SPECIMEN MATERIAL

A-level
PHYSICS
(7408/3BE)

Paper 3 – Section B (Electronics)

Specimen 2014 | Morning | Time allowed: 2 hours

Materials
For this paper you must have:
- a pencil
- a ruler
- a calculator
- a data and formulae booklet
- a question paper / answer book for Section A.

Instructions
- Answer **all** questions.
- Show all your working.
- The total time for both sections of this paper is 2 hours.

Information
- The maximum mark for this section is 35.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number ☐☐☐☐☐ Candidate number ☐☐☐☐

Surname

Forename(s)

Candidate signature ____________________

Section B

Answer **all** questions in this section.

0 1 . 1 **MOSFETs are commonly used in circuits where low power consumption is important to extend battery life.**

State and explain the property of MOSFET devices that makes them useful in these circuits.

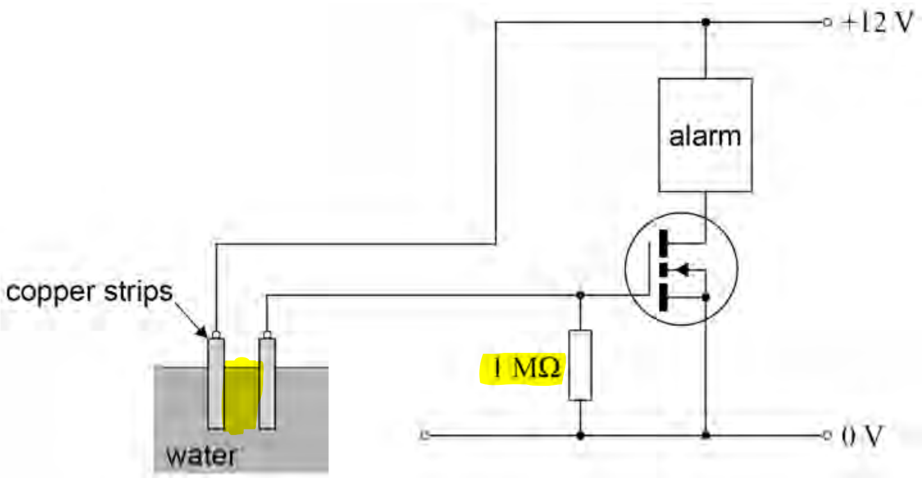
[2 marks]

• High input resistance ✓

• When in the ON or OFF states, there is little to no energy consumption. ✓

Figure 1 shows an N-channel enhancement mode MOSFET, being used as part of a circuit for the water level alarm in a garden pond.
When the gap between the copper strips is filled with water the MOSFET turns on and the alarm sounds.

Figure 1



0 1 . 2 Explain the reason for the 1 MΩ resistor in this application.

[2 marks]

• The resistor stops a static charge from building up on the gate ✓

• Ensures that when there is nothing between the probes, the gate voltage is zero. ✓

0 1 . 3 The circuit is tested by immersing the copper strips in the water, and bringing them closer together until the alarm sounds.
V_{th} for the MOSFET in **Figure 1** is 2.4 V.

Determine the resistance of the water between the copper strips when the alarm sounds.

[2 marks]

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

(V_{out} = 2.4V, R_1 = 1MΩ, V_{in} = 12V, R_2 = ?) ✓

$$\Rightarrow R_2 = \left(\frac{V_{in}}{V_{out}} \times R_1\right) - R_1$$

$$= \left(\frac{12}{2.4} \times 1\right) - 1 = 4$$

resistance = 4 ✓ MΩ

0 2 . 1 Describe what is meant by amplitude modulation (am).

[1 mark]

• The amplitude of the carrier varies in phase with the information (or audio) signal ✓

0 2 . 2 A radio wave has an unmodulated frequency of 120 kHz. It is amplitude modulated by a signal from an audio transducer of frequency 2.2 kHz.

Calculate the bandwidth of the modulated wave.

