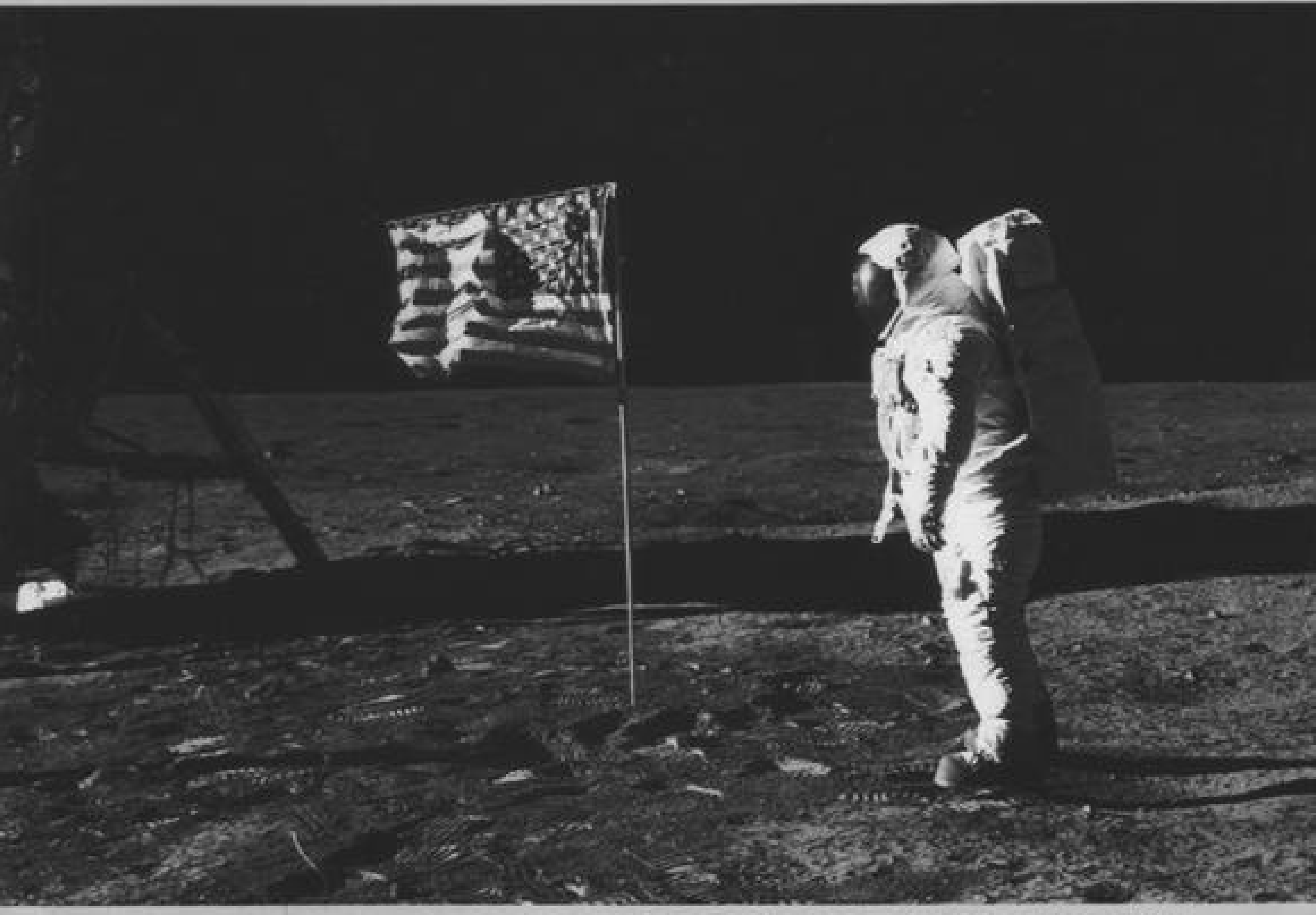
APOLLO 11

A Teacher Resource Book

Commemorating the
20th anniversary of the
Apollo 11 Moon Landing,
1969 - 1989



INTERNATIONAL COUNCIL OF ASSOCIATIONS FOR SCIENCE EDUCATION

Apollo 11

A Teacher Resource Book

**Commemorating the
20th Year Anniversary of the
Apollo 11 Moon Landing
1969-1989**

**Compiled and Edited
by**

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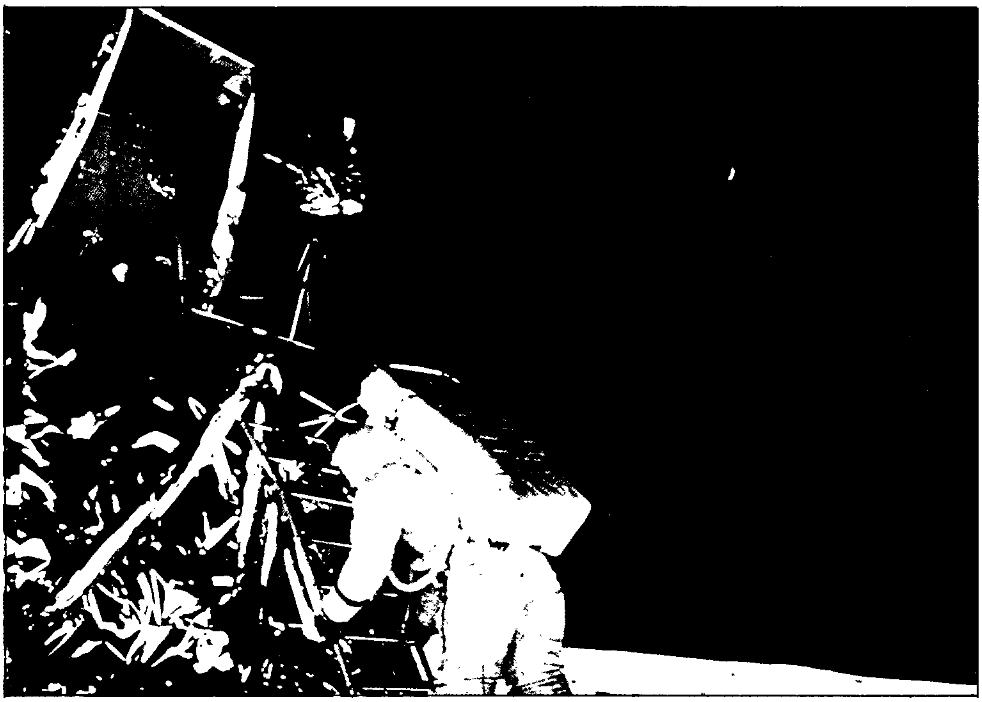
ICASE COMMEMORATIVE ISSUE

Compiled and Edited by Linda W. Crow and Donna L. Hare



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COMMEMORATIVE PUBLICATION

TEACHER RESOURCE MATERIAL

APOLLO 11

DECEMBER 1989

Preface

This booklet commemorates the twentieth anniversary of the Apollo 11 Moon landing and is intended as a teacher resource. It provides background information and activities for both elementary and secondary science students. In addition, it offers multidisiciplinary activities that can be used in language arts and english. Most of this material has been excerpted from NASA materials. NASA offers the largest source of these materials and this collection is only a small portion of what is available.

As Americans, we are pleased to be able to compile this booklet commenorating Apollo 11. This one landing became a focal point for all Americans. Perhaps President Kennedy said it best:

> ***'We set sail on this new sea because there is new knowledge to be gained, and new rights to be won, and they must be won and used for the progress of all people. For space science, like nuclear science and all technology, has no conscience of its own . . .***
>
> ***We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too."***

. . . *Excerpts from President Kennedy's remarks at Rice University in Houston, Texas, September 12, 1962.*

Acknowledgements

We are honored to have been chosen to compile and edit this issue commemorating the Apollo 11 moon landing. This project would not have been successful without the support of a number of colleagues. First, we thank NASA for providing a large portion of this material. Second, the Challenger Center Group was also helpful in also providing access to some important additions to this booklet. Lastly, we thank both John E. Penick and Jack Holbrook for their advice and assistance throughout this process.

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LWC
DLH

About the Authors

Linda W. Crow is currently an assistant professor at Baylor College of Medicine. As a college earth science teacher both at the community college and university for over ten years, she has focused her efforts toward providing science experiences from both teachers and students from elementary through graduate school. In 1975 and 1989, she received a National Science Teachers Association Award for innovations in college science teaching. Also at this time, she is the convention chairperson for the national meetings of the National Science Teachers Assocation in 1991 in Houston, Texas.

Donna L. Hare is currently a middle school life and earth science teacher in the Cypress Fairbanks Independent School District in Houston, Texas. As part of her professional activities, she is a regional coordinator for the Challenger Center for Space Science Education and is on the planning committee for the national meetings of the National Science Teachers Association in Houston in 1991.

Dedicated

to

the Crew of the Apollo 11

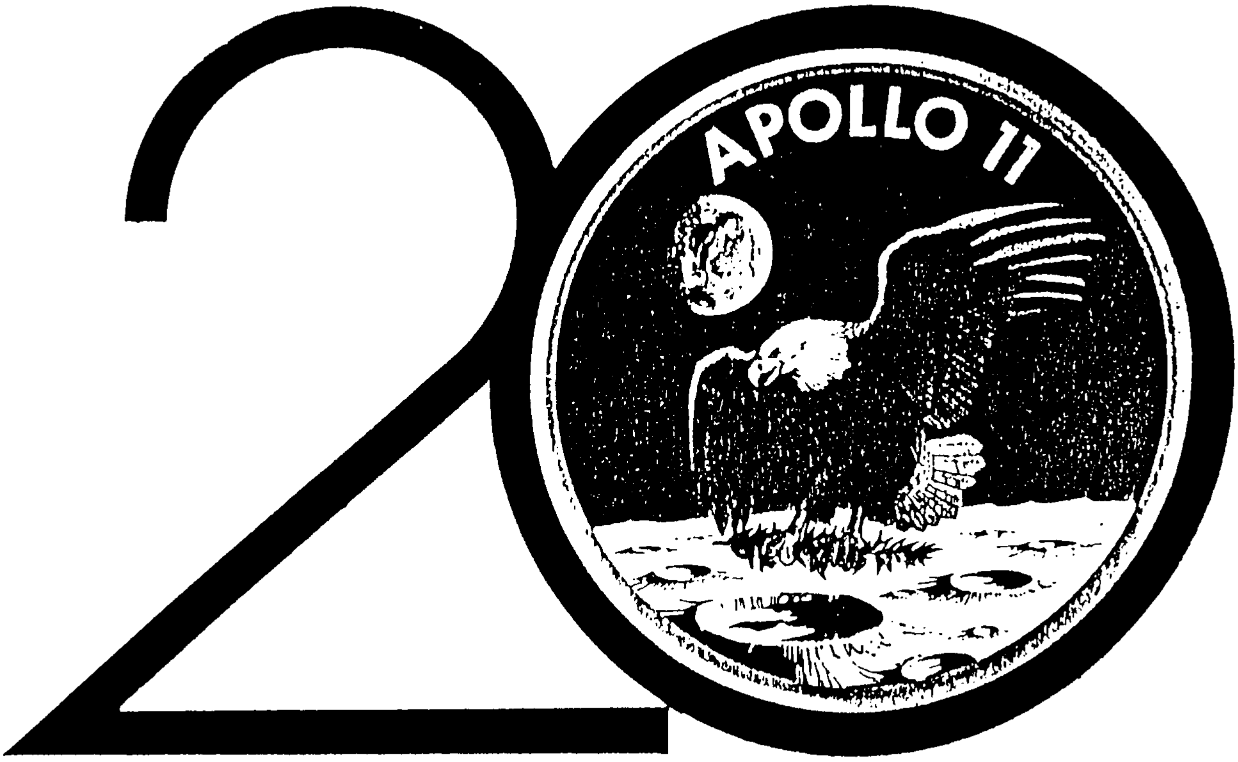
Armstrong, Collins and Aldrin-

and

to all space explorers from all countries

who have died fearlessly

in the investigation of space



"Houston Tranquility Base. The Eagle has landed."

July 29, 1969 4:18 p.m.

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Part I

History of Project Apollo

What Was Project Apollo?*

Project Apollo was the biggest and most complex project of the United States manned space flight program. Its goal, to land Americans on the moon and return them safely to earth accomplished:

1. Earth-orbital flights of up to 2 weeks duration during which crews gained experience in handling the basic spacecraft and conducted scientific observations requiring man's direct participation.

2. Earth-orbital flights during which crews gained experience in handling the basic spacecraft, and in deployment and docking with the 2-man lunar excursion module.

3. Landed an expedition that explored the moon and returned to earth.

COMPOSITION OF THE THREE-MAN APOLLO SPACECRAFT

1. Command Module

The command module was designed so that three men could work, eat, and sleep in it without wearing pressure suits. In addition to life support equipment, it contained windows, periscopes, controls, and instrument panels to enable the astronauts to pilot their craft.

The command module weighed about 5 U.S. tons (4.53 metric tons), stood 12 feet (3.65 m) tall, and had a base diameter of about 13 feet (3.96 m).

2. Service Module

The service module contained fuel and rockets so that the pilots could propel their craft in and out of lunar orbit and change their course in space. This segment weighed about 25 U.S. tons (22.7 metric tons), and measured 23 feet (7.01 m) high and was about 13 feet (3.96 m) in diameter.

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*Excerpted from *One, Two, Three and The Moon-America's Space Flight Program*, NASA, EP-8.

3. Lunar Excursion Module (LEM)

The lunar excursion module - informally called the "Bug" - was designed to carry two men from lunar orbit to the moon's surface, to be launched back into lunar orbit, and to rendezvous with the parent craft (Apollo command and surface modules). After the crew transferred to the command module, the parent craft jettisoned the excursion module.

When fully fueled and assembled, the Bug weighed some 12 U.S. tons (10.9 metric tons), was about 15 feet (4.57 m) high, and have a nominal diameter of 10 feet (3.04 m). Braking rockets enabled the module to hover, while the astronauts surveyed their landing area, and landed gently on the moon.

APOLLO STEP ONE - EARTH ORBITAL MISSIONS

In the first phase of the Apollo project, the command and service modules were launched into earth orbit by Saturn I.

The astronauts remained in space for as long as 2 weeks before returning to earth. During this time, they acquired experience in operating their craft.

APOLLO STEP TWO - RENDEZVOUS REHEARSALS

When the greater power of the Saturn IB launch vehicle becomes available, all three modules of the Apollo spacecraft were launched into earth orbit. At launch, the Bug was below the service module. In orbit, it was possible to move the command and service modules around and dock them nose to nose with the Bug. Airlocks were opened and two of the three astronauts climbed into the Bug.

APOLLO STEP THREE - EXPLORING THE MOON

The mission to the moon became possible when the enormous power of the Saturn V launch vehicle became available.

For the landing on the moon, more than 10 times the lifting power of the Saturn I is required. The three-stage Saturn V was able to boost into earth orbit the equivalent weight of 80 Mercury spacecraft.

Together with the three modules of the Apollo spacecraft, the Saturn V stood about 360 feet (109.7) tall (more than the length of a U.S. football field), and weighed about 6 million pounds (2.72 million kg.) at launch.

Part II

Information about the Moon

WHAT'S NEW ON THE MOON

Excerpted from What's New on the Moon by B. M. French,Nasa

The Apollo Program has left us with a large and priceless legacy of lunar materials and data. We now have Moon rocks collected from eight different places on the Moon. The six Apollo landings returned a collection weighing 382 kilograms (843 pounds) and consisting of more than 2,000 separate samples. Two automated Soviet spacecrafts named Luna -16 and Luna-20 returned small but important samples totaling about 130 grams (five ounces).

Instruments placed on the Moon by the Apollo astronauts as long ago as 1969 are still detecting moonquakes and meteorite impacts, measuring the Moon's motions, and recording the heat flowing out from the inside of the Moon. The Apollo Program also carried out a major effort of photographing and analyzing the surface of the Moon. Cameras on the Apollo spacecraft obtained so many accurate photographs that we now have better maps of parts of the Moon than we do for some areas on Earth. Special detectors near the cameras measured the weak X-rays and radioactivity given off by the lunar surface. From these measurements, we have been able to determine the chemical composition of about one-quarter of the Moon's surface, an area the size of the United States and Mexico combined. By comparing the flight data with analyses of returned Moon rocks, we can draw conclusions about the chemical composition and nature of the entire Moon.

Thus in less than a decade, science and the Apollo Program have changed our Moon from an unknown and unreachable object into a familiar world.

WHAT HAS THE APOLLO PROGRAM TOLD US ABOUT THE MOON?

What have we gained from all this exploration? Before the landing of Apollo 11 on July 20, 1969, the nature and origin of the Moon were still mysteries. Now, as a result of the Apollo Program, we can answer questions that remained unsolved during centuries of speculation and scientific study:

Is there life on the Moon?

Despite careful searching, neither living organisms nor fossil life have been found in any lunar samples. The lunar rocks were so barren of life that the quarantine period for returned astronauts was dropped after the third Apollo landing.

The moon has no water of any kind, either free or chemically combined in the rocks. Water is a substance that is necessary for life, and it is therefore unlikely that life could ever have originated on the Moon. Furthermore, lunar rocks contain only tiny amounts of the carbon and carbon compounds out of which life is built, and most of this carbon is not native to the Moon but is brought to the lunar surface in meteorites and as atoms blasted out the Sun.

What is the Moon made of?

Before the first Moon rocks were collected, we could analyze only two types of bodies in our solar system: of our own planet Earth and the meteorites that occasionally fall to Earth from outer space. Now we have learned that the Moon is chemically different from both of these, but it is most like the Earth.

The moon is made of rocks. The Moon rocks are so much like Earth rocks in their appearance that we can use the same terms to describe both. The rocks are all *igneous*., which means that they formed by the cooling of molten lava. (No sedimentary rocks, like limestone or shale, which are deposited in water, have ever been found on the Moon).

The dark regions (called "maria") that form the features of "The Man in the Moon" are low, level areas covered with layers of basalt lava, a rock similar to the lavas that erupt from terrestrial volcanoes in Hawaii, Iceland and elsewhere. The light-colored parts of the Moon (called "highlands") are higher, more rugged regions that are older than the maria. These areas are made up of several different kinds of rocks that cooled slowly deep within the Moon. Again using terrestrial terms, we call these rocks gabbro, norite, and anorthosite.

Despite these similarities, Moon rocks and Earth are basically different, and it is easy to tell them apart by analyzing their chemistry. The most obvious difference is that Moon rocks have no water at all, while almost all terrestrial rocks contain at least a percent or two of water. The moon rocks are therefore very well-preserved, because they never were able to react with water to form clay minerals or rust. A 3 1/2-billion-year-old Moon rock looks fresher than water-bearing lava just erupted from a terrestrial volcano.

Another important difference is that the Moon rocks formed where there was almost no free oxygen. As a result, some of the iron in lunar rocks was not oxidized when the lunar lavas formed.

What is the inside of the Moon like?

Sensitive instruments placed on the lunar surface by Apollo astronauts are still recording the tiny vibrations caused by meteorite impacts on the surface of the Moon and by small "moonquakes" deep within it. These vibrations provide the data from which scientists determine what the inside of the Moon is like.

About 3,000 moonquakes are detected each year. All of them are very week by terrestrial standards. The average moonquake releases about as much energy as a firecracker, and the whole Moon releases less than one-ten-billionth of the earthquake energy of the Earth.

A picture of the inside of the moon has slow been put together from the records of the thousands of moonquakes, meteorite impacts, and the deliberate impacts of discarded Apollo rocket stages on the Moon divided into a series of layers just as the earth is, although the layers of the Earth and Moon are different. The outermost part of the Moon is a crust about 60 kilometers (37 miles) thick, probably composed of calcium - and aluminum-rich rocks like those found in the highlands. Beneath this crust is a thick layer of denser rock (the mantle) which extends down to more than 800 kilometers (500 miles).

The deep interior of the Moon is still unknown. The Moon may contain a small iron core at its center, and there is some evidence that the Moon may be hot and even partly molten inside.

The moon does not have a magnetic field like the Earth's, and so the most baffling and unexpected result of the Apollo Program was the discovery of preserved magnetism in many of the old lunar rocks. One explanation is that the Moon had an ancient magnetic field that somehow disappeared after the old lunar rocks had formed.

What is the Moon's surface like?

Long before the Apollo Program scientists could see that the Moon's surface was complex. Earth-based telescopes could distinguish the level maria and the rugged highlands. We could recognize countless circular craters, rugged mountain ranges.

Because of the Apollo explorations, we have now learned that all these lunar landscapes are covered by a layer of fine broken-up powder and rubble about 1 to 20 meters (3 to 60 feet) deep. This layer is usually called the "lunar soil," although it contains no water or organic material, and it is totally different from soils formed on Earth by the action of wind, water, and life.

The lunar soil is something entirely new to scientists, for it could only have been formed on the surface on an airless body like the Moon. The soil has been built up over billions years by the continuous bombarding of the unprotected Moon by large and small meteorites, most of which would have burned up if they had entered the Earth's atmosphere.

These meteorites form craters when they hit the Moon. Tiny particles of cosmic dust produce microscopic craters perhaps 1/1000 of a millimeter (1/25,000 inch) across while the rare impact of a large body may blast out a crater many kilometers or miles in diameter. Each of these impacts shatters the solid rock, scatters material around the crater, and stirs and mixes the soil. As a result, the lunar soil is a well-mixed sample of a large area of the Moon, and single samples of lunar soil have yielded rock fragments whose source was hundreds of kilometers from the collection site.

However, the lunar soil is more than ground-up and reworked lunar rock. It is the boundary layer between the Moon and outer space, and it absorbs the matter and energy that strike the Moon from the Sun and the rest of the universe. Tiny bits of cosmic dust and high-energy atomic particles that would be stopped high in the Earth's protective atmosphere rain continually onto the surface of the Moon.

How old is the Moon?

Scientists now think that the solar system first came into being as a huge, whirling, disk-shaped cloud of gas and dust. Gradually the cloud collapsed inward. The central part became massive and hot, forming the Sun. Around the Sun, the dust formed small objects that rapidly collected together to form the large planets and satellites that we see today.

By carefully measuring the radioactive elements found in rocks, scientists can determine how old the rocks are. Measurements on meteorites indicate that the formation of th solar system occurred 4.6 billion years ago. There is chemical evidence in both lunar and terrestrial rocks that the Earth and Moon also formed at that time. However, the oldest known rocks on Earth are only 3.8 billions years old, and scientists think that the older rocks have been destroyed by the Earth's continuing volcanism.

The Moon rocks fill in some of this gap in time between the Earth's oldest preserved rocks and the formation of the solar system. The lavas from the dark maria are the Moon's youngest rocks, but they are as old as the oldest rocks found on Earth with ages of 3.1 to 3.8 billion years. Rocks from the lunar highlands are even older. Most highland samples have ages of 4.0 to 4.3 billion years. Some Moon rocks preserve e traces of even older lunar events. Studies of these rocks indicate that widespread melting and chemical separation were going on within the Moon about 4.4 billion years ago, or not long after the Moon had formed.

Even more exciting is the discovery that a few lunar rocks seem to record the actual formation of the Moon. Some tiny green rock fragments collected by the Apollo astronauts have yielded an apparent age of 4.6 billion years, the time at which scientists think that the Moon and the solar system formed. Early in 1976, scientists identified another Apollo 17 crystalline rock with the same ancient age. These pieces may be some of the first material that solified fro the once-molten Moon.

What is the history of the Moon?

The first few hundred million years of the Moon's lifetime were so violent that few traces of this time remain. Almost immediately after the Moon formed, its outer part was completely melted to a depth of several hundred kilometers. While this molten layer gradually cooled and solidified into different kinds of rocks, the Moon was bombarded by huge asteroids and smaller bodies. Some of these asteroids were the size of small states like Rhode Island or Delaware, and their collisions with the Moon created huge basins hundreds of kilometers across.

This catastrophic bombardment died away about 4 billion years ago, leaving the lunar highlands covered with huge overlapping craters and a deep layer of shattered and broken rock. As the bombardment subsided, heat produced by the decay of radioactive elements began to melt the inside of the Moon at depths of about 200 kilometers (125 miles) below its surface. Then, for the next half billion years from about 3 to 3.1 billion years ago, great floods of lava rose from inside the Moon and poured out overs its surface, filling in the large impact basins to form the dark parts of the Moon that we see today.

As far as we now know, the Moon has been quiet since the last lavas erupted more than 3 billion years ago. Since then, the Moon's surface has been altered only by rare large meteorite impacts and by atomic particles from the Sun and the stars. The Moon has preserved features formed almost 4 billion years ago, and if men had landed on the Moon a billion years ago, it would have looked very much as it does now. The surface of the Moon now changes so slowly that the footprints left by the Apollo astronauts will remain clear and sharp for millions of years.

WHERE DID THE MOON COME FROM

Excerpted with NASA materials

The exact origin for the moon remains a mystery. Although many scientists that study the moon now think that right after the Earth had been formed, about 4.6 billion years ago, an object perhaps at least the size of Mars or even larger hit the new formed Earth.

The collision resulted in materials from both Earth and the object to be thrown into space. Most of the debris fell back to Earth. some of the ejected material did remain in space and formed a ring around the Earth.

It was out of this material that the moon was created. The materials eventually joined together through their many collisions. Over a billion years passed before this process was completed.

After the moon was formed, debris hitting the surface blasted out basins. Many of the basins on the side facing Earth filled with lava from the moon's interior. These became some of the dark seas that we can now see on the moon.

As we view the moon in the night sky, we can see that there are light and dark regions on the moon. The light regions are the HIGHLANDS. The highlands are extremely rugged. There are lots of craters of all sizes here. Some of the craters are stacked on one another. Also the highlands often stand more than one-half a mile above the lunar seas or maria, this the term highlands.

The darker areas of the moon are the LOWLANDS. Generally, they are smoother with fewer large craters. The dark areas are sometimes called MARIA. This is the Latin word for seas. Most of the maria are on the side of the moon facing Earth. Maria comprises about 17 percent of the lunar surface. They have poetic names. Use the Major Lunar Seas map to help you identify some of the lunar seas. You will be able to see all of the seas when the moon is full. Which seas can you see during the first quarter moon? the last quarter moon?

You should also be familiar with the moon's TERMINATOR. This is the line of shadow across the disk of the moon. The terminator marks the division between sunrise and sunset.

The moon shines by reflected light. On an average the moon reflects about seven percent of the sunlight it receives.

The moon's diameter is 2160 miles (3484 km). As a comparison, Earth's diameter is 7918 miles (12,771 km). The surface area of the moon is about 14,600,000 square miles (37,800,000 sq km). This is about the size of the surface areas of North America and Europe combined.

The volume of the moon is much smaller than that of Earth. In fact, you could stuff just over 49 moons inside the Earth.

The moon's density is much less than Earth's. Density is determined by dividing the weight of an object into its volume. For the moon a cubic inch of lunar material would weigh about 1.9 ounces (54.3 g) -- about the weight of a candy bar. At the same time a cubic inch of Earth material would weigh 2.9 ounces (82.8 g).

The moon's gravity is one-sixth Earth's. This means that if you weighed 60 pounds (27.3 kg) on Earth you would weigh 10 pounds (4.54 kg) on the moon.

It was much easier to escape the moon than it is from Earth. Your spacecraft would only have to travel 1.48 miles (2.38 km) per second in order to leave the moon. From Earth your aircraft must travel almost 7 miles (11.3 km) each second to escape the Earth. The low escape velocity is one of the reasons that the moon has not been able to retain an atmosphere.

In addition to no atmosphere there has been no water found on the moon. You will not find ancient lake beds or rivers on the lunar surface.

It can be very hot or cold on the moon. At noon on the equator it can get up to 273°F (125°C). After sunset the temperature can drop to -243°F (-143°C).

Erosion on the moon does not take place through the action of wind or water like on Earth. Instead, erosion on the moon takes place because of the temperature extremes. Great extremes in temperature can cause the rocks to crack and break apart. Sometimes a boulder can roll down a lunar hill or mountain causing changes in the lunar landscape. Erosion also occurs through the bombardment of the moon's surface by meteoroids or cosmic particles, many of which are from the solar wind.

SURFACE FEATURES ON THE MOON

Some of the major lunar features are seas, craters, mountains, rills, and rays.

Seas - These are the darker areas on the moon. They are not bodies of water like their name suggest. They often have poetic names -- Mare Crisium (Sea of Crisis), Mare Imbrium (Sea of Showers). Thirty-six seas have been given separate names on the side of the moon facing Earth.

Craters - Craters are ringed structures on the moon. More than 30,000 of them (with diameters a little over one-half mile or .8 km) are visible with large telescope. There are 150 craters with diameters greater than 48 miles (77.4 km) across. Craters are most often named after famous astronomers, scientists, mathematicians, philosophers, musicians or other famous people. Some examples are Tycho, Copernicus, and Plato.

Mountains - There are several mountain ranges on the moon. Most of them are named after terrestrial mountains. There are the Alps, Appennines, and Pyrenees to name a few. Mountains on the moon were not created like Earth's mountains. Rather than crustal folding, lunar mountains consist of tilted crustal blocks that have been shattered by tectonic movements.

Rays - The rays appear to be some sort of surface deposit. Many form extensive radiating systems with a crater at or near the apparent point of origin. The ray system associated with Tycho is one of the best examples.

Rills - Rills are crack-like features in the moon's crust. Over 2000 rills have identified on the moon. They vary in length from a few miles (kilometers) to hundreds of miles (kilometers) and can be up to one-half mile or .8 km deep.

ROBOTIC EXPLORATION OF THE MOON

Excerpted from Nasa Materials

Before astronauts could land on the moon scientists needed to know what the moon was like in order to design the equipment to land there. In addition, some information about the surface was needed in order to select a landing site. Spacecraft are used to explore unknown regions to gather information needed by space scientists. Several other terms are also used to more clearly define the nature of the spacecraft such as satellite or probe. All spacecraft have common systems which operate and care the spacecraft. Some of the major systems are:

Environmental Control System: maintains proper temperature when a crew is on board, maintains adequate supply of oxygen and removes carbon dioxide from air; provides water when necessary.

Communication System: enables two-way data and/or voice transmission between Earth and the spacecraft.

Power System: provides power to operate the spacecraft whether it be batteries, solar cells, fuel cells, nuclear generated power, or solar power dynamic systems.

Propulsion System: provides capability to change velocity and direction of spacecraft. For example, a propulsion engine can be fired in a retrodirection (opposite to direction of motion) to slow the speed of a spacecraft to enable it to go from a circular to an elliptical transfer orbit. This orbit can be used later to transfer to another orbit with different dimensions by firing the propulsion engine at the appropriate time.

Navigation System: permits the determination of location and direction of flight of the spacecraft.

