THERMODYNAMICS

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

1. **DESCRIPTION:** Teams must construct an insulating device prior to the tournament that is designed to retain heat and complete a written test on thermodynamic concepts.

   A TEAM OF UP TO: 2 **EYE PROTECTION:** C

   IMPOUND: Yes **APPROXIMATE TIME:** 50 Minutes

2. **EVENT PARAMETERS:**
   a. Each team may bring one three-ring binder of any size containing information in any form and from any source attached using the available rings. **Participants may remove pages during the event**.
   b. Each team may also bring tools, supplies, writing utensils, and two **stand-alone** calculators of any type for use during any part of the event. These items need not be impounded.
   c. Each team must impound: their insulating device; **an** unaltered, glass or plastic, standard (height ~1.4 times the diameter) 250 mL beaker; **a device diagram and** copies of graphs and/or tables for scoring.
   d. Event supervisors will supply the hot water, devices for transferring measured volumes of water, **cotton balls**, and thermometers or probes (recommended).
   e. Prior to competition, teams must calibrate devices by preparing graphs/tables showing the relationship **between water temperature and testing parameters**. A labeled device picture/diagram should be included.
      i. Any number of graphs and/or data tables may be submitted but the team must indicate up to four to be used for the Chart Score, otherwise the first four provided are scored.
      ii. Graphs and/or tables may be computer generated or drawn by hand on graph paper. **Each data series counts as a separate graph**. A template is available at www.soinc.org.
      iii. Teams are encouraged to have a duplicate set to use, as those submitted may not be returned.
   f. Participants must wear eye protection during Part I. Teams without proper eye protection must be immediately informed and given a chance to obtain eye protection if time allows.
   g. Participants must be able to answer questions regarding the design, construction, and operation of the device per the Building Policy found on www.soinc.org.

3. **CONSTRUCTION PARAMETERS:**
   a. Devices may be constructed of and contain anything **except** the following materials/components: asbestos; mineral wool; fiberglass insulation; **commercially available thermoses/coolers/vacuum sealed devices**.
   b. The device must fit within a:
      i. 20.0 x 20.0 x 20.0 cm cube for Division B
      ii. 15.0 x 15.0 x 15.0 cm cube for Division C
   c. Within the device, participants must be able to insert and remove a beaker that they supply (see 2.c.).
   d. The device must also allow putting a thermometer/probe into the beaker via a hole **≥ 0.50 inches** in diameter all the way through directly above the beaker. The hole's top surface must be < 12 cm above the inside bottom beaker surface. **The hole's bottom surface may be inside the beaker but must not contact the water. Teams may plug the hole with a single cotton ball provided by the supervisor**.
   e. Devices will be inspected to ensure that there are no energy sources (e.g., electric components, battery powered heaters, chemical reactions, etc.) to help keep the water warm. At the event supervisor's discretion, teams must disassemble devices after testing in order to verify the construction materials.
   f. All parts of the device must not be significantly different from room temperature at impound.

4. **THE COMPETITION:**

   Part I: Device Testing
   a. At the start of each competition block, the supervisor will announce the volume of water (**Regionals: 100 mL; States: 75 - 125 mL, 25 mL increments; Nationals: 75 - 125 mL, 5 mL increments**) and the cooling time (Div. B: **25.0** mins; Div. C: **20.0-30.0** mins, **1-minute increments**). These parameters will be the same for all teams.
   b. The event supervisor will announce the temperature of the source water bath (60 - **75** ^{o}C) and the current room temperature. **Supervisors will do their best to keep this the same for all teams but must announce the actual values (in case of minor fluctuations) at the start of each competition block**.
   c. At the start of the competition block, teams will be given 5 minutes to set up or modify their devices and use their graphs and/or tables to begin temperature prediction calculations. Devices that do not meet the construction specs will not be allowed to be tested until brought into specification.

