Activity Title: It's Either Very Hot or Very Cold Up There!

Activity Objective(s): In this activity, and the follow-up activity next week, teams will design and conduct experiments that will help them understand the basic principles of thermal transfer – how things warm up and cool down. They will carefully gather data and then analyze that data in order to make generalizations about the factors that affect how things get warmer and cooler. These conclusions will be used in the design of a Lunar Thermos next week.

Graphic courtesy NASA.

Lesson Duration: One 60 min session

Grade Levels: 6 - 8

Process Skills: Experimental design, measuring, graphing, and data analysis.

Materials and Tools (per group of two or four students):

- Thermometers
- Timers
- Graduated cylinders
- Small plastic cups
- Hot and cold water from the tap
- Graph paper, if available

Club Worksheets: (Make copies for each student to put in binder)

1. Imagine
2. Plan – Experimental Design
3. Data Table
4. Challenge Closure / Summary
5. Fun With Engineering at Home

Club Facilitator or Teacher Notes by Stage:

(Based on those running 60-minute Clubs)

Stage 1: Set the Stage (Approx 10 minutes)

Explain to the students that there is no atmosphere on the Moon, so temperatures fluctuate through a wide range. In the shadowed areas the temperature is –180 ^{o}C (or – 300 ^{o}F), and in the sunlit areas it is about 100 ^{o}C (or 212 ^{o}F), which is the boiling point for water! These are serious extremes for human beings!

On the Moon, there are surfaces permanently exposed to the Sun, and surfaces permanently in shadow. It is in the permanently shadowed areas of some craters that the possible existence of ice has been speculated by some scientists.

Anyone living on the Moon, even for a short while, will have to deal with this temperature variation, and be properly protected from damaging effects. Thus we must understand how thermal energy is transferred, and, for our concerns, how we can prevent thermal energy from being transferred (to or from our bodies): in other words, how can we insulate ourselves from the wide variations of temperature in the lunar environment?

Finally, a quick review of several vocabulary terms might be useful:

- **Heat** = the transfer of energy from a warm place to a cooler place.
- **Temperature** = measurement of the energy associated with the motion of molecules in a substance.
- **Equilibrium** = two variables, parts, or conditions of a system in balance.

- Break the students into two or four-person teams. Give them the **challenge** (this is the "ASK" part of the engineering design process):
- Given a specific volume of a substance, let's choose water (since about 72% of the human body is water), design an experiment that enables us to understand how thermal energy flows, and what factors affect the rate of temperature change.

Stage 2: Plan Part-1 (Approximately 10 minutes)

This is the "IMAGINE" part of the engineering design process.

- Depending on the science background of the students, some amount of directed guidance/questioning may be necessary to help them design an experiment that makes sense.
- Some questions that might help with this process are:
  - What is the temperature in the room?

- How much water should we put in the cup? What if you doubled that amount?
- What temperature should we make the water in the cup at the start?
- How much time should we allow for the water to warm or cool?
- How can we keep track of our measurements so that we can see a change? (In other words, what should our data table look like?)
- Is there a difference between the rate that water cools and warms?
- What specific jobs are each member of the group going to perform?

Stage 3: Plan Part-2 (Approximately 5 minutes)

Briefly write out the step-by-step description of the experiment. Encourage the students to make diagrams of the experimental set-up.

Stage 4: Experiment: (approximately 20 – 30 minutes)

- Basically the most successful experiment would have the students using twice as much water in the second trial.
- Measure the temperature at the start (time = 0).
- Gently (very gently) stir the water continuously and measure the temperature every 30 seconds or minute for 10 or 15 minutes, recording the results in the data table. The team members should take turns reading the measurements and recording the results in the data table.
- If there are four team members, they could save time having two students do the test with the hot water while the other two students do the test with the cold water.
- In either case, for most clear results, the hot and cold samples must be nearly the same amount.
- Then repeat both tests using twice as much water and compare the results.
- Note-1: the most clear results will occur if both samples of water (hot and cold) are the same difference from room temperature, but this isn't a big deal.
- Note-2: more clear results will be observed if the samples begin with the temperature at the greatest difference from room temperature.
- Note-3: the thermometers have a small rubber "keeper" on them so that they will not roll on a table when laid down, however it is a good idea to tell the students that someone should always be holding the thermometer, and for sure never just stand it up in a cup and remove your hand

(because it will absolutely tip over, spilling the water and possibly breaking the thermometer).

- Note-4: Stirring the water very gently is helpful because the temperature of the water in a small sample is usually not uniform when left sitting.
- Note-5: The teacher must judge how much time to guide the students in running their individual tests. With a sample as small as 50 mL clear results should be obtained within 10 – 15 minutes.
- Note-6: Do the students predict that the temperature in either sample will eventually reach room temperature? (This is called "thermal equilibrium" – the temperature at which any objects in the same environment will reach when mutually sharing their thermal energy).

Stage 5: IMPROVE

The students must answer the questions posed in the challenge. Did the data show a clear process of thermal transfer? Was there a clear difference between warming up and cooling off? If the results are not clear, what modifications could they make to make a more successful test(s)?

Stage 6: Graphical Analysis: If there is time the students can graph the warming and cooling curves and see if they look alike. Put Temperature on the Y-axis and Time on the X-axis. Both cooling and warming curves could be plotted on the same graph for best comparison.

