

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.

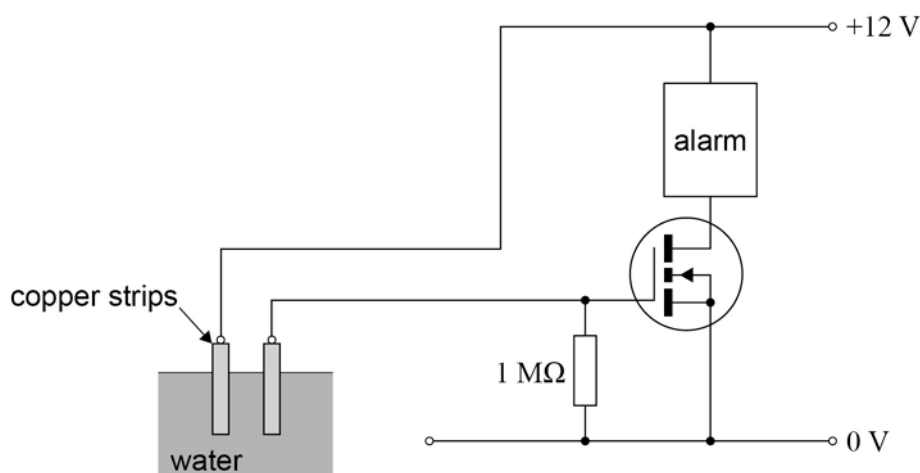
[2 marks]

MOSFETs have a very high input resistance (the gate is insulated), so there is no input current: they are controlled by pd only.

So there is very low / no energy consumption in both the ON and OFF states, which extends battery life.

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]

It prevents static charge building up on the gate (the gate-source acts as a capacitor). It makes the gate voltage 0 V when there is no water between the probes.

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]

$$\text{Potential divider: } V_{gate} = 12 \times 1 / (R_{probes} + 1) \quad (R \text{ in } M\Omega)$$

$$2.4 = 12 \times 1 / (R_{probes} + 1)$$

$$R_{probes} = (12 - 2.4) / 2.4 = 9.6 / 2.4 = 4.0 \text{ } M\Omega$$

$$\text{resistance} = \underline{4.0} \text{ } M\Omega$$

- 0 2 . 1** Describe what is meant by amplitude modulation (am). [1 mark]

The amplitude of the (high frequency) carrier wave is varied in phase (in step) with the information / 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]

$$\text{bandwidth} = 2 \times f_{\text{signal}} = 2 \times 2.2 \text{ kHz}$$

$$\text{bandwidth} = \underline{4.4} \text{ kHz}$$

- 0 2 . 3** Explain why frequency modulation (fm) is not used for commercial radio transmissions in the medium and long wave bands. [1 mark]

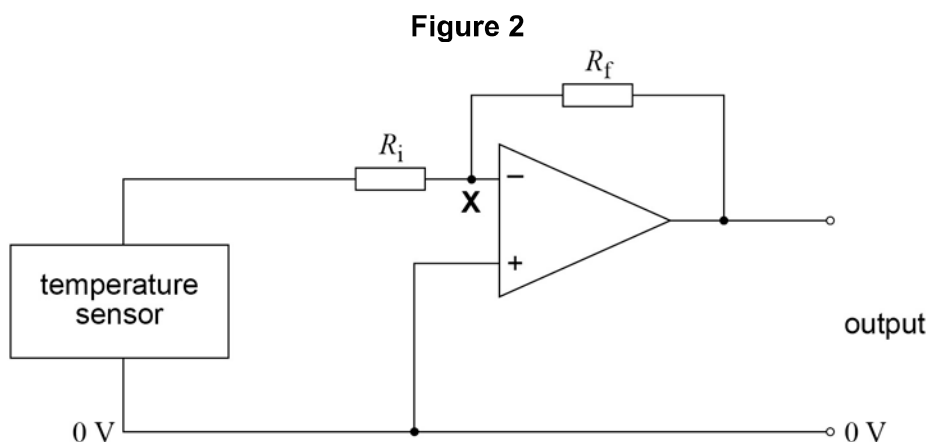
FM requires a large bandwidth, so it would limit the number of channels / stations if low frequency carriers were used.

