ESI Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

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# The Power Within a Peanut: Tremendous Energy Potential

**Lesson Plan for Grades 9-12**
**Length of Lesson:** **1 hr 30 min**

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**Date created:** [02/05/2015]

**Subject area/course:** Chemistry (energy in reactions), Mathematics (mathematical modeling)

**Materials:** *(for groups of 2-3 students)*

- Classroom electronic balances (gram scale)
- Bunsen burner
- Ring stand and clamps
- Fire treatable glass beakers or containers (50 or 100 mL)
- Thermometer (can read to 2 decimal places)
- Pin and tin foil (to prop up the peanut)
- Calculators
- Unsalted peanuts

**TEKS/SEs**

- §112.35. Chemistry, Grade $9^{th}$-$12^{th}$ (11B, 11D, 11E)
- §111.36. Mathematical Models with Applications, Grade $9^{th}$-$12^{th}$ (1A, 1B, 1C)

**Lesson objective(s):** Students will be able to…

- understand the law of conservation of energy and the processes of heat transfer
- perform calculations involving heat, mass, temperature change, and specific heat
- use calorimetry to calculate the heat of a chemical process
- compare and analyze various methods for solving a real-life problem
- use multiple approaches (algebraic, graphical, etc..) to solve problems from a variety of disciplines
- select a method to solve a problem, defend the method, and justify the reasonableness of the results

**Differentiation strategies to meet diverse learner needs:**

- Instructor may wish to use a different organic substance or food instead of peanuts (banana peels, tortilla chips, etc…)
- Instructors should require groups to perform multiple trials during the peanut calorimetry experiment to occupy more time and to reduce the impact of random errors.
- (Advanced) Offer particular students additional challenging assignments such as determining which countries have the highest and lowest average energy consumption per home.

**ENGAGEMENT**

- Instructor will pass around various food containers with nutrition facts. This will be an opportunity to ask students, "What are Calories?"
- After a brief discussion, the instructor can define a calorie as a unit of energy commonly associated with food. Instructor should also differentiate between "calories" and "Calories/kilocalories/dietary calories." – (see

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"How Calories Work" in resources section)

- The Instructor will focus specifically on the energy contained within a peanut by asking, "How many Calories are within a single peanut?" Students will make some predictions as the instructor records them on the board or word/excel document.
- In order to determine how many Calories are within a single peanut, the Instructor will explain the fundamentals of calorimetry – (see "Calorimeters and Calorimetry" in resources section)

**EXPLORATION**

- Students will create groups of 2-3. Each group will be given a single unsalted peanut.
- On a properly tiered and calibrated analytical balance, each student will measure the **mass** (in grams) of their peanut to 3 decimal places.
- Next, students will set up their ring stand and calorimeter according to instructions and diagram - (see "Peanut Lab" in resources section)
- Students will measure the temperature of the water prior to igniting the peanut.
- Students will then burn the peanut till it can sustain its own flame.
- Students will measure the final temperature of the water just as the flame of the peanut fizzles out.
- Using the Calorimetry equations, students will record and calculate the amount of **calories** and **Calories** (dietary calories) in that peanut as well as the **calories/mass** relationship.
- **NOTE**: *Students should be given additional peanuts to measure if they finish quickly or fail to get ideal results from the experiment.*

**EXPLANATION**

- Instructor will gather all students away from the lab are in order to create a data compilation of all the students' recordings.
- Instructor should use an excel spreadsheet to enter each group's mass and calorie experimental data. With the spreadsheet the instructor should also derive class mean values for the **average weight** of a peanut, **average amount of calories** (and Calories) in a peanut, and the **average calories/mass** for peanuts.
- Next, a discussion should be led which addresses why having a calories/mass value for peanuts can be useful and how it can be applied to different situations.
- Instructor will introduce the problem for the Elaboration section: A peanut factory is throwing out tons and tons of "ugly" peanuts because they don't want to sell them to paying customers. Environmentalists and engineers argue that there is a great deal of potential energy within the mounds of peanuts that were discarded.
- Instructor will remind and explain that calories are just a unit for energy and that there are other units of energy and power that people might be more familiar with. (joules, Watts, kilowatts, kilowatt hours)

