Passage I

Nuclear reactors release enormous amounts of nuclear energy through controlled chain reactions. For this reason, nuclear power has been considered a source of abundant energy. Nuclear power, however, poses several problems, the most serious of which is the radioactive waste produced by the use of nuclear energy. The waste is very dangerous and remains so for thousands of years. How and where to dispose of this waste safely is a dilemma that has not been resolved. In 1987, the US Congress authorized the Department of Energy to study Yucca Mountain in the southern desert of Nevada as a place to bury the highly radioactive nuclear fuel rods from nuclear power plants.

Geologist 1

The most feasible and safe method for disposing of highly radioactive material is to store it underground. Yucca Mountain was chosen because the thick layer of volcanic rock under the mountain could keep the radioactive waste isolated for thousands of years. Other factors that make the Yucca mountain region a good disposal site candidate include its remote location and sparse population. Also, there is little rainfall in the area, thus reducing the likelihood of seepage into and out of the disposal area. While there is evidence of past volcanic activity, the last volcanic activity is thought to have occurred several hundred to several thousand years ago. Research conducted in 2002 suggested that the probability of volcanic activity occurring near the Yucca Mountain site during the next 10,000 years is between 1 in 1,000 and 1 in 10,000.

Geologist 2

Burial of radioactive waste is the best disposal method. Yucca Mountain, however, is not the best site because it is hydrologically and geologically active. Burial at this site poses the risk of radioactive materials leaking out and contaminating surrounding soil and ground water. If a leak did occur, ground water contamination would be a major problem. Many of the surrounding cities, including parts of Las Vegas, receive some of their water from the aquifers in the area. The area around Yucca Mountain has numerous faults and even a small volcano nearby. Any significant geological activity could disturb waste containers. If earthquakes or volcanic eruptions occurred, the radioactive material at the site could be carried to the surface, threatening the entire region.

Passage II

Many scientists believe that comets form in frigid temperatures at the edge of our solar system or beyond and consist of rocky material, dust, and water ice. This theory is called the dirty snowball theory. According to the dirty snowball theory, a comet is a dense nucleus, about 50 percent to 80 percent of which is water ice, surrounded by a cloud of diffuse material called a coma (see Figure 1). A few comets have highly elliptical orbits that bring them very close to the Sun. As comets approach within a few AU of the Sun (an AU or astronomical unit is equal to the mean distance between the Earth and the Sun or about 93 million miles), the surface of the nucleus heats up, and volatile materials boil off carrying along small solid particles that reflect sunlight. Comets develop long tails of luminous material extending for millions of miles from the comet head. The theory, which virtually all astronomers accepted for years, explained the "outgassing" of comets as the effect of heating by the Sun. When a comet moves closer to the Sun, ices in the nucleus "sublimate," or evaporate into space, simultaneously ejecting dusty material held within the ices.

