DETECTOR BUILDING

See General Rules, Eye Protection & other Policies on www.soinc.org as they apply to every event.

1. **DESCRIPTION:** Teams will build a durable **Mass/Force-sensing Device** that will accurately measure and display both voltage and actual masses of different solid samples ranging from 30 to 1,000 grams.

   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, **Mass/Force**-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. 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, Micro:bit), a display, LED lights, and a participant-built sensor/probe. The sensor must produce a voltage which varies according to the mass of the object. The Device may be connected to a laptop and/or calculator. Wi-Fi/Internet connection is not allowed at any time during competition.
   b. The sensor must be student constructed from fundamental electronic components such as force sensitive resistors (FSR), strain gauges, capacitors, resistors, wires, DIP package integrated circuits, and surface mount adapter boards. All supporting circuits must be assembled on a breadboard. The following are construction violations: preassembled devices, load cells, printed circuit boards (except digital display boards), integrated circuit daughterboards.
   c. The construction of the device must allow the placement of an unknown mass ranging from 30 to 1,000 grams of at most 8 cm in diameter and no height obstructions for mass determination. The Device may not use any code libraries for calibration of the device.
   d. The Device must have a digital display that clearly shows voltage, and mass in grams to the nearest 0.1 grams. This can be displayed on a laptop or calculator. If the team chooses to use a laptop for display purposes, it CANNOT be used for the Written Test portion of the event.
   e. The Device must also be able to indicate the specific mass range 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 mass range of each zone will not be revealed until teams enter to compete, and may be different for different rotations. At States/Nationals, zones may require more than one color to be displayed at the same time.
   f. 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 total input voltage does not exceed 12 volts as calculated using each battery's voltage (as labeled by the manufacturer). Teams with devices using a total input voltage exceeding 12 volts or devices that the Event Supervisor deems unsafe will not participate in Device Testing.

4. **DESIGN LOG:**
   a. Teams must submit a Design Log with their Device.
   b. This Design Log should contain the following eight (8) Sections:
      i. A top-down photograph, diagram, or picture of the Device with the school name labeled on the device, labels identifying all the components and detailing their functions. This section should also include a brief summary explaining how the Device was constructed.
      ii. A data table with at least 10 trials showing the raw sensor reading (voltage, time, etc.) versus the corresponding masses in grams. If multiple fixed resistors are tried, include the data and graphs of all potential resistors.
      iii. Scatter-plot graph of this data with mass in grams on the Y-axis and voltage on the X-axis.
      iv. Function graph of the mathematical model supported by the data overlaid on a scatter-plot of the data.
      v. Equation of the above the mathematical model used to convert measured voltage to the corresponding mass in grams highlighted for easy identification.
      vi. Printout of the program with its code highlighted showing this exact mathematical equation or its code implementation converting the raw sensor reading (voltage, time, etc.) to grams.

vii. On the same program printout, highlight the code that will illuminate the appropriate LED(s) according to their assigned mass range(s).
viii. **A front cover labeled with the Team Name and the Team Number for the current tournament.**

c. If a 3-D printer, laser cutter, CNC machine or similar device was used as a tool to build the team's device, or any component thereof, the following information must also be supplied in the log. **Any such parts purchased as an end item or as part of a kit do NOT require this information.**
   i. Information about the tool hardware, software, materials, and supplies used
   ii. Details of the source of any digital files (e.g., CAD, STL, OBJ) utilized by the tool including but not limited to when and where the file was obtained, including the web address if downloaded from the internet
   iii. Descriptions of how the team constructed the final device from the tool created components
d. **All numerical values should be labeled with standard units (e.g., SI or English) appropriate to the dimension being measured. SI units should be the default standard.**
e. All logs will be returned to teams after inspection.

