AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.13 ELECTRONICS: DEVICES

SCORE	PERCENTAGE
/134	%

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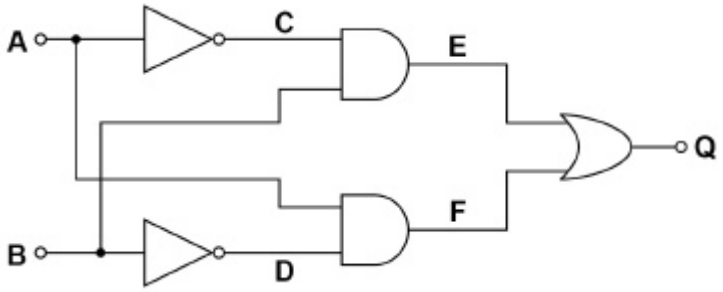
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Q1.

(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**.

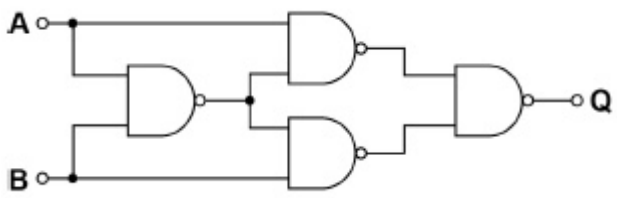
Complete the truth table.

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



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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**.

_____

_____

_____

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_____

(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

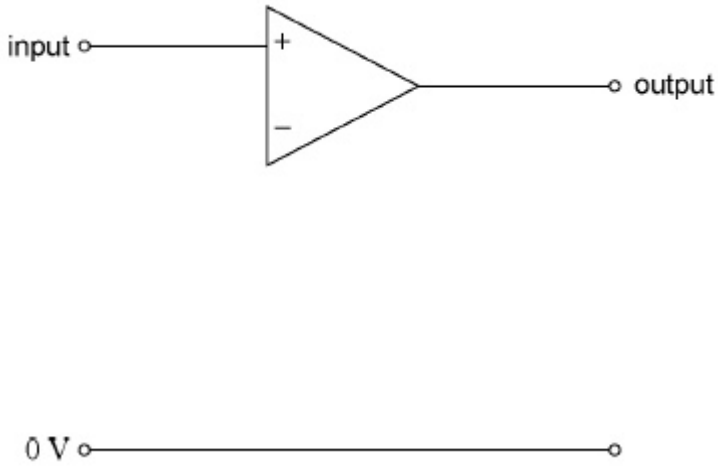
Calculate the input voltage V_{in} to the amplifier from the sensor.

V_{in} = _____ 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.

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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 kΩ 3.6 kΩ 10 kΩ 39 kΩ 150 kΩ

R_{in} **=** _____ **kΩ**

R_f **=** _____ **kΩ**

(2)

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

gain × bandwidth = 1.0 MHz

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

_____

_____

_____

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_____

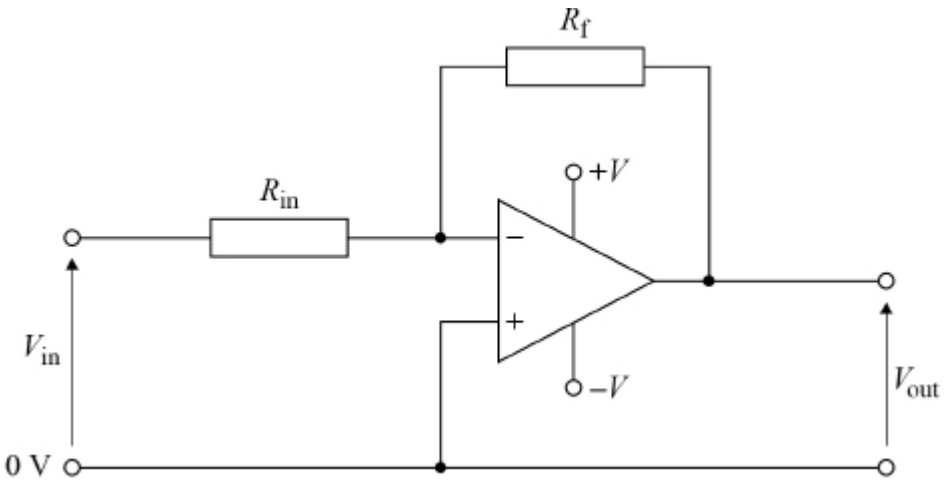
(2)

(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)

