5th Form Electronics

End of Year Exam 2019

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Additional Materials:
In addition to this examination paper, you will require a calculator.

Instructions to candidates:
Use black ink or black ball-point pen.
Answer all questions.
Write your name in the space at the top of this page
Write you answers in the spaces provided in this booklet.

Information for candidates:
The number of marks is given in brackets at the end of each question or part question.
The assessment of the quality of extended response (QER) will take place in question 9

Question	Max mark	Mark awarded
1	8	8
2	8	7
3	9	8
4	4	2
5	9	6
6	10	8
7	13	8
8	13	12
9	6	4
TOTAL	80	63

78.75%

INFORMATION SHEET

Resistor colour codes

black	0
brown	1
red	2
orange	3
yellow	4

green	5
blue	6
violet	7
grey	8
white	9

The fourth band colour gives the tolerance as follows:

gold ± 5%

silver ± 10%

Resistor E24 series values

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91

Useful equations

$$P = \frac{V^2}{R}$$

$$G = 1 + \frac{R_F}{R_1}$$

$$V_{OUT} = \frac{R_2}{R_1 + R_2} V_{IN}$$

$$G = -\frac{R_F}{R_{IN}}$$

$$I_D = g_M (V_{GS} - 3)$$

$$V_{OUT} = -R_F \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + ... \right)$$

$$I_C = h_{FE} I_B$$

$$T = 1.1RC$$

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

$$f = \frac{1}{T}$$

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

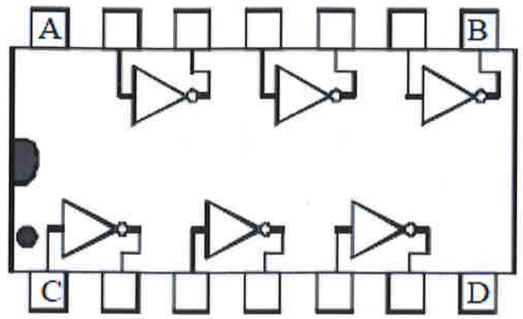
$$f = \frac{1.44}{(R_1 + 2R_2)C}$$

$$G = \frac{V_{OUT}}{V_{IN}}$$

$$\frac{T_{ON}}{T_{OFF}} = \frac{R_1 + R_2}{R_1}$$

Answer **all** *questions.*

1. *(a)* The diagram shows the pin out for an IC (integrated circuit).



(i) State the number of logic gates on this IC. ..... 6 ..... [1]

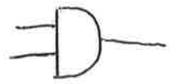
(ii) State the number of inputs on each gate. ..... 1 per gate 6 in total ..... [1]

(iii) State which pin (A, B, C or D) is pin 1 on this IC. ..... C ..... [1]

(iv) Name the type of logic gate found on this IC. ..... NOT ..... [1]

(b) Draw the logic gate symbol for:

(i) an AND gate; [1]



(ii) a NOR gate. [1]

(c) Here are five truth tables:

A.

Input		Output
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

B.

Input	Output
A	Q
0	1
1	0

C.

Input		Output
A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

D.

Input		Output
A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0

E.

Input		Output
A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

State which table is the truth table for:

(i) a NOT gate; ...B... [1]

(ii) a NAND gate. ...C... [1]

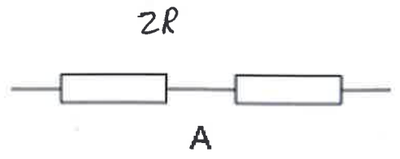
8

8

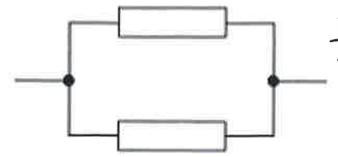
2. (a) Here are some different combinations of resistors. Each resistor has the same value.

