For
Examiner's
Use

2. the resistance of resistor X.

resistance = ... Ω [2]

(iii) State one effect on the amplifier output of reducing the resistance of resistor X.

....

.... [1]

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2 A block diagram for an electronic sensor is shown in Fig. 9.1.

Fig. 9.1

(a) Complete Fig. 9.1 by labelling the remaining boxes. [2]

(b) A device is to be built that will emit a red light when its input is at +2V. When the input is at –2V, the light emitted is to be green.

(i) On Fig. 9.2, draw a circuit diagram of the device.

input
either + 2V
or   – 2V

[2]
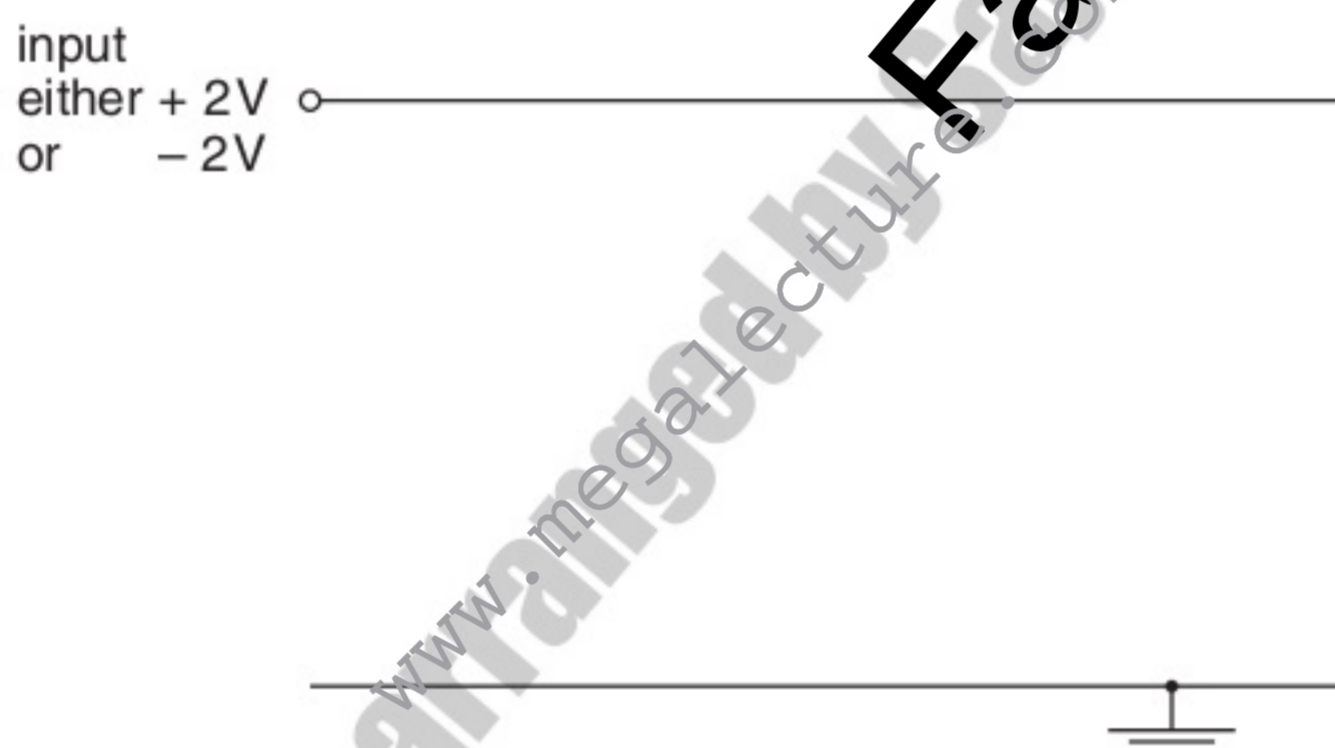
Fig. 9.2

(ii) Explain briefly the action of this device.

....

....[1]

3 (a) By reference to an amplifier, explain what is meant by *negative feedback*.

....

....

.... [2]

(b) An amplifier circuit incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.1.
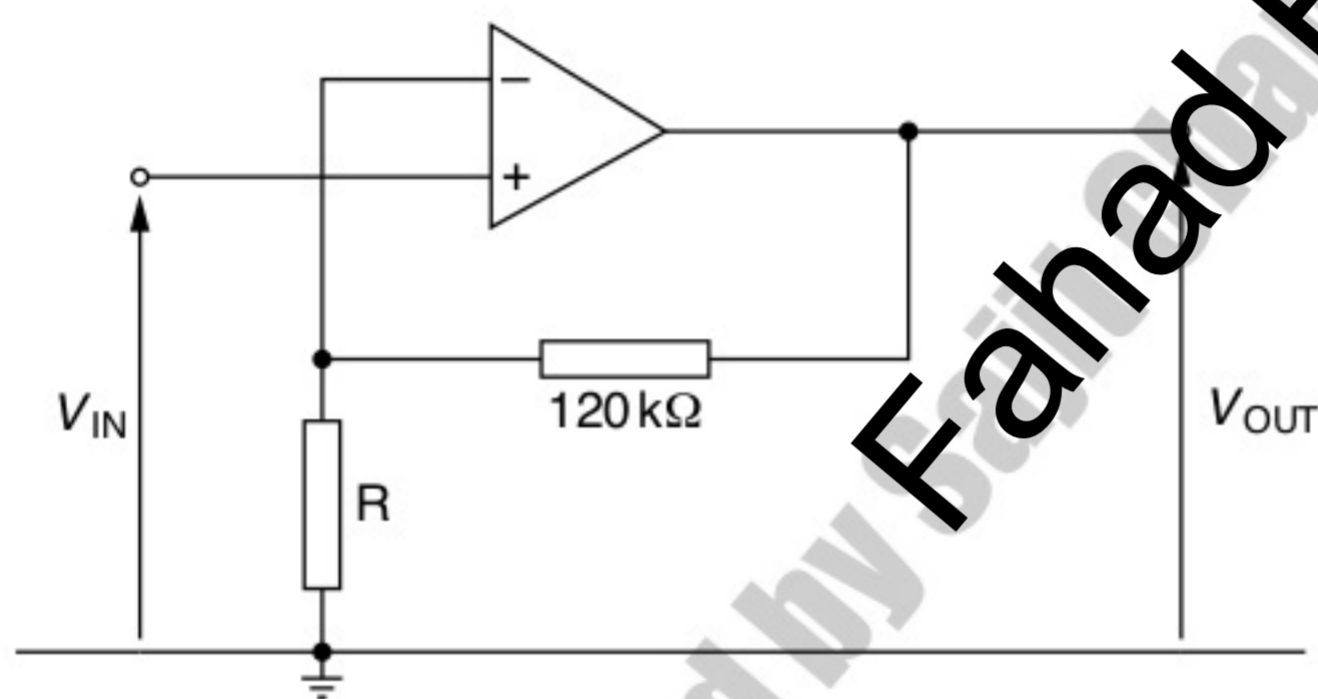
Fig. 10.1

The supply for the op-amp is ±9.0 V.
The amplifier circuit is to have a gain of 25.

Calculate the resistance of resistor R.

resistance = ... Ω [2]

(c) State the value of the output voltage V_{OUT} of the amplifier in **(b)** for input voltages V_{IN} of

(i) −0.08 V,

V_{OUT} = ... V [1]

(ii) +0.4 V.

V_{OUT} = ... V [1]

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For
Examiner's
Use

4 **(a)** Fig. 8.1 shows a circuit incorporating an ideal operational amplifier (op-amp).
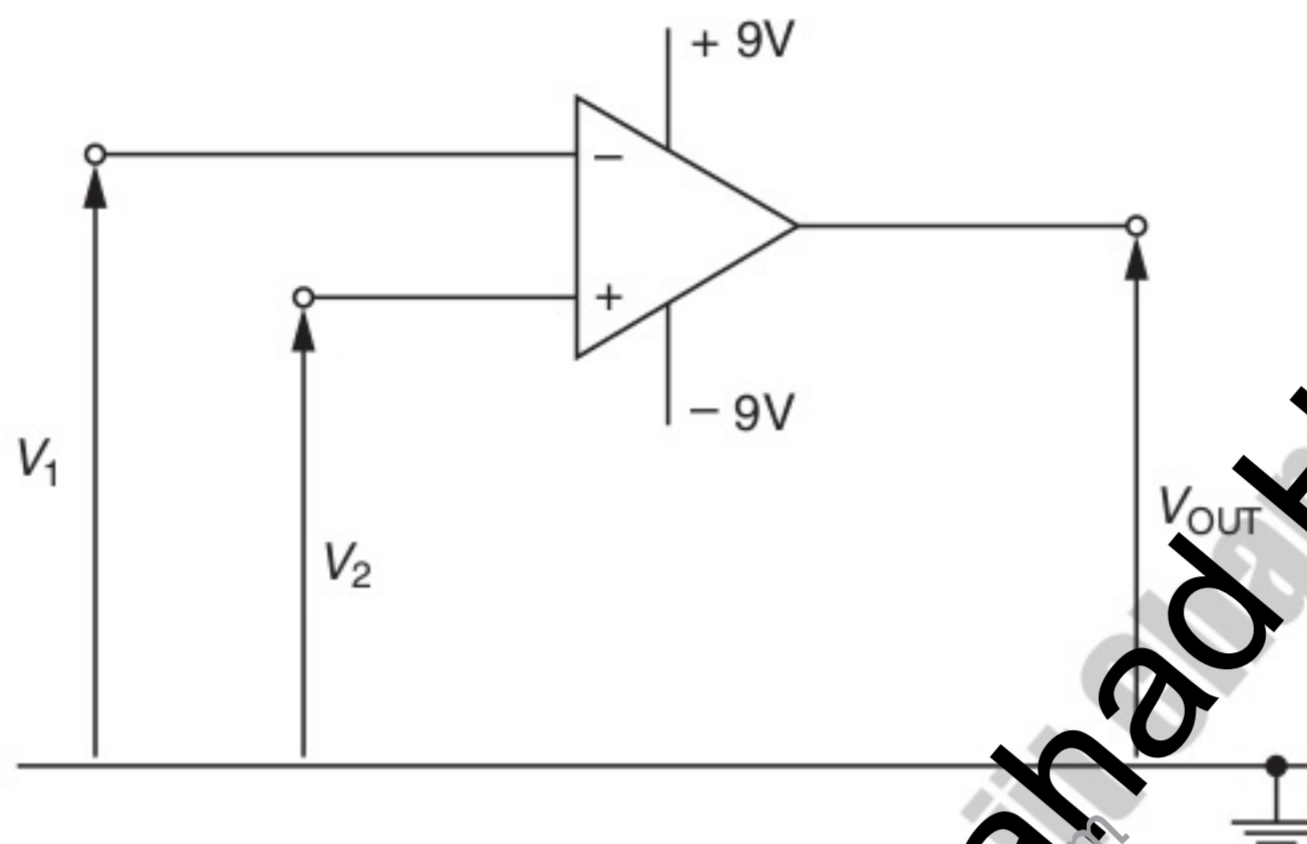
Fig. 8.1

The voltages applied to the inverting and the non-inverting inputs are V_1 and V_2 respectively.

State the value of the output voltage V_{OUT} when

(i) $V_1 > V_2$,

V_{OUT} = ... V

(ii) $V_1 < V_2$.

V_{OUT} = ... V

[1]

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(b) The circuit of Fig. 8.2 is used to monitor the input voltage V_{IN}.
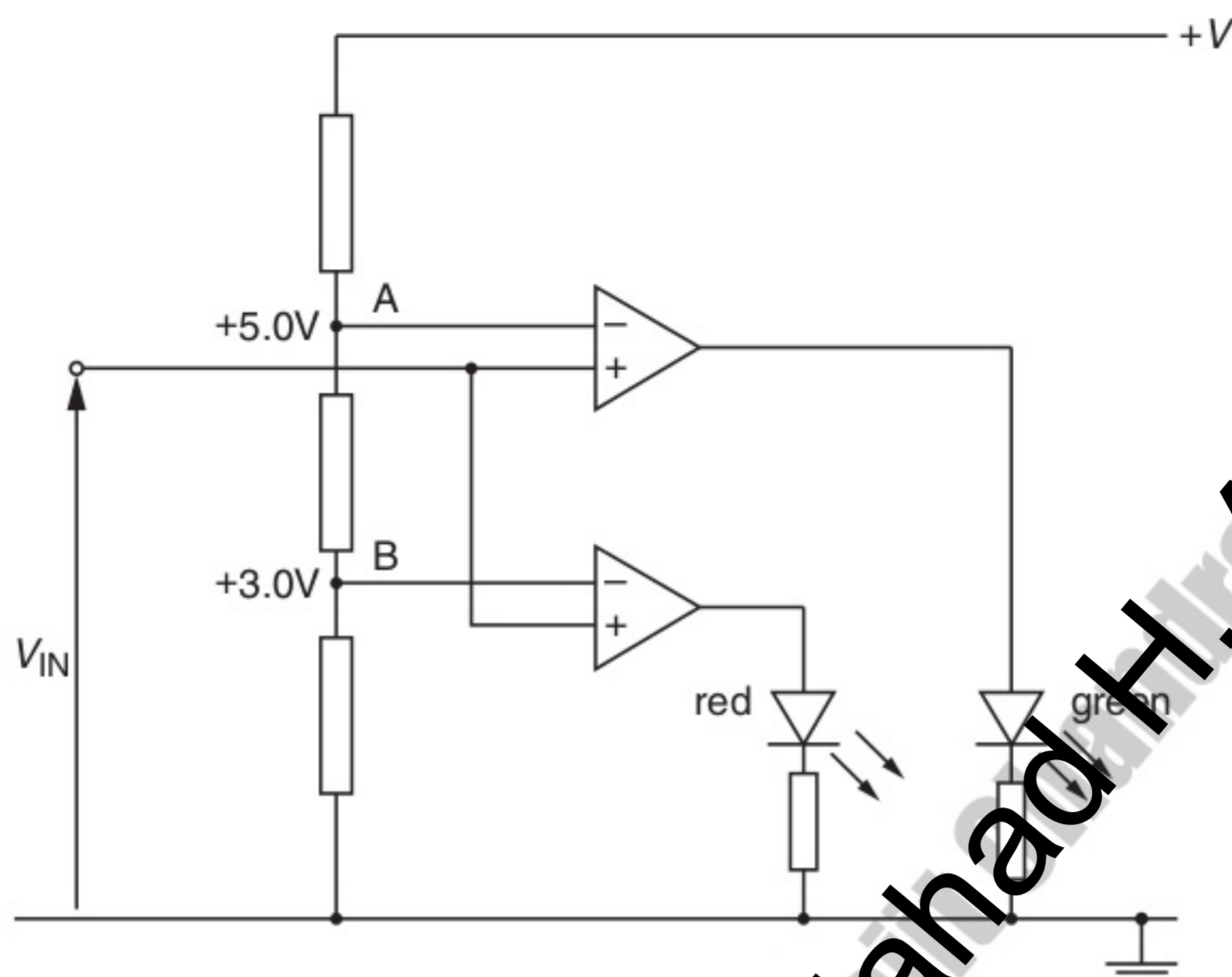
Fig. 8.2

At point A, a potential of 5.0V is maintained. At point B, a potential of 3.0V is maintained.

Complete Fig. 8.3 by indicating with a tick (✓) the light-emitting diodes (LEDs) that are conducting for the input voltages V_{IN} shown. Also, mark with a cross (✗) those LEDs that are not conducting.

