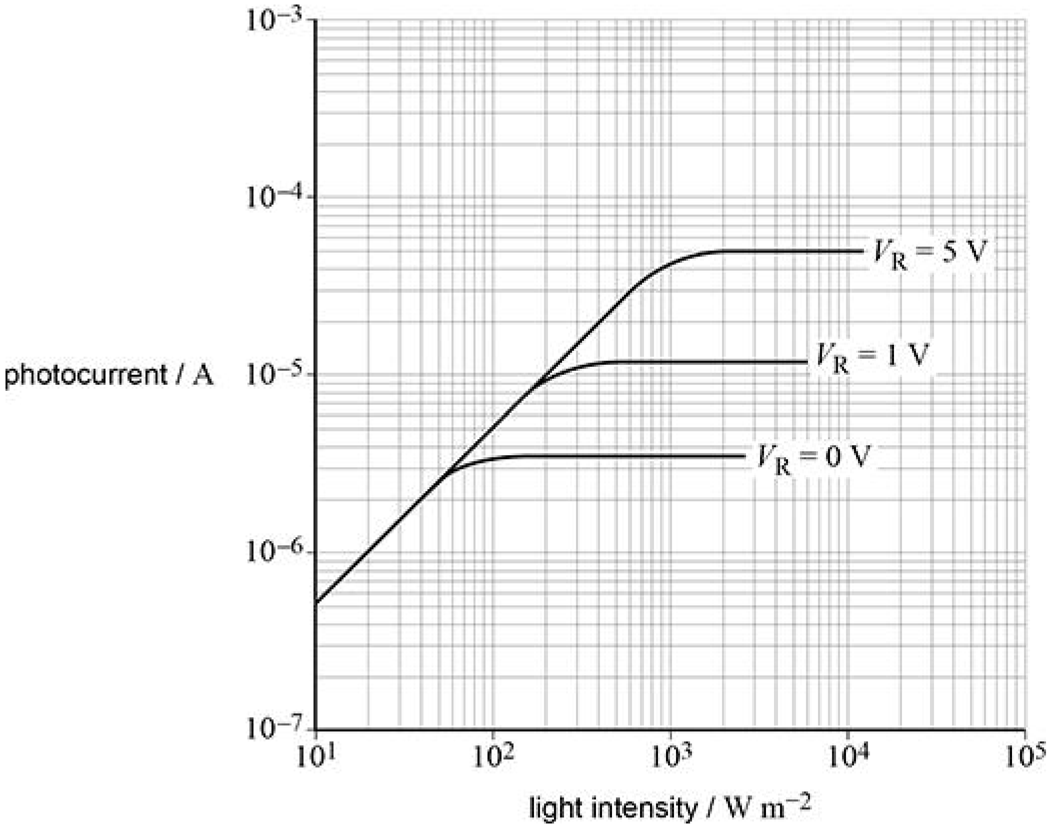
Q1.

(a) **Figure 1** shows the response of a photodiode for different values of reverse-bias voltage V_R.

Figure 1



The photodiode is used as the input for a light-intensity meter.

The light intensity changes from 100 $W m^{-2}$ to 400 $W m^{-2}$.

Explain which value of V_R in **Figure 1** should be used for this application. Go on to deduce the change in photocurrent for this change in light intensity.

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change in photocurrent = ____________________ A

(2)

(b) Describe how a photodiode is used in a particle detector to detect sub-atomic particles.

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(2)

(c) The particle detector produces an analogue signal that is the input voltage V_{in} to an amplifier circuit.
V_{in} is amplified by a factor of +10

Draw, on **Figure 2**, a circuit that uses a single operational amplifier to produce an amplification of +10

Use resistors with resistance values in the range 10 kΩ to 1 MΩ in the circuit.

On your diagram you should label:

- the value of the resistors
- the output of the circuit as V_{out}.

