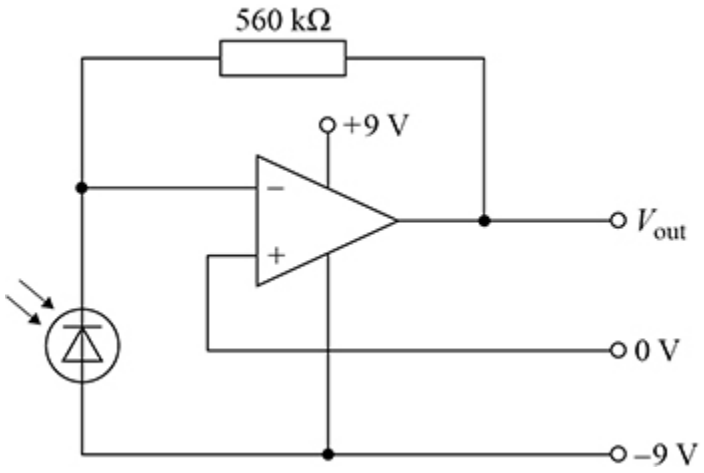
1. **Figure 1** shows the circuit for an infrared detector using a photodiode and an operational amplifier. In this application the operational amplifier uses a feedback resistor to give a voltage signal when the current in the photodiode changes.

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.

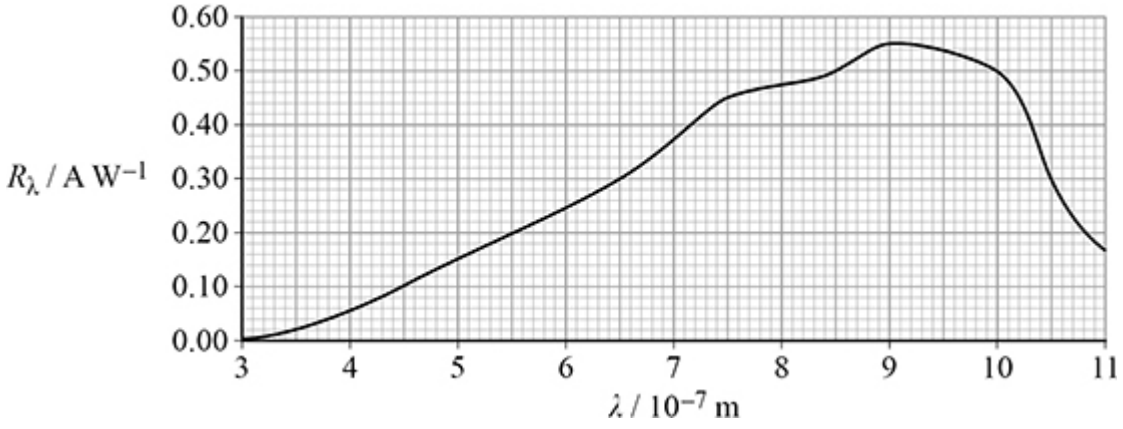
R_λ is defined as:

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

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

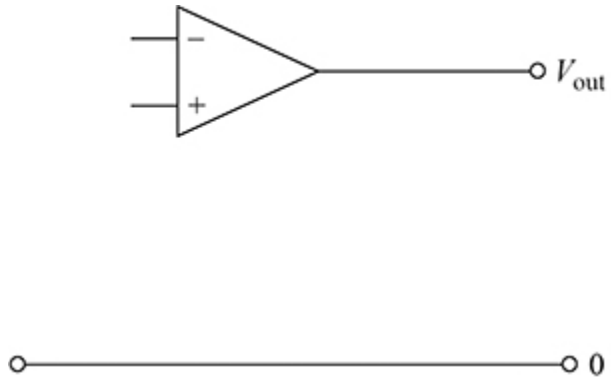
Complete **Figure 3** to show the amplifier circuit required.

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)

2. In a recording studio the output from a microphone is an analogue signal.
The equipment in the studio converts this analogue signal into a digital signal before storing it.

Discuss aspects of the analogue-to-digital conversion in this context.