**ELABORATION**

- Students will be challenged to determine how much energy (in Watts) could be potentially extracted from the tons of peanuts that were discarded by the peanut factory.
- In order to do this, students will have to go through a series of conversions to first determine how much energy in calories is in a mound (of a specified mass)
- Then, students will have to convert that amount of energy to a value in watts then kilowatts.
- Next, with proper research, students will be asked to determine how many houses could be powered in the U.S. for a week.

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**EVALUATION**

- Instructor will ask students how they got to their answer as well as what the student answers were.
- Students will be asked to defend their reasoning, calculations, and sources of information (i.e. the credibility of the websites which provided values for unit conversions, average energy consumption of the average American home, etc…)
- Instructor can ask:
    - Which sources are better than the others?
    - Which results seem the most logical?
    - What were some of the shortcomings or sources of error for this exercise?
- Instructor will finally explain that there are real careers for people to do exactly what the class did today. Nations, companies, and businesses often need the answers to questions that are too difficult to solve via direct measurement. For example, it would have take a gigantic calorimetry experiment to determine how much energy would have come from all of those peanuts directly.

**SOURCES AND RESOURCES**

- Dr. Michael Webber's Hot Science – Cool Talks Lecture #94
- Burn a Peanut Lab - http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCcQFjAB&url=http%3A%2F%2Flindblomeagles.org%2Fourpages%2Fauto%2F2012%2F10%2F7%2F43525835%2FBurn%2520a%2520Nut%2520Prelab.doc&ei=ZwPVVNLjLsuCsQSFloHgAw&usg=AFQjCNHPhpBc2DVw-z-dZlx7soVk066gyw&sig2=nKZCs94pECHKBVSYuK9UPQ&bvm=bv.85464276,d.cWc
- How Calories Work - http://health.howstuffworks.com/wellness/diet-fitness/weight-loss/calorie.htm
- Calorimeters and Calorimetry - http://www.physicsclassroom.com/class/thermalP/Lesson-2/Calorimeters-and-Calorimetry
- Peanut Lab - http://imet.csus.edu/imet1/dave/portfolio/peanut_lab.htm

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# The Power Within a Peanut: Tremendous Energy Potential

## EXPLORATION ACTIVITY or ACTIVITIES

**Purpose:** These activities are designed to provide students the hands on experience of measuring the chemical potential energy stored in a peanut. In order to do so, students will take the necessary measurements and setup the necessary calorimetry experiment to determine the calorie/mass ratio of peanuts. With this value, students can then explore relationships between actual daily energy consumption in the U.S. and it's equivalents in peanut chemical potential energy (energy stored in peanuts).

**Materials:** *(for groups of 2-3 students)*

- Classroom electronic balances (gram scale)
- Bunsen burner
- Ring stand and clamps
- Fire treatable glass beakers or containers (50 or 100 mL)
- Thermometer (can read to 2 decimal places)
- Pin and tin foil (to prop up the peanut)
- Calculators
- Unsalted peanuts

**Safety Information**: This lab involves several hazards that instructors should be aware of. Calorimetry, in this instance, involves the use of a flame to ignite organics (peanuts). Students should be briefed on burn hazards and be directed towards working fire extinguishers/fire blankets as well as emergency wash stations. Additional precautions should be taken for proper waste disposal, what to do with heated/hot materials, and what to do in the instance of broken glass. Always practice proper lab safety by wearing eye protection, gloves, and full length protective clothing.

