

1. **DESCRIPTION:** Teams will build a durable temperature-sensing Device that will accurately measure, and display temperatures between 0°C to 75°C to determine the temperature of four different water samples.

A TEAM OF UP TO: 2

EYE PROTECTION: None

IMPOUND: No

APPROXIMATE TIME: 50 minutes

2. **EVENT PARAMETERS:**

- a. Each team may bring one participant-constructed, temperature-sensing Device with a laptop or a calculator for programming/display, two calculators of any type, and one 2" or smaller three-ring binder, as measured by the interior diameter of the rings, containing information in any form and from any source. Sheet protectors, lamination, tabs and labels are permitted.
- b. At Regional tournaments, teams must bring their own digital Calibration Thermometer, accurate to the 0.1 degree Celsius, to calibrate their equipment and use as a reference during the event.
- c. Event Supervisors will provide warm water and ice water for calibration, water samples, and containers (e.g., paper cups, Styrofoam cups, bowls). At the State and National Competition, the Event Supervisors will provide each team with a digital Calibration Thermometer to reference and calibrate their sensor against.
- d. Teams must be able to answer questions regarding the design, construction, programming, and operation of the Device per the Building Policy found at www.soinc.org.

3. **CONSTRUCTION PARAMETERS:**

- a. Devices must be built using a microcontroller or microcontroller board (e.g., TI Innovator, Raspberry Pi, Arduino), a display, LED lights, and a participant-built sensor/probe. The sensor must produce a voltage which varies according to the temperature of the water. The Device may be connected to a laptop and/or calculator. WiFi/Internet connection is not allowed at any time during competition.
- b. The sensor must be constructed from one of the following two fundamental electronic components -- NTC/PTC thermistor or a legal analog output temperature device. Examples of legal and illegal sensors can be found on the event page at www.soinc.org. The sensor must not be constructed using preassembled sensors/probes that are already in a waterproof housing. (e.g., Vernier, PASCO, pre-assembled circuit boards or kits). The sensor and wires/cables, together, must be a minimum of 30.0 cm in length, small enough to be fit through an opening of 5.0 cm, and the end must be immersible up to 15.0 cm in water.
- c. The Device must have a digital readout that clearly displays the temperature in degrees Celsius and the potential in Volts. This can be displayed on a laptop or calculator. If teams choose to use a laptop for display purposes this laptop may not be used on the written exam.
- d. The Device must also be able to indicate the specific temperature zone using three separate LEDs - one red, one green, and one blue. RGB LEDs may be used, but must be wired for only one color. The exact temperature range of each zone will be not be revealed until teams enter to compete, and may be different for teams. At State and/or Nationals, zones may require more than one color to be displayed at the same time.
- e. Teams must not use electrical outlets at any time during the competition. If the Device is not powered by a connected laptop or calculator, then the Device must be powered by commercially available batteries. Multiple batteries may be connected in series or parallel as long as the expected voltage output across any two points does not exceed 12 Volts as calculated using each battery's voltage (as labeled by the manufacturer).
- f. Each Device must be clearly labeled with the team name and team number.

4. **DESIGN LOG:**

- a. Teams must submit a Design Log with their Device.
- b. This Design Log should contain:
 - i. A top-down photograph of the Device with labels identifying all the components and detailing their functions. This section should also include a brief summary explaining how the Device was constructed and the Sensor waterproofed.
 - ii. A data table with at least 10 trials showing the sensor voltage reading versus the corresponding temperature values in °C.
 - iii. Scatter-plot graph of this data with temperature on the Y-axis and voltage on the X-axis.
 - iv. Function graph of mathematical model supported by the data overlaid on scatter-plot of the data.
 - v. Equation of the above mathematical model used to convert measured voltage to the corresponding temperatures in °C highlighted for easy identification.
 - vi. Printout of program with code highlighted showing this exact mathematical equation converting voltage to temperature °C.

- vii. Program with the code highlighted that will illuminate the appropriate LED(s) according to their assigned temperature ranges.

5. **THE COMPETITION:**

Part I: Device Testing

- a. Only participants and Event Supervisors are allowed in the competition areas. Once participants enter the event area, they must not leave or receive outside assistance, materials, or communication.
- b. At the Regional Tournament, the teams will provide their own Calibration Thermometer for calibration and testing. For State/National Tournaments the Event Supervisors will provide each team with their own Calibration Thermometer (a standard digital thermometer), which will stay with the team throughout calibration and testing. Different teams may have different Calibration Thermometers.
- c. Teams may modify their code (e.g., alter the LED code to match the posted temperature zones) during the setup time.
- d. At the Regional Tournament, teams will have 10 minutes to setup their device and modify their code. For State/National Tournaments, once teams receive their Calibration Thermometer, they will have a total of 20 minutes to setup, modify their code, and calibrate their Device against their Calibration Thermometer. Teams will be allowed to use their Design Log to aid with calibration. Warm water ($< 75^{\circ}\text{C}$), ice water, and containers to hold and/or mix the water will be available for teams to use.
- e. After the setup/calibration time, the teams will rotate through the four different stations where they will use their Device to measure the water temperature. Each team will be allowed a maximum of 2 minutes for each of the 4 temperature determinations. The Event Supervisor will record the voltage and temperature displayed by the Device to the nearest 0.1°C , the LED color displayed by the Device, and the temperature displayed by the Calibration Thermometer to the nearest 0.1°C .
- f. Event Supervisors should do their best to keep the water sample temperatures the same for all teams, but fluctuations are acceptable as each team will be scored relative to their Calibration Thermometer.
- g. Teams who wish to file an appeal regarding Part I must leave their Design Log and Device in the competition area.

Part II: Written Test

- a. Teams will be given a written test to assess their knowledge of the theories behind the event. Teams may use the entire time block to take the written test. The written test will be limited to the following topics:
 - i. Relationships between resistance, voltage, and temperature (~25%)
 - ii. Theory of LEDs, working principles, and applications (~25%)
 - iii. The process of calibration - working with raw data and determining real world relationships (~25%)
 - iv. Operational knowledge of basic Device components (~25%)
- b. Unless otherwise requested, answers must be in metric units with appropriate significant figures.
- c. While working on the written test teams are not allowed to use any laptops they may have brought with them.

6. **SCORING:**

- a. Teams with the highest Total Score wins.
- b. A Total Score for each team will be determined as follows:
 - i. Total Temperature Accuracy Score (Maximum 60 points).
Accuracy Score = 60 pts - (total absolute error of the 4 temperature measurements x multiplier)
(1) Maximum absolute error x multiplier per station is 15.0
(2) Regional Multiplier = 2
(3) State Multiplier = 3
(4) National Multiplier = 4
 - ii. Correct LED colors (Maximum 20 points) 5 points are awarded for the correct LED colors (as determined by the temperature measured by the Device) at each station.
 - iii. Design Log (Maximum 28 points) 4 points are awarded for each correct section of the Design Log as well as being able to answer questions about each section.
 - iv. Written Test (Maximum 30 points)
- c. Tiebreakers: a) the lowest sum of the total absolute temperature errors; b) highest written test score.
- d. Teams with any construction or competition violations will be ranked behind teams without violations.

Recommended Resources: The Science Olympiad Store (store.soinc.org) carries the Detector Building Video Download and the Problem Solving/Technology CD; other resources are on the event page at soinc.org.