Guidance and Control System: generates steering commands and reacts to the commands.

Structure System: houses the various systems and protects them against the space environment.

The United States initiated three programs to find out more about the moon. There were the Ranger, Lunar Orbiter, and Surveyor Programs.

Ranger - The Ranger spacecraft was designed to crash into the lunar surface. Before impact Ranger was to send television pictures back to Earth. Between 1961 and 1965, nine Ranger spacecrafts were sent to impact the moon. Only three were successful. In all over 17,000 close-ups of the moon were sent back to Earth.

Surveyor - to determine the firmness of the lunar soil NASA sent five Surveyor aircrafts to soft land on the moon. Scientists needed to know if the moon was covered by a thick layer of dust that might swallow up the astronauts who landed there. The Surveyors determined that the moon could support the weight of a lunar landing craft.

Lunar Orbiter - Five Lunar Orbiter spacecrafts were successfully launched during 1966 and 1967. The Lunar Orbiters photographed the moon from orbit. Lunar Orbiters could photograph objects as small as a few yards across. Their photographs were very useful in selecting a lunar landing site.

WHAT WAS LEARNED ABOUT THE MOON FROM APOLLO

Excerpted from Nasa Materials

Lunar Ranging

Three laser reflectors were left on the moon by Apollo astronauts. Another was placed on the moon by the Soviet Lunakhod 2 lander. A laser reflector acts like a mirror and is designed to reflect pulses of laser light fired from Earth to the moon back to the Earth. Light travels 186,000 miles (300,000 km) a second. By determining the amount of time it takes for a laser signal to travel to the moon and back again enables space scientists to learn many interesting things about the Earth and moon. Distances can be measured with an accuracy of one inch. Using the laser reflectors space scientists have learned that:

- the average distance between the centers of the Earth and moon is 239,000 miles (385,484 km).
- the moon is receding from the Earth at about one and one half inches every year.
- the length of the Earth year varies about one-thousandth of a second each year.
- the Earth's shape is changing: land masses are gradually changing after being compressed by the great weight of the glaciers in the last ice age.

Moonquakes

There are several thousand moonquakes on the moon each year. There are three distinct kinds: those due to impacts, those produced artificially by impacting an object onto the lunar surface, and the third due to internal movements inside the moon. The moonquakes are not very strong. It seems the moon's surface is as stable as Kansas.

Lunar Surface

The entire moon appears to be covered with fragmented rock and dust. This rock and dust comes from the material blasted from impact craters. This debris blanket, from fine dust to large blocks of material on the lunar surface is called the REGOLITH. The finer component is called the lunar soil.

The lunar soil has layers caused by meteorite impacts. A meteorite is a pice of an asteroid, comet, or rock that strikes the surface, in this case the moon. Each impact causes a new layer from the blankets of material thrown out by the impact. The larger the impact the farther away the lunar rocks and soil can be hurled..

Each layer was exposed to the sun the soil reacted the sun's rays and particles. By studying th sun's effects on the lunar soil we can learn about the behavior of the sun over long periods of time.

The depth of the regolith varies. On the maria it can be up to 15 feet (4.57 m) deep. It can be much deeper in the highlands. It has been estimated that the lunar regolith accumulates at an average rate of two millimeters per million years. It is churned up by impacts. The effects are slow. The changes would be undetectable over a period of many human lifetimes.

On the surface you might find a rock known as "breccias" Breccias are fused rock fragments made up of shattered, crushed and sometimes melted pieces of rock. Breccias are produced from impacts.

No entirely new substances have been found on the moon. Moon rocks are made up of the same elements found on Earth. Sometimes though there are modifications due to the fact that the materials have developed under conditions which have been very different.

The lunar soils are dominated by four major minerals:

Group 1: pyroxene (pir-ox-sen) Pyroxenes are made up of three simple silicates of calcium, magnesium, and iron. Silicates contain silicon and oxygen. The lunar pyroxenes are combinations of all three of them.

Groups 2. Plagioclase (Pla-je-o-klaz) The main plagioclase mineral is calcium aluminosilicate which contains aluminum, calcium, silicon, and oxygen.

Groups 3. Olivine (Ol-i-veen) Composed of two iron and two magnesium silicate components.

Group 4. Ilmenite (il-men-it) Ilmenite contains iron, titanium, and oxygen.

Rocks in the highlands contain more aluminum and calcium than the lowland rocks. At the same time the lowlands rocks have a greater concentration of iron, magnesium and titanium.

There are also volatiles in the lunar soil. Everyone has felt the wind blowing against their faces. Sometimes the force of the wind is strong enough to cause great damage. However, not everyone knows that there is another kind of wind which has its beginning at the sun. It is called the solar wind.

You can not feel the solar wind on Earth because Earth's magnetosphere (mag-ne-to-sphere) protects us from it. The magnetosphere is the Earth's magnetic field which surrounds the Earth in space. However, the solar wind does hit the moon. The solar wind normally passes the moon traveling about 250 miles (403 km) per hour.

By Earth's measurements the solar wind is really a vacuum. In a space about the size of a sugar cube there are only 10 to 100 particles in the solar wind. In your classroom there would be about 10^{19} particles. That is 10 with nineteen zeros after it in the same space.

Over billions of years the solar wind has impacted the lunar surface. In so doing the solar wind has deposited materials in the lunar soil. The most common materials are the elements of carbon, hydrogen, nitrogen, sulfur, and helium. These elements in the lunar soil are referred to as volatiles. A volatile is an element in the lunar soil that readily becomes gaseous like hydrogen or helium.

There are not great quantities of volatiles in the lunar soil. As an example, the average concentration of carbon is one hundred parts per million. What does this mean? Lets use marbles to represent the lunar soil. If you had a million marbles from the lunar soil, only 100 of them would be carbon. Typical concentrations of hydrogen on the moon are about 40 parts per million.

One of the volatiles promises to be an excellent energy source on the moon. It is called helium-3. This is pronounced helium three. In fact someday helium-3 may be returned to Earth from the moon to provide our primary source of energy to heat our homes or do work. One ton of helium-3 when used as an energy source can supply the electrical needs for a city of 10 million people for a year. It has been estimated that 28 U.S. tons (25.45 metric tons) of helium-3 could have supplied the entire electrical demand for the United States in 1987.

Part III

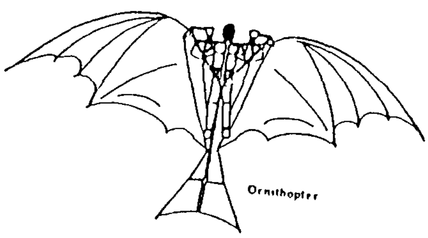
Activities for Primary Students

HISTORY OF FLIGHT*

Since the earliest times, people have watched the birds in the sky and dreamed of flying.

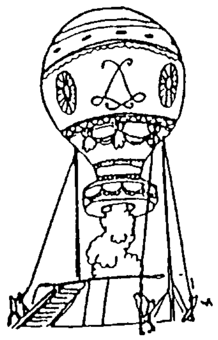
One of the oldest stories of flying is the Greek legend of Daedalus and his son, Icarus. To escape from the island of Crete, they fastened wings of feathers and beeswax to themselves. Daedalus flew safely to Naples but Icarus flew too close to the sun. The wax on his wings melted and he fell into the sea.

Around 1500 Leonardo DaVinci designed a flying machine called an ornithopter. It had flapping wings which were worked by a man's arms and legs. Though his flying did not work, DaVinci was the first real scientist in the history of flight.



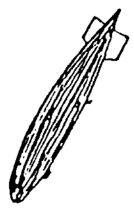
* Excerpted from *The History of Flight* by Hartsfield and Norlem, NASA Lewis Research.

The first successful flying machine was a balloon built by the Montgolfier Brothers in 1782. A duck, a sheep, and a rooster were the first passengers. In November of 1783, two men floated over Paris for 25 minutes in another Montgolfier balloon.



Montgolfier balloon

Now men were in the air, but they could only drift with the wind. There was little they could do to control the balloons.



The dirigible, also called an airship, was a balloon that had an engine and could be steered with a rudder. The first successful dirigible was flown in 1852. It was shaped like a cigar and had a steam engine that turned a propeller. The LaFrance airship, built in 1884, was the first airship which could be steered in any direction regardless of wind. It was powered by an electric motor.

In 1900 the first zeppelin was built. A zeppelin was a large rigid dirigible with a cigar shaped framework of aluminum. It was named for the man who designed it, Count Ferdinand von Zeppelin of Germany.

Zeppelins were used during World War I to drop bombs on London. After the war they were used to carry passengers across the Atlantic Ocean and to other parts of the world. The Hindenburg, the largest zeppelin, made 356 trips across the Atlantic Ocean. On may 6, 1937, it exploded and burned while trying to land in New Jersey. Thirty-six of the passengers were killed. After this accident no more zeppelins were built.

While the airships were being developed other aircraft were being built with wings.

In Germany, Otto Lilienthal was building gliders with curved wing tops and control surfaces. In 1890 he began flights that proved it was possible to use the lift of the air to fly machines that were heavier than air. He made more than 2,000 flights. His notes and drawings were studied by students of flight everywhere.

Even as boys, the Wright Brothers had been interested in flying. They often watched the buzzards flying and noticed how they twisted the back edge of one wing downward and the back edge of the other upward. They built a kite that had two wings with cords attached at the tips so the wings could be twisted, or warped.

After their success with the kite, the Wright Brothers experimented with gliders. In 1902, at Kitty Hawk, North Carolina, they made many successful flights in their third glider. This glider had two wings like the kite, but it also had an elevator and a rudder for control. Now they were ready to build a machine that could fly under its own power. In December of 1903 the brothers returned to Kitty Hawk with their new machine, the Flyer. It had a motor and propellers of their own design. On December 17, 1903, flights were made by Orville and Wilbur Wright. The first flight lasted for only 12 seconds and went 120 feet 36.6 km). In 1909, Louis Bleriot flew his monoplane across the English Channel from France to England. This was the first time anyone had flown across a body of water. It was also the first time an airplane had been flown from one country to another.

Also, in 1909, Madame LaBaronne de Laroche became the first woman pilot. In that same year the first army airplane was built.

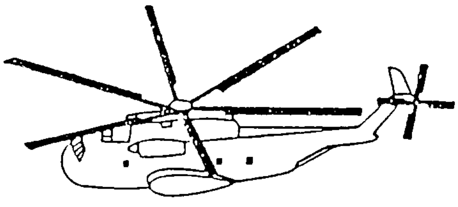
Glenn Curtiss, the father of naval aviation , flew his first successful seaplane in 1911. During that same year one of his other planes landed on the deck of a ship for the first time.

The need for better planes during World War I caused the airplane to be greatly improved during that time. Not only could they fly faster but they were much safer.

In May of 1918 the United States began air mail service between Washington, D.C. and New York City. After the war ended in November of 1918, many old war planes were made into mail planes. Soon mail service expanded all over the country.

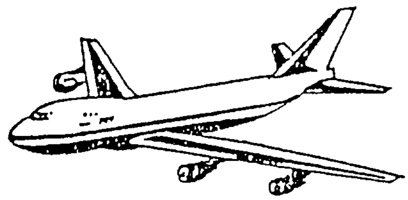
In 1919, a prize of 25,000 US dollars was offered for the first nonstop flight from New York to Paris. Charles Lindbergh won that prize. He left New York on May 20, 1927 in the "Spirit of St. Louis". He landed in Paris 33 hours and 30 minutes later, Lindbergh became an aviation hero overnight.

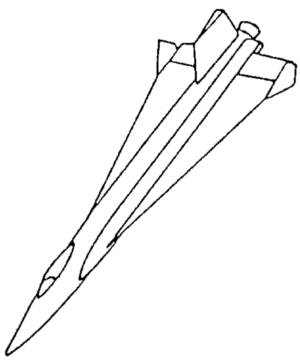
Amelia Earhart was another famous pilot. In 1932 she became the first woman to fly across the Atlantic Ocean alone. Her flight from Newfoundland to Ireland took about 14 hours. In 1937 she and her navigator set out on a flight around the world. They were last heard from when they were over the Pacific Ocean. All searches failed to find any trace of her or her aircraft.


Sikorsky CH-3C

While most designers were working to improve the airplane a few were working on the helicopter. In 1907 a helicopter was flown about 5 feet in the air but it was almost impossible to control. In 1939 Igor Sikorsky perfected the single-main-rotor helicopter.

The next 40 years saw many improvements in aviation. Airplanes grew from the single engine propeller planes, such as those flown by Lindbergh and Earhart, to present day jumbo jets such as the 747.

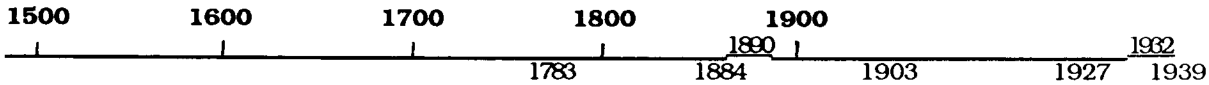




Humans are still dreaming about flying higher and faster. Research is being done to develop aircraft that can fly faster and also be quieter and more fuel efficient.

History of Flight Timeline

Match the dates with these statements about the history of flight.



A. Lindbergh flew non-stop from New York to Paris.

B. The Wright Brothers made the first successful power-driven flight.

C. Two men flew over Paris in Montgolfier balloon.

D. Amelia Earhart flew across the Atlantic Ocean alone.

E. The first zeppelin was built.

F. Otto Lilienthal began glider flights that proved it was possible to use the lift of the air to fly machines that were heavier than air.

G. Sikorsky built the first successful helicopter.

H. The La France airship was flown.

I. Leonardo Da Vinci designed the ornithopter.

ABC ORDER

Number each set in abc order

____	Earhart	____	balloon
____	Lindbergh	____	glider
____	Wright	____	zeppelin
____	Curtiss	____	airplane
____	Lilienthal	____	dirigible
____	Montgolfier	____	jet
____	Icarus	____	ornithopter
____	Zeppelin	____	monoplane
____	Sikorsky	____	biplane
____	Yeager	____	helicopter

Make a sentence by putting the words in abc order.

1. can float balloon a miles many

2. no has glider a power

3. hovers one helicopter a in spot

History of Flight
TRUE - FALSE

Answer the following statements by placing T in the blank if it is true, an F if it is false.

___ 1. The Wright Brothers built and flew the Wright Flyer at Dayton, Ohio.

___ 2. The first successful flight of men in a balloon was over Paris in 1783.

___ 3. Zeppelins were used to transport passengers.

___ 4. Amelia Earhart was the first person to fly across the Atlantic Ocean.

___ 5. Otto Lilienthal learned about gliders from the Wright Brothers.

___ 6. Airplanes were improved greatly during World War I.

___ 7. Charles Lindbergh flew from New York to Paris in the Spirit of St. Louis.

___ 8. Air mail service began in 1918 between New York and Paris.

___ 9. The Hindenburg was the largest zeppelin ever built.

___ 10. We are no longer trying to improve the airplane.

HOT AIR BALLOON PROJECT

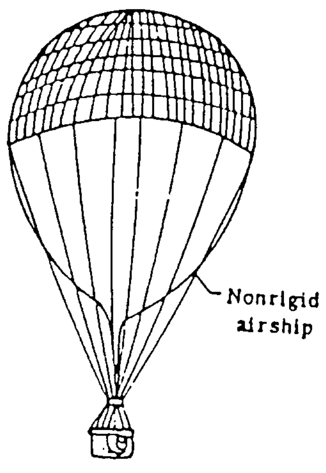
Blow up and tie securely a round balloon.

Cover the balloon with several layers of tissue paper and liquid starch. (4"x 4" or 10 cm x 10 cm tissue paper squares work well.)

Allow to dry overnight. The tissue paper will then be hard so the balloon can be popped. Cut an opening in the bottom and remove balloon.

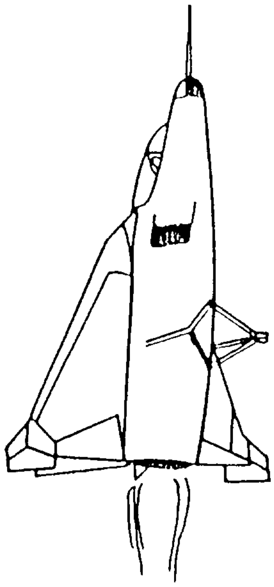
Attach a construct paper basket to the balloon with 4 strings. Have each student draw and cut out himself and one other person to put in the basket.

This can be extended to a creative writing activity. They could write a story about their trip in a balloon telling where they would go, why they chose this person to go along, exciting things that happened, etc.



History of Flight Puzzle

1. □ □ A □ □ □
2. □ □ I □ □ □
3. □ R □ □ □ □
4. □ □ □ P □ □ □ □
5. □ □ □ L □ □ □
6. □ □ □ □ A □ □
7. □ □ N □ □ □ □ □ □
8. □ E □



Ryan X-13 Vertijet

Find the answers in the story. Be sure to spell them correctly.

1. Flew too close to the sun
2. First aircraft with wings.
3. Brothers who invented the airplane.
4. A rigid dirigible; the Hindenburg was the largest.
5. The first successful flying machine.
6. The first woman to fly solo across the Atlantic.
7. Pilot of the Spirit of St. Louis.
8. A 747

History of Flight Sentences

Put the words in order to make sentences about the history of flight.

1. machines balloons were the first flying

2. largest the built Hindenburg was the zeppelin

3. the aircraft gliders with wings were first

4. successful Kitty Hawk made Wright Brothers the first the flight at powerdriven

5. across solo made Lindbergh the first flight nonstop Ocean the Atlantic

6. to fly across solo the first Amelia Earhart woman was the Atlantic

WORD PROBLEMS

Add or subtract the letters to find names of things that fly.

hair - h + plant - t + e

____

glum - um + i + den - n + r

____

by -y + all + look - lk + n

____

help - p+ i + chop - h + ter

____

king - ng + bite - bi

____

dirt - t + i + grits - rst + blue - u

____

daze - da + p + pelt - t + in

____

jam - am + he - h + t

____

T-25	L-30	W-85	V-46	M-75	0-86	F-92
C-10	E-35	R-12	G-18	B-38	U-40	A-100
H-5	P-64	I-55	N-70	D-80	S-50	

Place the correct number (bottom) and letter (top) on each problem.

___	___	___
20	10	20
+5	-5	+15

___	___	___	___	___	___
63	24	20	9	5	35
+22	-12	+35	+9	+0	-10

___	___	___	___	___	___	___	___
26	9	42	45	9	14	36	30
+12	+3	+44	-20	-4	+21	-24	+20

___	___	___	___
50	60	20	30
+25	+40	+60	+5

___	___	___
10	25	25
+15	-20	+10

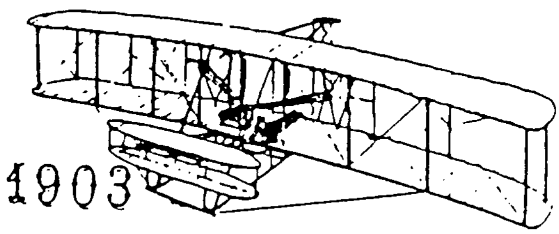
___	___	___	___	___
71	23	6	40	45
+21	+32	+6	+10	-20

___	___	___	___	___	___	___	___	___	___
60	20	20	60	45	90	40	80	80	70
-10	+20	-10	-50	-10	-40	+10	+12	-40	-40

___	___	___	___	___
50	51	41	65	9
+14	+35	+45	-30	+3

___	___	___	___	___	___
60	48	85	24	95	50
+20	-36	-30	+22	-60	+20

___	___	___	___	___	___
81	70	50	10	45	13
+11	-40	+5	+8	-40	+12



SECRET MESSAGE

A	B	C	D	E	F	G	H	I	J	K	L	M
1	3	5	7	9	11	13	15	17	19	21	23	25

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
2	4	6	8	10	12	14	16	18	20	22	24	26

20+3 8+9 9-7 4+3 2+1 6+3 5+5 7+6 7+8

20+5 8-7 2+5 7+2   7+7 9+6 18-9   6+5 9+8 6+4 7+5 6+8

6+6 8-4 21+2 2+2   6-4 7-3 1+1 9+3 5+9 9-5 10-4

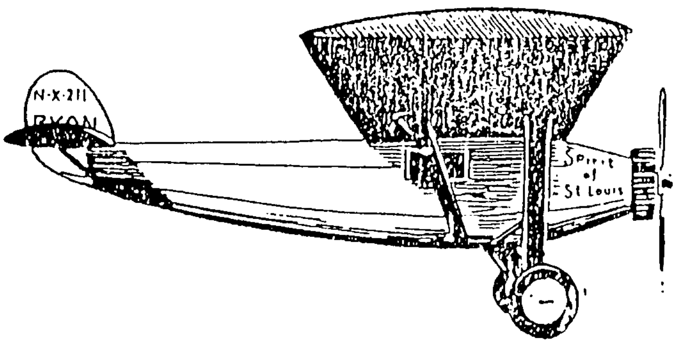
9+2 21+2 10+7 5+8 8+7 8+6   7-6 3+2 7+3 9-5 4+8 5+7

7+7 9+6 18-9   9-8 6+8 20+3 13-12 18-16 5+9 9+8 8-3

8-4 10-5 3+6 8-7 2+0   7+4 2+8 5-1 20+5

10-8 8+1 10+10   20+4 10-6 9+1 20+1   9+5 8-4

3+3 16-15 8+2 8+9 8+4



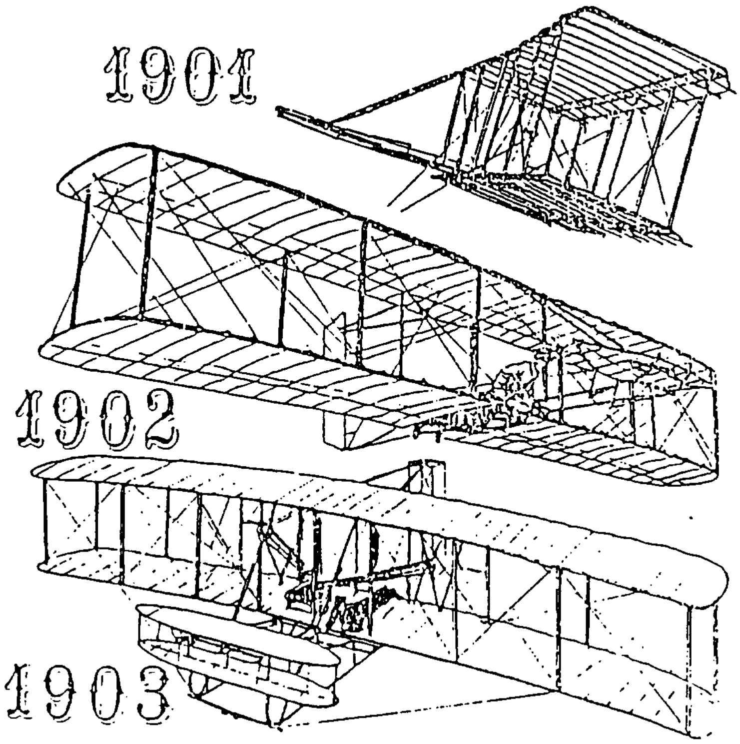
Word Search

History of Flight

Find the hidden words and circle them.

K	E	L	E	V	A	T	O	R	N
I	G	W	O	P	R	E	F	K	S
T	L	I	R	R	O	C	A	I	G
T	B	L	V	O	G	R	E	T	W
Y	E	B	I	P	L	A	N	E	R
H	F	U	L	E	I	M	G	S	I
A	J	R	L	L	D	T	I	L	G
W	R	A	E	L	E	X	N	W	H
K	F	L	Y	E	R	A	E	C	T
K	D	I	K	R	U	D	D	E	R

ELEVATOR
BIPLANE
FLYER
RUDDER
KITTY HAWK
KITES
WRIGHT
WILBUR
ORVILLE
PROPELLER
GLIDER
ENGINE



Part IV

Activities for Secondary Students

SPACE MENU ACTIVITIES*

The crew on a spaceflight of any length of time of more than a few hours will require food and liquids. In the early days of spaceflight the crew cabin had no stove or refrigerator onboard. This meant that all food carried onboard had to be of the kind that required no cooking or refrigerating. In later missions a convection oven and a refrigerating system were placed onboard.

Discuss with students the importance of a well-balanced meal, with a variety of different foods included.

Discuss the following questions:

- How would food be packaged?
- What kind of eating utensils would one use in space?
- How would you package a liquid and how would one drink a liquid in space?
- How might one solve problems of eating in an environment where everything floats around?
- Would there be any advantages of eating in an environment where things float?
- How would you handle seasoning of food in space?
- What would happen if foods contained a certain amount of air?
- Is it important that the food tastes good and be pleasant looking to the astronaut's eye? Why?
- How would you make food more like what we eat here on earth?

Allow students the opportunity to discover how NASA attempted to solve these problems. In groups they could experiment with paper, plastic, and other materials, and try to design containers and other means of dealing with the problems. They could bring materials from home. They can also share their results and evaluate their own or one another's efforts.

Have students develop a menu for a 2-week space flight, first with the early flights in mind, then one for later missions.

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* Excerpted from *Human Spaceflight* by Hartsfield and Hartsfield, NASA.

DRESSED FOR SPACEFLIGHT*

Space is hostile and deadly to the unprotected human because it lacks the atmospheric pressure, oxygen, and temperature control to sustain life. Without the filtering effects of the earth's atmosphere, the sun's heat can raise the temperature of an object in space to as high as 250 degrees F (113 degrees C), and can lower the temperature to as low as 250 degrees (-147 degrees C) below zero in the shadow.

The first pressure suit or spacesuit was designed to be worn by Wiley Post (1934), a world-renowned aviator who was attempting to set a high-altitude record in an airplane. The suit designed and built for Post resembled the type usually worn by deep-sea divers.

MERCURY

One of the first true spacesuits was developed for the Mercury program. It was designed after the U.S. Navy's Mark IV pressure suit which was used in high-speed flight. The suit was worn in case the spacecraft's environmental control system failed. The Mercury spacecraft's design played a large role in the development of the suit eventually worn during a mission.

The interior of the spacecraft was small, and the design of the craft's controls was such that mobility was not a prime requirement except shoulder and hand movement. With the short-duration flights, waste management could be achieved by proper pre-flight diet and the use of a urine collection device in the suit.

In the Mercury suit, oxygen was fed into the garment by a connector located in the torso area. The oxygen was first circulated to the extremities of the suit and then to the helmet for breathing. Exhaled waste bled off through a headpiece connector into the environmental control system where it was re-constituted for re-use.

The suit was usually made of four layers of loosely fitted material. The outer layer was a high-temperature-resistant metallic fabric. The second layer was a woven net fabric which served as a restraint layer to prevent the suit from ballooning when pressurized. The third layer was a rubberized fabric designed to make the suit airtight. The inner layer next tot the astronaut's body was a smooth soft nylon designed for comfort.

The helmet for the spacesuit, attached to a special neck ring, was padded to prevent head injury. The astronaut's

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* Excerpted from *Human Spaceflight* by Hartsfield and Hartsfield, NASA.

communications systems were built into the helmet. Gloves and custom-made boots completed the spacesuit.

GEMINI

In the two-man spaceflight program, Gemini, NASA faced the problem developing a fully pressurized spacesuit that would allow a member of the crew to leave the spacecraft for varying lengths of time and to operate in a micro-gravity environment of extreme temperature differences.

The basic Gemini suit had some similarity to the Mercury suit. It was a multi-layered garment consisting of an inner comfort liner, a gas bladder, a structural restraint layer, and an outer protective cover. To make the suit easier to put on and take off, quick disconnectors were located at the wrists for gloves, at the neck for the helmet, and at the waist for ventilation-gas connections.

A pressure-sealing zipper was added to make dressing and undressing easier. Body wastes were taken care of by a disposal system built into the suit. The basic suit was also provided with handkerchief, pencils, survival knife, scissors, neck and wrist dams (worn during recovery operations after gloves and helmet have been removed to prevent water form entering the suit), a parachute harness, and special built-in pockets on the arms and legs to hold flight books and charts.

On the Gemini 4 mission , an astronaut left the spacecraft to become the first American to walk in space. For this new experience, the suit had to be slightly modified. A different extravehicular (EVA) outer layer was added to the basic suit as well as pressure-thermal gloves, a helmet visor with temperature control coating, and a sun visor. The EVA outer layer consisted of nylon material for micro-meteroid protection, seven layers of aluminized superinsulation , and an outer covering of high-temperature resistant nylon cloth.

An additional change in the Gemini spacesuit was made for the Gemini 7 flight. A "lightweight" suit was designed for use within the spacecraft only. Its purpose was to provide maximum protection as well as comfort and freedom of movement.

The suit had a soft fabric hood which replaced the hard pre-shaped helmet worn previously. The lightweight suit weighed only 16 pounds (7.3 kg).

The new suit had two layers of material: the inner layer was the pressure-restraining neoprene-coated nylon bladder, and the outer layer was 6-ounce (171 g) high-temperature resistant nylon The new suit made it possible to travel in a shirt-sleeve environment.

Other changes in the Gemini spacesuit occurred on Gemini 8. The outer protective cover, or micro-meteroid layer, was reduced. On Gemini 9, changes were made in the lower portion of the Astronaut maneuvering Unit.(AMU).

APOLLO

The Apollo spacesuit had to provide the astronauts with protection. It had to protect them from temperatures ranging from -250 to +250 degrees F (-147 degrees C to 113 degrees C). Not only did the moon explorers' spacesuits have to offer protection from jagged rocks and the searing heat of the lunar day, but the suit also had to be flexible enough to permit stooping and bending as the crewmen gathered samples from the Moon.

A backpack portable life support system provided breathing oxygen, suit cooling, and pressurization for moonwalks lasting up to eight hours.

The Apollo spacesuit's mobility was improved over earlier suits by the use of bellows-like joints at the elbows and knees.

From the body out, the Apollo spacesuit began with a liquid-cooling garment similar to a pair of long underwear with a network of spaghetti-like tubing sewn into the fabric. Cool water, circulated through the tubing, transferred the body heart from the astronaut's body to the backpack and thence to space.

Next was a layer of lightweight heat-resistant nomex, followed by a gas-tight bladder of Neoprene-coated nylon , a nylon resistant layer to prevent the bladder from ballooning, a lightweight super-insulation of alternating layers of thin Kapton and glass fiber cloth, several layers of Myler and space material and finally, protective outer layers of Teflon-coated glass fiber Beta cloth and Teflon cloth. The suit had a total of 21 layers of material in its makeup.

The Apollo helmet was formed from high-strength Lexan plastic, and was attached to the spacesuit by a pressure-sealing neckring. Unlike the Mercury and Gemini helmets, the Apollo helmet was fixed and the astronaut's head was free to move about inside. While walking on the moon, Apollo astronauts wore an outer visor over the bubble helmet to shield against eye-damaging ultraviolet radiation.