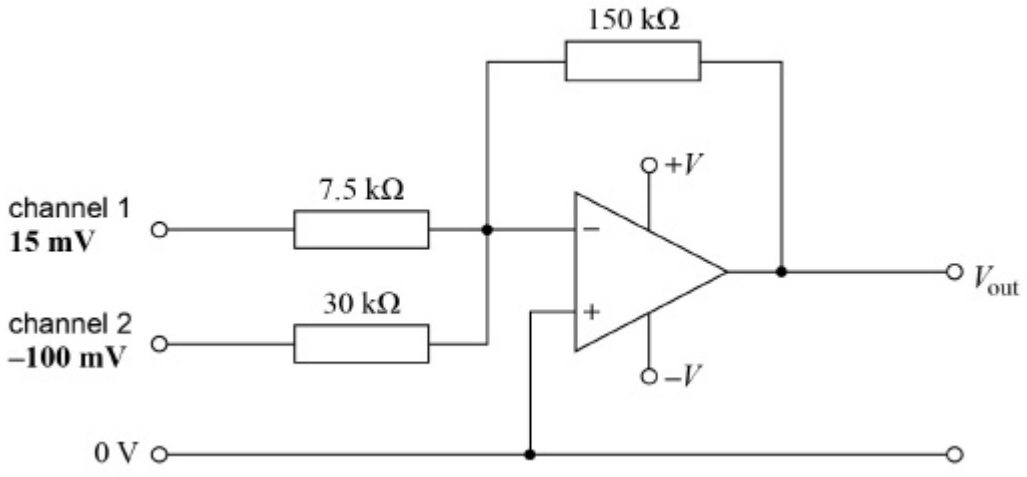
(c) Derive the expression for the inverting amplifier gain $\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$

(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

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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

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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

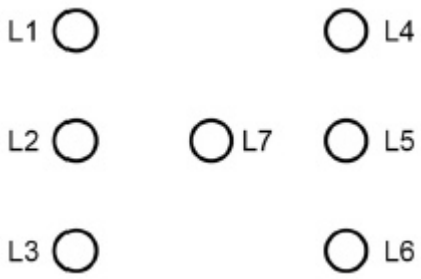
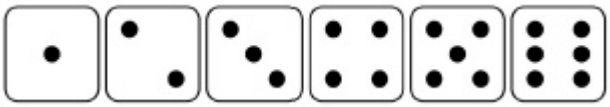


Figure 3 shows the sequence of numbers.

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)

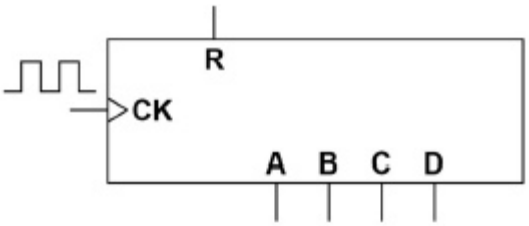
(b) Deduce the **simplest** Boolean expression that can be used to show how output L7 can be controlled by the logic inputs.

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(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)

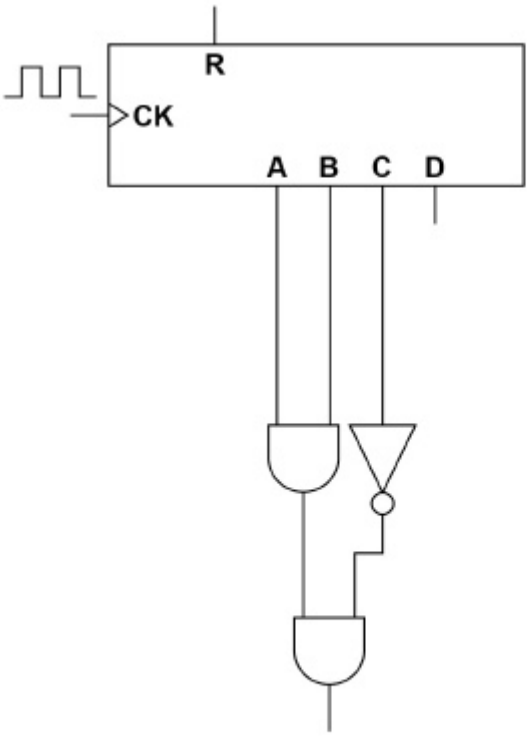
(d) The output of both L3 and L4 can be written as **$(A.B.\overline{C}) + (\overline{B}.C)$**

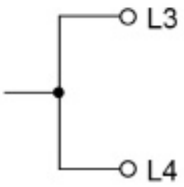
Figure 5 shows part of a logic circuit needed to represent this Boolean expression.

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

Figure 5

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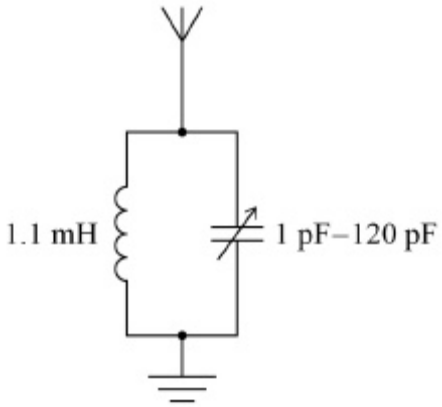
(3)

(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.

