THERMODYNAMICS C

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

1. **DESCRIPTION:** Teams will construct a device prior to the tournament designed to collect heat and complete a written test on thermodynamic concepts.

   A TEAM OF UP TO: 2 **APPROXIMATE TIME:** 50 minutes

   IMPOUND: Yes **CALCULATOR**: Class III

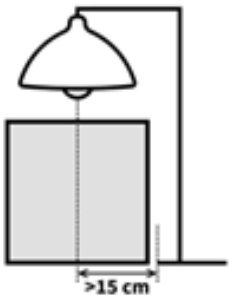
2. **EVENT PARAMETERS:**
   a. Each team may bring writing utensils.
   b. Each team may bring two Class III calculators for use during any part of the event.
   c. Each team may bring a collection of notes and resources, written/printed on paper, of any size containing information in any form and from any source. Binders, books, notebooks, folders, sheet protectors, lamination, tabs, and labels are permitted. Participants are responsible for organizing and containing their notes efficiently. They may separate or remove the pages from containers for use during any part of the event.
   d. Each team may bring one pre-constructed device, spare parts, tools (defined as items aiding setup, not part of the build), and any prepared graphs or tables for use in their calculations of the device's results. Only the device and spare parts must be impounded, and all items must be at room temperature when impounded.
   e. The Event Supervisors will provide the testing materials listed in the COMPETITION AREA section. Teams should not bring these materials.

3. **CONSTRUCTION PARAMETERS:**
   a. The team's device will be designed to collect heat from an Event Supervisor-provided lamp setup to raise the temperature of room-temperature water.
   b. Devices may be constructed of and contain anything except the following materials and components:
      i. Hazardous materials, including but not limited to: asbestos, mineral wool, and fiberglass
      ii. Thermometers, probes, commercially available thermoses, coolers, or vacuum sealed devices.
      iii. A team's use of any of the hazardous materials listed in 3.b.i. means that their device will not be allowed to be set up, modified or tested. Such teams will only be allowed to participate in the written test.
   c. Within the device, participants must be able to insert and remove a 9 oz disposable plastic party cup provided by the Event Supervisor filled with room-temperature water.
   d. The device, including the cup of water, must fit within a 30.0 cm x 30.0 cm x 30.0 cm cube when set up for testing.
   e. Parts of the device may be inside the cup, but no part of the device may contact the water. Nothing may be added to the water.
   f. Devices must have no energy sources (e.g., no electrical components, battery powered heaters, chemical reactions, etc.) to help warm the water. At the Event Supervisor's discretion, teams must disassemble their devices at the end of the testing period to verify the materials used in construction. A team's use of any of the materials listed in this rule will result in TS and PS scores of zero for the team.
   g. No part of the device may be significantly different from room temperature at the start of the event.
   h. Competitors must be able to answer questions regarding the design, construction, and operation of the device per the Building Policy found on www.soinc.org.

4. **COMPETITION AREA:**
   a. For each testing setup, the Event Supervisor will provide a clamp lamp with metal reflector and with a 100-125 watt heat lamp bulb. The bulb must not be tinted and may not be LED, halogen, or ceramic.
   b. The lamp will be mounted, facing down, above the Testing Surface. The Testing Surface is the surface that the team's device is placed on, like a table or countertop. Multiple identical setups may be used.
   c. The heights of the bulb and reflector above the Testing Surface must be the same for all teams. The height above the Testing Surface of the bottommost point of the bulb must be:
      i. Regionals: 40 - 50 cm height, in 5 cm increments
      ii. States: 40 - 55 cm height, in 5 cm increments
      iii. Nationals: 40 - 65 cm, in 1 cm increments



d. The Event Supervisor must mount the lamp in such a way so that the team's device can sit centered under the lamp. Any protruding parts of a lamp stand (such as the feet of the stand) must be no closer than 15 cm to the center of the bulb. See the diagram for an example.



e. The Event Supervisor will provide a source water bath, which is expected to be approximately room temperature. Event Supervisors will do their best to keep this the same for all teams.
f. The Event Supervisor will provide the thermometer for the measurement of the starting and final temperatures. The Event Supervisor thermometer may be a traditional, non-mercury thermometer or an electronic probe capable of measuring the temperature to a tenth of a degree Celsius. Multiple thermometers may be used, but, for each team, the same thermometer must be used to measure their starting and final temperatures. Non-contact thermometers are allowed. Competitors will not be allowed to use the Event Supervisor thermometers.
g. The Event Supervisor will provide one cup per team, containing 100 mL of water from the source water bath. The cup will be a disposable, clear plastic, 9 ounce party cup (approximately 3.9 - 4.0 inches tall, with a mouth of approximately 2.9-3.0 inches).