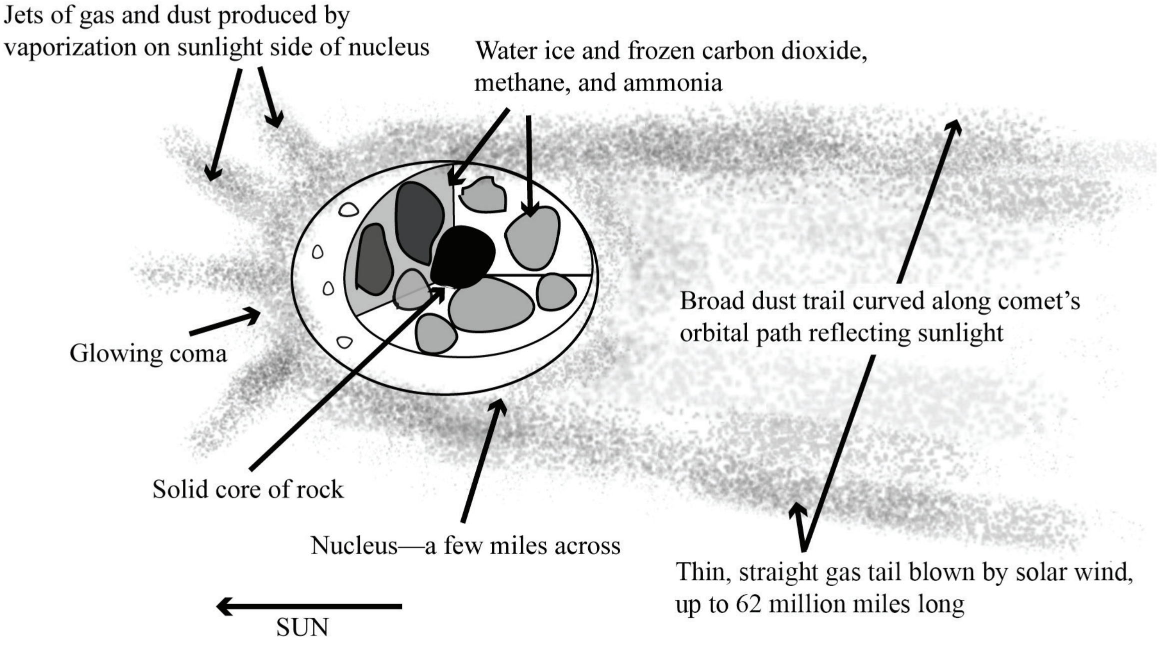

Figure 1

Scientist 1

In 1986, visits to Halley's Comet by the European *Giotto* and Russian *Vega* probes failed to locate surface water and raised the distinct possibility that the nucleus might not be ejecting water into space. In 2001, the *Deep Space 1* craft did a close flyby of the Comet Borrelly and detected no frozen water on the surface. Instead, a spectrum analysis suggests that the surface of the comet is dry. In 2004, the *Stardust* spacecraft passed by Comet Wild 2 and could not find even a trace of water on the surface. In 2005, the NASA *Deep Impact* mission found a smattering of water ice on the surface of comet Tempel 1. The problem is that, to account for the water supposedly being "exhaled" by Tempel 1, the investigators needed the comet to have 200 times more exposed water ice than was found. So far, it has not been possible to find very much ice in these so-called dirty snowballs.

Scientist 2

The dirty snowball model is still the best theory we have. It is not surprising that very little ice has been observed on the surfaces of comets. Readings are taken when the comets are in the inner solar system, where the Sun would have vaporized any water ices on the comet surface, leaving behind a crust of dark dust and rock particles. The majority of a comet's water ice is below the surface, and it is these reservoirs that feed the jets of vaporized water that form the coma.

Scientist 1

If a thin crust of dust hides the water below the surface of the nucleus, one would think that a newly formed crater would be exactly what was needed to stimulate the comet to produce water. In the case of Deep Impact and Comet Tempel 1, the probe crashed into the comet and removed many thousands of tons of material. Prior to impact, the calculated "water" output was 550 pounds per second; and not long after the impact, the calculated output was still 550 pounds per second. So despite the impressive explosion, the hypothesized sub-surface water was never observed.

Scientist 2

The scientific instruments used to study comets do not observe water directly. Instead, they detect the most abundant companion of cometary dust: the "hydroxyl" radical, OH. The coma's water has been broken down by the Sun's ultraviolet radiation, forming the hydroxyl radical along with atomic hydrogen and oxygen. The abundance of hydroxyl radical in a comet nucleus is a direct pointer to the abundance of water held by the nucleus.

Scientist 1

In their analysis of the coma, conventional astronomers begin with the assumption that water is evaporating in the heat of the Sun off the surface ices of the nucleus. They do not observe the water, but cite the effects of solar radiation on assumed water to account for the abundant hydroxyl radical in the coma. The hydroxyl radical is more likely the result of electrical activity. The role of electricity also explains the cometary coma, the spherical envelope around the nucleus. It could not be maintained by gravity because gravity is too weak. As the comet speeds around the Sun, the nucleus continues to hold in place the giant spherical cloud, up to 16 million miles or more in diameter.

Passage III

Relative humidity is a measure of how much water vapor is in the air relative to the total amount of water vapor that the air is capable of holding at a given temperature. Heat index is a combined measure of relative humidity and air temperature. The heat index provides a more accurate indication of the perceived—that is, felt—temperature than is provided by the air temperature alone.