V_{IN} / V	red LED	green LED
+2.0		
+4.0		
+6.0		

[3]

Fig. 8.3

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Use

(c) The input voltage V_{IN} in **(b)** is provided by a sensor circuit.

(i) Complete Fig. 8.4 to show a sensor circuit that will provide a voltage output that increases as the temperature of the sensor decreases. Show clearly the output connections from the circuit. [2]
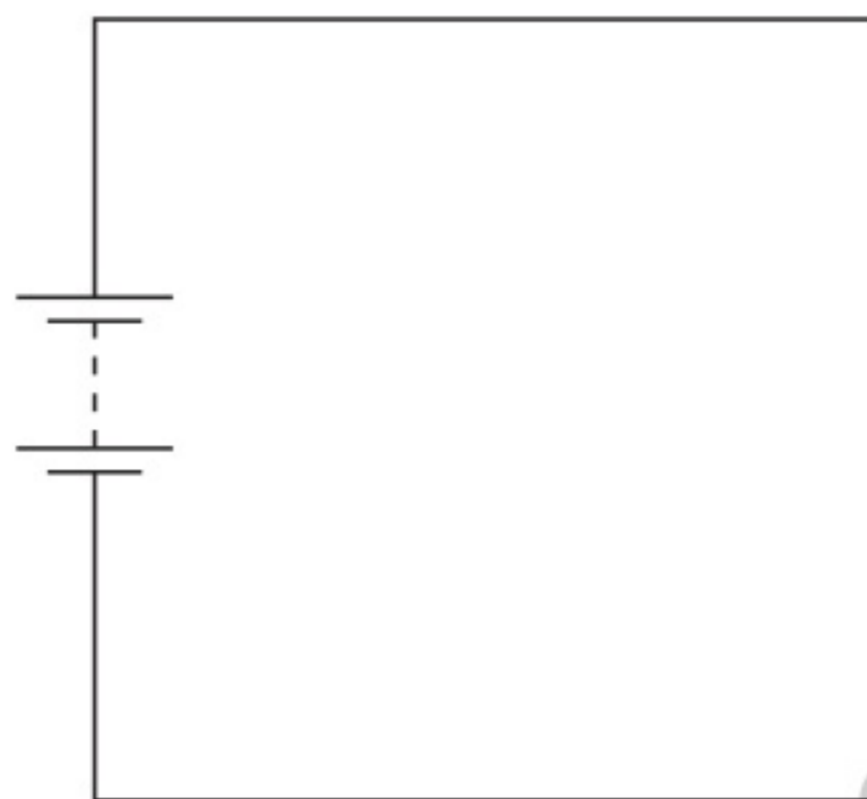
Fig. 8.4

(ii) Explain the operation of the sensor circuit.

....

....

....

....

....

....[3]

5 (a) The circuit for an amplifier incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.1.
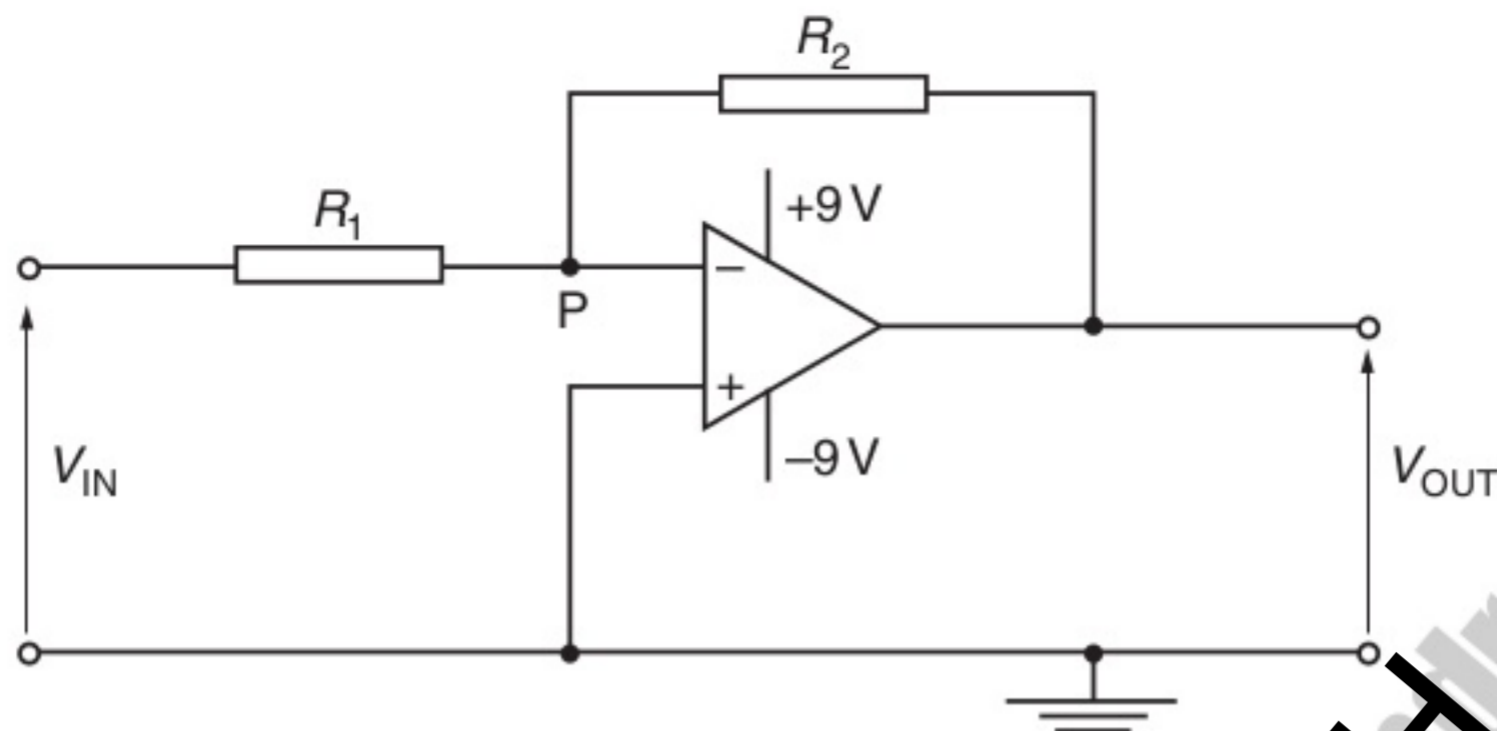
Fig. 10.1

(i) State

1. the name of this type of amplifier circuit,

....[1]

2. why the point P is referred to as a *virtual earth*.

....

....

....

....[3]

(ii) Show that the gain G of this amplifier circuit is given by the expression

$$G = -\frac{R_2}{R_1}.$$

Explain your working.

[4]

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For Examiner's Use

(b) The circuit of Fig. 10.1 is modified by connecting a light-dependent resistor (LDR) as shown in Fig. 10.2.
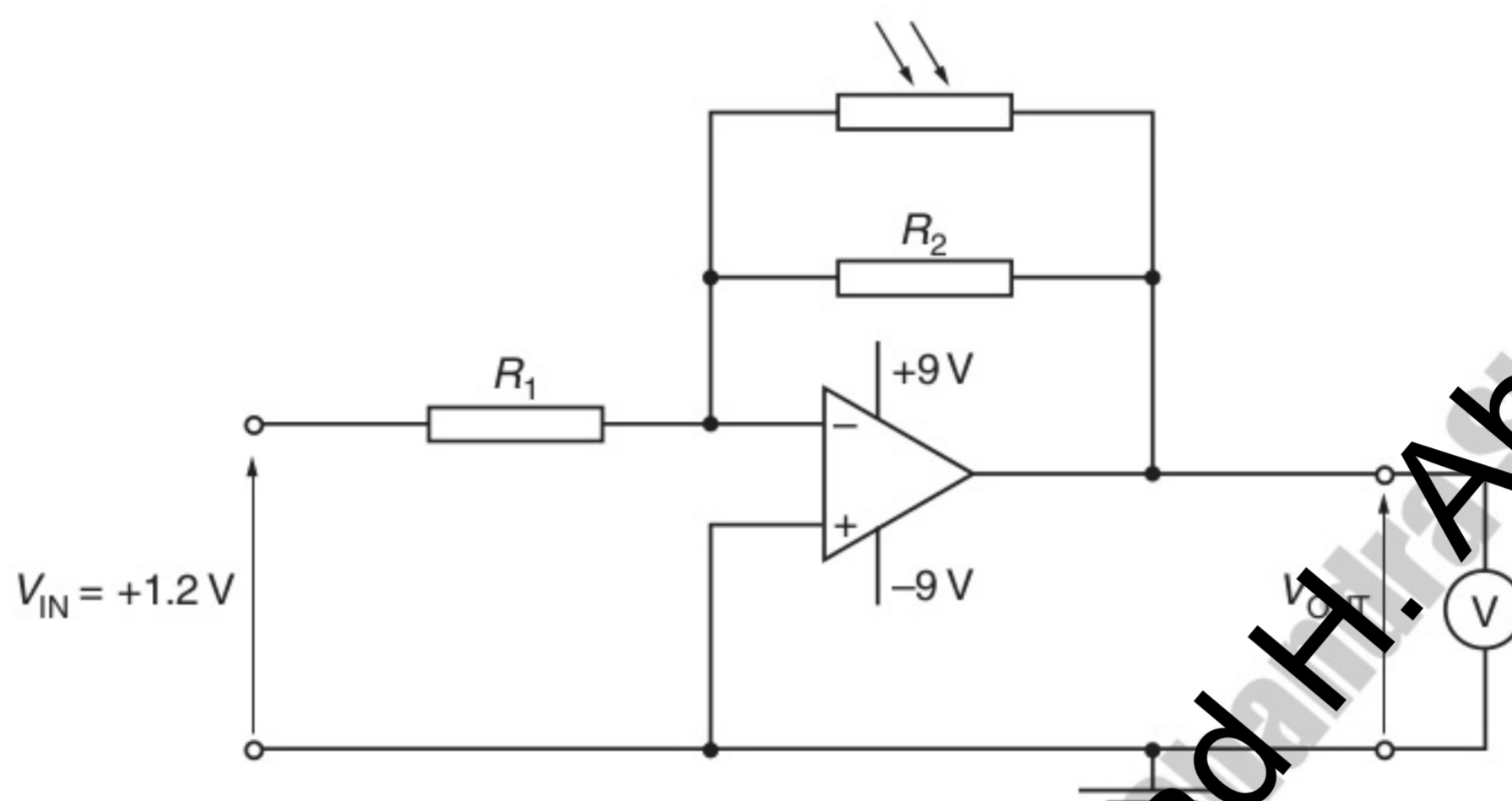
Fig. 10.2

The resistances R_1 and R_2 are 5.0 kΩ and 50 kΩ respectively.
The input voltage V_{IN} is +1.2 V. A high-resistance voltmeter measures the output V_{OUT}.
The circuit is used to monitor low light intensities.

(i) Determine the voltmeter reading for light intensities such that the LDR has a resistance of

    1. 100 kΩ,

reading = ... V [3]

    2. 10 kΩ.

reading = ... V [2]

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(ii) The light incident on the LDR is provided by a single lamp. Use your answers in **(i)** to describe and explain qualitatively the variation of the voltmeter reading as the lamp is moved away from the LDR.

....

....

....

....

....**[3]**

For
Examiner's
Use

6   A metal wire strain gauge is firmly fixed across a crack in a wall, as shown in Fig. 9.1, so that the growth of the crack may be monitored.
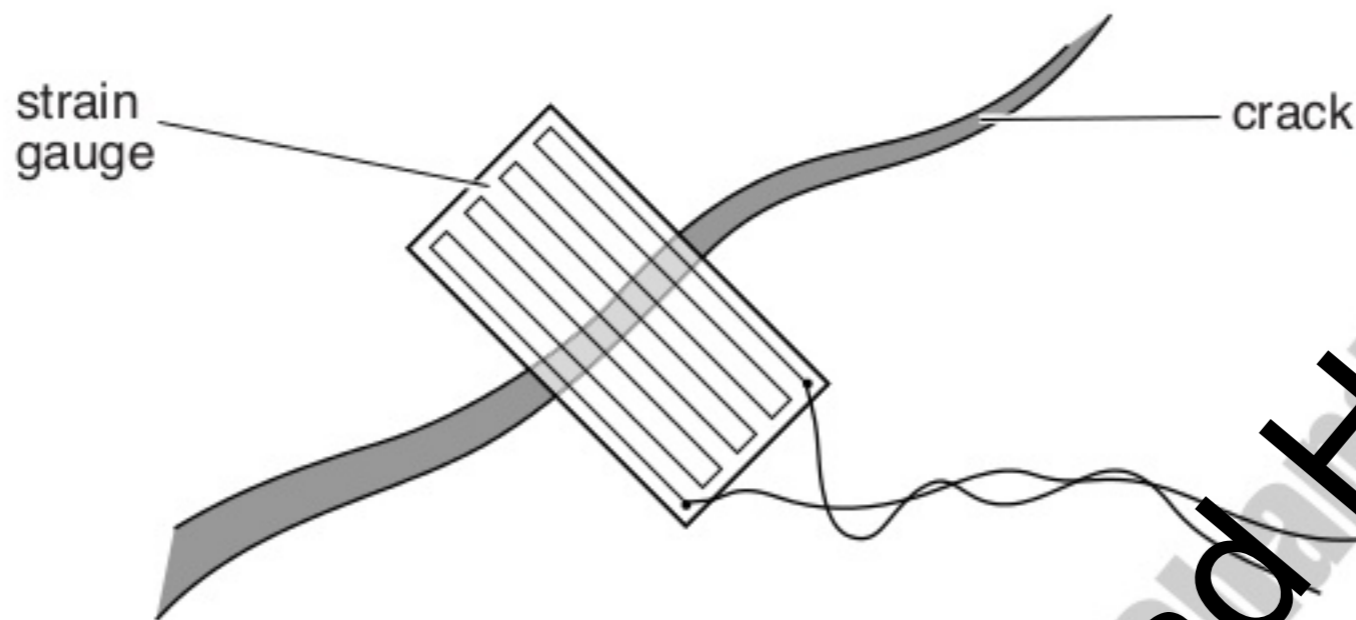
Fig. 9.1

(a) Explain why, as the crack becomes wider, the resistance of the strain gauge increases.

....

....

....

.... [3]

(b) The strain gauge has an initial resistance of 143.0 Ω and, after being fixed in position across the crack for several weeks, the resistance is found to be 146.2 Ω.

The change in the area of cross-section of the strain gauge wire is negligible.