d. **The supervisor, using his/her own measuring device, will dispense the volume of water into each team's beaker. A team may elect to install a beaker in a device prior to this but must leave sufficient access to the beaker**. Teams may secure/close access panels with fastening materials after **receiving water, but must do so in a manner to not delay dispensing to other teams**. Supervisors must record the time each team receives water and the room and source water temperature when dispensed.
e. Teams will use their graphs and/or tables to calculate the temperature of the water in their beaker at the end of the cooling time. **After receiving water, teams will be given at least 3, but no more than 5 minutes to make their final predictions. During this time, teams may use their own thermometers to measure the starting water temperature in their beaker, but after this time must remove them**.
f. At the end of the cooling period, the supervisor will record the ending time and the temperature in the beaker to the best precision of the available instrument. Supervisors may leave thermometers/probes in the devices for the entire cooling period but will announce if they will do so before impound. Otherwise they will insert a thermometer/probe into **the beaker in the device**, wait at least 20 seconds, and record the resulting temperature. Multiple thermometers/probes may be used at the supervisor's discretion.
g. The supervisor will review with the team the Part I data recorded on their scoresheet.
h. Teams filing an appeal regarding Part I must leave their device in the competition area.

Part II: Written Test

a. Teams will take a test on thermodynamics during the remaining time after all devices receive water.
b. Unless otherwise requested, answers must be in metric units with appropriate significant figures.
c. Teams will be given a minimum of 20 minutes to complete a written test consisting of multiple choice, true-false, completion, or calculation questions/problems.
d. The test will consist of at least **three** questions from each of the following areas:
   i. The history of thermodynamics
   ii. **Definition of temperature**, temperature scales and conversions, definitions of heat units
   iii. **Phases of matter, phase transitions, phase diagrams, latent heat, ideal gas law**
   iv. **Kinds of heat transfer, thermal conductivity, heat capacity, specific heat**
   v. Thermodynamic laws and processes (e.g., Carnot cycle and efficiency, adiabatic, isothermal)
   vi. **Division C only: Radiant exitance, entropy, enthalpy**

5. **SCORING:**
   a. High score wins. All scoring calculations are to be done in degrees Celsius (°C).
   b. The Final Score = TS + CS + HS + PS; a scoring spreadsheet is available at www.soinc.org.
   c. Test Score (TS) = (Part II score / Highest Part II score for all teams) x 45 points
      i. Chart Score (CS) = max of 10 points
      ii. Heat Score (HS) = **20 x (lowest k of all teams) / k**, **where k is from Newton's law of cooling: k = - (1 / cooling time) x ln((start water temp - room temp) / (final water temp - room temp))**
      iii. Prediction Score (PS) = **25 - 2.5*abs(prediction - final temp)**. The minimum PS possible is 0 points.
   d. One of the submitted graphs and/or tables, selected by the event supervisor, must be scored as follows for the Chart Score. Partial credit may be given.
      i. 2 points for including data spanning at least one variable range listed in **4.Part I.a.**
      ii. 2 points for including at least 10 data points **in each data series**
      iii. 2 points for proper labeling (e.g. title, team name, units)
      iv. 0.5 points for each graph or table turned in (up to 2 points total as long as they are not the same)
      v. 2 points for including a labeled device picture or diagram
   e. If a team violates any COMPETITION rules, their **PS score** will be multiplied by 0.9 and **their k will be multiplied by 1.1** when calculating the scores.
   f. If any CONSTRUCTION violation(s) are corrected during Part I, or if the team misses impound, their **PS** will be multiplied by 0.7 and their **k will be multiplied by 1.4** when calculating the scores.
   g. Teams disqualified for unsafe operation or do not having a conforming insulating device at the start of Part I receive zero points for their **HS and PS** scores. Teams will be allowed to compete in Part II.
   h. Tie Breakers will be applied in the following order: i. Best TS, ii. Best PS, iii. Best HS.

Recommended Resources: The Science Olympiad Store (store.soinc.org) carries the Chem/Phy Science CD; other resources are on the event page at soinc.org.