



# **A-Level Physics**

## **Operational Amplifier**

### **Question Paper**

**Time available: 52 minutes**

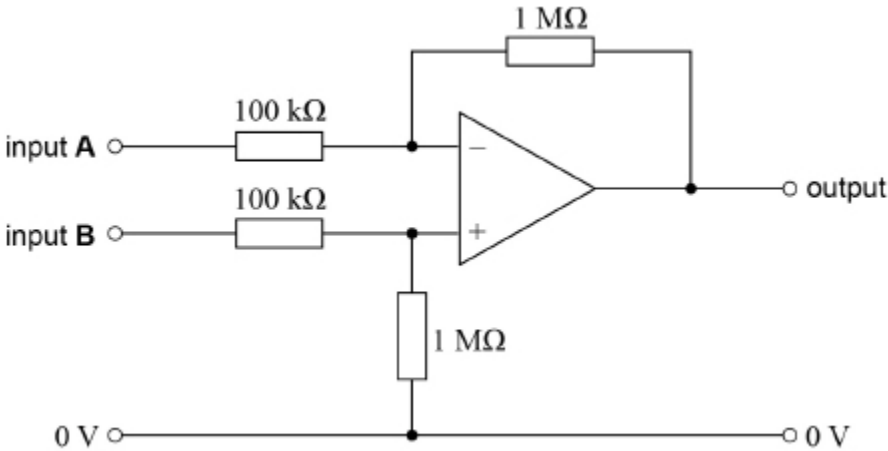
**Marks available: 45 marks**

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1.

Figure 1 shows an operational amplifier circuit used in an audio mixing desk.

Figure 1



The power supply for the amplifier is -12 V and +12 V but this is not shown in Figure 1.

(a) What is the operational amplifier configuration shown in Figure 1?  
Tick (✓) **one** box.

- non-inverting amplifier
- comparator
- summing amplifier
- difference amplifier

(1)

- (b) The circuit shown in **Figure 1** is tested by making the following connections:
- input **A** is connected to an audio signal of amplitude 150 mV
  - input **B** is connected to 0 V.

Calculate the amplitude of the output voltage.

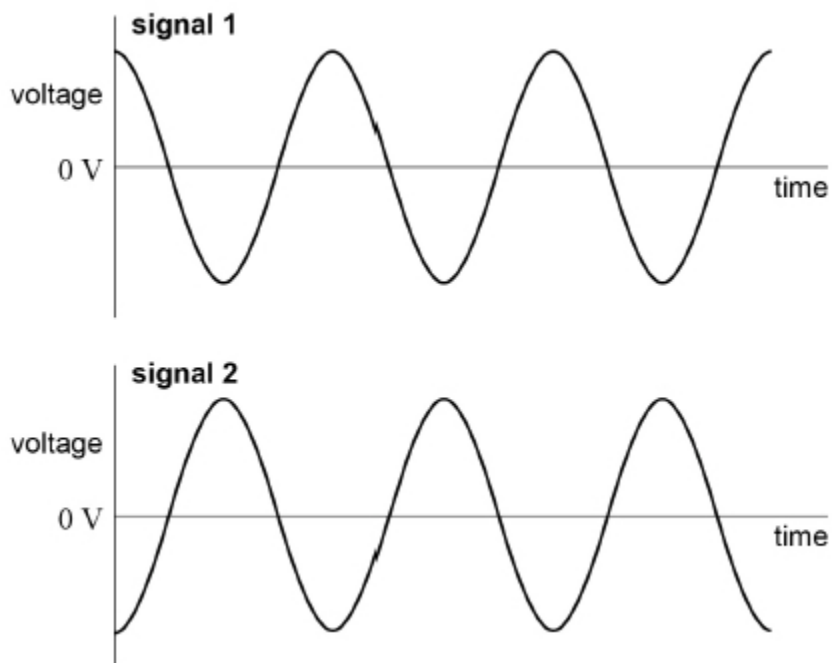
output voltage = \_\_\_\_\_ V

(2)

- (c) A microphone converts a sound wave into the voltage signal labelled **signal 1** in **Figure 2**. At the same time the microphone produces a second signal, labelled **signal 2**. **Signal 2** is the inversion of **signal 1**.

