TEMPERATURE COEFFICIENT OF THERMISTOR – NTC & PTC

PROJECT REPORT

Submitted by

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Register No : AB20PHY021

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Submitted to

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BACHELOR DEGREE OF SCIENCE IN PHYSICS-2023

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(AUTONOMOUS)
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CERTIFICATE

This is to certify that the project report entitled " **TEMPERATURE COEFFICIENT OF THERMISTOR –NTC & PTC** " is an authentic work done by NIVYA ANTONY, St. Teresa's College (Autonomous), Ernakulam, under my supervision at Department of Physics, St Teresa's College (Autonomous), Ernakulam, for the partial requirements for the award of Degree of Bachelor of Science in Physics during the academic year 2022-23. The work presented in this dissertation has not been submitted for any other degree in this or any other university.

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ERNAKULAM

B.Sc. Physics

PROJECT REPORT

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Year of work: 2022-'23

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Date: 25-04-2023

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DECLARATION

I, **NIVYA ANTONY** final year B.Sc. Physics student, Department Of Physics, St. Teresa's College, Ernakulam do hereby declare that the project work entitled **'TEMPERATURE COEFFICIENT OF THERMISTOR –NTC & PTC'** has been originally carried out under the guidance and supervision of **Dr. MARY VINAYA**, Assistant Professor, Department Of Physics, St. Teresa's College (Autonomous), Ernakulam in partial fulfillment for the award of the degree of Bachelor of Physics. I further declare that this project is not partially or wholly submitted for any other purpose and the data included in the project is collected from various sources and are true to the best of our knowledge.

PLACE: Ernakulam

DATE: 19-04-2023

Nivya Antony

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CONTENTS

ABSTRACT

Thermistor is a two-terminal solid state thermally sensitive transducer, that allows a significant change in its resistive value with respect to change in ambient temperature. It is a non-linear device which does not obey Ohm's law. It is commonly used as temperature sensors having many applications to measure the temperature of both liquids and ambient air. In this paper we will analyze the trends and the applications of temperature sensors. NTC & PTC Thermistors are measured and characteristics curves are determined as expression of mathematical functions.

CHAPTER 1: INTRODUCTION

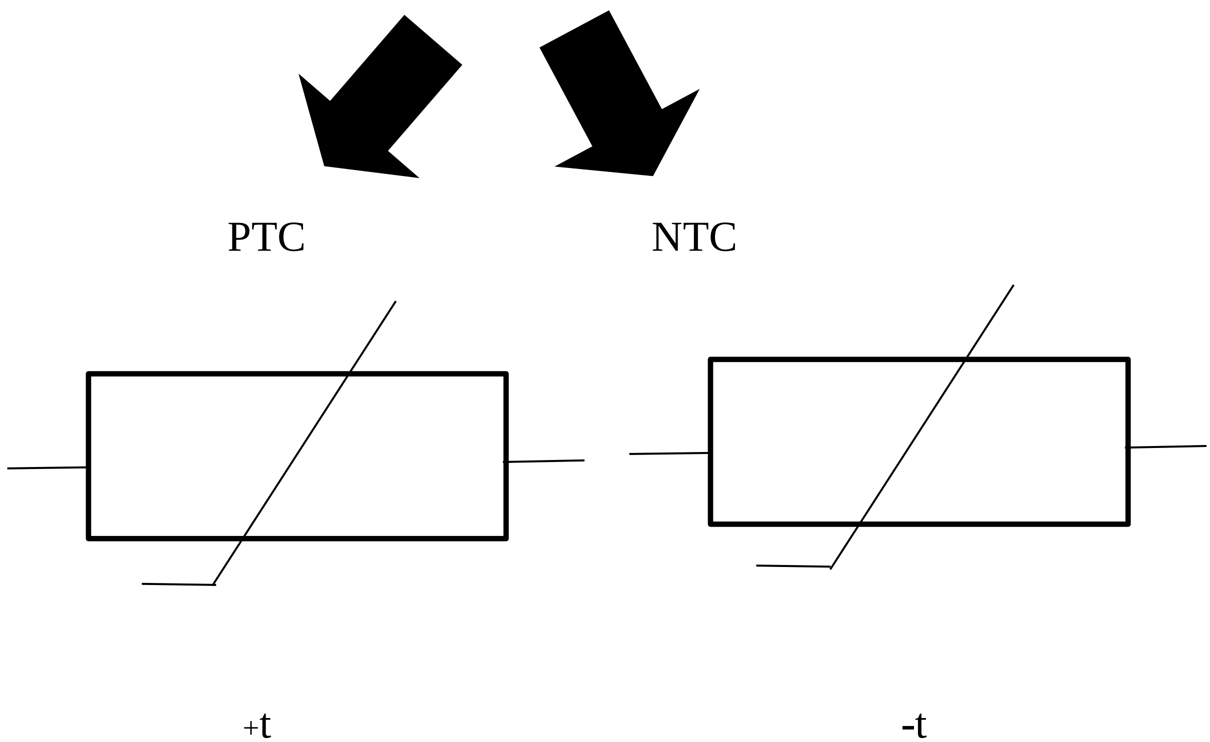
1.1 Introduction

THERMISTORS

The name “THERMISTOR”, is a combination of the words THERM-ally sensitive res-ISTOR. The resistance of all resistors whether fixed or variable has some dependency on the temperature. This is indicated by the temperature coefficient of resistors. The temperature coefficient can be either positive or negative. Therefore, there are two types of thermistors available: NEGATIVE TEMPERATURE COEFFICIENT (NTC) of resistance and POSITIVE TEMPERATURE COEFFICIENT (PTC) of resistance. For fixed or variable resistors, the temperature coefficient must be minimum. The resistors that are designed to change in temperature are called Thermistors or Thermal Resistor.

