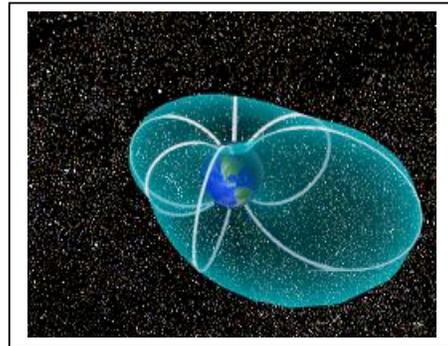
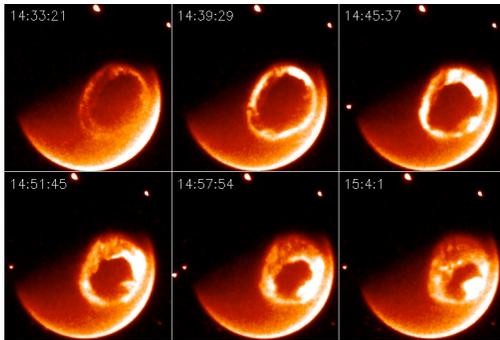


# Adventures in Space Science Mathematics



A collection of mathematics and reading activities for *Grades 7-9* that explore the Sun-Earth System.

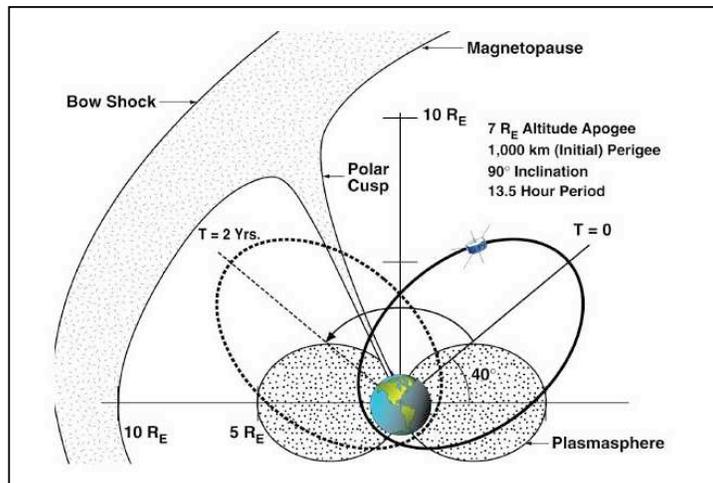
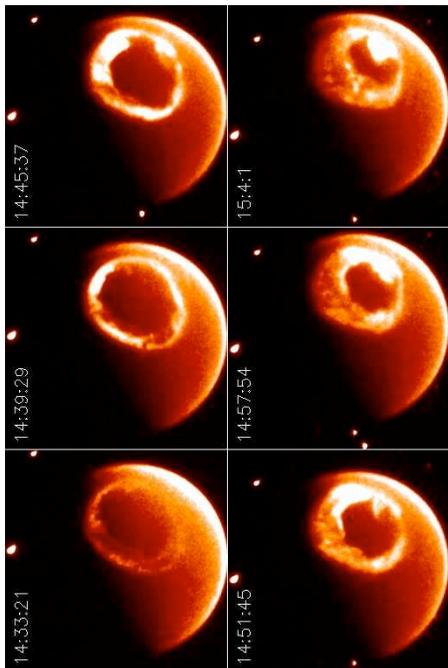
This series of math activities will help students understand some of the real-life applications of mathematics in the study of the Sun and Earth as a system. Through math and reading activities, students will learn:

- How to search for trends and correlations in data
- How to extract the average, maximum and minimum from data
- How to use scientific notation to work with very large and small numbers
- How to use a scale drawing to estimate the sizes of an aurora
- How to use the Pythagorean Theorem to calculate magnetic field strength
- How to use simple equations to convert raw data into physical quantities

This booklet was created by the NASA, IMAGE satellite program's Education and Public Outreach Project.

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A series of images (left) of the Northern Lights from space taken by the IMAGE satellite. The satellite orbits Earth in an elliptical path (above), which takes it into many different regions of Earth's environment in space.

For more classroom activities about aurora and space weather, visit the **IMAGE** website at:

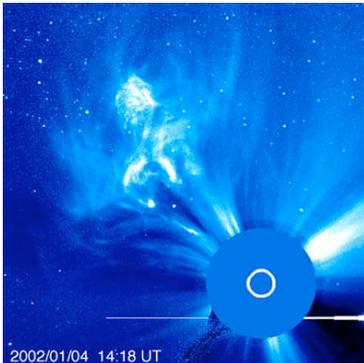
<http://image.gsfc.nasa.gov/poetry>

## Introduction



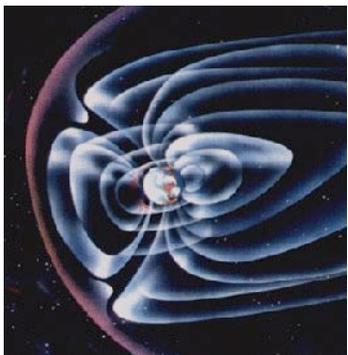
We live next to a very stormy star, the Sun, but you would hardly notice anything unusual most of the time. Its constant sunshine hides spectacular changes. But unless you lived in the Arctic and Antarctic regions of Earth, you would have no clue. Only the dazzling glow of the Northern Lights suggests that invisible forces are clashing in space. These forces may cause all kinds of problems for us, and our expensive technology (Activity 1). It doesn't take long for a 'solar storm' to get here, either. Once they arrive, that change Earth's magnetic field (Activity 2), and these lead to the displays of the aurora which humans have marveled at for thousands of years. Aurora light up the sky with billions of watts of power (Activity 3) and cover millions of square kilometers (Activity 4). Why does all this happen? (Photo- Auroral curtain by Jan Curtis)

## Space Weather



It has to do with Earth's magnetic field and how it is disturbed by solar storms and the solar wind. The wind carries its own magnetic field with it (Activity 5), and travels at speeds of millions of kilometers per hour (Activity 6). Scientists keep track of this interplanetary storminess using numbers that follow its ups and downs (Activity 7) just like meteorologists follow a storm's speed, pressure and humidity. Periods of increased and decreased solar activity (Activity 8) come and go every 11 years. Solar flares also have their own story to tell (Activity 9) just like flashes of lightning in a bad storm. (Photo - Coronal Mass Ejection seen by SOHO satellite)

## Models and Forecasting



Scientists have to keep track of many different kinds of phenomena in the universe, both big and small. That's why they have invented a way to write very big and very small numbers using 'scientific notation (Activity 10, 11, 12). They also have to master how to think in three-dimensions (Activity 13) and how to use mathematical models (Activity 14). Once they find the right models, they can use them to make better predictions (Activity 15) of when the next solar storm will arrive here at Earth, and what it will do when it gets here! (Sketch of Earth's magnetic field)



## Hey! Who Turned Out the Lights?

Astronomers were busily tracking "Active Region 5395" on the Sun when suddenly it blasted-out a huge cloud of super-hot gas on March 10, 1989. Three days later, and seemingly unrelated to the solar blow-out, people around the world saw a spectacular, and entertaining, Northern Lights display. The distant solar storm 93 million miles away had silently set in motion a chain of events reaching from the Sun's fiery surface to the skies overhead. Most newspapers that reported this event thought that the spectacular aurora was the most newsworthy aspect of the storm. Seen as far south as Florida and Cuba, the most people in the Northern Hemisphere had never seen the Northern Lights dancing in their evening skies. But this particular explosion of matter and energy did much more than just dazzle and confuse the casual sky watcher as it painted the heavens with shifting colors and shapes.

At 2:45 AM on March 13, electrical currents created by the impact of this storm found their way into the electrical circuitry of the Hydro-Quebec Power Authority. Giant capacitors tried to regulate these currents but failed within a few seconds as automatic protective systems took them off-line one by one. Suddenly, the entire 9,500 megawatt output from Hydro-Quebec's La Grande Hydroelectric Complex began to waver. Power swings tripped the supply lines from the 2,000 megawatt Churchill Falls generation complex, and 18 seconds later, the entire Quebec power grid collapsed. The cascading of events lasted barely 97 seconds. It was much too fast for human operators to react, but it was more than enough time for 21,500 megawatts of badly needed electrical power to suddenly disappear from service.

For nine hours, large portions of Quebec were plunged into darkness. A thousand miles away, even Maryland, Virginia and Pennsylvania were affected as half of the capacitors in the Allegheny Power System went off-line. In many ways, it was a sanitized calamity. It was wrapped in a diversion of beautiful colors, and affected a distant population mostly while they slept. There were no houses torn apart, or streets flooded from powerful hurricanes. There was no dramatic TV News footage of waves crashing against the beach. There were no tornadoes cutting a swath of destruction through Kansas trailer parks.

The calamity passed without mention in the major metropolitan newspapers, yet six million people were affected as they awoke to find no electricity to see them through a cold Quebec wintry night. Some engineers from the major North American power companies were not so calm. They worried how this Quebec blackout could easily have escalated into a \$6 billion catastrophe affecting most US East Coast cities. All that prevented 50 million people in the US from joining their Canadian friends in the dark were a few dozen heroic capacitors on the Allegheny Power Network. *(Excerpted from the book "The 23rd Cycle". Author: Dr. Sten Odenwald)*

- 1. If the solar storm took 3 days to travel 150 million kilometers to Earth, how fast was it traveling in kilometers per hour?**
- 2. How much time elapsed between the arrival of the storm at Earth, and the time when the Quebec power system failed?**
- 3. How long did the blackout continue?**
- 4. What kinds of severe problems could occur in a typical city during a blackout in the daytime? In the nighttime?**

Space Weather: <http://image.gsfc.nasa.gov/poetry/weather01.html>

## A Solar Storm Timeline

Scientists using the NASA's IMAGE satellite have been studying how the Earth's environment changes during a solar storm. This environment is filled with invisible clouds of gas. It is a bit of a mystery how these clouds are created by solar storms which pass by Earth.