The "Dressed for Spaceflight" unit will help you find the answers to these questions.

1. Who was the first pressure suit designed for?

   ____

2. How many layers are there in Mercury suit?

   ____

3. What was added to the Gemini suit which made it easier to put on and take off?

   ____

4. Why did the space suit on Gemini 4 have to be modified?

   ____

5. When was the Gemini "lightweight" suit first used?

   ____

6. What did the Gemini "lightweight" suit allow the astronaut to do?

   ____

7. The Apollo space suits had to be flexible enough to allow the astronauts ______________ and ______________.

8. How long could astronauts stay out on the moon?

   ____

9. In the Apollo space suit, what purpose did the longjohns serve?

   ____

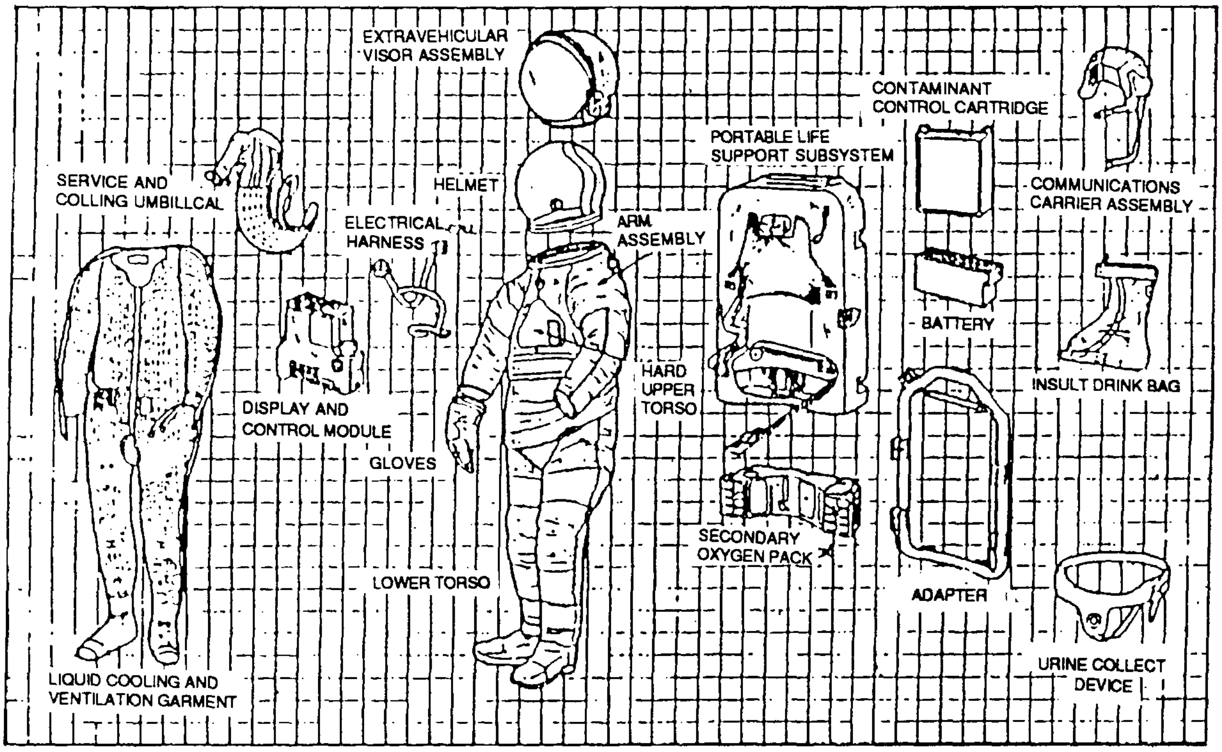
10. How many layers did the Apollo suits contain?

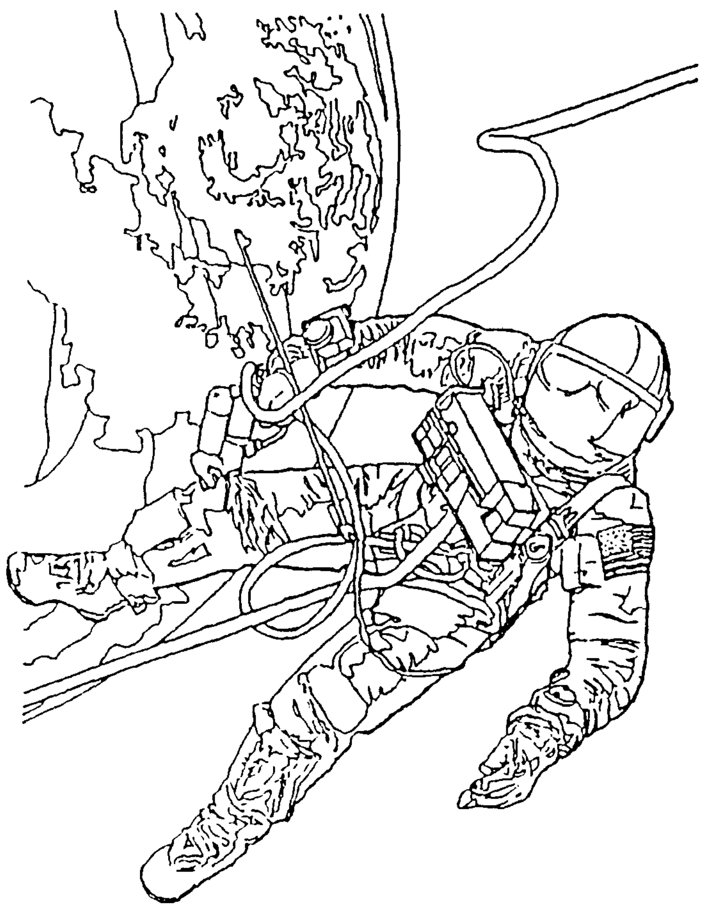
    ____

11. Why was an outer visor worn over the helmet during moon walks?

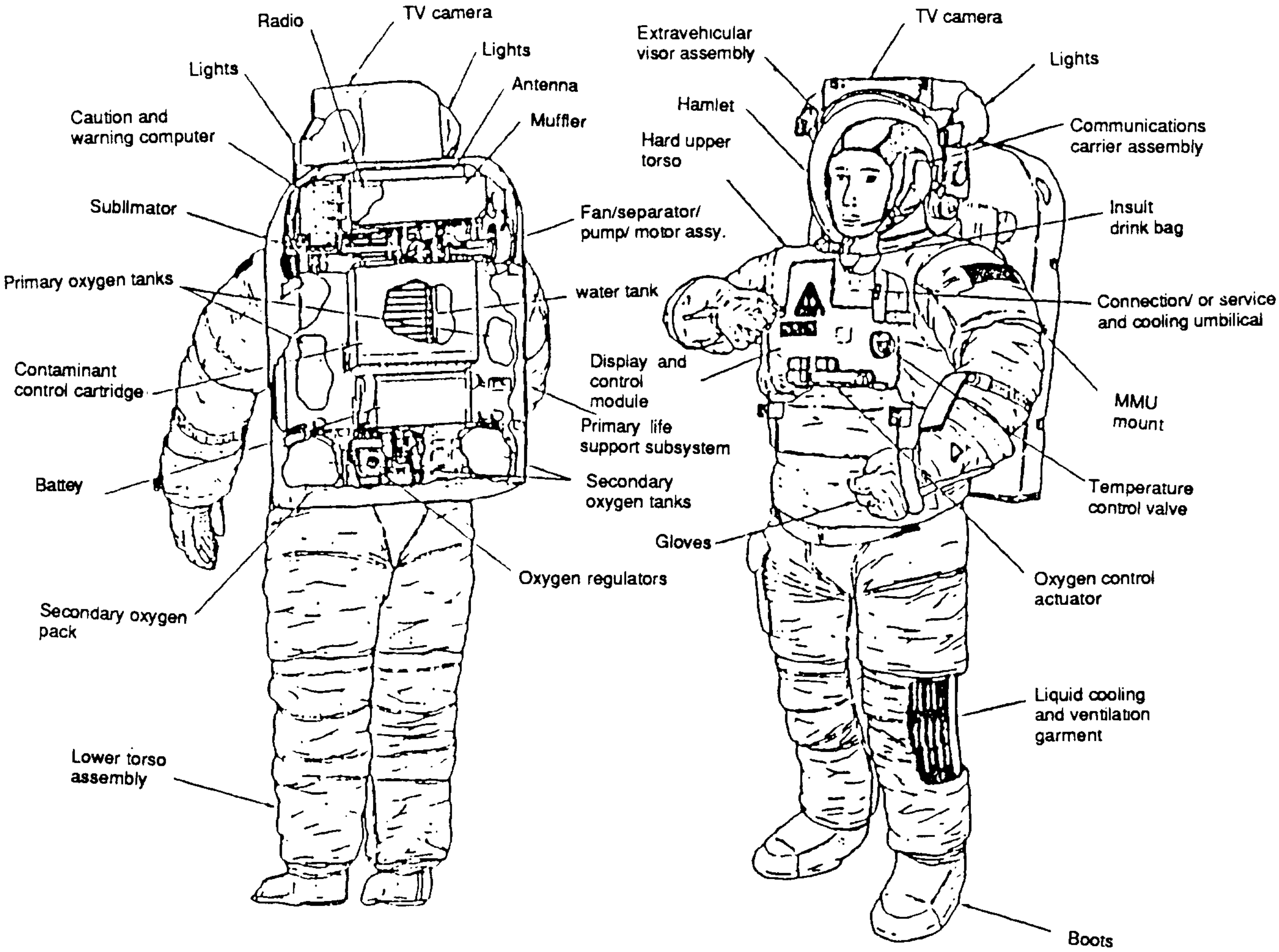
    ____

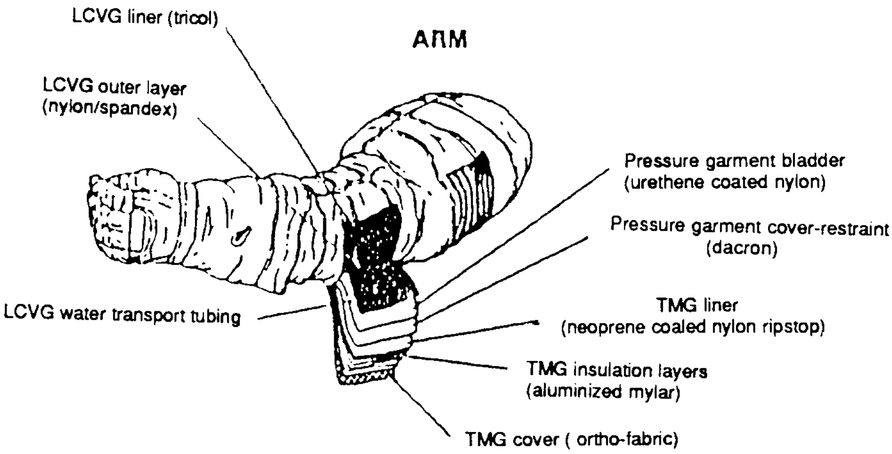
Space Suit/Life Support System or Extravehicular Mobility Unit





Extravehicular Mobility Unit





WASTE MANAGEMENT SYSTEMS FOR HUMAN SPACEFLIGHT*

For astronauts to live comfortably and safely in the closed environment of a spacecraft, the management of human waste is among the life support functions which be carried out efficiently. A spacecraft's waste management system must be reliable, sanitary, and psychologically acceptable to the crew. Systems to handle crew members' bodily waste have evolved from simple assemblies likes used on Mercury flights to the present-day complicated equipment on board the space shuttle orbiters. The systems have become easier to operate and more earth-like, a feat difficult to accomplish in the zero gravity of space, where materials and liquids tend to float about in a state of "weightlessness."

MERCURY

When Mercury flights began to extend into durations of over an hour provisions were made for handling human waste matter. Astronauts wore a urination bag contained in their spacesuits. On the flight of Mercury-Atlas 9, which lasted more than 24 hours, astronauts used a waste management system made up of two units, a urination bag and a storage bag with a syringe-pump and hose. The syringe provided pressure to draw the urine the in-suit bag to the storage bag.

Bags for defecations were not provided for any of the mercury missions. Crewmen ate a low-residue diet for three days prior to launch so they would not have a bowel movement. They carried emergency containers for emesis (vomiting), if vomiting should occur, on each of the Mercury missions.

During the Gemini program, astronauts used a system similar to that used in the Mercury program. It consisted on one urination bag for use during launch and another for use in-flight. The bag used during launch was Y-shaped. It fit on the inside of the spacesuit around the pelvis. The bag had two openings, one with a fitted rubber sleeve that the astronaut attached to this body, and another opening used for emptying the bag. The waste was dumped overboard the spacecraft through an overboard dump system.

The other system was used after the astronauts attained orbit. It was a flexible bag with a roll-on rubber sheath. The voided urine was then vented overboard.

Gemini missions 7 and 9 had a sample valve which allowed the astronauts to draw off a specimen of urine for medical examination back on earth.

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* Excerpted from *Human Spaceflight* by Hartsfield and Hartsfield, NASA.

The feces could be flushed overboard like the liquid waste because of the possibility of contaminating instruments on the outside of the spacecraft. On Gemini flights, the astronauts used a plastic bag with a 4-inch (10 cm) circular opening to collect the feces. first the astronaut placed a germicidal pouch in the bag to prevent or reduce gas and bacterial growth. Then he attached the bag to this buttocks using surgical-adhesive tape. After defecation, he removed the bag, placed soiled toilet tissues in it, and pressed the adhesive surfaces firmly together. The bags were then returned to earth in the spacecraft.

As in the Mercury program, Gemini astronauts ate low-residue foods prior to their flights and took emesis containers on the spacecraft.

APOLLO

For the manned missions to the moon in the Apollo program, provisions had to be made for collecting, inactivating, and stowing feces for 14-day periods.

The feces collection assemblies consisted of an inner bag, germicide, and an outer bag. The inner bag was nearly identical to and was used the same way as the bag in the Gemini program. After use the inner bag was placed in the outer bag, pressed to rupture the germicide pouch, and stowed in a waste compartment. The compartment was vented to space to remove odors.

There was also a fecal containment system worn by the astronauts under their pressurized suits during extravehicular activities. The system functioned like a baby's diaper to allow for emergency defecation. It was an elastic underwear with an absorbent liner around the buttock area.

There were basically two modes for collecting urine, depending on whether or not the astronaut wore his pressurized spacesuit. While wearing his spacesuit, an astronaut urinated into a detachable roll-on cuff connected to a flexible rubber-coated fabric bag. The urine collection systems of the command module and the lunar module had a basic difference. The system in the command module dumped the urine overboard; the system in the lunar module store it to prevent contamination of the lunar surface.

In the command module, the astronauts used with a funnel or a roll-on cuff receiver with a bag and an outlet for attachment to the waste management system. Each Apollo crewman had his own cuff-and-bag device.

Read the description of the Waste Management Systems used in spaceflight, then answer the questions below.

1. What are the three main requirements a waste management system must meet:

    ____________________,
    ___________________, and
    ___________________________.

2. On a Mercury mission only one form of human waste had to be handled. Name that form.

    ____

    Why only one?

    ____

3. What is emesis?

    ____

4. On Gemini missions what was the shape of the urine bag used during launch?

    ____

5. On the Gemini missions, after urine was eliminated from the astronaut's body, what happened to it?

    ____

6. On what missions were the first samples of urine collected for medical examination?_________________

7. What type of bag was used on Gemini to collect the solid waste material?

    ____

8. How long were the Apollo missions?

    ____

9. During extravehicular activities the Apollo astronauts wore a fecal containment system under the pressurized suits. It looked like a

    ____

10. Why was urine <u>not</u> dumped overboard the lunar module while it sat on the moon?

____

Who Am I?

4 R	9 A	6 K	8 S	10 C	5 G	7 S
9 R	6 E	8 T	10 U	9 M	7 H	9 S
8 A	6 R	4 I	5 L	7 E	9 T	10 N
9 R	10 N	5 E	7 P	6 W	10 I	8 F
9 O	5 N	7 A	8 F	4 D	10 N	9 N
5 N	7 R	8 O	10 G	9 G	6 I	10 H
7 D	10 A	10 M	8 R	6 N	8 D	4 E

Find out who the famous astronaut is. Count the number of letters is your name. If you have less than 4 letters, add 2. If your name has exactly 4 letters do not add or subtract - use that number, 4. If you have more than 10 letters in your name subtract 3 and use that number. Place your number in the box in the upper right hand corner of the page. Follow the chart from left to right and work down, starting in the upper left corner of the chart. List all the letters that go with your number and discover your famous astronaut.

HUMAN REACTION TIME*

PART I

During a space flight astronauts are required to be able to respond quickly to any given situation. Unexpected problems may arise during a space flight that require a rapid response to the problem. The faster the reaction time of an astronaut and the crew, the better they will have in dealing with a given situation.

Students can measure their reaction time by using the reaction time card (following page) in this manner:

1. Divide the class into teams of two students each. While one does the activity, the other student time his/her responses.

2. Have one student start with a finger on square one and touch each square in numerical order. The other student should record the time. Then have the same student touch the squares in reverse order. Record the time again.

3. Students should then reverse roles.

4. Allow the students to do the activity for 2 or 3 days in a row to see if their reaction time improves.

5. Compare results of boys versus girls, age groups, left-handed versus right-handed students, etc., by recording group averages on the blackboard.

6. Allow students to put their own symbols in the blank squares. They might try to devise an ordering system which is faster than numbers.

10 seconds . . . . .slow
9 seconds . . . . .average
8 seconds . . . . .very good
7 seconds . . . . .excellent

---

* Excerpted by *Human Spaceflight* by Hartsfield and Hartsfield, NASA.

Reaction Time Card

TIME ________ SECONDS

8	11	5	2
1	12	9	7
6	3	10	4

TIME ________ SECONDS

TIME ________ SECONDS

4	11	7	1
6	9	10	5
2	8	12	3

TIME ________ SECONDS

Numerical

Day 1___________Time

Day 2___________Time

Day 3___________Time

Reverse

Day 1_____Time

Day 2_____Time

Day 3_____Time

Note: Try with the other hand to see if there is a difference in reaction time.

HUMAN REACTION TIME

PART 2

Another method of measuring a person's reaction time is with the scale included here. Duplicate the scale and paste it over a meterstick. The heavy black line should be taped at bottom, then paste the other strip at the bottom of the first one. The markings are in 1/100ths of a second.

1. Divide class into teams, 3 or 4 in each team.

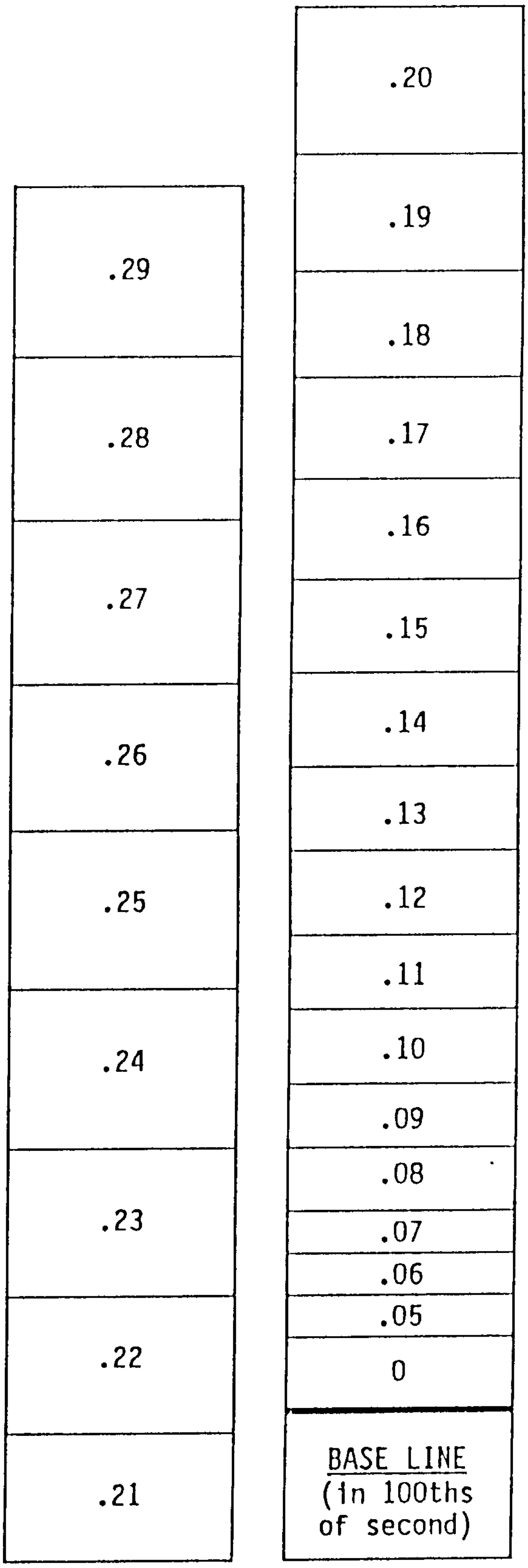
2. Taking turns, have one student rest his/her right or left forearm on table or desk top with hand extended over the edge. Have another team member drop the meterstick so that it passes vertically between subject's index finger and thumb, so that he/she may catch it after it starts to fall.

3. The student should start with thumb and index finger apart and width of the meterstick. This way a standard width is used by all persons.

4. Start by placing meterstick at zero between student's thumb and index finger. Release stick and have student catch it.

5. Record the number where student's finger grasp the stick. Note: If stick is missed the score is 29, not zero.

6. Have each student perform the test three times and take an average.



7. Try another way. Tape a child's small cricket clicker to top of meterstick. Blindfold student and have him/her catch the stick with eyes closed, responding to the "click" of the clicker.

8. Repeat 3 times and take an average.

Have students record their averages, both sight and sound. Is there a difference? Does everyone have the same reaction time?

A SOFT LANDING?*

Landing a spacecraft with scientific instruments or astronauts aboard on the moon or another planet is unlike landing on the Earth. Since those bodies have no atmosphere, or a very thin one, landing will be difficult. Parachutes cannot be used because no air, or very little air, is available to operate them. Also, the pull of gravity by each of the bodies is different. However, for this activity we will use the earth's gravitational pull.

An activity to illustrate this problem is an EGG DROP.

1. Discuss with class the problems of landing in a thin atmosphere.

2. Class could be divided into cooperative groups of 2 or 3 students.

3. Each group should be given a raw egg, which should first be placed in a ziplock plastic bag to eliminate mess in the event of an unsuccessful landing. The raw egg is to be packaged in a container approximately 6" x 6" (15 cm x 15 cm) with no outside fins to assist in the descending of the egg.

4. If possible, secure help from local airport people. Have a pilot drop the eggs from the plane at 500 feet (150 m) altitude over the school grounds or a near open area.

5. If a plane is unavailable, use a different approach. Give each student a raw egg, a plastic bag, and 2 full pages from newspapers. Students are to place the egg in the bag. The egg should be dropped from a second or third story window, or the roof of a one-story building, using only the 2 pages of newspaper to control the descent. The students may use the paper in any way they wish.

6. Allow a few days for student to research their project.

7. Any cracked or broken egg will be considered a failure in protection of the student's payload.

8. After the experiment discuss with students better ways of packaging their payload.

9. Check the library to see what NASA has used, and also what is considered a safe landing speed.

10. Ask students what types of problems one would have landing a payload on Venous, Jupiter or other planets.

Note: Another variation of the Egg Drop activity is to assign it as a project (or make it optional for extra credit) to be done together with a parent or guardian at home. This is a way to involve parents in learning. Parents or other helpers could be invited to school on "drop day."

---

* Excerpted from *Human Spaceflight* by Hartsfield and Hartsfield, NASA.

EXCERCISING FOR SPACEFLIGHT

It is necessary for astronauts traveling in space to maintain good physical fitness. Due to limited space in the cabin, activities to maintain good physical fitness must be designed for these areas.

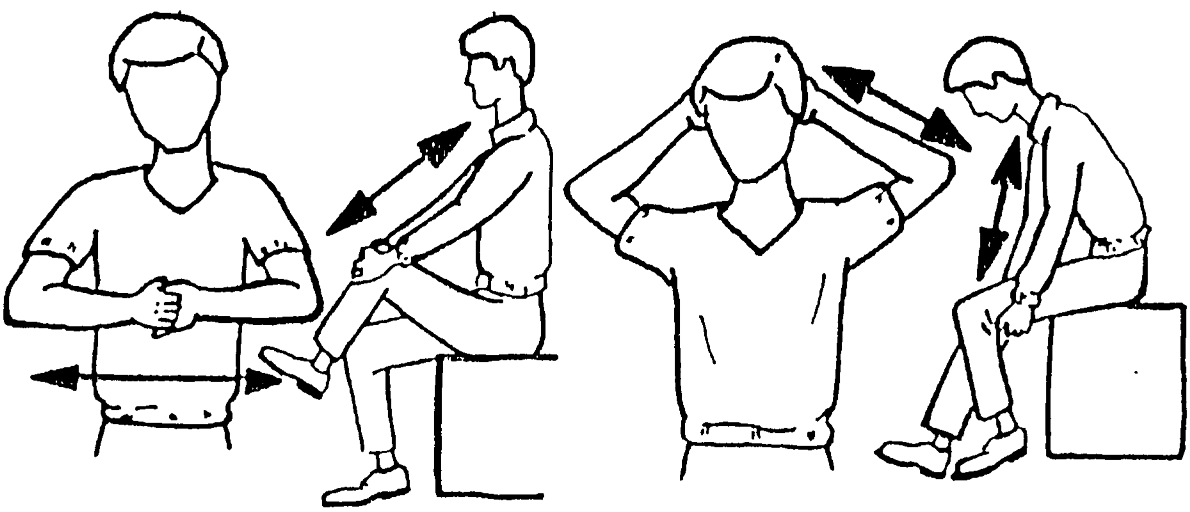
To simulate exercise done by the astronauts while in flight, try the following basic isometrics:

1. Grasp the right hand in left hand and pull in opposite directions while hands are held together for 5 seconds, 10 seconds, and 20 seconds.

2. Grasp left leg at the knee with clasped hands. Pull leg toward chest 10 times. Repeat procedure with other leg.

3. Clasp hands behind head. Pull in opposite directions.

4. In a seated position, clasp hands under legs. Pull in opposite direction.



PULSE RATE TEST

Astronauts must be in good physical condition to fly in space.

To give students an understanding of some of the activities astronauts use to stay fit, let them their pulse rate under various conditions. In addition to locating a step approximately 18 inches (46 cm) high, you will need the following materials; chart for recording pulse rate (see below) and pencils.

1. Divide the class into teams. Have the students take their partner's pulse rate at rest, and record it for future reference. The teacher may need to assist the students in the beginning so the proper technique is used when the pulse rate is taken.
2. Have students step up onto the step and down again at a rapid rate for 2 or 3 minutes -- approximately 20 times.
3. Wait 3 minutes; again take pulse and record it. Repeat after 5 minutes. Compare to the previous pulse rates.

PULSE RATE CHART

	NAME	AT REST	IMMEDIATELY FOLLOWING EXERCISE	3 MINUTES AFTER EXERCISE	5 MINUTES AFTER EXCERCISE
1.					
2.					
3.					
4.					
5.					

CODED MESSAGES

During a spaceflight a large quantity of data has to be transmitted back to earth at a high speed. To speed up the flow rate, it is easier to send this information in a coded system.

The statements below are in code. In this code, the number A is 11 because it is in the first row, first column; for K, 25 (row 2, column 5); and N, 33. Note that since I and J are together, to use other letters in a word using I or J will be the clue as to which letter to use.

	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I/J	K
3	L	M	N	O	P
4	Q	R	S	T	U
5	V	W	X	Y	Z

42 45 43 43 24 11 33   13 34 43 32 34 33 11 45 44   54 45 42 24

22 11 22 11 42 24 33   12 15 13 11 32 15   44 23 15   21 24 42 43 44

35 15 42 43 34 33   24 33   43 35 11 13 15.   11 31 11 33

43 23 15 35 11 42 14   52 11 43   44 23 15   21 24 42 43 44

11 32 15 42 24 13 11 33   24 33   43 35 11 13 15.   15 14

52 23 24 44 15   52 11 43   44 23 15   21 24 42 43 44

35 15 42 43 34 33   44 34   11   43 35 11 13 15   52 11 31 25.

23 11 42 42 24 43 34 33   43 13 23 32 24 44 44   52 11 43   44 23 15

31 11 43 44 35 15 42 43 34 33 44 34 52 11 31 25 34 33

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

44 23 15 32 34 34 33. 31 24 43 44 12 15 31 43 52 44 23 15

_ _ _ _ _ _ _. _ _ _ _ _ _ _ _ _ _ _ _

14 11 44 15 11 33 14 32 24 43 43 24 34 33 21 34 42 15 11 13 23

_ _

34 44 23 15 43 15 35 15 34 35 31 15.

_ _ _ _ _ _ _ _ _ _ _ _.