In your answer you should include:

- what is meant by quantisation
- factors that affect the quality of the digital version of the analogue signal
- the advantages and disadvantages of digitising the analogue signal.

You may use diagrams to help make clear aspects of your answer.

(Total 6 marks)

3. Pulse code modulation (PCM) is used to encode live music as an uncompressed digital audio file.
Sampling of the analogue signal is carried out at 44.1 kHz.
A 16-bit system is used to encode each of the two channels that make up the stereo signal.

(a) Explain why the sampling frequency used is suitable for this task.

(2)

(b) Calculate the number of quantisation levels available on a 16-bit encoding system.

number of quantisation levels = _____

(1)

(c) A recorded piece of stereo music lasts for 3.5 minutes.

Calculate the size, in megabytes, of the digital file needed to store this recording.

file size = _____ megabytes

(2)

(d) The music file is used by a call centre to play as background music while a phone call is on hold. However, the telephone network is designed to use a bandwidth of 0.3 kHz – 3.4 kHz.

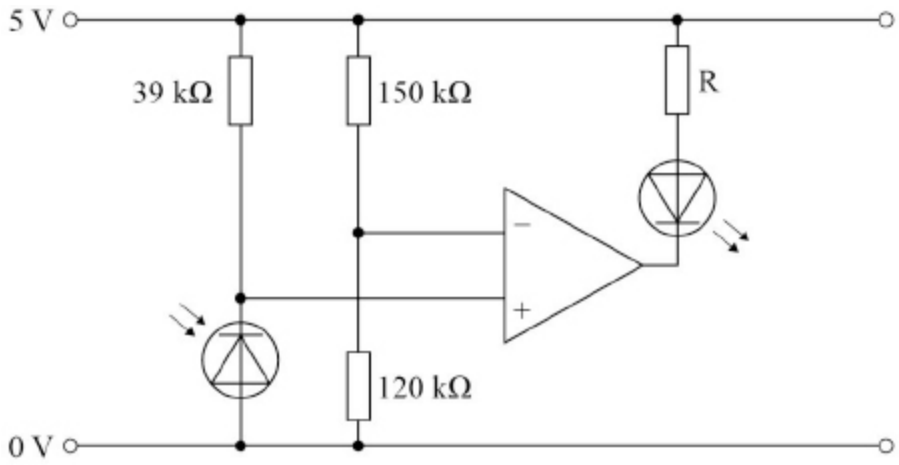
Compare the quality of the music heard by the telephone caller with that of the original file heard when played directly from a compact disc.

(2)

(Total 7 marks)

4. **Figure 1** shows a circuit containing a photodiode and an ideal operational amplifier. This circuit is used to monitor the intensity of monochromatic radiation.