A psychrometer is used to monitor heat index and consists of two traditional bulb thermometers: one “dry” and one “wet.” The dry-bulb thermometer indicates the ambient temperature (current air temperature without regard to humidity or wind). The wet-bulb thermometer is covered with a wet cloth, or wick, and is exposed to moving air for a period. The moisture from the wick evaporates and cools the bulb, lowering its temperature. Once both bulb temperatures are stable, the readings are recorded. A small difference between bulb temperatures—due to a low evaporation rate on the wet-bulb wick—indicates a high relative humidity. A large difference between bulb temperatures—due to a high evaporation rate on the wet-bulb wick—indicates low relative humidity.

To determine the measure of relative humidity, the intersection of the dry-bulb and wet-bulb temperatures is located on a psychrometric graph (Figure 2). Absolute humidity is the amount of water carried in the air, as measured in grams of water per kilogram of air. The ratio of the absolute humidity to the maximum amount of water that the air can hold gives the relative humidity, expressed as a percentage.

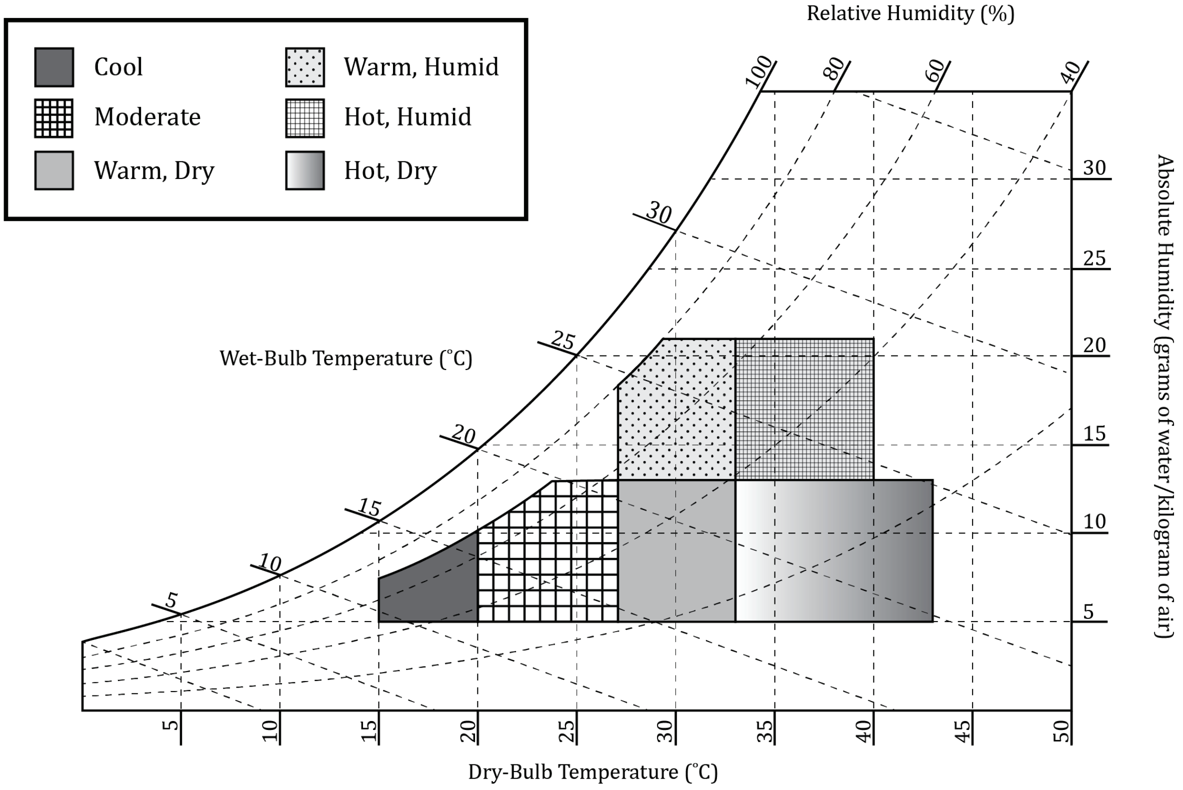

Figure 2

To determine the heat index, the intersection of the dry-bulb temperature and the relative humidity is located on a heat index graph (Figure 3). Certain ranges of heat indices correspond to warning level categories regarding sunstroke and heat exhaustion. There are four main warning levels as indicated in Table 1.

