Keep the Heat
Thermodynamics Lab

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Overview

- Two Overall Components
  - Insulating device demonstration
  - Written Test
  - Eye Protection required – Splash rated eyewear
  - Binder of any size
    - Be practical –
      - If you can't find it - it does no good to have it.
- Scoring
  - 5 components
    - Test Score – 50 points
    - Plot Score – 10 points
    - Prediction Score – 25 Points max
    - Heat Retention Score – approx 25 Points
    - Ice Bonus (Division C only) – 12.5 points max

Insulating device

- Only use:
  - Wood (Sawdust is OK), Paper, Cardboard, Aluminum Foil
  - Fastening materials (not for insulation purposes….slippery slope)
- Explicitly not allowed (but not limited to):
  - Foam of any type, plastic (except as part of a “fastening material”), fiberglass
- **Check www.soinc.org for updates about allowed / disallowed materials**
- Div. C - 20.0 cm cube, Div. B – 30.0 cm cube
- No electrical components or chemical reactions (or other energy sources)
- Contain a removable standard 250 mL Pyrex beaker
  - Two unmodified beakers are required on inside of the device and one outside. Both must be exactly the same.
- Have a hole in top
  - For insertion of the temperature probe
  - 1.5 cm hole, muse be less than 5 cm from the top, not covered

Current SOINC.org Questions and Answers

- (section: 3 / paragraph: a / line: 1)

- 11/20/2011 - 21:09 What is meant by organic granular material?
- Organic material is matter that has come from a once-living organism, is capable of decay or the product of decay, or is composed of organic compound. Granular material is a conglomeration of discrete solid, macroscopic particles characterized by a loss of energy whenever the particles interact (the most common example would be friction when grains collide). Thus, organic granular material could be described as a collection of pieces of organic material. Some examples of organic granular materials are rice, coffee, corn flakes, sugar, nuts, popcorn, coal, pieces of cork, leaves, etc.

- 11/20/2011 - 21:30 Would clay, sand, and/or dirt (such as top soil, potting mix) be considered an organic granular material?
- Some dirt can be considered organic however do not assume all dirt is organic. Some dirt and soils contain inorganic materials and would not be allowed. Clay and sand are conglomerations of organic and inorganic materials therefore are not allowed due to their inorganic components.

- 11/20/2011 - 21:38 Is cork acceptable as "wood"?
- Cork is not wood but it is organic and must be granular if used. Please see the posted FAQ for organic granular material.

- (section: 4 / paragraph: a / sub-paragraph: iv. / line: 1)