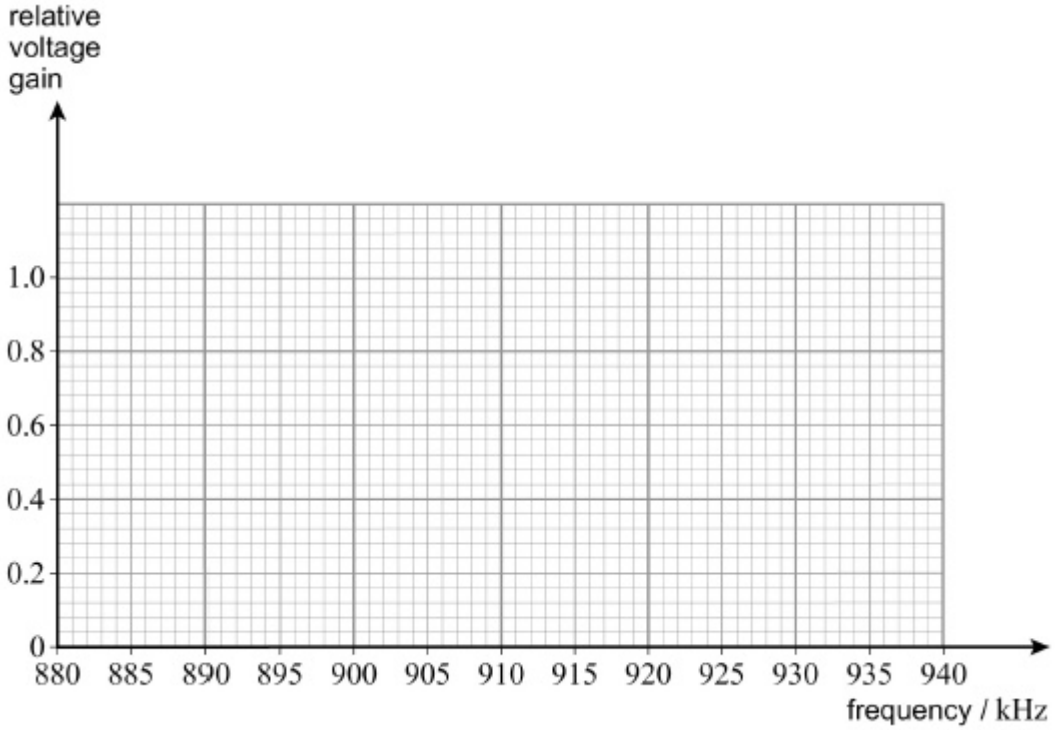
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capacitance = _____ pF

(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.

_____

_____

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(2)

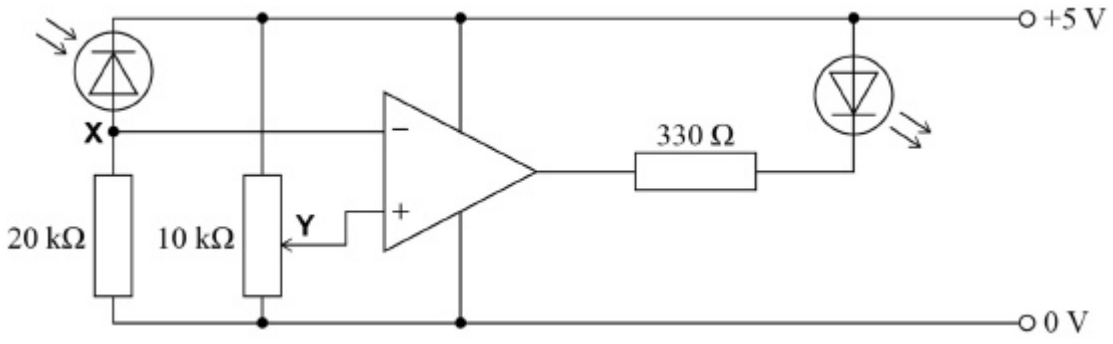
(Total 7 marks)

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.

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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 ☐

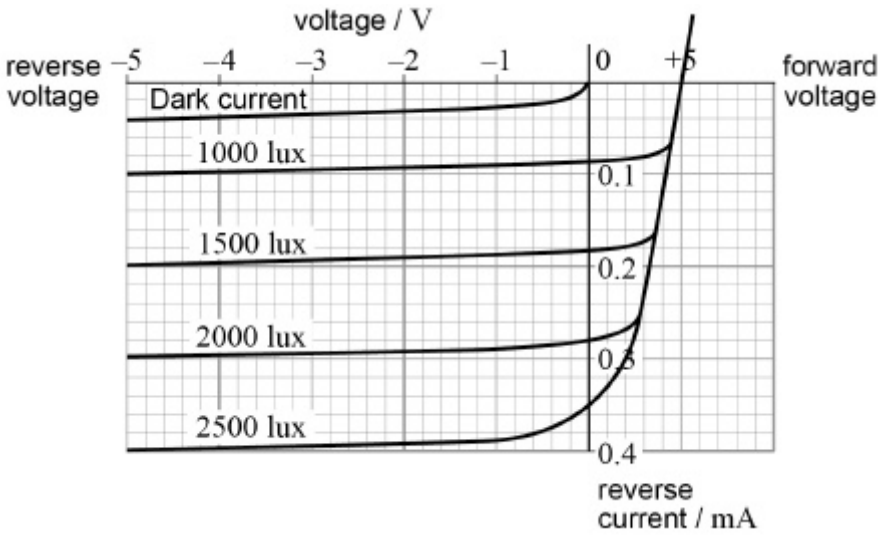
Summing amplifier ☐

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



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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 10kΩ 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.

