1. Nov/2020/Paper_41/No.7

An ideal operational amplifier (op-amp) is to be used in a comparator circuit.
Part of the comparator circuit is shown in Fig. 7.1.

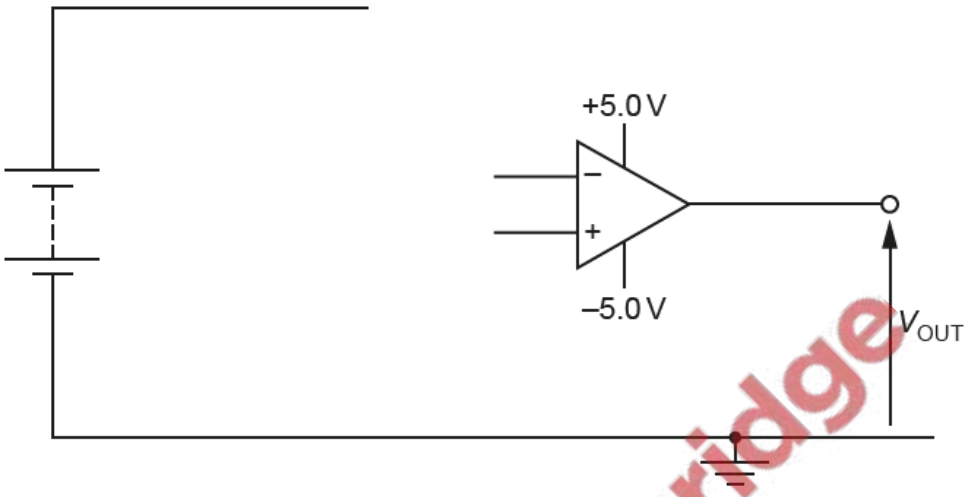

Fig. 7.1

Three resistors, each of resistance 1000 Ω, and a negative temperature coefficient thermistor are available to complete the circuit.

The circuit is to be designed so that, at low temperatures, the output V_{OUT} is –5.0 V and at higher temperatures, the output V_{OUT} is to be +5.0 V.

(a) On Fig. 7.1, draw the input circuit to the inverting and non-inverting inputs of the op-amp. [4]

(b) State a suitable value for the thermistor resistance when the thermistor is at:

(i) low temperature where V_{OUT} is –5.0 V

..... [1]

(ii) a higher temperature where V_{OUT} is +5.0 V.

..... [1]

[Total: 6]

2. Nov/2020/Paper_42/No.8

(a) An ideal operational amplifier (op-amp) is said to have infinite bandwidth and infinite slew rate.

State what is meant by:

(i) *infinite bandwidth*

.....

..... [1]

(ii) *infinite slew rate*.

.....

..... [1]

(b) An amplifier circuit incorporating an op-amp is shown in Fig. 8.1.

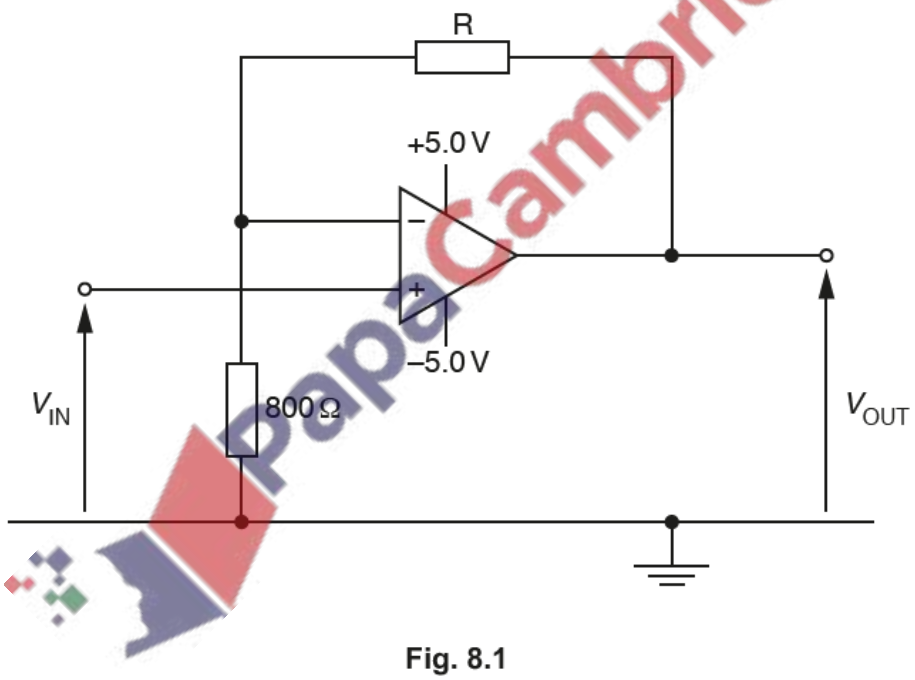

Fig. 8.1

The resistance of resistor R is to be fixed so that, for an input potential difference V_{IN} of 0.40 V, the amplifier is on the point of saturation.