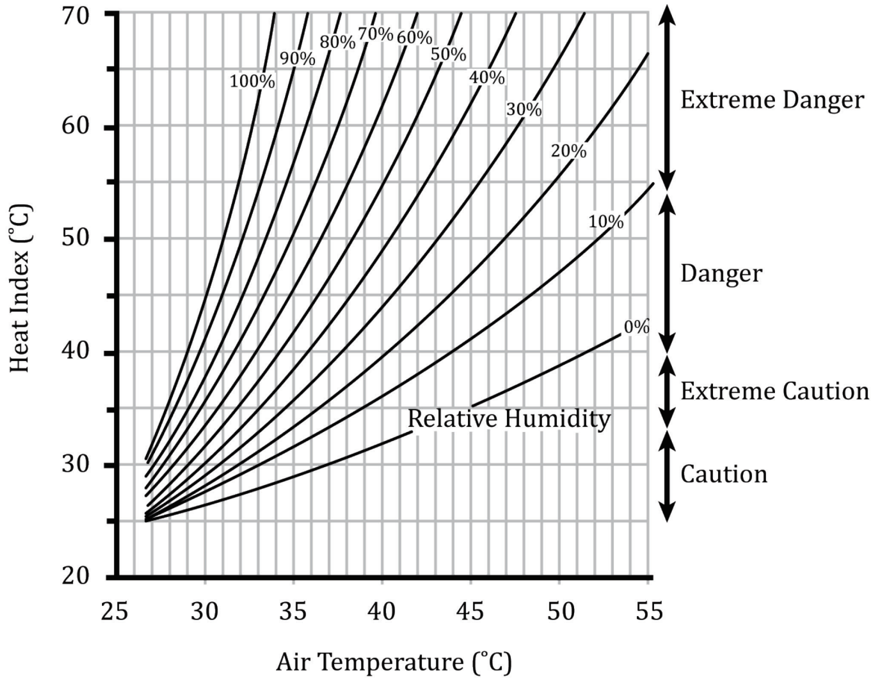

Figure 3

Table 1: Heat Index Warning Categories	
Caution	Fatigue is possible with prolonged exposure and/or physical activity.
Extreme Caution	Sunstroke, heat cramps, and heat exhaustion are possible with prolonged exposure and/or physical activity.
Danger	Sunstroke, heat cramps, and heat exhaustion are likely. Heatstroke is possible with prolonged exposure and/or physical activity.
Extreme Danger	Heatstroke/sunstroke is highly likely with continued exposure.

A group of students used a psychrometer to conduct dry- and wet-bulb measurements at several locations in and around their school. The results are summarized in Table 2.

Table 2: Experimental Measurements			
Measurement Location	Dry-Bulb Temperature (°C)	Wet-Bulb Temperature (°C)	Relative Humidity (%)
Classroom	23	13	30
Basement	16	11	50
Shower room	27	24	80
Greenhouse	32	26	60
Outdoors	30	27	80

Passage IV

A charged particle experiences a force when moving through a magnetic field. If a magnet is placed in the vicinity of a current-carrying wire of conducting material, the wire will experience a force due to the interaction between the magnetic field and the charged particles moving through the wire.

To study the interaction between a current-carrying wire and a magnetic field, a group of students conducted a series of experiments using a current balance (Figure 4), in which a current passing through a conducting loop of wire, or current loop, is acted on by the magnetic field produced by a permanent magnet. The current in the loop is produced using a variable power supply connected to the loop. The magnet, with a channel in its center, is placed on a digital electronic scale.

