Space I

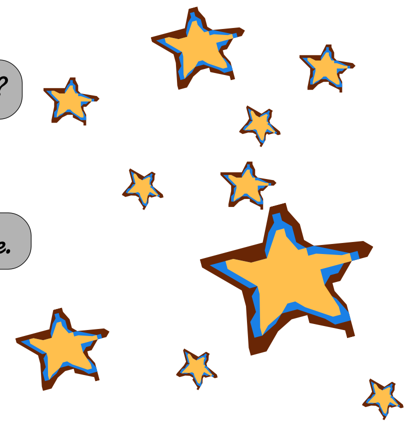
Worksheet 9

A worksheet produced by the Native Access to Engineering Programme

What is space?

The word "space" has many meanings, even just within the context of engineering.

How many different types of space can you identify?



One definition of space, as provided by WordNet, is

5: any region in space outside the Earth's atmosphere.

The space in this definition is sometimes referred to as outer space.

Tales of space

The Aborigines of Australia say that the Southern Cross, a constellation of 4 bright stars by which sailors in the southern hemisphere navigate, is a reminder of death. Two of the stars, they say, are the eyes of Yuwi, the spirit of death; the other two are the eyes of the first person on Earth to be claimed by him.

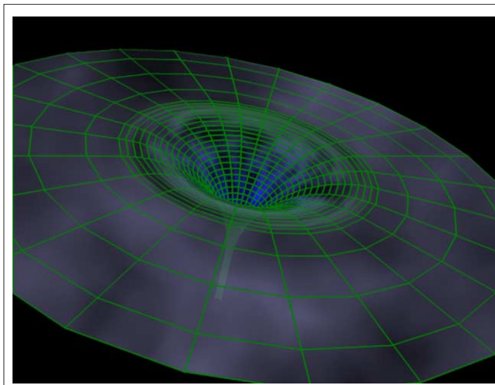
The Tlingit of the Northwest coast tell the story of how Raven brought light to the world by transforming himself into the grandson of a great chief whose daughter kept the sun, the moon and the stars in intricately carved cedar boxes. Raven tricked the chief, who loved him very much, into letting him play with the boxes. He opened them up and let the stars and moon escape through the smokehole of his mother's house. Raven then transformed himself back into a bird and flew away with the box containing the sun. After he opened it up the Earth was never completely dark again.

What are your nations' teachings about outer space?

Today our fascination with space continues. We still tell tales about travelling to the stars. Some of these stories, like Star Wars, manage to capture the imaginations of people all over the planet. Yet, as easy as space flight and adventure seem in movies, books and traditional tales, the truth is we have only just started exploring our own tiny area of the galaxy.

Gravity: Living in a well

Getting into space isn't easy because we live in a gravity well. Gravity is the force that holds us to the planet. It is a force which depends on both mass and distance: the more massive a planet is the more gravity it has and the closer you get to a planet the more gravity you experience.



A black hole is the strongest type of gravity well.

Can you think of what effects a gravity well might cause?

Escaping a gravity well takes a whole lot of force. In order to get from Earth to the Moon, Mars or any other planet, we have to produce enough force to move an object at 11.2 km/s. This is known as the escape velocity. Every planet has its own unique escape velocity based on the relationship between its radius and mass.

It is calculated by the formula $v_{esc} = \sqrt{\frac{GM_{Planet}}{R_{Planet}}}$

Where
G is the Universal Gravitational Constant equal to 6.672 x 10^{-11} $n.m^2/kg^2$,
M_{planet} is the mass of the planet in kilograms, and
R_{planet} is the radius of the planet in meters.

How fast is 11.2 m/s in km/h?

Most of the vehicles we send into space never leave the Earth's gravity completely. Satellites, the Space Shuttle and the International Space Station all orbit the earth. Sending vehicles into orbit requires a lower take off velocity than sending them to other planets. In fact, vehicles which stay in what is referred to as low Earth orbit only require a take-off velocity of about 7.8 km/s or 28,000 km/hr.