_____

_____

_____

_____

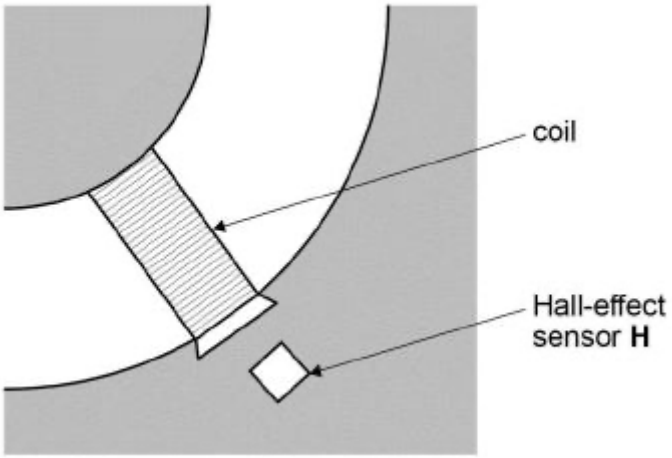
(2)

(Total 6 marks)

Q7.

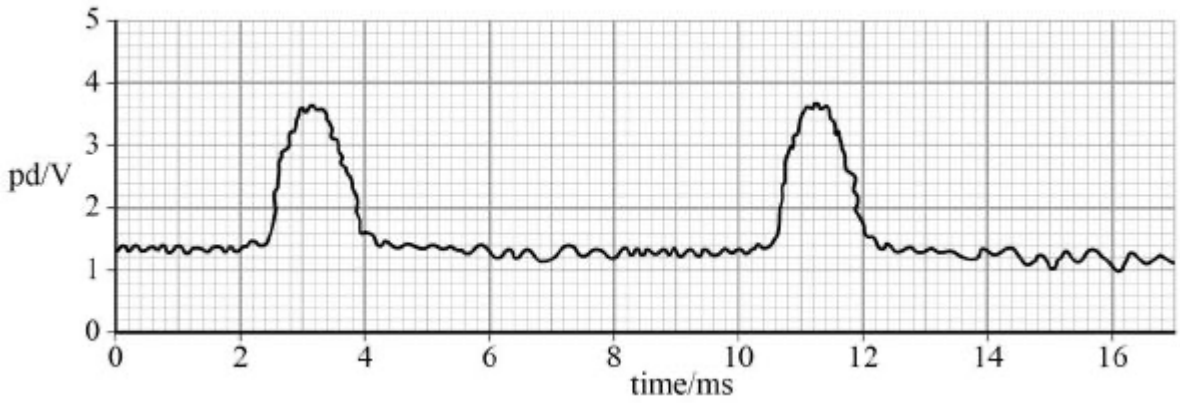
The diagram shows part of the motor from a computer disk drive.

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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.

_____

_____

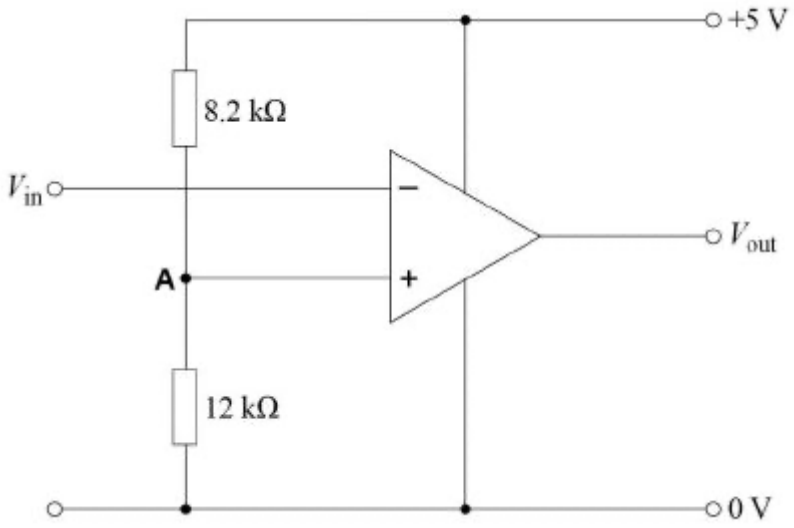
_____

(1)

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(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.

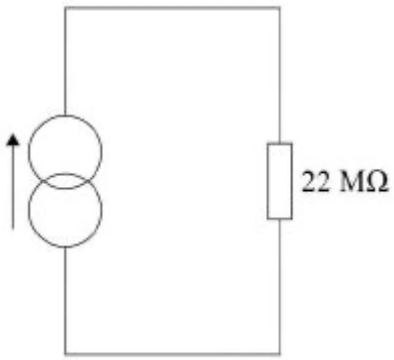
(1)

(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 $\mathrm{M\Omega}$ resistor.



(a) The output from the current generator is 5.0×10^{-10} A.

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

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(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 $\mathrm{M\Omega}$.

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

(2)

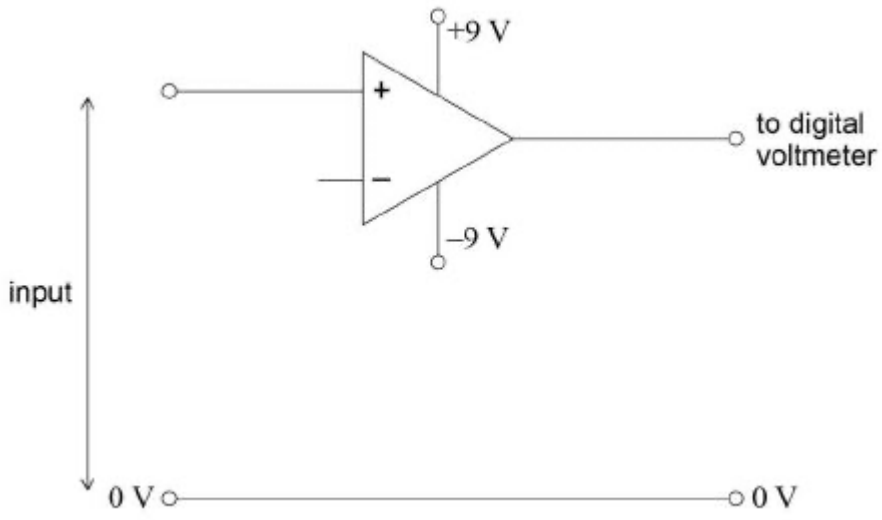
(c) The student then decides to use a non-inverting operational amplifier to interface to the digital voltmeter.