Figure 1



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

comparator ☐

differential amplifier ☐

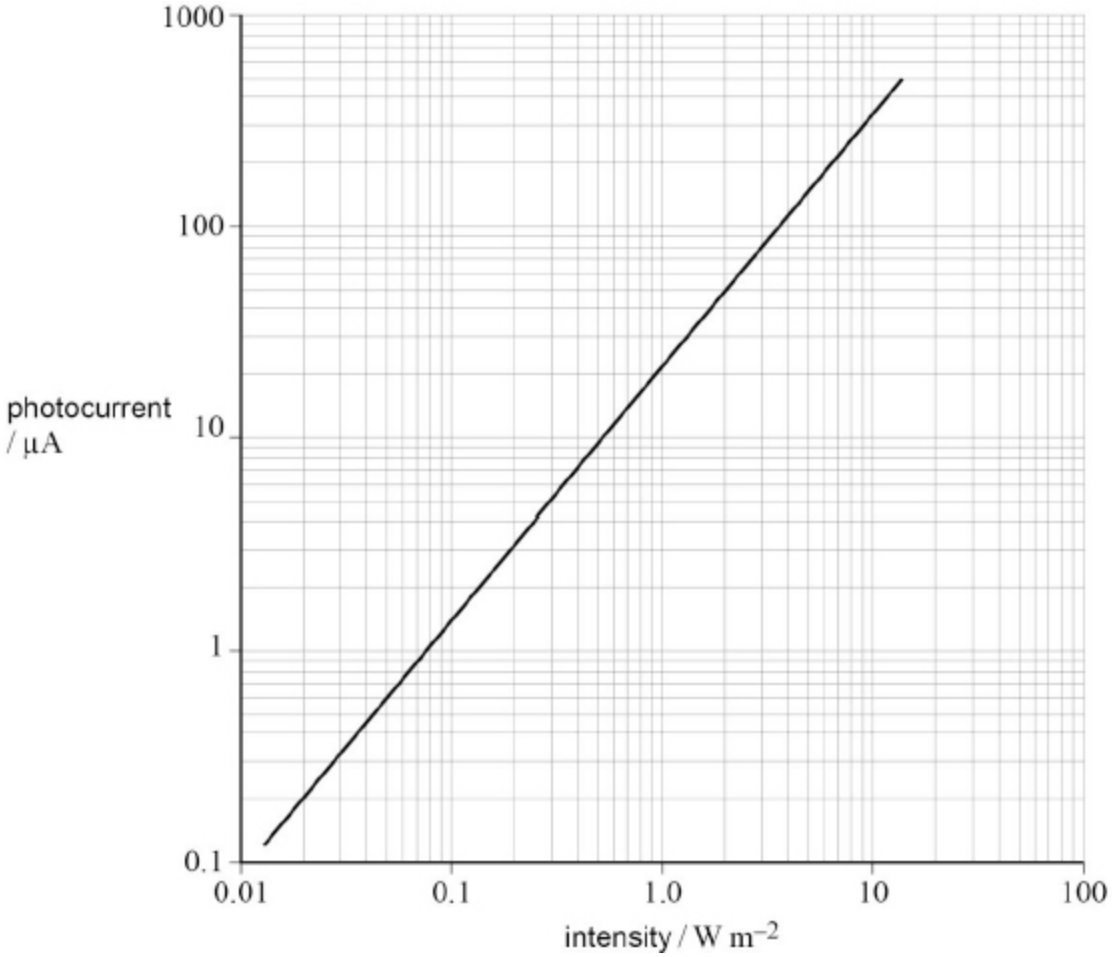
inverting amplifier ☐

non-inverting amplifier ☐

(1)

(b) **Figure 2** shows the variation of photocurrent with intensity for the monochromatic radiation incident on the photodiode.

Figure 2



Radiation of intensity 3.0 W m^{-2} is incident on the photodiode.

Show that the voltage at the non-inverting terminal (V_+) of the operational amplifier is 1.9 V.

(3)

(c) The intensity of radiation incident on the photodiode remains at 3.0 W m^{-2}.

Deduce whether the light-emitting diode (LED) in **Figure 1** is on or off.

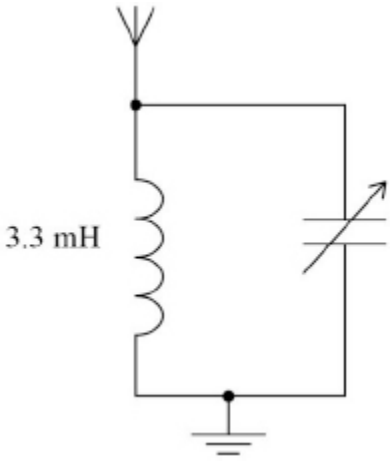
(2)

(Total 6 marks)

5. **Figure 1** shows the filter circuit that forms the first stage in an amplitude modulated (AM) radio receiver.

The circuit contains a 3.3 mH inductor and a variable capacitor.

Figure 1



(a) The circuit is tuned to receive a radio station transmitting at a frequency of 1053 kHz.

Calculate the value of the capacitance needed to receive this station.

capacitance = _____ pF

(1)

(b) The circuit is retuned to receive a different radio station by setting the variable capacitor to a value of 9.3 pF.

The table shows the capacitance range of four variable capacitors **W**, **X**, **Y** and **Z**.

Comment on the suitability of these capacitors for this application and state your preference.