Achieving escape velocity or just getting into orbit

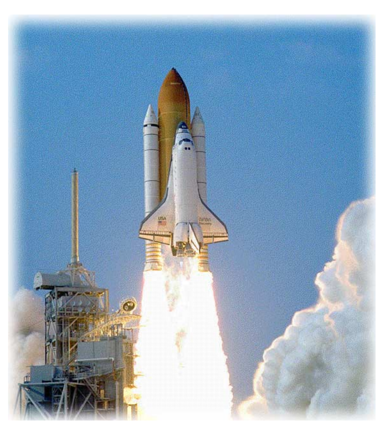
When astronauts go into space they have to take everything they'll need with them - food, water, tools, medical equipment etc. They have to travel in a vehicle which will protect them from the heat of take-off and reentry. The same vehicle also has to protect them from the environment of space (more on this later). All of these needs mean that space ships get to be quite big and very heavy.

Why does a rocket get so hot during takeoff and re-entry?

Even getting into low-Earth orbit requires a huge amount of force (and energy). Why? Well, it's just basic physics.

A space ship always starts at rest with no velocity. In order to achieve orbit, its velocity must reach at least 7.8 km/hr. A change in velocity is called acceleration. If you've ever watched a space shuttle take off, you know that it accelerates quite quickly. Newton's Second Law of Motion says that force is equal to mass times acceleration, or mathematically, F=ma

where
F is the force required in $Kg.m/s^2$ or Newtons (N),
M is the mass of the object in kilograms, and
a is the object's acceleration in m/s^2.



So, with the huge mass of the space shuttle and its quick acceleration an awful lot of force, or thrust, is required to get it into orbit. The thrust to push a space shuttle or rocket into orbit is provided by burning fuel, called propellant.

The environment of space

Canadian astronaut Julie Payette working in the Space Shuttle.

NASA
http://spaceflight.nasa.gov/gallery/images/shuttle/sts-96

Space and even the other planets in our solar system are pretty hostile environments for most living things from Earth, and even some non-living things. Space is a vacuum; there is no air, no pressure, no gravity, huge temperature variations and no protection from the Sun's radiation. All of these factors impact on the design of space vehicles. Satellites must be made from materials which can withstand high doses of radiation and changes in temperature. The Space Shuttle and the International Space Station, must provide people working in space with an artificial environment close to that of the Earth.

We can design space vehicles with Earth-like air, pressure and temperature but what aspect of being on Earth hasn't found its place in our space vehicles yet?

Even though they may have atmospheres, the environments of other planets provide similar challenges. So, before we can travel to Mars we will have to figure out how to live there first.

Can you think of any place on Earth which might mimic Mars?

NASA scientists have recently undertaken trips to the Canadian Arctic to test equipment and train under conditions similar to what they might expect on Mars. The experimental site is in the Haughton Crater on Devon Island in Nunavut. It has a landscape similar to Mars and temperatures there are close to what would be found on a Martian summer day. Who knows, perhaps one day the Canadian Space Agency and NASA will decide that the best people to explore Mars are those who are already familiar with the conditions found in Canada's far North.

Engineers in space

Many different kinds of engineers are involved in space exploration. Very few get the chance to actually work beyond the bounds of our planet, but many spend their time on Earth figuring out how we could work, live and travel in space.

Aerospace engineers research, design and produce space vehicles like satellites, rockets and robots which can explore the surface of other planets. Canadian aerospace engineers designed the Canadarm which is used on the Space Shuttle to help launch new satellites and retrieve older ones for repair.

Food engineers have designed packaging for use in space that allow for easy rehydration of food and come equipped with suction cups that can be attached to a surface.

Why does food have to be engineered for space?

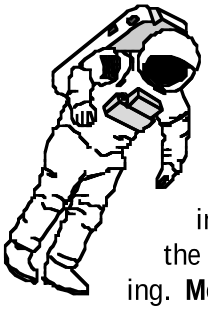
The Canadarm is used to help with maintenance on the Hubble Space Telescope.

NASA
http://spaceflight.nasa.gov/gallery/images/shuttle

Food engineered for space.

Food in Space
http://ipsec.scribernet.com/station/astronaut.html

Propulsion engineers figure out how to move space vehicles. They have to think about vehicles moving in many different situations both within and outside a planet's atmosphere. These engineers also calculate trajectories, or the path a vehicle will follow during its flight. Jerry C. HighEagle is a Native scientist at NASA who helped to calculate the return trajectory of Apollo 13 when it experienced difficulties on its way to the moon.