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

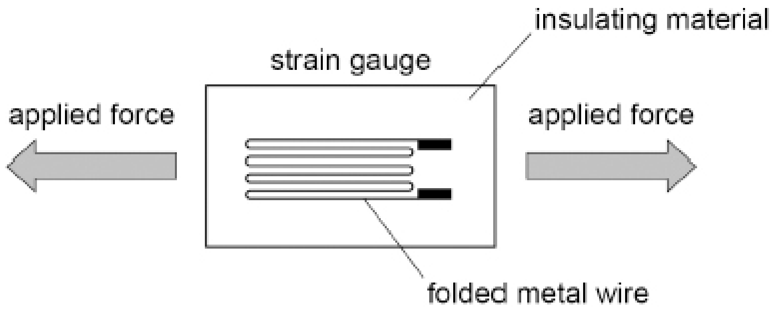
Figure 2

(3)
(Total 7 marks)

Q2.

Figure 1 shows a strain gauge that consists of a folded metal wire glued to a piece of insulating material.

Figure 1



The resistance of the metal wire:

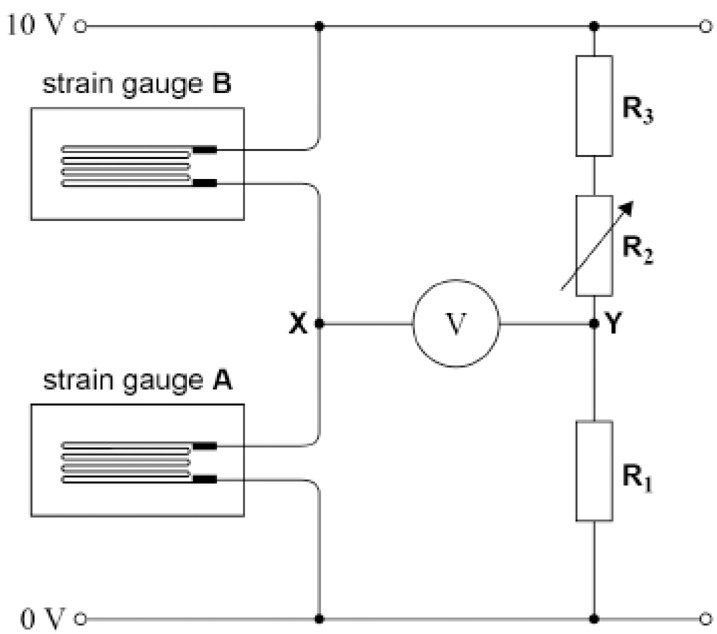
- increases when the gauge is stretched by forces applied as shown
- changes when there is a change in temperature.

(a) **Figure 2** shows a circuit that contains two identical strain gauges **A** and **B**. The resistance of each strain gauge is 120.00 Ω when the strain is zero.

R_1 is a 560 Ω fixed resistor.
R_2 is a 100 Ω variable resistor.
R_3 is a 510 Ω fixed resistor.

Assume that the voltmeter is ideal.

Figure 2



The circuit is used to measure changes in strain in a metal beam.
A is glued firmly to the metal beam.
B is placed on the beam near **A** but is not glued to the beam.

Initially, with the gauges under zero strain, $\mathbf{R_2}$ is adjusted to produce 0 V on the voltmeter.
When the beam bends, **A** stretches and **B** remains unstretched.
The resistance of **A** increases to 120.06 Ω.

Calculate, in mV, the new reading on the voltmeter.

reading on the voltmeter = ____________________ mV

(3)

(b) Explain the advantage of using strain gauge **B** rather than a 120.00 Ω resistor in the circuit.