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

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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.

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(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 $^{\circ}\mathrm{C}$) according to the equation

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

During the course of the year the temperature of the pond varies between 4$^{\circ}\mathrm{C}$ and 22$^{\circ}\mathrm{C}$. 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.

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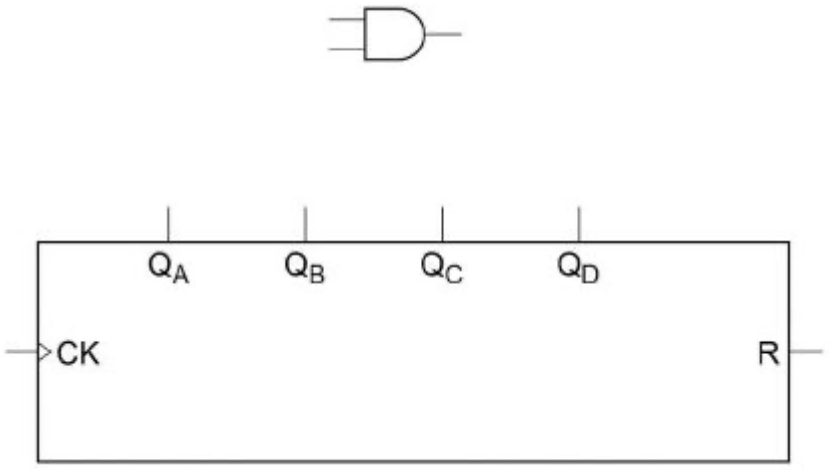
(2)

(Total 11 marks)

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.

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(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

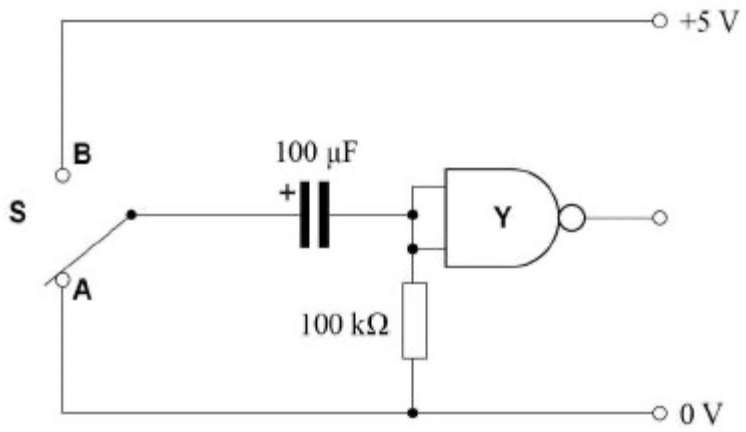
$$=\overline{D}.\overline{C}.B.\overline{A} + \overline{D}.C.\overline{B}.A + \overline{D}.C.B.A + D.\overline{C}.\overline{B}.\overline{A}$$

(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.

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_____

(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

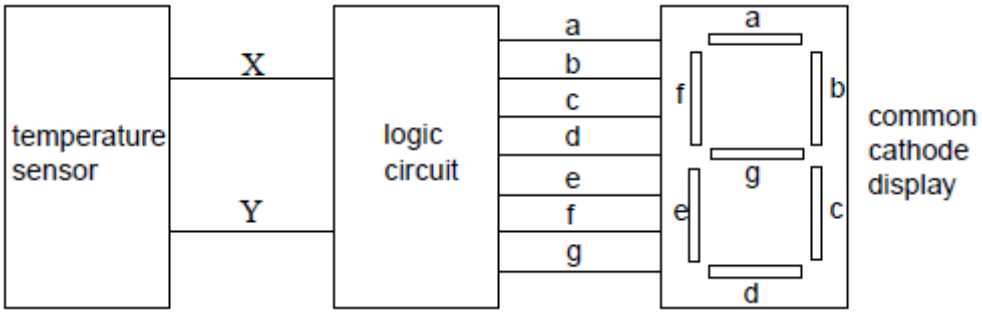


Table 1 shows the operation of the system.

Table 1

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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**.