Calculate the percentage increase in the width of the crack. Explain your working.

increase = ... % [3]

7 The circuit of Fig. 10.1 may be used to indicate temperature change.
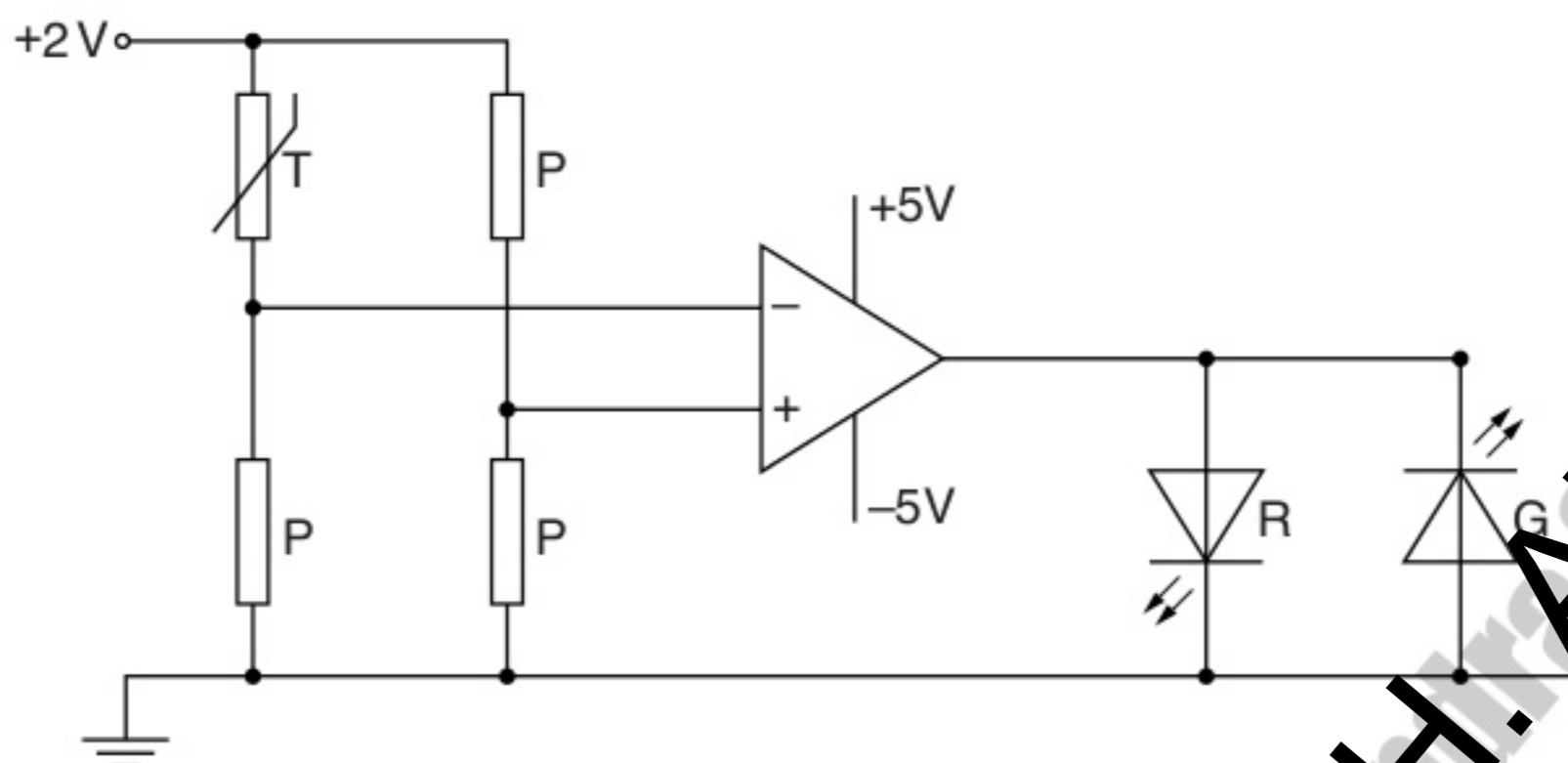
Fig. 10.1

The resistance of the thermistor T at 16°C is 2100 Ω and at 18°C the resistance is 1900 Ω. Each resistor P has a resistance of 2000 Ω.

Determine the change in the states of the light-emitting diodes R and G as the temperature of the thermistor changes from 16 °C to 18 °C.

....

.... [4]

For
Examiner's
Use

8   An amplifier incorporating an operational amplifier (op-amp) has three inputs A, B and C, as shown in Fig. 9.1.
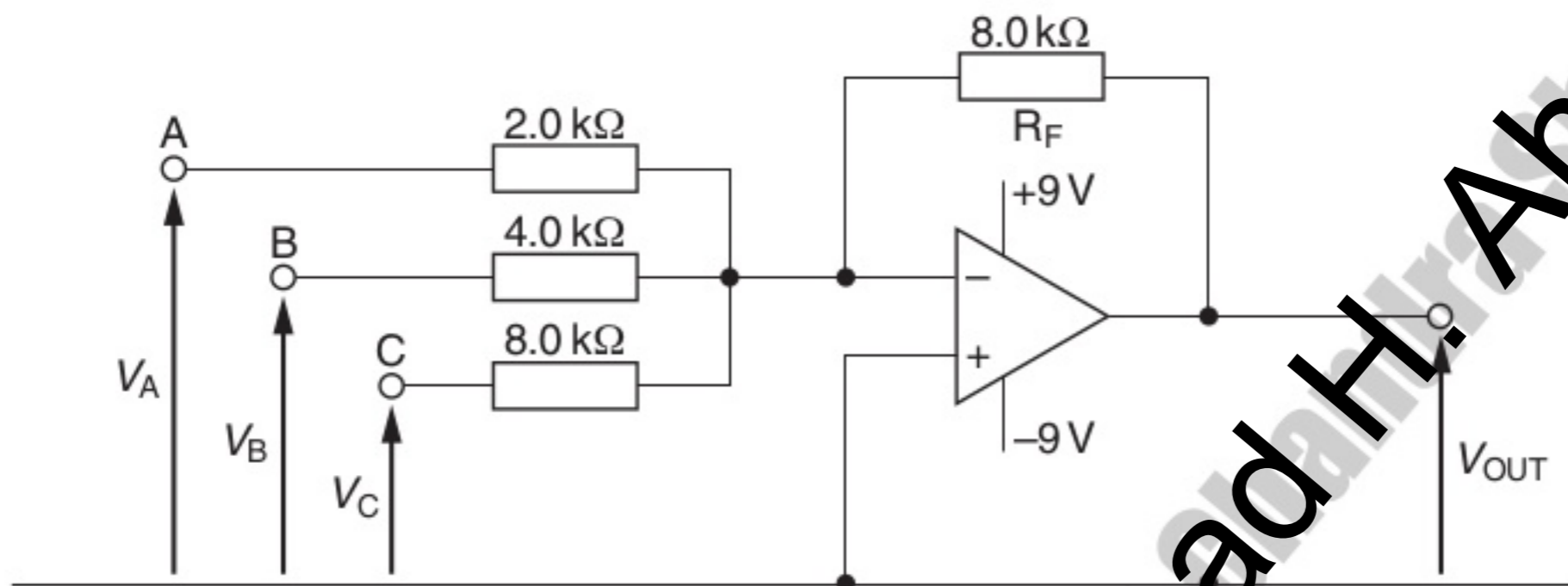
Fig. 9.1

Negative feedback is provided by the resistor R_F of resistance 8.0 kΩ.

For each of the inputs A, B and C, the amplifier may be considered as a single input amplifier. That is, each input is independent of the other two.

When the amplifier is not saturated, the output potential V_{OUT} is given by the expression

$$V_{OUT} = -(4V_A + GV_B + V_C),$$

where V_A, V_B and V_C are the input potentials of the inputs A, B and C respectively and G is a constant.

(a) State two effects of negative feedback on an amplifier.

   1. ....

   ....

   2. ....

   ....

[2]

(b) In the expression for the output potential V_{OUT}, the constant G is the gain associated with input B. Show that the numerical value of G is 2.

[1]

(c) The input potentials V_A, V_B and V_C are either zero or 1.0V.

The magnitudes of some output potentials for different combinations of V_A, V_B and V_C are shown in Fig. 9.2.

V_A/V	V_B/V	V_C/V	V_{OUT}/V
0	0	1	1
0	1	0	……
1	0	0	4
1	0	1	5
1	1	0	……
1	1	1	……

Fig. 9.2

(i) Complete Fig. 9.2 for the three remaining values of V_{OUT}. [1]

(ii) Suggest a use for this circuit.

.... [1]

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9 **(a)** Negative feedback may be used in amplifier circuits. State

    (i) what is meant by *negative feedback*,

....

....

.... [2]

    (ii) two effects of negative feedback on an amplifier incorporating an operational amplifier (op-amp).

1. ....

....

2. ....

....

.... [2]

(b) Fig. 9.1 is a circuit for an amplifier that is used with a microphone.
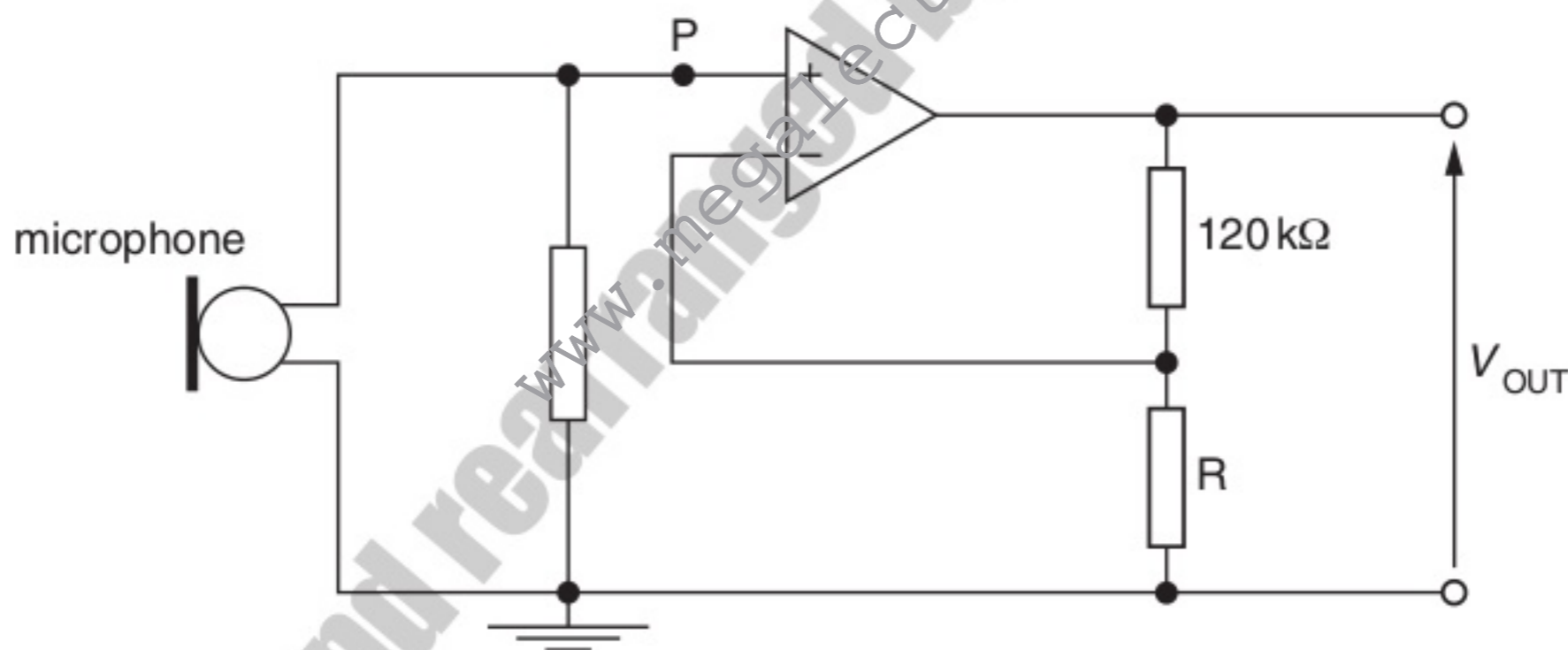

Fig. 9.1

The output potential difference V_{OUT} is 4.4 V when the potential at point P is 62 mV.

Determine

(i) the gain of the amplifier,

gain = ... [1]

(ii) the resistance of the resistor R.

resistance = ... Ω [2]

(c) The maximum potential produced by the microphone at point P on Fig. 9.1 is 95 mV.
The power supply for the operational amplifier may be either +/– 5 V or +/– 9 V.

State which power supply should be used. Justify your answer quantitatively.

....

....

....

.... [3]

10 (a) State the name of an electrical sensing device that will respond to changes in

(i) length,

.... [1]

(ii) pressure.

....

(b) A relay is sometimes used as the output of a sensing circuit.

The output of a particular sensing circuit is either +2V or −2V.

On Fig. 10.1, draw symbols for a relay and any other necessary component so that the external circuit is switched on only when the output from the sensing circuit is +2V.
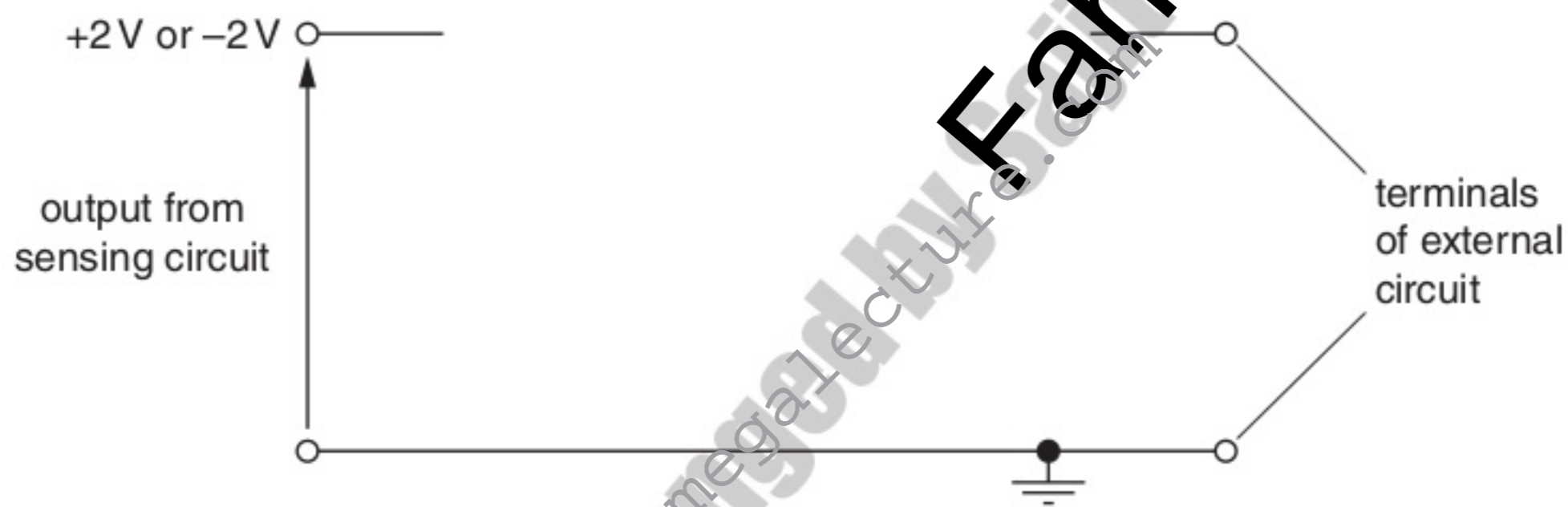
+2V or −2V

output from
sensing circuit

terminals
of external
circuit

Fig. 10.1

[4]

11 The circuit diagram of Fig. 9.1 is an amplifier circuit incorporating an operational amplifier (op-amp).
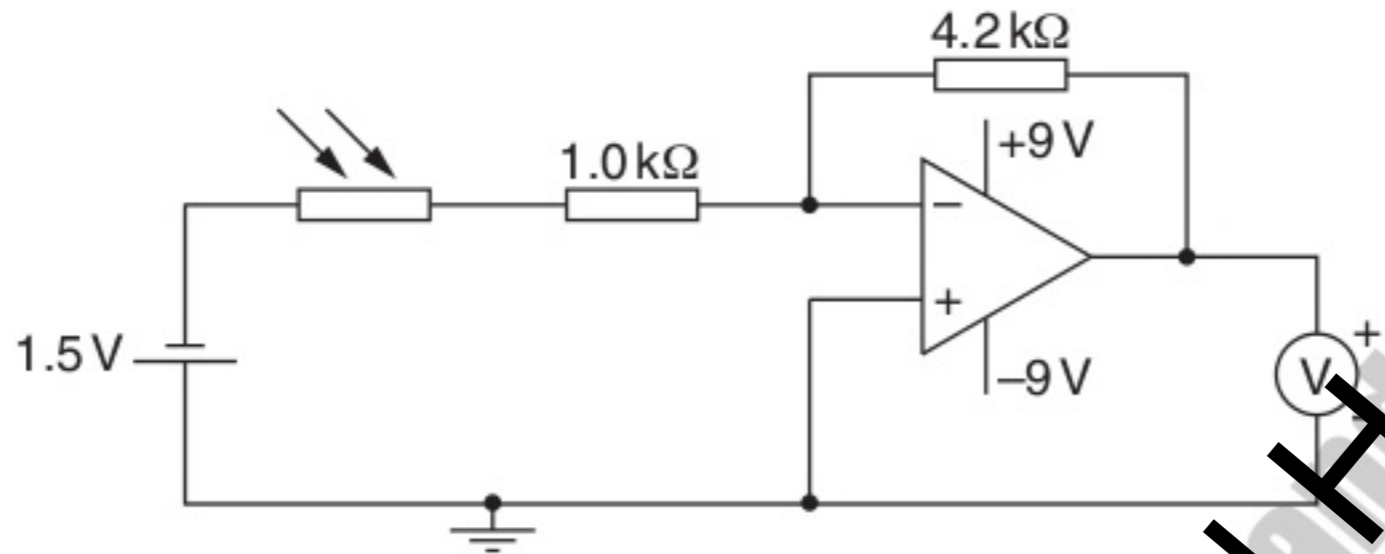

Fig. 9.1

(a) (i) On Fig. 9.1, mark, with the letter X, the virtual earth. [1]

(ii) Explain what is meant by a *virtual earth*.