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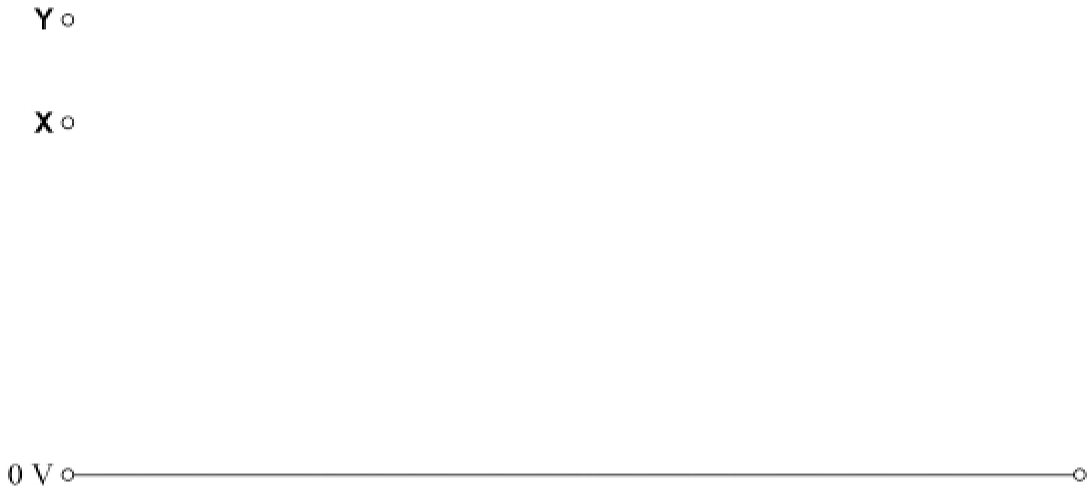
(2)

(c) The voltages at **X** and **Y** in **Figure 2** are now used as inputs to an operational amplifier.
The operational amplifier is configured as a difference amplifier with a gain of +5

Complete **Figure 3** to show the difference amplifier circuit.
Any resistors used must be labelled with their values. These values must be in the range 10 kΩ–10 MΩ.
Do not show the supply rails.

Figure 3



(3)
(Total 8 marks)

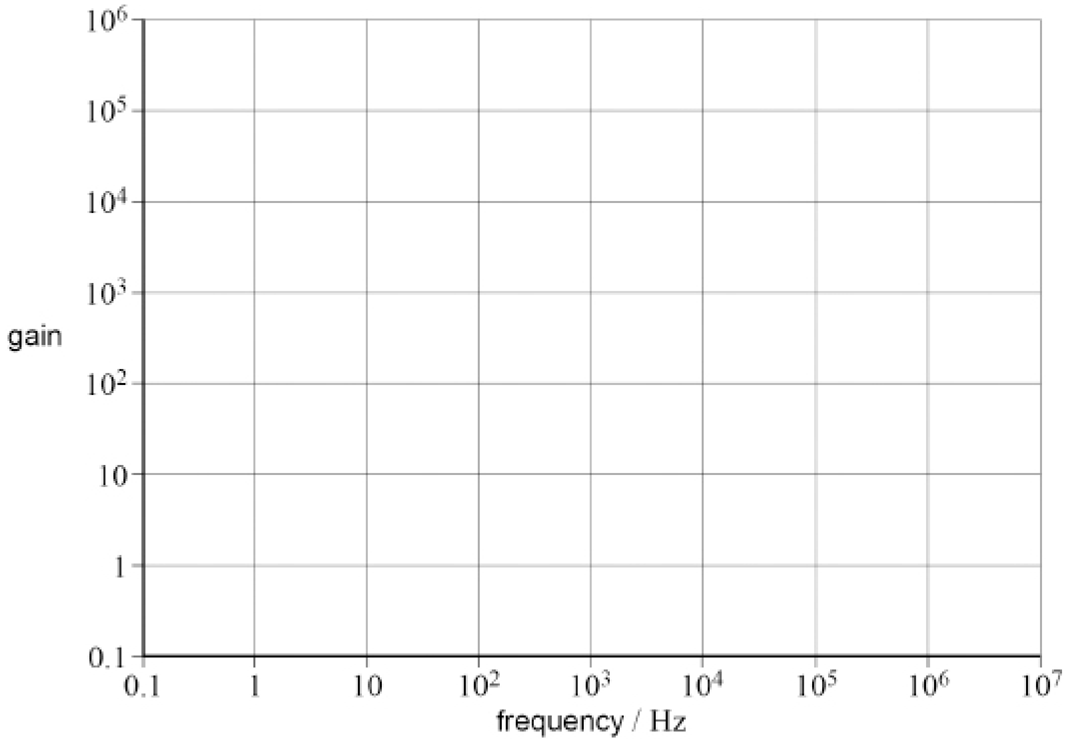
Q3.

