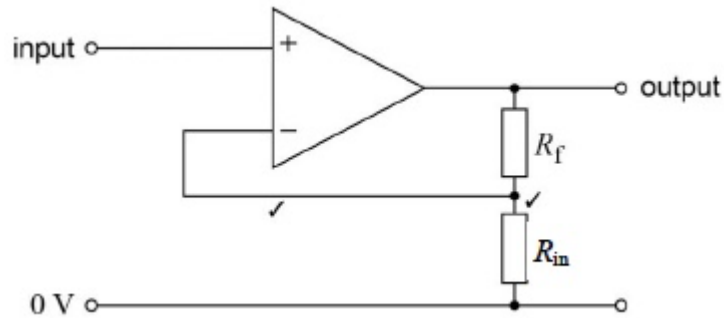
Q2.

- (a) Voltage in = Voltage out / Voltage gain

$$= 3 \text{ V} / 40$$

$$= 75 \times 10^{-3} \text{ V} \checkmark$$

1



(b)

Two resistor chain, correctly labelled connected between output and ground
Inverting input connected to mid-point of resistor chain

2

(c)
$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_{in}}$$

$$40 = 1 + \frac{R_f}{R_{in}}$$
 calculation to give resistor ratio of 39 ✓

$$R_{in} = 1 \text{ k}\Omega ; R_f = 39 \text{ k}\Omega$$
 ✓

2

(d) 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. ✓

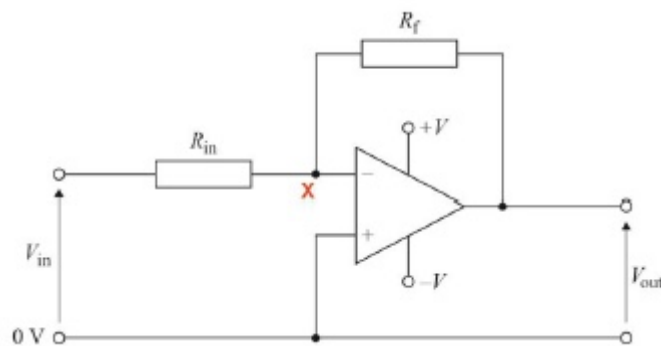
1 mark - relevant calculation

1 mark - reference to only providing $\frac{1}{2}$ require amplification / gain so not suitable

2

[7]

Q3.



(a)

Correct position of X:

1

(b) The non-inverting input
(non-inverting)

1

(c)
$$I = \frac{(V_{in} - V_x)}{R_{in}} = \frac{(V_x - V_{out})}{R_f}$$

But $V_x = 0 \text{ V}$ (a virtual earth)
$$I = \frac{V_{in}}{R_{in}} = -\frac{V_{out}}{R_f}$$

Making use of: $I_{in} = -I_f$

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

Making use of virtual earth concept

2

(d) Voltage gain (Channel 1) = $-R_f / R_{in}$

$$-(150 \text{ k}\Omega / 7.5 \text{ k}\Omega)$$

$$-20$$

Both number **and** sign must be correct

1

(e) $V_{out} = -R_f (V_{in \text{ Ch1}} / R_1 + V_{in \text{ Ch2}} / R_2)$

$$= -150 \text{ k}\Omega ((15 \text{ mV} / 7.5 \text{ k}\Omega) + (-100 \text{ mV} / 30 \text{ k}\Omega))$$

$$= -((0.3) + (-0.5)) = 0.2 \text{ Volts}$$

Evidence of correct method

Answer **and** correct sign

1

(f) 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

[6]

Q4.

(a)

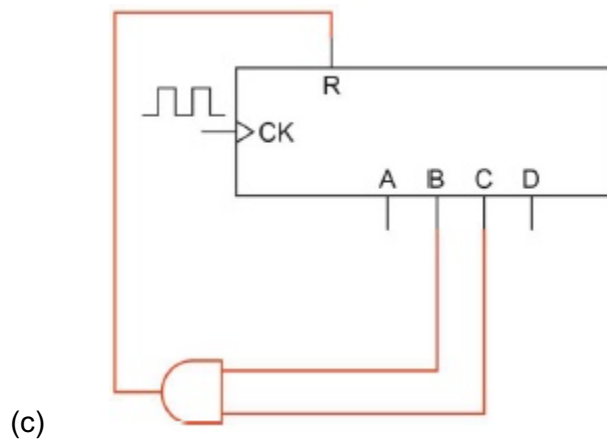
Number shown on die	Logic inputs			Logic outputs						
	C	B	A	L1	L2	L3	L4	L5	L6	L7
1	0	0	0	0	0	0	0	0	0	1
2	0	0	1	1	0	0	0	0	1	0
3	0	1	0	1	0	0	0	0	1	1
4	0	1	1	1	0	1	1	0	1	0
5	1	0	0	1	0	1	1	0	1	1
6	1	0	1	1	1	1	1	1	1	0
Reset 6 → 1										