---

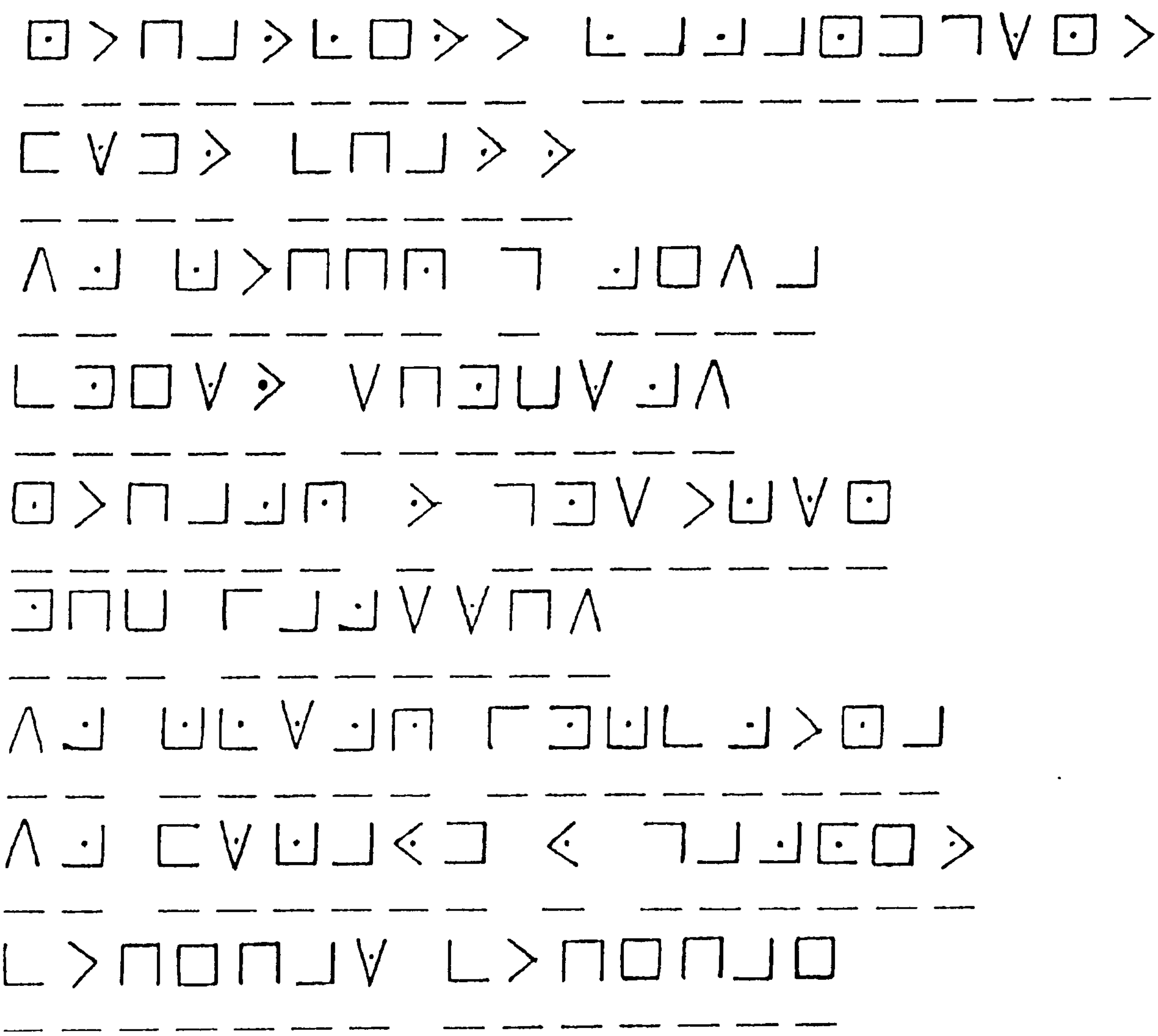
1. Write a message below, then encode it into a number code on a separate piece of paper. Give it to a friend to decode.

---

2. Invent a new code system of your own and write a message using it. See if a friend can "break" your code.

SPACE TRAVELERS

Below are the coded names of famous space travelers. To find out their names, solve the code by substituting a letter for each shape. Then, in the space provided on the next page, tell something unique about each one.



1.
2.
3.
4.
5.
6.
7.
8.
9.

1. --

2. --

3. --

4 --

5. --

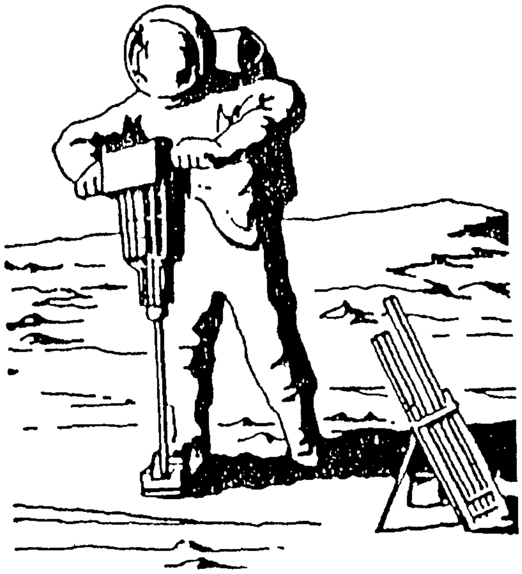
6. --

7. --

8. --

9. --

UNSCRAMBLE THE WORDS



APOLLO	AIRLOCK
FUEL CELL	PAYLOAD
OXYGEN	RUNWAY
ORBIT	DEHYDRATION
PRESSURE	SOYUZ
SATELLITES	ASTRONAUT
MECO	MATE
COSMONAUT	SPACE STATION

1. KOCAIRL

2. YZOUS

3. NEDHYDRATIO

4. LLEUFELC

5. LPOALO

6. TOMCOUASN

7. TSNAARUOT

8. DYPAAOL

9. OCEM

10. AMET

11. ILTLESTESAT

12. XGOYNE

----

13. TIRBO

----

14. YAWUNR

----

15. RSSUPREE

----

16. TTSSNOIAAEPC

PRONUNICATION SKILLS

Match the following words with their correct dictionary pronunciation

1.	ASTRONAUTS	___	RE-'EN-TRE
2.	LUNAR	___	'OR-BET-ER
3.	REENTRY	___	'SPLASH-, DAUN
4.	GEMINI	___	'LU-NER
5.	MICROGRAVITY	___	'SAT-L-,ĪT
6.	ORBITER	___	'TRED-MIL
7.	SATELLITE	___	'AS-TRE-,NOT
8.	SPLASHDOWN	___	'KAZ-ME-,NOT
9.	TREADMILL	___	'AK-SI-JEN
10.	SPACE SUIT	___	'MI-KRO-'GRAV-ET-E
11.	OXYGEN	___	'SPA-,SUT
12.	COSMONAUT	___	'JEM-E-NI

How many syllables are in each of the following words:

1.	___	fallout	8.	___	Apollo
2.	___	spacecraft	9.	___	suborbital
3.	___	orbit	10.	___	Enterprise
4.	___	shuttle	11.	___	countdown
5.	___	booster	12..	___	runway
6.	___	spacelab	13.	___	atmosphere
7.	___	revolution	14.	___	airlock

COMPOSITION: WRITING A PARAGRAPH

Write a paragraph on one of the topics listed below. Be sure to follow the guides printed here for you.

HOW TO WRITE A PARAGRAPH

Have your topic clearly in mind.
Indent the first word of the paragraph
Write a first sentence that will suggest the topic
Make sure that every sentence keeps to the topic.
Make every sentence develop or tell more about the topic.
Begin and end each sentence correctly.
Include at least four sentences.

SUGGESTED TOPICS

1. Apollo Mission
2. Space Shuttle
3. Astronauts
4. Living in Space
5. Space Station
6. A space-related topic of your choice: ____________________

SPACE SPELLING

1.	Gemini	11.	Apollo	21.	Payload
2.	Orbit	12.	Soyuz	22.	Telescope
3.	Shuttle	13.	Cosmonaut	23.	Deorbit
4.	Aerospace	14.	Astronaut	24.	Gravity
5.	Mercury	15.	Spacesuit	25.	Rocket
6.	Boosters	16.	Docking	26.	Oxygen
7.	Orbit	17.	Orbiter	27.	Weightlessness
8.	Cockpit	18.	Cabin	28.	Armstrong
9.	Reentry	19.	Skylab	29.	Glenn
10.	Spacelab	20.	Runway	30.	Shephard

Suggestions for spelling activities. Select one activity each day.

1. Divide words into syllables. Use the dictionary to check spelling and mark the vowels.

2. Put words into alphabetical order.

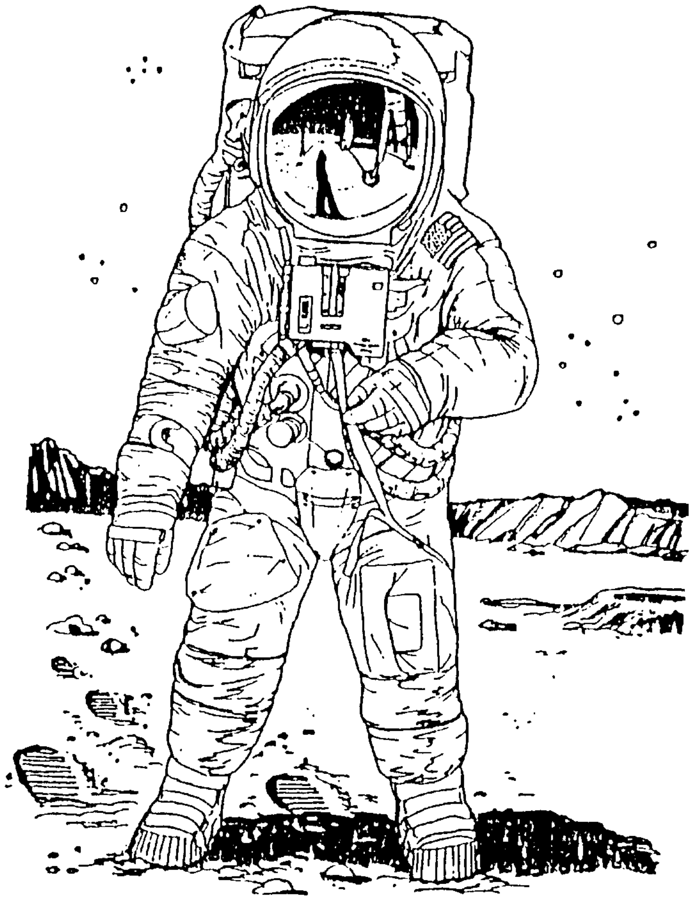
3. Look up the definition of each word and copy it on your paper. Now use the word in a sentence which uses that definition.

4. Create a wordsearch. Be neat! Someone else will be finding the words you hide in the puzzle.

5. Create a story using 10 or 15 of these words. Underline each word used. Have some of the words misspelled. Ask other students to proofread the story. If an underlined word is misspelled, write it correctly. If the words is spelled correctly, make an asterisk (*).

SUBJECT AND VERB

Draw a line between the subject and the predicate. Draw one line under the simple subject. Draw two lines under the verb in the predicate.



Neil Armstrong landed on the moon July 20, 1969.

He said, "God's speed all the way, John Glenn."

Deployable, erectable, and manufactured are the three main kinds of large space structures.

Astronaut Edward White made the first space walk on Gemini 4.

Guion Bluford is the first American black astronaut to perform a spaceflight.

One June 18, 1983, Sally Ride became the first American woman to fly in space.

The Apollo 13 mission was aborted after the service module oxygen tank ruptured.

Apollo 17 was the first night launch of American Astronauts.

In July of 1975, a U.S. spacecraft docked with a Russian spacecraft in the ASTP program.

The Mercury program is the name of the one-man space missions.

The Gemini 7 astronauts made the first docking of one space vehicle with another.

The USS Hornet served as the recovery ship for Apollo 12.

The astronauts on the Apollo-Soyuz mission made the last scheduled water landing.

"Houston, Tranquility Base here, the Eagle has landed."

To remain seated on the shuttle toilet, the user must insert feet into foot restraints and snap together the seat belt.

Around the year 2000, NASA plans to erect a lunar base on the moon.

SUBJECT AND PREDICATE

Write each subject below. Add a predicate to each subject and make a complete sentence. Use punctuation and capital letters correctly.

1. the first moon explorers
2. Russian Yuri Gagarin
3. spacelab
4. Apollo
5. Skylab
6. spacesuit
7. redstone
8. external tank
9. space station
10. lunar rover

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____

DICTIONARY SKILLS

Part I

From the list on the next page, find the word that goes best with the definition. Words should be used only once.

---

1. A person who flies in space, whether as a crew member or a passenger.

---

2. The first stage of a missle or rocket.

---

3. A body of small mass but larger volume compared to a planet, often developing a long, luminous and partly transparent tail when close to the sun.

---

4. The Russian term for what in the U.S.A. is called an astronaut.

---

5. The hours, minutes, and finally the seconds, of time remaining before the launch of a rocket.

---

6. The technique of connecting two or more spacecraft in space.

---

7. A device which protects people or equipment from high temperatures, in front of a reentry capsule as it reenters the earth's atmosphere.

---

8. Of or pertaining to the moon.

---

9. National Aeronautics and Space Administration

---

10. An orbit which passes over the north and south poles.

---

11. Engines or devices fired to reduce the speed of a spacecraft.

---

12. Useful cargo carried aboard a spaceship.

13. America's reusable space ship

14. The United States' first human space program.

15. The act of going outside the spacecraft.

16. Name for the U.S. two-man space mission.

17. To come into or go out of orbit.

18. Joint United States and U.S.S.R. space mission launched in 1975.

19. Clothing worn by an astronaut for EVA.

20. Used as a life support system for extravehicular activity.

a)	backpack	h)	lunar	o)	heat shield
b)	deorbit	i)	booster	p)	astronaut
c)	Gemini	j)	comet	q)	docking
d)	cosmonaut	k)	polar orbit	r)	ASTP
e)	Mercury	l)	countdown	s)	retro-rockets
f)	payload	m)	spacesuit	t)	NASA
g)	shuttle	n)	extravehicular		

DICTIONARY SKILLS

PART 2

Place the Space Vocabulary words listed below in the blanks shown between the correct dictionary guide words.

1. abort
2. yaw
3. telescope
4. deorbit
5. satellite
6. payload
7. Vostok
8. cockpit
9. runway
10. gravity
11. cosmonaut
12. spacesuit
13. rocket
14. astronaut
15. docking
16. boosters

1. dentil ______________________________ dependable
2. ruble-seat ______________________________ rupee
3. astragalus ______________________________ atavism
4. pawn ______________________________ peach
5. voluptuous ______________________________ vulcanite
6. cochlea ______________________________ codfish
7. satchel ______________________________ sauna
8. graupel ______________________________ grease
9. boogie-woogie ______________________________ borax
10. xylophone ______________________________ yearling
11. docile ______________________________ dormitory
12. teleran ______________________________ tendon
13. Cosmoline ______________________________ cotter
14. rocker ______________________________ rogue
15. spa ______________________________ spar
16. ablaza ______________________________ absent

FIRST WORDS RECORDED FROM THE MOON

A	D	E	F	G	H	I	K	L	M	N
16	54	14	50	25	48	81	33	30	40	24

O	P	R	S	T
36	49	42	21	12

On July 2, 1969 at 10:56 p.m., Astronaut Neil Armstrong put his left foot on the moon. It was the first time in history that man had ever stepped on anything that had not existed on or originated from the earth. The first words said by Astronaut Armstrong are famous words today. Work the problems below to find out what Armstrong's first words were.

___	___	___	___	___		___	___	___
4	8	4	6	7		9	3	2
x3	x6	x4	x2	x3		x4	x8	x7

___	___	___	___	___		___	___	___	___
3	8	2	6	10		18	10	9	23
x7	x5	x8	x5	3		x3	+2	+5	+16

___	___	___		___		___	___	___
35	18	20		11		16	9	19
+15	+18	+22		+5		+24	+7	+5

___	___	___		___	___	___	___	___
12	12	7		5	9	2	6	2
x3	x2	x7		x5	x9	x8	x4	x6

___	___	___	___		___	___	___
5	7	8	7		94	74	87
x6	x2	x2	x7		-44	-38	-45

___	___	___	___	___	___	___
63	32	60	77	122	79	111
-23	-16	-36	-44	-41	-55	-57

ASTRONAUT HUNT

W	O	R	D	E	N	A	L	D	R	I	N
T	N	A	I	L	C	O	L	L	I	N	S
C	A	S	H	E	P	A	R	D	O	T	W
I	D	H	M	U	B	E	A	N	Y	L	I
R	T	A	A	R	M	S	T	R	O	N	G
W	H	I	T	E	G	T	S	D	U	K	E
I	R	S	T	E	V	A	N	S	N	C	R
N	B	E	I	L	O	F	E	N	G	O	T
C	E	R	N	A	N	F	W	U	F	N	O
O	L	D	G	S	C	O	T	T	E	R	L
G	U	F	L	O	A	R	O	O	S	A	N
N	A	T	Y	A	N	D	E	R	S	D	S

Find these Apollo astronauts in the puzzle

CONRAD	BEAN
SCOTT	ROOSA
ANDERS	HAISE
MATTINGLY	SHEPHARD
DUKE	WORDEN
COLLINS	STAFFORD
IRWIN	WHITE
ALDRIN	ARMSTRONG
YOUNG	SWIGERT
EVANS	CERNAN

FIND A WORD ABOUT THE MOON

S	A	T	E	L	L	I	T	E	A
U	B	O	A	X	M	A	L	M	B
N	T	Q	R	P	O	P	S	E	A
A	G	E	T	D	O	O	O	G	S
H	I	J	H	K	N	L	L	M	A
O	R	B	I	T	N	L	A	A	L
Q	S	T	L	U	N	A	R	R	T
R	O	C	K	P	L	A	N	E	T

MARE

BASALT

MOON

ORBIT

EARTH

AGE

SEA

ROCK

LUNAR

SOLAR

SATELLITE

Potential Personnel for Moon Colony

NOTICE: Because of budgetary cut-backs, the funds for personnel for the moon colony has been drastically cut. You will be able to select only ten people to staff the colony in the beginning. List them, giving the reasons for their selection. Each person would be expected to stay on the colony for at least six months.

If funds become available, some of you will be able to select five more individuals. Those decisions will depend on the reasons you state for the five additional staff you decide to take if possible. Be sure that your statements are convincing!

Medical doctor	Nurse	Lawyer	Teacher
Cook	Military person	News Reporter	Librarian
Policeman	Computer Expert	Communication	Minister
Politician	Astronaut	Expert	Janitor
Administrator	Fireman	Psychiatrist	Pharmacist
Aeronautical Engineer	Astronomer	Geologist	Meteorlogist
Rocket Expert	Mathematician	Entertainer	Historian
Mechanic	Chemist	Biologist	Other

LUNAR LANDER

E 3	O 8	A 6	I 4	C 9	F 7	A 5
Q 5	H 9	A 3	R 8	A 7	N 6	N 4
T 4	A 9	U 5	T 6	G 3	L 9	L 7
C 7	L 9	E 9	R 4	I 8	A 6	A 5
R 5	R 6	L 3	N 9	E 4	G 9	E 6
E 3	E 9	P 4	I 5	I 4	O 8	D 4
O 7	U 5	R 9	N 8	N 7	S 6	S 5

Count the number of letters in your first name. If you have less than 5, add 2. If you have more than 10, subtract 3. Follow the chart from left to right and work down listing all the letters that go with your number and discover your *Lunar Lander.*

LUNAR LANDER QUESTIONS

1. What is the name of your "Lunar Lander"?

2. What mission was your "Lunar Lander" used on?

3. Did your "Lunar Lander" land on the moon?

4. List the name of the three astronauts on your mission?

   ________________________, __________________ and

   ________________________.

5. List the names of the two astronauts who walked on the moon during your lunar landing?

   ________________________ and

   ____

6. How long were the astronauts on the moon?

   ____

7. What was the launch date of your "Lunar Lander"?

   ____

8. How many days did your mission take?

   ____

9. List the amount of lunar rock samples collected during your mission.

   ____

10. What was the name of the command module used your mission?

    ____

11. What was the name of the command module used on your mission?

    ____

12. Was your recovery ship used for any other mission?

    ____

APOLLO LANDING SITES

There have been six manned landings on the moon. Below is a listing of the latitude and longitude of each landing. Locate each Apollo landing site on the moon photo preceding this page. Place a capital "A" and the flight number at the landing site: Example A-11

APOLLO 11

Landed in the Sea of Tranquility (00.6° N Latitude/23.5° E Longitude

APOLLO 12

Landed in the Ocean of Storms (03.0° S Latitude/23.4° W Longitude

APOLLO 14

Landed at Fra Mauro (03.7° S Latitude/17.5° W Longitude

APOLLO 15

Landed at Hadley-Appenine (26.1° N Latitude/03.7° E Longitude)

APOLLO 16

Landed at Descartes (09.0° S Latitude/15.5° E Longitude)

APOLLO 17

Landed at Taurus-Littrow (20.0° N Latitude/30.0° E Longitude)

Which of the Apollo landing sites was the furthest North?

Which of the Apollo landing sites was the furthest East?

Which of the Apollo landing sites was the furthest South?

DIRECTIONS ON THE MOON

By agreement of the astronomers, it has been decided that on the moon, east is the direction in which the sun rises, and west the direction in which the sun sets. Therefore, Mare Crisium is on the east side of the moon and Mare Humorum on the west. North is at the top of the lunar maps that you will use during your study of the moon.

The moon also has longitude and latitude. A point near the crater Bruce is the starting point for measuring the lunar coordinates -- longitude 0°, latitude 0°. A north latitude is measured towards the moon's north pole.

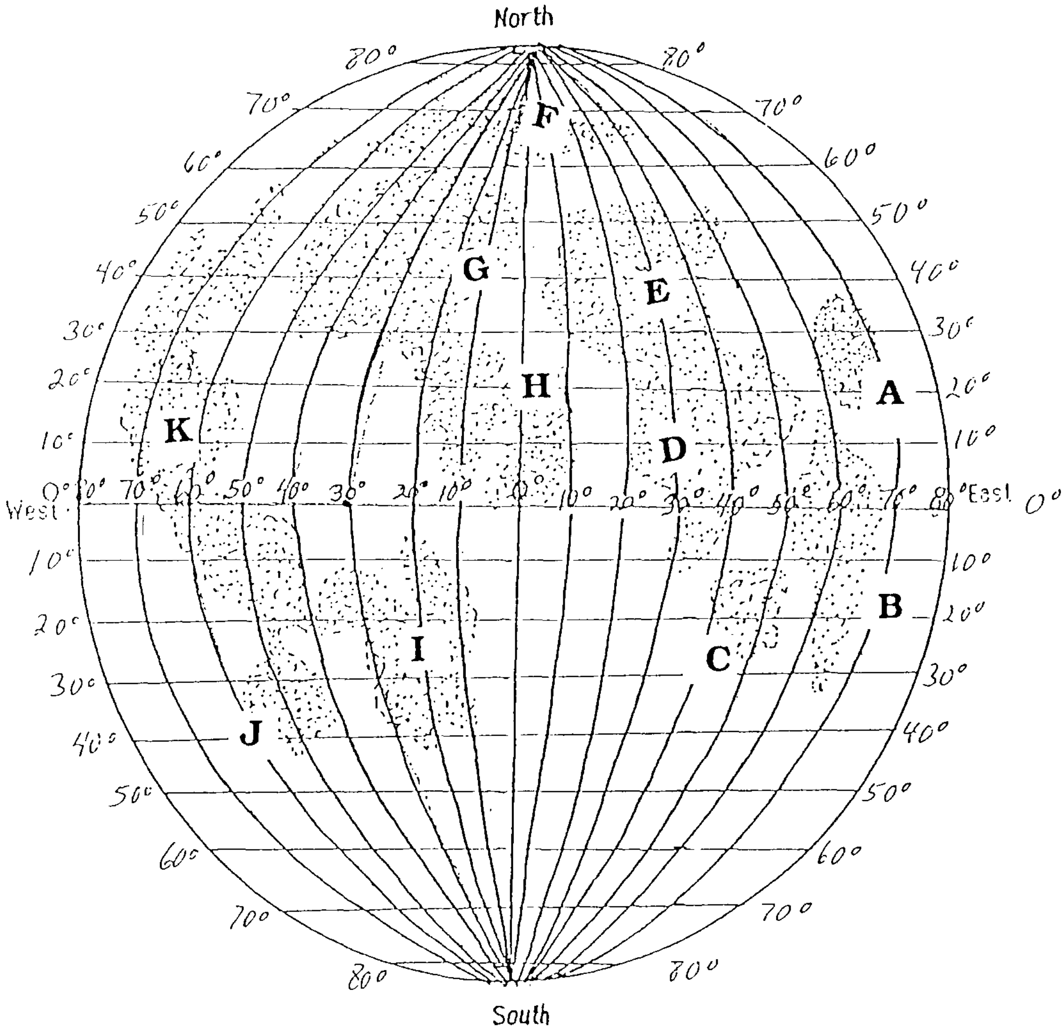
Longitude is measured east or west on a moon map. From the center (0°) towards the east side of the moon is east longitude. West longitude is towards the west.

If you were at the moon's equator, one degree of longitude is equal to 18.84 miles (30.38 km). That means to go from 18° east longitude to 19° east longitude you would have to go 18.84 miles (30.38 km). To travel one degree longitude on Earth's equator you would have to go a little over 69 miles (111 km).

Find the following craters on the moon map.

Crater	Latitude	Longitude
Bruce	1°N	0°
Copernicus	10°N	20°W
Atlas	47°N	44°E
Tycho	43°S	11°W
Lockyer	46°S	37°E

Moon Map



Key
A. Mare Crisium (Sea of Crisis)
B. Mare Fecunditatis (Sea of Fertility)
C. Mare Nectaris (Sea of Nectar)
D. Mare Tranquillitatis (Sea of Tranquility)
E. Mare Serentatis (Sea of Serentity)]
F. Mare Frigoris (Sea of Cold)
G. Mare Imbrium (Sea of Showers)
H. Mare Vaporum (Sea of Vapors)
I. Mare Nubium (Sea of Clouds)
J. Mare Humorium (Sea of Moisture)
K. Oceanus Procellarum (Ocean of Storms)[1]

HUMANS TO THE MOON

To introduce the Apollo program and the might Saturn V rocket you should do the following activity. Once you have completed it, you will have a greater appreciation of how powerful the saturn rocket was. The first thing you need to do is to go and have someone time how long it takes for you to run one hundred feet (60 m). Round the amount of time off to the nearest whole second. For example, if it took you 8.2 seconds to run the hundred feet round the time off to eight seconds. On the other hand, if your time was 8.6 seconds, round your time off to 9 seconds. Now refer to the Time Chart to Run to the Moon. Find out how many days it will take you to run to the moon at the place you ran without ever stopping to eat or sleep.

TIME CHART TO RUN TO THE MOON

Time to Run 100 Ft (or 60m) (Seconds)	Time to Run to the Moon (Days)
5	730.2 (365.1)
6	876.4 (438.1)
7	1022.2 (511.1)
8	1168.7 (584.2)
9	1314.6 (657.2)
10	1460.8 (730.2)
11	1606.2 (803.2)
12	1752.2 (867.2)
13	1898.3 (949.3)
14	2046.2(1022.3)
15	2190.7(1095.4)
16	2336.3(1168.4)
17	2481.8(1241.4)
18	2629.3(1314.5)
19	2775.8(1387.5)
20	2921.8(1460.6)

The three man astronaut crew rode to and from the moon in the Command Module. Two crew members descended and ascended from the surface in the Lunar Module. The third crew member remained behind in the Command Module. The crew consisted of a commander, command module pilot, and lunar module pilot.

On the surface the astronauts collected rocks, set up specific stations, and photographed the moon. After their work was done on the lunar surface, the two astronauts left the lunar surface in the ascent part of the Lunar Module. Once rejoined with the third astronaut, they fired the engines of the service module to provide the speed necessary to escape the lunar gravity to return to Earth.

The crew reentered the Earth's atmosphere in the Command Module which had a heat shield. Parachutes were used to slow the spacecraft down before splashdown in the ocean. The astronauts were recovered by a recovery ship.

Six crews of astronauts landed on the moon. For each of these Apollo missions find the landing site on the lunar map. The locations are given as part of each mission's description. It should be noted that the landing latitudes and longitudes have been rounded off to the nearest whole degree.

Apollo 11, July 16-24, 1969. This was the first manner lunar landing. The landing site int eh Sea of Tranquility was selected because it allowed for a "free return" orbital path for the translunar on the surface, a lunar sample was immediately collected to ensure the return of lunar surface material to Earth in case of an emergency cancellation of the moon walk activities. About 48 pounds (27.6 kg) of moon rocks were collected.

Landing site: **1° N. Latitude**
23° E. Longitude

Apollo 12, November 14-24, 1969. The crew landed on a ray from the crater Copernicus in the Ocean of Storms. This was the first time that Apollo Lunar Surface Experiment Package (ALSEP) was used. The ALSEP consisted of six experiments and a central station One of the experiments was to detect moonquakes. The landing site was very near the Surveyer 3 spacecraft. Parts of which were retrieved and returned to Earth for study. Two moon walks were made. About 75 pounds (34 kg) of moon rocks were collected.

Landing Site **3° S. Latitude**
23° W.Longitude

Apollo 14 January 31-February 9, 1971. The crew landed in the Fra Mauro region. There were two moon walks. This was the first use of the modular equipment transporter (MET). The MET is really a lunar rickshaw. The astronauts set off small explosive charges to create seismic waves which could be studied to learn more about the lunar surface. In addition, this was the first time that lunar astronauts experienced working in hilly terrain or more properly for the moon, lurain. The astronauts walked about three miles on foot. About 95 pounds (43 kg) of moon rocks were returned to Earth.

Landing Site **4° S. Latitude**
17° W. Longitude

Apollo 15. July 26-August 7, 1971. This was the first of the extended lunar missions. The landing was near Mt. Hadley. These missions included increased hardware capability, a larger scientific payload, and a battery-powered lunar roving vehicle. The crew spent 67 hours on the lunar surface. They made three moon walks. Using the lunar rover they were able to travel 17.4 miles (28 km) across the lunar surface collecting rocks and taking pictures. They also set up the ALSEP. One of the experiments measured the rate at which heat subsatellite was placed into orbit. The crew collected about 169 pounds (76 kg) of moon rocks.

Landing Site **26° N. Longitude**
4° E. Longitude

Apollo 16. April 16-27, 1972. This is the only manned landing in the lunar central highlands. Two sampling areas were targeted for the mission: Cayley Formation and the mountainous Descartes highlands. Three moon walks were made. The lunar rover traveled 16.6 miles. Another subsatellite was launched around the moon from orbit. The astronauts collected 211 pounds (96 kg) of rocks.

Landing Site **9° S. Latitude**
16° E. Longitude

Apollo 17. December 7-19, 1972. This was the final Apollo landing. It was made in the Taurus-Littrow Valley on the southeastern rim of the Serentatis basin in an area of mountains, low hills, and plains. Four moon walks were taken. The astronauts spent just over 22 hours working on the moon. Improved scientific experiment equipment was set up on the moon. The astronauts traveled 21 miles in the lunar rover and collected 242 pounds (110 kg) of moon rocks.

Landing Site **20° N. Latitude**
31° E. Longitude

ACTIVITIES IN PLANETARY CRATERING

The following activities demonstrate the fundamental principles of impact crater formation. They are only simulations. True impact or volcanic craters are formed under conditions that exceed by far your ability to duplicate in the classroom. The physical variables do not scale upward in a simple way to compare with actual crater formation. However, the appearance of the crater models formed in these activities closely approximates that which is observed on planetary surfaces. The activities, therefore, are excellent for stimulating discussions on the lunar landscape, terrestrial craters and the evolution of planetary surfaces.

In the impact cratering experiments the student will study the craters created when objects on different masses and traveling with different velocities strike a target of fine sand. There are several important concepts to be learned.

1. There is a relationship between the velocity and mass of the "meteorite" and the size of the crater.

2. Craters can be divided into distinct zones: floor, wall, rim, ejected materials and rays.

3. The relative age of surface features can be estimated using craters.

The activity on comparing cratering processes is a natural extension of the impact experiments. Because the majority of craters found on planets are produced by impacts, it is logical to perform that activity first.