(a) A particular operational amplifier has the following properties:

- open-loop gain = 1 × 10^5
- break frequency (cutoff frequency) = 10 Hz
- gain × bandwidth = 1 MHz.

Draw, on **Figure 1**, the variation of gain with frequency for this operational amplifier in open-loop mode.

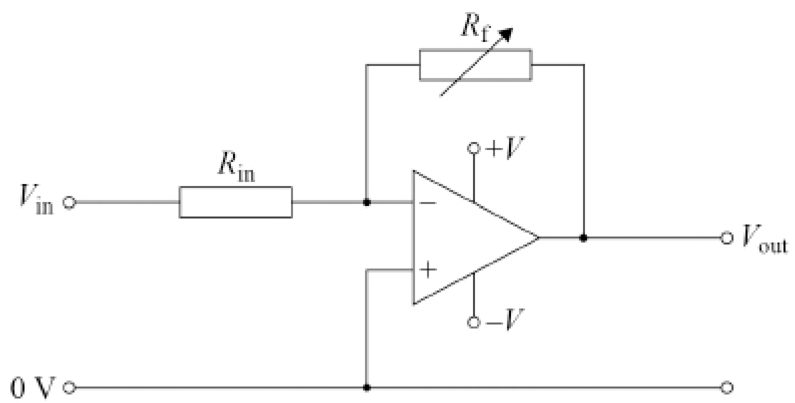
Figure 1



(2)

(b) **Figure 2** shows the operational amplifier being used in an inverting amplifier circuit.

Figure 2



Annotate **Figure 2** with:

- an **X** to indicate a point that acts as a virtual earth
- arrows to show the direction of current I in both resistors when the

input voltage V_{in} is negative.

(2)

(c) The value of R_f in the feedback loop in **Figure 2** is increased.

State and explain the effect of this change on the bandwidth of the inverting amplifier.

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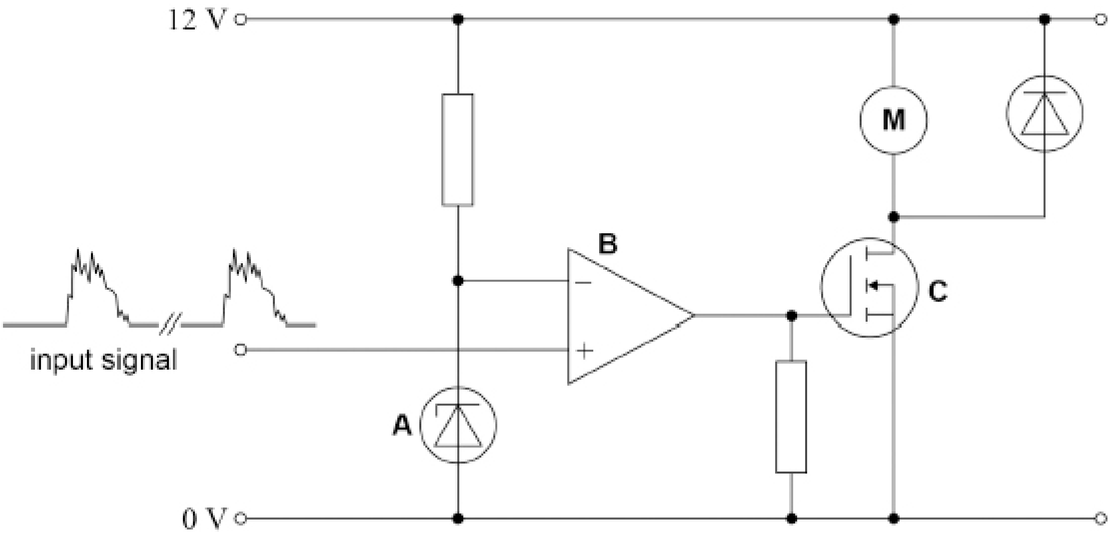
(2)
(Total 6 marks)

Q4.