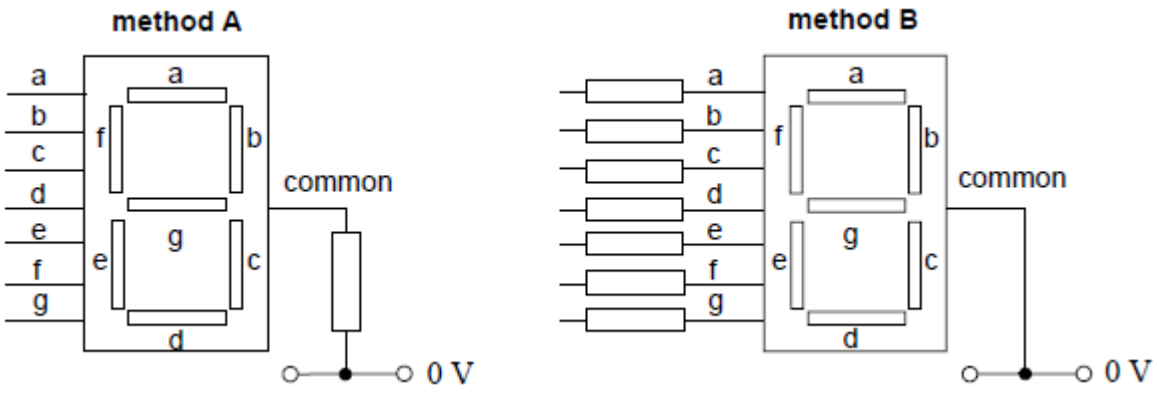
AND EXOR OR NAND NOR NOT

(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

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(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 kΩ 1.5 kΩ

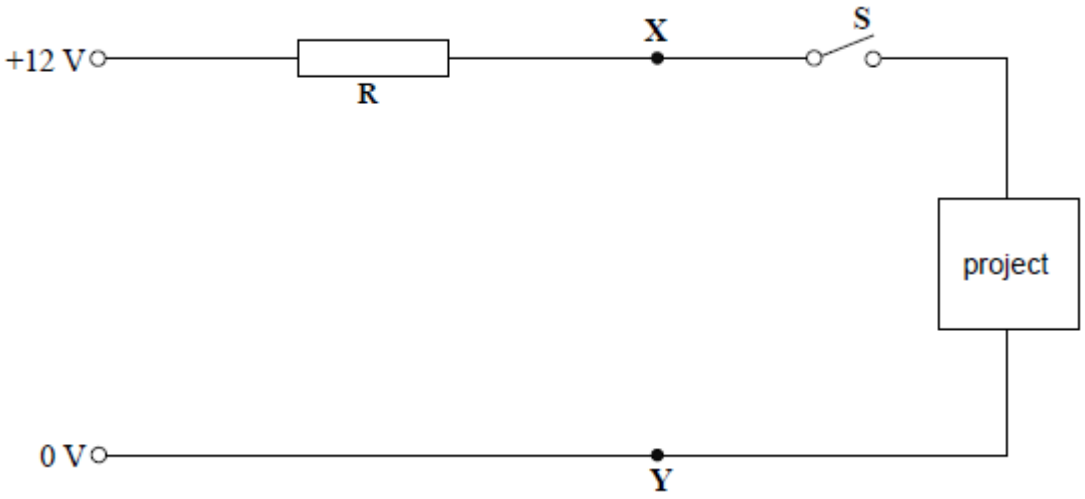
(1)

(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.

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(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)

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(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.