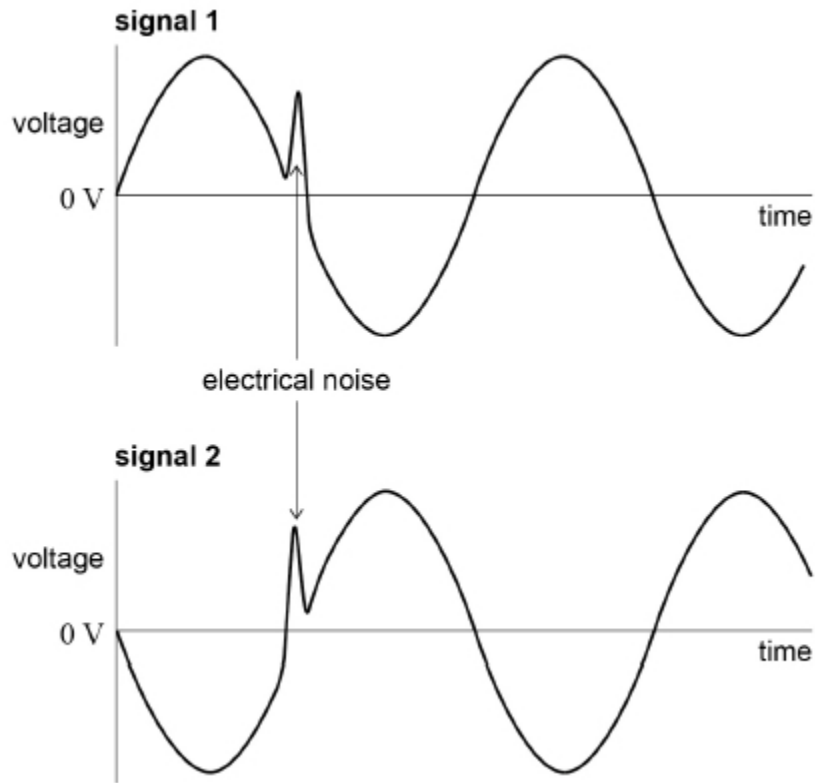
These two signals travel along two separate wires in the same cable.

**Figure 2**



**Figure 3** shows some electrical noise that has been picked up and added to the signals as they travel through the cable from the microphone to the operational amplifier circuit in **Figure 1**.

**Figure 3**



The connections made in question (b) are removed.

**Signal 1** is connected to input **A** and **signal 2** is connected to input **B**.

Explain how the operational amplifier circuit affects the noise and strength of the output signal.

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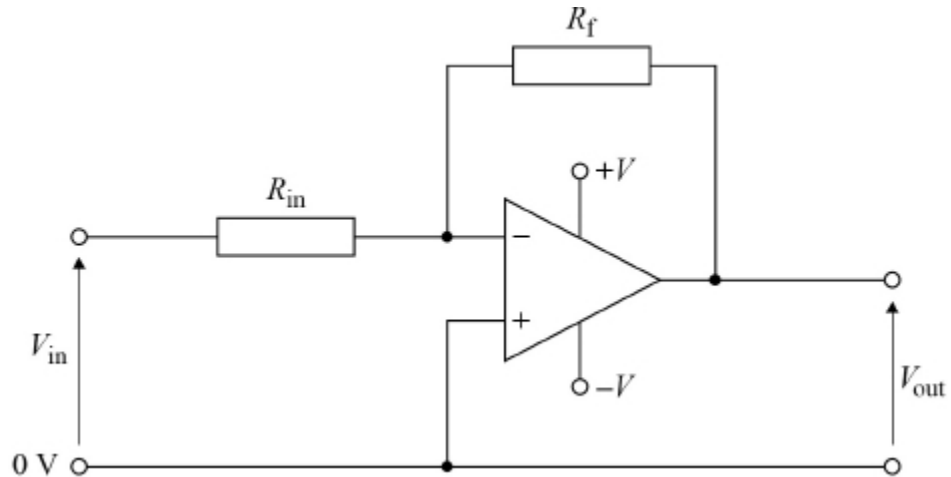
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(3)  
(Total 6 marks)

2.

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.

