Does the resistance of certain components decrease with an increase in temperature?

EEP 11.1 **S**

Problem

Determine whether and how the resistance varies depending on temperature using an NTC resistor.

Equipment

Plug-in board	06033.00	1
Lamp holder E10	17049.00	1
Filament lamp, 4 V/0.04 A, E10, 1 pc.	06154.03	(1)
NTC resistor, 1.3 Ω	39110.03	1
Wire building block	39120.00	1
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 25 cm, blue	07360.04	1
Connecting cables, 50 cm, red	07361.01	2
Connecting cables, 50 cm, blue	07361.04	2
Multi-range meter	07028.01	2
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1
Matches		

Set-Up and Procedure

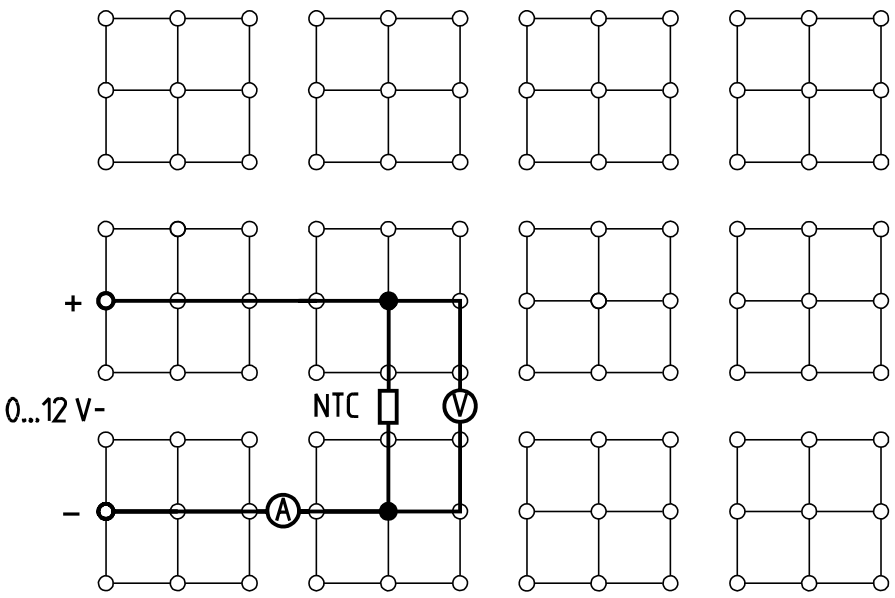
First Experiment

— Set up experiment as shown in Fig. 1. Select measurement ranges of 10 V- and 30 mA-.
— Switch on power supply unit and set voltage to 3 V- initially. Measure current and note under (1).
— Set voltage on power supply unit to the maximum value and observe the current meter closely (2). As soon as the indicator approaches 30 mA, turn voltage down a bit until the current is constant at I = 30 mA. Now, measure the necessary voltage U and note (3). **Important!** The current must not exceed 30 mA, since this could destroy the NTC resistor.
— Switch power supply unit off.
— Touch the NTC resistor and note its temperature. Enter observation under (4).

Second Experiment

— Remove the wire building block from the circuit and put the filament lamp in its place.
— Switch on power supply unit and set direct voltage to maximum value.
— Observe filament lamp and current meter. Measure the maximum value for current I_{max} and the voltage necessary for this U_{max} at the NTC resistor.
— Note measurements and observations under (5).
— Warm NTC resistor with a lighted match. **Important!** You should hold the lighted match with the flame next to the resistor at least 5 mm away. Too much heat will destroy the resistor. Also, make sure the current does not exceed 30 mA!
— Keep observing the current meter after removing the flame from the resistor. Touch the NTC resistor again to cool it off more quickly.
— Note observations under (6).
— Switch power supply unit off.

Fig. 1



Observations and Measurement Results

(1) At U = 3 V-: I = ...
(2) Observation:

(3) With I = 30 mA the necessary voltage is: U = ...
(4) Observation:

(5) For I_{max} = ... necessary voltage: U_{max} = ...
Observation:

(6) Observations:

Evaluation

1. Why does the current continue to rise in the first experiment when the voltage at the NTC resistor reaches a certain value?

2. How large are the resistance values for the components at the start (U = 3 V) and at the end of the first experiment?

3. In the second experiment, at what point does the current stop increasing after attaining a certain value after the heat source is removed from the NTC resistor?

Room for notes

(Does the resistance of certain components decrease with an increase in temperature?)

In connection with Ohm's Law, the students have already learned that metallic conductors generally have a resistance which increases with increasing temperature.
Now, they should discover that the opposite is true for NTC resistors (**N**egative **T**emperature **C**oefficient). The first experiment does not just serve as an introduction to this topic. It is also useful in demonstrating the terms self-heating (in the first experiment) and external heating (in the second experiment). The second experiment should be used to confirm these concepts.

Notes on Set-Up and Procedure
The experiment set-ups should not present a problem to the students if they are already relatively familiar with connecting and operating the multi-range meters.
When heating externally with the lighted match, they should be extra careful not to destroy the NTC resistor.

Observations and Measurement Results
(1) For U = 3 V: I = 3 mA.
(2) At maximum voltage, I increases very rapidly at first, then more and more slowly and would exceed 30 mA.
(3) For I = 30 mA, the necessary voltage is: U = 9.6 V.
(4) Observation: The NTC resistor feels warm. It is clearly warmer than room temperature.
(5) For I_{max}= 26 mA, the necessary voltage is: U_{max} = 8.9 V.
Observation: The current increases rapidly to about 10 mA, then more and more slowly until attaining its maximum value.
At about 15 mA, the filament lamp begins to shine weakly. It shines more and more brightly until the current remains constant. It does not, however, attain its maximum brightness (because its nominal current is 40 mA).
(6) Observations: Current increases rapidly to the maximum allowable value of 30 mA as soon as a lighted match is held to the NTC resistor.
The current drops as soon as the match goes out. If the NTC resistor is touched, thereby cooling it more quickly, then the current drops even faster. The current returns to its original value of approx. 26 mA when the experiment set-up is left alone.

Evaluation
1. The resistance value for the NTC resistor decreases as its temperature increases. This occurs when the current exceeds a certain value, thus warming the component even more.
2. U = 3 V; I = 3 mA; from this, we get R = 1000 Ω = 1 kΩ (initially);
U = 9 V; I = 30 mA; from this, we get R = 300 Ω (in the end).
3. The resistance value of the filament lamp increases as the temperature of the filament increases. This counteracts the effect of the NTC resistor, and the current stops increasing at a certain value.

Notes
NTC resistors are also referred to as NTC thermistors. They are widely used in circuits for measuring technique, control technique, and automatic control.
Their behavior is due to an increase in the concentration of floating charge carriers as the temperature increases. This effect is predominant over the increase of conductive resistance when there is an increase in temperature which is caused by the more intense interaction of the floating charge carriers with the unit cubes.
Question number 3 under Evaluation offers an opportunity to expand upon the laws of series connections. Rephrase the answer in the following way: In a series connection of a filament lamp and an NTC resistor, the partial voltage at the NTC resistor decreases while the partial voltage at the filament lamp increases until

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Room for notes