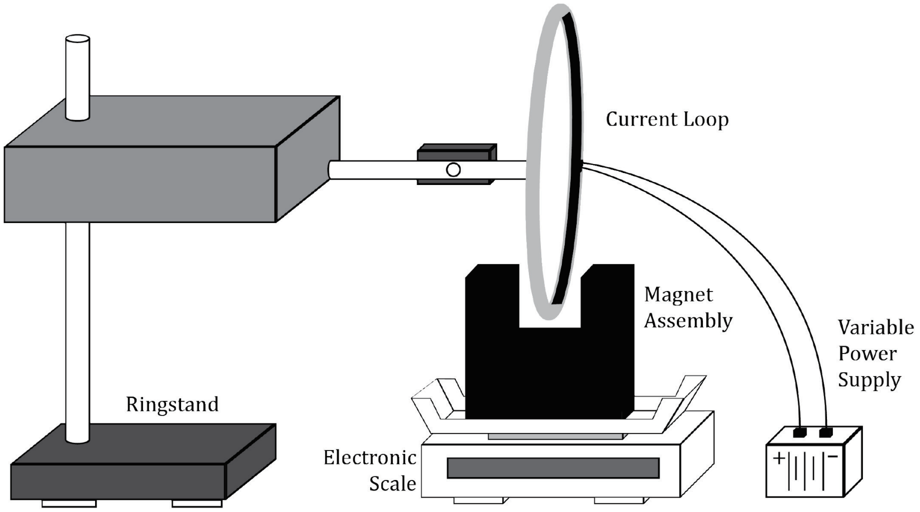

Figure 4

When lowered into the channel of the magnet, the current loop experiences a force due to the magnetic field produced by the magnet, as given by:

$$F = ILB \qquad \text{(Equation 1)}$$

where I is the current in the wire in amperes (A), L is the length of the current loop in meters (m), and B is the magnetic field strength in teslas (1 T = 1 kg/A/s^2). The standard unit of force is the newton (1 N = 1 kg • m/s^2).

Newton's third law of motion, or the law of action-reaction, states that the force on the current loop is equal to the force on the scale. According to Newton's second law of motion, the force on the scale is:

$$F = ma \qquad \text{(Equation 2)}$$

where m is the scale reading in kilograms (kg) and a is the acceleration due to gravity (9.8 m/s^2).

Experiment 1

To demonstrate how currents through the loop are affected by a magnetic force, the students applied different currents to a loop of length 2.4 cm. First, with the magnet in place and no current loop, the scale was zeroed so that scale readings with the current loop in the magnet channel correspond solely to the force acting on the current loop. Then the current loop was placed in the magnet channel without any part of the loop touching the magnet. The power supply was set to 0.5 A and the scale reading was recorded. This was repeated for increased current in steps of 0.5 A up to a maximum of 4.0 A. The students used Newton's second law of motion to calculate the force on the scale and thus the force on the current loop. The results are summarized in Table 3.

Table 3: Experiment 1 Data and Calculations			
Trial	Current, I (A)	Scale Reading, m (10^{-4} kg)	Force, F (10^{-2} N)
1	0.5	3.6	0.35
2	1.0	7.2	0.71
3	1.5	10.7	1.05
4	2.0	14.3	1.41
5	2.5	18.0	1.76
6	3.0	21.6	2.12
7	3.5	25.1	2.46
8	4.0	28.8	2.82

Experiment 2

To determine how the length of the current loop affects the magnetic force acting on it, Experiment 1 was repeated using four different current loop lengths: 1.2 cm, 2.4 cm, 3.6 cm, and 4.8 cm. The scale reading was recorded while 1.5 A of current was applied to each current loop length lowered into the magnet channel. The results are summarized in Table 4.

Table 4: Experiment 2 Data and Calculations			
Trial	Loop Length, L (10^{-2} m)	Scale Reading, m (10^{-4} kg)	Force, F (10^{-2} N)
1	1.2	5.4	0.53
2	2.4	10.7	1.05
3	3.6	15.9	1.56
4	4.8	21.6	2.12

Experiment 3

To determine how the strength of the magnetic field affects the magnetic force acting on the current loop, Experiment 1 was repeated using different numbers of parallel magnets. Each time a magnet was added, the scale was zeroed. For each magnet arrangement, the scale reading was recorded while 1.5 A of current was applied to a 2.4 cm loop lowered into the center magnet channel. The results are summarized in Table 5.

Table 5: Experiment 3 Data and Calculations			
Trial	Number of Magnets	Scale Reading, m (10^{-4} kg)	Force, F (10^{-2} N)
1	1	10.7	1.05
2	2	21.6	2.12
3	3	32.3	3.17
4	4	42.9	4.20

Passage V

The electrical resistance of a conductor represents its opposition to the flow of electrons and is defined by the relationship known as Ohm's law:

$$R = \frac{V}{I} \qquad \text{(Equation 3)}$$

where R is the conductor's resistance in ohms (Ω), V is the potential difference across the conductor, or voltage, measured in volts (V), and I is the electrical current applied to the conductor in amps (A). The material from which a conductor is made, the length of the conductor, the diameter of the conductor, and the temperature of the conductor are all things that impact its resistance.