1.2 CLASSIFICATION OF THERMISTOR

There are two types of Thermistors:



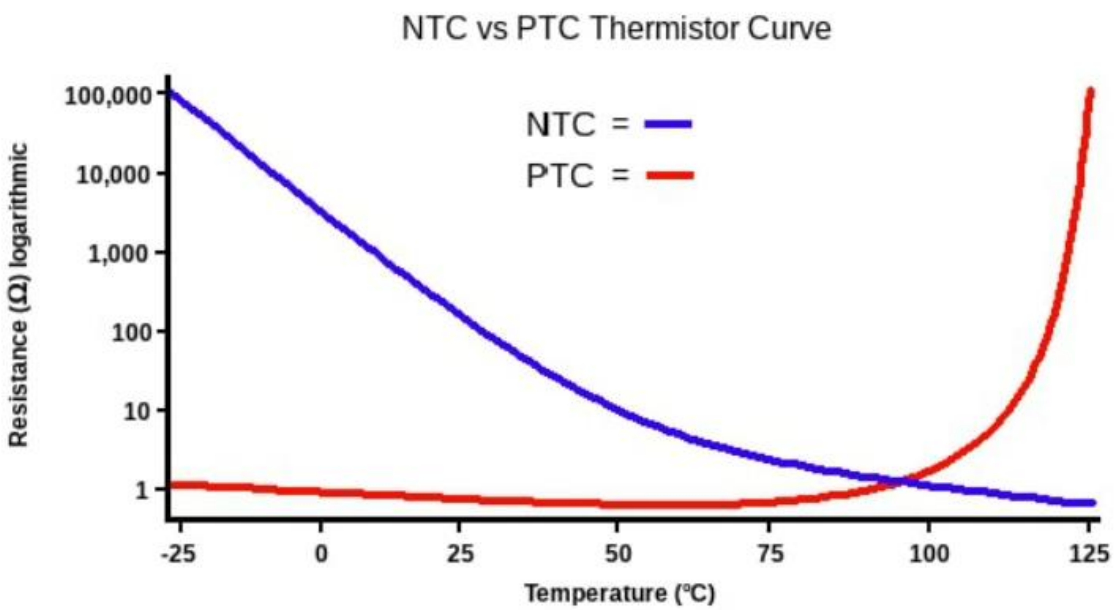
PTC Thermistors are those whose resistance increases with an increase in temperature.

NTC Thermistors are those whose resistance decreases with an increase in temperature.

Only NTC is commonly used to measure temperature.

TEMPERATURE V/S RESISTANCE GRAPH OF NTC AND PTC

The resistance of an NTC Thermistor falls with rise in temperature following an exponential characteristic over a wide range of temperatures. In The PTC temperature, it shows a large increase over a small temperature range. Although NTC Thermistors are widely used than PTC type.



The Thermistor temperature characteristics curve illustrates the temperature responses to the change in resistance which is thermal sensitivity offered by the change in resistance as the temperature changes. In general terms they are NTC and PTC. Thermistors have a merit of relatively high resistance.

1.3 Generation of Thermistors

NTC THERMISTORS

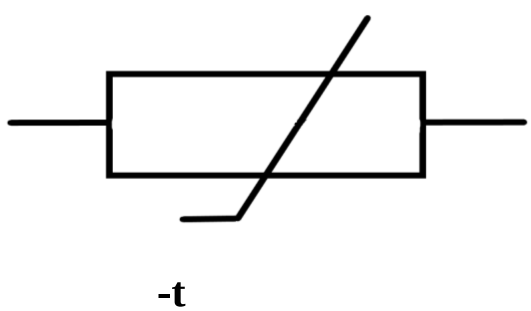
They are made of materials that have high temperature coefficients of resistance (TCR), the value that describes resistance changes with temperature. Negative TCR, or NTCR, ceramics are materials whose electric resistance decreases as temperatures rises.

NTC thermistor major material is Mn, Ni, Cu.

NTC thermistor is mainly applied in inrush current suppressing limiting, temperature sensing measurement, temperature compensation, temperature control, etc.

NTC's are manufactured by sintering semiconductor ceramic materials prepared from mixtures of metallic oxides of cobalt, nickel, manganese etc... that exhibit small polaron conduction. Under normal temperatures there is an energy barrier to moving electrons from site to site. As thermal energy rises with temperature, however, the ability of electrons to surmount this barrier increases, so that resistivity goes down—hence the NTCR behavior.

IEC standard symbol for NTC



PTC THERMISTORS

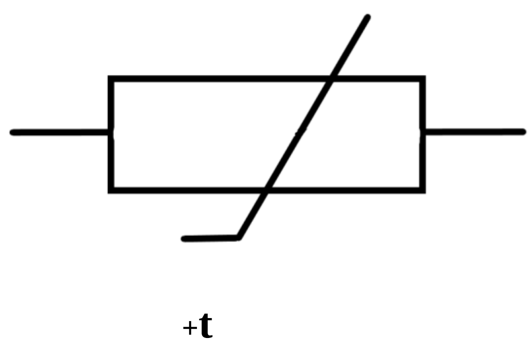
The PTC thermistors are made from doped barium titanate semiconducting material. This material has a very large change in resistance for a small change in temperature.

PTC Thermistor major material is $BaTiO_3$

High sensitivity and case of handling encourages their use in many applications. Some examples of these applications are resistance compensation circuit and temperature measuring devices.

PTC thermistor is mainly applied in over-current overload and short circuit protection, telecom protection, lighting soft switching time delay, motor starting, temperature sensing & protection, self-regulation heating etc.

IEC standard symbol for PTC thermistor.



VARIOUS TYPES OF THERMISTORS

Types of Thermistors based on Material

In addition to the character of the resistance modification, they can also be classified according to the type of material utilized.

- Bead Thermistor
- Disc and Chip Style thermistor
- Cylindrical Thermistor
- Glass Encapsulated Thermistor
- PAN Thermistor Temperature Sensing Probes
- Precision Interchangeable Thermistors

Bead Thermistor

Bead thermistors are manufactured in the shape of a bead. It is made of connecting the wire directly to the ceramic body. They offer better stability with a quick response time. Their structure allows it to operate at very high temperatures. To further protect it from mechanical damage, they are encapsulated in glass. They are the smallest in size which is why they have the quickest response time. But they have low current handling capabilities.