The figure below shows a circuit that has an input signal which is a noisy square wave.
The circuit is used to remove the noise and switch a motor **M** on and off.



Explain the functions of components **A**, **B** and **C**.

For each of these components you should:

- explain its role in the circuit
- identify the characteristic properties that make the component suitable for this role.

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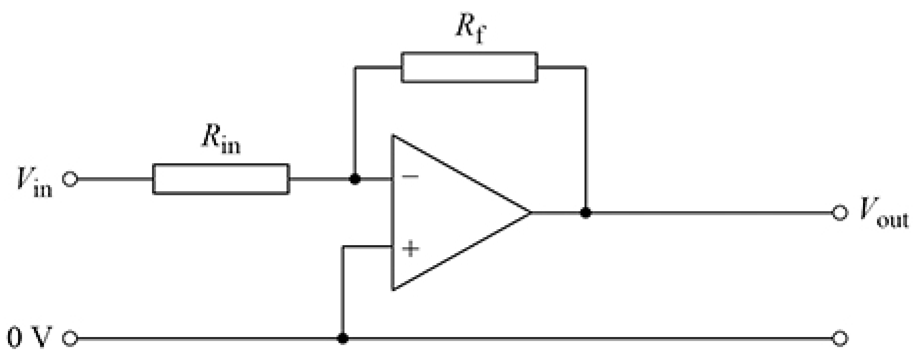
(Total 6 marks)

Q5.

Figure 1 shows a circuit containing an ideal operational amplifier. A signal V_{in} is applied to one of the amplifier inputs.

Figure 1



(a) Draw an **X** on the circuit in **Figure 1** to indicate a virtual earth point.

(1)

(b) Show that the closed loop voltage gain for the amplifier in **Figure 1** is given by:

$$\frac{R_f}{R_{in}} = -\frac{V_{out}}{V_{in}}$$

State any assumptions made in your answer.

assumptions ____

____

(2)

(c) **Figure 2A** shows the input signal V_{in} that is applied to the circuit in **Figure 1**.