**Procedure:**

**Exploration**:

- Students will create groups of 2-3. Each group will be given a single unsalted peanut.
- On a properly tiered and calibrated analytical balance, each student will measure the **mass** (in grams) of their peanut to 3 decimal places.
- Next, students will set up their ring stand and calorimeter according to instructions and diagram - (see "Peanut Lab" in resources section)
- Students will measure the temperature of the water prior to igniting the peanut.
- Students will then burn the peanut till it can sustain its own flame.
- Students will measure the final temperature of the water just as the flame of the peanut fizzles out.
- Using the Calorimetry equations, students will record and calculate the amount of **calories** and **Calories** (dietary calories) in that peanut as well as the **calories/mass** relationship.

**NOTE**: *Students should be given additional peanuts to measure if they finish quickly or fail to get ideal results from the experiment.*

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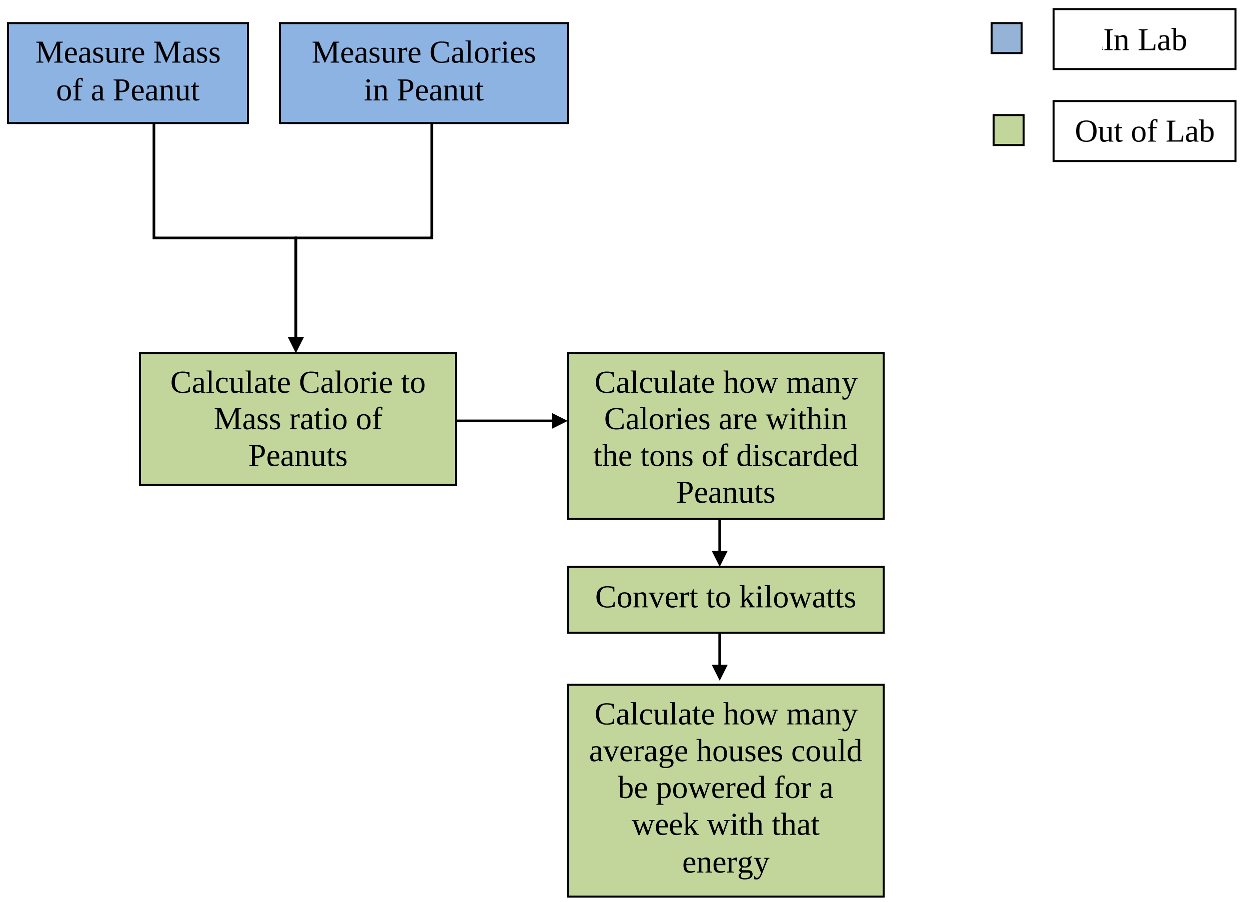
**Elaboration**:

- Students will be challenged to determine how much energy could be potentially extracted from the kilos of peanuts that were discarded by the peanut factory.
- In order to do this, students will have to go through a series of conversions to first determine how much energy in calories is in a mound (of a specified mass)
- Then, students will have to convert that amount of energy to a value in kilowatthours.
- Next, students will be asked to determine how many houses could be powered in the U.S. for a day



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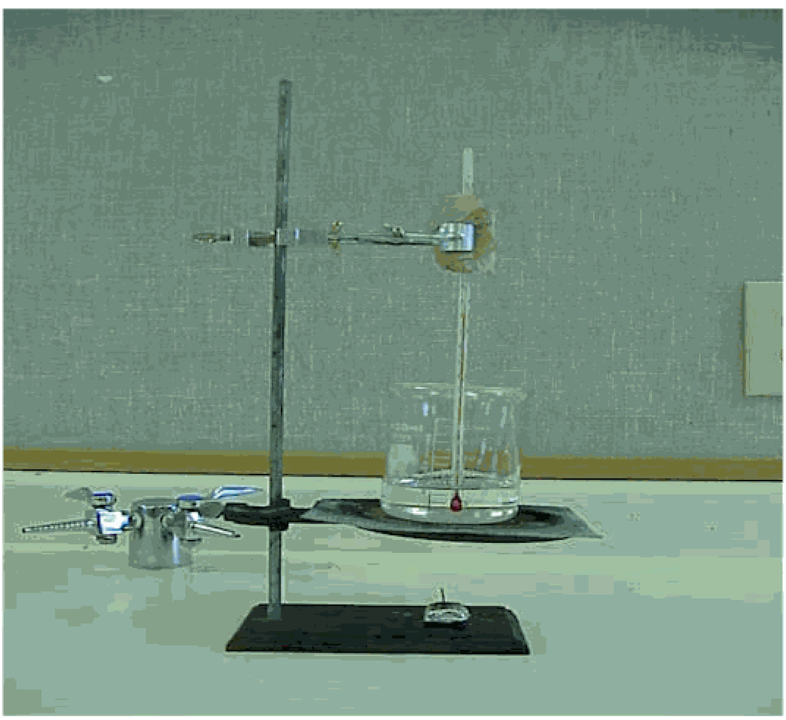
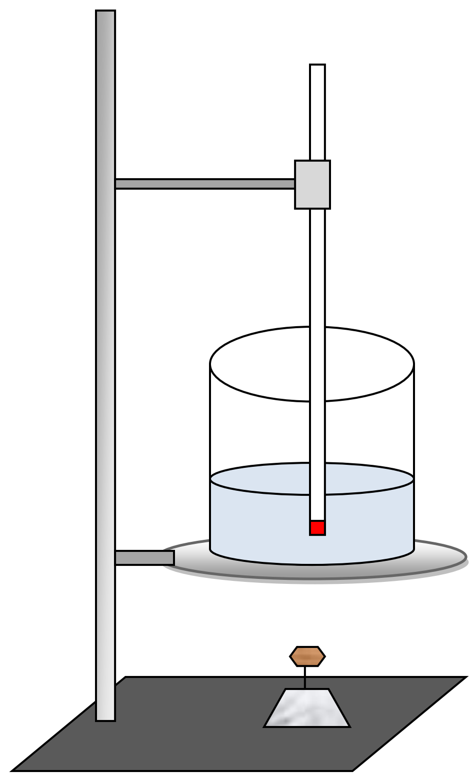
**TEACHER PAGE(S)**

- Create a group with 2 to 3 students. Your group will be given a peanut to conduct the experiment with
- On a properly tiered and calibrated analytical balance, you and your group will measure the **mass** (in grams) of their peanut to 3 decimal places.
  Peanut Mass (g): __0.600_______
- Next, set up the ring stand and calorimeter according to the diagram below. The thermometer should be positioned slightly above the bottom of the beaker. Approximately 25 mL of water should be used. Position the peanut and peanut holder so that it is centered under the beaker. Make sure that the beaker and ring stand heights are adjusted so they are close enough to the peanut to be heated bat far enough so that they are not in direct contact.





