Name:			Date:
MISSION	**7**	$E=mc^2$	***Materials***

In Albert Einstein's famous 1905 equation $E=mc^2$, the speed of light, c, in meters per second is a very large number. If you square the speed of light, the product is huge. Multiply that times a small amount of mass and the amount of energy produced is hard to imagine. The equation seems as far-fetched as "Parallel Universes" from **Mission 5**.

You need:

- ❏ 6 or more Norland Calculator Robots
- ❏ 6 or more Graphing Calculators
- ❏ 1 2-3" Rubber Ball (Neutron)

Name:			Date:
MISSION	**7**	**E=mc²**	***Background & Instructions***

Background:

The speed of light in a vacuum is 299,792,458 meters per second. Use your graphing calculator to calculate what happens to the speed of light when it is "squared." You will get an answer in scientific notation. Write this number in standard form below.

Think of this as a conversion factor for changing mass into energy. If any mass is pushed back across the = sign and multiplied times the number above, the resulting energy can be enormous.

During the early stages of World War II, governments began to realize that the equation, $E=mc^2$, offered a potential to harness massive power in the form of a nuclear bomb. Because of this potential, individuals were asked to go to great lengths for their country and the common good. In efforts to prevent Nazi Germany from developing a nuclear device, a member of the Norwegian underground was asked to kill his fellow countrymen who were aboard a ferry carrying materials needed for the German nuclear effort. He did it, ultimately based on the potential of the equation above.

On August 6, 1945, the power of the equation was realized in the atomic bomb dropped on Hiroshima, Japan, by America. Neutrons were sent into the nucleus of an enriched uranium atom splitting it and releasing two neutrons that in turn struck other uranium atoms. In the resulting chain reaction, two became four, four split into eight, and so on until approximately 2^{80} atoms were split. Energy equivalent to 13-15 kilotons of TNT was released and temperatures in excess of 300,000°C (540,000°F) were produced.

Instructions:

Simulation of Nuclear Fission Chain Reactions

The following program is a progressive doubling program. The numbers, like atoms being split, will double before your eyes from 4 to 8 to 16 to a VERY LARGE number.

```
PROGRAM:ATOMSPLT
   :ClrHome
   :0->X
   :2->Y
   :Input "2*2^X:
   ",Z
   :Z-1->Z
   :Lbl A
   :Y*2->Y
   :X+1->X
   :Disp Y
   :If X<Z:GoTo A
```

Start the program and key in [2][0] (2^{20}) and press [ENTER], try [4][0], finally key in [8][0] (2^{80}) and press [ENTER]. You will get an answer in scientific notation. Round the decimal to the hundredth place and write this number in standard form below.

Write the program for a robot chain reaction, NEUTONB or NEUTONL. Half the robots need NEUTRONB and the other half need NEUTRONL. The programs can be written easily by first creating the program names and then recalling the **RELAY** program from Mission 6.

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From the new NEUTONB or NEUTONL program press y, then K. Press ç, then scroll over to **EXEC** and select **RELAY**. Press Í twice and the instructions from **RELAY** will be added to NEUTONB or NEUTONL. Edit the commands and times as necessary.

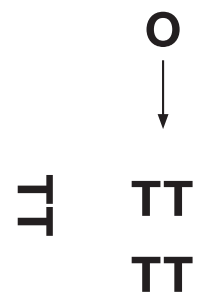
```
PROGRAM:NEUTRONB
    :Send({211})
    :Get(R)
    :Send({100,120})
    :Get(R)
    :Send({120,82})
    :Get(R)
    :Send({222})
    :Get(R)
```

In the program NEUTONB, the "B" is for back. After the bumper is hit, the robot backs up, turns around, and then heads the opposite direction until it hits other robots or some other object.

```
PROGRAM:NEUTRONL
    :Send({211})
    :Get(R)
    :Send({111,70})
    :Get(R)
    :Send({102,40})
    :Get(R)
    :Send({222})
    :Get(R)
```

In the program NEUTONL the "L" is for left. After the bumper is hit, the robot pauses, turns 90° left and then moves forward until it hits other robots or some other object.