....

....

....

....[3]

(b) In bright sunlight, the light-dependent resistor (LDR) has resistance $200\,\Omega$.

(i) Calculate, for the LDR in bright sunlight, the voltmeter reading.

reading = ... V [3]

(ii) The sunlight incident on the LDR becomes less bright.
State and explain the effect on the voltmeter reading of this decrease in brightness.

....

....

....

....[3]

9 An amplifier circuit incorporating an operational amplifier (op-amp) is shown in Fig. 9.1.
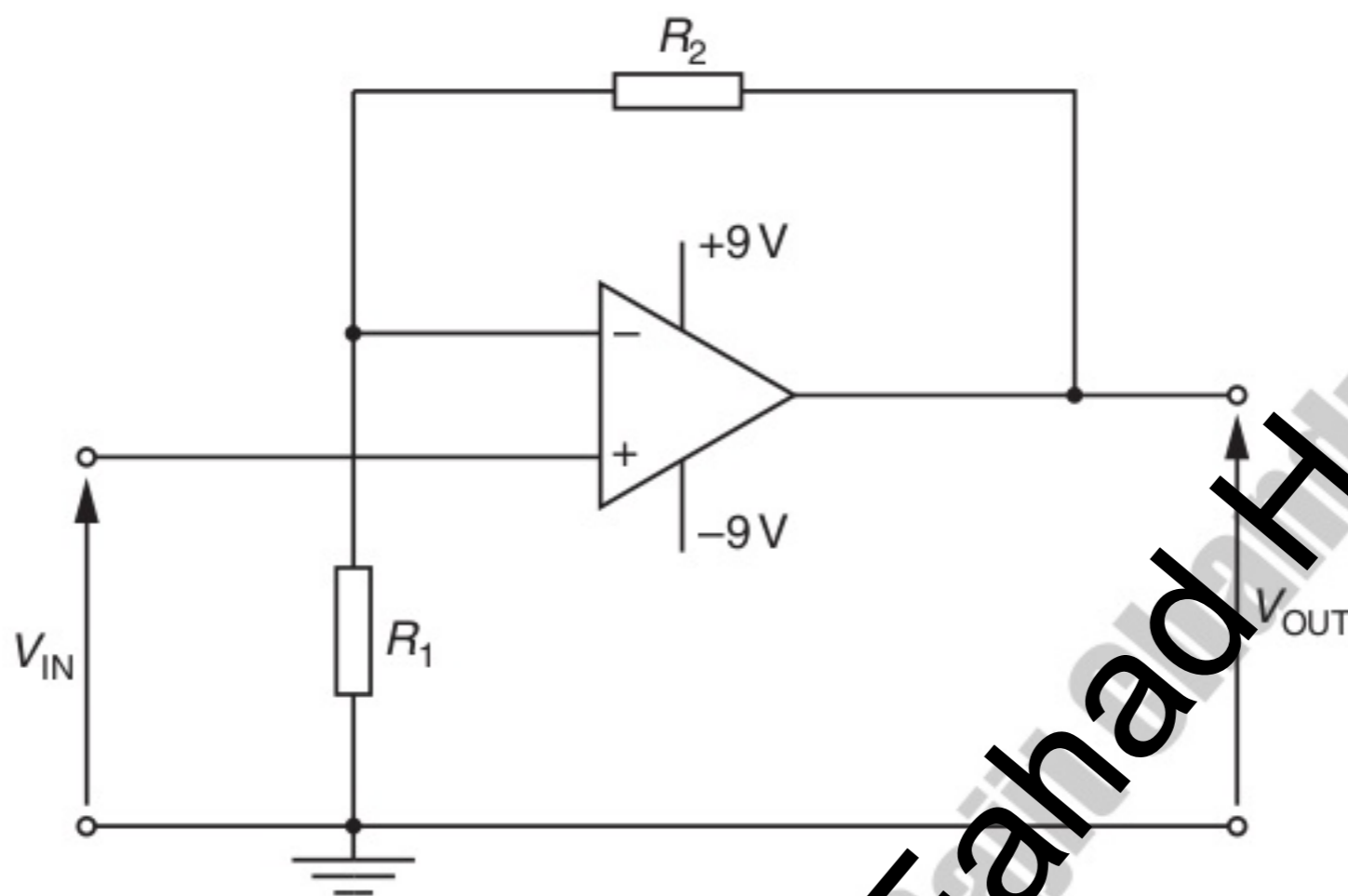
Fig. 9.1

(a) State

   (i) the name of this type of amplifier circuit,

    ....[1]

   (ii) the gain G in terms of resistances R_1 and R_2.

    ....[1]

9702/41/O/N/10

(b) The value of R_1 is 820 Ω. The resistor of resistance R_2 is replaced with a light-dependent resistor (LDR).
The input potential difference V_{IN} is 15 mV.
Calculate the output potential difference V_{OUT} for the LDR having a resistance of

(i) 100 Ω (the LDR is in sunlight),

$$V_{OUT} = \text{..} \text{ V } [2]$$

(ii) 1.0 MΩ (the LDR is in darkness).

$$V_{OUT} = \text{..} \text{ V } [1]$$

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[Turn over

10 (a) State three properties of an ideal operational amplifier (op-amp).

1. ....

2. ....

3. ....

(b) A circuit incorporating an ideal op-amp is to be used to indicate whether a door is open or closed.
Resistors, each of resistance R, are connected to the inputs of the op-amp, as shown in Fig. 10.1.
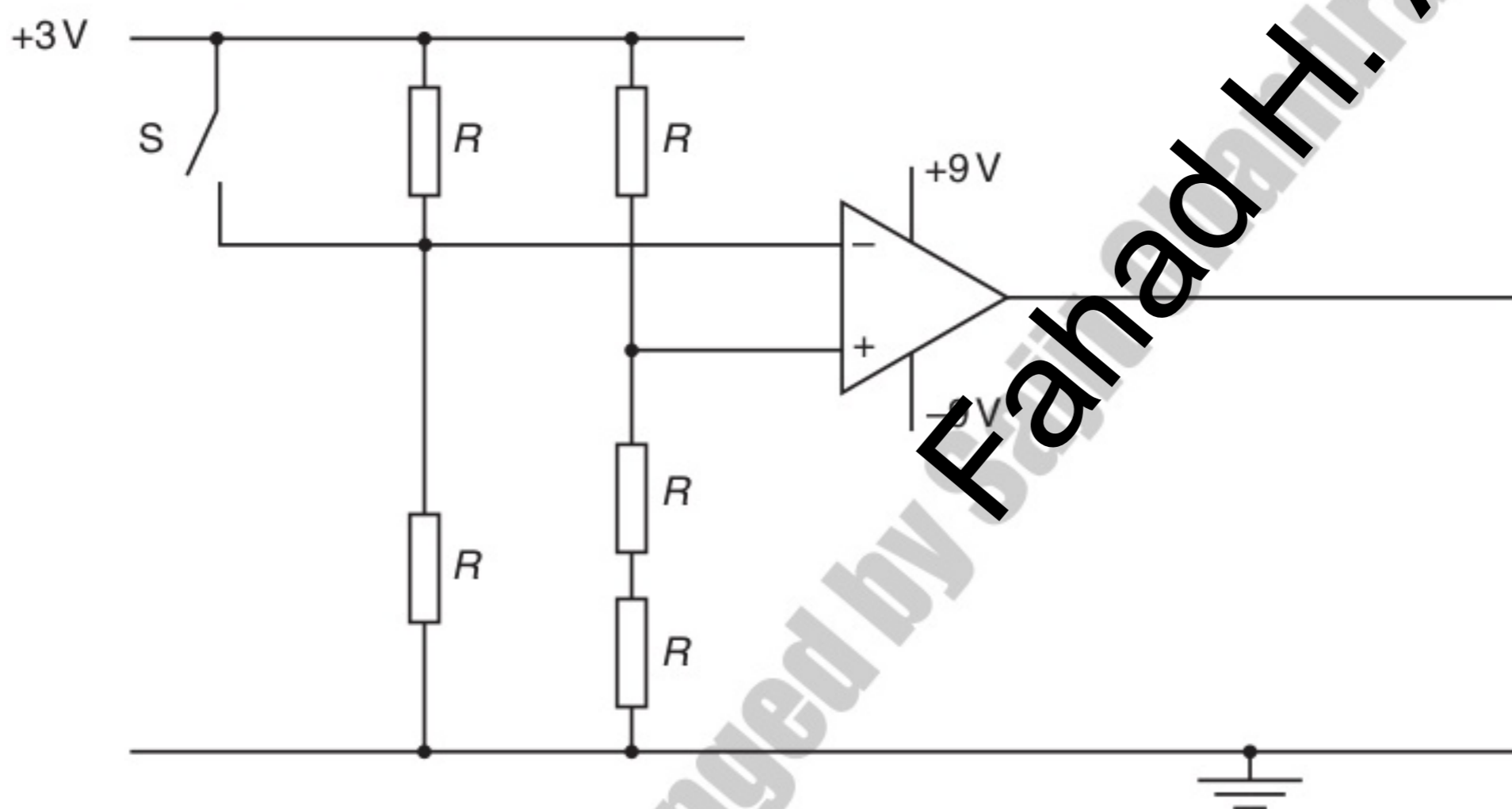

Fig. 10.1

The switch S is attached to the door so that, when the door is open, the switch is open.
The switch closes when the door is closed.

(i) Explain why the polarity of the output of the op-amp changes when the switch closes.

....

....

....

.... [3]

(ii) A red light-emitting diode (LED) is to be used to indicate when the door is open. A green LED is to indicate when the door is closed.

On Fig. 10.1,

1. draw symbols for the LEDs to show how they are connected to the output of the op-amp, [1]

2. identify the green LED with the letter G. [1]

Please turn over for Question 11.

For
Examiner's
Use

9 (a) An operational amplifier (op-amp) may be used as a comparator.
State the function of a comparator.

....

....

....[2]

(b) The variation with temperature θ of the resistance R of a thermistor is shown in Fig. 9.1.
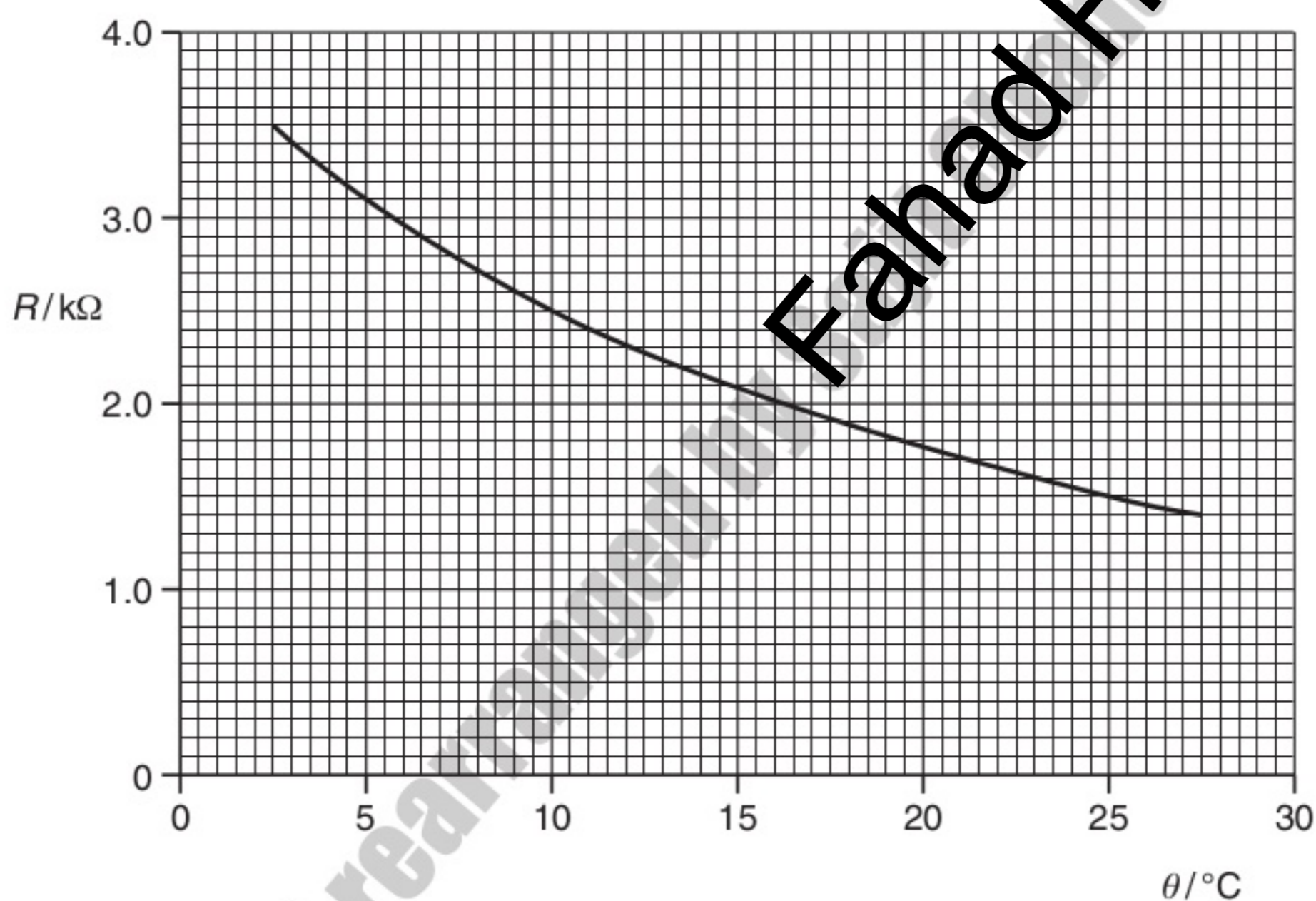