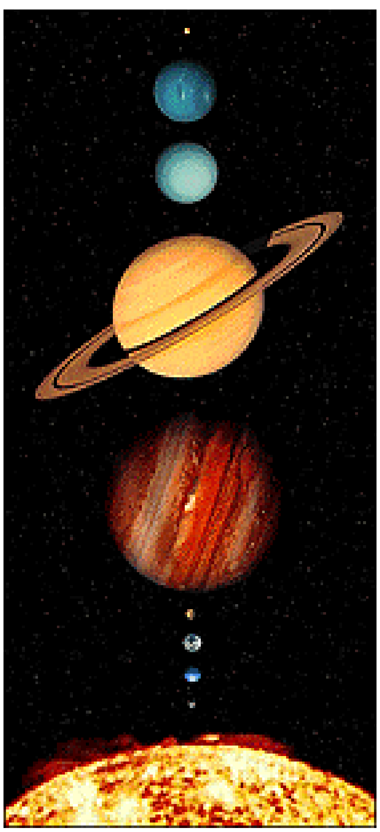


What's different about moving in an atmosphere and a vacuum?

Space flight would be much more difficult without the use of computers, so **computer and electrical engineers** play a large role in the aerospace industry. They develop all the electronics which keep the vehicles working. **Mechanical and building engineers** design onboard ventilation and air filtration systems so that astronauts can breathe easily while working in space.

Both space vehicles and people need to be protected from extremes of temperature, pressure and radiation. **Materials engineers** are responsible for the space shuttle heat tiles which keep it from burning up upon reentry into the Earth's atmosphere. They are also responsible for the special suits astronauts wear during take off and landing which protect them from changes in temperature and pressure.

What other types of engineer and scientists do you think are involved in space exploration?



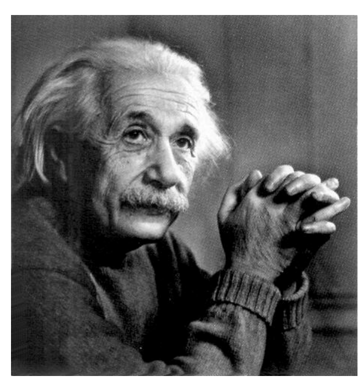
The speed limit

Right now our exploration of space is limited to a small region very close to Earth. We orbit our planet regularly. We have visited the moon, sent robots to Mars, and flown satellites past other planets as well as the sun. We have even managed to send two satellites beyond the outermost planets and on their way out of our solar system. Those satellites called Voyager 1 and 2, were launched from Earth in 1977 and past the outermost planet (at the time) Neptune, in 1989. Neptune is more than 4 billion kilometers away from Earth, and it took Voyager twelve years to get there.

Is Neptune still the planet furthest from the sun?
Do you know why?

Elders say that on spiritual journeys, like those taken within a sweatlodge, we have the ability to travel faster than light. In the physical world there appears to be a limit to how fast we can go.

Do you know what the limit is?
What famous scientist discovered the speed limit?



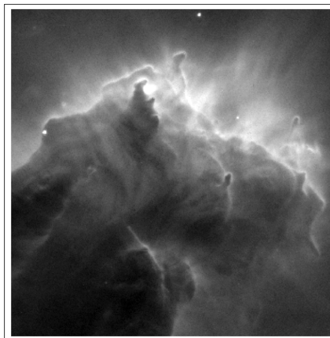
University of Frankfurt
http://wwww.th.physik.uni-frankfurt.de/~jr/gif/phys/einst_7/jpg

According to Albert Einstein we cannot go faster than the speed of light which is 300 000 km/s. At this speed it takes 8 minutes to get from the Sun to the Earth, one tenth of a second to get from Iqaluit to London, England , but it would still take 4.2 years to reach the nearest star.

If Einstein was right, and no one has proven him wrong yet,what are our chances of visiting other planets?

