**Q1.**The circuit shown in **Figure 1** uses an ideal op-amp as a voltage comparator. It is used in a frost warning device in which the LED lights when the temperature falls to 0°C.
**Figure 2** shows the variation of resistance with temperature of the thermistor.

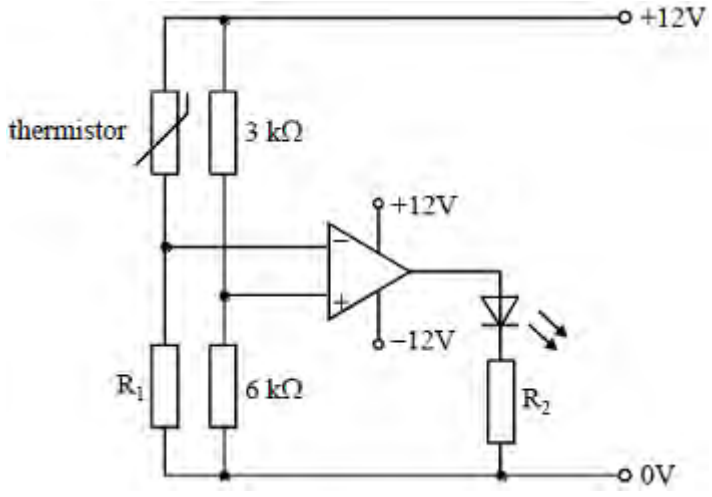


**Figure 1**

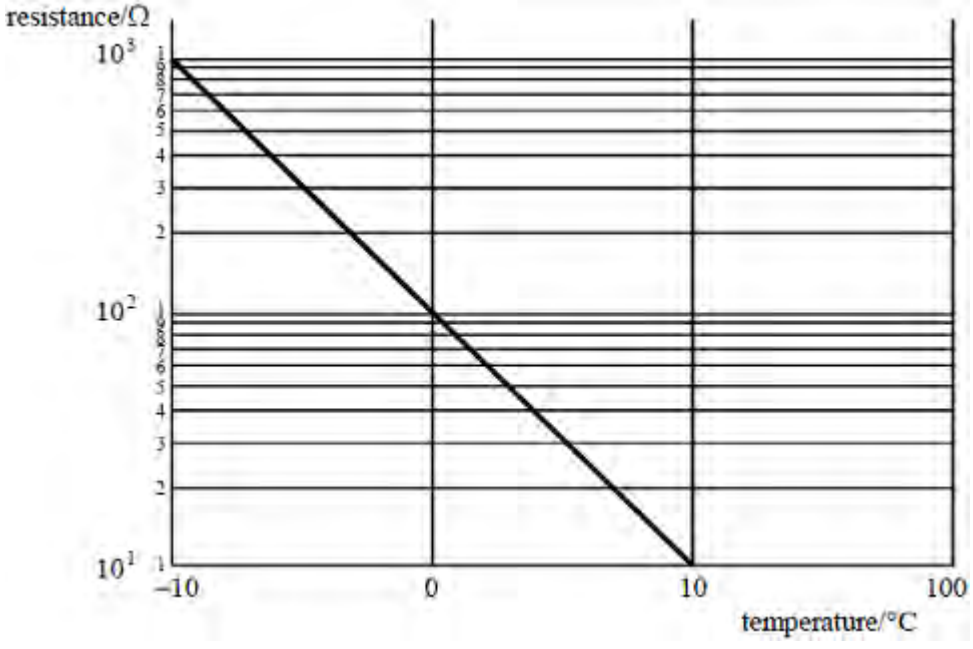


**Figure 2**

(a) Calculate the voltage at the non-inverting input of the op-amp.

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**(1)**

(b) Calculate the resistance of $R_1$ to allow the output to switch at 0°C.

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**(2)**

(c) When the LED is on, the current through it is 20 mA and the p.d. across it is 2.0 V.

Calculate

(i) the resistance of resistor $R_2$,

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.....

(ii) the power dissipated in this resistor.

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**(4)**

(d) In practice, what value of resistor from the E24 series should be used for $R_2$?