Using a simple circuit (Figure 5), a group of students investigated the dependence of a conductor's electrical resistance on its length, material, and diameter. The ammeter measures the current produced by a variable power supply. The voltmeter measures the potential voltage across the conductor.

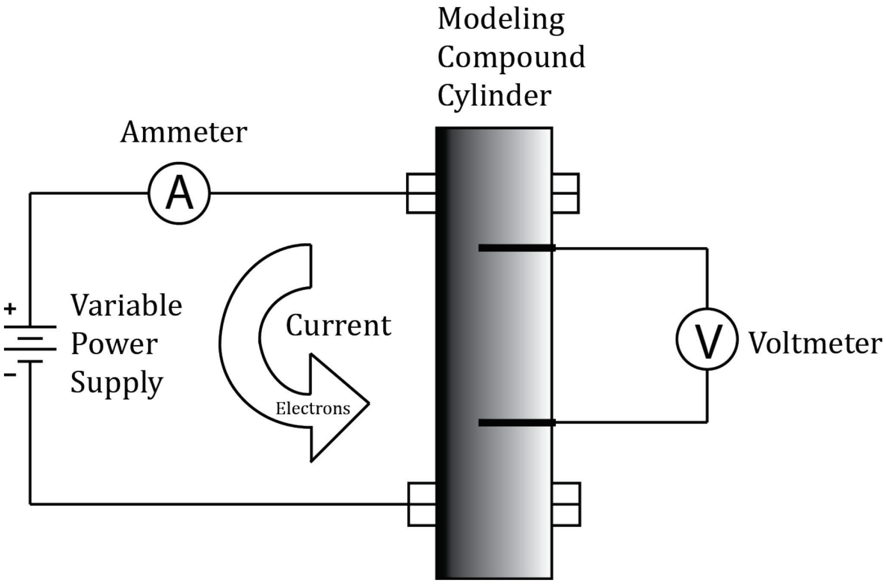

Figure 5

Experiment 1

To study the effect of a conductor's length on its resistance, the students used red modeling compound to make a cylinder 0.01 m in diameter and slightly longer than 0.1 m in length. The cylinder was connected to the circuit and a current of 0.04 A was applied. The voltmeter probes were inserted in the cylinder with a separation of 0.02 m and the voltage reading recorded. The separation distance between the probes is the conductor length. The separation was then increased by 0.02 m and the voltage recorded again. This was repeated until a total separation (conductor length) of 0.10 m was reached. The students calculated the resistance for each conductor length using Ohm's law. The results are summarized in Table 6.

Table 6: Experiment 1 Results			
Trial	Conductor Length (m)	Voltage, V (V)	Resistance, R (Ω)
1	0.02	1.58	39.5
2	0.04	3.15	78.8
3	0.06	4.79	119.8
4	0.08	6.34	158.5
5	0.10	8.10	202.5

Experiment 2

To study the effect of a conductor's material on resistance, the students repeated Experiment 1 for an identical cylinder made of blue modeling compound. The results are summarized in Table 7.

Table 7: Experiment 2 Results			
Trial	Conductor Length (m)	Voltage, V (V)	Resistance, R (Ω)
1	0.02	1.22	30.5
2	0.04	2.43	60.8
3	0.06	3.76	94.0
4	0.08	4.96	124.0
5	0.10	6.15	153.8

Experiment 3

To study the effect of a conductor's diameter on resistance, the students used red modeling compound to make three cylinders, each 0.12 m long and with diameters of 0.01 m, 0.02 m, and 0.03 m, respectively. Each cylinder was connected to the circuit with a voltmeter probe separation of 0.10 m and an applied current of 0.04 A. The resulting voltage reading was recorded for each cylinder diameter and the resistances calculated. The results are summarized in Table 8.

Table 8: Experiment 3 Results			
Trial	Conductor Diameter (m)	Voltage, V (V)	Resistance, R (Ω)
1	0.01	8.10	202.5
2	0.02	2.04	50.9
3	0.03	1.02	25.5