Disc and Chip Style Thermistors

The body of such a thermistor is shaped in the form of a disc or chip. It has a larger metal surface. Due to its larger surface, they have a slower response time and have higher current handling capabilities than the bead type.

Cylindrical Thermistor

Such thermistor's body is pressed into a cylindrical shape. They have a larger size as compared to other types. They are robust and reliable.

Glass Encapsulated Thermistors

The thermistors are sealed in a glass body to improve their operating temperature range. It is an air-tight glass body that improves its stability and protects it from mechanical damage. Glass encapsulated thermistors can operate at above 150° C.

PAN Thermistor Temperature Sensing Probes

The PAN thermistor is made from a special type of metal oxide that is extremely sensitive to temperature. It has very high accuracy with a tolerance up to ±0.2°C. It has a very quick response time with great precision.

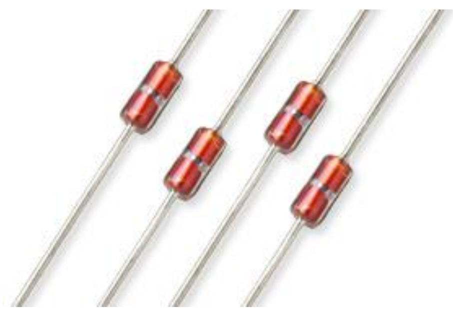
Precision Interchangeable Thermistors

They are the most precise thermistor manufactured based on a specific characteristics curve. They are fast and have long-term stability with high-temperature accuracy. They offer interchangeability over the range of 0°C to 70°C. They do not require individual calibration.

BEAD THERMISTOR

DISC AND CHIP STYLE

CYLINDRICAL THERMISTOR

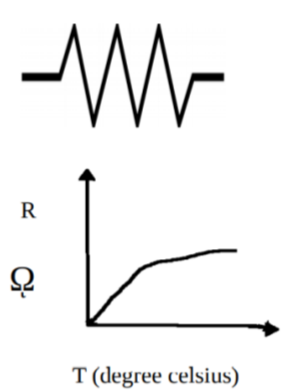
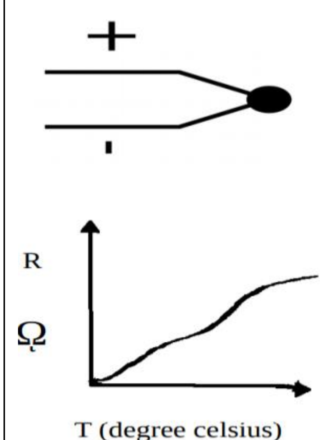
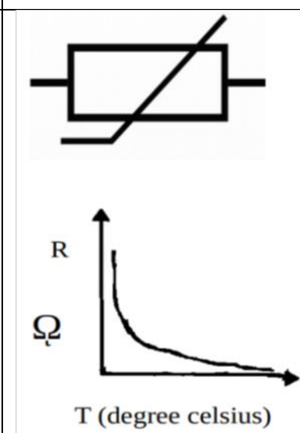


GLASS ENCAPSULATED
THERMISTOR

PAN THERMISTOR TEMPERATURE SENSING PROBES

PRECISION INTERCHANGEABLE THERMISTORS

1.4 COMPARISON OF THERMISTORS WITH OTHER

	RTD	THERMOCOUPLE	THERMISTOR
Temperature range	-260° to 850°C (-436°to 1562°F)	-270° to 1800°C (-454°to 3272°F)	-80° to 150°C (-112° to 302°F) (typical)
Sensor cost	moderate	low	low
System cost	moderate	high	moderate
Stability	best	low	moderate
Sensitivity	moderate	low	best
Linearity	best	moderate	poor
Specify for	○ General purpose sensing ○ Highest accuracy ○ Temperature averaging	○ Highest temperatures ○ Self-powered ○ rugged	○ Best sensitivity ○ Narrow ranges (e.g.: - medical) ○ Point sensing
Output characteristics			

CHAPTER 2: THEORY

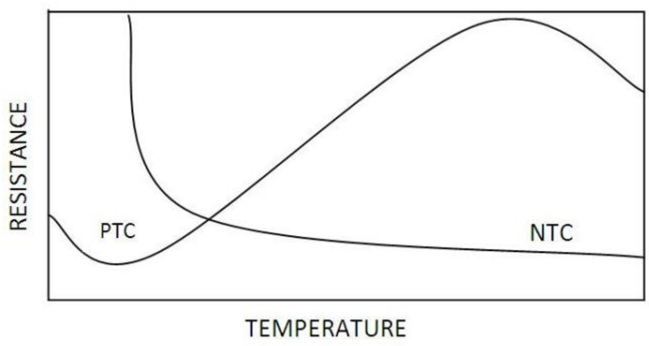


Fig 2.1.1

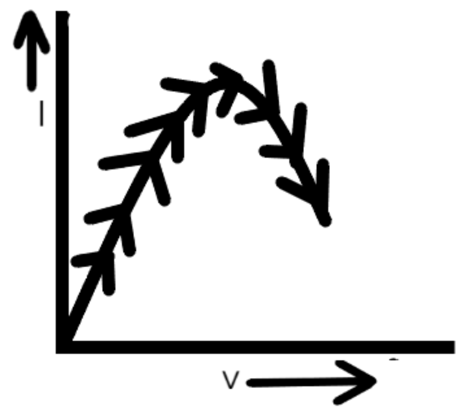


Fig 2.1.2

For NTC thermistors, Fig. 2.1.1 depicts a graph between the component's temperature (T) and resistance (R). The band theory of solids can be used to explain the general behaviour of the R - T curve for an NTC thermistor. When the temperature is low, the valence band has a much higher electron density than the conduction band. This results in a significant resistance. As the thermistor's temperature rises, some electrons in the valence band gain enough thermal energy to cross the energy gap (Eg) separating the two bands and enter the conduction band. As a result, the resistance decreases as the electron density in the conduction band rises (Fig 2.1.1).