Make an initial "uranium atom" by placing an "L" programmed robot to the left and wheel to wheel with a "B" programmed robot. This first pair of robots can be positioned with the bumper of the "B" robot touching and slightly behind the bumper of the "L" robot. Both robots will be activated when the bumper of the "L" robot is struck.
Set additional pairs of robots ("uranium atoms") about one foot apart with bumpers together and in position to be hit (split) by incoming single robots ("neutrons"). Add as many pair as you can. In the diagram below **TT** represents two robots together with bumpers touching and **O** is the rubber ball ("neutron bullet") coming in to start the chain reaction.



Roll the rubber ball ("neutron bullet") towards the "L" robot in your first robot pair and a chain reaction will start with energy being released as each pair (uranium atom) is split apart. One neutron becomes two, two becomes four and so on. As shown by the equation:

235U + 1 neutron -> 2 neutrons + 92Kr +142Ba + ENERGY

Different products like $_{92}$Kr and $_{142}$Ba can be produced in this reaction, but are not shown in this simulation.

Radioisotope Thermoelectric Generators

Radioactive elements, such as plutonium, decay according to $E=mc^2$. Mass is converted to energy and heat is given off. This heat can be used to make electricity. Radioisotope Thermoelectric Generators (RTGs) use bi-metallic thermocouples to convert heat to electricity. These types of generators have no moving parts and produce electricity for long periods of time, making them ideal for satellites and space probes.

Recent spacecrafts that have used RTGs include Cassini and New Horizons. There are RPGs on the Moon left by Apollo missions 12-17 to run scientific experiments. Units similar to RTGs, that just use the heat from radioisotope decay, keep the Mars Exploration Rovers warm on Mars.

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MISSION	**7**	**E=mc²**	***Questions***

1. Besides atomic weapons and RTGs, what are some other applications of nuclear decay, nuclear fission, and $E=mc^2$?

2. How does the equation $E=mc^2$ apply to the energy being generated by the sun?

3. If it were possible to change a one kilogram textbook (mass) completely into energy, it would produce enough electricity to light 47,000 60-watt light bulbs for one year. In metric energy units this equivalent to 90,000,000,000,000,000 joules. Write this number in scientific notation and explain why scientific notation is useful.

"Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world."
—Einstein

4. On a separate sheet of paper, make up your own famous equation (like $E=mc^2$) that will change the way we view the universe. Explain the meaning of each part of the equation and how understanding the equation will benefit the world.

How to create a spectacular chain reaction demonstration using ping-pong balls can be found at: *http://www.ap.stmarys.ca/demos/content/modern/mousetrap_reactor/mousetrap_reactor.html*

ThinkQuest's Nuclear Processes home site has links to student level information on this topic: *http://library.thinkquest.org/17940/index.html*

Book reference: *$E=mc^2$: A Biography of the World's Most Famous Equation*, by David Bodanis. For more information on the Norwegian Resistance and Germany's nuclear efforts during World War II see: *http://www.pbs.org/wgbh/nova/hydro/*

For more information on Radioisotope Thermoelectric Generators see: *http://en.wikipedia.org/wiki/Radioisotopic_Thermoelectric_Generator*

In standard form, $299{,}792{,}458^2$ equals:
89,875,517,870,000,000
With the scientific notation decimal rounded to the second places, 2^{80} in standard form equals:
1,210,000,000,000,000,000,000,000.

For **question 1**, other applications of $E=mc^2$ include: nuclear submarines, nuclear power plants, smoke detectors with radioactive americium inside, red-glowing emergency exit signs with radioactive tritium inside, some medical diagnostic devices, radiation treatment of cancer, carbon-14 dating, and our sun. See pages 192-194 in Bodanis' book.

For **question 2**, the energy produced by the sun makes our planet habitable. This energy is produce by nuclear fusion where hydrogen atoms are combined to make helium. Also see nuclear fusion at the ThinkQuest Web site.

For **question 3**, in scientific notation 90,000,000,000,000,000 equals 9.0×10^{16}.

For **question 4**, answers will vary.