Determine:

(i) the gain of the amplifier circuit

gain = ... [2]

(ii) the resistance of resistor R.

resistance = ... Ω [2]

[Total: 6]

3. June/2020/Paper_41/No.7

The output of a microphone is processed using a non-inverting amplifier. The amplifier incorporates an operational amplifier (op-amp).

(a) State, by reference to the input and output signals, the function of a non-inverting amplifier.

.....

.....

..... [2]

(b) The circuit for the microphone and amplifier is shown in Fig. 7.1.

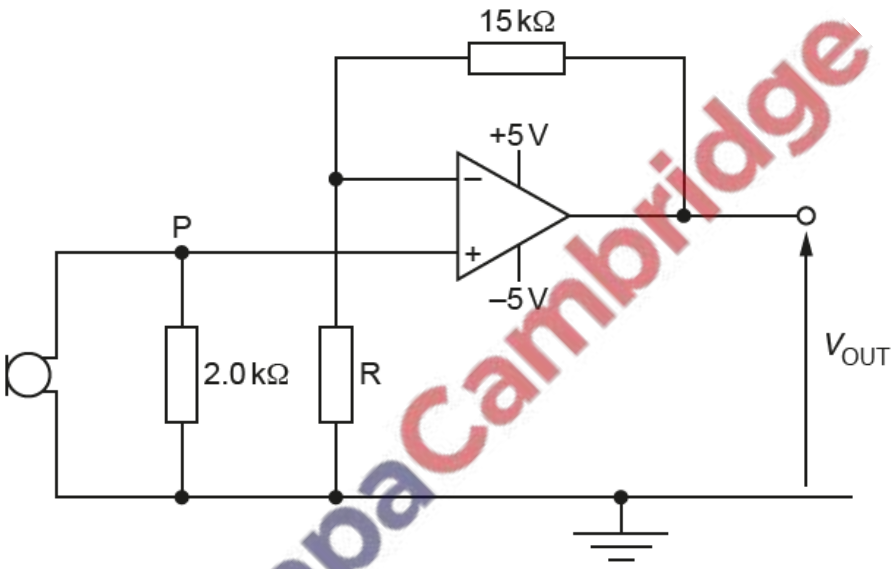

Fig. 7.1

The output potential difference V_{OUT} is 2.6 V when the potential at point P is 84 mV.

Determine:

(i) the gain of the amplifier circuit

gain = ... [1]

(ii) the resistance of resistor R.

resistance = ... Ω [2]

(c) For the circuit of Fig. 7.1:

(i) suggest a suitable device to connect to the output such that the shape of the waveform of the sound received by the microphone may be examined

..... [1]

(ii) state and explain the effect on the output potential difference V_{OUT} of increasing the resistance of resistor R.

.....

.....

..... [2]

[Total: 8]

4. June/2020/Paper_42/No.8

(a) An ideal operational amplifier (op-amp) is connected to a load resistor.
The op-amp is assumed to have infinite bandwidth and zero output resistance.

State:

(i) what is meant by *infinite bandwidth*

.....

..... [1]

(ii) the effect, if any, on the output voltage of increasing the load resistance.

.....

..... [1]

(b) A student designs the circuit shown in Fig. 8.1 in order to indicate changes in temperature of the thermistor T.

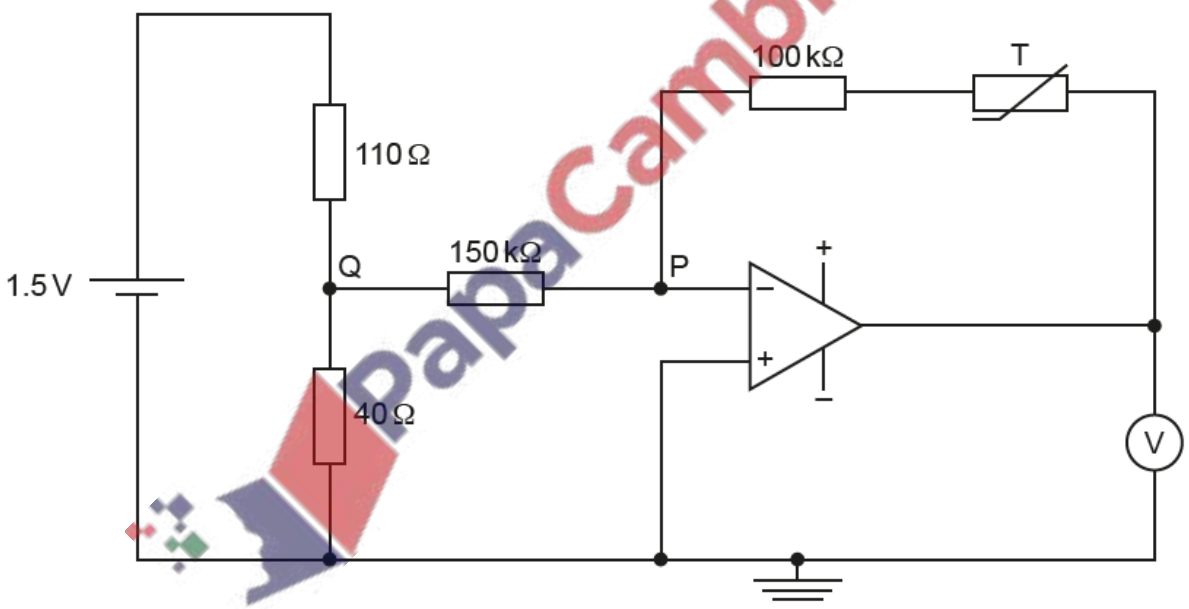

Fig. 8.1

(i) Explain why point P is known as a *virtual earth*.