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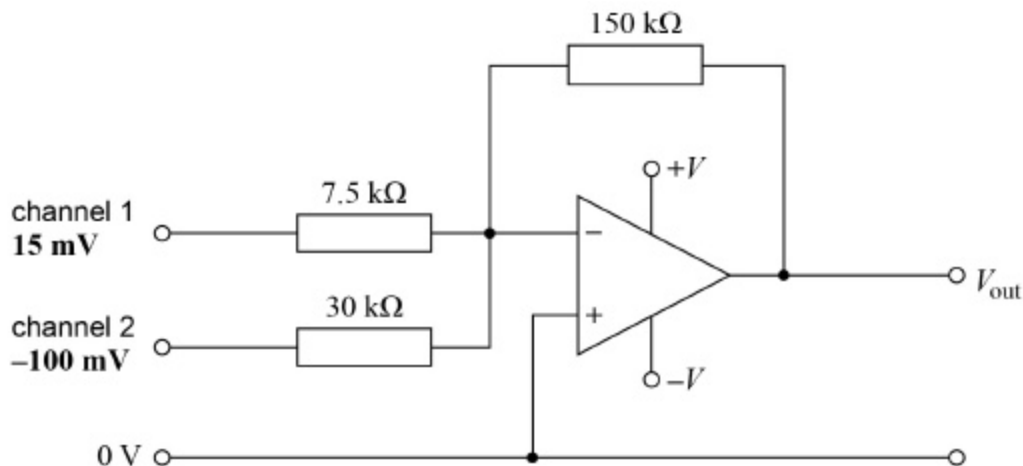
(1)

(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.

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(1)

(Total 8 marks)

3.

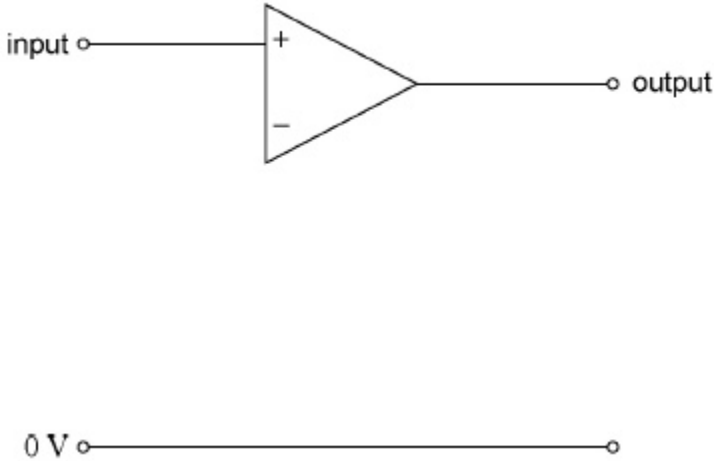
- (a) An ultrasound sensor produces an output that needs to be amplified to 3.0 V. The amplifier used has a voltage gain of 40.

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.



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 $\Omega$       3.6 k $\Omega$       10 k $\Omega$       39 k $\Omega$       150 k $\Omega$

$$R_{in} = \underline{\hspace{2cm}} \text{ k}\Omega$$

$$R_f = \underline{\hspace{2cm}} \text{ k}\Omega$$

(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.

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(2)

(Total 7 marks)

4.

A student reads in a medical physics book that the electrocardial potential difference across a typical person's chest has a peak value of 2 mV. She wishes to record this on her computer, which requires a peak input signal of 1 V and decides to build a difference amplifier.

- (a) Calculate the voltage gain required from the difference amplifier.

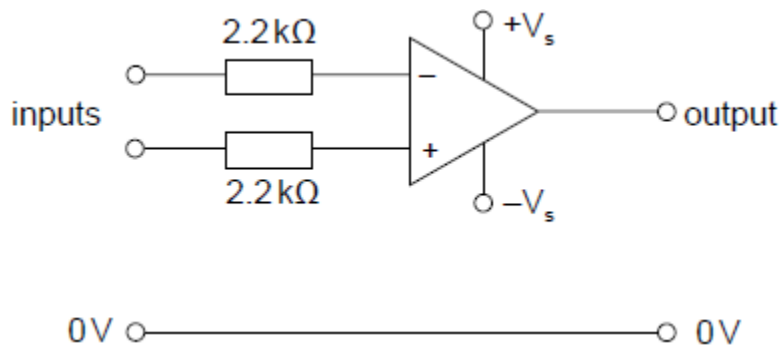
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(3)

- (b) Complete the circuit diagram below for the difference amplifier by adding **two** resistors.



(4)



(c) Calculate a suitable value for the resistors in part (b).

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**(3)**

In practice, the results were very disappointing. Her teacher suggested that it was because the input resistance of the difference amplifier was too low and that each input should be buffered by an op-amp voltage follower.

(d) (i) State the approximate input resistance of the difference amplifier inputs.