$\frac{1}{R} + \frac{1}{R} = \frac{1}{R_{tot}}$

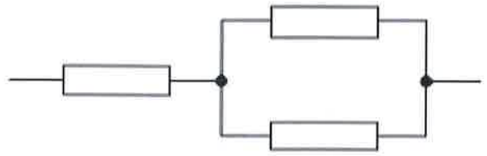
$\frac{2}{R} = \frac{1}{R_{tot}}$



A



B



C

State which combination has the smallest resistance. ...D... [1]

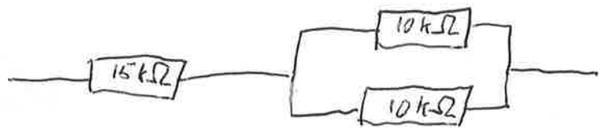
(b) The following resistor values are available to a student.

10 kΩ 15 kΩ

Resistor values may be selected **once, more than once or not at all.**

In the space below, draw a labelled network of three resistors that will produce a combined resistance 20 kΩ. [2]

$\frac{1}{10} + \frac{1}{10} = \frac{1}{R_{tot}}$



(c) Here are five truth tables:

A.

Input		Output
A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

B.

Input	Output
A	Q
0	1
1	0

C.

Input		Output
A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

D.

Input		Output
A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0

E.

Input		Output
A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

State which table is the truth table for:

(i) a NOT gate; ...B... [1]

(ii) a NAND gate. ...C... [1]

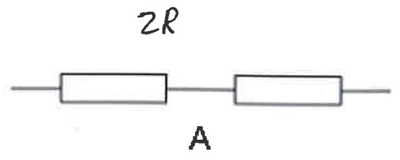
8

8

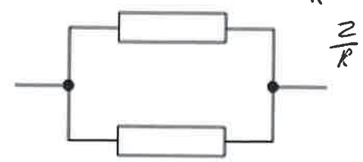
2. (a) Here are some different combinations of resistors. Each resistor has the **same** value.

$\frac{1}{R} + \frac{1}{R} = \frac{1}{R_{tot}}$

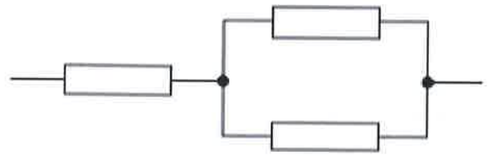
$\frac{2}{R} = \frac{1}{R_{tot}}$



A



B



C

State which combination has the smallest resistance. ...B... [1]

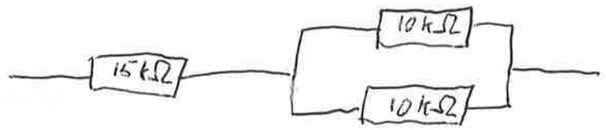
(b) The following resistor values are available to a student.

10 kΩ 15 kΩ

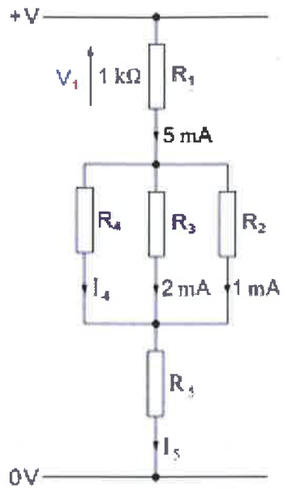
Resistor values may be selected **once, more than once or not at all.**

In the space below, draw a labelled network of **three** resistors that will produce a combined resistance 20 kΩ. [2]

$\frac{1}{10} + \frac{1}{10} = \frac{1}{R_{tot}}$



(c) The diagram shows part of a circuit.



(i) State which of the following is true. [1]

A. I_5 is bigger than 5 mA.

B. I_5 is equal to 5 mA.

C. I_5 is smaller than 5 mA.

Answer ..... B .....

(ii) Calculate the value of I_4. [1]

5 - 2 - 1
= 2

I_4 = ... 2 ..... mA

(iii) State what is the E24 colour code for resistor R_1. [3]

Band 1 ..... Brown .....

Band 2 ..... Black .....