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

Less noise: noise distorts the amplitude of signals, which is difficult to reduce in AM (signal and noise amplified equally). In FM there is no information in the amplitude, so the original signal can be recovered as long as the frequencies in the bandwidth are detectable.

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.



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]

It is not actually connected to 0 V. The op-amp has a very large open-loop gain, so the pd between the V_+ and V_- inputs must be almost zero, otherwise it would saturate.

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 k Ω and the value of R_f is 270 k Ω .

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

[2 marks]

$$\text{gain} = -R_f / R_i = -270 \text{ k}\Omega / 22 \text{ k}\Omega = -12.3$$

$$V_{IN} = 50 \times 0.01 = 0.50 \text{ V}$$

$$V_{OUT} = -12.3 \times 0.50 = -6.1 \text{ V}$$

$$V_{OUT} = \underline{-6.1} \text{ V}$$

Turn over ►

- 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 °C.

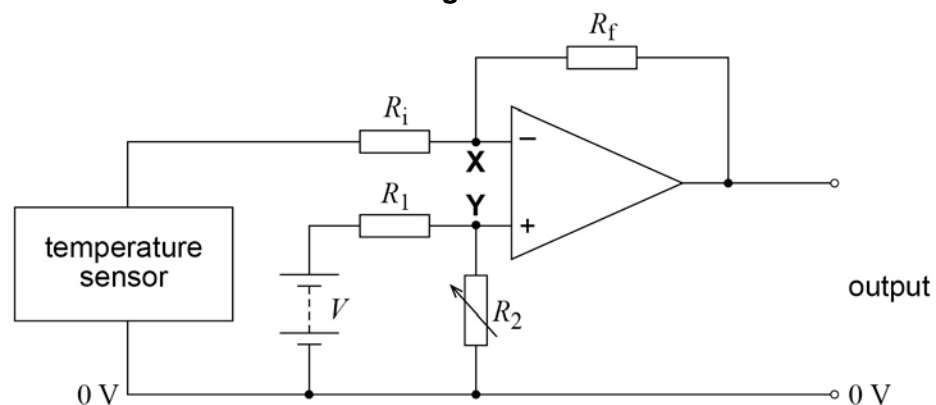
[2 marks]

At 122 °C, $V_{IN} = 122 \times 0.01 = 1.22 \text{ V}$, so the size of $V_{OUT} = 12.3 \times 1.22 = 15.0 \text{ V}$, which equals the supply voltage.

The op-amp saturates, so any higher temperature gives no 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]

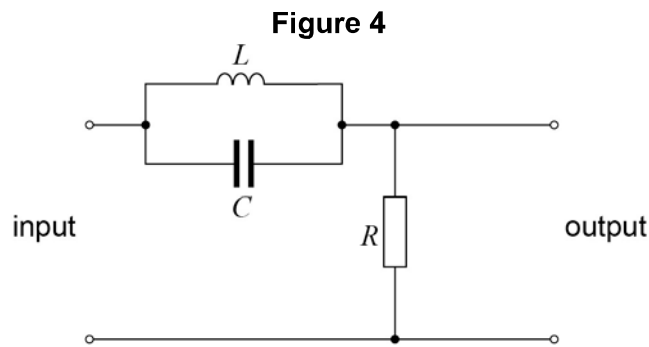
The level is fixed by controlling the pd V_2 at the + input (Y) using V and R_2 ; it turns off at a higher temperature if V at the + terminal is higher.

The output is determined by $(R_f/R_i)(V_2 - V_1)$, V_1 being the sensor pd at X. As the temperature rises V_1 increases; when $V_1 = V_2$ the output changes from + to - (switches), causing the heater to 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.



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.

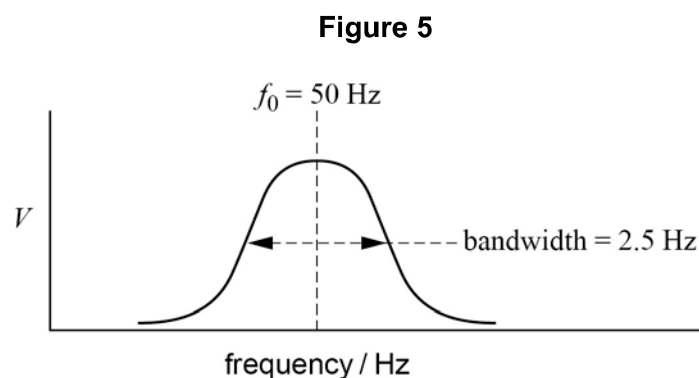
[2 marks]

$$f_0 = 1 / (2\pi\sqrt{LC})$$

$$C = 1 / (4\pi^2 f_0^2 L) = 1 / (4\pi^2 \times 50^2 \times 2.0)$$

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.