[1 mark]

$2 \times 2.2 = 4.4\text{kHz}$

bandwidth = 4.4 ✓ kHz

0 2 . 3 Explain why frequency modulation (fm) is not used for commercial radio transmissions in the medium and long wave bands.

[1 mark]

If we use low frequency carriers, there would be a limited number of channels, as fm requires a large bandwidth. ✓

0 2 . 4 State and explain **one** advantage of transmitting digital signals using frequency modulation (fm) rather than amplitude modulation (am).

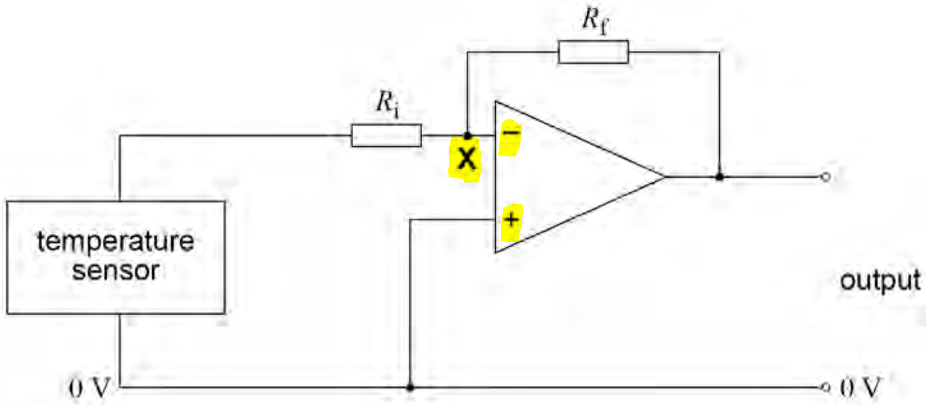
[2 marks]

• Noise distorts the amplitude of signals, and this is difficult to reduce using am. ✓

• For fm, there is no information in the amplitude, so as long as the frequencies in the bandwidth are detectable, the original signal can be recovered. ✓

0 3 **Figure 2** shows a circuit that includes an ideal operational amplifier. A student uses this circuit to amplify the signal from the sensor before further processing by the system.

Figure 2



0 3 . 1 Point X in **Figure 2** is said to be a virtual earth.

Explain the meaning of the term virtual earth in this type of circuit.

[2 marks]

• This point is not connected directly to the "0V" point ✓
• The voltage between the positive and negative inputs must be zero (or very small), or there will be saturation ✓

0 3 . 2 The temperature sensor produces a signal that changes by 10 mV for every degree Celsius change in temperature. The signal is 0 mV when the temperature of the sensor is 0 °C.

The value of R_i is 22 kΩ and the value of R_f is 270 kΩ.

Calculate the output voltage V_{OUT} of the circuit in **Figure 2** when the sensor is at a temperature of 50 °C.

[2 marks]

$$V_{IN} = 50 \times 0.01 = 0.5V$$

$$\frac{V_{OUT}}{V_{IN}} = -\frac{R_f}{R_i} \checkmark \Rightarrow \frac{V_{OUT}}{0.5} = -\frac{270{,}000}{22{,}000}$$

$$V_{OUT} = \frac{-270}{22} \times 0.5 = -6.1V$$

V_{OUT} = −6.1 ✓ V

0 3 . 3 The circuit is powered by a -15 V - 0 - +15 V supply. Explain why this circuit will not detect temperatures above 122 ºC.