Band 3 ..... Orange Red .....

R = 1k52

7/8

3. *(a)* Electronic sub-systems can be classed as either sensing, signal processing or output sub-systems.

For example, a transducer driver is a **signal processing** sub-system.

Here are five other sub-systems:

latch lamp unit NAND gate switch unit solenoid unit

Complete the table by adding the name of each sub-system in the correct column. [3]

Sensing sub-system	Signal processing	Output sub-system
Switch unit	transducer driver	Lamp unit
	NAND Gate	Solenoid unit
	Latch	

(b) Design an electronic system for road works on a motorway. The road works often go on for many miles so hazard warning lamps are placed alongside the road works to warn drivers of the dangers.

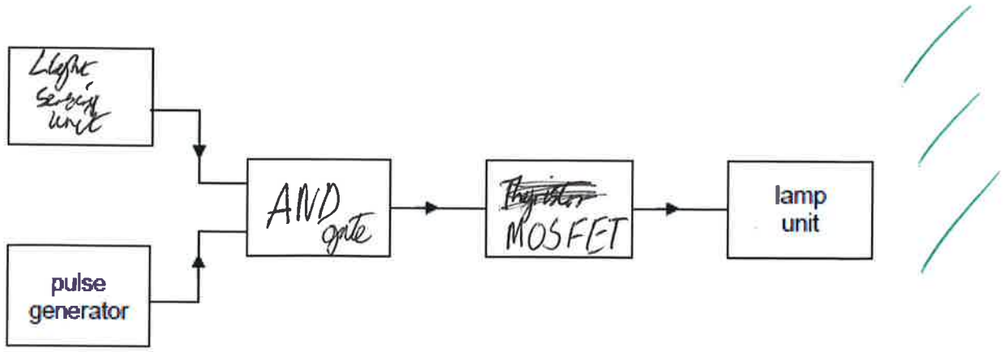
Specification for the system
The lamps:
- need to switch on when it gets dark
- flash on and off continuously
- switch off when it gets light.

The following sub-systems are available.

lamp unit **OR gate** **thyristor** **light sensing unit** **buzzer unit**

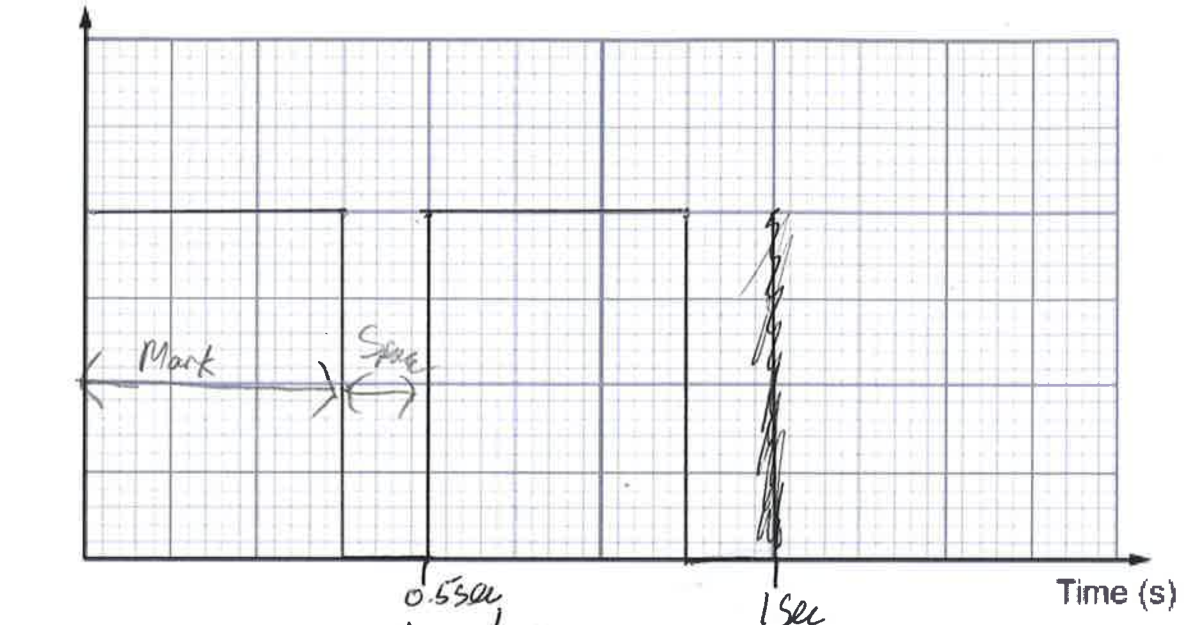
time delay **temperature sensing unit** **AND gate** **MOSFET**