Fig. 9.1

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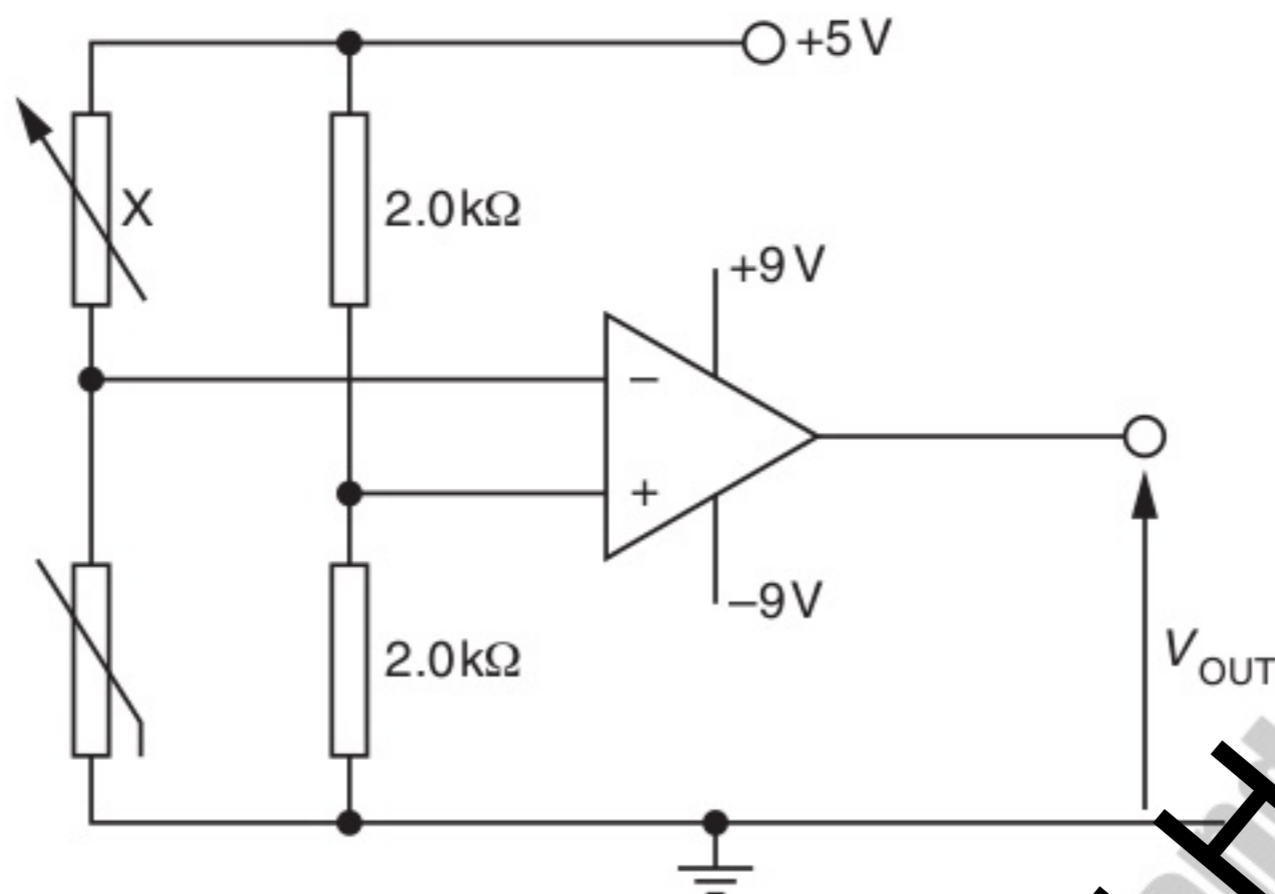The thermistor is connected into the circuit of Fig. 9.2.

Fig. 9.2

The op-amp may be considered to be ideal.

(i) The temperature of the thermistor is 10 °C.
Determine the resistance of the variable resistor X such that the output potential V_{OUT} is zero.

resistance = ... Ω [2]

(ii) The resistance of the resistor X is now held constant at the value calculated in **(i)**. Describe the change in the output potential V_{OUT} as the temperature of the thermistor is changed from 5 °C to 20 °C.

....

....

....

....

....[4]

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For
Examiner's
Use

9 (a) Describe the structure of a metal wire strain gauge. You may draw a diagram if you wish.

....

....

....

.... [3]

(b) A strain gauge S is connected into the circuit of Fig. 9.1.
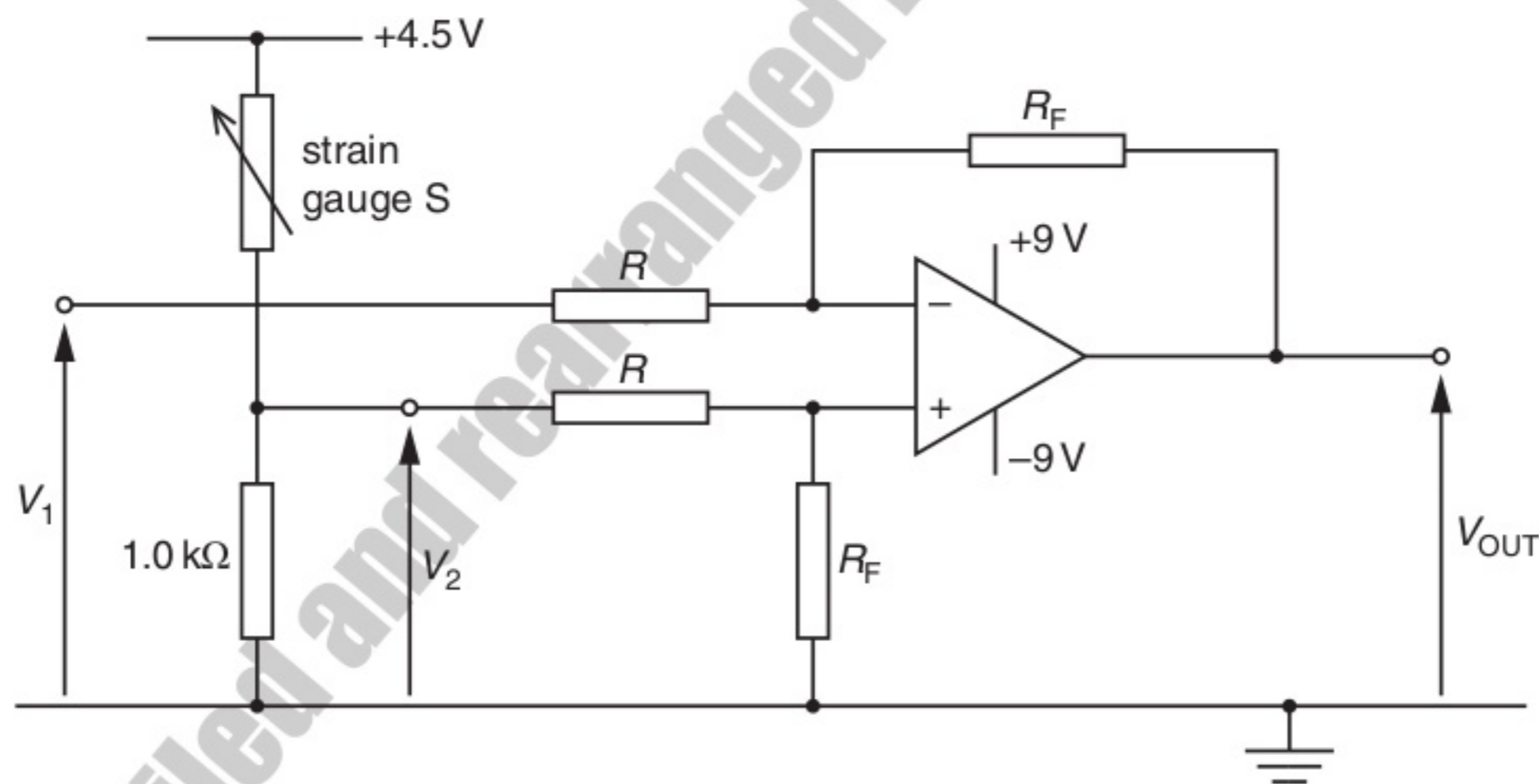

Fig. 9.1

The operational amplifier (op-amp) is ideal.
The output potential V_{OUT} of the circuit is given by the expression

$$V_{OUT} = \frac{R_F}{R} \times (V_2 - V_1).$$

(i) State the name given to the ratio $\dfrac{R_F}{R}$.

.... [1]

(ii) The strain gauge S has resistance 125 Ω when not under strain.
Calculate the magnitude of V_1 such that, when the strain gauge S is not strained, the output V_{OUT} is zero.

V_1 = ... V [3]

(iii) In a particular test, the resistance of S increases to 128 Ω. V_1 is unchanged.
The ratio $\dfrac{R_F}{R}$ is 12.
Calculate the magnitude of V_{OUT}.

V_{OUT} = ... V [2]

For Examiner's Use

9 **(a)** State two effects of negative feedback on the gain of an amplifier incorporating an operational amplifier (op-amp).

1. ....

....

2. ....

....

[2]

(b) An incomplete circuit diagram of a non-inverting amplifier using an ideal op-amp is shown in Fig. 9.1.
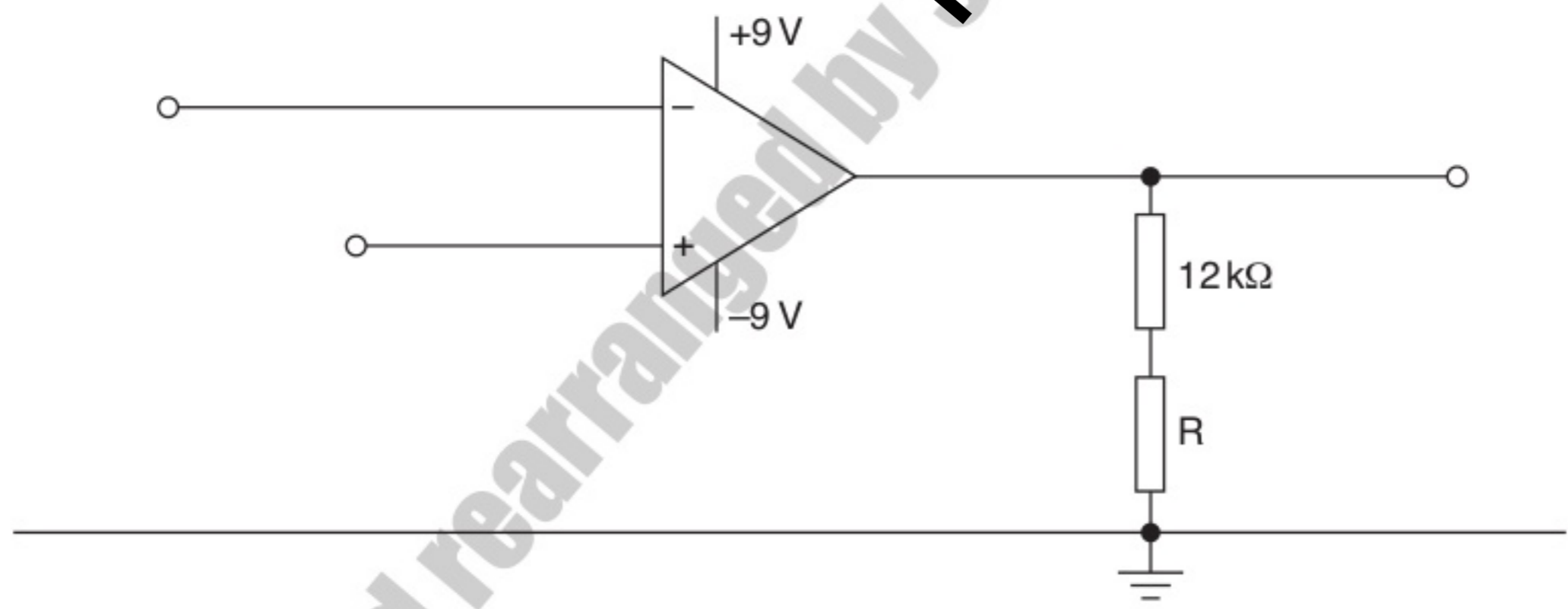

Fig. 9.1

(i) Complete the circuit diagram of Fig. 9.1. Label the input and the output. [2]

(ii) Calculate the resistance of resistor R so that the non-inverting amplifier has a voltage gain of 15.

resistance = ... Ω [2]

(c) On Fig. 9.2, draw a graph to show the variation with input potential V_{IN} of the output potential V_{OUT}.
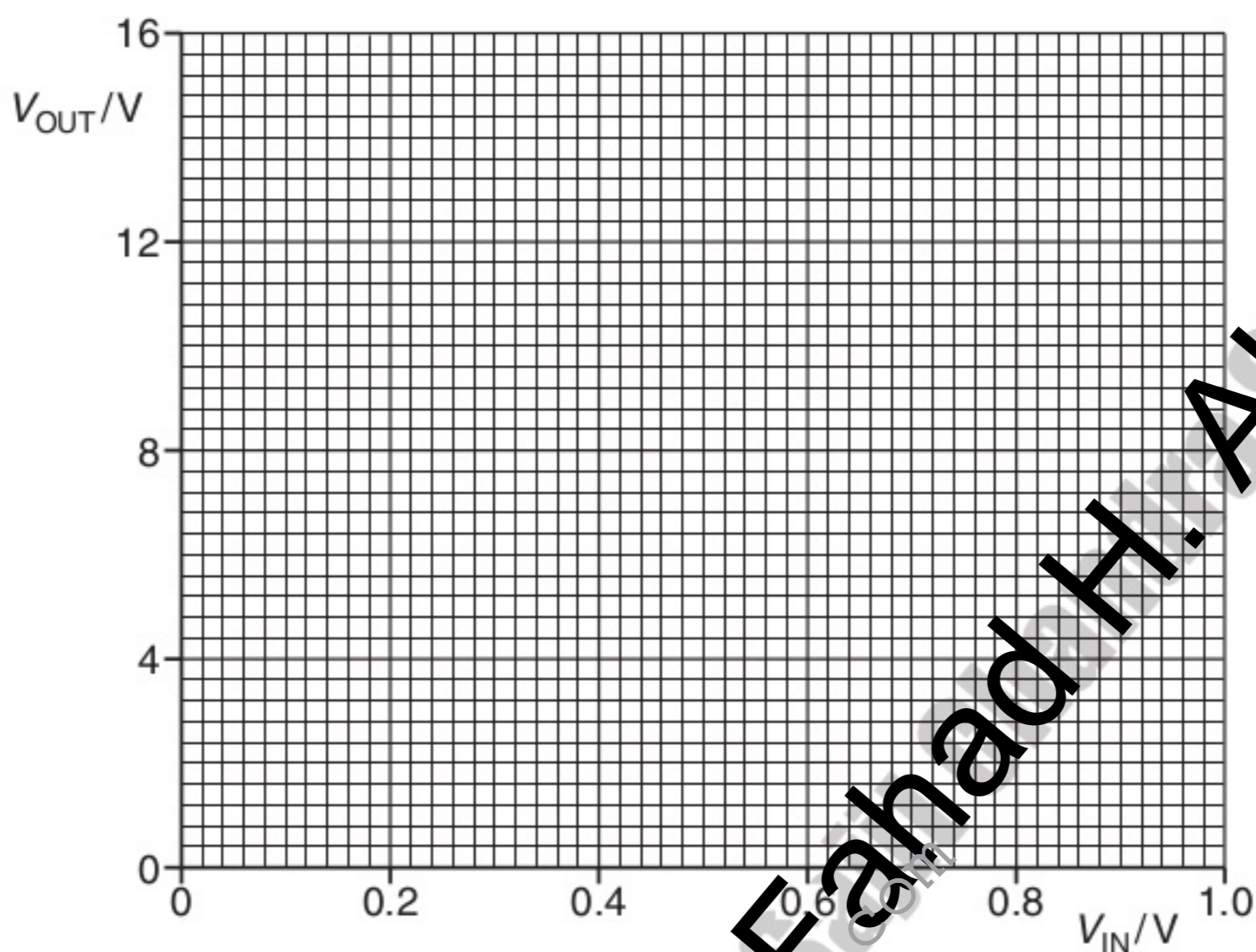You should consider input potentials in the range 0 to +1.0V.