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

2

(b) **L7 = NOT A**; Accept: $L7 = \bar{A}$

1

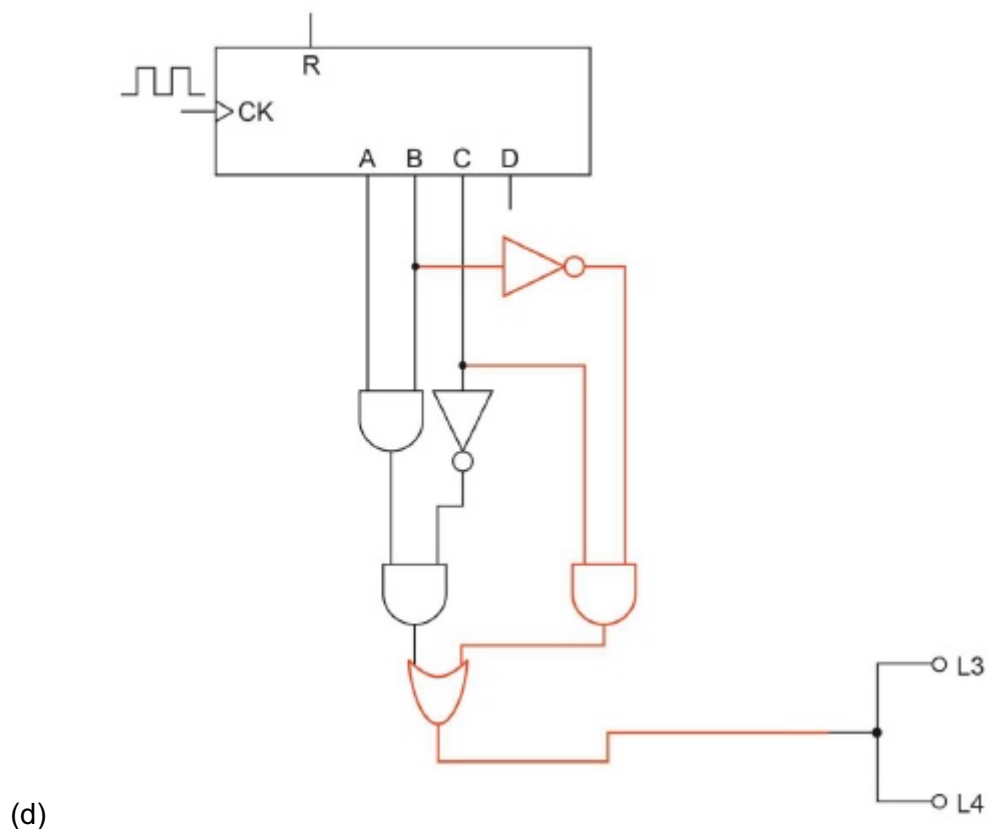


1 mark for reset condition from B and C

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



1 mark - NOT gate from B:

1 mark - AND gate from $\bar{B}$ and C:

1 mark - OR gate connecting the two conditions:

3

[8]

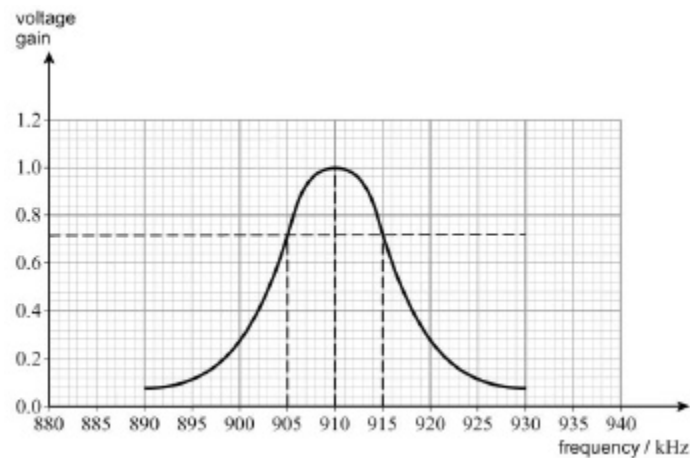
Q5.