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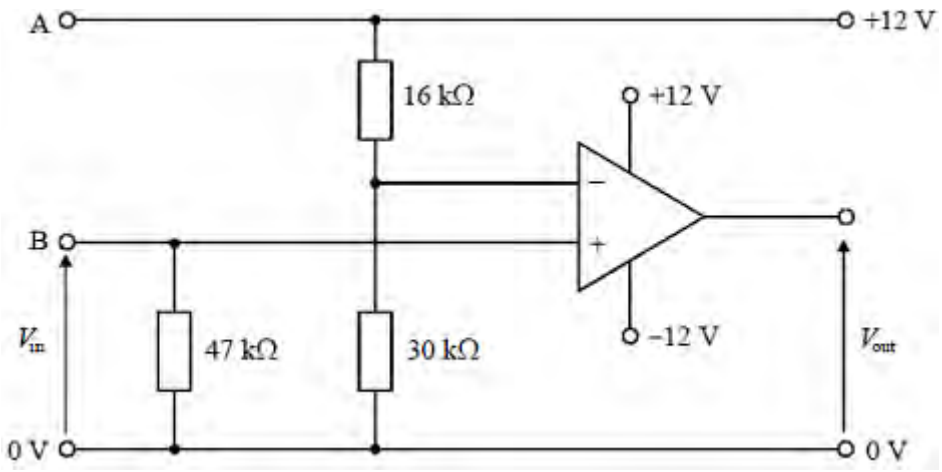
**(1)**

**(Total 8 marks)**

**Q2.**In the circuit shown, an ideal operational amplifier is used as a voltage comparator.




(a) The voltage $V_{in}$ is steadily increased from 0 V. Calculate $V_{in}$ when the sign of $V_{out}$ changes from negative to positive.

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**(2)**

(b) (i) The op-amp is required to operate an LED. Add to the circuit an LED and its limiting resistor so that the LED lights when $V_{in}$ is less than the value calculated in part (a).

(ii) Explain why the LED functions in the position you have drawn it.

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(iii) Calculate the minimum value for the limiting resistor with the LED. Assume that the LED has a voltage drop of 2.0 V across it when emitting and a maximum current of 25 mA through it.

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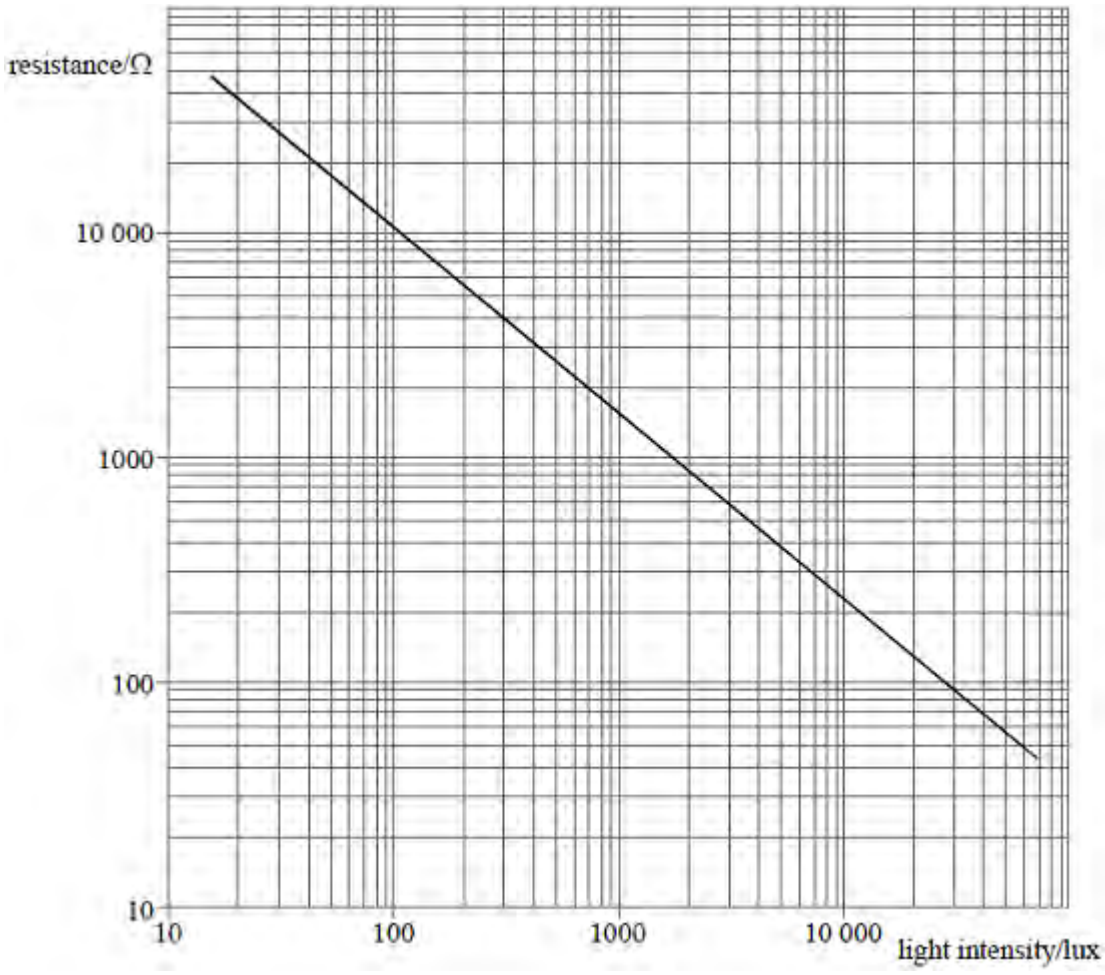
**(5)**