Capacitor	Range / pF
W	2–9
X	3–10
Y	4.5–20
Z	10–50

_____

_____

_____

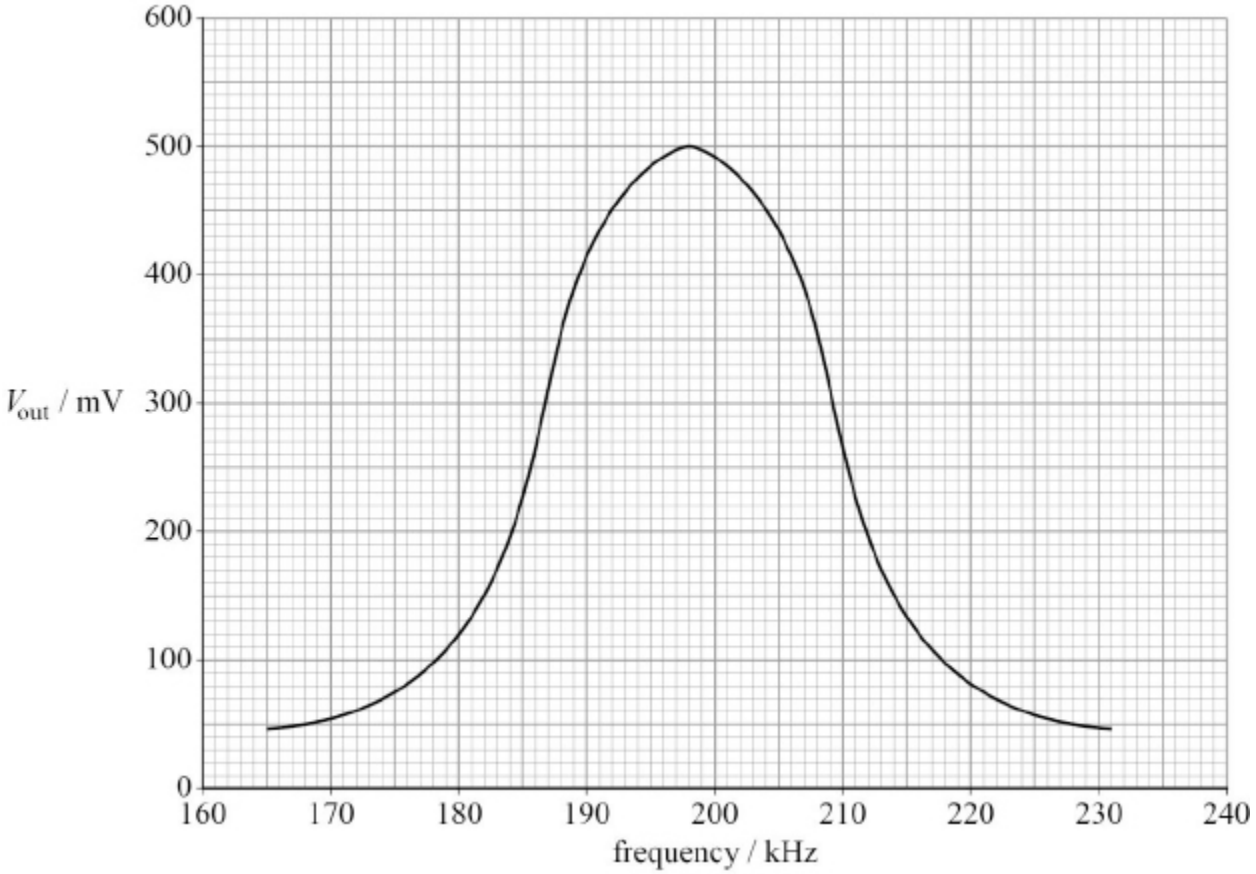
_____

_____

(2)

(c) **Figure 2** shows part of the frequency response curve for a different filter circuit.

Figure 2



Determine the bandwidth of the filter circuit.

bandwidth = _____ kHz

(2)

(d) Calculate the Q factor of the filter circuit in part (c).

Q factor = _____

(1)

(e) The radio station is tuned using a different filter circuit with a very low Q factor.

