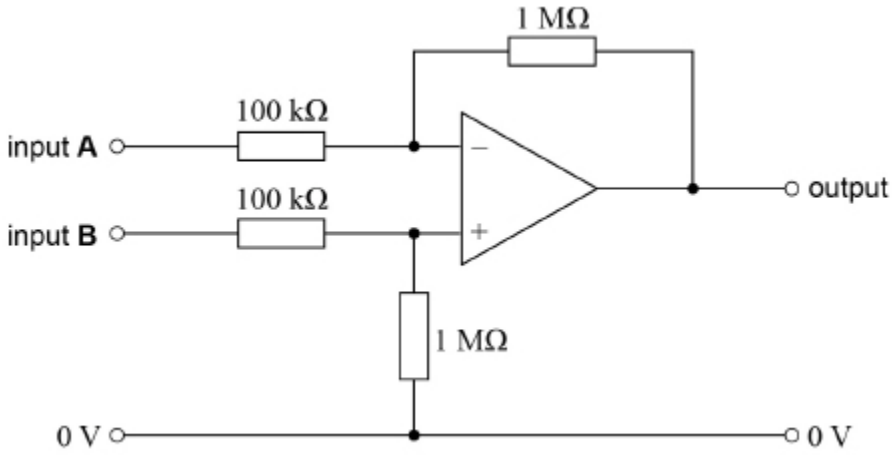
1. **Figure 1** shows an operational amplifier circuit used in an audio mixing desk.

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

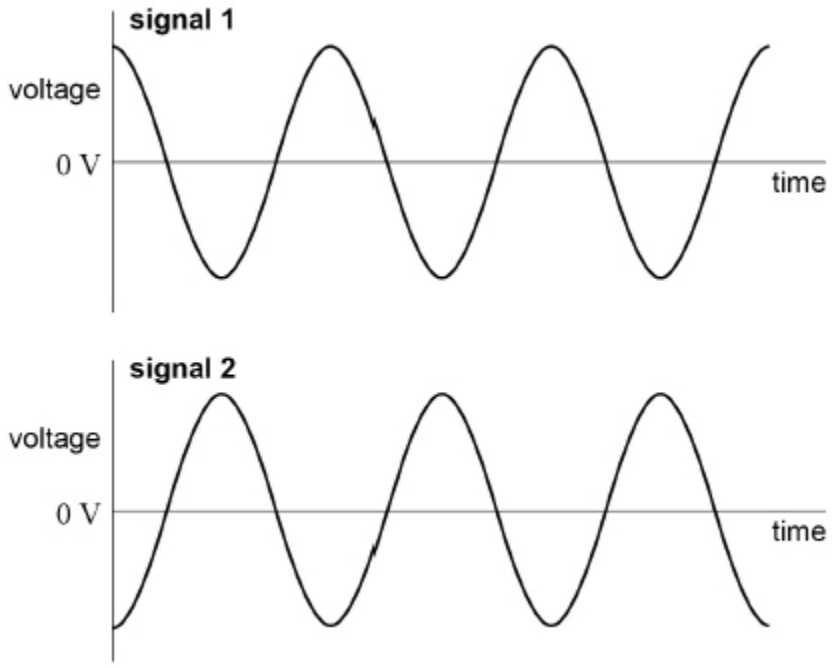
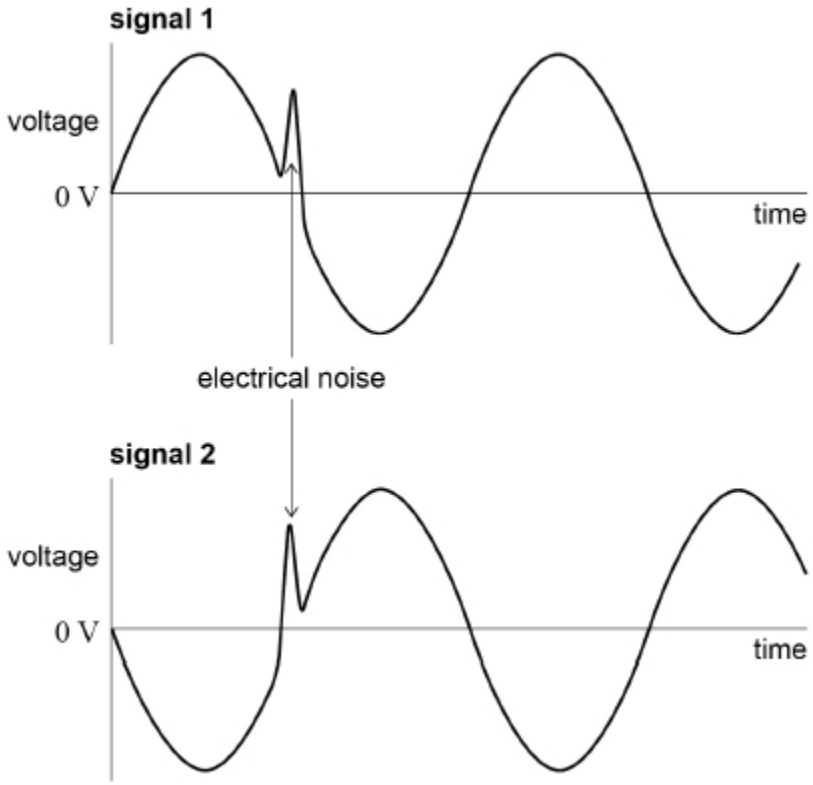


Figure 3 shows some electrical noise that has been picked up and added to the signals as they travel through the cable from the microphone to the operational amplifier circuit in **Figure 1**.