On Earth explosion craters are formed by large-scale events such as nuclear explosions. With the exception of subtle differences in the ejecta patterns, explosion craters are to some degree analogs for impact craters. Craters can also be formed during volcanic eruptions. These craters are typically seen either on volcanic summits or on the flanks of volcanic cones. Volcanic craters have also been identified on the Moon, Mars, and most recently as active volcanoes on Io, one of the satellites of Jupiter.

IMPACT CRATERING

STUDENT SHEET

OBJECTIVES

1. To model impact craters in the laboratory
2. To recognize the conditions that control their size and appearance.
3. To understand their influence on the geology of a planet.

MATERIALS

1. A tray or very strong box at least 2 feet (61 cm) on a side and about 4 inches (10 cm) deep.

2. A large supply of extremely find sand, 8-100 µm if possible. Flour and salt (50/50 mixture) can be used instead of sand.

3. Four identical marbles or small ball bearings.

4. One steel ball bearing about 1/2 inch (1.2 cm) in diameter.

5. Three solid spheres about 1 inch (2.54 cm) in diameter, all the same size but made of different materials (example: glass, plastic, steel; or glass, wood, aluminum; etc.)

6. Meter stick

7. 10 cm ruler

8. Kitchen tea strainer

9. Two dark colors of dry tempra paint (powder): e.g. red and blue

10. Toy slingshot

11. Safety glasses or goggles

12. Large pack of assorted marbles

13. Laboratory balance to weigh projectiles

14. Watering or sprinkling can or paint mister

Impact craters are those craters formed when meteorites strike the surface of a planet. They are found on all of the terrestrial planets, on Earth's Moon, and on many of the satellites of the outer planets. Impact craters are not easily recognized on Earth because of the intense weathering and erosion that wears away its surface. On the Moon over 80 percent of the surface looks much the same as it did over 3-1/2 billion years ago, heavily cratered and very rugged. About half fo the surface of Mars is also ancient, but preserved cratered terrain. Although only 40 percent of Mercury has been photographed by spacecraft, over two-thirds of its surface is heavily cratered.

Various geological clues and studies of the lunar rocks returned by the Apollo missions indicate that about 3.9 billion years ago asteroid-size chunks of matter were abundant in the solar system This was a time of intense bombardment of the young planets, affecting Earth by breaking up and modifying parts of its crust. Mountain building, plate tectonics, weathering and erosion have largely removed all traces of the Earth's early cratering period. but the near absence of weathering on the Moon has allowed the evidence of this ancient period (considered to be the last stage of planetary accretion) to be preserved.

PART A: THE FORMATION OF CRATERS

The following experiments deal with the relationships among projectile mass, velocity and crater size. Impacts involve the transfer of energy from the projectile to the target (ground). Kinetic energy (energy of motion) is defined as K.E. = $1/2 \, mv^2$, where m = mass and v = final velocity.

PROCEDURE AND QUESTIONS

1. **The Importance of Mass.** Pour sand into the tray to a depth of at least 3 (7.6 cm) inches. Smooth the surface of the sand with the edge of the meterstick. Divide the surface into two equal areas. Weigh each projectile and record the mass in table. From a height of 2 meters (6') drop each of the large sphere (three different types) into one area. Carefully measure and record the diameter of

the craters formed by the impacts without disturbing the sand. Fill in the table below.

OBJECT	TYPE OF OBJECT	MASS OF OBJECT	CRATER DIAMETER
Sphere #1		g	cm
Sphere #2		g	cm
Sphere #3		g	cm

2. Look at your results carefully. Which sphere created the largest crater?

3. What is the only difference in the way each crater was made

4. Each sphere represents a meteorite. What can you say about the importance of the mass of a meteorite in making a crater?

5. Did any sphere appear to fall faster than the others? Did it really? Why or why not?

6. The importance of Velocity. Locate the four identical marbles. Weight each marble and record its mass below. Drop one marble into the second area from a height of 10 cm and another from 2 meters. The third projectile should be launched from the slingshot extended 23 cm (9"), the fourth, from the slingshot extended 36 cm (14"). Without disturbing the sand, carefully measure the crater diameter.

CAUTION: The slingshot is a potentially hazardous device. Use extreme caution when it is employed in this activity. Under no circumstances should it be aimed horizontally.

Complete the following table:

	VELOCITY	MASS	CRATER DIAMETER
Marble 1	1.40 m/s	g	cm
Marble 2	6.26 m/s	g	cm
Marble 3	10 m/s +	g	cm
Marble 4	30 m/s +	g	cm

+approximate

7. Did you measure any difference in the diameters of the craters?

____

8. What is the only difference in the way each crater was made?

____

9. In this case each marble (meteorite) had the same mass. What did dropping two marbles from different heights and propelling the other two accomplish?

____

10. Besides diameter do you notice any other difference in appearance among the craters.

____

11. Which do you think is more important in creating larger craters, more mass or more velocity? Why?

____

12. Calculate the *kinetic energy*+ upon impact for each marble in Question 6.

	KE	
Marble 1	________________________	joules (ergs)
Marble 2	________________________	joules (ergs)
Marble 3	________________________	joules (ergs)
Marble 4	________________________	joules (ergs)

13. Examine the results in Part A. Summarize your conclusions regarding the size, mass, and velocity of impacting projectiles, and its kinetic energy (indicated by the size of the resulting crater).

PART B: THE STRUCTURE OF A CRATER

1. Remove all projectiles from the sand and smooth the surface well. Again, divide the tray into two areas. With your instructor's help sprinkle a very fine layer of deep tempra color over the sand using the tea strainer. The layer of colored powder should cover the surface just enough to conceal the white sand.

CAUTION: Wear the goggles and be sure that no glass or breakable materials are in the vicinity of the activity.

+ **If mass is measured in kilograms and velocity in m/s, then the kinetic energy is given in joules. As you are measuring mass in grams and velocity in m/s, your values need to be divided by 1000 to obtain the kinetic energy in joules. Alternatively if mass is measured in grams and velocity in cm/s, then the kinetic energy is given in ergs.**

Map View **Side View**

(This is an ideal example of a small fresh crater)

4. Label the drawings with the words rim, ejecta and impact crater. Notice the sharp details of the crater.

5. Where do you find the thickest ejecta?

____

6. What do you think caused the crater rim to form?

____

7. The colored powder represents the most recent sediment deposited on a planet's surface. Any material beneath the top layer must have been deposited at an earlier time (making it physically older). If you were examining a crater on the Moon, where would you probably find the oldest material? Why do you think so.?

____

____

PART C: CRATERING AS A GEOLOGICAL PROCESS

1. In the second area create another crater as in Part B. Locate the large pack of assorted marbles. Drop each marble in the pack from an arbitrary height into the second area so that each one impacts at a different speed. Be careful to drop the marbles near but not directly on top of the crater formed by the slingshot method. Watch the process very carefully as you do it

2. How does the appearance of the original crater from Part B change as you continue to bombard the area.

3. What do you think is an important source of erosion on the Moon?

4. Are all craters bowl-shaped? Describe.

5. From all that you have seen, what does the appearance of a crater tell you about its age ?

PART D. THE EFFECT OF INCIDENCE ANGLE

1. The target (surface) into which a projectile (meteorite) impacts also helps to control the final crater's form. The angle of incidence is also important. You will now investigate both of these variables.

It is important to control all other variables. Be sure to use identical projectiles in each of the four parts. It is suggested that you use a simple device (e.g., a piece of string) to ensure that the slingshot is stretched the same distance each time (controlling the velocity). For best results the projectile must impact at high velocity; therefore, the slingshot should be greatly extended. **This activity is potentially the most hazardous.**

2. Mix the sand in the tray thoroughly, adding more sand if necessary, to return the sand to a uniform color. Remove all projectiles. Smooth the top again with the meter stick. Divide the tray into four equal areas. Again sift a layer of tempra color over the entire tray.

3. In one quarter-section produce a crater using the slingshot to launch a marble fired normally (at 90°, or vertical) to the target surface. On the page provided sketch a plan (map) view and cross section of the crater. Be sure to sketch the pattern of the *ejectas*. Where did it come from?

____

What would you expect to find beneath the ejecta?

____

4. In the second quarter-section, produce a crater with a marble launched at about 65° to the surface (estimate the angle). Sketch the crater in the appropriate place. Is there a marked difference between the two craters or ejecta pattern.

5. In the third quarter-section, produce a crater with a marble launched at about 40° to the surface. Be sure no one is "down range" in case the projectile ricochets. Sketch the crater.

6. In the fourth quarter-section, produce a crater with a marble launched at about 5-10° to the surface. Be sure no one is "down range" in case the projectile ricochets. Sketch the crater. Note the *asymmetric* cross section.

7. Examine the sand craters and your sketches. What are the relationships between impact angle, crater morphology (shape, form) and ejecta distribution?

DIAGRAM FOR PART D, STEPS 3 & 4

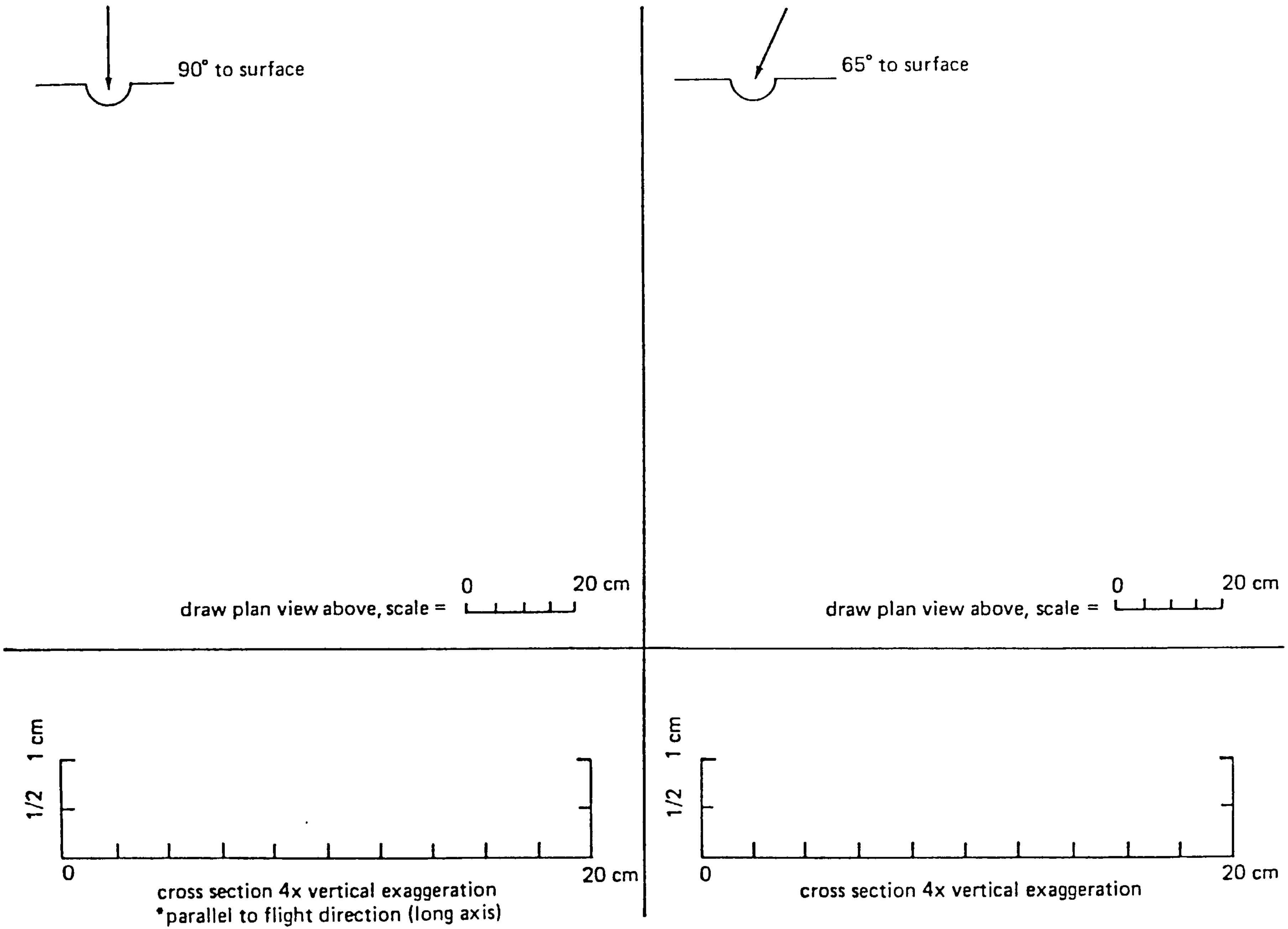
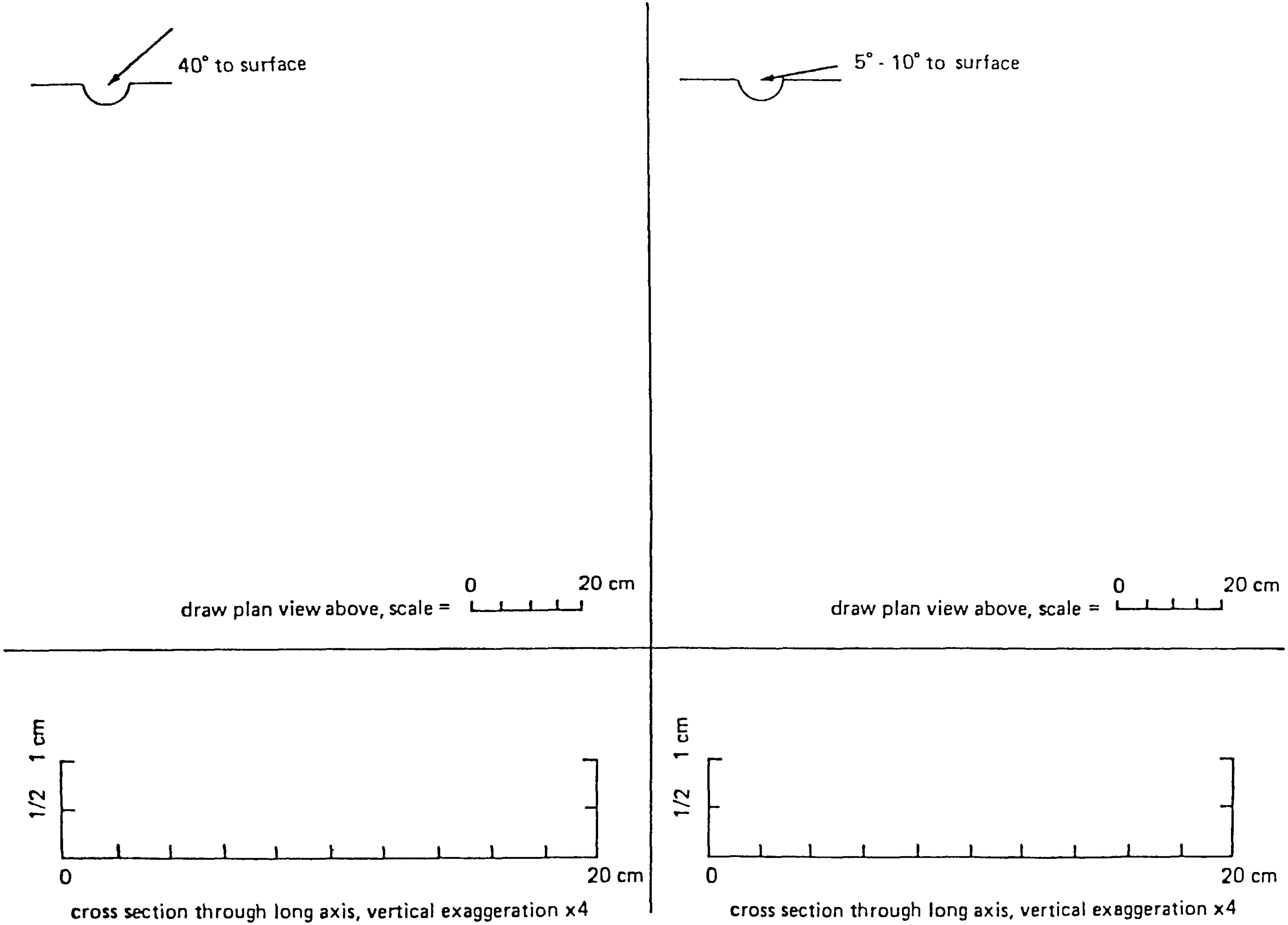


DIAGRAM FOR PART D, STEPS 5 & 6



PART E: THE EFFECT OF TARGET STRENGTH

1. Again thoroughly mix the sand in the tray and level the surface. Sprinkle and soak the sand with water; drain off any excess water. With th sieve sprinkle one color of the dry tempra paint evenly over the surface and let it soak completely. Shoot a marble from the slingshot into the wet sand and measure the diameter of the crater. Record observations in the space below.

___

2. Even out the wet, colored sand by striking or jarring the box several times. Next, sprinkle through the sieve clean, dry white sand on top of the wet colored sand until a few mm layer of dry sand is formed. With the slingshot, fire a small marble vertically into the sand in one half of the tray. How does the resulting crater compare in diameter to the crater formed in wet sand only?

   ___

   In dry sand only?

   ___

   Sketch the profile of your crater and describe the appearance.

   ___

3. Pour more sand into one large corner of the tray to increase the dry sand layer to double its thickness. Form another crater with the slingshot in this thicker layer. How does this differ from the crater formed in the thinner layer of sand?

   ___

   How do these craters compare to the crater formed completely in dry sand?

   ___

What effect does the thickness of the dry sand layer have on both the appearance of the crater and crater diameter?

4. Carefully smooth the dry sand to uniform layer over the entire tray Sprinkle the second color tempra evenly through the sieve on top of this layer. Draw a cross section that shows the sequence of layers from top to bottom. Fire a marble with the slingshot into the tray and describe the resulting pattern of material thrown out of the crater (impact ejecta). Where is the ejecta the thickest? Describe the ejecta pattern by color of tempra.

____

____

Draw a new cross section showing the sequence of layers from top to bottom: near the rim; one crater diameter from the rim; and four crater diameters from the rim.

Which layer goes the farthest?

____

5. If you were on Mercury and wanted to examine the oldest rocks around a crater, where would you most likely find them?

6. The gravitational acceleration at the surface of a planet also helps to control the final crater's final form. How would craters on the Moon differ from those formed on Earth due only to gravity (neglecting all other effects)?

____

How would gravity modify craters with age?

____

____

7. What other environmental factors control the crater's initial form after impact. Describe how these effects would be realized.

____

IMPACT CRATERING

TEACHER SHEET

OBJECTIVES

1. To model impact craters in the laboratory
2. To recognize the conditions that control their size and appearance.
3. To understand their influence on the geology of a planet.

MATERIALS

1. A tray or very strong box at least 2 feet (61 cm) on a side and about 4 inches deep.

2. A large supply of extremely find sand, 8-100 um if possible.

3. Four identical marbles or small ball bearings.

4. One steel ball bearing about 1/2 inch (1.2 cm) in diameter.

5. Three solid spheres about 1 inch (2.54 cm) in diameter, all the same size but made of different materials (example: glass, plastic, steel; or glass, wood, aluminum; etc.)

6. Meter stick

7. 10 cm ruler

8. Kitchen tea strainer

9. Two dark colors of dry tempra paint (powder): e.g. red and blue

10. Toy slingshot

11. Safety glasses or goggles

12. Large pack of assorted marbles

13. Laboratory balance to weigh projectiles

14. Watering or sprinkling can or paint mister

Impact craters are those craters formed when meteorites strike the surface of a planet. They are found on all of the terrestrial planets, on Earth's Moon, and on many of the satellites of the outer planets. Impact craters are not easily recognized on Earth because of the intense weathering and erosion that wears away its surface. On the Moon over 80 percent of the surface looks much the same as it did over 3-1/2 billion years ago, heavily cratered and very rugged. About half fo the surface of Mars is also ancient, but preserved cratered terrain. Although only 40 percent of Mercury has been photographed by spacecraft, over two-thirds of its surface is heavily cratered.

Various geological clues and studies of the lunar rocks returned by the Apollo missions indicate that about 3.9 billion years ago asteroid-size chunks of matter were abundant in the solar system This was a time of intense bombardment of the young planets, affecting Earth by breaking up and modifying parts of its crust. Mountain building, plate tectonics, weathering and erosion have largely removed all traces of the Earth's early cratering period. but the near absence of weathering on the Moon has allowed the evidence of this ancient period (considered to be the last stage of planetary accretion) to be preserved.

PART A: THE FORMATION OF CRATERS

The following experiments deal with the relationships among projectile mass, velocity and crater size. Impacts involve the transfer of energy from the projectile to the target (ground). Kinetic energy (energy of motion) is defined as K.E. = $1/2\ mv^2$, where m = mass and v = final velocity.

PROCEDURE AND QUESTIONS

1. **The Importance of Mass.** Pour sand into the tray to a depth of at least 3 inches. Smooth the surface of the sand with the edge of the meterstick. Divide the surface into two equal areas. Weigh each projectile and record the mass in table. From a height of 2 meters (6') drop each of the large sphere (three different types) into one area. Carefully measure and record the diameter of the

craters formed by the impacts without disturbing the sand. Fill in the table below.

OBJECT	TYPE OF OBJECT	MASS OF OBJECT	CRATER DIAMETER
Sphere #1	*Type* A	*lightest* g	*smallest* cm
Sphere #2	*Type B*	*medium* g	*medium* cm
Sphere #3	*Type C*	*heaviest* g	*largest* cm

The numbers will depend on the material used in the experiment, but the trend should be clear: as mass increases, so does crater diameter.

2. Look at your results carefully. Which sphere created the largest crater?

   The most massive.

3. What is the only difference in the way each crater was made?

   The mass was varied.

4. Each sphere represents a meteorite. What can you say about the importance of the mass of a meteorite in making a crater?

   Crater diameter increases with increasing mass.

5. Did any sphere appear to fall faster than the others? Did it really? Why or why not?

   All spheres reached the sand in the same amount of time, regardless of mass. Galileo was reported to have shown this about 400 years ago.

6. The importance of Velocity. Locate the four identical marbles. Weight each marble and record its mass below. Drop one marble into the second area from a height of 10 cm and another from 2 meters. The third projectile should be launched from the slingshot extended 23 cm (9"), the fourth, from the slingshot extended 36 cm (14"). Without disturbing the sand, carefully measure the crater diameter.

CAUTION: The slingshot is a potentially hazardous device. Use extreme caution when it is employed in this activity. Under no circumstances should it be aimed horizontally.

Complete the following table:

	VELOCITY	MASS	CRATER DIAMETER
Marble 1	1.40 m/s	g	***small*** **cm**
Marble 2	6.26 m/s	g	***medium*** **cm**
Marble 3	10 m/s +	g	***large*** **cm**
Marble 4	30 m/s +	g	***very large*** **cm**

+approximate

7. Did you measure any difference in the diameters of the craters?

   Yes, as velocity increases, so does crater diameter.

8. What is the only difference in the way each crater was made?

   Velocity.

9. In this case each marble (meteorite) had the same mass. What did dropping two marbles from different heights and propelling the other two accomplish?

   This varies the velocity at impact.

10. Besides diameter do you notice any other difference in appearance among the craters.

    No, all look qualitatively similar.

11. Which do you think is more important in creating larger craters, more mass or more velocity? Why?

    Velocity increases have more effect on crater diameter than mass increases. Velocity has a greater contribution to the energy of impact.

12. Calculate the *kinetic energy* (+)upon impact for each marble in Question 6.

	KE	
Marble 1	1/2 x m_1 kg x (1.40 m/s)^2	joules (ergs)
Marble 2	1/2 x m_2 kg x (6.26 m/s)^2	joules (ergs)
Marble 3	1/2 x m_3 kg x (10 m/s)^2	joules (ergs)
Marble 4	1/2 x m_4 kg x (30 m/s)^2	joules (ergs)

*13. Examine the results in Part A. Summarize your conclusions regarding the size, mass, and velocity of impacting projectiles, and its kinetic energy (indicated by the size of the resulting crater).

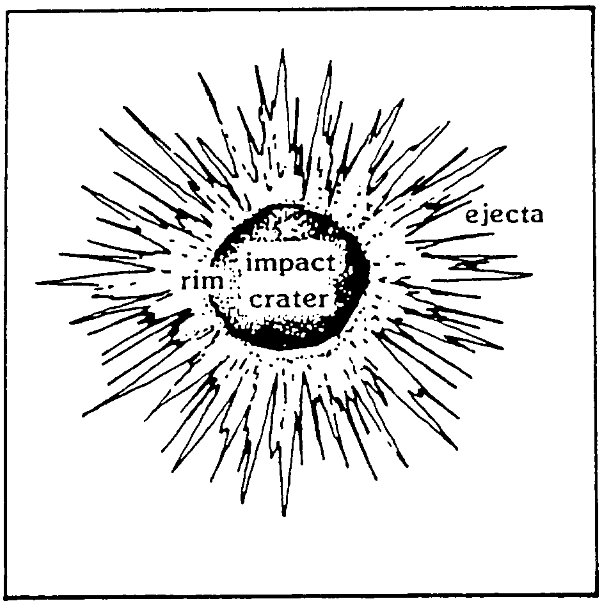
The greater the energy released on impact, the larger the crater. Mass and velocity contribute to energy, not size. Velocity contributes as the square, mass linearly.

PART B: THE STRUCTURE OF A CRATER

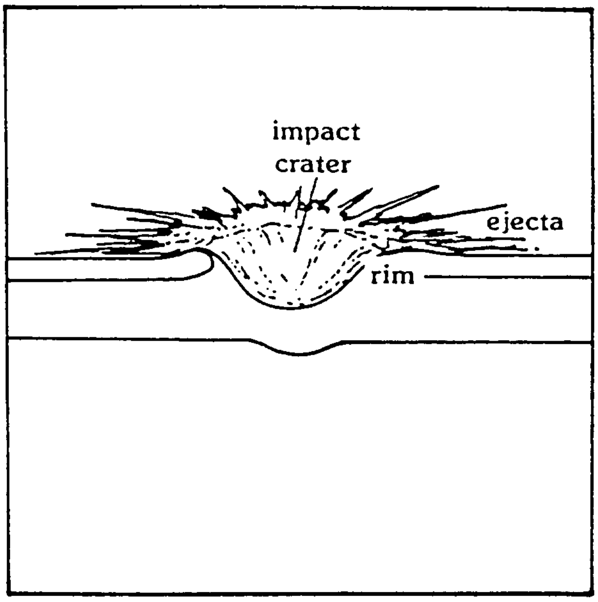
1. Remove all projectiles from the sand and smooth the surface well. Again, divide the tray into two areas. With your instructor's help sprinkle a very fine layer of deep tempra color over the sand using the tea strainer. The layer of colored powder should cover the surface just enough to conceal the white sand.

CAUTION: Wear the goggles and be sure that no glass or breakable materials are in the vicinity of the activity.

+ **If mass is measured in kilograms and velocity in m/s, then kinetic energy is given in joules. If you measured the mass of each marble in grams then m_1 to m_4 is obtained by dividing by 1000 in each case.**
Alternatively if mass is measured in grams and velocity in cm/s, then the kinetic energy is given in ergs.



Map View



Side View

(This an ideal example of a small fresh crater)

4. Label the drawings with the words rim, ejecta and impact crater. Notice the sharp details of the crater.

5. Where do you find the thickest ejecta?

   On the rim.

6. What do you think caused the crater rim to form?

   Deposition of sand thrown out of cavity formed by impact.

7. The colored powder represents the most recent sediment deposited on a planet's surface. Any material beneath the top layer must have been deposited at an earlier time (making it physically older). If you were examining a crater on the Moon, where would you probably find the oldest material? Why do you think so.?

   Near the rim. Because the deepest material ejected lands closest to the crater, i.e., on the rim.

PART C: CRATERING AS A GEOLOGICAL PROCESS

1. In the second area create another crater as in Part B. Locate the large pack of assorted marbles. Drop each marble in the pack from an arbitrary height into the second area so that each one impacts at a different speed. Be careful to drop the marbles near but not directly on top of the crater formed by the slingshot method. Watch the process very carefully as you do it

2. How does the appearance of the original crater from Part B change as you continue to bombard the area.

   It loses its crispness.

3. What do you think is an important source of erosion on the Moon?

   Impact cratering.

4. Are all craters bowl-shaped? Describe.

   No -there is a variety of shapes.

5. From all that you have seen, what does the appearance of a crater tell you about its age.?

   The younger the crater, the crisper the features; the older, the more subdued.

PART D. THE EFFECT OF INCIDENCE ANGLE

1. The target (surface) into which a projectile (meteorite). impacts also helps to control the final crater's form. The angle of incidence is also important. You will now investigate both of these variables.

It is important to control all other variables. Be sure to use identical projectiles in each of the four parts. It is suggested that you use a simple device (e.g., a piece of string) to ensure that the slingshot is stretched the same distance each time (controlling the velocity). For best results the projectile must impact at high velocity; therefore, the slingshot should be greatly extended. **This activity is potentially the most hazardous.**

2. Mix the sand in the tray thoroughly, adding more sand if necessary, to return the sand to a uniform color. Remove all projectiles. Smooth the top again with the meter stick. Divide the tray into four equal areas. Again sift a layer of tempra color over the entire tray.

3. In one quarter-section produce a crater using the slingshot to launch a marble fired normal (at 90°, or vertical) to the target surface. On the page provided sketch a plan (map) view and cross section of the crater. Be sure to sketch the pattern of the *ejectas*. Where did it come from?

   Ejecta comes from sand below the tempra layer that was excavated by impact.

   What would you expect to find beneath the ejecta?

   Undisturbed sand.

4. In the second quarter-section, produce a crater with a marble launched at about 65° to the surface (estimate the angle). Sketch the crater in appropriate place. Is there a marked difference between the two craters or ejecta pattern.

   The craters and ejecta pattern should appears

5. In the third quarter-section, produce a crater with a marble launched at about 40° to the surface. Be sure no one is "down range" in case the projectile ricochets. Sketch the crater.

6. In the fourth quarter-section, produce a crater with a marble launched at about 5-10° to the surface. Be sure no one is "down range" in case the projectile ricochets. Sketch the crater. Note the *asymmetric* cross section.

7. Examine the sand craters and your sketches. What are the relationships between impact angle, crater morphology (shape, form) and ejecta distribution?

   High impact angles produce more nearly bowl-shaped craters with symmetric ejecta patterns; shallow impact angles produced elongated or elliptical craters and asymmetric or "butterfly wing" ejecta.