This activity uses satellite data to study a solar storm and its impact on Earth's environment in space.

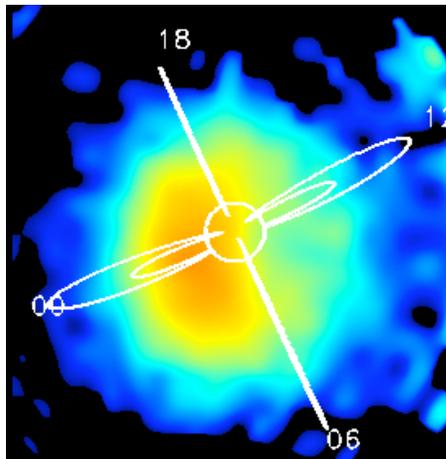


IMAGE spots a plasma storm near Earth.

**Scientists construct a timeline to investigate how natural phenomena change in time. This is often the first step in identifying their causes.**

➤ Drawing conclusions from

Now you try!

### Here's how to do it!

15:21 A solar flare erupts on the Sun

15:30 A disturbance is detected on Earth

How many minutes later was the Earth disturbance witnessed after the flare erupted?

$$\begin{array}{r}
 15\text{hours } 30\text{minutes} \\
 - 15\text{hours } 21\text{minutes} \\
 \hline
 9 \text{ minutes later.}
 \end{array}$$

### Solar Storm Timeline

Day	Time	What Happened
Tuesday	4:50 PM	Gas eruption on Sun
Thursday	3:36 AM	Plasma storm reaches Earth.
Thursday	5:20 AM	Storm at maximum intensity.
Thursday	5:35 AM	Auroral power at maximum.
Thursday	11:29 AM	Aurora power at minimum.
Thursday	2:45 PM	Space conditions normal

1) How much time passed between the solar gas eruption and its detection near Earth?

2) How long after the plasma storm reached Earth did the aurora reach their maximum power?

3) How long did the storm last near Earth from the time the plasma was detected, to the time when space conditions returned to normal?

□ **Extra for Experts!**

If the Earth is 150 million kilometers from the sun, how fast did the storm travel from the Sun in kilometers per hour?

Space Weather: <http://image.gsfc.nasa.gov/poetry/weather01.html>

## Aurora Power!

Scientists use decimal numbers a lot when measuring objects or processes! This activity uses data from the National Oceanic and Atmospheric Administration (NOAA) POES satellite to compare the Northern Lights displays in terms of how many watts of energy they produce.

**Note: A kilowatt is one thousand watts, but a gigawatt is one billion watts! A kilowatt of electricity can run a small house, but a gigawatt can run a small city.**



*Auroras are very common to see in northern regions of Canada and Alaska. They light up the skies in swirling color.*

**Scientists make measurements that are usually expressed in decimal form.**

- Applied decimal arithmetic: addition, subtraction and division

**Now you try!**

### Aurora Power

Date	Power
4-11-01	528.1
4-18-01	828.3
11-24-01	497.7
2-18-00	17.6
8-27-01	96.5
11-6-01	484.7
5-23-02	387.3
2-5-02	244.8
9-4-02	580.2

#### Here's how to do it!

How much more powerful was an aurora with 987.45 gigawatts, than an aurora with 324.98 gigawatts?

$$\begin{array}{r}
 987.45 \text{ gigawatts} \\
 - 324.98 \text{ gigawatts} \\
 \hline
 662.47 \text{ gigawatts}
 \end{array}$$

This table lists some major storms detected by the NOAA POES satellite, and the total power that they produced in gigawatts (Gw). Use this table to answer the questions below.

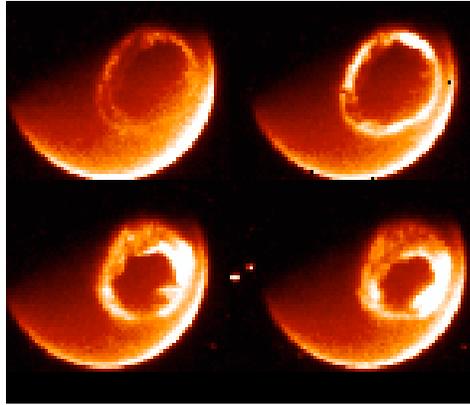
- 1) What was the difference in power between the strongest and weakest aurora detected?
- 2) If 48 storms like the one on February 18, 2000 were combined, how much different would they be than the power from the strongest storm in the table?
- 3) What is the sum of the power for all nine storms?
- 4) How many times more powerful was the April 18, 2001 storm than the storm detected on August 27, 2001?