Question 4 continues on the next page

Turn over ►

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

[1 mark]

$$Q = f_0 / \text{bandwidth} = 50 / 2.5$$

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]

The resonant frequency becomes 25 Hz ($f_0 \propto 1/\sqrt{L}$, so four times L halves f_0).

The peak is higher than the original at the resonant frequency (less resistance, so less energy loss), and the peak is sharper / narrower.

0 5

Compare the advantages and disadvantages of optic fibre and copper wire for transmitting information.

[6 marks]

Physical: copper will corrode unless it is well protected, whereas glass optic fibre does not corrode. Copper cable is heavier and more expensive, while optic fibre is thinner, lighter and less expensive.

However, copper is easy to join, whereas optic fibres are harder to join together (the cores must be accurately aligned).

External interference and security: copper can pick up electromagnetic interference (noise) and suffers from cross talk between neighbouring wires. Optic fibre carries light, so it is immune to electromagnetic noise and can be used in 'noisy' environments.

Copper can be tapped without breaking the cable, so it is less secure; optic fibre cannot be tapped unless the cable is broken into, so it is more secure.

Signal carrying properties: copper has high attenuation, so the signal degrades and needs regenerating (repeaters) more often. Optic fibre has low attenuation, but its pulses can suffer smearing (pulse broadening due to dispersion), which limits the pulse rate. Copper has a relatively low bandwidth, so lower information-carrying capacity and fewer channels. Optic fibre has a much greater bandwidth, so it has greater information-carrying capacity, more channels and can send more than one signal at once, e.g. data and talk. Signals travel at a similar speed (about $2 \times 10^8 \text{ m s}^{-1}$) in both.

Overall, optic fibre is better for long distance, high data rate links, while copper is cheaper and simpler to install and join for short links.

Turn over ►

0 6

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

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

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.

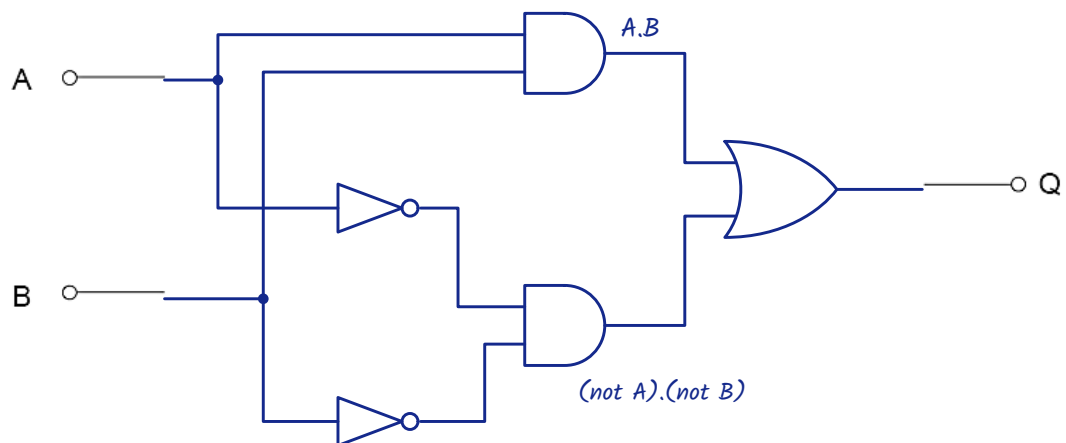
Complete the missing two entries in the truth table.

[1 mark]**Table 1**

A	B	$\bar{A}$	$\bar{B}$	$A \cdot B$	$\bar{A} \cdot \bar{B}$	Q
0	0	1	1	0	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]**Figure 6****END OF QUESTIONS****Turn over ►**

There are no questions printed on this page.