An NTC thermistor's I-V characteristic also exhibits the behaviour depicted in Fig. 2.1.2. The negative temperature region corresponds to a portion of the characteristic. The following explanation explains the general behaviour in relation to the I-V plot. The power dissipated in the thermistor is insufficient to noticeably raise the temperature of the thermistor's material for sufficiently low currents and voltages. In this instance, Ohm's law is upheld, and the curve emanates from the origin in a straight line. However, the temperature of the thermistor rises for higher currents and voltages. As a result, resistance is reduced (Fig 2.1.1). Therefore, the voltage across the thermistor drops for a given value of current passed. Ohm's law is not followed in this region, and the characteristics are consistent with a negative coefficient of resistance. Metal oxides, such as those of Fe, Mn, and Co are frequently used as raw materials in the production of NTC thermistors. Since the primary mixture is an intrinsic semiconductor, the relevant semiconductor theory can be used to ascertain the temperature coefficient of resistance, the forbidden energy gap, etc.

The conductivity is proportional to (n_i) the intrinsic charge carrier concentration if the electron and hole mobilities are assumed to be temperature independent.
The component's resistance is not equal to the gradient of the I-V curve. Resistance is defined as current divided by potential difference. R = V/I, not dV/dI.

CHAPTER 3: EXPERIMENTAL DETAILS

3.1 AIM:

To calculate the temperature coefficient of resistance by determining the resistance of a thermistor for different values of temperatures.

3.2 PRINCIPLE:

The variation of resistance is given by the equation

$$\mathbf{R = R_0 e^{-mT}}$$

Taking the ln of the above equation;

$$\mathbf{\ln R = \ln R_0 - mT}$$

where,

R_0 is the resistance at 0^0C

m is the slope of the temperature v/s lnR graph

Temperature Coefficient of resistance of thermistor is defined as

$$\boldsymbol{\alpha = (1/R_{min})(\Delta R/\Delta T)}$$

where,

R_{min} is the minimum resistance observed

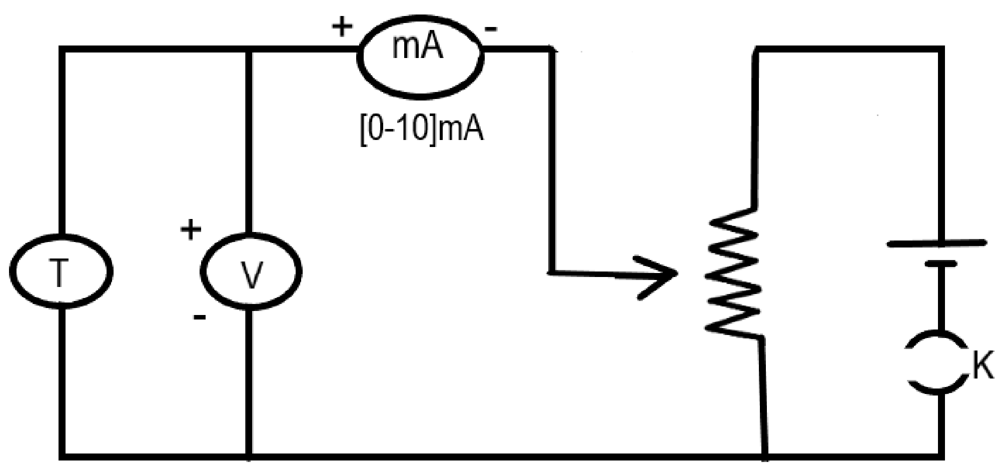
($\Delta R/\Delta T$) represents the slope of the R-T graph

3.3 APPARATUS

- Thermistor [NTC, PTC]
- Ammeter [0-10mA]

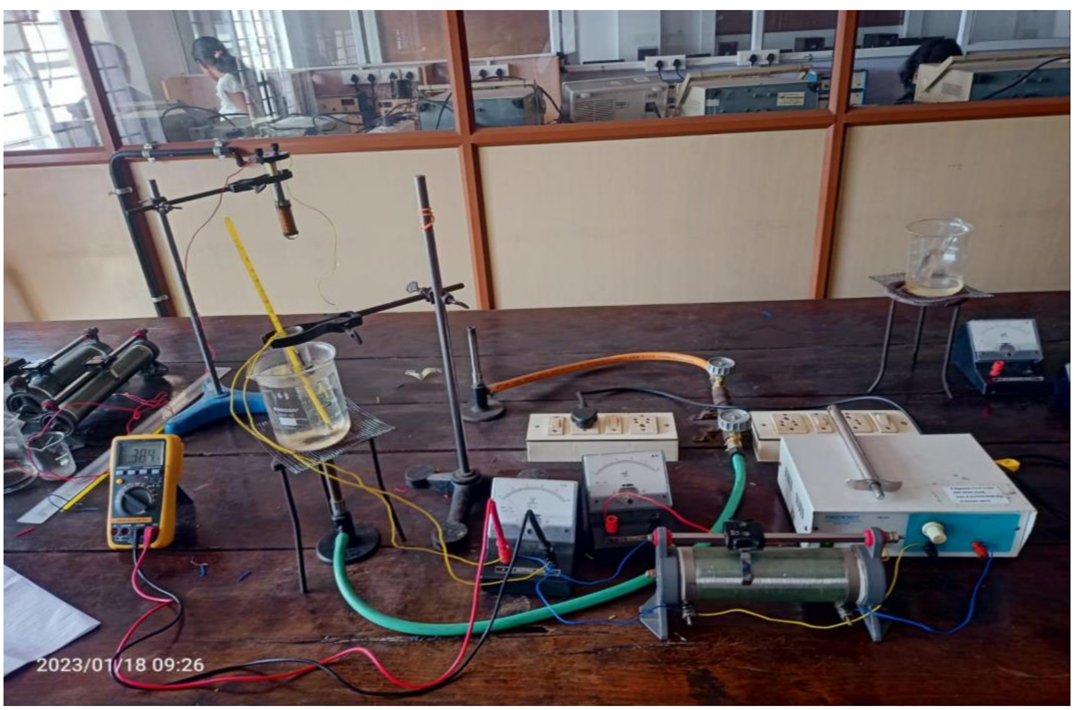
- Digital Multimeter
- Rheostat
- Oil in a test tube and beaker containing water
- Thermometer
- DC power supply

3.4 CIRCUIT DIAGRAM



3.5 PICTURES OF THE APPARATUS USED:


0 2 4 6 8 10
mA
MR - 100
CLASS 2.0
OK
+ DC MOVING COIL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3.6 PROCDURE

Connections are made as shown in the figure. **T** in the circuit diagram represents the thermistor. Voltmeter readings are obtained using digital multimeter. The ammeter used is in the milli ammeter range. Thermistor is dipped in the test tube containing oil. Then the test tube is kept inside the beaker containing water up to 300ml- 400ml. The key is closed. The ammeter reading is kept constant at 4mA by adjusting the rheostat.