PART E: THE EFFECT OF TARGET STRENGTH

1. Again thoroughly mix the sand in the tray and level the surface. Sprinkle and soak the sand with water; drain off any excess water. With th sieve sprinkle one color of the dry tempra paint evenly over the surface and let it soak completely. Shoot a marble from the slingshot into the wet sand and measure the diameter of the crater. Record observations in the space below.

   Small, marble-sized crater with clumpy ejecta.

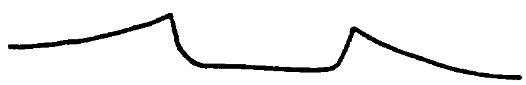
2. Even out the wet, colored sand by striking or jarring the box several times. Next, sprinkle through the sieve clean, dry white sand on top of the wet colored sand until a few mm layer of dry sand is formed. With the slingshot, fire a small marble vertically into the sand in one half of the tray How does the resulting crater compare in diameter to the crater formed in wet sand only?

   Larger crater than in wet sand.

   In dry sand only?

   Smaller than in dry sand.

   Sketch the profile of your crater and describe the appearance.



3. Pour more sand into one large corner of the tray to increase the increase the dry sand layer to double its thickness. Form another crater with the slingshot in this thicker layer. How does this differ from the crater formed in the thinner layer of sand?

   Larger crater, smaller floor.

How do these craters compare to the crater formed completely in dry sand?

Smaller overall, but flatter floor.

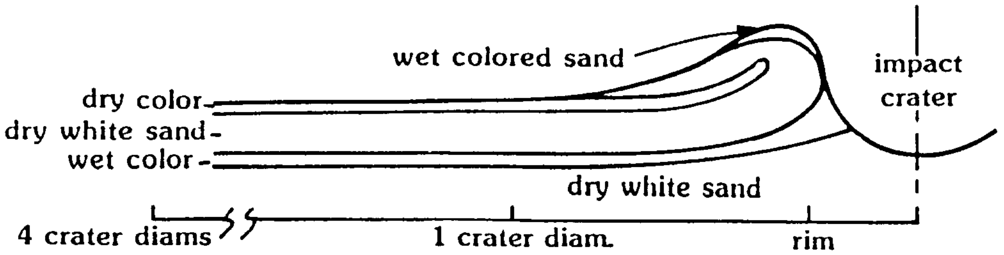
What effect does the thickness of the dry sand layer have on both the appearance of the crater and crater diameter?

The thicker the overlying dry layer, the closer the crater approaches the dry sand craters.

4. Carefully smooth the dry sand to uniform layer over the entire tray Sprinkle the second color tempra evenly through the sieve on top of this layer. Draw a cross section that shows the sequence of layers from top to bottom. Fire a marble with the slingshot into the tray and describe the resulting pattern of material thrown out of the crater (impact ejecta). Where is the ejecta the thickest? Describe the ejecta pattern by color.

The deepest color is closest to the rim; the sallowish color is farthest from the rim. Ejecta is thickest near the rim.

Draw a new cross section showing the sequence of layers from top to bottom: near the trim; one crater diameter from the rim; and four crater diameter from the rim.



Which layer goes the farthest?

The topmost layer.

5. If you were on Mercury and wanted to examine the oldest rocks around a crater, where would you most likely find them?

   Near the rim.

6. The gravitational acceleration at the surface of a planet also helps to control the final crater's form. How would craters on the Moon differ from those formed on Earth due only to gravity (neglecting all other effects)?

   Lower profiles, larger surface area of ejecta.

   How would gravity modify craters with age?

   Higher gravity decreases degradation by multiple impacts, but increases degradation by slumping.

7. What other environmental factors control the crater's initial form after impact. Describe how these effects would be realized.

   Atmospheric effects, entrapped fluids or volatiles in the target, etc.

COMPARING CRATERING PROCESSES

TEACHER SHEET

OBJECTIVES

1. By using lab materials, the formation of craters through impact, eruptive, and explosive processes will be simulated.

2. The effects of different cratering processes on landscape development will be compared.

3. Through the use of photographs and direct observation, the origins of specific craters can be determined.

MATERIALS

1. Tray of very fine sand (100μm)
2. Protective goggles
3. Marbles and slingshot
4. Polaroid camera with cable release
5. 3 packs of Polaroid black and white film
6. Black cardboard or posterboard (18"x30"or 45.7 cm x 76.2 cm)
7. High intensity strobe light variable to at least 15 flashes per second.
8. 3 foot (91.4 cm) plastic tube
9. Pump
10. Thin skin balloons
11. Protractor
12. Tracing paper
13. Curtain/plastic sheet

PROCEDURE AND QUESTIONS

PART A: IMPACT CRATER PROCESS

1. Focus the camera on the tray of sand from a distance of 2 to 3 feet (61 cm to 91.4 cm). To get good photos, the film must be exposed long enough to catch 2 flashes from the strobe light (about 1/8 second). Start the exposure just before the marble is fired and stop it right after it appears to hit the ground.

CAUTION: ALL STUDENTS MUST WEAR SAFETY GOGGLES DURING THIS PORTION OF THE EXERCISE. THIS IS ESPECIALLY IMPORTANT HERE BECAUSE THE FLASHING STROBE LIGHT OFTEN CAUSES ERROR IN AIM.

Step 1 may have be repeated several times to get a good photograph. Save all photographs.

2. a. Before looking at the photograph, describe how you think the sand thrown from the impact (called "ejecta") will look.

   Experience in Unit Two should yield similar answers.

   b. Sketch the crater and the path the material appears to take based on the photograph and observations.

   c. How does the crater formed differ from the predictions?

   Instruction should lead a discussion of various student answers.

   d. Take at least three more photographs. Arrange them in a time sequence beginning with an exposure the instant before impact and ending with one after the impact. How does the ejecta pattern change?

   Ejecta is laid down by moving "curtain" of debris from the rim of the crater outward.

3. **IMPACTS AT AN ANGLE**: Repair and smooth the sand surface and photograph another impact with the angle of impact at 45^{o} from the horizontal. Be sure that no one is down range and that you fire in the direction of the hanging curtain. How do the ejecta paths differ from the vertical impact?

   Ejecta from the vertical impact are thrown out at about a 45^{o} angle. The sheet os ejecta moves outward in a symmetrical pattern, producing the appearance of an enlarging, inverted cone. As the path of the projectile departs from the vertical, the ejecta cone becomes *asymmetrical and distorted in the down-range direction.*

PART B. EXPLOSIVE CRATER PROCESS

1. Attach the plastic tube to the bicycle pump. Check for air leaks. Next, pull the balloon tightly over the other end of the tube and slip on the clamp. This means that you are using only a small portion of the balloon and that the thin skin of the balloon will burst easily when the pump is used.

2. Bury the tube in the sand but turn up the end in the center of the box so that it is almost vertical and about 3/4" below the surface of the sand.

3. As in the impact experiment, start the Polaroid picture exposure immediately BEFORE the quick single push of the bicycle pump and stop the exposure immediately afterwards (1/8 second). If the balloon did not burst, check for air leaks or tighten the clamp on the balloon.

   a. Before looking at the photo, again predict what you think you will see.

      Instructor should lead a discussion of various student answers.

   b. How does your prediction compare with the photo? Sketch the crater and ejecta pattern.?

      See photos and discussion

   c. How does the resulting crater (which is a "low-energy" explosion crater) compare with the impact crater?

      In appearance, the crater shape is similar. However, the ejecta pattern is chaotic and dispersed with ejecta thrown out at all angles. The impact ejecta pattern is well-ordered with ejecta leaving at a 45^{o}

angle . Note that the ejecta pattern and crater appearance will vary with different depths of burial of the balloon. In high energy explosions, an impact crater can be reproduced if the depth of the explosion is shallow.

PART C: ERUPTIVE CRATER PROCESS

The ejecta thrown out in this process is directed nearly vertical and returns to the surface near the crater. In this exercise, students have produced three craters with raised rims. The processes of formation as shown by the stop-action photos are very different.

1. After completing the previous experiment, leave the tube buried in the sand. Smooth the surface of the sand over the end of the tube.

2. For the final photograph, start the exposure immediately BEFORE pushing the pump (do not push as hard as for the balloon). Now what do you predict for the pattern of ejecta?

   Answers will vary.

3. Sketch the pattern that you observed.

4. What geological process might produce a similar pattern?

   Volcanic eruptions could produce such a crater.

5. Place the photographs you have taken side by side. Compare the crater and features formed by each of the three processes.

   a. How are all three similar?

      All three craters could produce a crater.

   b. How are they different?

Answers will vary but many students will note that the explosion and volcanic craters are not as symmetrical as the impact craters.

c. Which have raised rims?

All craters formed have raised rims.

d. Which crater formed the widest ejecta pattern?

Answers will vary. The explosive crater or the impact crater ejecta patterns will probably be widest.

e. How do the ejecta patterns compare to one another?

Answers may vary.

f. Which process had the biggest effect on the surrounding material?

Impact has the greatest effect

COMPARING CRATERING PROCESSES

TEACHER SHEET

PRE-LAB

15 minutes. Go over techniques of using the Polaroid camera.

LAB

Two class periods

POST-LAB

1. Discuss results of photos or observations.

NOTES FOR SET-UP FOR LAB

1. Because of the sand thrown out by impact and the use of the slingshot, goggles are necessary for each student. The slingshot is important because a high velocity projectile is needed to produce a good ejecta blanket.

2. Prepare the lab set-up before class in order to avoid loss of time in beginning the exercise.

3. A Polaroid camera was selected for this exercise to allow students an opportunity to have an instant and permanent record of the exercise. Action is stopped by use of the strobe and students can reshoot if necessary. If desired, a 35mm camera or instamatic with a 2' (61 cm) focus can be used; however, this will delay examination of photographs and errors in procedure will not be detected until the film results are viewed. The school newspaper or yearbook photographers may be able to assist you in developing the film.

4. Instructions for setting up the lab:

   a. Fill the tray to the brim with 100 μm sand and arrange the strobe and camera.

   b. If the Polaroid has an electric eye, set the film speed setting to 75 (even though the film speed is 3000) and the exposure control on front of the camera to "Darker." This permits a longer exposure time for the shutter and a smaller f/stop (lens opening). If the Polaroid does not have an electric eye, but has numbered settings, set the number to "6" and flip the exposure from "1" to "B" before each picture. If the resulting photographs are too light, increase this number accordingly.

c. Focus the camera on th target surface and place the black posterboard in front of and beneath the strobe light as shown. This arrangement provides a black background. The flash rate on the strobe should seem like rapid blinks. Too many flashes during the exposure produces a dispersed cloud; too few, and the event may be missed entirely.

d. In using the camera, it is best if you have a cable release attached to the Polaroid - this will help eliminate jarring the camera unnecessarily. If the camera does not accept a cable release, be sure that the camera is on a film surface; push the button and release carefully.

5. Be sure the student photographers know how to operate a Polaroid before starting the activity.

NOTE: *ALTHOUGH THE INSTRUCTIONS AND PRECAUTIONS MAY SEEM INVOLVED, THE EXERCISE CAN BE DONE EASILY AND SUCCESSFULLY.*

Comparison of the formation of impact craters, low-energy explosion craters, and simulated volcanic craters, as recorded in a sand box with strobe light. The formation of an impact crater is a relatively well ordered event in which the ejecta leave the surface at approximately a 45^{o} angle from the horizontal. As the crater enlarges, the inverted cone sheet of ejecta, called the *ejecta plume,* enlarges. Ejecta arrive first in an annulus close to the crater. As crater formation continues, the ejecta strike the surface at increasing distances. Note that in all three photographs, two stages in crater formation have been recorded: the earliest stage is represented by the inner ejecta plume; the second stage, by the broad-based ejecta plume.

In contrast to the impact process, an exploding balloon buried beneath the sand produces a relatively chaotic and dispersed ejecta pattern. Ejecta blown through a tube are directed vertically and return to the surface near the crater. the former example is analogous to an explosion crater, whereas the latter approximates a volcanic eruption. All three groups of experiments produce craters with raised rims but the mechanics of formation varies significantly. This realization is important for understanding the appearance of craters on other planets and the effect of their formation on the surrounding terrain.

COMPARING CRATERING PROCESSES

STUDENT SHEET

OBJECTIVES

1. By using lab materials, the formation of craters through impact, eruptive, and explosive processes will be simulated.

2. The effects of different cratering processes on landscape development will be compared.

3. Through the use of photographs and direct observation, the origins of specific craters can be determined.

MATERIALS

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3. Marbles and slingshot
4. Polaroid camera with cable release
5. 3 packs of Polaroid black and white film
6. Black cardboard or posterboard (18"x30" or 45.7 cm x 76.2 cm)
7. High intensity strobe light variable to at least 15 flashes per second.
8. 3 foot (91.4 cm) plastic tube
9. Pump
10. Thin skin balloons
11. Protractor
12. Tracing paper
13. Curtain/plastic sheet

PROCEDURE AND QUESTIONS

PART A: IMPACT CRATER PROCESS

1. Focus the camera on the tray of sand from a distance of 2 to 3 feet (61 cm to 91.4 cm). To get good photos, the film must be exposed long enough to catch 2 flashes from the strobe light (about 1/8 second). Start the exposure just before the marble is fired and stop it right after it appears to hit the ground.

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Step 1 may have be repeated several times to get a good photograph. Save all photographs.

2. a. Before looking at the photograph, describe how you think the sand thrown from the impact (called "ejecta") will look.

   b. Sketch the crater and the path the material appears to take based on the photograph and observations.

   c. How does the crater formed differ from the predictions?

   d. Take at least three more photographs. Arrange them in a time sequence beginning with an exposure the instant before impact and ending with one after the impact. How does the ejecta pattern change?

3. **IMPACTS AT AN ANGLE**: Repair and smooth the sand surface and photograph another impact with the angle of impact at 45^{o} from the horizontal. Be sure that no one is down range and that you fire in the direction of the hanging curtain. How do the ejecta paths differ from the vertical impact?

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2. Bury the tube in the sand but turn up the end in the center of the box so that it is almost vertical and about 3/4" (1.9 cm) below the surface of the sand.

3. As in the impact experiment, start the Polaroid picture exposure immediately BEFORE the quick single push of the bicycle pump and stop the exposure immediately afterwards (1/8 second). If the balloon did not burst, check for air leaks or tighten the clamp on the balloon.

   a. Before looking at the photo, again predict what you think you will see.

   b. How does your prediction compare with the photo? Sketch the crater and ejecta pattern.?

   c. How does the resulting crater (which is a "low-energy" explosion crater) compare with the impact crater?

PART C: ERUPTIVE CRATER PROCESS

1. After completing the previous experiment, leave the tube buried in the sand. Smooth the surface of the sand over the end of the tube.

2. For the final photograph, start the exposure immediately BEFORE pushing the pump (do not push as hard as for the balloon). Now what do you predict for the pattern of ejecta?

3. Sketch the pattern that you observed.

4. What geological process might produce a similar pattern?

5. Place the photographs you have taken side by side. Compare the crater and features formed by each of the three processes.

   a. How are all three similar?

   b. How are they different?

   c. Which have raised rims?

   d. Which crater formed the widest ejecta pattern?

e. How do the ejecta patterns compare to one another?

f. Which process had the biggest effect on the surrounding material?

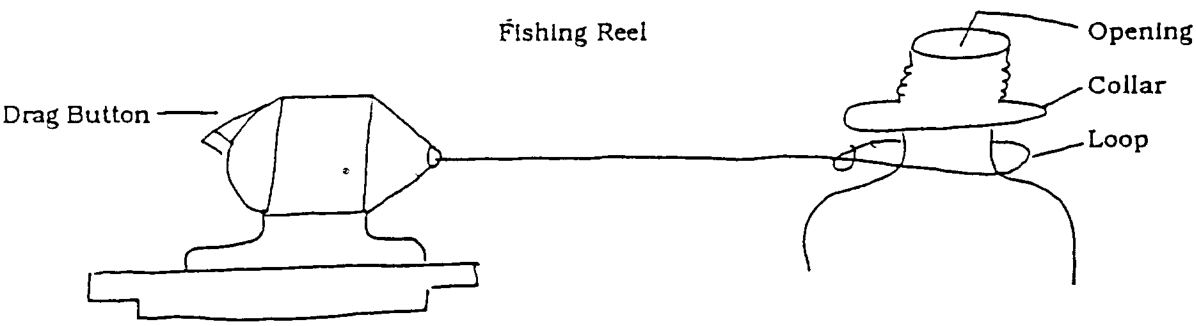
BOTTLE ROCKETS[1]

TEACHER SHEET

Launching bottles: (See Plans for Building Rocket Launcher)

1. The bottom of the 2 liter plastic soda bottle will be the "nose" of the rocket. The opening of the bottle will be seated and locked on the launch platform.

2. Tie a loop of the fishing line from the fishing reel onto the neck of the bottle just past the collar



3. Depress the drag button which will allow the line to play out freely.

4. Invert the bottle and seat the opening over the cone washer on the launch platform.

5. Slide the pull bracket assembly toward the bottle so that the two long nails lock firmly over the collar of the bottle.

6. Extend your tape measure (at least 50' or 15 m) in a straight line in front of the launch platform.

7. Make sure the platform is firmly anchored in place by pounding the anchoring spike into the ground.

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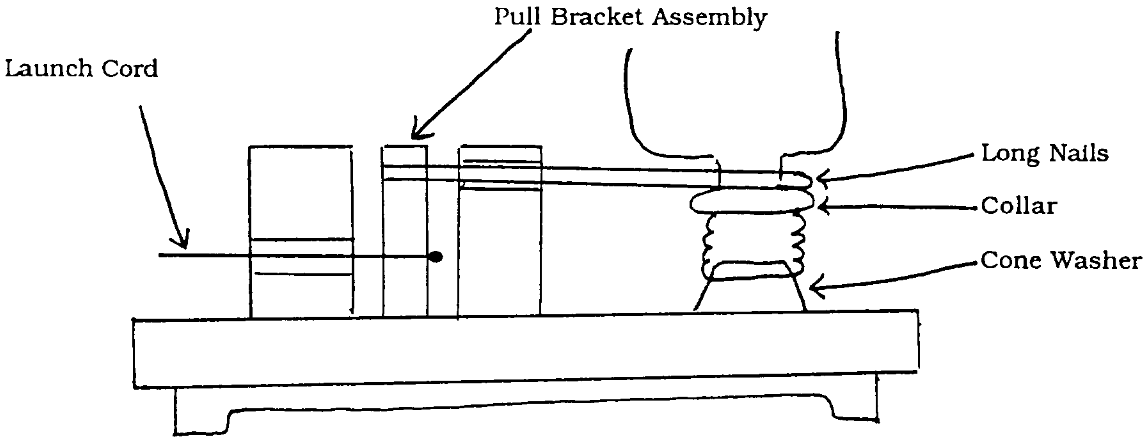
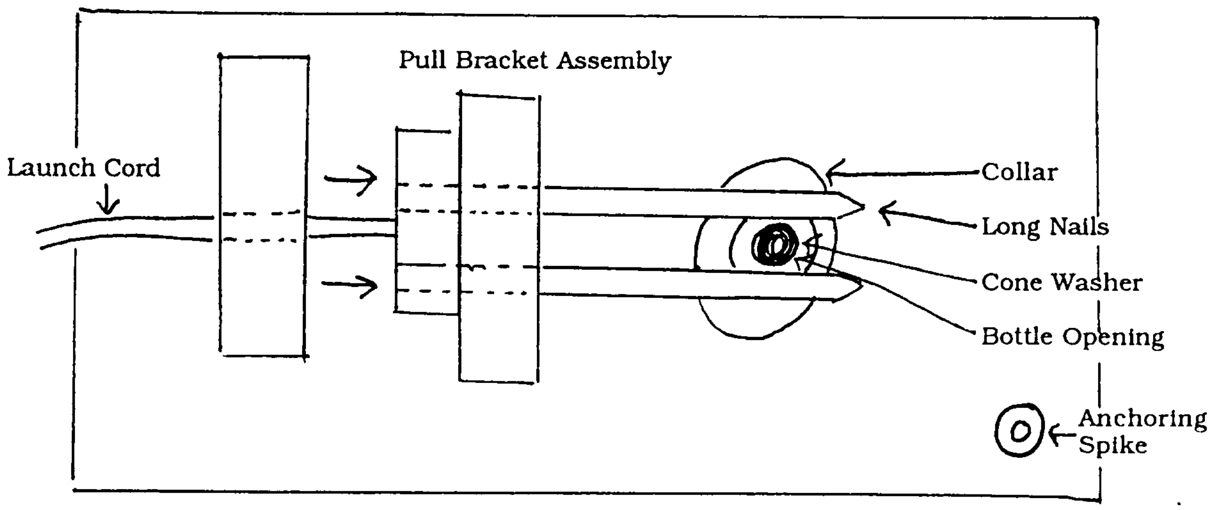
[1]Activity created by Donna Hare, Labay Middle School, Houston, Texas.

Side View of Rocket Launcher



Overview of Rocket Launcher



Slide pull bracket assembly forward so that nails lock over the collar of the inverted bottle.

8 Have the launch personnel move to the end of the launch cord as far from the platform as possible.

9. Have another member of the launch team begin pumping the foot pump with long rapid strokes keeping watch on the pressure gauge and stopping when the desired pressure (150, 300 & 450 kPa) is reached.

10. Make sure all personnel are clear of the platform areas.

11. Begin counting down at 5 and pull the launch cord sharply away from the platform at zero.

12. When the bottle lands, turn the crank on the fishing reel 1/4 turn to lock the line.

13. Retrieve the bottle and extend the connected line as far as you can down the measuring tape. Record the amount of line played out. This is the total flight distance of the launch. Record this data in the data and graphing selections of your worksheets.

14. Repeat steps 3-13 increasing the pressure to 40 and 60 psi on successive trials to complete a baseline of performance for your platform with an non-modified bottle.

15. Record any observations you are able to make about the actual flight of the bottle-trajectory, stability, etc. Make a note of ideas for modifying the bottle to make it more aerodynamic.

16. Use the sheet called " Your Design #1" to draw plans for modifying your bottle. Remember, the bottom of the bottle will be the nose of the rocket.

Important: The shell of the bottle must remain intact in order to contain the air pressure. DO NOT use staples, thumbtacks, or any other method which might pierce the bottle to attach modifications.

17. Students should consider and balance the benefits of various modifications vs the effect of their additional weight. You may even wish to incorporate the use of a balance or scale at this point.

18. When initial modifications are complete, repeat steps 2-15.

19. Use the sheet called "Your Design #2" to draw plans for final modification of your bottle rocket.

20. Repeat steps 2-15 one more time.

21. Record and finish graphing your flight distances on the "Graphing Form".

22. Study your data to draw your conclusions about the effects of your modifications on the performance of your rocket.

BOTTLE ROCKETS

STUDENT SHEET

A. Trial #1

1. Launch an unmodified bottle. Use 150,300 and 450 kPa (20, 60, 60 psi) of pressure in 3 successive tests.

2. Measure the fishing line "played out" in each test to determine the total flight distance and record the distance of each launch in the "Results of Trial #1 (baseline)" section on your Data Sheet.

3. Use the spaces provided on the Bottle Rocket Graphing Sheet to record and graph the distances you obtained in trial #1.

B. Trial #2

1. Use your modifications and notes from trial #1 to draw your plans for modifications of your 2 liter bottle on the sheet marked "Your Design #1".

2. Follow your notes and design plans to modify your 2 liter rocket. (Note: Be very careful not to puncture the bottle in any way in executing your modifications. This could cause a serious pressure loss - even bursting.)

3. When your modifications are complete and stabilized (all glue is dry), repeat the test launch procedures as in Trial #1. Record your results on the appropriate sheets in the sections provided for Trial #2.

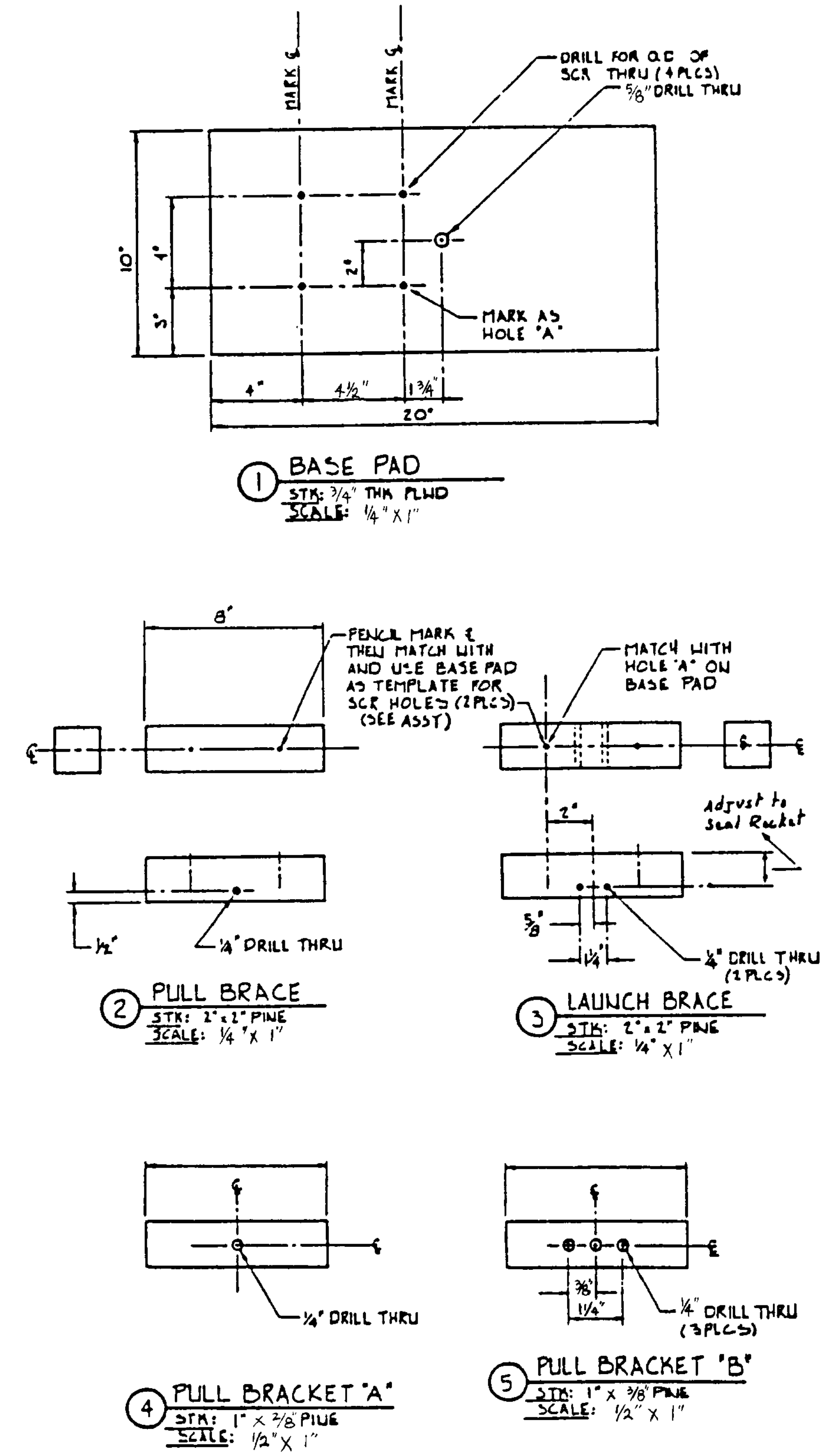
C. Trial #3

1. Use your compiled observation and modification notes from your previous trials along with any additional research you may do to draw your plans for further modifications of your 2 liter rocket on the sheet marked "Your Design #2".

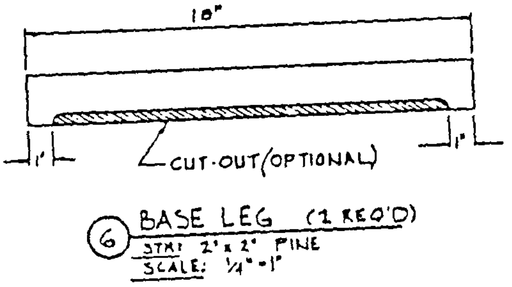
2. Follow your notes and design plans to modify your 2 liter rocket. (Note: you may wish to use a new bottle at this point to make sure that your rocket shell will be air-tight.)

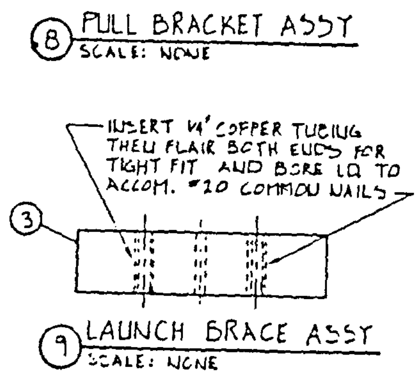
3. When your modifications are complete and stabilized, repeat the test launch procedures as in Trials #1 & 2. Record your results on the appropriate sheets with sections provided for Trial #2. Make notes on "Possible Modifications" you might make if you were to go further with your testing

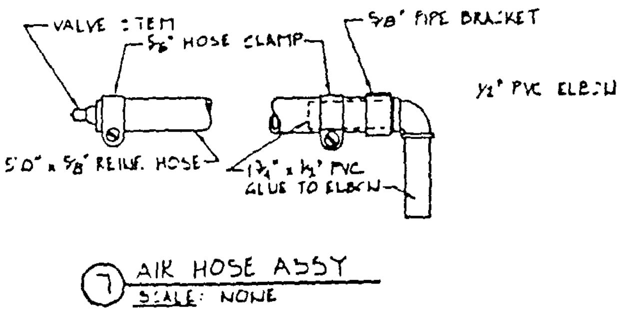
Plans for Building a Rocket Launcher*

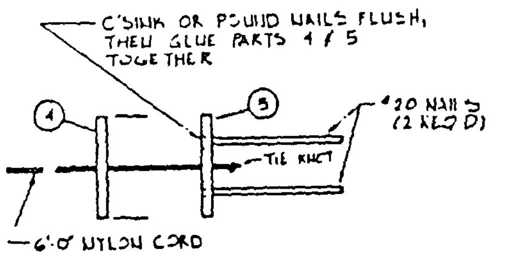


* Invented by Dr. Ron Bonnstetter, University of Nebraska, USA.