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**.

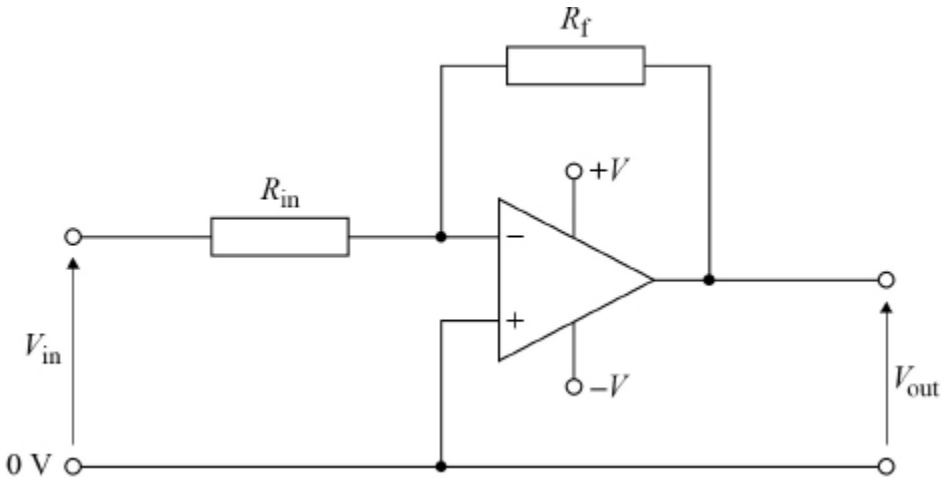
Explain how the operational amplifier circuit affects the noise and strength of the output signal.

(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.

_____

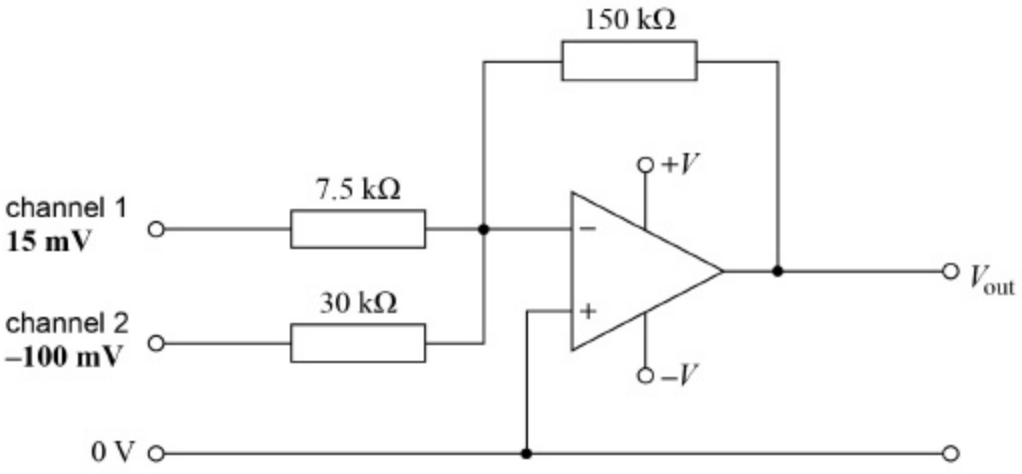
(1)

(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.

_____

_____

_____

(1)

(Total 8 marks)

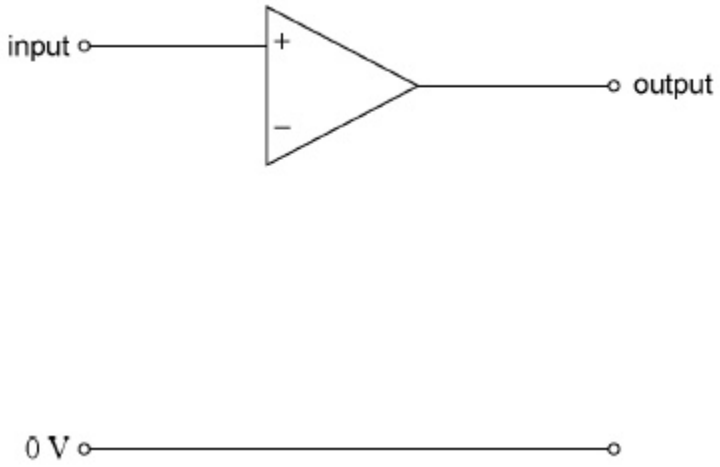
3. (a) An ultrasound sensor produces an output that needs to be amplified to 3.0 V
The amplifier used has a voltage gain of 40

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

V_{in} = _____ 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 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