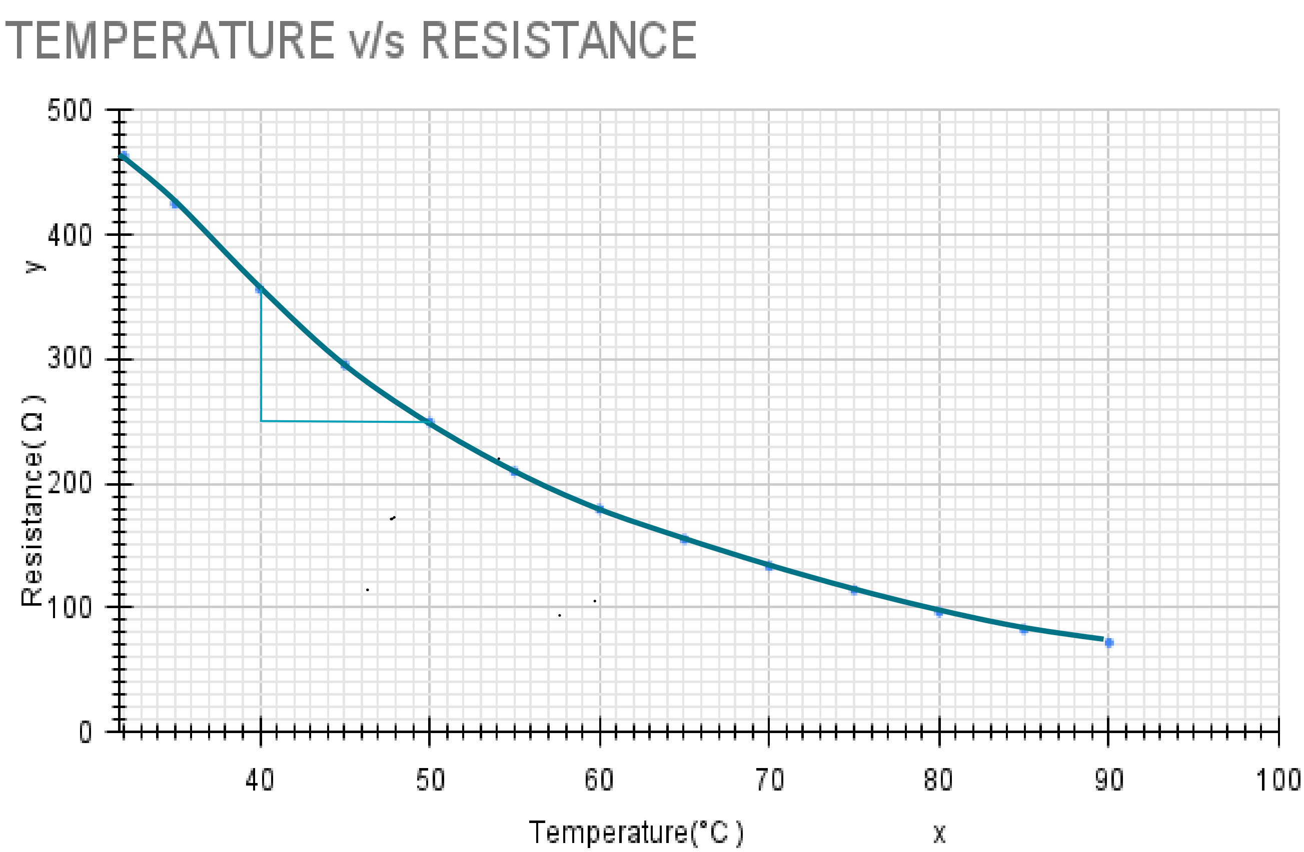
The thermistor is heated. In order to note down the readings of the temperature a thermometer is inserted in the test tube. The voltage is taken down for various temperature with an interval of 5^oC. This is done until the temperature is up to 90^oC. Ensure that the current is kept constant at 4mA. The variation in the ammeter when the temperature is raised is bring back to 4mA by adjusting rheostat. After reaching 90^oC thermistor is allowed to cool down. Voltmeter reading for different temperature while cooling is note down. The voltage is taken down for various temperature with an interval of 5^oC. Obtained readings are tabulated and calculations are done so as to obtain the resistance of the thermistor for different temperatures.

3.7 OBSERVATION TABLE- NTC THERMISTOR

TEMPE-RATURE °C	VOLTAGE(V)			R (Ω)	lnR (Ω)	lnR From graph lnR_o-mT (Ω)
	HEAT-ING	COOL-ING	MEAN			
32°C	1.904	1.805	1.854	463.5	2.666	2.6
35°C	1.792	1.609	1.700	425	2.628	2.5
40°C	1.506	1.345	1.425	356.25	2.551	2.45
45°C	1.242	1.122	1.182	295.5	2.470	2.4
50°C	1.044	0.950	0.997	249.25	2.396	2.3
55°C	0.864	0.812	0.838	209.5	2.321	2.22
60°C	0.745	0.690	0.717	179.25	2.253	2.2
65°C	0.647	0.593	0.62	155	2.190	2.1
70°C	0.551	0.516	0.533	133.25	2.124	2
75°C	0.472	0.443	0.457	114.25	2.057	2.08
80°C	0.385	0.387	0.386	96.5	1.984	1.96
85°C	0.326	0.335	0.330	82.5	1.916	1.9
90°C	0.286	0.289	0.287	71.75	1.855	1.8