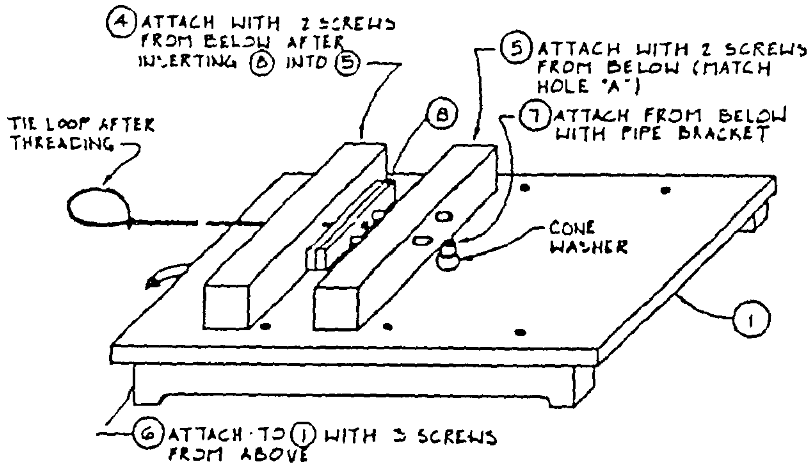








Materials:
1 1/2" PVC Female Elbow
4 inch length of 1/2" PVC Pipe
1 each7/16" cone washer (rubber)
5 feet 1/2" reinforced garden hose
2 1/2" hose clamps
1 1/2 " pipe bracket
2 #20 common nails
6 feet length heavy nylon string
1 G.M. valve stem
10 1 3/4" long wood screws
1 20 inch X 10 inch 3/4" thick plywood
4 2 inch X 2 inch board
2 1 inch X 3/8 inch board



STUDENT SHEET
DATA SHEET

Results of Trial #1 (Baseline)

Distance ______________ ______________ ______________

150 kPa (20 psi) 300 kPa (40 psi) 450 kPa (60 psi)

Observations: ____

____

____

____

____

Modifications:____

____

____

____

Results of Trial #2 (Baseline)

Distance ______________ ______________ ______________

150 kPa (20 psi) 300 kPa (40 psi) 450 kPa (60 psi)

Observations: ____

____

____

____

____

DATA SHEET

PAGE 2

Modifications::____

____

____

____

Results of Trial #3 (Baseline)

Distance	__________	__________	__________
	150 kPa (20 psi)	300 kPa (40 psi)	450 kPa (60 psi)

Observations: ____

____

____

____

____

Possible Modifications::____________________________________

____

____

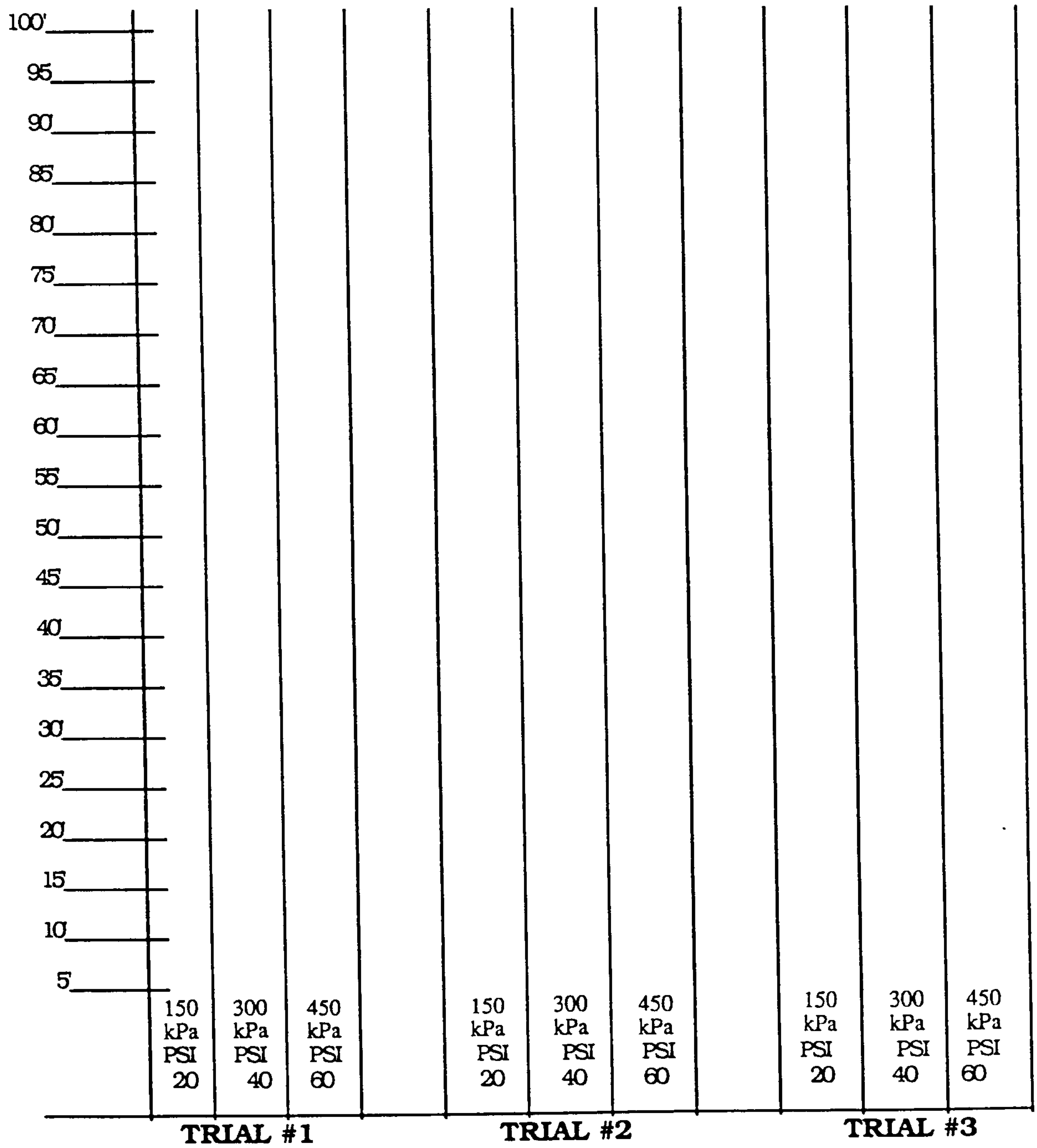
____

STUDENT SHEET

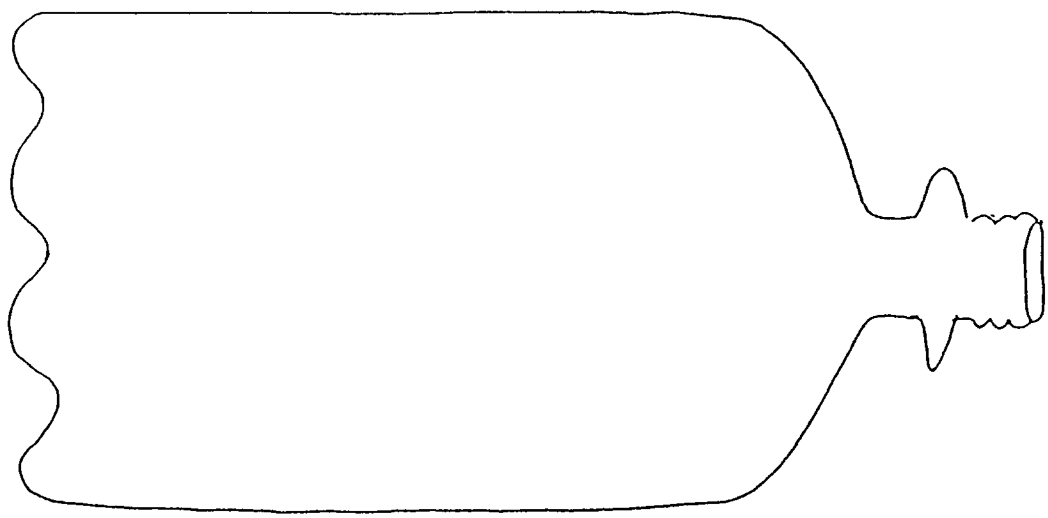
BOTTLE ROCKETRY

Pressure Tests:

	distance 150 kPa (20 psi)	distance 300 kPa (40 psi)	distance 450 kPa (60 psi)
Trial #1	________	________	________
Trial #2	________	________	________
Trial #3	________	________	________



Your Design #1



Your Design # 2

MAKING AND DATING MOON CRATERS*

STUDENT SHEET

MATERIALS AND APPARATUS: (per group)

pan, approximately 10"x12" (25 cm x 30 cm)
mixture of flour and salt, enough to fill pan to depth of 3 cm
marbles of different sizes
meter sticks

PROCEDURES: Part I

1. CAUTION: THIS ACTIVITY CAN BE VERY MESSY IF DIRECTIONS ARE NOT FOLLOWED CLOSELY.

2. With your partner, experiment with making craters with the pebbles or marbles. What generalizations can you make?

   ----

3. Choose two marbles or pebbles of different size. Drop them from the same height, being careful to keep the craters that are formed from overlapping or touching. Measure the diameter of the craters.

   Large marble/pebble: ____________________

   Small marble/pebble: ____________________

   Which marble makes the larger crater?

   ----

* Excerpted from Activities in Planetary Geology, NASA, EP-179.

Explain your answer.

----

4. Next choose two marbles/pebbles that are the size. Drop one from a height of 10 centimeters above the pan. Drop the other from a height of 1 meter above the pan. Measure and record the diameters of the craters.

   Crater formed by marble/pebble dropped from 10 cm

   Crater formed by marble/pebble dropped from 1 meter ____________________

   Which crater is larger? ________________
   How can you explain this difference?

----

5. Drop two marbles/pebbles, one at a time so that the two craters partially overlap. Sketch the results below.

   Which crater is seen as the more complete, the one made by the first marble/pebble you dropped, or the one made by the second marble/pebble you dropped?

PART II

1. Using a map of the lunar surface attached to this activity, determine the relative ages of the overlapping craters numbered 1-5, 6-7, and 8-10.

   In the group numbered 1-5, list the craters according to their relative ages.

   Oldest crater ______
   ______
   ______
   ______
   Youngest crater ______

   In group number 6-7, which is older? ____________

   Which crater is younger? ________________

   In group 8-10, which crater is the oldest?
   ____

   Which crater is the youngest? ________________

2. After you have determined which crater in each group is the oldest, can you think of a way to determine which of all the craters 1-10 is the oldest?

____

____

____

____

DISCUSSION QUESTIONS/CONCLUSIONS:

Part I

1. What factors affect the size of impact craters?

----

2. How were the craters you made in flour similar to the craters of the moon?

----

3. How were they different?

Part II

1. Why is it difficult to apply the concept of overlapping craters when trying to interpret the relative age of moon craters from Earth?

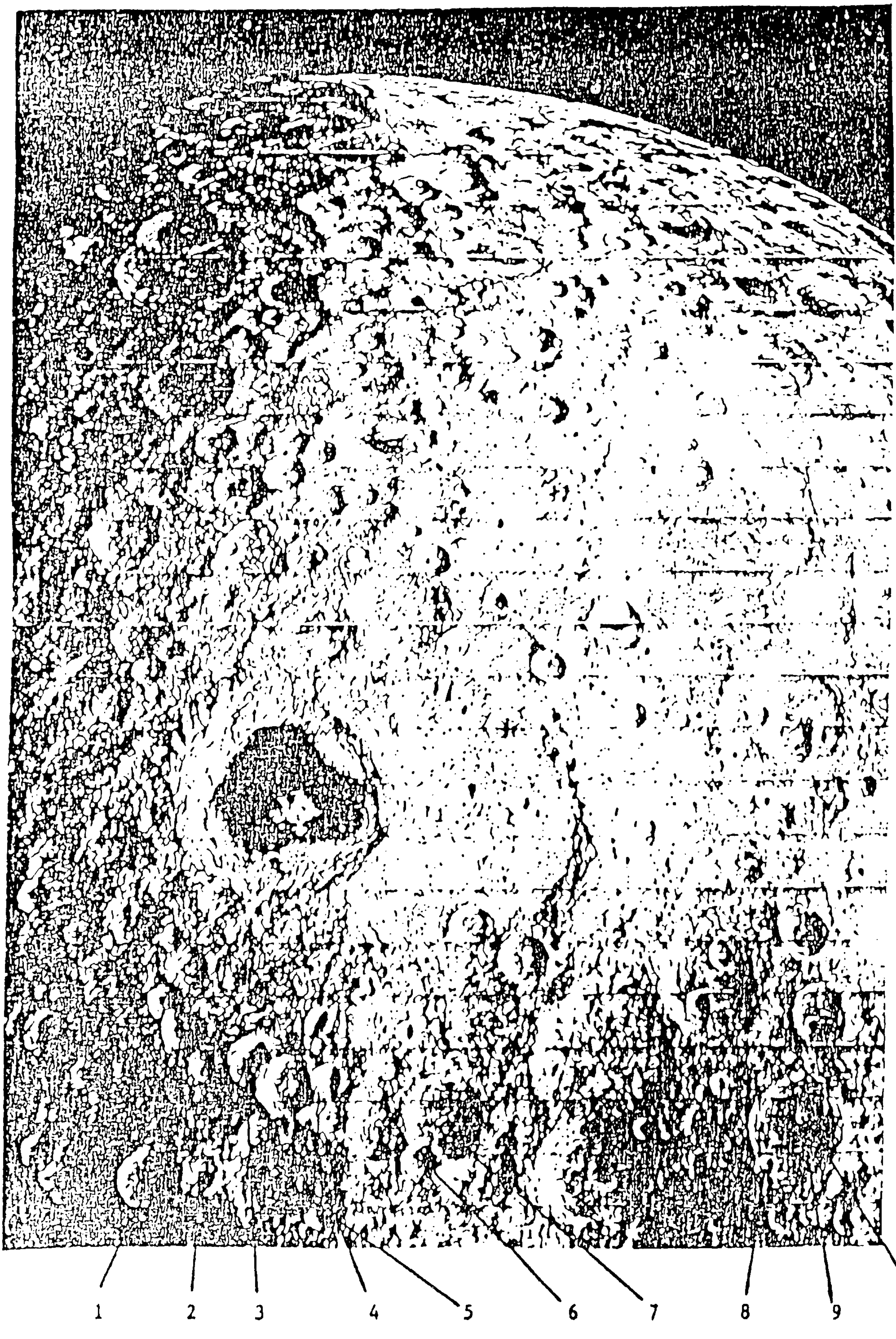
----

2. In the absence of overlapping feature, how could you estimate the age of a lunar crater?

What characteristics would you look for?

EXTENSION:

1. Some lunar craters have been formed by volcanic activity. How are volcanic craters different from impact craters.?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MAKING AND DATING MOON CRATERS

TEACHER SHEET

Purpose: To demonstrate features of impact craters and to demonstrate how to date the relative ages of moon craters.

Time Needed: One class period for Part I and one class period for Part II.

Background Information:

It is generally thought that the majority of the craters of the moon are the result of meteorite impacts over time, although there are other craters that are the result of volcanic activity. The size of an impact crater is determined by two factors:

1. the size of the impact object; and
2. the velocity at which the impact object hit the surface.

The relative age of impact craters can be established by determining which craters overlap which other ones. If two craters formed at different times are near enough to each other that they touch or overlap, the more complete crater will be the younger of the two.

SPECIAL PROCEDURES AND SAFETY INSTRUCTIONS:

1. Have students work in pairs or in small groups.

2. This activity can be very messy if discipline is not maintained.

3. A 50/50 mixture of flour and salt yields the best craters.

PART II

1. Using a map of the lunar surface attached to this activity, determine the relative ages of the overlapping craters numbered 1-5, 6-7, and 8-10.

In the group numbered 1-5, list the craters according to their relative ages.

Oldest crater _*3*____
_*4*____
_*5*____
_*2*____
Youngest crater _*1* ____

In group number 6-7, which is older? *7*

Which crater is younger? *6*

In group 8-10, which crater is the oldest? *10*

Which crater is the youngest? *8***

IMPACT CRATERING ON A RAINY DAY

STUDENT SHEET

OBJECTIVE:

To illustrate the way in which planetary surfaces can be dated by analyses of craters, you will create impact features with raindrops and will study the craters formed in order to find out the effect of both continuous impacting of a surface and the angle of illumination on the appearance of the cratered terrain.

MATERIALS

1. Rainy day (or something to duplicate raindrops, such as water sprinkled through a fine-mesh window screen)

2. 4 *petri* dishes (per group)

3. Very fine sand (100 um)

4. Light source (spot type)

5. Optional: Polaroid camera an film

PROCEDURE AND QUESTIONS

1. Fill each petri dish with the fine sand. Place one dish in the light rain for about 5 seconds (or until several craters have formed). How do the crater sizes vary?

Are the craters clustered together? Do they overlap?

----

2. Form a crater in the second dish with your finger. Place this dish in the rain for approximately 30 seconds.

   a. What does the surface look like now?

   ----

   b. What happened to the large crater you formed?

   ----

   c. What do you suppose would happen to the larger crater if you left it in the rain for 5 minutes (10 times as long)?

   ----

   d. Are there more overlapping craters here than in No. 1?

   ----

   e. Do any of the craters form chains of three or more (three or more in a row)?

----

3. Form another "finger" crater in each of the other two dishes. Place one dish in the rain for two minutes; the other for four minutes.

   a. What has happened to the large craters? Does this agree with your prediction in No.2?

   ----

   b. Do you see more tiny craters in either of the dishes? which dish has the most tiny craters?

   ----

4. The angle of the light affects what you see. During a full Moon, you can see less detain on the Moon's surface than you can during the other phases. Turn off the overhead lights and, with the spot light, shine the light across the surface of the dishes. Try shining the light from the following angles and describe what you see.

   a. 90^{o} (directly above the craters)

   ----

   b. 45^{o} (1/2 of a right angle):

   ----

   c. 20^{o}

d. 10^{o}

IMPACT CRATERING ON A RAINY DAY

TEACHER SHEET

OBJECTIVE:

To illustrate the way in which planetary surfaces can be dated by analyses of craters, you will create impact features with raindrops and will study the craters formed in order to find out the effect of both continuous impacting of a surface and the angle of illumination on the appearance of the cratered terrain.

MATERIALS

1. Rainy day (or something to duplicate raindrops, such as water sprinkled through a fine-mesh window screen)

2. 4 *petri* dishes (per group)

3. Very fine sand (100 μm)

4. Light source (spot type)

5. Optional: Polaroid camera an film

PROCEDURE AND QUESTIONS

1. Fill each petri dish with the fine sand. Place one dish in the light rain for about 5 seconds (or until several craters have formed). How do the crater sizes vary?

During a slow, steady rain, many craters will be similar in size.

Are the craters clustered together? Do they overlap?

Although craters typically are not clustered, a few clusters do develop. They may overlap.

2. Form a crater in the second dish with your finger. Place this dish in the rain for approximately 30 seconds.

   a. What does the surface look like now?

      The large crater formed by the finger becomes degraded (eroded) by the rain impacts.

   b. What happened to the large crater you formed?

      It becomes less sharp and distinct.

   c. What do you suppose would happen to the larger crater if you left it in the rain for 5 minutes (10 times as long)?

      It would probably disappear.

   d. Are there more overlapping craters here than in No. 1?

      Yes,

   e. Do any of the craters form chains of three or more (three or more in a row)?

      Answers will vary.

3. Form another "finger" crater in each of the other two dishes. Place one dish in the rain for two minutes; the other for four minutes.

   a. What has happened to the large craters? Does this agree with your prediction in No.2?

      The large craters become degraded (eroded)

   b. Do you see more tiny craters in either of the dishes? which dish has the most tiny craters?

Tiny craters should be found in both dishes with the dish exposed for four minutes having the greater number. However, the change in appearance between the surfaces in these two dishes is not as drastic as the change between the previous two surfaces. In other words, the longer the surface is exposed to impact cratering, the more difficult it becomes to distinguish the "age" difference between them. The same problem occurs on certain planetary surfaces where cratering was so extensive that old craters were destroyed almost as rapidly as new craters were formed. This condition was called "equilibrium:"

4. The angle of the light affects what you see. During a full Moon, you can see less detain on the Moon's surface than you can during the other phases. Turn off the overhead lights and, with the spot light, shine the light across the surface of the dishes. Try shining the light from the following angles and describe what you see.

   a. 90^{o} (directly above the craters)

      Small craters are nearly invisible. Little detail visible.

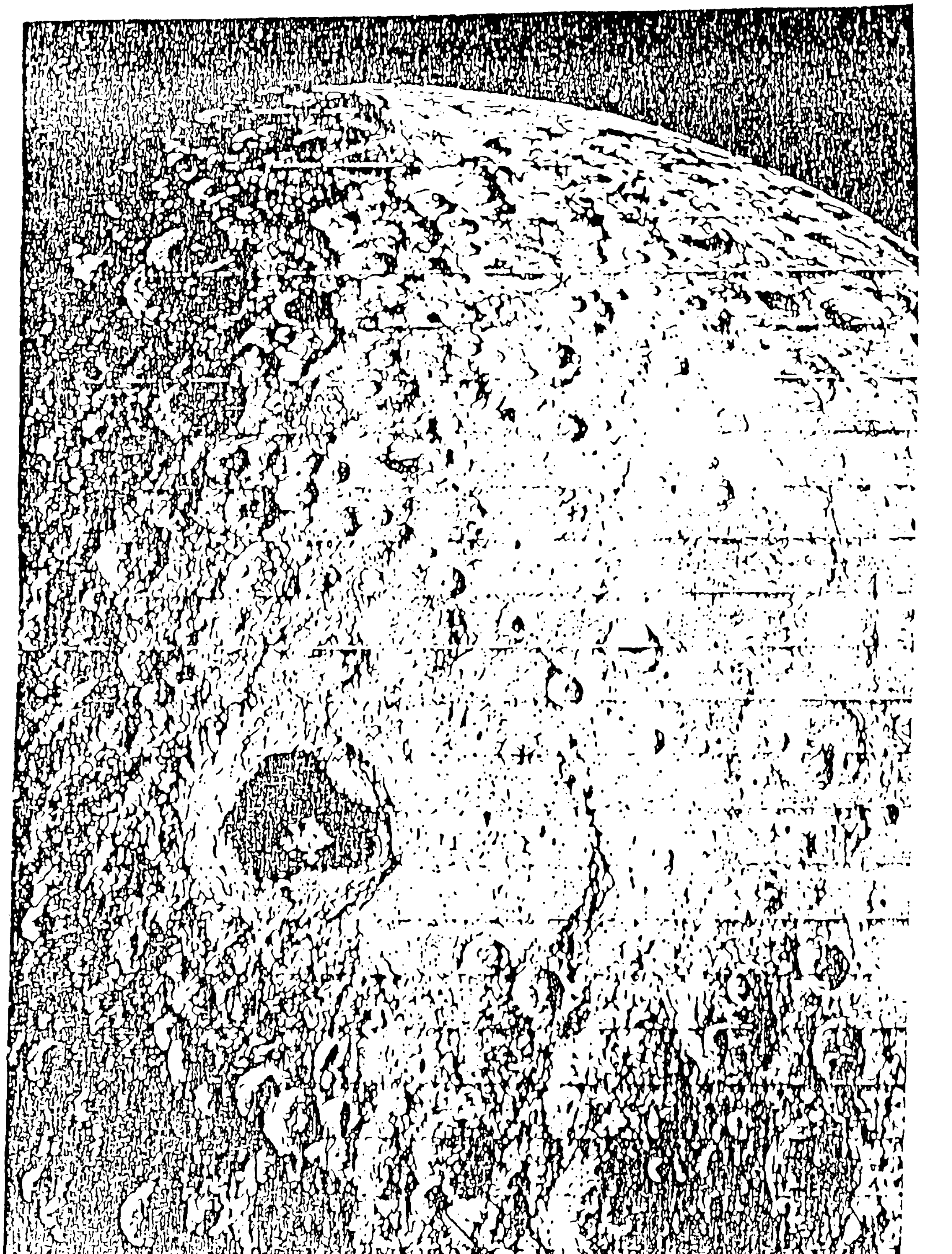
   b. 45^{o} (1/2 of a right angle):

      Shadows help point out many surface features. Small craters are obvious.

   c. 20^{o}

      ----

   d. 10^{o}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KEEPING A JOURNAL OF THE MOON'S MOTION*

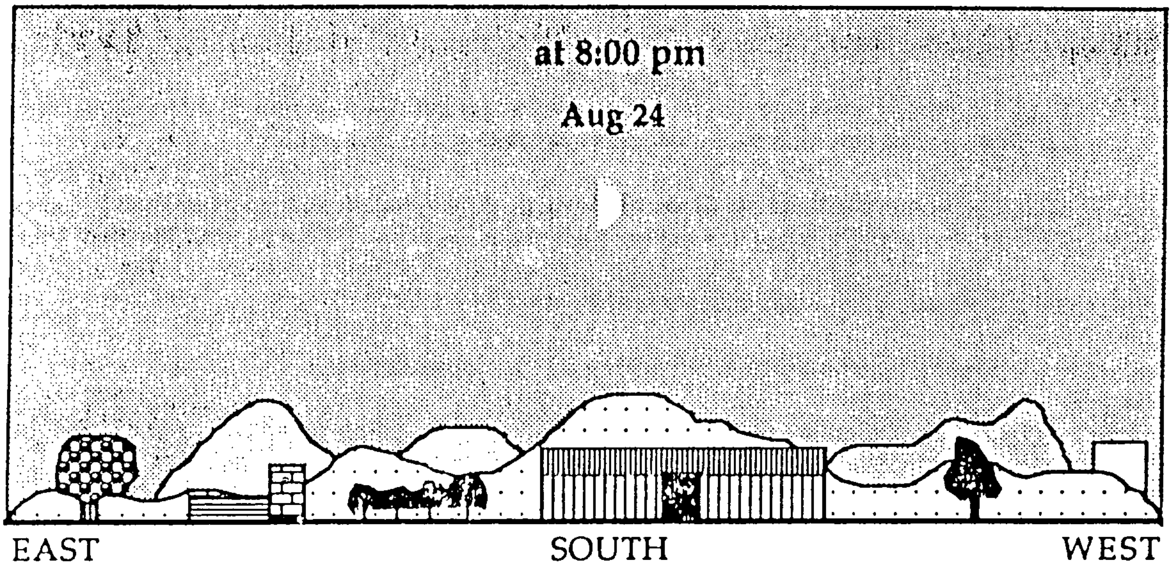
PURPOSE

To record observations of the Moon's appearance and location in the sky at the same time and from the same location for a period of about two weeks.

WHAT DO YOU THINK?

Write the answers to questions and/or problems in the spaces provided.

2.1 *The illustration below shows the Moon's shape and position in the sky for the date and time shown.*



On the above illustration, draw the Moon's shape and location at 8:00pm on:

August 23 and August 27 (put the date above each of your drawings)

(Note that the observations are made at the same time of the day.)
(If you think the Moon would not be visible, explain why.)

MATERIALS

sheet of plain paper, 21.5 cm x 28 cm (8.5 in x 11 in) or larger
pencil (or try colored pencils, felt-tip pens, or paint on poster board)
directional compass
watch
Chart 2.1 on page 155

PROCEDURE

1. Choose a specific time to make your observations. Depending on the phase of the Moon, this choice might have to be late afternoon, early evening or in the morning.

2. Find a location convenient to your home or work with as clear a view as possible of the southern sky. When facing south, you should be able to look east (to your left) and west (to your right) without any major obstacles blocking your view. (NOTE: If you do not have a compass to determine directions, call the direction of the setting Sun <u>West</u>.)

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*Reproduced with permission from Project STAR, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, 02138.

*Reproduced with permission from Project STAR, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, 02138.

3. Pick a spot for viewing that you will be able to find each time you make an observation. Push a stick or stone into the ground, or make a scratch or chalk mark on a paved surface to help you find the spot. Make all your observations from this location.

4. On your sheet of paper, draw the horizon features (see Question 2.1 for an example). Include buildings, trees, power lines, hills, and anything else that falls into your field of view. These landmarks will help you locate the position of the Moon on your drawing. And, mark east, south, and west along your horizon. Place south in the center of your drawing. Write the location (neighborhood and/or street name) of your observation spot on this chart.

5. Draw the shape of the Moon on your observation sheet, and place it where it appears in the sky. If there are any bright stars or planets nearby, include them in your drawing. Write the date next to the drawing of the Moon.

6. On Chart 2.1, record the weather conditions and anything unusual you observe about the Moon or the sky. Pay special attention to the Moon's apparent shape and color.

7. Make all your observations of the Moon at the same time (you must be no more than 15 minutes early or late) from the same location for as many nights as possible. (Make at least five observations.)

Note: The information from this activity will be used in ACTIVITY 5.

Answer the following questions after completing all your observations.

2.2 *How did the appearance of the Moon change?*

2.3 *How did the position of the Moon change?*

2.4 *As seen in the sky, was the Moon getting farther from or closer to the Sun or did it seem to stay in the same position with respect to the Sun?*

2.5 *Over the period of your observations, did you see more or less of the "lit-up" part of the Moon as it changed its position with respect to the Sun?*

2.6 *Why do you think the Moon's position on the sky changed as it did?*

2.7 *Why do you think the Moon's apparent shape changed as it did?*

DISCUSSION QUESTIONS

2.8 *Was the Moon setting earlier, later, or at the same time from one night to the next?*

2.9 *Was the difference between the time of sunset and moonset getting longer, shorter, or staying the same from one night to the next?*

2.10 *Was the angle between the Sun and the Moon increasing, decreasing, or staying the same during your observation period?*

2.11 *From your observations, estimate the time it would take for the Moon to return to the same place in the sky it was on the first night you started keeping a journal.*

2.12 *Compare your journal of the real sky with your predictions from Question 2.1.*

QUESTIONS TO TEST YOURSELF

1. Is the Moon in the same place in the sky at the same time every night?

2. How does the position of the Moon in the sky change from one night to the next?

3. How does the appearance of the Moon change from one night to the next?

EXTENSIONS

1. Keep observing the sky from the same location until the Moon returns to the same place in the sky or until it appears the same shape as it did when you began your journal. Note the date. How many days did it take the Moon to undergo this cycle?