Stage 7: Challenge Closure

- Hand out the Challenge Closure / Summary Sheets (please collect one per team and save in a folder for NASA).

Challenge Closure (Answer Key):

- In science the term "**equilibrium**" refers to a system being in balance. What were the two factors (related to heat) that were trying to balance each other in today's investigation?
  - 1) The heat of the room and 2) the heat of the water inside the cup
- As in today's experiment, if you set out a cup of hot water on a table, what change, if any, will happen to its temperature, and when will that change stop?

  The hot water will cool down until its temperature is the same as the air in the room
  - Describe this in terms of the flow of energy:

  The energy in the hot water will flow out of the water into the surrounding air in the room until they are the same
- If you set out a cup of cold water on a table, what change, if any, will happen to its temperature, and when will that change stop?

  The cold water will warm up until its temperature is the same as the air in the room
  - Describe this in terms of the flow of energy:

  The energy in the air in the room will flow into the water in the cup until they are the same
- Imagine an astronaut stepping out of her warm space vehicle onto the surface of the Moon; what two factors would be operating that are similar to the factors that you investigated in your experiment?

- The warmth of the astronaut
- The extreme heat or cold of the Moon

- Imagine that same astronaut, dressed as you are today, stepping out onto the surface of the Moon:
  - What thermal problems would she encounter?

    She would be either frozen or toasted
  - Would she want her body temperature to achieve equilibrium with the Moon's temperature?

    No way!
  - How could equilibrium be prevented?

    Put her in a protective suit that will insulate her from extremes of temperature

Stage 9: Previewing Next Week (approximately 5 minutes)

- The Moon is a very harsh environment. There is no atmosphere to protect astronauts and their equipment from solar radiation and the extreme temperature swings between night and day. Next week, we will begin to find ways to protect astronauts from those extreme temperature changes by experimenting with insulation.

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1. ASK:

Goal: Given a specific volume of a substance, let's choose water (since about 72% of the human body is water), **design an experiment** that enables us to understand how thermal energy flows (this is called "heating" or "cooling"), and what factors affect the rate of temperature change.

Materials:

- Thermometer (must use the Celsius scale)
- Graduated cylinder
- Small plastic cups
- Hot and cold water from a tap

2. IMAGINE:

Brainstorm some possible solutions to the questions:

What is an "experiment"?

What things do we have to "control"?

What things will we measure?

How will I know my conclusion is correct?

3. PLAN:

Here are some questions that might help in designing the experiment:

What is the temperature in the room?

How much water should we put in the cup? What if you doubled that amount?

What temperature should we make the water in the cup at the start?

How much time should we allow for the water to warm or cool?

How can we keep track of our measurements so that we can see a change?

Is there a difference between the rate that water cools and warms?

4. TEST

DATA TABLE:

Room Temperature = _____

Cool down: **Trial – 1** **Trial – 2**

Volume (mL) = _____ **Volume (mL) = _____**

Time (min)	Temp (^{o}C)	Time (min)	Temp (^{o}C)

Analysis: Does the data indicate a pattern or a trend?

What difference is there when the volume of water is increased?

Warm up: **Trial – 1** **Trial – 2**

Volume (mL) = _____ **Volume (mL) = _____**

Time (min)	Temp (^{o}C)	Time (min)	Temp (^{o}C)

Does the data indicate a pattern or a trend?

What difference is there when the volume of water is increased?

5. Summary

In science the term "**equilibrium**" refers to a system being in balance. What were the two thermal factors (things related to heat) that were trying to achieve balance in today's investigation?

_____

And

_____

- As in today's experiment, if you set out a cup of hot water on a table, what change, if any, will happen to its temperature, and when will that change stop?
    - Describe this in terms of the flow of energy:
- If you set out a cup of cold water on a table, what change, if any, will happen to its temperature, and when will that change stop?
    - Describe this in terms of the flow of energy:
- Imagine an astronaut stepping out of her warm space vehicle onto the surface of the Moon; what two factors would be operating that are similar to the factors that you investigated in your experiment?
    - _____
    - _____
- Imagine that same astronaut, dressed as you are today, stepping out onto the surface of the Moon:
    - What problem (other than the fact that there is no air) would she encounter?
    - Would she want her body temperature to achieve equilibrium with the Moon's temperature?
    - How could equilibrium be <u>prevented</u>?

Team Name:_____

Fun with Engineering at Home

Activity 9: *It's Either Very Hot or Very Cold Up There!*

Today we designed and conducted experiments with energy flowing into or out of containers of water. We chose water to experiment with because it is such a large part of the human body, and if we try to inhabit the Moon we will have to pay close attention to keeping the human body safe from the extremes of temperature on the surface of the Moon.

- **Home Challenge**: During this week talk with your parents and friends about all the ways we keep the human body safe from extremes of temperature on the Earth (even though the range of variation is not nearly as great as that found on the Moon).
- List four ways we do something with our bodies to prevent temperature extremes from affecting them (two related heat; two related to cold):
    - _____
    - _____
    - _____
    - _____
- Now list four things we do to change the environment we live in so that the environment does not harmfully affect us because of temperature extremes (two related to heat; two related to cold):
    - _____
    - _____
    - _____
    - _____

HAVE FUN!!