Select the correct sub-systems to complete the block diagram design. [3]



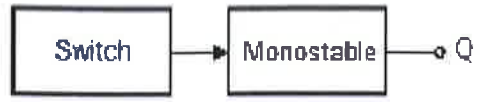
(c) The pulse generator is constructed from a 555 IC which has a mark-space ratio of 3:1 and a frequency of 2 Hz. On the grid below:

- draw two cycles of the output of the astable [3]
- clearly label the mark and space
- add a suitable scale to the time axis.

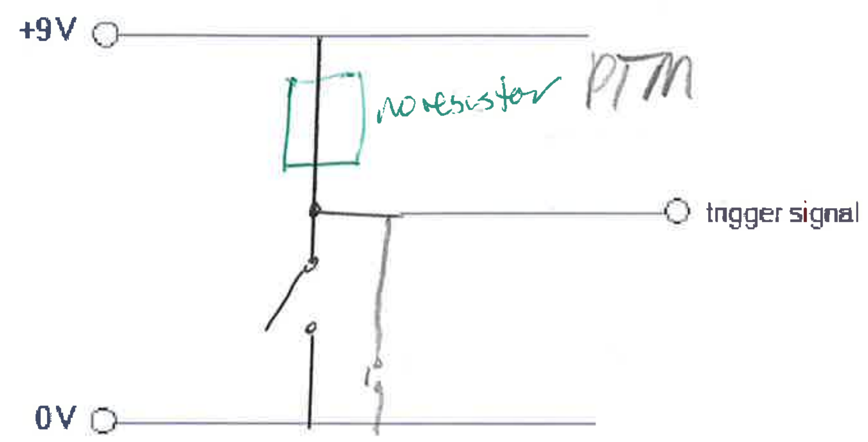


9

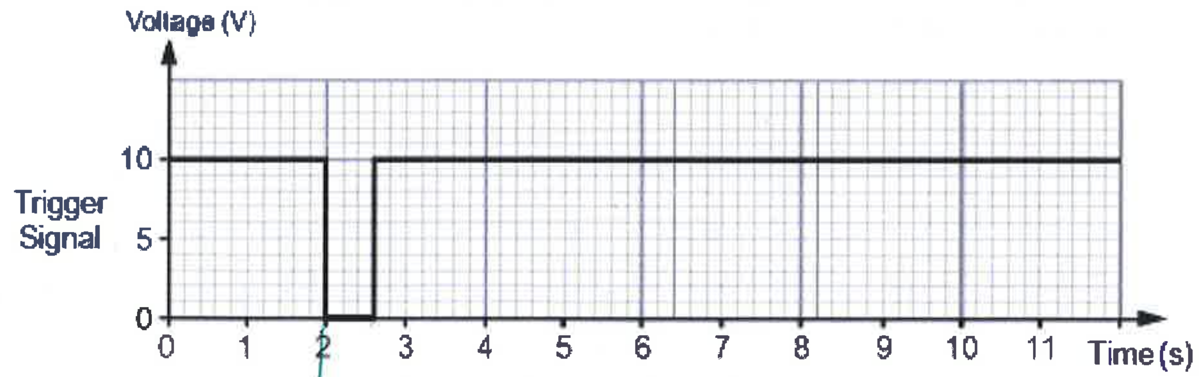
4. A switch sub-system is used to trigger a monostable sub-system.