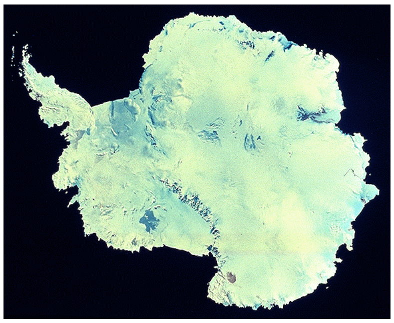
So where are we going?

While we may not be able to get far from Earth physically we can still visit the stars and even planets outside our solar system because of the work of astronauts, engineers and scientists in space exploration. The Hubble telescope can take pictures of new stars forming in far distant space, arrays of radio telescopes can listen for signals which may one day indicate there is life somewhere else in our galaxy. Space will always capture our imaginations because it is a great unknown.



An image from the Hubble Telescope of gasses forming a new star.

Hubble Top Ten
http://oposite.stsci.edu/pubinfo/gif/M16HaBW.gif

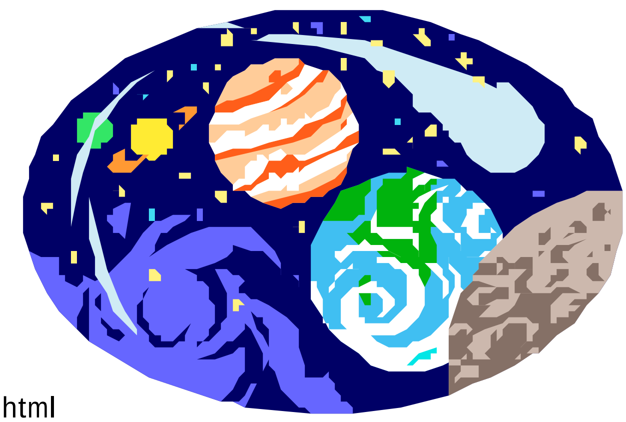


This satellite image of Antarctica helps scientists to see how the icesheet is shrinking. Satellite imagery is vital to shipping in the southern Atlantic and Pacific, as it gives warning of large icebergs that have calved off the frozen continent.

Earth Observing Sytem
http://eospso.gsfc.nasa.gov/eos_edu.pack/p27L.gif

The Maya, the Inca, the Egyptians and people all over the world studied the stars for centuries before space flight. They built monuments which aligned with specific stars or planets and were able to measure precise times for planting and harvesting crops. We are just learning what ancient astronomers knew so well, that the exploration and study of the stars can teach more about the planet on which we live.

What can we learn about Earth from space?



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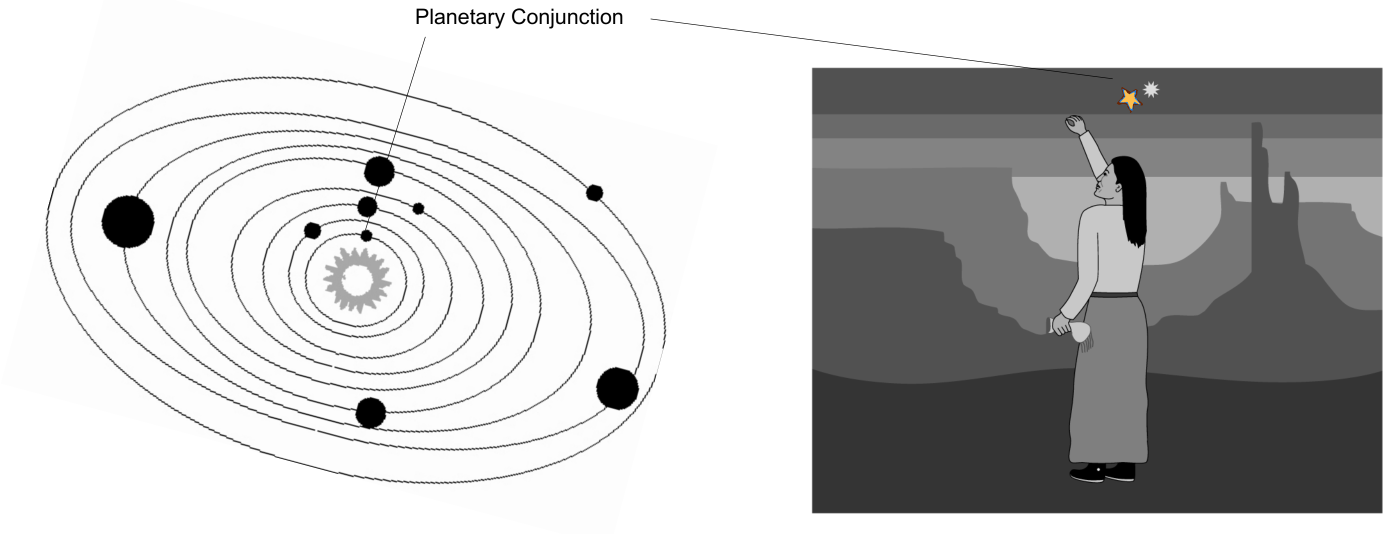
Special thanks to Tara Williams at Johnson Space Centre, Houston for her help in research.