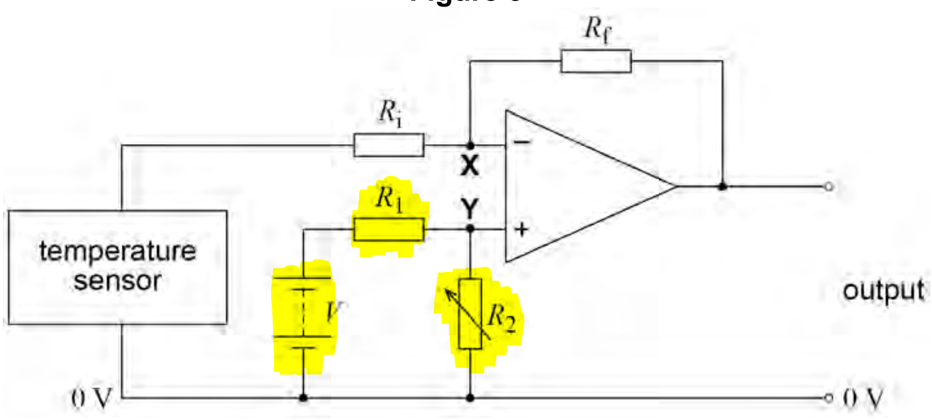
[2 marks]

At 122°C, $V_{OUT} = 122 \times 0.01 \times \frac{270,000}{22,000} = 15.0V$ ✓

A temperature higher than this will not give a further increase in V_{OUT} ✓

0 3 . 4 A student suggests a modification to the circuit in **Figure 2** to form a difference amplifier circuit for a thermostat. The modified circuit is shown in **Figure 3**.

Figure 3



The output controls a circuit that switches the heater off when the output is positive.

Explain how this circuit operates so that the heater switches off when the temperature reaches a pre-determined level.

[3 marks]

• Using the variable resistor, the user can select the potential difference at the positive (+) input ✓

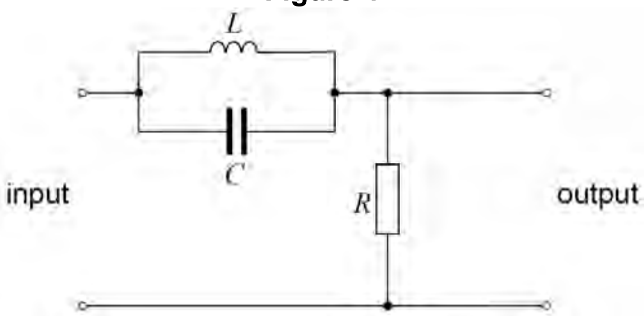
• Output is determined by $\frac{R_f}{R_i}(V_2 - V_1)$ ✓

• At the point where $V_1 = V_2$, the output changes from positive to negative, so the heater will switch off. ✓

0 4 An engineer uses copper cable to connect an intercom system between her office and workshop. The signals have to travel a long distance and she finds that interference (hum) from the mains supply is a problem.
She reduces the interference using a filter tuned to the frequency of the mains supply. The mains frequency is 50 Hz.

Figure 4 shows her solution which is based on a parallel L–C resonant circuit.

Figure 4



0 4 . 1 The engineer uses a 2.0 H inductor.

Calculate the required value for C for the filter to operate at 50 Hz.

[2 marks]

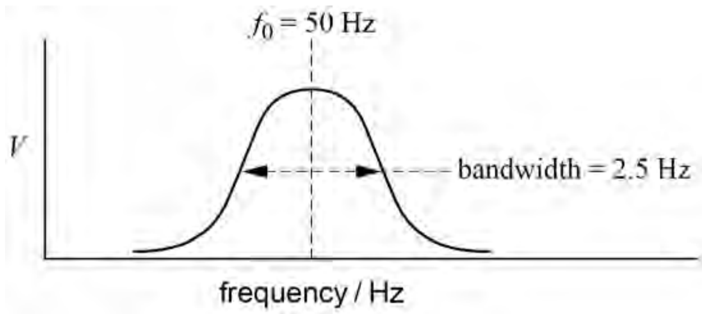
$f_0 = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = \frac{1}{4\pi^2 f_0^2 L} = \frac{1}{4\pi^2 \times 50^2 \times 2.0}$ ✓

$= 5.07 \mu F$

capacitance = 5.1×10^{-6} ✓ F

Figure 5 is the response curve for the inductor-capacitor circuit which shows how the pd V across the inductor-capacitor circuit varies with frequency.