<u>GRAPH</u>

NTC



TEMPERATURE v/s RESISTANCE
500
400
300
200
100
0
y
Resistance(Ω)
40
50
60
70
80
90
100
Temperature(°C)
x

CALCULATIONS

FROM TEMPERATURE VS. RESISTANCE

slope(m) = ($\Delta R/\Delta T$)

= (350 - 250)/ (50 – 40)

= 100/10

= 10

R_{min} = 71.75

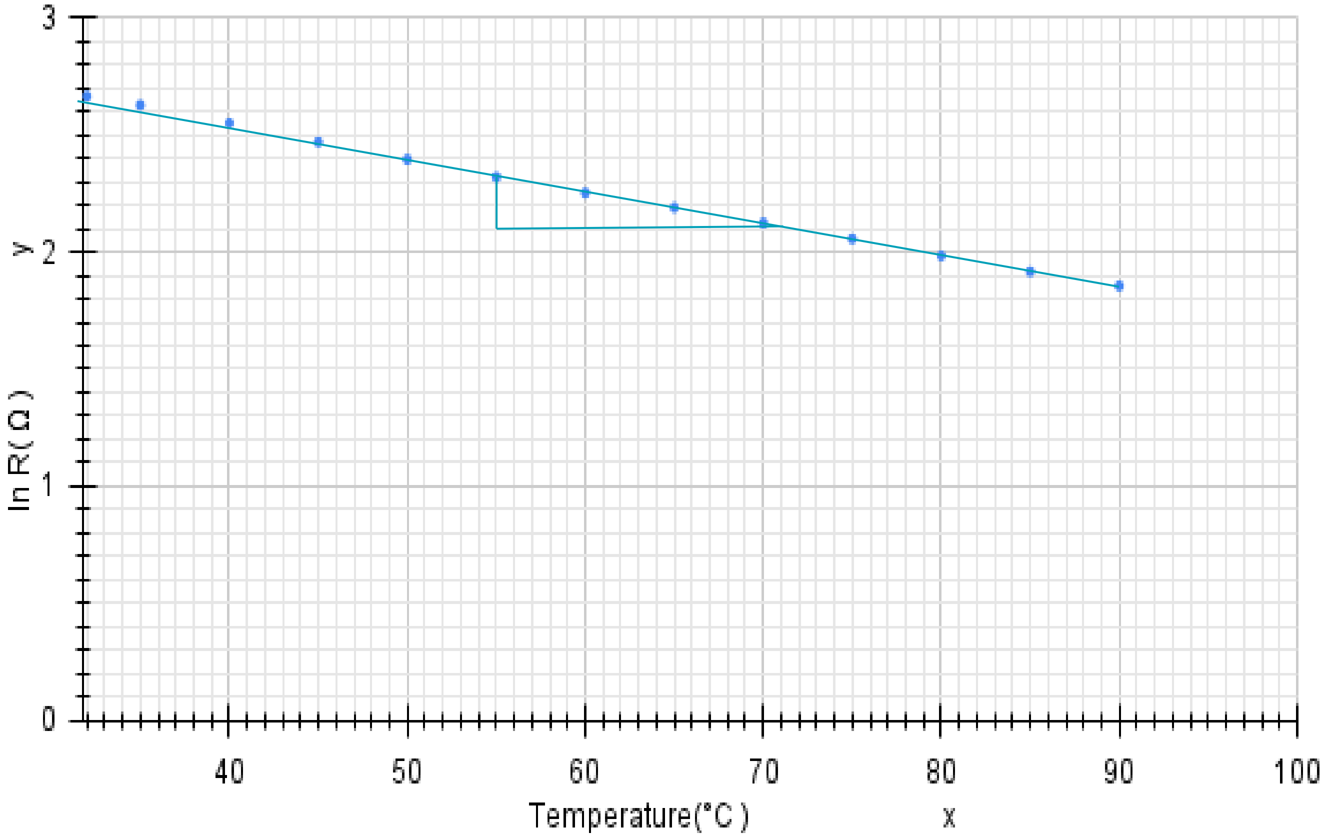
Temperature Coefficient from graph

$\alpha = -(1/R_{min})(\Delta R/\Delta T)$

= - (1/71.75) (10)

= - 0.139372/^{0}C

TEMPERATURE v/s ln R



SUBSTITUTION

Constant current I = 0.004A

V= 1.854V

R = V/I = 1.854/0.004 = 463.5Ω

From Temperature – lnR graph

$\ln(R_0) = 2.6\Omega$

slope(m) = (ΔR/ΔT)

= (2.3 - 2.1)/ (70 – 55)

= 0.2/15

= 0.01333

$\ln(R) = \ln(R_0) – mT$

= 2.6 – (0.01333*32)