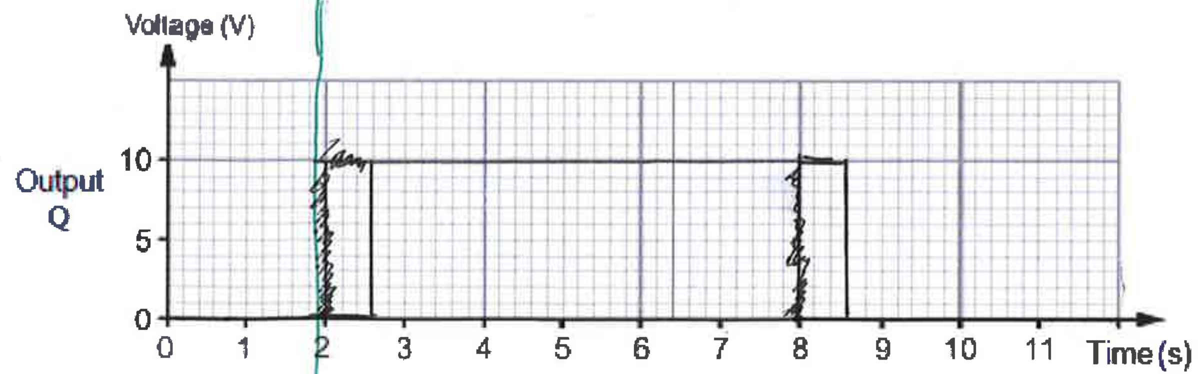


(a) Draw the circuit diagram for the switch sub-system so that it produces a logic 0 output when a switch is pressed. [2]



(b) The graph below shows the trigger signal to the monostable. Draw the output at Q if the period of the monostable is 6 s. [2]

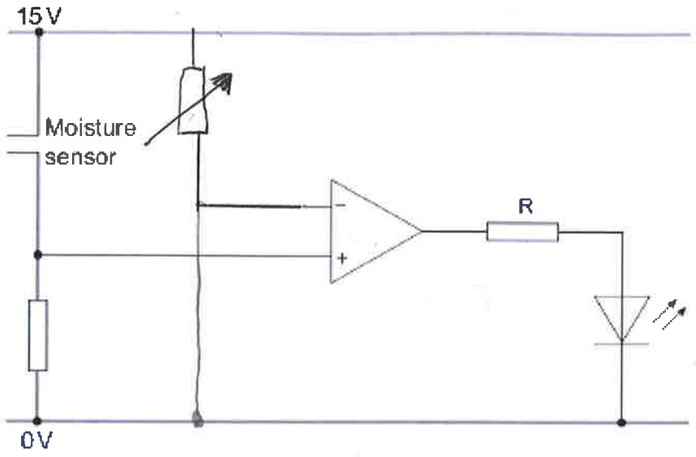




4

5. A comparator is used in a system to warn when a plant needs watering.
A moisture sensor is placed in the plant pot. It is connected to the comparator, which lights a high intensity LED when the soil in the plant pot is too dry.

Part of the circuit diagram is shown below.



The comparator has saturation values of 14 V and 0 V.

(a) **Add to the diagram** a single component to provide a variable voltage at the inverting input of the comparator. [2]

(b) When lit, the LED has a 2 V voltage drop across it, and a current of 40 mA. Calculate the resistance of resistor R, needed to protect the LED when the output of the comparator is in positive saturation. [4]