_____

_____

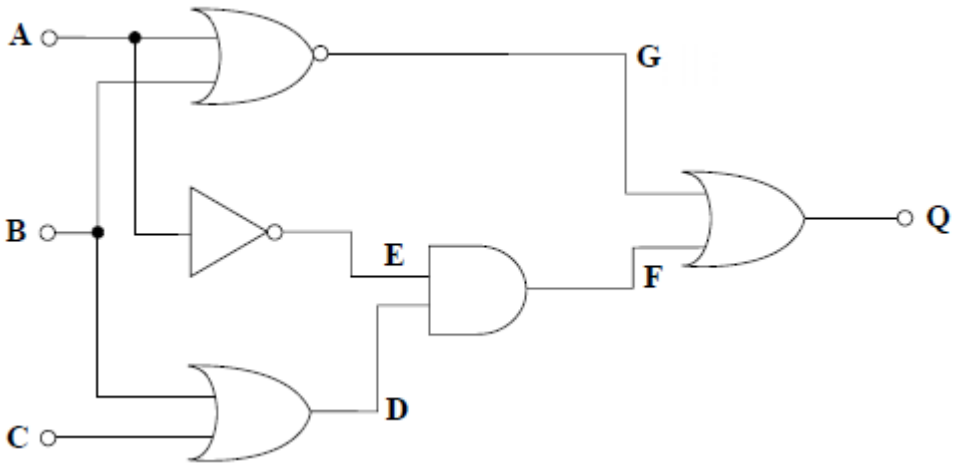
_____

(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			

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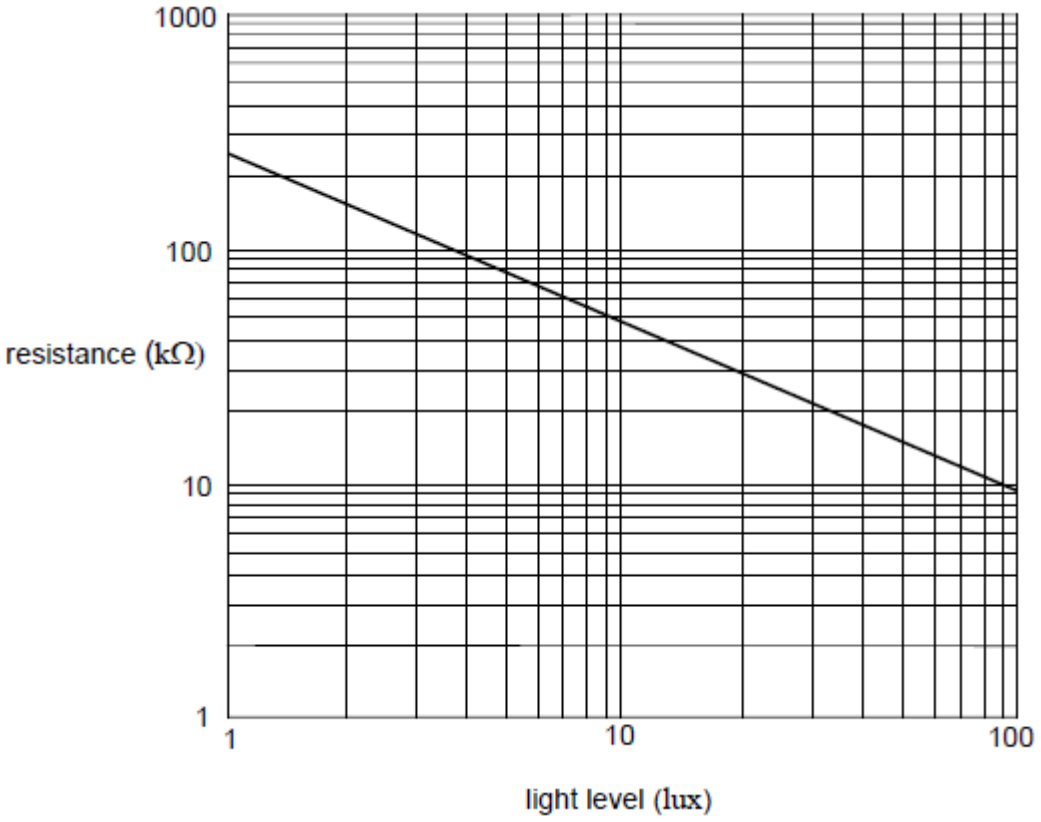
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

(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.

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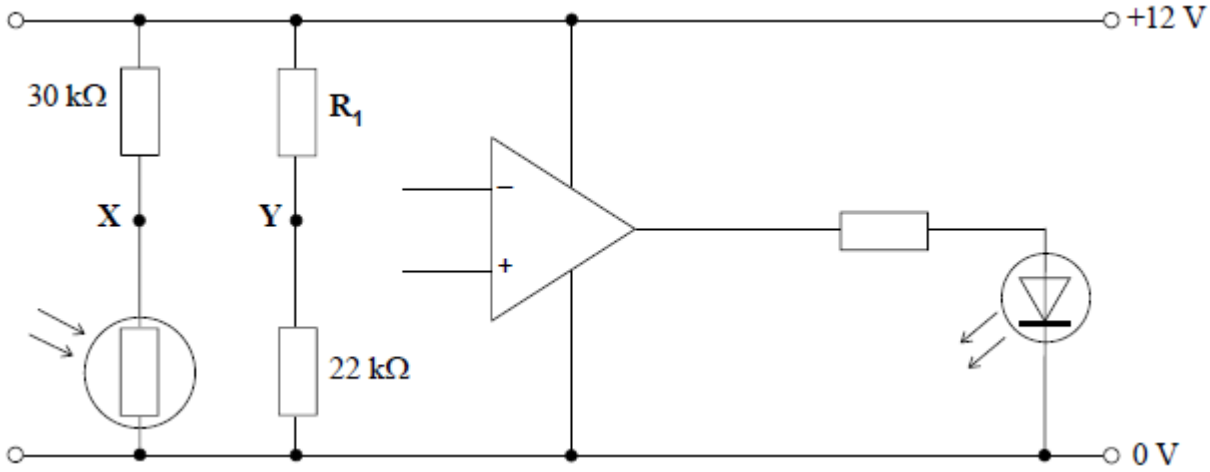
State the value of this light level by reading from the graph in **Figure 1**.

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 $\mathbf{R_1}$ 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.

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_____

_____

_____

_____

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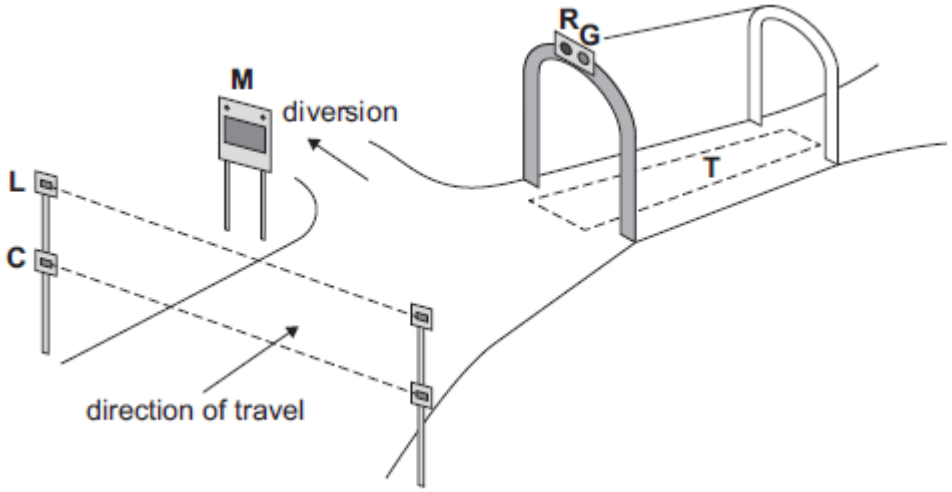
(3)

(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.