(c) An LDR is now connected between the points A and B in the circuit. The characteristic of the LDR is shown below.




Determine the light intensity at which the LED switches.

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**(3)**

**(Total 10 marks)**

**Q3.**(a) State **two** characteristics of an operational amplifier.

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**(2)**

(b) (i) Draw a circuit diagram showing an operational amplifier used as an inverting voltage amplifier.

(ii) Give suitable values for the components you have used in the circuit for a voltage amplification of magnitude 150.

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**(4)**

(c) When *negative feedback* is used with an amplifier the bandwidth increases.

(i) Explain what is meant by negative feedback as applied to the circuit drawn in part (b).

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(ii) Give **one** other advantage of using negative feedback in this application.

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(iii) State what is meant by the bandwidth of an amplifier.

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(iv) Indicate on the graph below, by means of a horizontal line, the bandwidth of the amplifier whose characteristic is shown.

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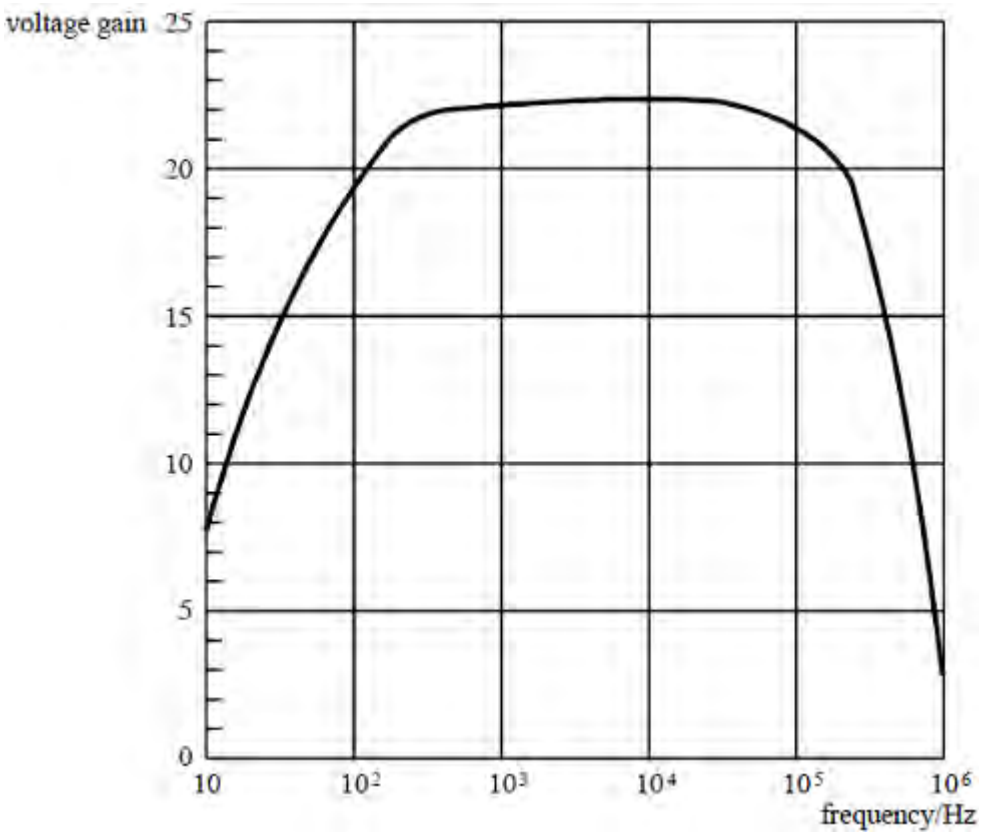


**(5)**
**(Total 11 marks)**