State and explain **one** effect of this change on the sound heard by a listener.

_____

_____

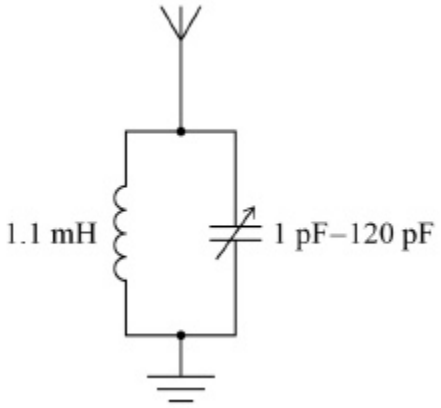
_____

(1)

(Total 7 marks)

6. **Figure 1** shows the first-stage filter circuit for a simple AM receiver. The circuit can be adjusted to resonate at 910 kHz so that it can receive a particular radio station.

Figure 1



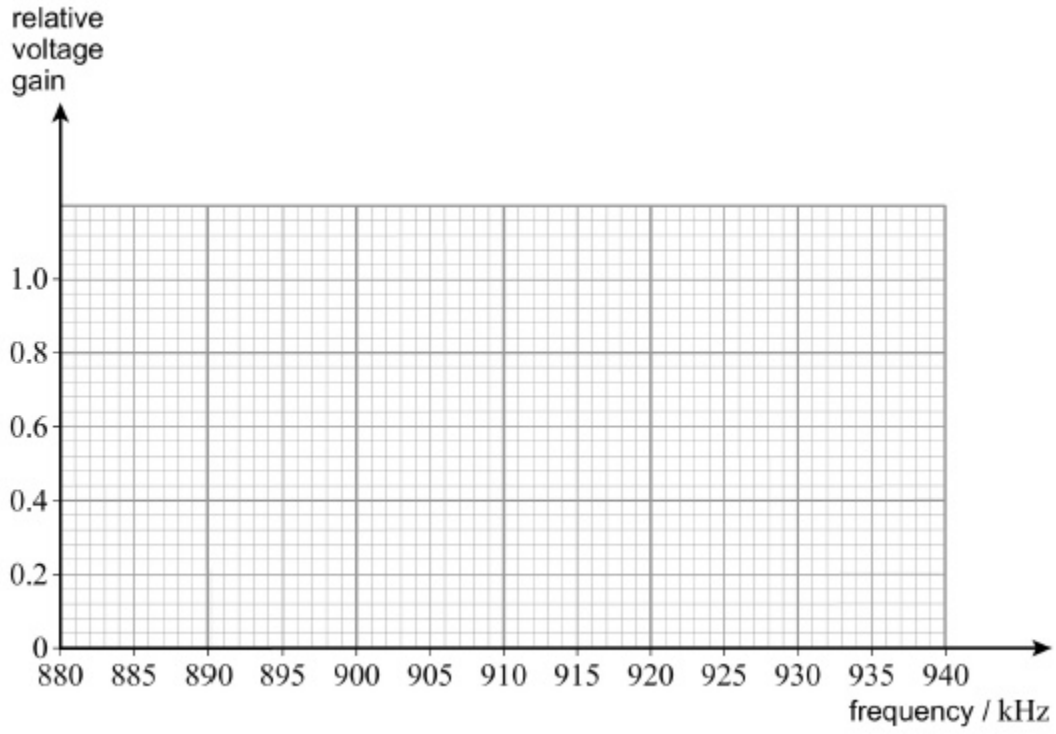
(a) Calculate the value of the capacitance when the circuit resonates at a frequency of 910 kHz.

capacitance = _____ pF

(2)

(b) Draw on **Figure 2** an ideal response curve for the resonant circuit, labelling all relevant frequency values based upon a 10 kHz bandwidth.

Figure 2



(3)

(c) The *Q*-factor for the practical tuning circuit has a smaller value than the ideal one assumed in question (b).

Discuss the changes the listener might notice when tuning to this station due to the practical *Q*-factor being smaller.

_____

_____

_____

_____

_____

_____

(2)

(Total 7 marks)