Aurora: <http://image.gsfc.nasa.gov/poetry/educator/Qaurora.html>

# How big is an aurora?

The IMAGE satellite orbits Earth, and has a camera that can view the Northern and Southern Lights from space. As the solar activity level increases and decreases, the size of the aurora increases and decreases.

This activity will let you use data from this satellite to measure the diameter of the Auroral Oval and its changes during a solar storm event.



The ring of Northern Lights from space.

**Scientists use satellites to study phenomena that are too vast to be studied from the ground.**

➤ Photographs can be used to measure the size of an object.

Now you try!

### Here's how to do it!

1. With a ruler, measure the diameter of the Earth's disk in millimeters in the illustration. (Answer: About 30 mm)
2. The diameter of the Earth in this image is 13,000 kilometers, so the scale of the image is  $(13000 \text{ km}) / (30 \text{ mm}) = 433 \text{ kilometers/mm}$ .
3. The diameter of the Oval is about 15 mm, so using the image scale, the diameter of the Oval is:

$$15 \times 433 = 6,500 \text{ kilometers}$$



This photograph is from the IMAGE 'Far-Ultraviolet Imager' instrument obtained on July 14, 2000. It shows the size of the auroral oval during a severe solar storm.

1) Estimate the inside and outside diameters of the auroral oval.

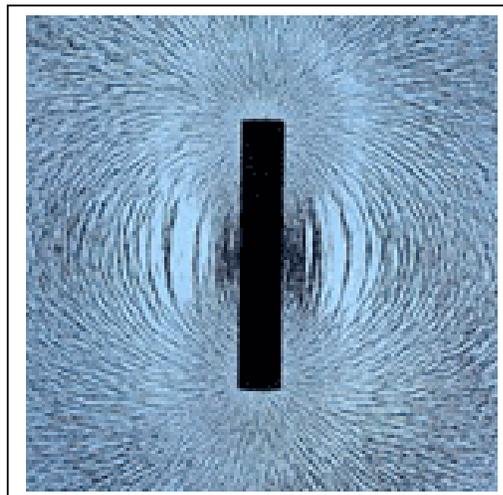
2) Calculate the oval's area in millions of square kilometers.

Aurora: <http://image.gsfc.nasa.gov/poetry/educator/Qaurora.html>

## Solar magnetism!

When a solar storm travels through space, it carries part of the Sun's magnetic field with it. The Advanced Composition Explorer (ACE) satellite measures the strength of this field and its polarity (North or South). This polarity information is recorded as a negative (south) or a positive (north) number.

In this exercise, you will learn how to work with negative and positive numbers.



The magnetic field of a toy magnet.

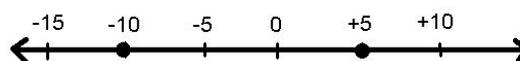
**The sign of a number (+ or -) is used by scientists to record information about magnetic polarity (North or South) or the direction of motion (forward or backward).**

- Negative and positive numbers can be understood by using a number line.

Now you try!

### Here's how to do it!

The ACE satellite measures the solar wind magnetic field on two days and records the value -10.0 on Monday, and +5.0 on Tuesday. By how much did the magnetic field change between the two days?



Answer:  $(+5) - (-10.0) = +15.0$

Draw a number line, and plot the following points. Then answer the questions.

### Solar Wind Magnetism Data Series

-15, +5, -2, -15, -20, -8, +4,  
+8, +5, +2, +5, -15, +6

- What is the range of the measurements?
- What is the smallest value recorded?
- What is the largest value recorded?
- What is the median value recorded?
- What is the average value recorded?

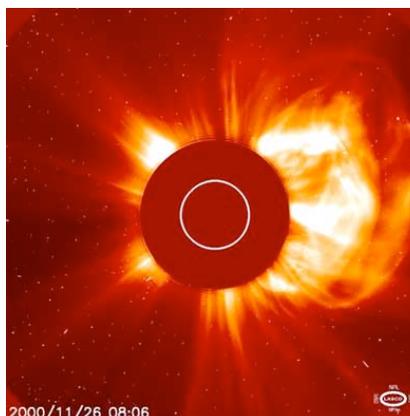
Solar Magnetism:

<http://sunearth.gsfc.nasa.gov/sechtml/tut.html>

## Solar storm speeds

The sun often ejects clouds of gases into space. Some of these fast-moving clouds can be directed at Earth. Astronomers call them Coronal Mass Ejections (or CMEs). When these CMEs arrive, they can cause spectacular aurora, damage satellites, or cause electrical blackouts.

In this exercise, you will learn how scientists use the speeds of these clouds to predict when they will arrive at Earth.



The Sun ejects clouds of gas into space carrying billions of tons of matter.

**Scientists need to know how fast things move in order to study where they come from and what causes them.**

- The speed of an object is defined as the distance it travels divided by the time it takes.