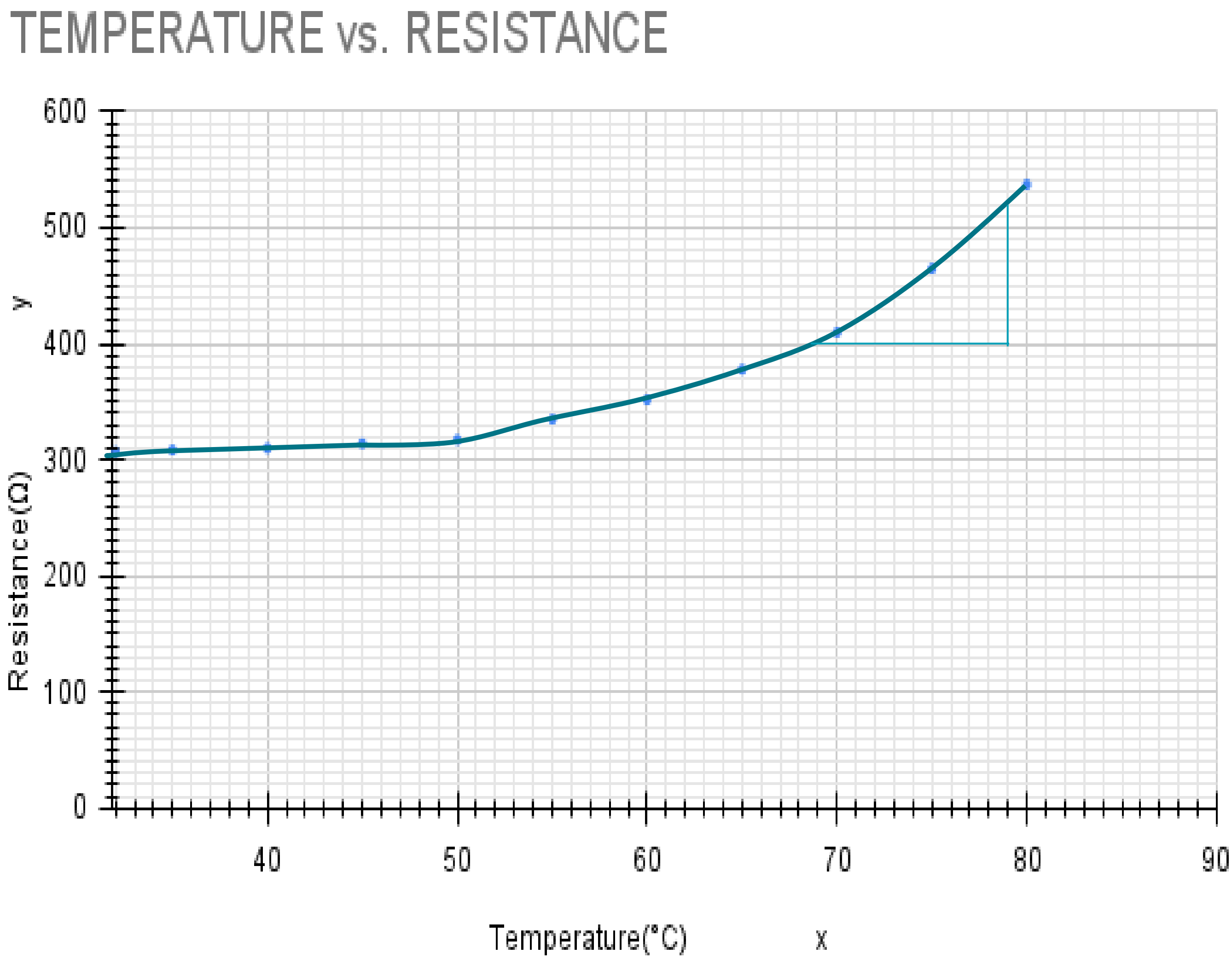
= 2.1744

3.8 OBSERVATION TABLE- PTC THERMISTOR

TEMPER-ATURE °C	VOLTAGE(V)			R (Ω)	lnR (Ω)	lnR From graph lnR_o-mT (Ω)
	HEAT-ING	COOL-ING	MEAN			
32°C	1.241	1.215	1.228	307	5.726	5.2
35°C	1.246	1.221	1.2335	308.375	5.7313	5.4
40°C	1.251	1.227	1.239	309.975	5.736	5.5
45°C	1.277	1.235	1.256	314	5.749	5.7
50°C	1.281	1.257	1.269	317.25	5.759	5.8
55°C	1.370	1.308	1.339	334.75	5.813	5.83
60°C	1.438	1.376	1.407	351.75	5.862	5.85
65°C	1.551	1.471	1.511	377.75	5.934	5.9
70°C	1.697	1.580	1.6385	409.625	6.0152	6
75°C	1.916	1.802	1.859	464.75	6.141	6.1
80°C	2.218	2.079	2.1485	537.125	6.286	6.2

<u>GRAPH</u>

PTC-


TEMPERATURE vs. RESISTANCE
600
500
400
300
200
100
0
y
Resistance(Ω)
40
50
60
70
80
90
Temperature(°C)
x

CALCULATION

FROM TEMPERATURE VS. RESISTANCE GRAPH

slope(m) = $(\Delta R/\Delta T)$

= (520 - 400) / (79 - 69)

=(120/10)