$V_R = 12V$
$I_R = 40mA$
$V = IR$
$R = \frac{V}{I}$
$R = \frac{12}{40 \times 10^{-3}}$
$R = 300$
$V_R = 14 - 2 = 12V$

resistance = 300Ω

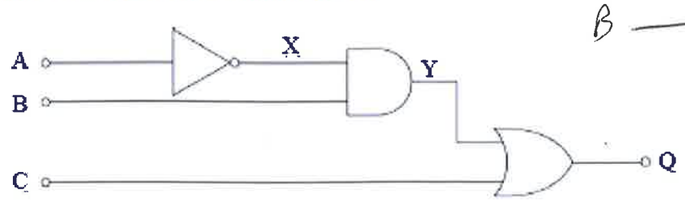
(c) Determine the power dissipated in this resistor when the LED has a current of 40 mA flowing through it. [3]

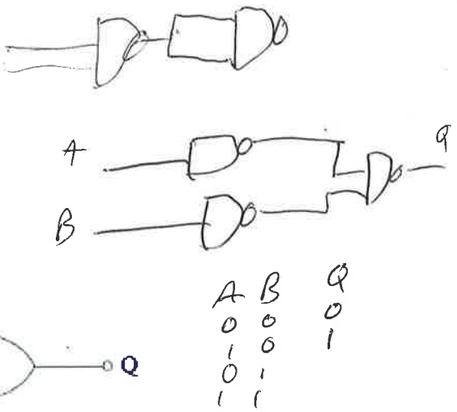
$P = \frac{V^2}{R}$ $R = I^2R$
$P = \frac{30}{(40 \times 10^{-3})^2}$
$P = 0.48W$

power = 0.48W

6
9

6. The diagram below shows a logic system.





(a) Write down in terms of the inputs A, B and C the Boolean expressions for: [3]

(i) Output X $\overline{A}$

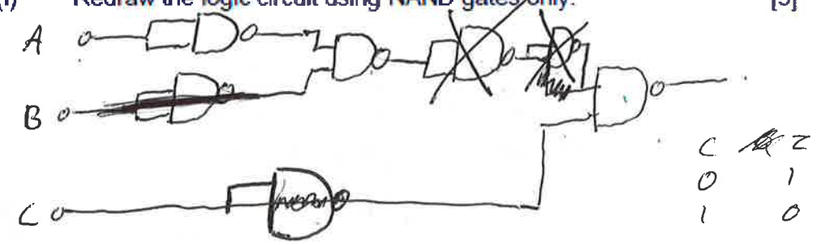
(ii) Output Y $\overline{A}+B$ $\overline{A}.B$

(iii) Output Q $(\overline{A}+B)+C$

(b) Complete the following truth table for this logic system. [3]

C	B	A	X	Y	Q
0	0	0	1	0	0
0	0	1	0	0	0
0	1	0	1	1	1
0	1	1	0	0	0
1	0	0	1	0	1
1	0	1	0	0	1
1	1	0	1	1	1
1	1	1	0	0	1

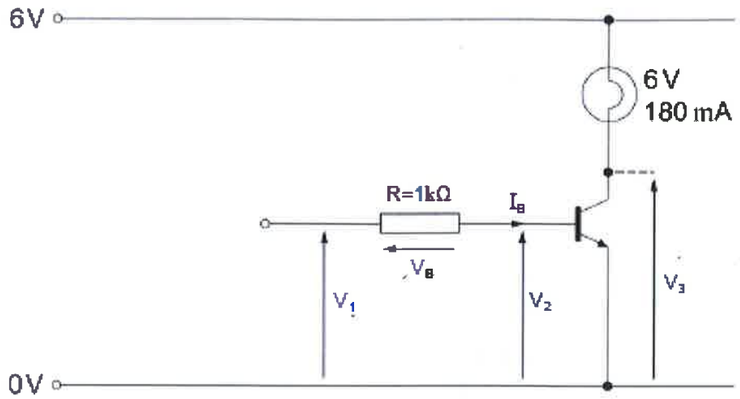
(c) (i) Redraw the logic circuit using NAND gates only. [3]



(ii) Cross out all redundant gates on the diagram above in (c) (i). [1]