Math problems

1. Each planet in the solar system takes a different amount of time to orbit the Sun: the Earth takes 365 days, or 1 year; Mars takes 687 Earth days or 1.9 Earth years; Pluto takes 90591 Earth days or 248 Earth years. It is rare that the orbits of 2 or more planets line up with the orbit of Earth, when they do it is called a conjunction of the planets.

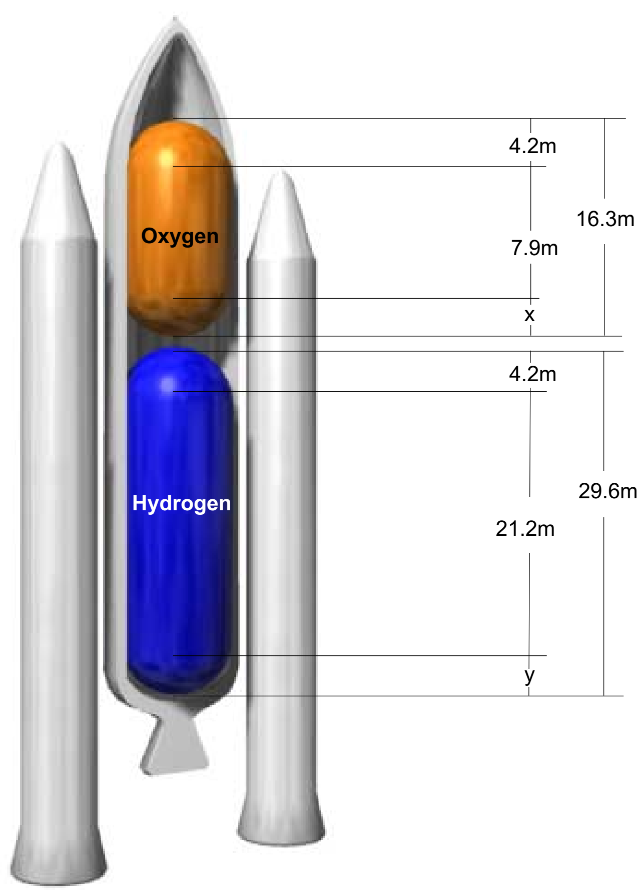


On a clear summer night a long time ago, one of your ancestors looked up into the night sky and saw two very bright stars very close together in the sky. What she was actually seeing was a conjunction of the planets Jupiter and Saturn with Earth. Jupiter orbits the sun every 12 years, Saturn every 30 years. If your ancestor saw the “bright stars” in 1682, when is the next time we can expect to see a conjunction of Earth, Jupiter and Saturn?

2. The Space Shuttle uses both liquid and solid propellant during launch. The initial thrust for launch is provided by combining liquid oxygen and hydrogen in the external tank shown to the right. These two propellants are highly combustible, so they are actually held in separate tanks with the external tank prior to launch.

You are brand new engineer with the Canadian Space Agency and are training with your counterparts at NASA. You have to order the right amount of fuel for the next shuttle launch. How much liquid hydrogen and liquid oxygen do you request?

The tanks have a diameter of 8.4m.



These problems are based on problems found at Space Mathematics, http://vesuvius.jsc.nasa.gov/er/seh/math.html.