Fig. 9.2

[2]

(d) The output of the amplifier circuit of Fig. 9.1 may be connected to a relay.
State and explain one purpose of a relay.

....

....

....[2]

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For
Examiner's
Use

9 **(a)** State two effects of negative feedback on the gain of an amplifier incorporating an operational amplifier (op-amp).

1. ....

....

2. ....

....

[2]

(b) An incomplete circuit diagram of a non-inverting amplifier using an ideal op-amp is shown in Fig. 9.1.
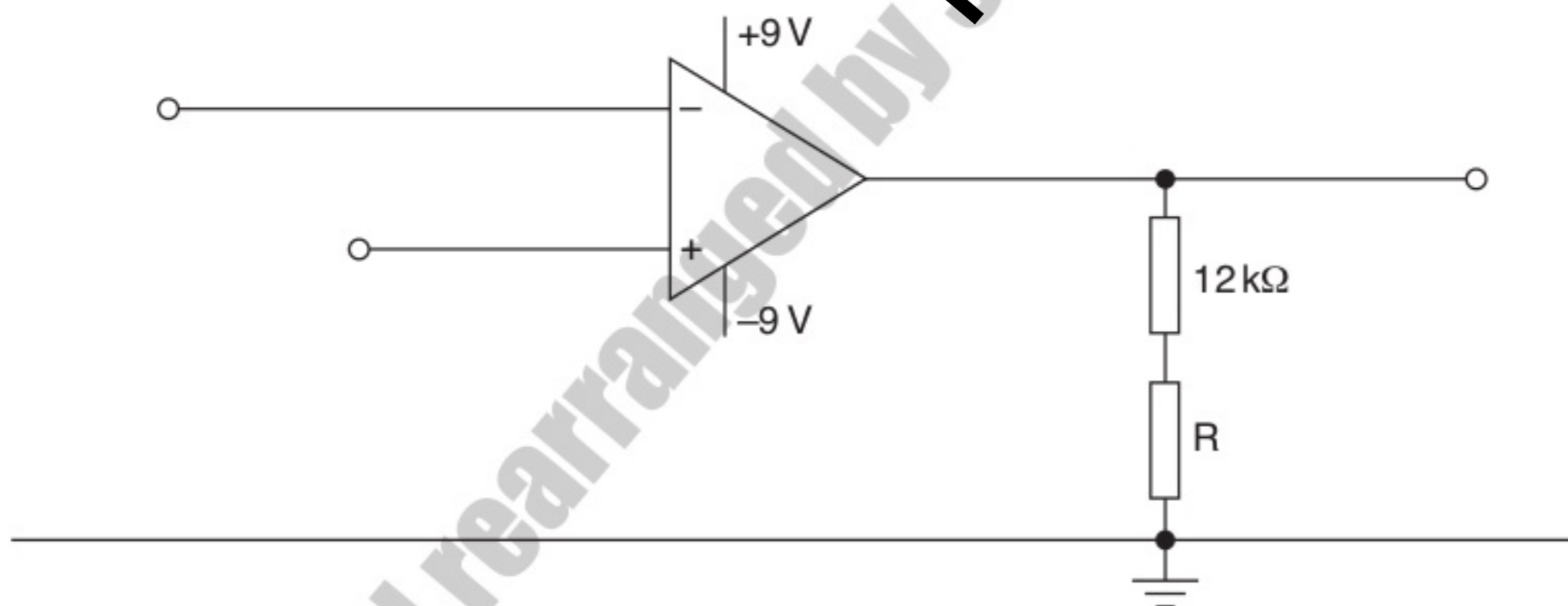

+9 V

12 kΩ

R

−9 V

Fig. 9.1

(i) Complete the circuit diagram of Fig. 9.1. Label the input and the output. [2]

(ii) Calculate the resistance of resistor R so that the non-inverting amplifier has a voltage gain of 15.

resistance = ... Ω [2]

(c) On Fig. 9.2, draw a graph to show the variation with input potential V_{IN} of the output potential V_{OUT}.
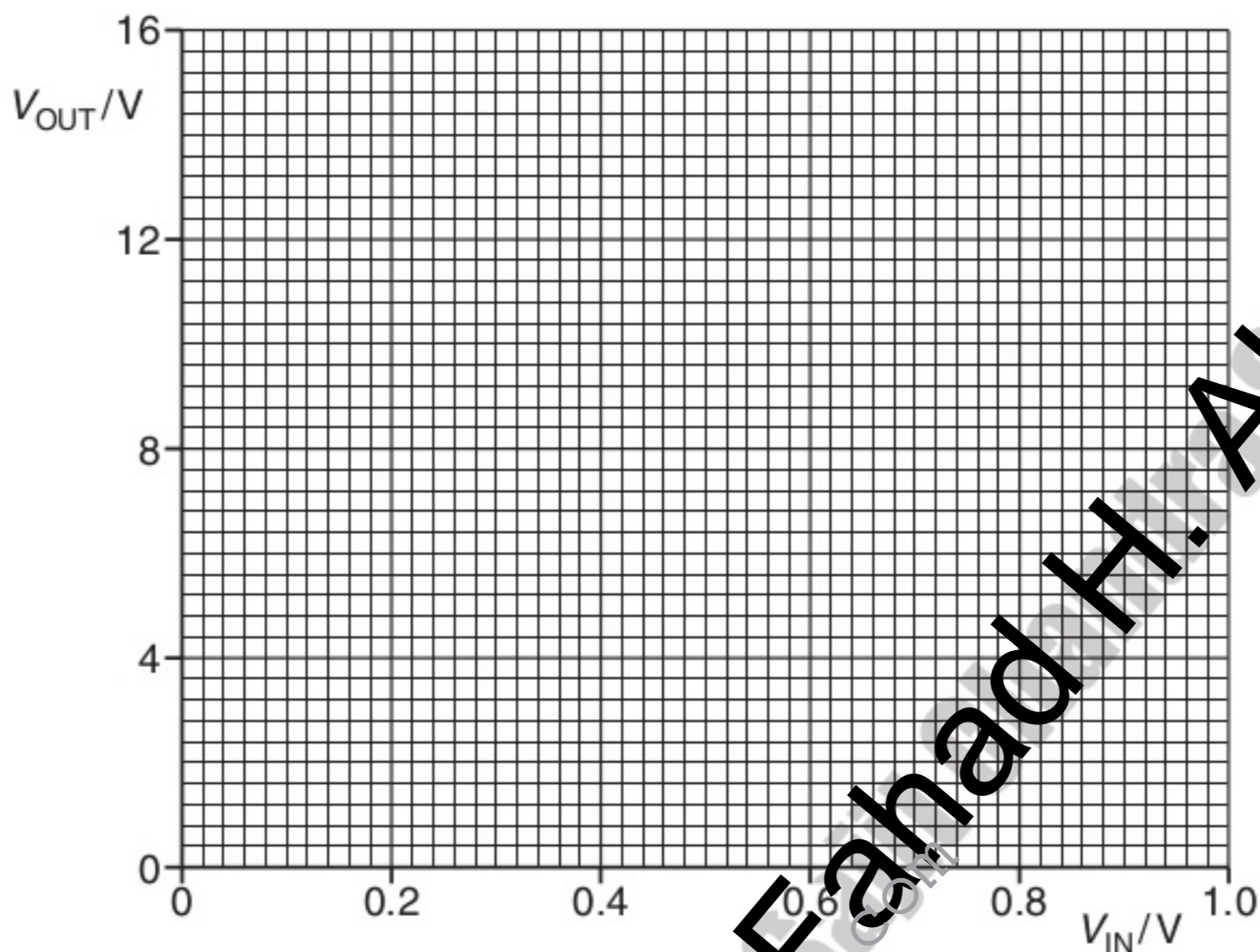You should consider input potentials in the range 0 to +1.0V.

Fig. 9.2

[2]

(d) The output of the amplifier circuit of Fig. 9.1 may be connected to a relay.
State and explain one purpose of a relay.

....

....

....[2]

For
Examiner's
Use

9 **(a)** The resistance of a light-dependent resistor (LDR) is approximately 500 Ω in daylight. Suggest an approximate value for the resistance of the LDR in darkness.

resistance = ...

(b) An electronic light-meter is used to warn when light intensity becomes low. A light-dependent resistor is connected into the circuit of Fig. 9.1.
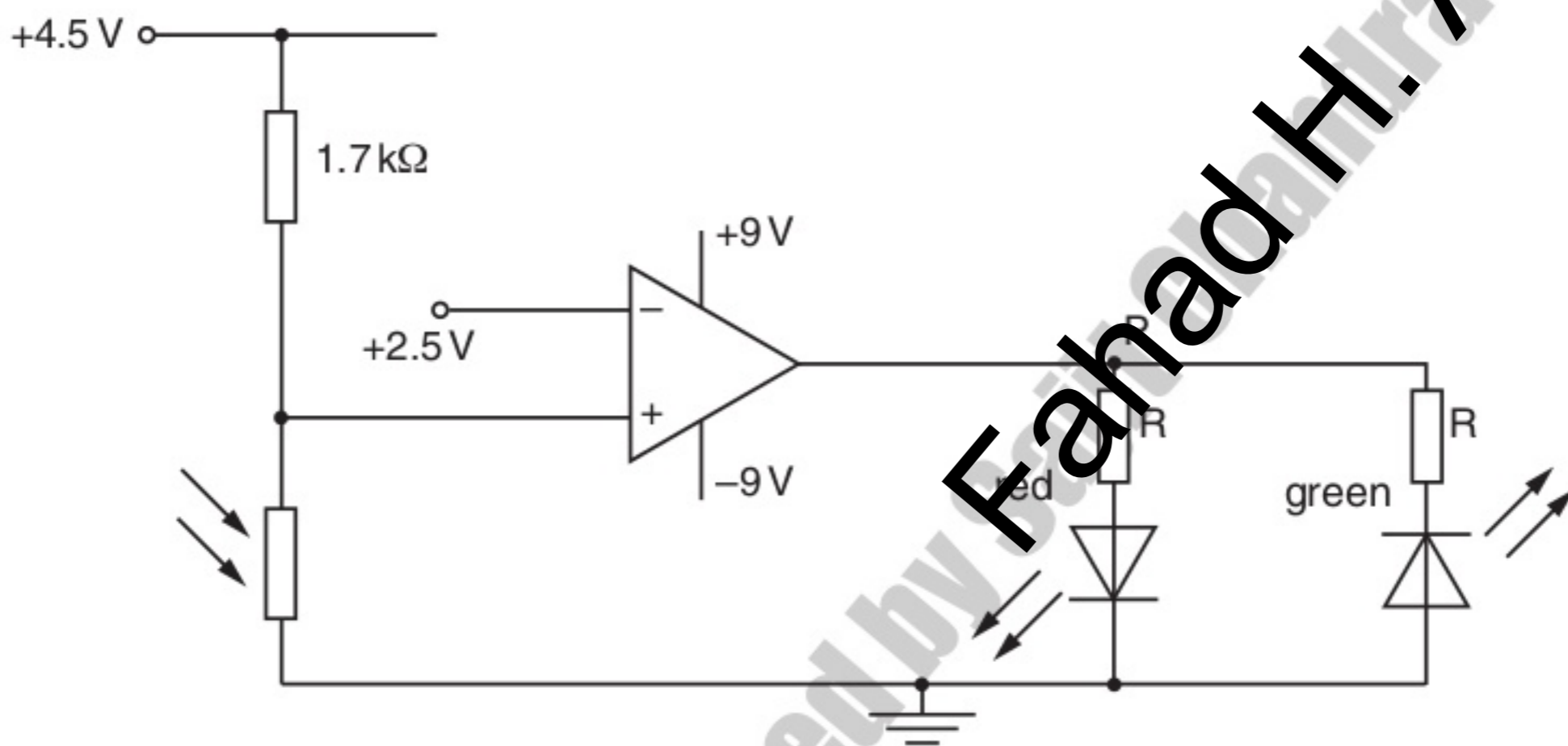

Fig. 9.1

The operational amplifier (op-amp) is ideal.
The resistors R are to ensure that the light-emitting diodes (LEDs) do not over-heat.

(i) On Fig. 9.1, mark the polarity of the point P for the red LED to be emitting light. [1]

(ii) The LDR is in daylight and has a resistance of 500 Ω.
State and explain which diode, red or green, will be emitting light.

....

....

....

.... [3]

(iii) The intensity of the light decreases and the LDR is in darkness.
State and explain the effect on the LEDs of this change in intensity.

....

....

.... [2]

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For
Examiner's
Use

10 A student designs an electronic sensor that is to be used to switch on a lamp when the light intensity is low. Part of the circuit is shown in Fig. 10.1.
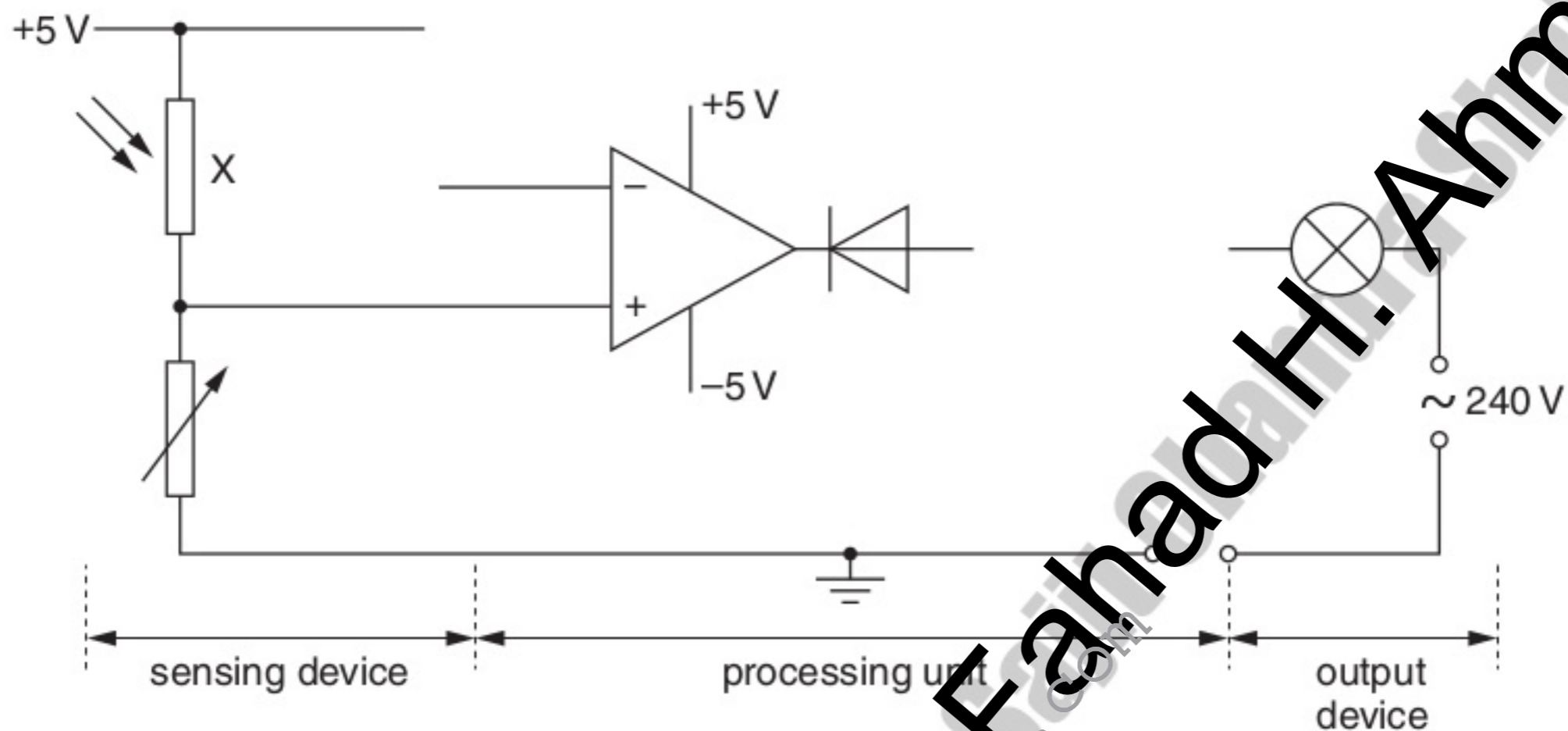

Fig. 10.1

(a) State the name of the component labelled X on Fig. 10.1.