- (a) $f = 1 / (2\pi \sqrt{LC})$
 $C = 1 / f^2 4\pi^2 L$
 $C = 1 / (910 \times 10^3)^2 \times 4 \times \pi^2 \times 1.1 \times 10^{-3}$
 $C = 27.8 \text{ pF}$ (accept 28pF)

Formula with correct substitution / evidence of correct working

Answer

1
1



(b)

General shape around f_0 and to max of 1.0 on relative voltage gain axis

1

10 kHz bandwidth
at 0.71 gain

1

Frequencies (905 – 910 – 915) kHz (identified / used)

1

(c) 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

[7]

Q6.

(a) Photoconductive (accept reverse bias)

1

(b)

	Tick (✓) if correct
Non-inverting amplifier	
Comparator	✓
Summing amplifier	
Difference amplifier	

1

(c) Light level ~ 1000 lux +/- 10%

1

- (d) $V_x = IR$; $V_x = 100 \mu A \times 20 k\Omega = 2 V$ 1
- (e) Rule that if $V_- > V_+$ then V_{out} is 0 V (low) 1
- Voltage drop across LED so LED is ON
- Do not allow LED is ON if supported by incorrect reason* 1

[6]

Q7.

- (a) Period $T (= 11.3 - 3.2) = 8.1 \pm 0.2 \text{ ms}$. ✓
- Number of revolutions per second $\left(= \frac{1}{T} = \frac{1}{8.1 \times 10^{-3}} \right) = 120 (\pm 10) (\text{rev s}^{-1})$. ✓ 2
- (b) Signal is noisy **OR** output is not at appropriate levels for logic circuit. ✓ 1
- (c) $V_A \left(= \frac{12}{12 + 8.2} \times 5 \right) = (+)2.97 V$ ✓ 1
- (d) Output pd switches between 0 and +5V. ✓
- Output pd is inverted compared to input pd. ✓
- Waveform has vertical sides cutting curve at about 3V. ✓
- MAX 2

[6]

Q8.

- (a) $V_B (= IR = 5 \times 10^{-10} \times 22 \times 10^6) = 0.011 V (11 \text{ mV})$ ✓ 1
- (b) Resistance of voltmeter and $22 M\Omega$ in parallel $\approx 1 M\Omega$ ✓
- Current of $5 \times 10^{-10} A$ in this combination gives pd $\approx 0.5 \text{ mV}$ ✓
- Qualitative answer can score both marks.* 2
- (c) Operational amplifier has very large input resistance. ✓
- This ensures that the $22 M\Omega$ resistor is not shunted by a lower resistance **or** ensures that (almost) all the current is in resistor rather than shared. ✓ 2
- (d) Two resistors labelled e.g. R_1 and R_F in correct connections. ✓✓
- i.e. R_F between -ve input and output, R_1 between 0V and -ve input.*
- 1 mark only if resistors are labelled wrong way round or are unlabelled.* 2

(e) 9.5 M Ω ✓

1

(f) Voltage gain = $\frac{R_1 + R_F}{R_1}$ gives $20 = \frac{0.5 + R_F}{0.5}$
 from which $10 = 0.5 + R_F$ (giving $R_F = 9.5 \text{ M } \Omega$) ✓

1

[9]

Q9.

- (a) 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 marking this question.

L3 5-6 marks	All three bullet points of the question are addressed in good detail.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3-4 marks	The answer includes some discussion of two or three of the three bullet points.	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	The answer addresses one bullet point in some detail but the others may be neglected.	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 marks	Little or no discussion of relevant content.	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

The following statements could be present:

- description of variable amplitude of AM carrier wave
- description of variable wavelength of FM carrier wave.