8
10

7. The circuit diagram shows a transistor switch used as a transducer driver.



(a) The input voltage V_1 = 0.2V. Complete the table below.
The transistor is switched off. [2]

Input voltage, V_1 (V)	V_2	V_3
0.2	0.2	6

(b) The lamp is rated at 6V, 180 mA.
Calculate the power dissipated in the lamp when it is switched on fully. [2]

$P = IV$ $P = I^2R$ $P = \frac{V^2}{R}$
$P = 6 \times 180 \times 10^{-3}$ $P = (180 \times 10^{-3})^2 \times 1 \times 10^3$ $P = \frac{36}{1 \times 10^3}$
$P = 1.08$ $P = 32.4$ 1080 36

power = ... mW

(c) The input voltage is changed until the transistor is saturated. The transistor has a current gain (h_{FE}) of 90.

Calculate:

(i) the base current I_B; [2]

$h_{fe} = \frac{I_c}{I_b}$ $I_b = \frac{I_c}{h_{fe}}$
$I_b = \frac{180 \times 10^{-3}}{40}$
$I_b = 2$

I_B = ... mA

(ii) the voltage V_B across the base resistor; [2]

$V = IR$
$V = 2 \times 10^{-3} \times 1 \times 10^3$
$V = 2$

V_B = ... V

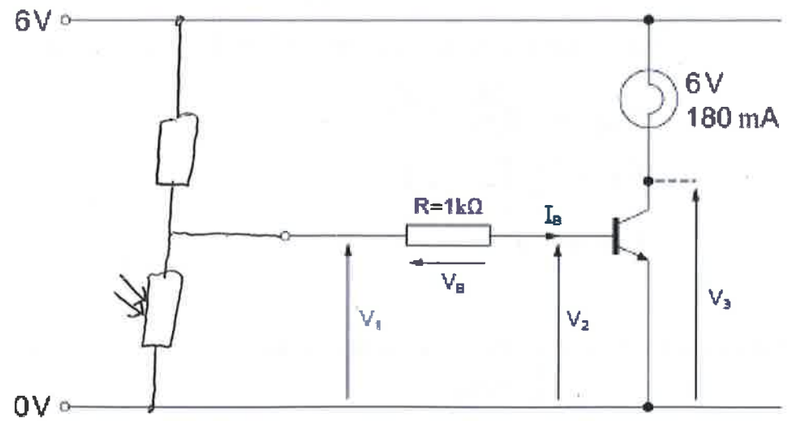
(iii) the input voltage V_1 from the sensing system; [1]

V_1 = ... V

(iv) state the new values of V_2 and V_3. [2]

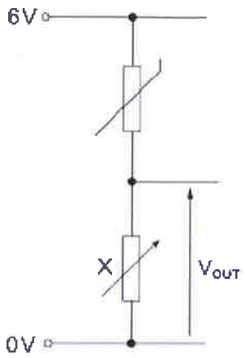
V_2 = ...
V_3 = ...

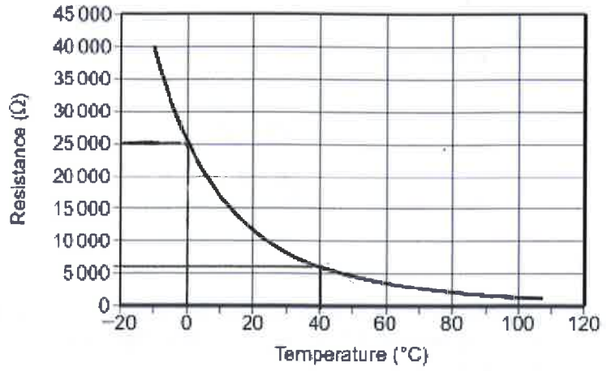
(d) Complete the circuit by adding a suitable light sensing circuit to the input of the transistor switch on the circuit diagram below, so that the lamp comes on in the dark. [2]



8
13

8. Here is the circuit diagram for a temperature sensing unit and the characteristic curve for the thermistor.





(a) (i) State the resistance of the thermistor at 0 °C. [1]