.....

.....

.....

..... [3]

(ii) Calculate the potential at point Q.

potential = ... V [2]

(iii) At a temperature of 13 °C, the resistance of the thermistor T is 230 kΩ.

Show that the potential difference measured with the voltmeter is 0.88 V.

[2]

(c) The resistance of the thermistor T in **(b)** decreases as its temperature rises.

Explain the effect of this change in temperature on the potential difference measured with the voltmeter.

.....

.....

..... [2]

[Total: 11]

5. March/2020/Paper_42/No.7

(a) On Fig. 7.1, sketch the temperature characteristic of a negative temperature coefficient (n.t.c.) thermistor. Label the axes with quantity and unit.

Fig. 7.1

[2]

(b) An n.t.c. thermistor and a resistor are connected as shown in Fig. 7.2.

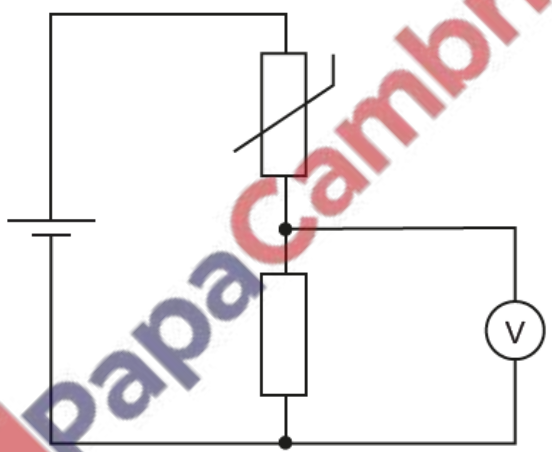

Fig. 7.2

The temperature of the thermistor is increased.

State and explain the change, if any, to the reading on the voltmeter.

.....

.....

..... [2]

(c) The variation with the fractional change in length $\Delta x/x$ of the fractional change in resistance $\Delta R/R$ for a strain gauge is shown in Fig. 7.3.

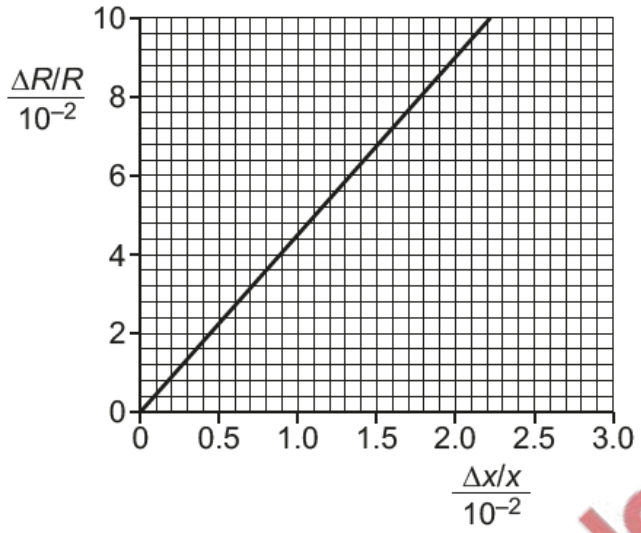

Fig. 7.3

The unstrained resistance of the gauge is 120 Ω. Calculate the new resistance of the gauge when it is extended to a strain of 0.020.

resistance = ... Ω [3]

[Total: 7]

6. March/2020/Paper_42/No.11

Electrons are accelerated through a potential difference of 100 kV. They are then incident on a metal target, they decelerate, and X-ray photons are emitted.

(a) Calculate the maximum possible frequency of the emitted X-ray photons.

frequency = ... Hz [2]

(b) Explain why an aluminium filter may be placed in the X-ray beam when producing an X-ray image of a patient.

.....

.....

.....

.....

.....

..... [3]

(c) The linear attenuation (absorption) coefficients μ for X-rays in bone, blood and muscle are given in Table 11.1.

Table 11.1

	μ/cm^{-1}
bone	3.0
blood	0.23
muscle	0.22

(i) A beam of these X-rays is incident on a person.

Calculate the percentage of the intensity of the X-ray beam that has been absorbed after passing through 0.80 cm of blood.

percentage of intensity absorbed = ... % [2]

(ii) In an X-ray image, white regions show greater absorption of X-rays than dark regions.

State and explain the difference between the X-ray image of bone compared to that of muscle.

.....

.....

..... [2]

[Total: 9]