For AM :

- amplitude of carrier wave varies at frequency of superimposed signal whilst frequency (or wavelength) of carrier wave is constant

- *advantages of AM:*
 - *modulation is simpler to produce so equipment is less complex*
 - *fewer transmitters needed*
- *disadvantages of AM*
 - *more subject to interference and distortion*
 - *waveband has limited capacity.*

For FM:

- *frequency of carrier wave varies at frequency of superimposed signal whilst amplitude of carrier wave is constant*
- *advantages of FM:*
 - *less prone to interference*
 - *clearer reception*
 - *waveband has greater capacity*
- *disadvantages of FM:*
 - *signal less diffracted because of shorter wavelength so more difficult to receive*
 - *require more transmitters.*

6

(b) $\lambda \left(= \frac{c}{f} \right) = \frac{3.00 \times 10^8}{434 \times 10^6} = 0.691 \text{ (m)} \checkmark$

Length of aerial = 0.173 (m). $\checkmark$

2

(c) At 4 °C $f = 7.3(6\theta + 273)$ gives $f = 7.3(6 \times 4 + 273) = 2170 \text{ Hz} = 2.2 \text{ (kHz)} \checkmark$

1

(d) Bandwidth calculation based on higher frequency signal f_H i.e 3.0 kHz $\checkmark$ required bandwidth = $2 f_H = 6.0 \text{ kHz} \checkmark$

2

[11]

Q10.

- (a) Connections shown from Q_B and Q_D to AND gate inputs. $\checkmark$
Connection shown from output of AND gate to re-set terminal R of counter. $\checkmark$

2

- (b) Process numbers identified as 2, 5, 7, 8 and converted to 10, 101, 111, 1000 respectively. $\checkmark$

1

- (c) Q_A, Q_B, Q_C and Q_D [or **A, B, C, D**] identified with 1, 2, 4 and 8 respectively [or with 1, 10, 100, 1000 or $2^0, 2^1, 2^2$ and 2^3]. $\checkmark$

Interpretation of expression as

$\bar{D}.\bar{C}.B.\bar{A}$ meaning $(0+0+2+0) = 2$

OR $\bar{D}.C.\bar{B}.A$ meaning $(0+4+0+1) = 5$

OR $\bar{D}.C.B.A$ meaning $(0+4+2+1) = 7$

OR $D.\bar{C}.\bar{B}.\bar{A}$ meaning $(8+0+0+0) = 8$

(i.e. 2 OR 5 OR 7 OR 8).✓

Allow 1 mark for confusing whether A or D is the least confusing bit.

Allow ECF from incorrect process numbers in part (b) but only allow MAX 1 if 3 process numbers or fewer are identified.

2

[5]

Q11.

- (a) No pd across $100\text{ k}\Omega$ (since no current through it) so both inputs are 0 V / logic 0 and output there for logic 1.✓

1

(b)
$$\left(V = V_0 \left(1 - e^{-\frac{t}{RC}} \right) \right) \text{ and } RC = 10\text{ s gives } 2.5 = 5.0 \left(1 - e^{-\frac{t}{10}} \right) \checkmark$$

Solution gives $t = 6.93\text{ s}$.✓

2

- (c) Any appropriate time delay application that leaves a device switched ON or OFF for a short time after activation or deactivation.✓

e.g. Car interior light as driver leaves vehicle, intruder alarm exit delay.

1

[4]

Q29.

(a)

A	B	a	b	c	d	e	f	g	Display
0	0	0	0	0	1	1	1	0	L
0	1	1	0	1	1	0	1	1	S
1	0	1	0	1	1	0	1	1	S
1	1	0	1	1	0	1	1	1	H

1 mark for row L

1 mark for row S (both)

1 mark for row H

3

- (b) EXOR gate

1

- (c) (i) Different combinations produce different brightness
1 Disadvantage

1

- (ii) $R = V/I$; $(5V - 2.2V) / 20mA$; $2.8V / 20mA = 140\Omega$
 1 mark for 2.8V drop
 1 mark for answer

2

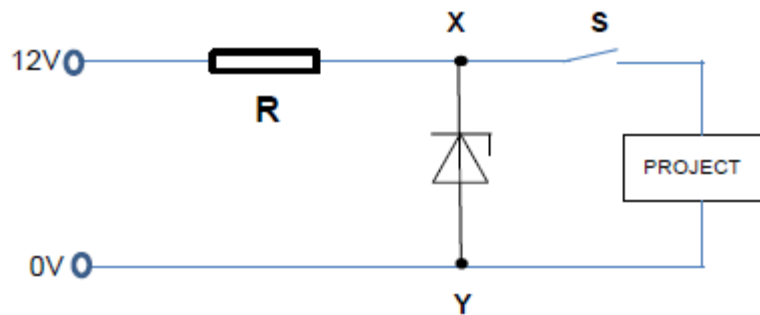
- (iii) $E24 = 150\Omega$
 1 mark for answer

1

(8)

Q30.