=12

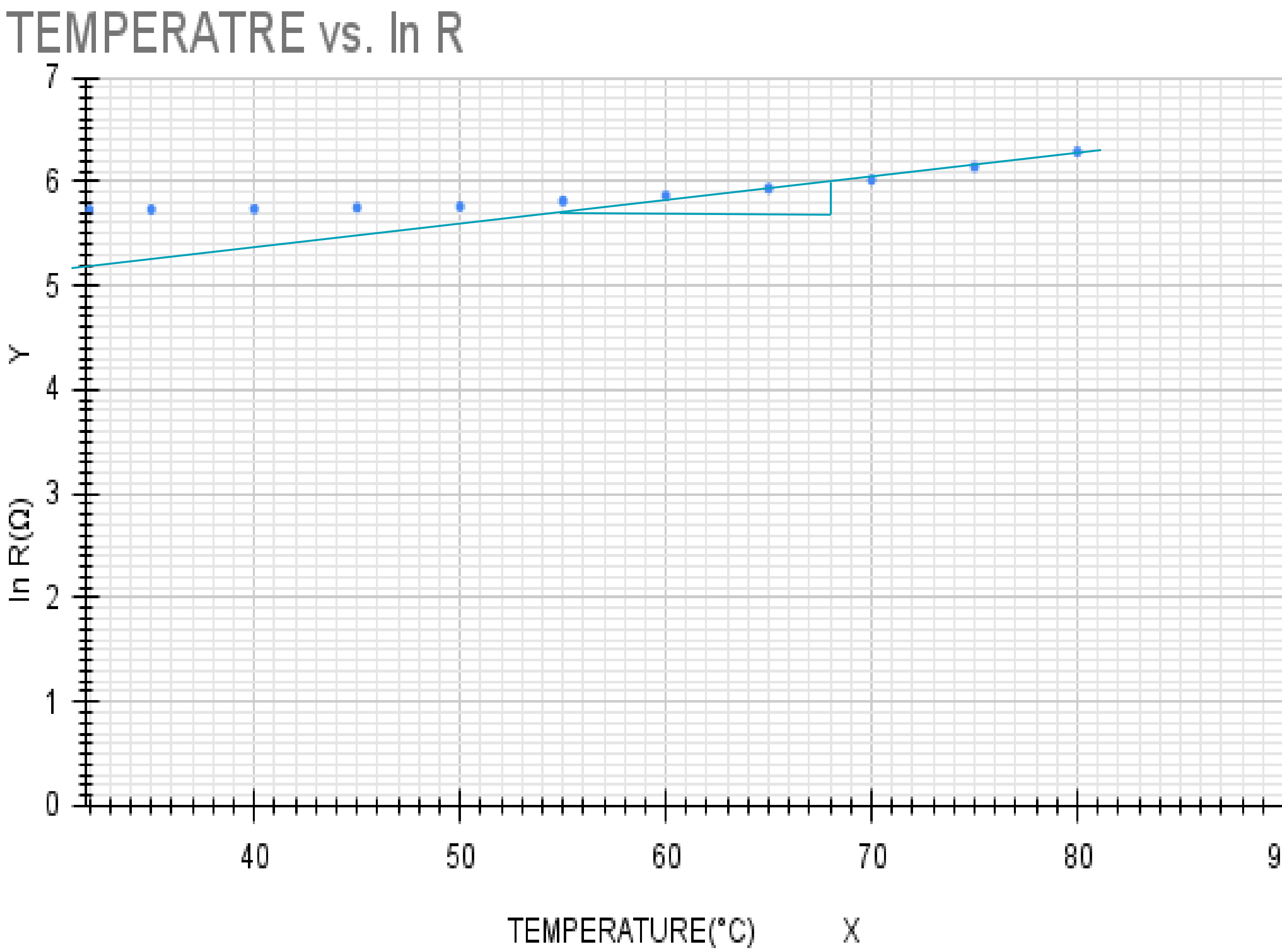
R_{min} = 307

Temperature Coefficient from graph

$\boldsymbol{\alpha = (1/R_{min})(\Delta R/\Delta T)}$

= (1/307) *12

= 0.039087/^{0}C


TEMPERATRE vs. ln R
Y
ln R(Ω)
0
1
2
3
4
5
6
7
40
50
60
70
80
90
TEMPERATURE(°C)
X

SUBSTITUTION

From temperature – lnR graph

$lnR_0 = 5.1$

slope(m) = $(\Delta R/\Delta T)$

= (6 – 5.7) / (68 – 55)

= 0.3/13

= 0.0230

$lnR = lnR_0 - mT$

= 5.1-(0.0230*32)

=4.364

<u>3.9 RESULT</u> :

Resistance of the thermistor for different temperature is determined.

Temperature coefficient of NTC thermistor =

$$\boldsymbol{\alpha = -\ 0.139372/^{0}C}$$

Temperature coefficient of PTC thermistor =

$$\boldsymbol{\alpha = 0.039087/^{0}C}$$

CHAPTER 4: APPLICATIONS OF THERMISTOR

1.Temperature Measurement

The Thermistor can be used as the sensing component of an electrical thermometer or pyrometer since it is a sensitive heat detector. The nose of a temperature probe can easily be modified to accommodate the little bead thermistor.

2.Heater Control

A thermistor may be placed inside an oven or heat chamber to serve as a temperature sensor for automatic control of the heaters.

3.Limiter

The nonlinear resistance of the thermistor may be employed in simple circuits for signal limiting, peak compression, and voltage regulation.

4.Electronic equipment inside of cars

Thermistors perform vital roles in the overall function of vehicles. Thermistors measure cooling water and oil temperatures, as well as monitoring exhaust gas temperature and keeping passengers comfortable in the car.

5. Household Thermistor Uses

- Thermistors in microwaves and boilers keep an eye on interior temperatures to prevent them from becoming too high.

- Thermistors used in circuit breakers prevent power surges and guarantee that the right quantity of power is being applied to connected devices.
- Thermistors are frequently used as the temperature sensing element in digital thermometers because they have a quick response time and are precise.

6. Thermistor Uses - Commercial

- Vehicle Cabin Heat - Thermistors are frequently employed to keep the vehicle at the proper temperature.
- Manufacturing - In manufacturing facilities, thermistors are utilised as "circuit breakers"; if the temperature rises dangerously, the thermistor will cause the circuit to break.
- Thermistors are utilised in HVAC refrigeration applications to monitor and manage building operations. Control and effectiveness are thus increased.
- Thermistors are utilised in 3D printers because temperatures need to be carefully controlled.
- Thermistors can be used in the food and beverage industry to track internal temperatures.

7. Thermistor Uses – Medical Field

Ventilator:

The medical ventilator's humidity sensor helps the patient feel comfortable by supplying warm, humid air. Real-time monitoring and controlling are required when adding water to the air stream. The air flow sensor delivers a signal to the sleep ventilator when the patient exhales, telling it to lower the speed of the ventilator fan to prevent the patient from feeling uncomfortable. In order to give the patient air that is at the right humidity level, the humidity sensor measures the air's relative humidity, absolute humidity, and moisture content.

Infusion pumps:

The contact force sensor in the infusion pump is to ensure that the infusion pump and the insulin pump pipeline are unobstructed.

Anesthetic Machine:

To help the patient breathe easily and prevent throat pain brought on by breathing in dry, cold air, the anaesthesia machine uses a thermometer sensor to measure the air temperature and humidity.

4.2 CONCLUSION

A Thermistor's Primary function is to gauge a device's internal temperature. The thermistor is a minor but crucial component of a bigger system in a temperature-controlled system. The thermistor's temperature is kept under observation by a temperature controller. Thermistor are utilised in a wide variety of industries due to their lower costs, lower production cost,and smaller size, which allows them to fit in tighter locations. They provide safety for the industrial spaces and appliances by detecting the exponential rise in temperature. Other than temperature sensors, they have the highest sensitivity. As a result, they are a blessing that improves human lives.

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