**Now you try!**

### Here's how to do it!

The ACE satellite measures the speed of the solar wind and clouds of gas from the Sun. Its sensor detects a cloud moving at 980 kilometers per second. How long will it take for it to travel from the spacecraft to Earth, if the distance is 1.5 million kilometers?

$$\begin{aligned} \text{Answer: Time} &= (1,500,000 \text{ km}) / (980 \text{ km/sec}) \\ &= 1,530 \text{ seconds} \end{aligned}$$

### Cloud Speeds

Date	Speed
5-10-02	423.0
5-18-02	497.0
5-23-02	897.0
7-12-02	548.0
7-20-02	931.0
7-23-02	516.0
9-19-02	756.0
1-11-02	647.0
1-19-02	455.0
3-05-02	705.0
3-18-02	480.0
3-29-02	379.0
4-01-02	795.0
8-10-02	469.0

The table shows cloud speeds measured in kilometers per second. Assume that the clouds detected by the ACE satellite were the CMEs produced on the Sun.

- 1) What was the fastest speed measured?
- 2) What was the slowest speed measured?
- 3) What was the average speed measured?
- 4) What is the fastest speed in miles per hour?
- 5) If the Sun is 150 million kilometers from Earth, how many hours would it take the fastest and the slowest CMEs to reach Earth?

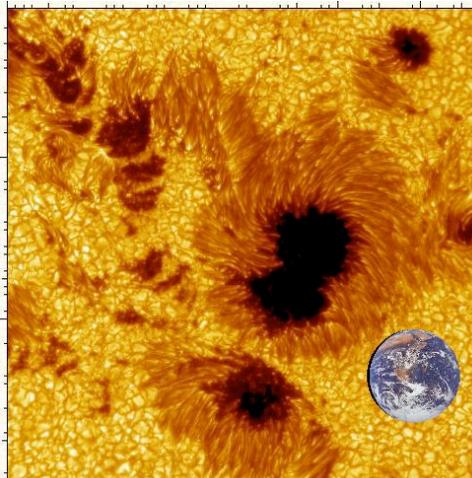
More about CMEs:

<http://sunearth.gsfc.nasa.gov/sechtml/litho5.html>

## Space weather indicators

Sunspots are a sign that the Sun is in a stormy state. Sometimes these storms can affect Earth and cause all kinds of problems such as satellite damage and electrical power outages. They can even harm astronauts working in space.

Scientists use many different kinds of measurements to track this stormy activity. In this exercise, you will learn how to use some of them!



This sunspot is as big as Earth!

**Looking at sequences of numbers can help you identify unusual events that depart from the average trend.**

- Every sequence can be defined by its largest, smallest and average values.

**Now you try!**

### Here's how to do it!

An astronomer counts sunspots for 5 days and gets the following sequence:

149, 136, 198, 152, 145

Maximum = 198

Minimum = 136

Mean =  $(149+136+198+152+145)/5 = 156$

Median = 149

Find the maximum, minimum, mean and median of each sequence.

1) Number of Sunspots

241	240	243	229	268	335	342	401	325	290	276	232	214
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

2) Number of Solar Flares

5	7	13	8	9	14	9	13	16	6	14	15
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3) Aurora Power (measured in billions of watts!)

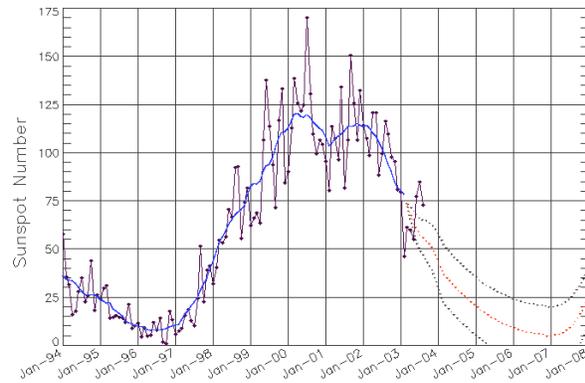
171.2	122.2	219.4	107.9	86.2	112.4	76.2	39.8	153.9
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More about sunspots: <http://image.gsfc.nasa.gov/poetry/educator/Sun1012.html>



The Sun is an active star that goes through cycles of high and low activity. Scientists mark these changes by counting sunspots. The numbers of spots increase and decrease about every 11 years in what scientists call the Sunspot Cycle.

This activity will let you investigate how many years typically elapse between the sunspot cycles. Is the cycle really, exactly 11-years long?



The sunspot cycle between 1994 and 2008

**Scientists study many phenomena that run in cycles. The Sun provides a number of such 'natural rhythms' in the solar system.**

- Sequences of numbers often have maximum and minimum values that re-occur periodically.