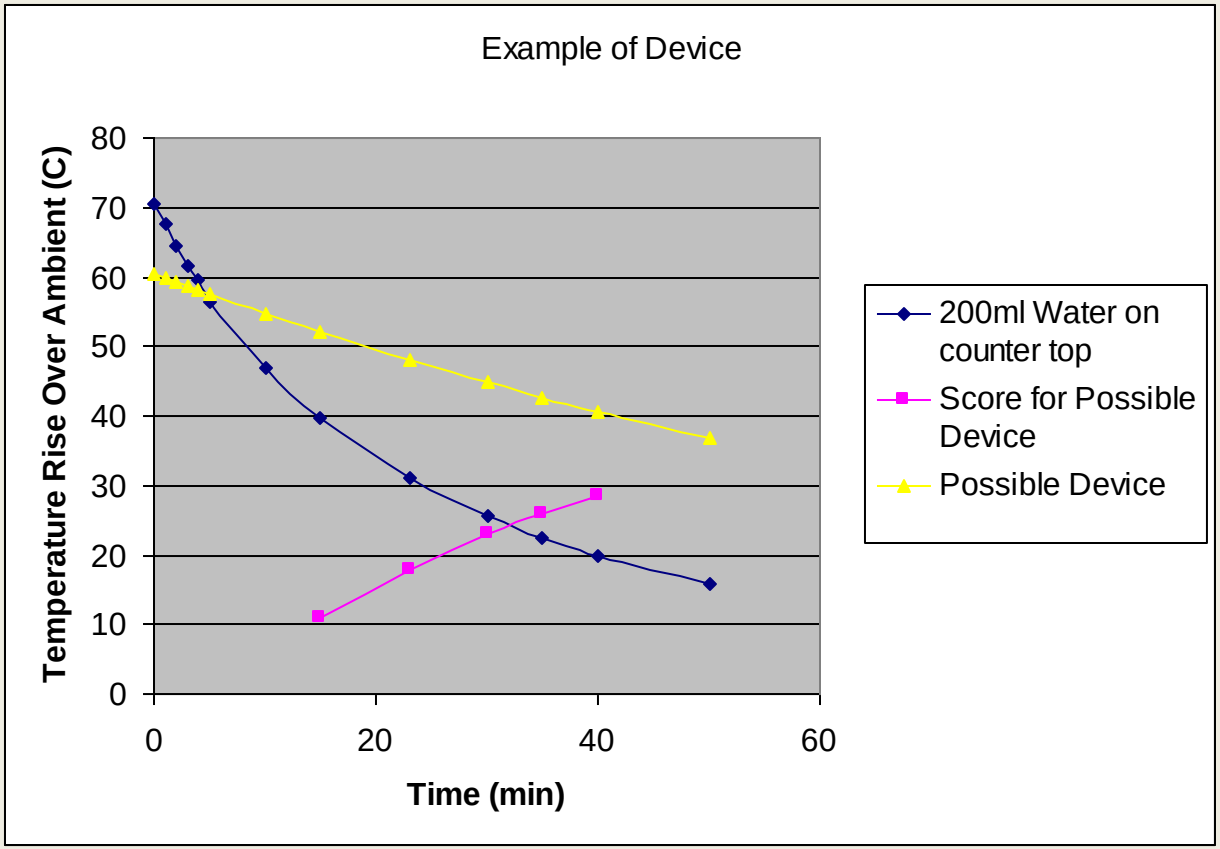
- 10/28/2011 - 14:25 Does the event supervisor or the student pour the water into the beakers?
- That is up to the individual event supervisor, although the recommendation is that the event supervisor transfers the water. The student(s) load the beaker into their device.

Plots

- Provide up to 5 graphs demonstrating the performance of the device for various starting temps and quantities of water
- Scoring
  - 2 points if labeled w/ school and students' names
  - 2 points for appropriate title and X-axis and Y-axis labels
  - 2 points for appropriate units and axis increments
  - 1 point for each data plot on a graph or graphs turned in (up to 4 total)

Insulating Device Testing

- Competition and testing:
  - Temperature (between 60 – 90 °C), volume of water (50 – 150 mL) and time (20-40 mins) is the same for all teams, announced after impound.
  - Division C only: option to add up to 100 mL of ice water (bonus applies)
  - Teams add hot water to both beaker in device and reference beaker sitting on table
  - Temperature of each recorded at end of time



Insulating Device Tips

- For Performance
  - Consider the methods for heat transfer
    - Conduction
    - Convection
    - Radiation
  - How do you limit each of these methods for heat loss
  - Consider the heat equations
    - What are the steps to heat transfer
    - What happens to materials that come in contact with the hot water
  - Consider Reliability
    - Steam can destroy cardboard and other materials after a few tests
    - Foil can be used to protect cardboard from steam
    - Must support the weight of the water
    - Must be able to be assembled and disassembled for inspection
- Material Resources
  - Balsa Wood www.lonestar-balsa.com
  - Free sawdust from Lowe's, Home Depot
  - Craft store
  - Shipping materials

Test Component

- Topics include
  - Temperature conversion
  - Definitions of Heat units
  - Thermal conductivity
  - Heat capacity
  - Specific heat
  - Laws of thermodynamics
  - History of thermodynamics
  - Thermodynamic processes

Thermodynamics Explains It All

- **Everything happens because heat is flowing from a hot place to a cold place. Nothing happens without heat flow. There are no exceptions.** That's why thermodynamics, which is generally a mechanical engineering course, is usually required for graduation with a mechanical, electrical, civil, or chemical engineering degree.
- Furthermore, thermodynamics is an exact science. If one can do the math, it is possible to calculate the maximum amount of work that can be done, or the actual efficiency of any machine, entirely from an analysis of temperature differences and heat flow. So, if a machine needs to do more work than can be done by the heat flow associated with it, that machine cannot possibly be built.
- Thermodynamics is, from an engineer's point of view, the ultimate science. It explains the operation of the entire natural universe.