- Measure the temperature of the water before you ignite your sample peanut
  Water initial temperature (Celsius) _25.00___
- Use a Bunsen burner or gas torch to light the peanut. Your goal is to apply just enough flam so that the peanut can independently hold a flame but not so much that you burn the peanut. Wait for the peanut to fizzle out and then quickly record the final temperature of the water.
  Water final temperature (Celsius) _25.44___

**NOTE**: *Students should be given additional peanuts to measure if they finish quickly or fail to get ideal results from the experiment.*

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Due to the thermal heat capacity of water, it takes 1 calorie to raise 1 mL of water 1 degree Celsius. This energy in calories is equivalent to the calories stored in the peanut. How many calories were stored in that peanut? Show your work below.
____11_______ calories (not kilocalorie)

$Q=mc\Delta T$
Heat (calories) = mass of water (1mL = 1g) x specific heat (1 calorie/g degree Celsius) x change in temperature
Heat = 25g (water) x 1 calorie/g $^{o}$C x (25.44 $^{o}$C – 25.00 $^{o}$C) = 11 calories per peanut

Do you think your calculation is an over or under estimate? Why?

This calculation is an underestimate because a great deal of the heat potentially stored in the peanut escaped and was not used to heat the water. Our measurement of the energy in the peanut is based off of a secondary source, the water.

Now, using your mass measurement from before, calculate the ratio of calories/gram of peanut.
____18___ calories/gram of peanut

STOP! Proceed to next section when instructed

Elaborate:

How many calories are within 1.4 x $10^{10}$ kilograms of discarded factory peanuts?
__4.54 x $10^{14}$_ calories

(18 cal/g) x (1000 g / 1 kg) x (1.4 x $10^{10}$ kg) = 2.52 x $10^{14}$ cal

Convert the value above into Kilowatts (1kWh = 860,420.65 kilocalories)
__292,880 ___ kilowatts (kWh)

(2.52 x $10^{14}$ cal) x (1 Cal/ 1000 cal) x (1 kWh/ 860,420.65 Cal) = 292,880 kWh

The average U.S. home consumes 10,908 kilowatthours (kWh) per month. How many houses could be powered with the energy stored in the peanuts, for a day?
_805__ Houses

(10,908 kWh/ house*month) ÷ 30 days = (363.6 kWh/ house*day)
292,880 kWh ÷ (363.6 kWh/ house*day) x 1 day ≈ 805 houses