25 kΩ

(ii) The variable resistor is set at a resistance of 5 kΩ. Calculate V_{OUT} at 0 °C. [3]

$V_{out} = \frac{R_2}{R_1+R_2} \times V_{in}$

$V_{out} = \frac{5}{30} \times 6$

$V_{out} = 1$

V_{OUT} = 1 V

(b) What happens to V_{OUT} when the temperature increases? [1]

I Increases

(c) At 40 °C, V_{OUT} needs to be 5.4 V. Determine the new resistance of the variable resistor at 40 °C. [4]

Thermistor resistance = 6 kΩ

$V_{out} = \frac{R_2}{R_1+R_2} \times V_{in}$

$5.4 = \frac{x}{6+x} \times 6$

$32.4 + 5.4x = 6x$

$32.4 = 0.6x$

$x = 54$

Check $\frac{54}{60} \times 6$

$V_{out} = 5.4$

resistance = 54 kΩ

(d) The temperature sensor is now connected to a MOSFET. When the temperature is 40 °C a fan is switched on which produces cool air. The fan draws a current of 3 A.

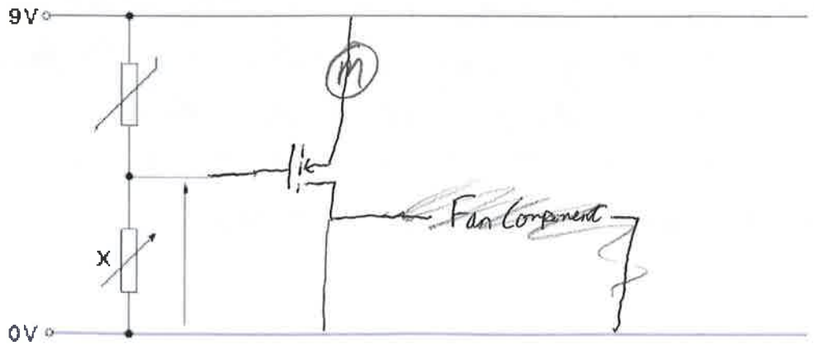
(i) Determine the minimum value of g_M for the MOSFET. [2]

$I = g_m (V_{gs} - 3)$

$\frac{I}{V_{gs}-3} = g_m$

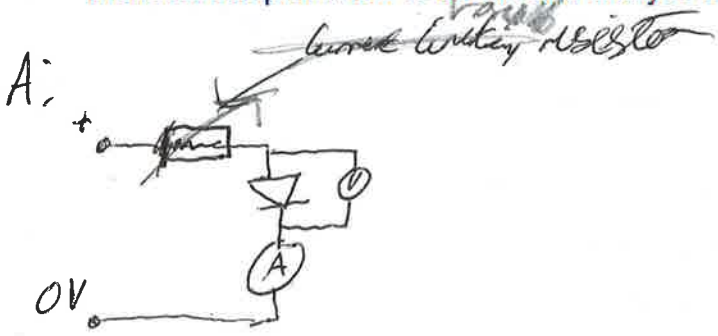
$g_m = \frac{3}{2.4}$ g_m = 1.25 S

(ii) Complete the circuit diagram below to show the final design of the cooling system. [2]



12
13

9. Describe a method to investigate the forward-biased I-V characteristics of a silicon diode and explain how to obtain and analyse a series of measurements. [6 QER]



4

Set up the circuit as shown, with a variable voltage of 0 to + rail, and gradually vary the voltage in a suitable increment. At each point, note down the voltage and current. Repeat 3x then average your readings to ensure better accuracy at each point. Now can then sketch an I-V graph to easily visually demonstrate its characteristics and discover the breakdown point of the diode. You can also use the equation $R = \frac{V}{I}$ to calculate the diode resistance at each voltage. Describe the gaps that ought to be done. Describe how to what for perfect results.

End of paper