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

Part I: Written Test

a. The written test will assess the team's knowledge of thermodynamics.
b. Unless otherwise requested, answers must be in metric units with appropriate significant figures.
c. The test will consist of at least three questions from each of the following areas:
   i. Thermodynamic systems, intensive and extensive properties of a system, definition of temperature, the zeroth law of thermodynamics, temperature scales and conversions, definitions of heat-related units
   ii. Phases of matter, phase transitions, phase diagrams, latent and sensible heat, ideal gas law
   iii. Kinds of heat transfer, thermal conductivity, heat capacity, specific heat
   iv. Processes (e.g., adiabatic, isothermal, isochoric, isobaric), thermodynamic cycles, engines, efficiency, and the first and second laws of thermodynamics
   v. Historical perspective of the contributions of Kelvin, Joseph Black, Joule, Carnot, Planck, Clausius, Boltzmann, and Maxwell to the field of thermodynamics
   vi. **State/National only:** Radiant exitance, blackbody radiation, the Stefan-Boltzmann law, and the third law of thermodynamics
   vii. **State/National only:** Entropy and enthalpy
d. Questions on the test will use the following mathematical content:
   i. Standard arithmetic operations, including ratios, exponents, and absolute value.
   ii. Algebraic manipulations, including derivations involving multiple steps and variables.
   iii. Geometric calculations, including computing the volume or area of common shapes.
   iv. No questions may require the use of trigonometry or calculus.

Part II: Device Testing

a. At the start of each competition block, the Event Supervisor will announce the height of the bulb above the Testing Surface, the Heating Time, room temperature, and the temperature of the source water bath. The Event Supervisor will also announce the bulb's specifications, which should include the wattage and bulb measurements. These parameters and bulb specifications must be the same for all teams, except for slight incidental variations in temperature. It is recommended that the Event Supervisor provide this information in written form. The Heating Time is:
   i. 10 minutes at Regionals,
   ii. 10 - 15 minutes at States/Nationals in 1 minute increments
b. The teams will be given 3 minutes of Device Setup Time to set up or modify their device and begin making their prediction of the water temperature at the end of the Heating Time. Teams may attempt to fix any construction violations during this time. This time is not paused for any construction re-checks. No modifications may be made to the device after the Device Setup Time finishes except for inserting/removing the cup of water.

c. The Event Supervisor, using their own measuring device and thermometer, will dispense 100 mL of water into a cup for each team and measure and record the starting temperature to the nearest tenth of a degree Celsius. The Event Supervisor will inform the team of the starting temperature of the team's water. The water may be distributed to teams at the same time or in a staggered manner. Event Supervisors will not leave a thermometer in teams' devices or measure the water temperature while the cups are in teams' devices.
d. Once a team receives their water and its Event Supervisor-measured temperature, they will have up to 1 minute of Water Setup Time to insert the cup of water into their device. Teams may not alter or manipulate the cup or the water in it beyond inserting the cup into their device.
e. At the end of the Water Setup Time, the Event Supervisor will turn on the lamp and start a timer for the Heating Time. The team may not touch their device or the lamp testing setup during the Heating Time. Teams that do so will receive a score of zero (0) for their TS and PS scores.
f. The team must finalize their prediction of the final temperature of their cup of water before the end of the Heating Time, or they will receive no Prediction Score (PS). Teams must make their prediction in degrees Celsius. Teams may also be allowed to work on the written test during the Heating Time at the discretion of the Event Supervisor.
g. At the end of the Heating Time, the Event Supervisor will turn off the lamp. The team must then completely remove the cup of water from their device and place it on the Testing Surface next to their device. The cup must be completely separated from all device components before the Event Supervisor measures the final temperature. The Supervisor will then record the final temperature to the nearest tenth of a degree Celsius. Both the team and the Supervisor should attempt to accomplish these tasks within one minute to minimize water cooling.
h. The Event Supervisor will review with the team the Part II data recorded on their scoresheet.
i. Teams filing an appeal regarding Part II must leave their device in the competition area.

6. **SCORING:**
   a. High Score wins.
   b. All scoring calculations are to be done in degrees Celsius.
   c. Final score (FS) = ES + TS + PS; The maximum possible FS is 100 points. A scoring spreadsheet is available at www.soinc.org.
   d. Exam Score (ES) = (Part I score / Highest Part I score for all teams) x 50 points
   e. Temperature Score (TS) = (TG / Highest TG of all teams) x 30 points
      i. Temperature Gain (TG) = final cup water temp - starting cup water temp
      ii. The lowest possible TG is 0 points.
      iii. A team utilizing any of the materials in rule 3.f will receive a TS of 0.
      iv. A team touching their device or the lamp testing setup during the Heating Time will receive a TS of 0.
   f. Prediction Score (PS) = (PE / Highest PE of all teams) x 20 points
      i. Prediction Estimate (PE) = 1 - abs(final cup water temp - predicted final cup water temp) / final cup water temp.
      ii. The lowest possible PE is 0 points.
      iii. A team utilizing any of the materials in rule 3.f will receive a PS of 0.
      iv. A team that does not give a final temperature prediction before the end of the Heating Time or that touches their device or the lamp testing setup during the Heating Time will receive a PS of 0.
   g. If a team violates any COMPETITION rules, their TS and PS values will be multiplied by 0.9 per violation when calculating the scores
   h. If a team has any CONSTRUCTION violations at the end of their Setup Time, their TS and PS values will be multiplied by 0.7 per violation when calculating the scores.
   i. Teams that are not allowed to compete in Part II due to unsafe operations or do not bring a device receive zero points for their TS and PS scores. Teams will be allowed to compete in Part I.
   j. Tie Breakers: 1st - Best TS; 2nd - Best ES; 3rd - preselected test questions