### Here's how to do it!

Consider the following measurements taken every 5 minutes:

100, 200, 300, 200, 100, 200, 300, 200

1. There are two maxima (value '300').
2. The maxima are separated by 4 intervals.
3. The cycle has a period of  $4 \times 5 = 20$  minutes.
4. The pairs of minima (value = 100) are also separated by this same period of time.

## Now you try!

### Sunspot Numbers

Solar Maximum | Solar Minimum

Year	Number	Year	Number
2000	125	1996	9
1990	146	1986	14
1980	154	1976	13
1969	106	1964	10
1957	190	1954	4
1947	152	1944	10
1937	114	1933	6
1928	78	1923	6
1917	104	1913	1
1905	63	1901	3
1893	85	1889	6
1883	64	1879	3
1870	170	1867	7

This table gives the sunspot numbers for pairs of maximums and minimums in the sunspot cycle.

1) From the solar maximum data, calculate the number of years between each pair of maxima.

2) From the solar minimum data, calculate the number of years between each pair of minima.

3) What is the average time between solar maxima?

4) What is the average time between solar minima?

5) Combining the answers to #3 and #4, what is the average sunspot cycle length?

More about sunspot cycles: <http://image.gsfc.nasa.gov/poetry/educator/Sun79.html>

## Solar flares

Solar flares are powerful explosions of energy and matter from the Sun's surface. One explosion, lasting only a few minutes, could power the entire United States for a full year. Astronauts have to be protected from solar flares because the most powerful ones can kill an astronaut if they were working outside their spacecraft.

In this exercise, you will learn how scientists classify flares, and how to decode them.

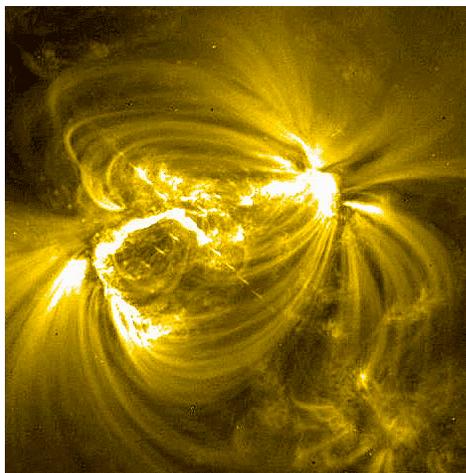


Image of Sun showing flare-like eruption.

**Scientists create alphabetic and numerical scales to classify phenomena, and to assign names to specific events.**

- Simple equations can serve as codes.

Now you try!

### Here's how to do it!

A solar flare scale uses three multipliers defined by the letter codes C = 1.0, M=10.0, X=1000.0.

- A solar flare might be classified as M5.8 which means a brightness of  $(10.0) \times (5.8) = 58.0$ .
- A second solar flare might be classified as X15.6 which means  $(1000.0) \times (15.6) = 15,600.0$

The X15.6 flare is  $(15,600/58) = 269$  times brighter than the M5.8 flare.

The GEOS satellite has an X-ray monitor that records daily solar flare activity. The table below shows the flares detected between January 11 and March 3, 2000.

Flare Codes for Major Events

Date	Code	Date	Code
1-11	M1.5	2-12	M1.7
1-12	M2.8	2-17	M2.5
1-18	M3.9	2-18	C2.7
1-22	M1.0	2-20	M2.4
1-24	C5.3	2-21	M1.8
1-25	C6.8	2-22	M1.2
2-3	C8.4	2-23	C6.8
2-4	M3.0	2-24	M1.1
2-5	X1.2	2-26	M1.0
2-6	C2.4	3-1	C6.9
2-8	M1.3	3-2	X1.1

1) What was the brightest flare detected during this time?

2) What was the faintest flare detected during this time?

3) How much brighter was the brightest flare than the faintest flare?

4) What percentage of the flares were brighter than M1.0?

More about sunspot cycles: <http://image.gsfc.nasa.gov/poetry/educator/Sun79.html>

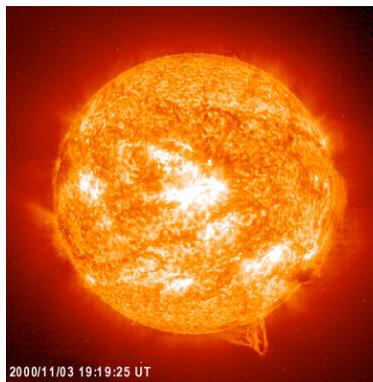


## Scientific notation II

Physicists and astronomers almost always use very small or very large numbers in the calculations or measurements.

Scientific notation is the best, and most compact, way to work with very large and small numbers.

This activity will review how to divide numbers in this form.



$$\text{Density of Sun} = \frac{1.9 \times 10^{33} \text{ grams}}{1.38 \times 10^{33} \text{ cubic cm}}$$

**Scientific Notation simplifies calculations with large or small numbers.**

- Scientific Notation provides an easy means to divide large and small numbers together.