(a)



1 mark for Zener symbol
 1 mark for orientation

2

- (b) (i) $80mA + 5mA = 85mA$
 Answer – 1

1

- (ii) $12V - 5.1V = 6.9V$
 Calculation and answer – 1

1

- (iii) $R = 6.9V / 85mA = 81\Omega$
 Calculation and answer – 2

2

- (c) (i) $P = V^2 / R_P = (6.9 \times 6.9) / 75P = 0.64W$
 Hence P is approx. 0.6W
 Calculation and answer – 2

2

- (ii) $I = V / R$ $I = 6.9 / 75$ $I = 92mA$
 Calculation and answer – 2

2

[10]

Q31.

- (a) $D = C + B$

1

$$E = \overline{A}$$

$$G = \overline{A+B}$$

3

(b)

INPUTS			INTERMEDIATE OUTPUTS		
C	B	A	D	E	G
0	0	0	0	1	1
0	0	1	0	0	0
0	1	0	1	1	0
0	1	1	1	0	0
1	0	0	1	1	1
1	0	1	1	0	0
1	1	0	1	1	0
1	1	1	1	0	0

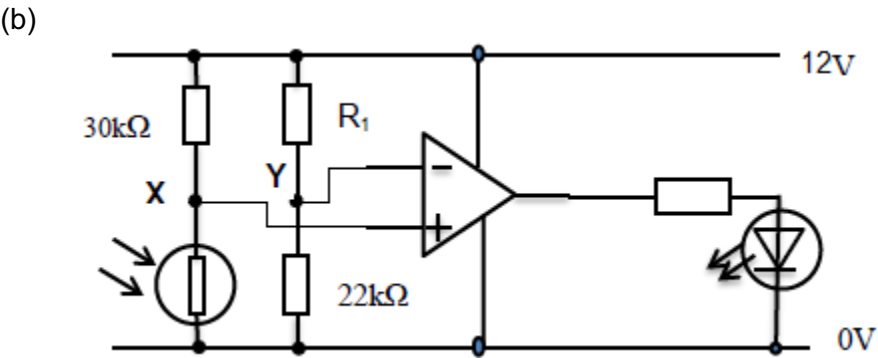
2 marks for each of correct columns D & G
 1 mark for column E

5
 (Total 8 marks)

Q32.

- (a) (i) Log graph enables a wide range of values to be displayed on the same axis.
 Allow – (enables values to be displayed as straight line)
- (ii) 7 lux

1
 1



1 mark for connections correct way round

1

(c) (i) $60\text{ k}\Omega / (60\text{ k}\Omega + 30\text{ k}\Omega) \times 12\text{ V} = 8\text{ V}$

Working – 1

Answer – 1

2

(ii) $R_1 = 11\text{ k}\Omega$ to give same value at Y as switching voltage at X (2:1 ratio)
(No ecf on value)

Reason / calculation – 1

Answer – 1

2

(d) The op-amp is not ideal and will saturate above 0V

Saturation – 1

Need to drop voltage

Voltage drop – 1

Acceptable method

Method – 1

3

(Total 10 marks)

Q33.

(a)

INPUTS			OUTPUTS		
Tunnel Sensor T	Car Sensor C	Lorry Sensor L	Message Display M	Red Stop light R	Green Go light G
0	0	0	0	0	1
0	0	1	0	0	1
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	1	0
1	0	1	0	1	0
1	1	0	0	1	0
1	1	1	1	1	0

Column M – 2 marks

Column G – 2 marks

4

(b) $R = T + (C.L)$

1 mark for terms

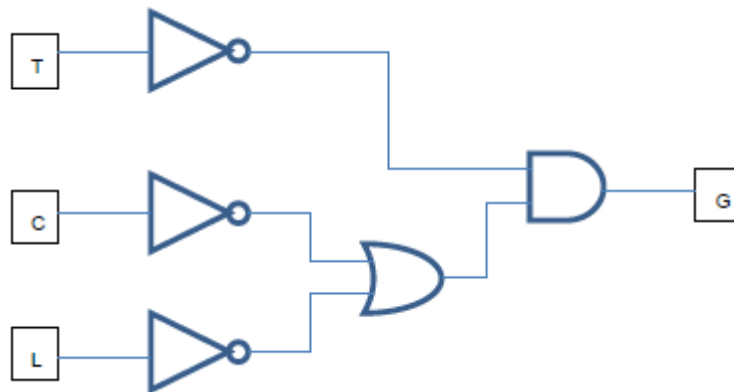
1 mark for OR

Or for full expression $S = T + (\bar{T} \cdot C \cdot L)$

Max 1 mark

2

(c)



3

(Total 9 marks)

Q34.