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**(1)**

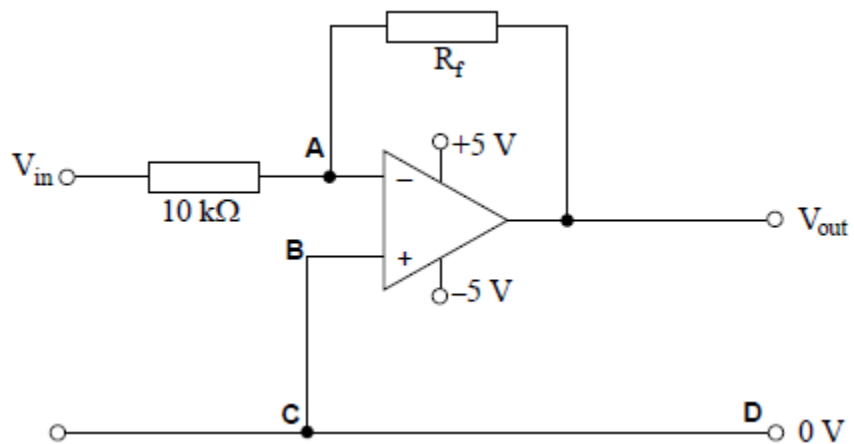
(ii) Draw the circuit diagram of an op-amp voltage follower.

**(2)**

**(Total 13 marks)**

5. 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**.

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(2)

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

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(1)

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

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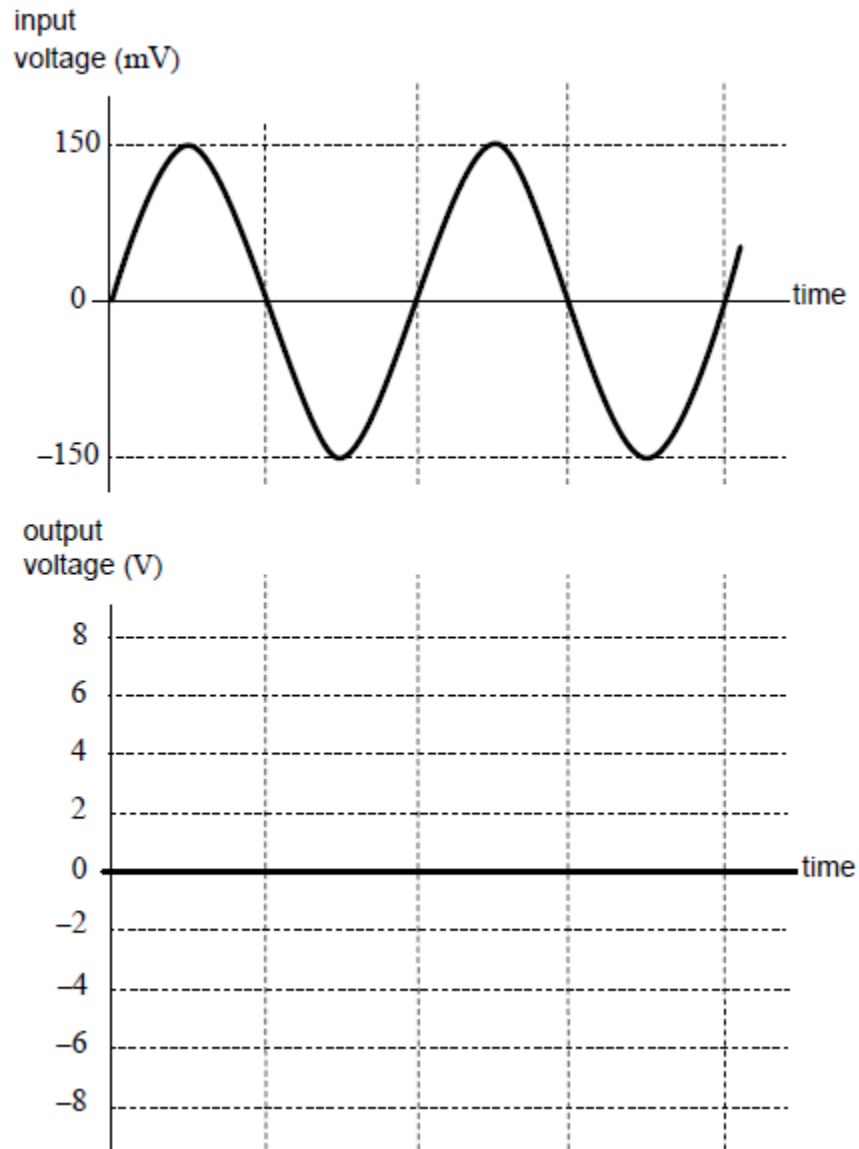
(3)

- (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**



(4)  
(Total 11 marks)