**Now you try!**

### Here's how to do it!

State the problem:  $7.5 \times 10^{-11} / 4.5 \times 10^{+20}$

Group the factors:  $(7.5 / 4.5) \times (10^{-11} / 10^{+20})$

Subtract the exponents:  $1.67 \times 10^{(-11 - (+20))}$

Answer:  $1.67 \times 10^{-31}$

Perform these divisions using scientific notation.

1) Density of a star in grams/cc:

$$2.1 \times 10^{33} / 3.1 \times 10^{32}$$

2) Speed of solar wind in km/sec:

$$1.47 \times 10^8 / 2.7 \times 10^5$$

3) Density of a proton in grams/cc:

$$1.64 \times 10^{-24} / 3.7 \times 10^{-38}$$

4) Speed of Sun around Milky Way in centimeters/second :

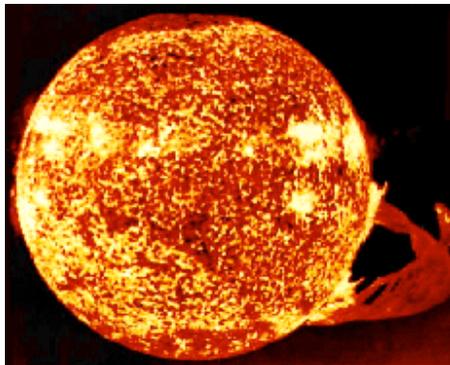
$$2.7 \times 10^{23} / 6.3 \times 10^{15}$$

## Scientific notation III

Physicists and astronomers almost always use very small or very large numbers in the calculations or measurements.

Scientific notation is the best, and most compact, way to work with very large and small numbers.

This activity will review how to multiply numbers in this form.



Surface area of the Sun =  $4 \times (3.141) \times (6.97 \times 10^5)^2$  square kilometers

*Scientific notation simplifies calculations with large or small numbers.*

- Scientific Notation provides an easy means to multiply large and small numbers together.

Now you try!

### Here's how to do it!

State Problem:  $1.5 \times 10^{-11} \times 4.5 \times 10^{+20}$   
 Group the factors:  $(1.5 \times 4.5) \times (10^{-11} \times 10^{+20})$   
 Add the exponents:  $6.75 \times 10^{(-11+20)}$   
 Answer:  $6.75 \times 10^9$

Multiply these numbers using scientific notation.

1) Energy in ergs of Sun in 1 year:

$$4.1 \times 10^{33} \times 3.1 \times 10^7$$

2) Number of seconds in 1 year:

$$8.6 \times 10^4 \times 3.65 \times 10^2$$

3) Centimeters in 1 light year:

$$6.32 \times 10^4 \times 1.47 \times 10^{11}$$

4) Mass of a large star in grams:

$$1.64 \times 10^{-24} \times 3.5 \times 10^{57}$$

5) Number of stars in the visible universe:

$$2.5 \times 10^{11} \times 7.5 \times 10^{10}$$

In the Cartesian 'X-Y' coordinate system, a pair of 2 numbers (x, y) define the address of a point on the plane. Because we live in a 3-dimensional world, a third number needs to be added to define a point (x, y, z). Many physical quantities are represented in this way.

This activity will let you use data from NASA's ACE satellite to calculate the strength of the solar wind's magnetic field using the Pythagorean Theorem.



A perspective drawing of Earth's 3-dimensional magnetic field.

**Scientists represent many physical quantities by triplets of numbers which form the sides of a 3-dimensional triangle in space.**

- A simple extension of the Pythagorean Theorem lets you calculate 3-dimensional quantities. Here's what it looks like:

$$W^2 = X^2 + Y^2 + Z^2$$

Now you try!

**Here's how to do it!**

A scientist measures the three components to the velocity (in kilometers per second) of a satellite (x, y, z) and finds:

(145.0, 103.0, 523.7)

The total speed, V, of the satellite is given by

$$V^2 = (145.0)^2 + (103.0)^2 + (523.7)^2$$

$$V^2 = 21,025.0 + 10,609.0 + 274,261.7$$

$$V^2 = 305,895.7$$

$$V = 553.1 \text{ kilometers per second}$$

## Solar Wind Velocity

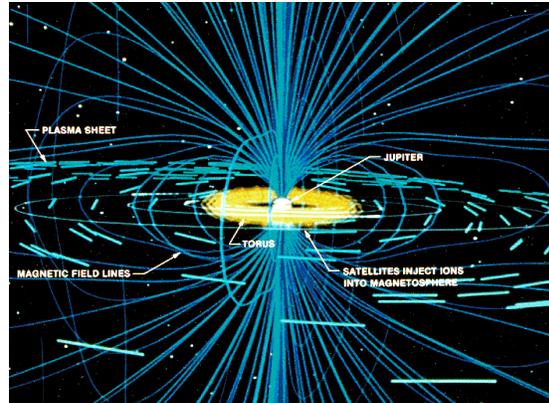
Date	X	Y	Z	B <sup>2</sup>	B
1-7	10.9	-5.7	-1.0		
1-10	-10.2	+11.4	-4.0		
4-17	+9.6	-18.6	+14.5		
5-23	-4.8	+22.2	+16.6		
5-28	-0.88	+0.94	+0.18		
7-11	-2.8	-3.6	+1.2		

In 2002, the ACE satellite measured the three components to the solar wind magnetic field at a location 1.5 million kilometers from Earth. The table above gives the data for a series of these observations. Use the 3-dimensional Pythagorean Theorem, together with the three magnetic field measurements (X, Y, Z), to calculate the total strength of the solar wind field.