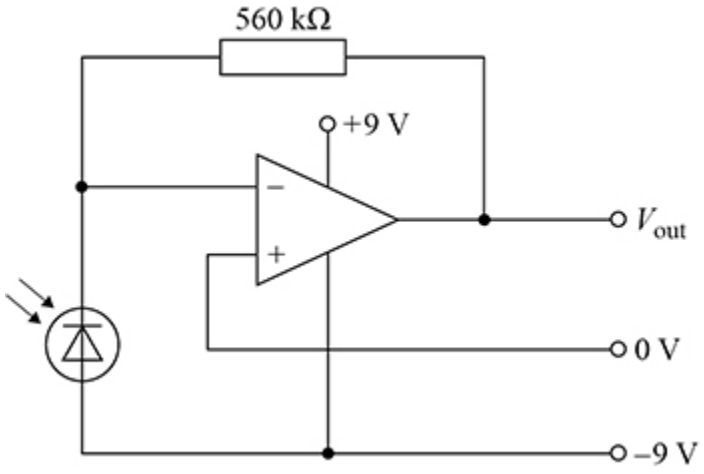
Discuss whether this operational amplifier is suitable for amplifying the sensor's output voltage.

(2)

(Total 7 marks)

4. **Figure 1** shows the circuit for an infrared detector using a photodiode and an operational amplifier. In this application the operational amplifier uses a feedback resistor to give a voltage signal when the current in the photodiode changes.

Figure 1



(a) State the mode in which the photodiode is being used in **Figure 1**.

(1)

(b) In the circuit shown in **Figure 1**, there is a current in the photodiode even when there is no light incident on it. This current is called the dark current.

In an optical communication system, the dark current needs to be very small in comparison to the photodiode current.

Explain why.

_____

_____

(1)

The responsivity R_λ of a silicon photodiode is a measure of its sensitivity to light at a given wavelength λ.

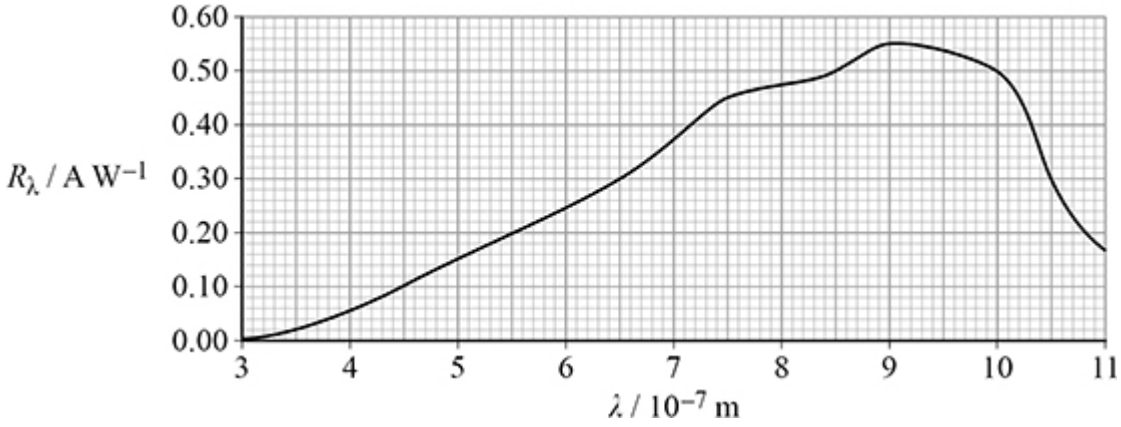
R_λ is defined as:

$$R_\lambda = \frac{I_p}{P}$$

where I_p is the current in the photodiode and P is the incident light power at the given wavelength.

Figure 2 shows the spectral response graph for this photodiode.

Figure 2



(c) Monochromatic radiation of wavelength 850 nm and power 4.0 μW is incident on the photodiode in **Figure 1**.

Calculate the output voltage of the detector circuit.

output voltage = _____ V

(3)

(d) The output from the detector circuit in **Figure 1** needs to be amplified by a factor of +4

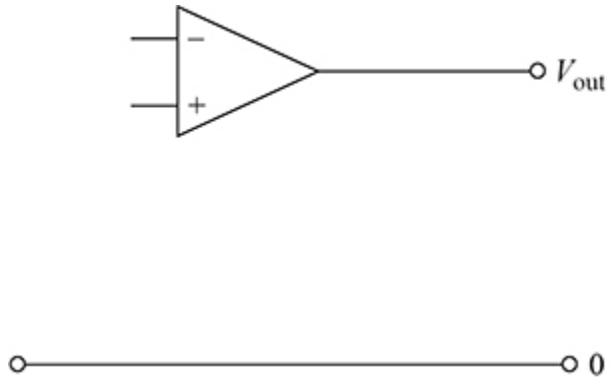
Complete **Figure 3** to show the amplifier circuit required.

In your completed circuit you should:

- label the input point as $\mathbf{V_{in}}$
- label your Figure with the values of resistance for any resistors used in your circuit. Any resistance values must lie within the range 1 kΩ to 100 kΩ.

Do **not** show the power supplies to the operational amplifier.

Figure 3



(3)

(Total 8 marks)