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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** = $\overline{T}.(\overline{C}+\overline{L})$

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

Figure 2



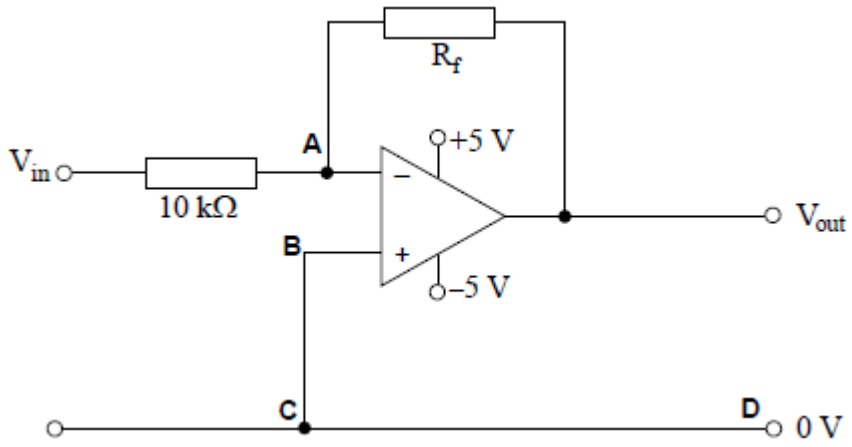
(3)
(Total 9 marks)

Q34.

Figure 1 shows an inverting op-amp amplifier subsystem.

Figure 1

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(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)

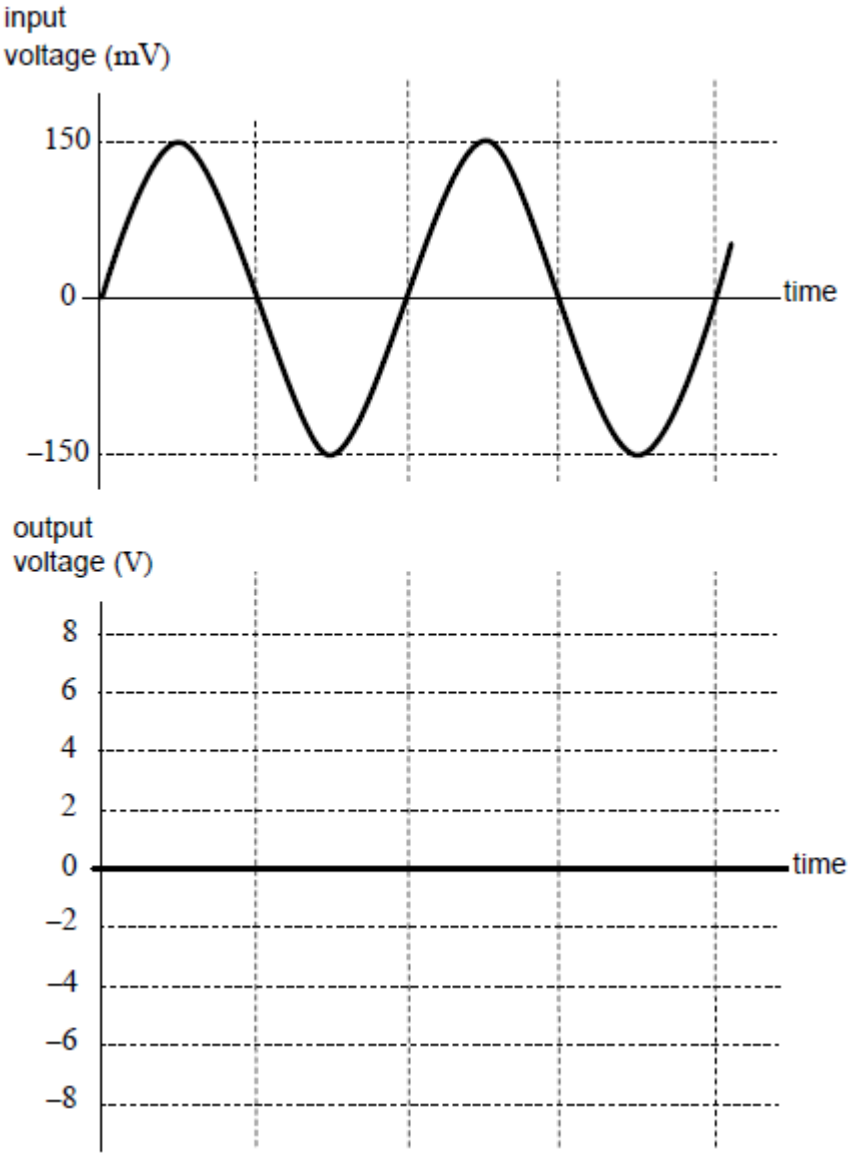
(c) The amplifier subsystem in part **(b)** is used to increase the signal voltage from an electric guitar.

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

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(4)

(Total 11 marks)

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