Figure 5



Question 4 continues on the next page

0 4 . 2 Calculate, from the graph, the Q factor of the inductor-capacitor circuit.

[1 mark]

$$Q \text{ factor} = \frac{f_0}{f_B} = \frac{50}{2.5} = 20$$

Q factor = 20 ✓

0 4 . 3 The inductor is replaced to one that has an inductance of 8.0 H and a lower resistance than that of the original inductor. The capacitor is not changed.
Describe how this change affects the response curve of the inductor-capacitor circuit.

[2 marks]

Resonant frequency f_0 becomes 25Hz* ✓

Peak higher than original at resonant frequency ✓

$$*C = \frac{1}{4\pi^2 f_0^2 L}, \text{ so } L \propto \frac{1}{f_0^2}$$

Multiplying the inductance by 4 would cause the resonant frequency to halve.

0 5 Compare the advantages and disadvantages of optic fibre and copper wire for transmitting information. **[6 marks]**

① Physical ② External interference
③ Signal-carrying properties

① Physical Properties

- Copper will corrode without protection, whereas glass fibre optic cable will not.
- Glass is more difficult to join together, but it is cheaper and lighter. Also the glass cable doesn't need to be as thick.

② External Interference

- Signal can be intercepted in a copper cable without breaking it. This cannot happen in a fibre optic cable.
- Copper cables can pick up noise, but no electromagnetic radiation (such as light or infrared) can enter a fibre optic cable easily, as it relies on total internal reflection without refraction

③ Signal-carrying Properties

- Copper cables are subject to high attenuation (compared to fibre optic cables where this is low) but pulses in a fibre optic cable can suffer smearing
- Copper cables have fewer channels whereas fibre optic cables can carry more channels.

Fibre optic cables have a greater information-carrying capacity

QWC ✓

0 6 The Boolean equation for a particular logic circuit with inputs A and B and output Q is:

$$Q = (A.B) + (\overline{A}.\overline{B})$$

0 6 . 1 **Table 1** shows intermediate logic signals for the circuit, and the overall output, Q, for all combinations of the inputs A and B.

Complete the missing two entries in the truth table.

[1 mark]

Table 1

A	B	$\overline{A}$	$\overline{B}$	A . B	$\overline{A}$. $\overline{B}$	Q
0	0	1	1	0	1	1
0	1	1	0	0	0	0
1	0	0	1	0	0	0
1	1	0	0	1	0	1

0 6 . 2 Complete the diagram in **Figure 6** to show the logic circuit that has the same function as the Boolean equation given in part 6**.** Your circuit should contain only **two** AND gates, **two** NOT gates, and **one** OR gate.

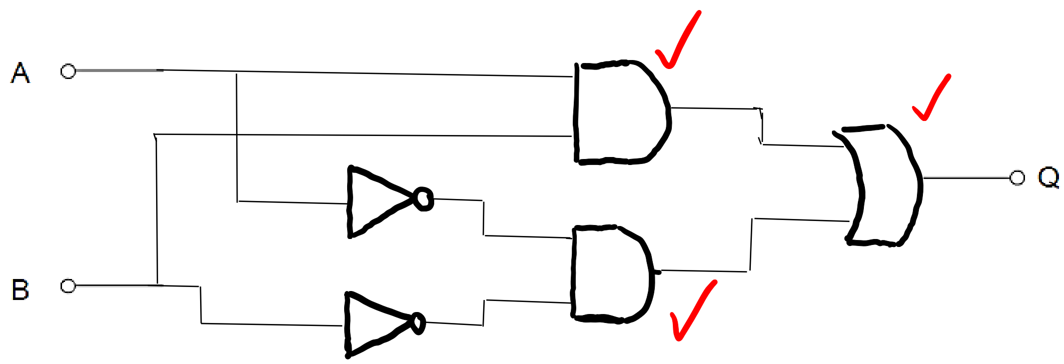
[3 marks]

both inputs on to give an output

input is always opposite to output

if one input or the other is on (but not both or neither), the output is on

Figure 6



END OF QUESTIONS

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