(a) (i) A
(at inverting input)

1

(ii) a point on the circuit where the voltage is 0v / ground
but not connected to 0v / is almost 0v / simulates 0v
assuming that the op-amp has not saturated

2 max

(iii) 10kΩ (must have units unless 10,000 which assumes standard)
oe 10,000Ω / 10K etc

1

(b) correct formula rearranged
calculation / substitution
470kΩ

3 for just correct answer with units

3

(c) inverted,
same frequency,
shape shows evidence of correct gain
maximum amplitude 3v to 5v

4

[11]

Examiner reports

Q1.

- (a) This question tested the ability of students to write a Boolean expression to represent a given logic circuit. The question was answered well (70% of students gained both marks) and most students opted for the algebraic version, although a few gave a written version which received equal credit. Future questions of this nature will probably be written asking specifically for the **algebraic** version.
- (b) This question tested the knowledge of truth tables for a range of logic gates and the ability to analyse a combinational logic system. Overall, the question was answered well, with 79% of students scoring two marks.
- (c) This question was a little more demanding. A few students became side-tracked by expecting the manufacturer of the system also to make the logic IC's. However, most students were able to produce a viable answer based on cost and space. 86% gained at least one mark here. *Students should be shown a diagram of a typical 2-input logic gate arrangement on an IC, even if they do not use the IC.*
- (d) This was a straight recall question. Many students (79%) correctly identified the **Q** column in the truth table as being that of the exclusive OR gate.

Q2.

- (a) This proved to be a simple calculation for most students, with 84% gaining the mark.
- (b) Just under 50% of the students picked up maximum marks for correctly drawing the non-inverting amplifier. Although many produced the arrangement shown in the mark scheme, other arrangements of the resistor chain were accepted. However, a significant proportion of students (40%) were unable to score on this question.
- (c) The first mark here was given for identifying the correct formula and then for showing the resistor ratio to be 39. When faced with this information, it is always worth checking to see if using 1 k Ω for the lower resistor leads to a sensible value for the top resistor. This produced the second mark. Most students scored well on this question, with 68% gaining both marks.
- (d) The best answers for this question came from students who appreciated that there would be a 50 kHz signal going into an operational amplifier having a gain-bandwidth product of 1 MHz, leading to a maximum gain of only 20. This approach comes from the question which asked candidates to: 'Discuss whether **this** operational amplifier is suitable...' 29% of students scored both marks. However, one mark was given if students got as far as showing that the operational amplifier really needed to have a gain-bandwidth product of twice that of the amplifier used in the circuit. The main error here was produced by students thinking that the 50 kHz signal was being transmitted by an AM system wrongly leading to a total bandwidth of 100 kHz. *It will always be made clear in the question if AM/FM transmission is in use.*

Q3.

- (a) The virtual earth point was identified correctly by many students.
- (b) The terminal was correctly identified by most students.

- (c) A significant number of students did not explain their thinking behind the derivation. The key points in the mark scheme included the same current flowing in the input and feedback resistors, and the use of the virtual earth point when considering the voltage across the resistors.
- (d) Unfortunately, a number of students ignored or forgot the sign in this relatively straightforward calculation. Both sign and number were needed for the single mark.
- (e) This calculation was a little more complex, particularly involving the signs. The allocation of two marks enabled students who showed proof of a correct method to gain some credit, even if an error was made in the final step.
- (f) A range of sensible answers was accepted. It was a pity that some students lost sight of the application, but on this occasion the mark was awarded just for a simple statement of fact.

Q4.

- (a) Most students did not appear to be distracted by the context of this question and the truth table was done well.
- (b) A small number of students committed to analysing this using a complex piece of Boolean algebra, which did not lead to the simplest solution. Most, however, spotted the short-cut.
- (c) A number of students were thrown by two aspects of this circuit which has been designed so that '0' or a blank is never shown on the display.
 - (i) The counter starts at 0000, but the logic process allows the display to be '1' (1 dot). Effectively the display is always one ahead of the decimal equivalent of the binary code on the counter.
 - (ii) The reset binary code is 0110 and only lasts for a split second, so no output is shown for this code. However, when the reset has been completed then the counter code will be 0000 and the display will show decimal '1' (1 dot).