.... [1]

(b) On Fig. 10.1, draw the symbols for

    (i) two resistors to complete the circuit for the sensing device, [2]

    (ii) a relay to complete the circuit for the processing unit. [2]

(c) **(i)** State the purpose of the relay.

    ....

    .... [1]

    (ii) Suggest why the diode is connected to the output of the operational amplifier (op-amp) in the direction shown.

    ....

    ....

    .... [2]

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9702/41/M/J/12

[Turn over

9 An operational amplifier (op-amp) may be used as part of the processing unit in an electronic sensor.

(a) State four properties of an ideal operational amplifier.

1. ....

2. ....

3. ....

4. ....
[4]

(b) A comparator circuit incorporating an ideal op-amp is shown in Fig. 9.1.
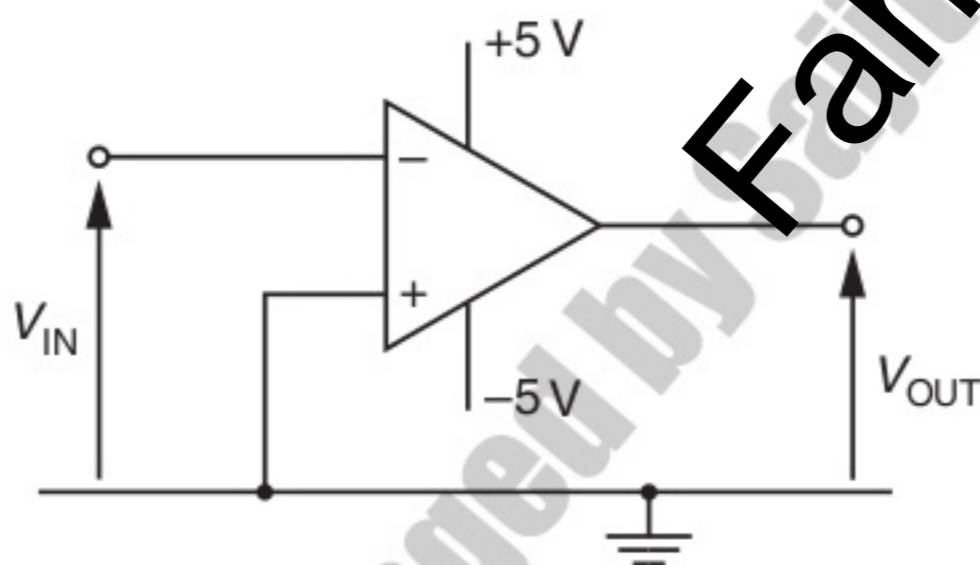

Fig. 9.1

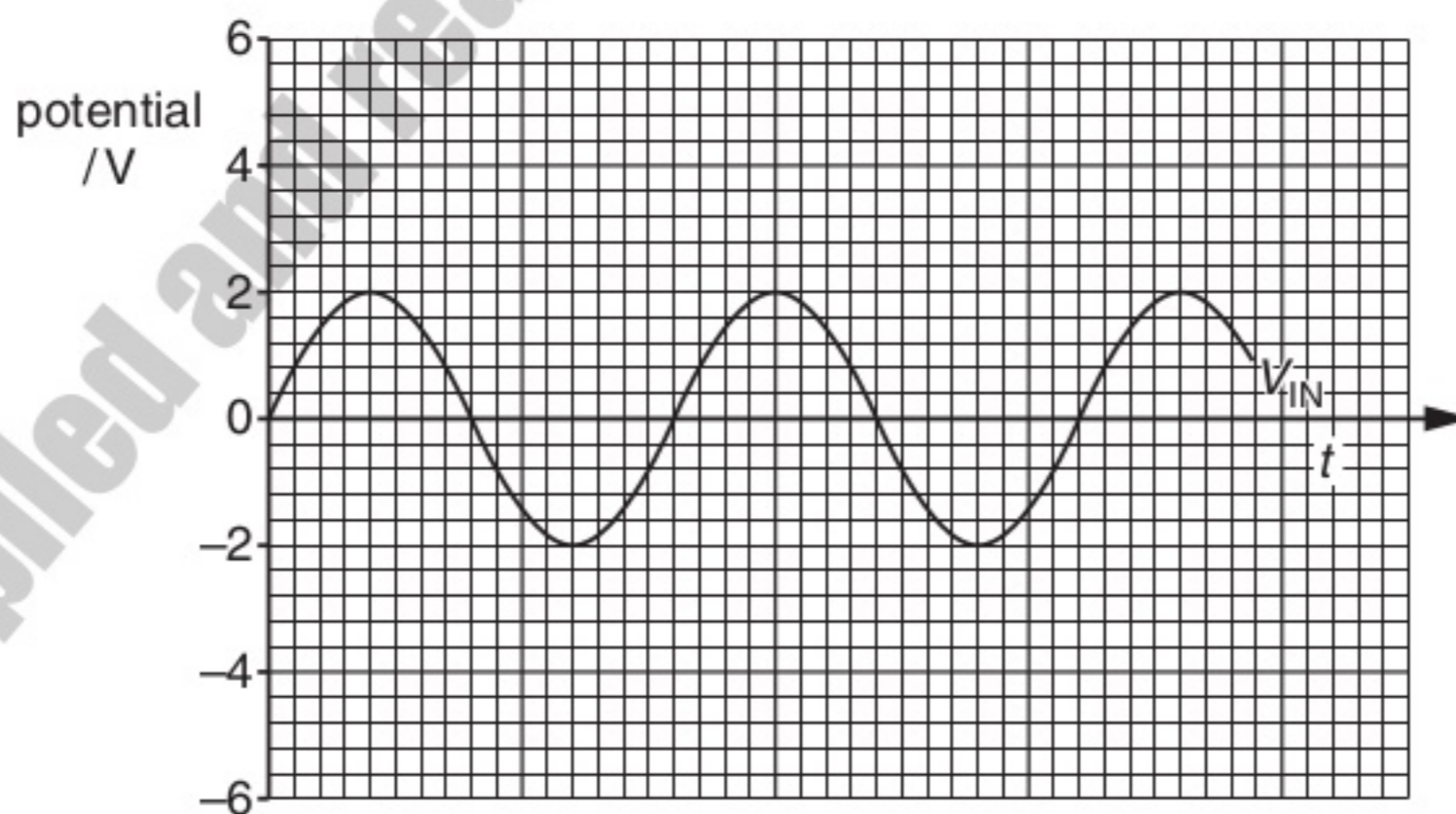The variation with time t of the input potential V_{IN} is shown in Fig. 9.2.

Fig. 9.2

On the axes of Fig. 9.2, draw a graph to show the variation with time t of the output potential V_{OUT}.
[3]

(c) The output potential V_{OUT} is to be displayed using two light-emitting diodes (LEDs). A diode emitting red light is to indicate when V_{OUT} is positive and a diode emitting green light is to be used to indicate when V_{OUT} is negative.

Complete Fig. 9.3 to show the connections of the two LEDs to the output of the op-amp. Label each LED with the colour of light that it emits.
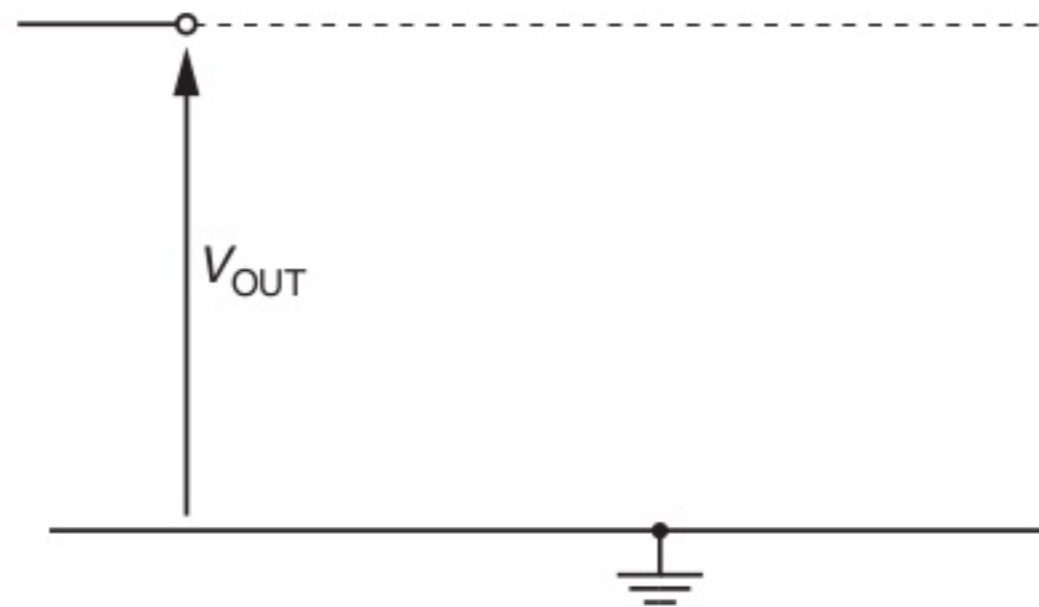

Fig. 9.3

[3]

For
Examiner's
Use

10 A student designs an electronic sensor that is to be used to switch on a lamp when the light intensity is low. Part of the circuit is shown in Fig. 10.1.
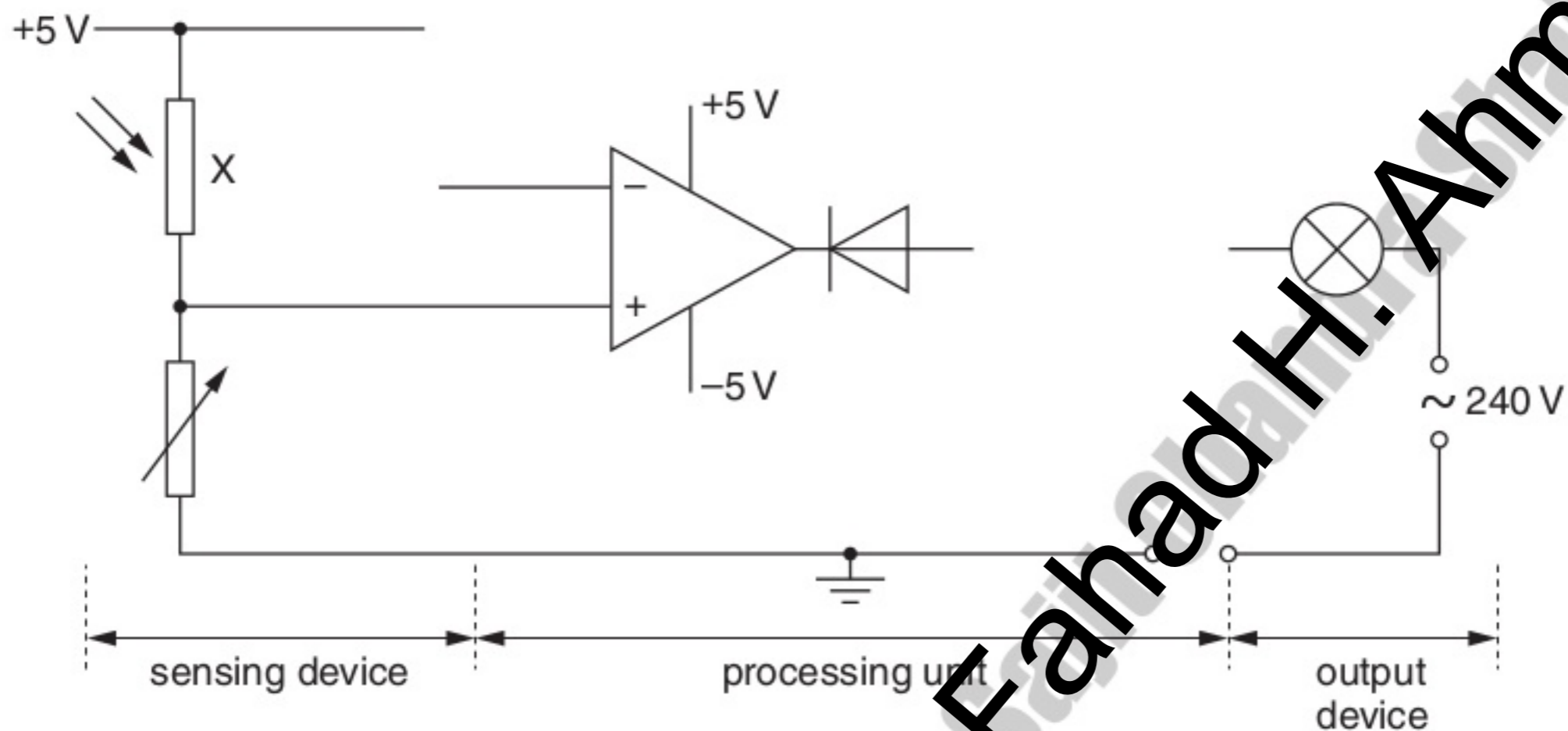

Fig. 10.1

(a) State the name of the component labelled X on Fig. 10.1.

.... [1]

(b) On Fig. 10.1, draw the symbols for

    (i) two resistors to complete the circuit for the sensing device, [2]

    (ii) a relay to complete the circuit for the processing unit. [2]

(c) **(i)** State the purpose of the relay.

    ....

    .... [1]

    (ii) Suggest why the diode is connected to the output of the operational amplifier (op-amp) in the direction shown.

    ....

    ....

    .... [2]

For Examiner's Use

9 An operational amplifier (op-amp) may be used as part of the processing unit in an electronic sensor.

(a) State three properties of an ideal op-amp.

1. ....

2. ....

3. ....