Temperature is not Heat

- It is natural to confuse heat with temperature. That's because the more you heat something, the higher its temperature becomes. But heat and temperature aren't the same things. Heat is a form of energy. A difference in temperature causes heat to flow. Just remember, **heat is something that flows and temperature is what makes heat flow.**
- You can melt more ice with 1,000 gallons of 90 degree (F) water than 1 teaspoon of 200 degree (F) water. That is because there is more heat in 1,000 gallons of 90 degree water than there is in 1 teaspoon of 200 degree water. Just because the teaspoon is hotter, it doesn't mean that it contains more heat than all those gallons of cooler water.

Laws of Thermodynamics –

- **The Zeroth Law**
- The Zeroth Law simply says there is no heat flow between objects that are the same temperature. In essence, the Zeroth Law is just a definition of what temperature is.
- **The First Law**
- **The First Law is that heat cannot be created or destroyed.** (This is also known as the law of conservation of energy.) Heat can only flow from place to place, or change form.
- **The Second Law**
- The Second Law says that entropy always increases in a **closed** system.
- **The Third Law**
- The Third Law says that an ideal engine would convert 100% of the heat into useful work only if its exhaust temperature were absolute zero. In other words, 100% efficiency is impossible.

Laws of Thermodynamics

- The first three laws of thermodynamics rather cynically this way:
  - The First Law says you can’t win.
  - The Second Law says the best you can do is to break even.
  - The Third Law says you can only break even at absolute zero.

Sample Questions – Temp Conversion

- What is 56.0 °C in?
  - Fahrenheit
    - 133 °
  - Kelvin
    - 329 K
  - Rankine
    - 592 °R

Sample Questions – Heat Units

- What letter is generally used to denote heat in equations?
  - Q
- A small candy bar has 52 calories. If all of its energy were converted to heat, by how much would it raise the temperature of 1 L of water?
  - 52 °C
- How many BTU's are in one gram calorie?
  - 0.003964 BTU

Thermal Conductivity

- Stainless Steel has a thermal conductivity of ~45.0 W/m·K and Silver has a thermal conductivity of ~430 W/m·K. Based only on that information, which would be the better:
  - Heatsink for a computer chip
    - Silver
  - Casing for an oven
    - Stainless Steel

Sample Questions – Heat Capacity

- What is the specific heat capacity of dry air in J/g·K at 0 °C ?
  - 1 (1.0035 w/o sig figs)
- Other sample about raising temperature and phase changes are readily available in science textbooks. ($C = Q/\Delta T$)

Sample Questions – Specific Heat

- What is the relationship between Heat Capacity and Specific Heat?
  - Specific heat is the heat capacity per unit mass
- Competition questions will involve the temperature a mass will increase after absorbing an amount of energy.

Sample Questions – Laws of Thermodynamics

- What thermodynamic process is most closely related to the 1st Law of Thermodynamics?

– Adiabatic

- What does the equation $k = R/N_A$ describe?

– The Boltzmann constant (related to entropy and the 2nd Law)

- What is Nernst's theorem?

– The entropy of a perfect crystal approaches zero as temperature approaches absolute zero (the 3rd Law)

Sample Questions – History of Thermodynamics

- Who discovered the mechanical equivalent of heat?
  - James Joule
- In what year was the concept of Absolute Zero first postulated?
  - 1702
- What is the fundamental assumption of Max Planck's "quantum hypothesis"?
  - That the energy of atomic systems can be quantized.

Sample Questions – Thermodynamic Processes

- What is a process called if the net heat transfer to the working fluid is zero?
  - Adiabatic
- If a cylinder containing water, topped by a fixed piston is heated by a bunsen burner what is the thermodynamic process?
  - Isochoric
- If the above experiment is repeated, but the piston is released, what is the thermodynamic process?
  - Isobaric

WebSites

- http://www.ridgenet.net/~do_while/sage/v7i1f.htm
- http://hyperphysics.phy-astr.gsu.edu/hbase/heacon.html#heacon
- Wickipedia