5. **<u>THE COMPETITION</u>:**

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. Event Supervisors will provide the labeled samples of unknown mass (three (3) at Regional/Invitational Tournaments, and four (4) at State/National Tournaments) that teams will need to measure. Multiple sets of the mass samples may be used as long as the masses are the same for each set to the precision of the ES' scale.
c. The Event Supervisor's scale will be made available for teams to use during their setup period - however, teams will need to bring their own calibration samples. The same scale must be used for all teams to verify their devices and for the measurement of the official masses.
d. Teams may modify their code (e.g., alter the LED code to match the posted mass ranges during the setup time.
e. At all Tournaments, teams will have 5 minutes to set up their Device, verify their Device with the scale provided by the Event Supervisor, and modify their code.
f. After the setup/calibration time, the teams will measure the unknown mass samples. Teams will have 1 minute to measure each sample. The Event Supervisor will note if a voltage is being displayed, and then record the mass in grams to the nearest 0.1 gram as displayed by the Device, along with the LED color displayed for each mass.
g. The Event Supervisor will review with teams the data recorded on their scoresheet.
h. 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. Voltage dividers and the effect of different fixed resistors and the output voltage recorded.
   ii. Types of force sensors and their working principles.
   iii. The relationship between force, stress, strain, and resistance.
   iv. The relationship between force (weight), mass, pressure.
   v. The conversion from analog reading to voltage.
   vi. Theory of LEDs, working principles, and applications.
   vii. The process of calibration - working with raw data and determining real world relationships.
   viii. Operational knowledge of basic Device components.
   ix. **Topics for State and National Tournaments only:**
      (1) Capacitance
      (2) Piezoelectricity
      (3) Wheatstone Bridges
      (4) Unless otherwise requested, answers must be in metric units with appropriate significant figures.
      (5) While working on the written test teams are not allowed to use any laptops they may have brought with them.

6. **SCORING:**
   a. The team with the highest Total Score wins.
   b. Total Score = Build Score + Written Test Score + Design Log Score
   c. Build Score: There will be three unknown masses at Regionals (Maximum 57 points) and four unknown masses at States/Nationals (Maximum 76 points)
      i. Accuracy Score for each mass = 15 pts - (relative error of the mass measurement x multiplier) but will not go below 0 pts.
         (1) Regional Multiplier = 20
         (2) State Multiplier = 30
         (3) National Multiplier = 40
         (4) Teams not able to produce a reading will receive an accuracy score of 0 for that mass.
      ii. LED Score for each mass = 4 pts awarded for the correct LED color (as determined by the mass displayed by the Device).
      iii. Teams that violate rules 3.a-b. will have the Build Score multiplied by 0.6 for each violation.
      iv. Teams that violate rules 3.c-e. will have the Build Score multiplied by 0.8 for each violation.
      v. Teams that did not participate in Device Testing will receive a Build Score of 0.
   d. Written Test Score = (raw score / highest score achieved by teams) x 50 pts (Maximum 50 points)
   e. Design Log Score (Maximum **32** points): **Points for the Design Log will be awarded or deducted as follows:**
      i. **Four (4) points are awarded for each completed section of the Design Log specified in 4.b.i-viii. as well as being able to answer questions about each section.**
      ii. **Points are deducted from the Design Log Score as follows:**
         (1) **If any digital manufacturing techniques were used as part of the build by the team as described in 4.c. four (4) points will be deducted for each section of 4.c. that was not addressed or is incomplete (Maximum 12 point penalty).**
         (2) **One (1) point may be deducted for each section specified in 4.b.ii.-vii. where appropriate units were not provided with numerical values (Maximum 4 point penalty).**
   f. Teams that violate any rule under "THE COMPETITION" will have the Total Score multiplied by 0.9.
   g. Tiebreakers:
      i. Highest Build Score
      ii. Highest Written Test Score
      iii. Selected questions on the Written Test.

Recommended Resources: The Science Olympiad Store (store.soinc.org) carries a variety of resources to purchase for this event; other resources are on the Event Pages at soinc.org

This event is sponsored by Texas Instruments