Thermos – Hot or Not?
A design challenge exploring heat and thermodynamics

Central Question: Can you design and build a thermos according to a customer's specifications?

Knowledge Probe: **(5 pts)**

- What is heat? How is heat transferred or lost in a system?
- What is thermal conductivity?
- How do different materials work to prevent heat loss?
- Fourier's Law:

$$q = \frac{k \cdot A \cdot (T_H - T_C)}{L}$$

q = heat transferred per unit time (W)
A = heat transfer area (m^2)
k = thermal conductivity of material (W/m x k)
$\mathbf{T_H}$ = hot temperature (K)
$\mathbf{T_C}$ = cold temperature (K)
L = material thickness (m)

Rules:

The thermos needs to meet the following specifications:

1. Hold 200 mL of water
2. Cost less than $3 for all materials and have the lowest total design cost
3. Use only materials listed below, as provided by the teacher
4. Have the least amount of heat loss (smallest drop in temperature of boiling water after 10 minutes)
5. Be built and tested in two class periods

Materials	Thermal Conductivity (W/m x K)	Cost ($)
Water (for insulation)	0.60	0.25 mL
Aluminum foil	250	0.05/inch
Cotton balls	0.03	0.15/each
Paper cup	0.05	0.55/each
Sand	0.25	0.01/gram
Plastic cup	0.23	0.15/each
Styrofoam cup	0.03	0.85/each
Foam insulation	0.03	0.05/inch
Masking tape	0.08	0.05/inch

Investigative Plan: **(20 pts)**
Describe the building process. Include a cross section sketch of your thermos and a table, as shown below. You will design, create, and test two prototypes. For the second, discuss what changes you made to the first design, another cross section sketch and another table as shown below.

Materials	Quantity	Cost ($)

Observations: **(12 pts)**
Create a data table that records the following information for the two different prototypes: temperature in ^oC and time (up to 10 minutes). Include data tables for two other groups' prototypes as a comparison to yours.

Data Analysis: **(12 pts)**

- Graph the heat loss of both of your prototypes on the same graph (MUST be graph paper!).
- Include the following information for each of your prototypes: total design cost, total temperature loss (ΔT), cost/change in temperature ($/$\Delta T$).
- Answer the following questions concerning Fourier's Law (as shown in the knowledge probe section above):
  1. The value of q should be _____ (big or small) if you want less heat loss.
  2. The value of q should be _____ (big or small) if you want more heat loss.
  3. The value of k should be _____ (big or small) if you want less heat loss.
  4. The value of k should be _____ (big or small) if you want more heat loss.

Evaluation: (20 pts)

Answer the following questions in complete sentences:

1. Based on your cost/change in temperature ratio, which was your best design?
2. Why did you choose the materials you did? What was the most important factor in choosing your materials – thermal conductivity or cost?
3. How could you improve your design?
4. What role did you perform in your group – generator, implementer, challenger, or chameleon?

Scoring Rubric:

Category	**Points possible**	**Points earned**	**Description**
Meets specifications	**6**		Hold 200 mL of water, costs < $3, built and tested in two class periods
Lab notebook	**69**		Thorough completion of components outline above
Total	**75**		
Extra Credit	**+6**		**+3 for lowest overall cost** **+3 for least heat loss (ΔT)**