As a result of the above, students were still able to gain credit for using a single AND gate, even if they did not use the correct tap off points on the counter.

- (d) Most students were able to draw/complete the logic diagram from the Boolean expression provided. This is a vital skill in the digital section of the specification.

Q5.

- (a) Some students struggled with extracting C from the formula, and one or two lost some powers of ten. Again, it is recommended that students always show all stages of their working, so that some credit can be gained even if the final answer is wrong.
- (b) Most students answered this question well, although a significant number failed to show on the graph the appropriate frequencies matched to the ~ 0.7 voltage gain point.
- (c) Some students were rather 'clinical' in their response to this question and forgot to relate their answer to the context of the 'listener'.

Q6.

- (a) This proved to be a straightforward question.
- (b) This also proved to be straightforward.
- (c) This was a complex graph, but most students produced a result that was within the acceptable range of values given in the mark scheme.
- (d) It was disappointing to see a number of students not being able to follow through an Ohm's Law calculation when given all necessary values. Otherwise the question was answered well.
- (e) This question required students to correctly apply the comparator rule to give 0 Volts output, then to appreciate that the voltage drop across the LED would turn it on.
A number of students successfully gained the first mark but then wrongly assumed that a 0 Volt output would turn the LED off, forgetting that the comparator would sink current.

Q29.

- (a) A high percentage of candidates correctly completed the truth table.
- (b) Only a few candidates who achieved success in section (a) did not go on to gain the mark here.
- (c) Answers relating to the dimming of segments as more segments were lit were less evident, but the calculation and selection of the E24 resistor proved to be straight forward.

Q30.

- (a) An easier start than last year as the position for the component was already given. A large number of candidates were successful here although one or two protective resistors crept in and some symbols had the circle with a free-floating centre character which detracted from the quality of the answer.
- (b) This section of the question was straight forward for the majority of candidates.
- (c) The power calculations proved to be more selective in terms of response. Good candidates spotted the need for a V^2 / R approach in (i), whilst the easier calculation in (ii) proved to be a more demanding concept as the calculation needed to be centred on the data for the series resistor R.

Q31.

- (a) This part was answered well with a high proportion of candidates gaining full marks.
- (b) The truth table proved to be slightly more demanding, but still allowed a large percentage of the candidature access to some marks.

Q32.

- (a) The mark in part (i) was most often lost by the explanation being too general – e.g. 'it's better'. However, the reading required from the graph in part (ii) was accurately achieved by most candidates.

- (b) A significant number of candidates were able to connect the inputs to the correct pins of the op-amp to make the circuit function as described.
- (c) The question appeared to expose the lack of understanding of how a transistor-based control circuit can be used to interact with an independent power circuit via an interface (relay).
- (d) This part follows the established question of looking at how saturation affects the output voltage characteristics of real op-amps and how this differs to the characteristic for an ideal one. Candidates are expected to formulate their answer based on the limitations of the op-amp in comparator mode as given in the question.

The latter part of the answer should have focused on how to make the low output voltage from the op-amp smaller than the forward voltage of the LED rather than just reducing the current. Solutions that would have appreciably affected circuit operation when the op-amp gave a high output or potentially cause damage to the LED did not gain credit.

Q33.

- (a) A high percentage of candidates correctly completed the truth table. The loss of just a single mark was mainly due to the green light being left on when a lorry was detected.
- (b) Just over half of the candidates were able to construct the correct Boolean expression for the red light from the given completed column in the truth table.
- (c) Part (c) was done very well, with most candidates opting for the solution given on the mark scheme. However, a few candidates also produced an equally valid design based on an expansion of the given expression for **G**.

Q34.

- (a)
 - (i) Most candidates selected the correct option.
 - (ii) A large number of answers tended to repeat the word 'earth' used in the question, scoring only one point.
 - (iii) The vast majority gave the correct answer.
- (b) Many gave the correct answer, but workings showing clearly how it was arrived at were less common.
- (c) Many were able to sketch an inverted wave of the same frequency, several gave evidence of using the gain to calculate a theoretical peak voltage, but few noticed the power supply limitation of the circuit.