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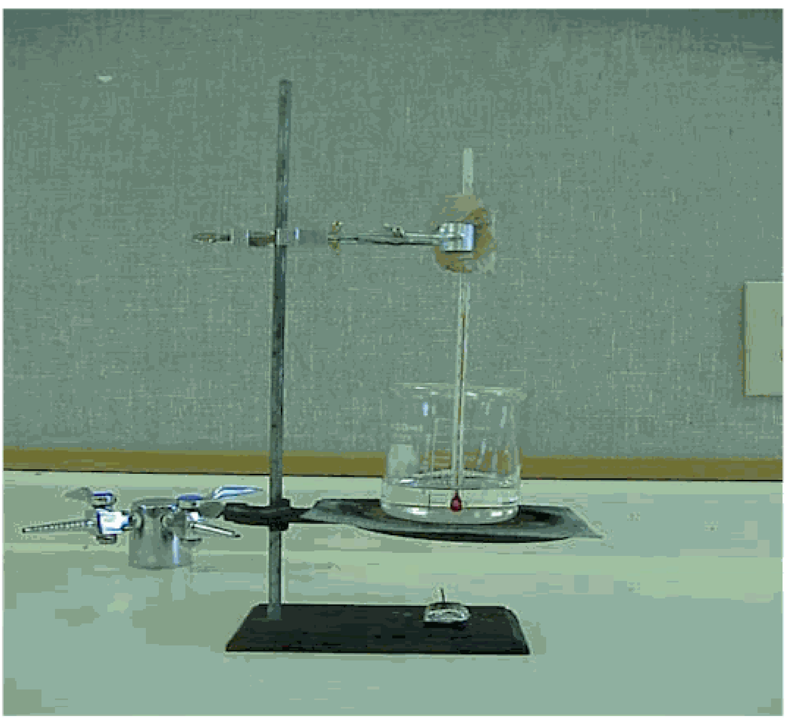
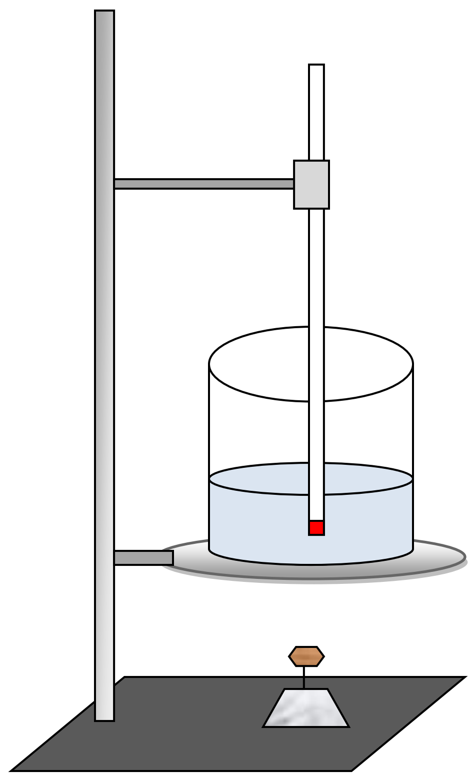
**STUDENT PAGE(S)**

- Create a group with 2 to 3 students. Your group will be given a peanut to conduct the experiment with
- On a properly tiered and calibrated analytical balance, you and your group will measure the **mass** (in grams) of their peanut to 3 decimal places.
  Peanut Mass (g): __________
- Next, set up the ring stand and calorimeter according to the diagram below. The thermometer should be positioned slightly above the bottom of the beaker. Approximately 25 mL of water should be used. Position the peanut and peanut holder so that it is centered under the beaker. Make sure that the beaker and ring stand heights are adjusted so they are close enough to the peanut to be heated bat far enough so that they are not in direct contact.





- Measure the temperature of the water before you ignite your sample peanut
  Water initial temperature (Celsius) _________
- Use a Bunsen burner or gas torch to light the peanut. Your goal is to apply just enough flam so that the peanut can independently hold a flame but not so much that you burn the peanut. Wait for the peanut to fizzle out and then quickly record the final temperature of the water.
  Water final temperature (Celsius) _________

**NOTE**: *Students should be given additional peanuts to measure if they finish quickly or fail to get ideal results from the experiment.*

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___________ calories (not kilocalorie)

Do you think your calculation is an over or under estimate? Why?

Now, using your mass measurement from before, calculate the ratio of calories/gram of peanut.
_______ calories/gram of peanut

**STOP! Proceed to next section when instructed**

**Elaborate**:

How many calories are within $1.4 \times 10^{10}$ kilograms of discarded factory peanuts?
________ calories

Convert the value above into Kilowatts (1kWh = 860,420.65 kilocalories)
________ kilowatts (kWh)

The average U.S. home consumes 10,908 kilowatthours (kWh) per month. How many houses could be powered with the energy stored in the peanuts, for a day?
________ Houses