**Enter the answer in the last column.**

Scientists use, and create, many different kinds of equations to help them quantify their data, and make predictions.

A scientific theory describes how quantities ought to be logically related to each other, and provides a mathematical procedure for working with nature in a symbolic way.



A model of Jupiter's magnetic field.

**Equations are used to extract information from data, and to model how qualities (speed, distance, temperature etc) are interrelated.**

- Equations help scientists extract information from basic data, and allow them to make predictions.

### Here's how to do it!

If a pebble falls from the top of a building and takes 10.0 seconds to reach the ground, how high is the building? This equation predicts the distance of the fall (H) based on the time (T)

$$H = 9.8 T^2$$

with T=10.0 seconds :

$$H = 9.8 (10)^2 \text{ meters} = 980 \text{ meters}$$

### Now you try!

Evaluate the following equations for the indicated values of the variables:

1)  $d = d_0 + V_0T + 1/2 a T^2$  for  $a = 32$ ,  $V_0 = 25.7$ ,  $d_0 = 5.5$  and  $T = 15.7$

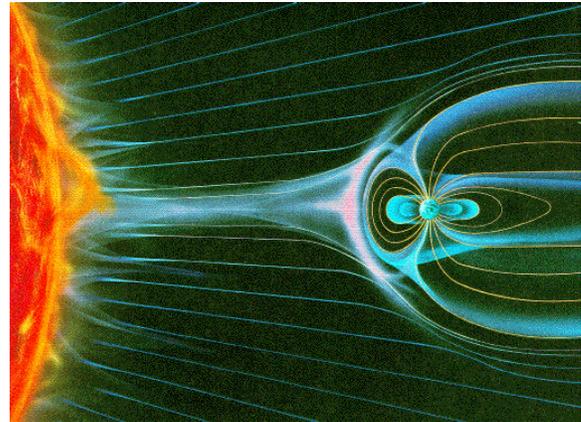
2)  $E = m c^2$  for  $m = 15$  and  $c = 299,792.5$

3)  $L = 4\pi R^2 S T^4$  for  $R = 6.9 \times 10^{10}$ ,  $S = 0.000058$  and  $T = 5770.0$

4)  $M = 9.54 \times 10^{15} T m^3$  for  $T = 3987.6$  and  $m = 30.5$

A solar flare is a violent explosion of magnetic energy on the sun. A Coronal Mass Ejection is a billion-ton cloud of gas exploding from the solar surface. Scientists can detect these 'solar storms' and measure how Earth's environment changes.

What scientists would like to learn is, how do you predict what will happen near Earth by looking at events taking place on the Sun, or in space?



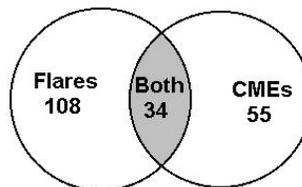
*Storms from the Sun sometimes make their way to Earth. Space physicists try to predict what will happen when these storms arrive, and forecast their arrival.*

*Statistical data can be used to draw conclusions about cause-and-effect relationships, even though the details of the process are unknown.*

➤ Venn diagrams help astronomers sort out statistical information.

**Here's how to do it!**  
 In 2000, 142 solar flares, and 89 Coronal Mass Ejections were spotted on the Sun. 34 flares happened at nearly the same time as CMEs. What percent of CMEs are not accompanied by solar flares?

Now you try!



$$\frac{89-34}{89} = 0.62$$

or 62 %

1) In the sample problem above, what percentage of solar flares do not happen during CMEs? A news reporter says that solar flares produce CMEs. Is this an accurate statement? Explain.

2) A NASA satellite called ACE measures changes in the magnetism of the gas flowing away from the sun. During 2000 it detects 56 severe magnetic changes. Another satellite called SOHO detects 55 CMEs of which 29 happen at the same time as the ACE disturbances. The IMAGE satellite detects aurora in the polar regions of Earth. A total of 63 bright Aurora are detected during the 56 ACE magnetic 'storms'. There are 31 cases where aurora are seen at the same time as the magnetic disturbances. a) What percentage of CMEs cause magnetic disturbances? b) What fraction of magnetic disturbances lead to major aurora on Earth?

3) Can CME's be reliably used to predict when the next Aurora will occur? Explain.