Figure 2A

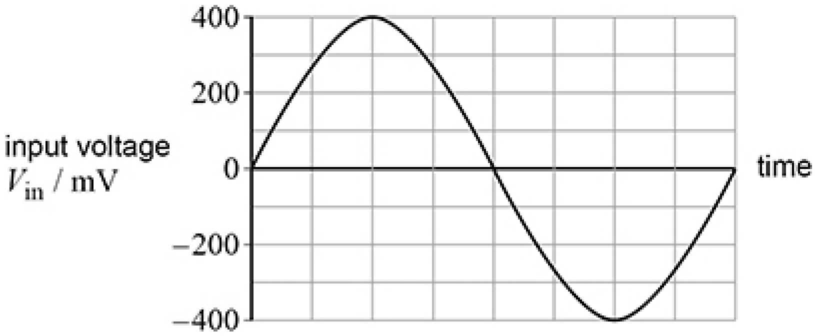
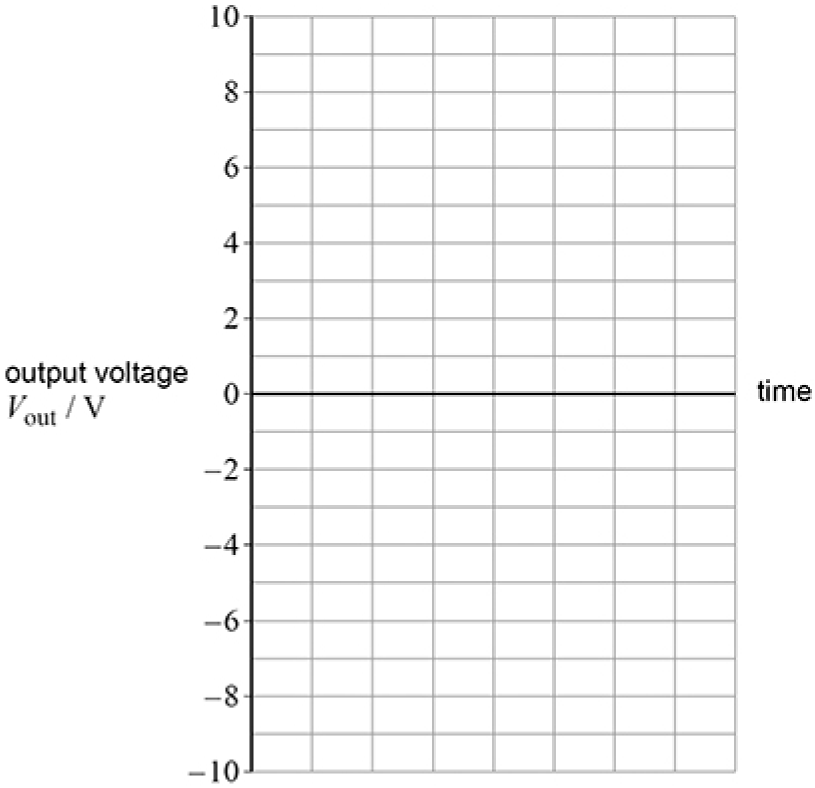


Figure 2B



The circuit in **Figure 1** has a closed loop gain of -20 and has power-supply voltages of ± 6.0 V.

Draw, on **Figure 2B**, the output waveform from the operational amplifier circuit over the same time interval as that shown on **Figure 2A**.

(2)

(d) A student converts the circuit in **Figure 1** into one that will add two input signals V_1 and V_2.

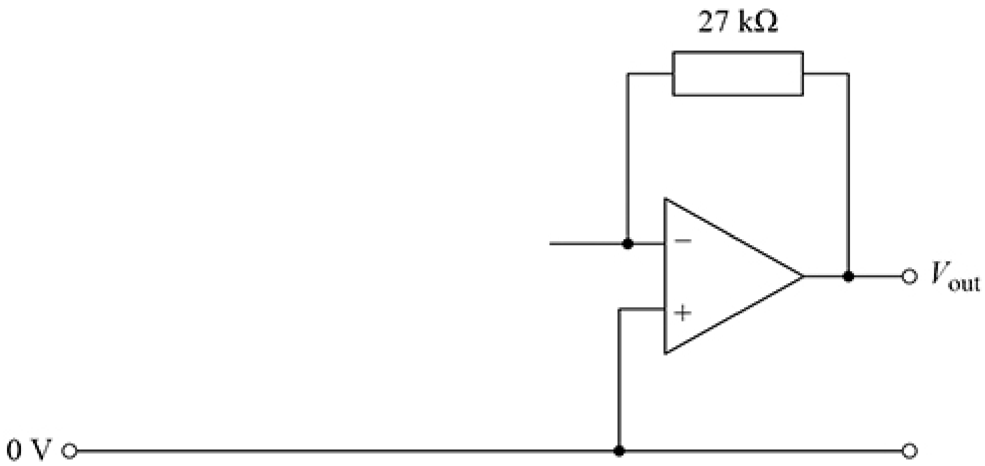
The new circuit produces an output voltage V_{out} so that:

$$V_{out} = -(1.5V_1 + 0.75V_2)$$

The circuit is to include a $27\ k\Omega$ feedback resistor.

Complete **Figure 3** to show the circuit that the student constructs. Annotate your circuit with the values of any additional components.

Figure 3



(3)
(Total 8 marks)