[3]

(b) A comparator circuit incorporating an ideal op-amp is shown in Fig. 9.1.
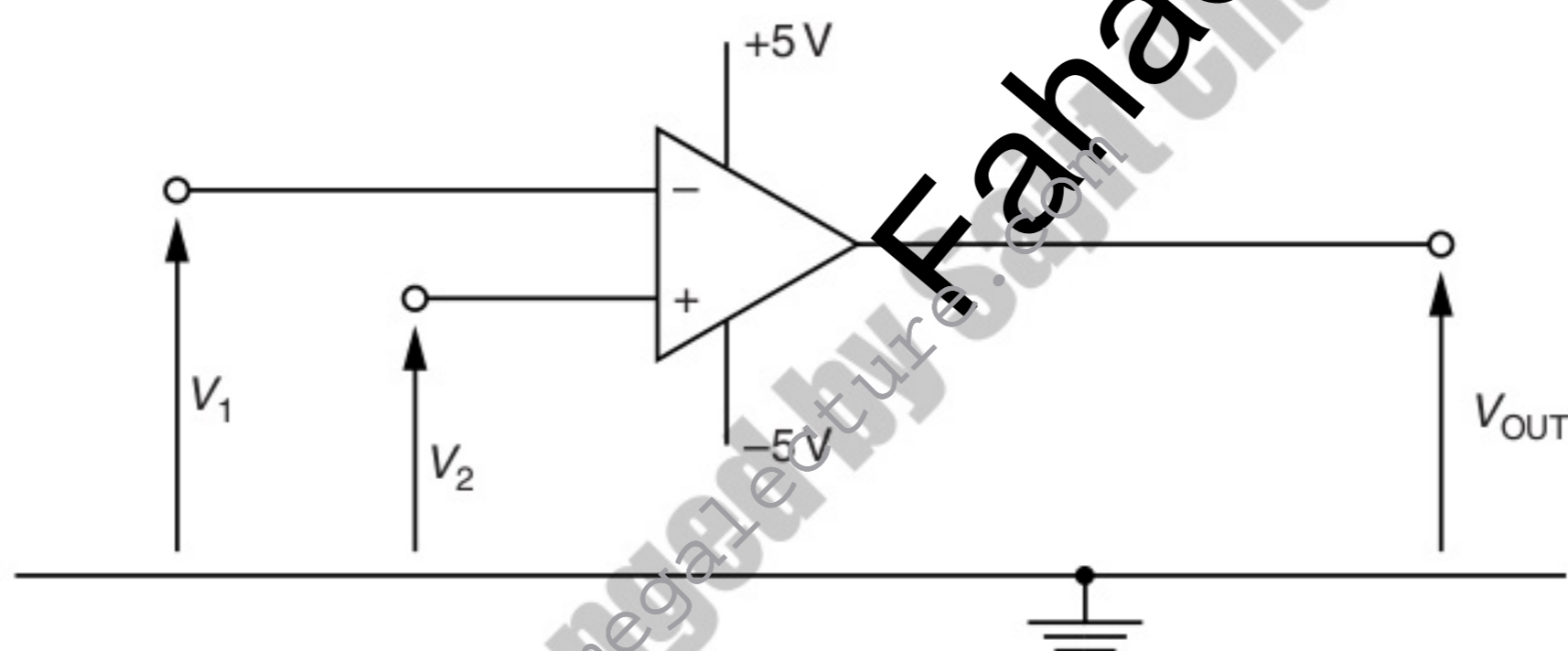

Fig. 9.1

(i) In one application of the comparator, V_2 is kept constant at +1.5 V.
The variation with time t of the potential V_1 is shown in Fig. 9.2. The potential V_2 is also shown.
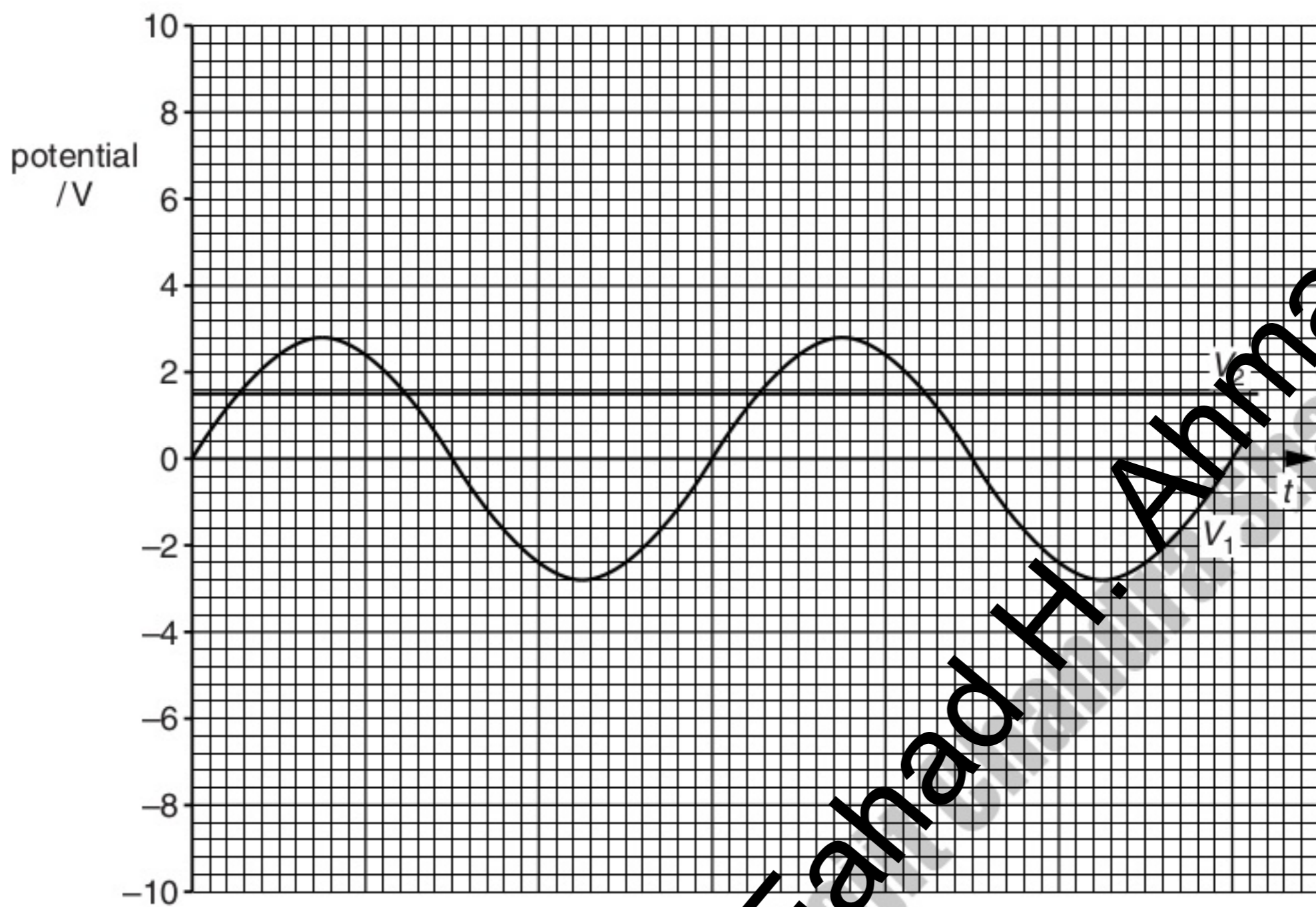
Fig. 9.2

On Fig. 9.2, show the variation with time t of the output potential V_{OUT}. [4]

(ii) Two light-emitting diodes (LEDs) R and G are connected to the output of the op-amp in Fig. 9.1 such that R emits light for a longer time than G.

On Fig. 9.1, draw the symbols for the two diodes connected to the output of the op-amp and label the diodes R and G. [3]

For
Examiner's
Use

9 A student designs an electronic sensor to monitor whether the temperature in a refrigerator is above or below a particular value. The circuit is shown in Fig. 9.1.
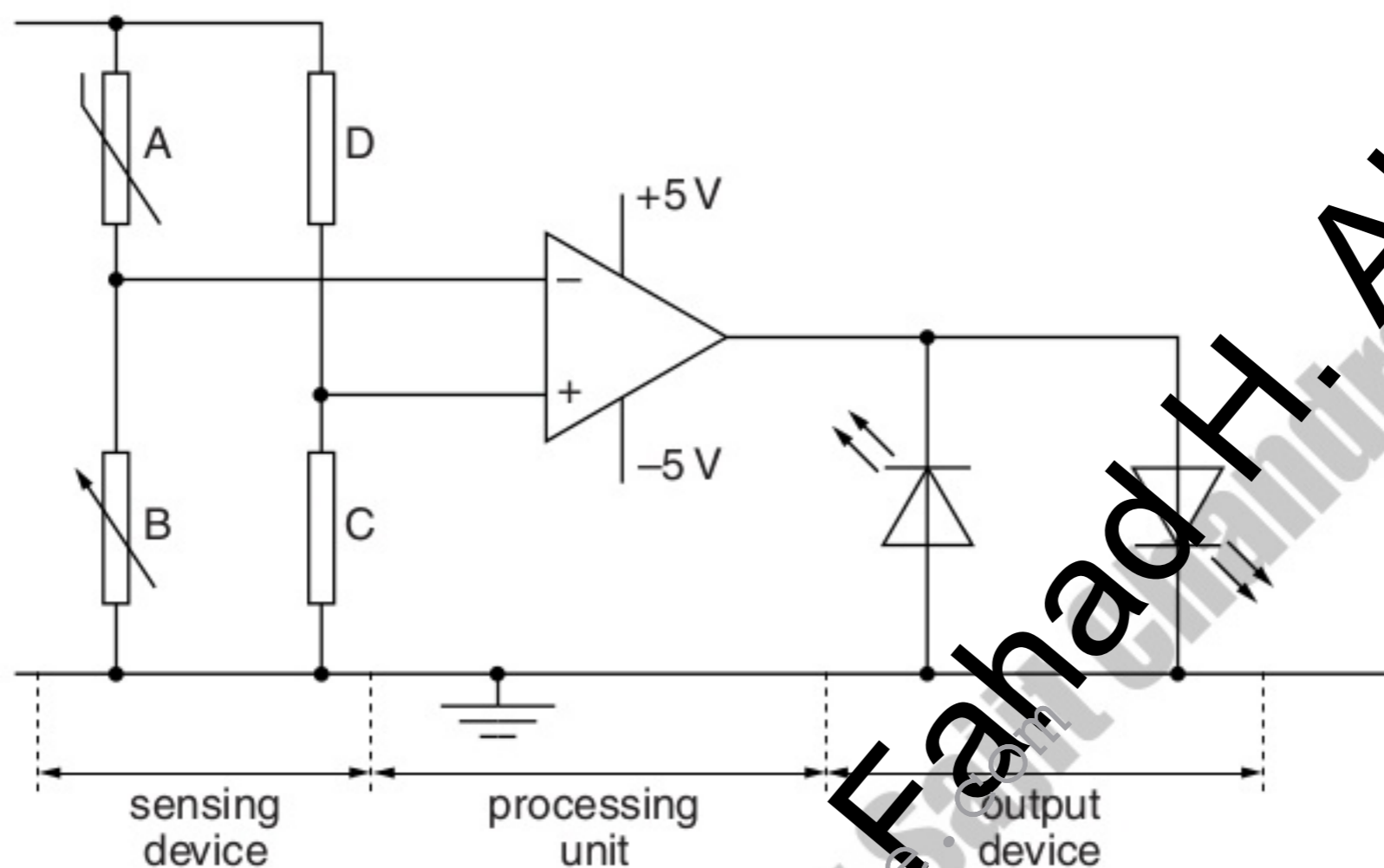

Fig. 9.1

(a) Name the components used in the output device.

....[1]

(b) An operational amplifier (op-amp) is used as the processing unit. Describe the function of this processing unit.

....

....

....[2]

(c) State the function of

(i) the resistors C and D,

....

....[1]

(ii) the resistor B.

....

....[1]

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(d) The output device of the circuit in Fig. 9.1 is changed so that the new output device may be used to switch on a high-voltage circuit.

For Examiner's Use

   (i) State the component that is used in the new output device.

      ....

      ....

   (ii) Draw on Fig. 9.2 to show how the component in **(i)**, together with a diode, are connected so that the high voltage may be switched on when the output of the op-amp is negative.
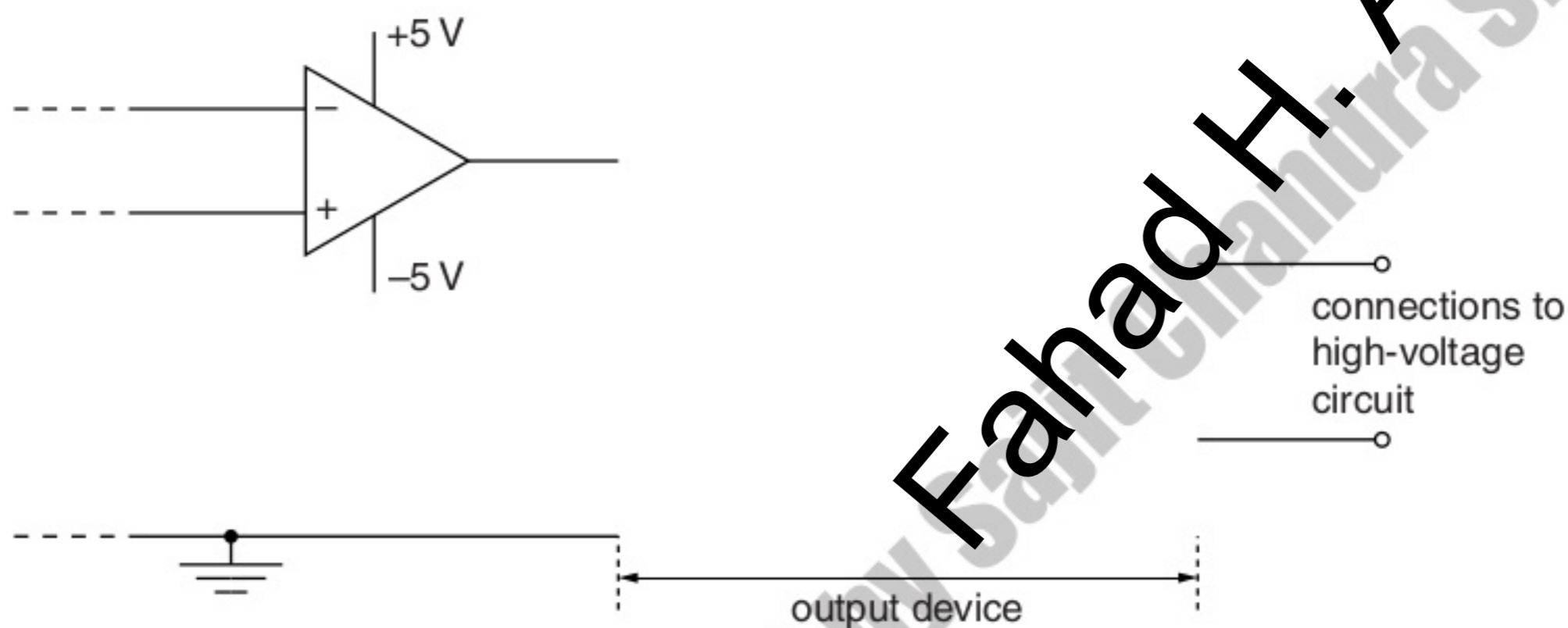

+5 V

−5 V

connections to high-voltage circuit

output device

Fig. 9.2

[2]