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Engineering a Spacesuit using Heat Transfer Knowledge (Curriculum Exchange)

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Engineering a spacesuit to go on a spacewalk

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Engineering Challenge for Grades 3-5: Design a model spacesuit that will help a spacewalker to survive 20 minutes in the extremes of outer space and be economical. This challenge requires about three 40 minute periods and has been piloted as a formative assessment in a unit on heat.

Motivation

Astronauts go on spacewalks to make repairs, do experiments and test new equipment [(1)]. Two big challenges in spacewalks are, first, that space can feel very cold (-250 degrees F) to an astronaut in the shade and, second, space can feel very warm (250 degrees F) in the Sun [(2)]. The reason for this is that an astronaut will be exposed to about *7 times* the amount of radiation that we, on the Earth's surface, experience due in part to the reflectivity of the surface and atmosphere [(3)].

Learning goals

The science standards and science concepts that are appropriate at grades 3-5 are:

1. When warmer things are put with cooler ones, heat moves from the warmer ones to the cooler ones (2nd law of thermodynamics).
2. When warmer things are put with cooler ones, the warm things get cooler and the cool things get warmer until they are all the same temperature (thermal equilibrium).
3. A warmer object can warm a cooler one by contact or at a distance (energy transfer via conduction and radiation). [(6)]

Some of the misconceptions students commonly have with regard to heat and temperature are:

- Heat is a kind of substance.
- Inability to separate heat and temperature.
- A confusion between the temperature and the "feel" of an object. [(4)] [(5)]

This challenge should provide an opportunity to address these. While basic thermodynamics are embedded in this activity and known misconceptions can be addressed, teaching thermodynamics is not an easy task.

Method

Since astronauts experience such different extremes, testing must take place under two different conditions. Therefore, students test swatches of the materials (paper, cotton, bubble wrap, aluminum foil) under a heat lamp and in the freezer. Students record the data and based their material selections for their astronaut (water bottle) within the allocated budget. After purchasing the materials, groups worked together to protect the astronaut from losing heat after 20 minutes in the freezer. Temperature readings were recorded and evaluated for a second trial testing. Designs were noticeably improved for the 20 minute freezer test. Final temperatures were recorded and evaluated. Groups were asked to choose their most successful engineering design and explain their success.

Engineering Requirements/Constraints

- The astronaut should survive being in the freezer for 20 minutes with a minimum temperature drop
- The astronaut should survive being in the 'hot box' for 20 minutes with a minimum temperature drop
- The space suit is limited to cost $5 (Material costs for space suit might be: cotton $1, bubble wrap $3, paper $2, aluminum foil $4; price constraint should be enough to allow 2-3 layers; prices should be adjusted so that well performing materials are more expensive so that it encourages greater creativity)

Materials

- Small bottles of water (astronaut); Water (humans are 90% water)
- Testing areas: Access to freezer and Hot Box (heat lamp, ring stand, box, aluminum foil)
- IR temperature guns
- Materials for space suit cotton, bubble wrap, cardboard, aluminum foil and tape

Rubric for assessment

- The temperature of the astronaut stayed within range after a simulated space walk
- The cost of the design met the requirements.
- The design is well constructed.
- The description and work in the Engineer's Notebook is complete and well reasoned.

References:

(1) NASA, http://www.nasa.gov/audience/forstudents/k-4/stories/what-is-a-spacewalk-k4.html#.VMqrqC6gu5I

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(4) Carlton K., Teaching about heat and temperature, *Physics Education 35 101*, 2000.

(5) Taber K.S., Finding the optimum level of simplification: the case of teaching about heat and temperature, *Physics Education 35 5*, 2000

(6) AAAS, NSTA, Atlas of Science Literacy, 2001.