2. Start a Moon journal for the morning sky.

Chart 2.1 Moon Journal

Location of Observation Site:__________________

Time:___________

	DATE	MOON COLOR	WEATHER	DRAWING OF MOON'S SHAPE
1				
2				
3				
4				
5				
6				
7				

Modeling the Phases of the Moon*

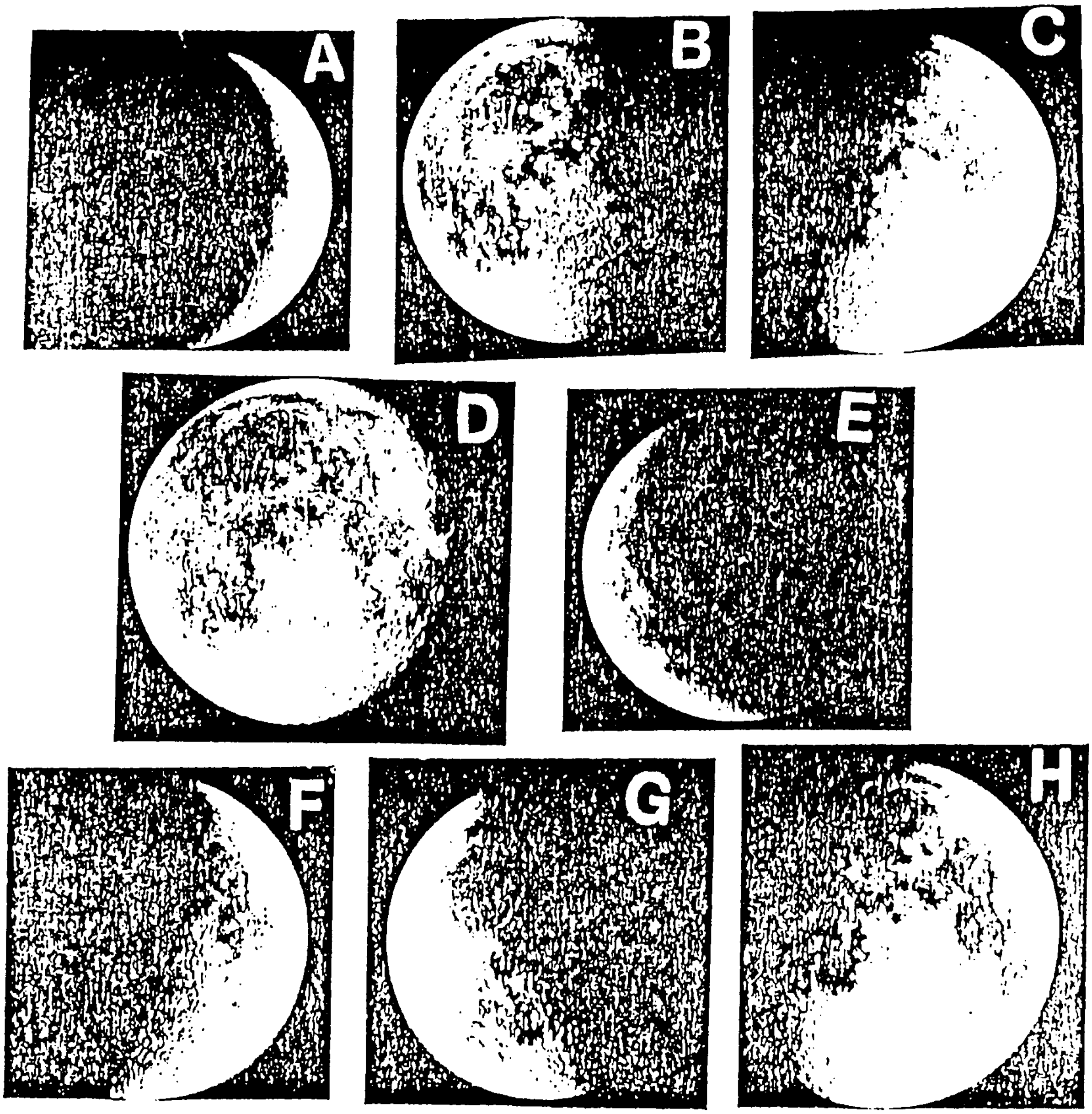
PURPOSE

To use the information from your Moon Journal (ACTIVITY 2) to predict changes in the appearance of the Moon and to predict the rising and setting times of the Moon.

WHAT DO YOU THINK?

Write answers to questions and/or problems in the spaces provided.

5.1 *Cut out the pictures of the Moon on this page.* *Go to page* 157



photos courtesy of D. Scott Birney, Whitin Observatory, Wellesley College, Wellesley, MA

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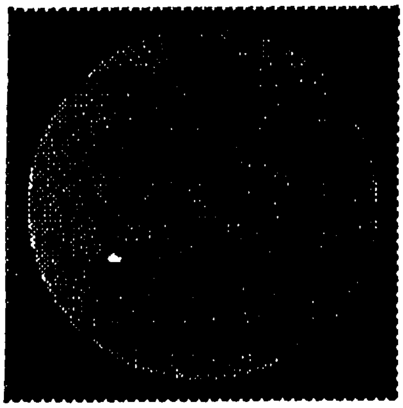
Choose the picture that you think best represents the appearance of the Moon 3 days after the New Moon. Tape it onto the square labeled "day 3". Tape the remaining pictures onto the squares in the sequence that you think represents the rest of the Moon's cycle to 26 days after the New Moon.



day 0 ___NEW MOON___ day 3 ______________ day 6 ______________

day 7 ______________ day 10 ______________ day 16 ______________

day 21 ______________ day 23 ______________ day 26 ______________

5.2 If the Moon appeared as in picture B, at what time on that day would it be highest in the sky?

ACTIVITY 5A ______ IDENTIFYING THE PHASES OF THE MOON

MATERIALS

- Styrofoam ball (painted gray or black), 6.4 cm (2.5 in) in diameter
- pencil or pen
- light source (unfrosted 200-watt bulb), with clamp socket
- scissors
- Chart 5.1 on page 163
- cardboard sheet, 21.5 cm x 28 cm (8.5 in x 11 in)
- transparent tape
- stapler
- journal from ACTIVITY 2

PROCEDURE

1. Place the 200-watt light bulb as high as possible in the front of the room. Be sure no one blocks the light. This bulb should be the only source of light in the room; it represents the light of the Sun.

2. Sit or stand at a place with plenty of arm room and face the bulb. You should be about 2 to 3 meters away from the bulb. Your head represents the Earth.

3. Stick a pencil or pen into the painted Styrofoam ball. This ball represents the Moon. Hold the pencil upright in your left hand with the ball at eye level. Extend your arm toward the light source and move the ball from right to left. This movement represents the motion of the Moon around the Earth. Notice how the shape and size of the lit part of the ball changes.

4. Carefully cut Chart 5.1 out of the book. This is a diagram showing an overhead view of a person holding a ball as described in Step 3. The 16 small circles surrounding the head on the chart represent the positions of the Moon in its orbit around the Earth at about two day intervals.

5. Repeat Procedure 3, but this time stop and observe the ball in each of the sixteen positions shown on the drawing.

6. With a pencil, darken in the large white disks to match the appearance of the ball at each position. **Be sure that what is shaded on the sphere is what is darkened on your diagram.** After darkening one circle, rotate the sheet clockwise to the next circle. Keep the circle you are darkening at the top.

7. When you have filled in all the disks on the chart, cut the outer circle along the dark line and cut the lines between each darkened circle. **Do not cut the inner edge of the circle.**

8. Each disk is now a separate tab. Fold each gray tab up so it is perpendicular to the sheet. You now have a model showing the phases of the Moon. It is based on the Moon's position relative to the Earth and Sun. (In this model the person's head is always facing the Sun.)

9. Staple or tape the chart to the sheet of cardboard. The finished device should look like Figure 5.1.

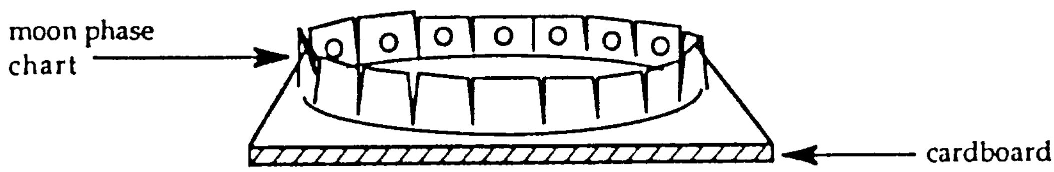


Figure 5.1

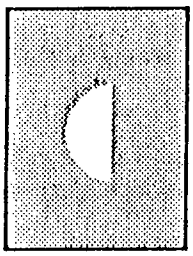
The names of the phases of the Moon for days after New Moon are as follows:

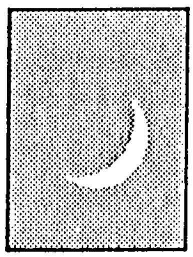
day number	Name of phase
0	NEW MOON
0 to 7.5	WAXING CRESCENT MOON
7.5	FIRST QUARTER MOON
7.5 to 15	WAXING GIBBOUS MOON
15	FULL MOON
15 to 22.5	WANING GIBBOUS MOON
22.5	LAST QUARTER MOON
22.5 to 30	WANING CRESCENT MOON

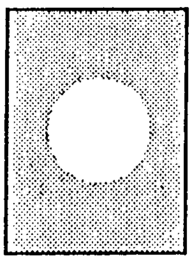
10. Write the name of the lunar phase under its proper picture on Chart 5.1.

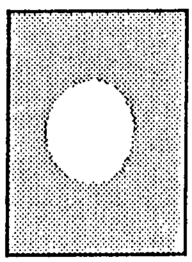
Use your finished chart to answer the following questions.

5.3 *From the diagrams below, identify the phase of the Moon and the number of days after the New Moon:*

(a)  *Phase* __________ *day* __________

(c)  *Phase* __________ *day* __________

(b)  *Phase* __________ *day* __________

(d)  *Phase* __________ *day* __________

5.4 *If you saw only a picture of the Moon, how could you tell where the Sun was when the picture was taken?*

5.5 *If you were to see the First Quarter Moon today, what phase would you see two days later?*

5.6 *If you were to see the First Quarter Moon today, what phase would you have seen ten days ago?*

5.7 *At the First Quarter Moon, does the Moon appear to the left or to the right of the Sun?*

5.8 *At the First Quarter Moon, is the apparent angle between the Sun and the Moon greater than, less than or equal to 90°?*

5.9 *If it were a Full Moon today, how many days later would the Moon be in its Last Quarter phase?*

5.10 *If the Moon were in its Last Quarter phase, in what phase would the EARTH appear to be if you were standing on the Moon?*

5.11 *If you were standing on the Moon and saw the EARTH in its Full phase, in what phase would the Moon be?*

5.12 *If you looked at the horizon and saw the Full Moon just rising, where would you look to see the Sun?*

5.13 *An inmate is planning to break out of prison. On August 2nd the prisoner sees a First Quarter Moon. The inmate has read "Basic Escape Planning" by O. verderWaal and knows that getting caught is what ruins most escapes. A dark night would help him avoid detection. Based on the Moon phase sighting above, on what date should the prisoner try to get out? Explain your choice of date. (This is only one example of how your study of the Moon's phases may be useful to you later in life.)*

5.14 *(a) Refer to the predictions you made in Question 5.1. Compare your picture sequence with the phase drawings on Chart 5.1. Make corrections as needed.*

(b) Write the phase name under the appropriate photograph.

5.15 *Refer to the journal of Moon drawings from ACTIVITY 2. Label the pictures you drew with the proper day number and phase name.*

Timing Moonrise, Moonnoon, and Moonset*

PURPOSE

To construct a device to determine the location of the Moon in the sky for a given day of the month, time of day, and phase of the Moon.

MATERIALS

Moon Phase chart from ACTIVITY 5A
Chart 5.2 on page 164
Chart 5.3 on page 164
Tape or paste
Pin or tack

PROCEDURE

1. Cut out the EARTH TIME circle diagram on Chart 5.2.

2. Tape or paste this circle onto the center circle of your Moon Phase chart from ACTIVITY 5A. Be careful to match the phases printed on Chart 5.2 with those you wrote on the Moon Phase chart. "New Moon" should be in the same direction as the Sun.

3. Note the sixteen small circles on Chart 5.2. Circle 1 has the time Noon written above it. Turn the chart around to small circle 5. Write "Midnight" above this circle. Write "6 PM" above circle 3.

   5.16 What time would be written above small circle 7?

4. Write this and the remaining times above the other numbered small circles.

5. Cut out the TIME/HORIZON POINTER diagram in Chart 5.3 and pin or tack it to the Chart 5.2, the Moon Phase combination. Chart 5.3 should spin freely around the pin while Chart 5.2 is attached to the Moon Phase chart. The time which the pointer shows is the time when the Moon is being observed.

   The following Moon problems deal with the relationship among three quantities: 1) the PHASE of the Moon, 2) the TIME (approximate Standard Time) of the observation, and 3) the POSITION of the Moon in the sky. If you know any two of these quantities, you can find the other using this device.

EXAMPLE 1
At NOON where in the sky would you see the First Quarter Moon?

Turn the pointer so it points at NOON.
Find the First Quarter Moon. According to the pointer device, the Moon is near the EASTERN HORIZON which means the Moon would be rising at NOON.

EXAMPLE 2
At what time would the Waxing Gibbous Moon be in the Southwest?

Find the Waxing Gibbous Moon.
Turn the pointer circle until this Moon is halfway between South and West.
Notice the time at which the TIME pointer is pointing. It is MIDNIGHT.

---

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Use this device to answer the following questions:
(NOTE: Refer to the middle drawing for the Crescent and Gibbous phases)

5.17 *If the Moon were to set at 3 pm, what would be its phase?*

5.18 *If the Moon were rising at midnight, what wo: 'd be its phase?*

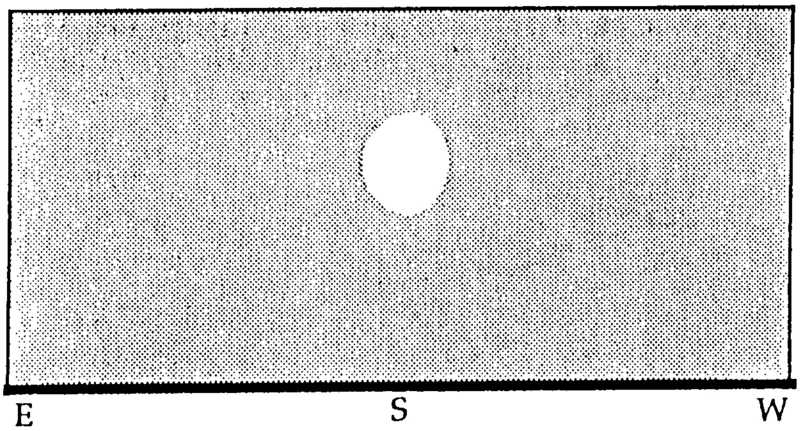
5.19 *If the Moon were at its highest at 9 pm, what would be its phase?*

5.20 *When does the Last Quarter Moon rise?*

5.21 *When does the Waxing Crescent Moon set?*

5.22 *If the Moon were Full, at what time of day would it be highest in the sky?*

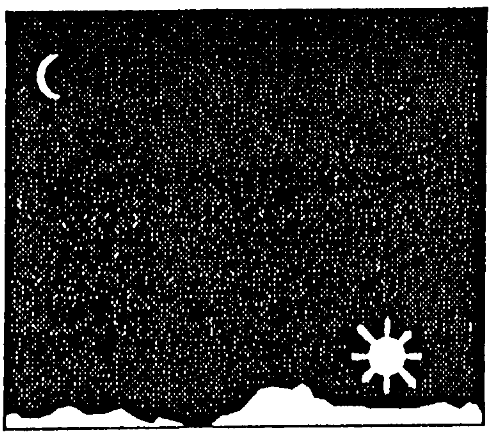
5.23 *From the diagram below, identify the phase of the Moon and the approximate time of day:*



Phase __________

Time __________

5.24 *Explain what is wrong in the following picture and how it could be corrected:*



5 PM

wrong because: ____________________

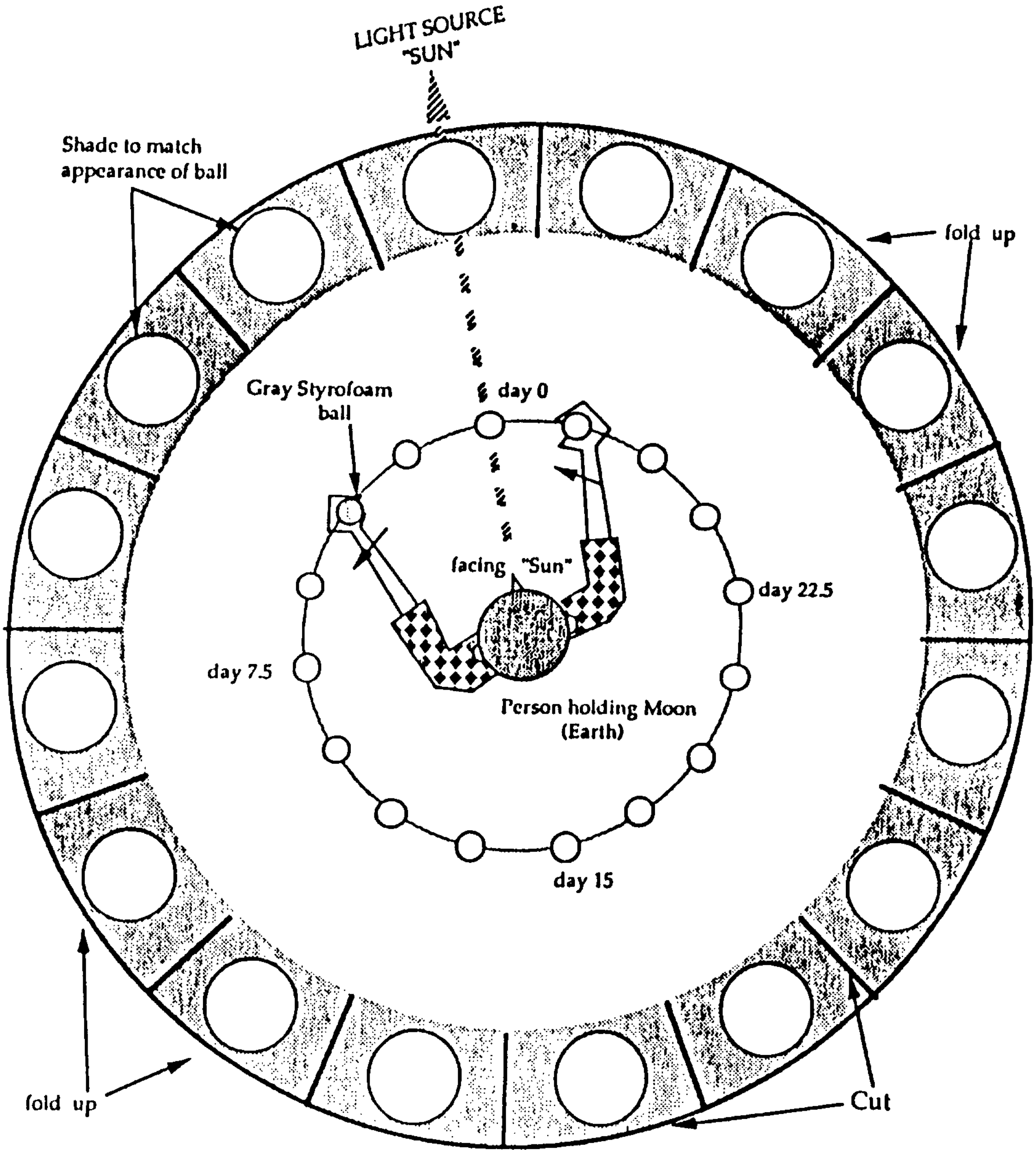
____

____

to correct it: ____________________

____

____



<u>Chart 5.1 LUNAR PHASE DRAWINGS</u>
Face toward light source (the"Sun"). Move a gray styrofoam ball to the positions indicated. Imagine yourself standing in the position of the person in the diagram. In the corresponding circles, draw how the ball would appear as you would see it. Cut along the heavy black lines only.

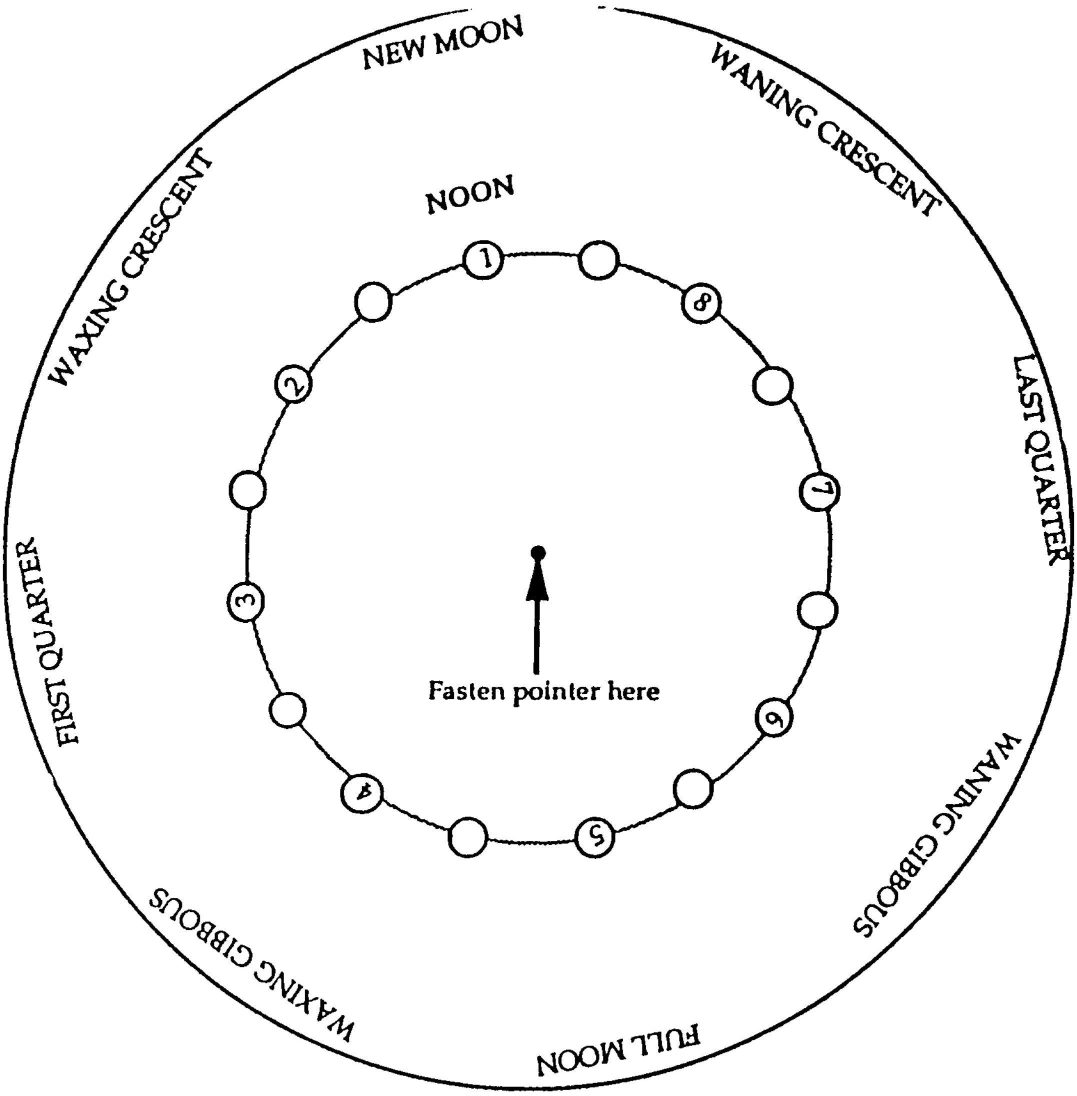


Chart 5.2 TIME ON EARTH CIRCLE

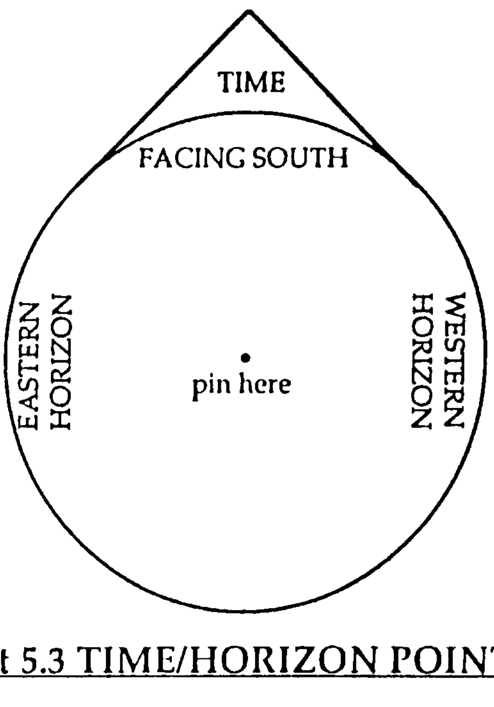


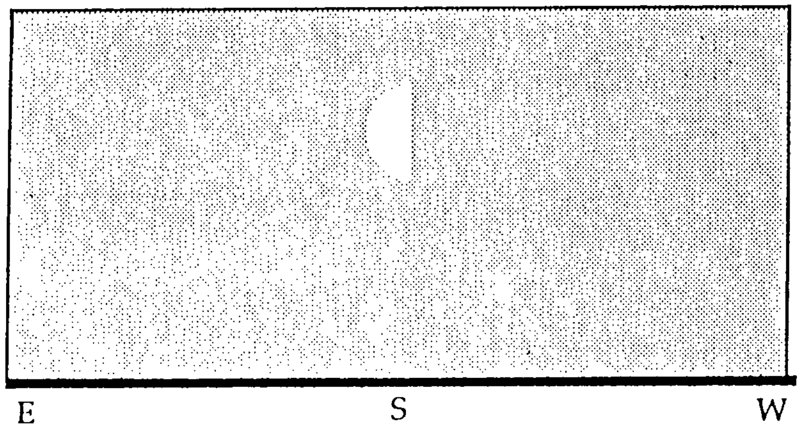
Chart 5.3 TIME/HORIZON POINTER

HOMEWORK

Write answers to questions and/or problems in the spaces provided.

5.25 From each diagram below, identify the phase of the Moon and the approximate time of day:

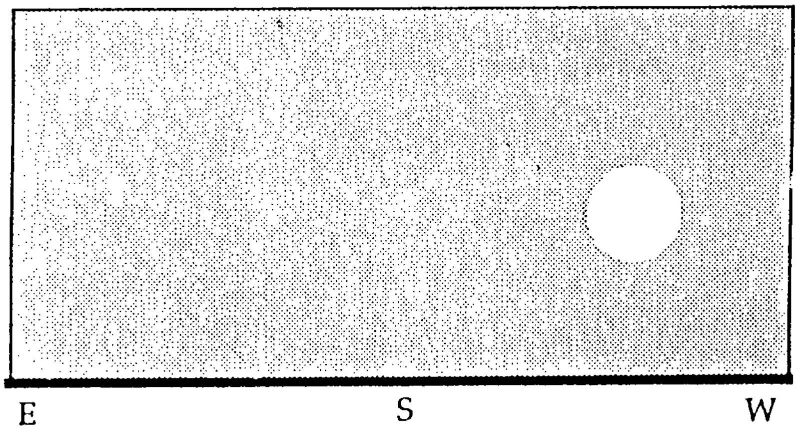
(a)



Phase __________

Time __________

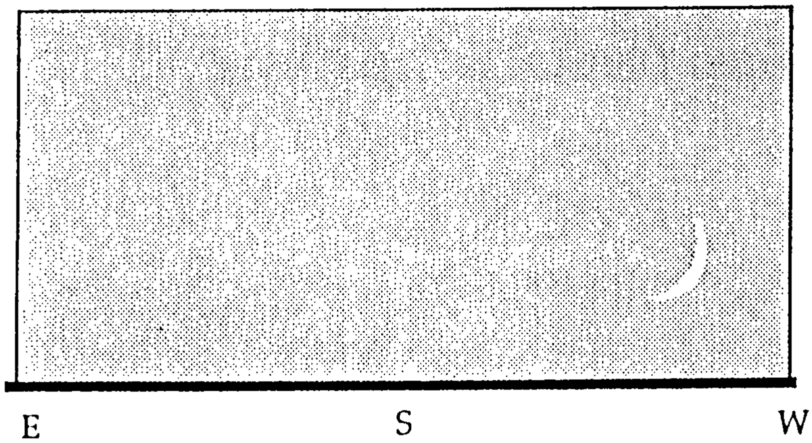
(b)



Phase __________

Time __________

(c)

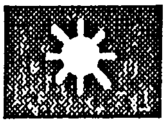


Phase __________

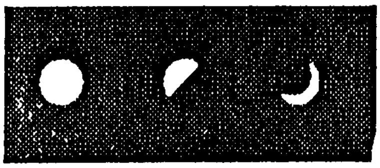
Time __________

5.26 *Explain what is wrong in the following pictures and how these pictures could be corrected:*

Key to diagrams:

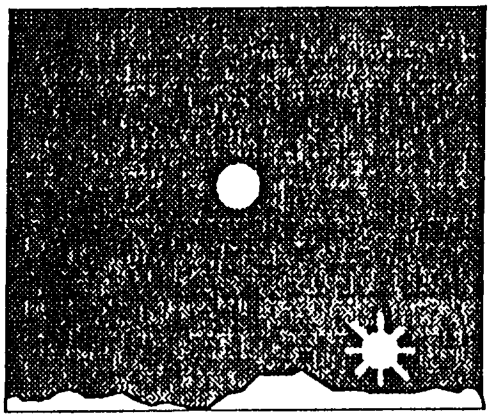


the Sun



the Moon (in various phases)

(a)



5 P.M.

wrong because: ______________________________

____

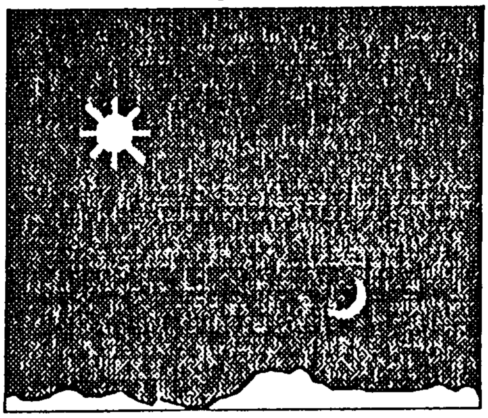
____

to correct it: ______________________________

____

____

(b)



NOON

wrong because: ______________________________

____

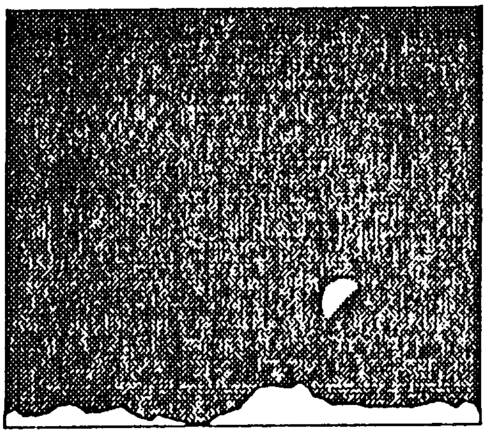
____

to correct it: ______________________________

____

____

(c)



MIDNIGHT

wrong because: ______________________________

____

____

to correct it: ______________________________

____

____

DISCUSSION QUESTIONS

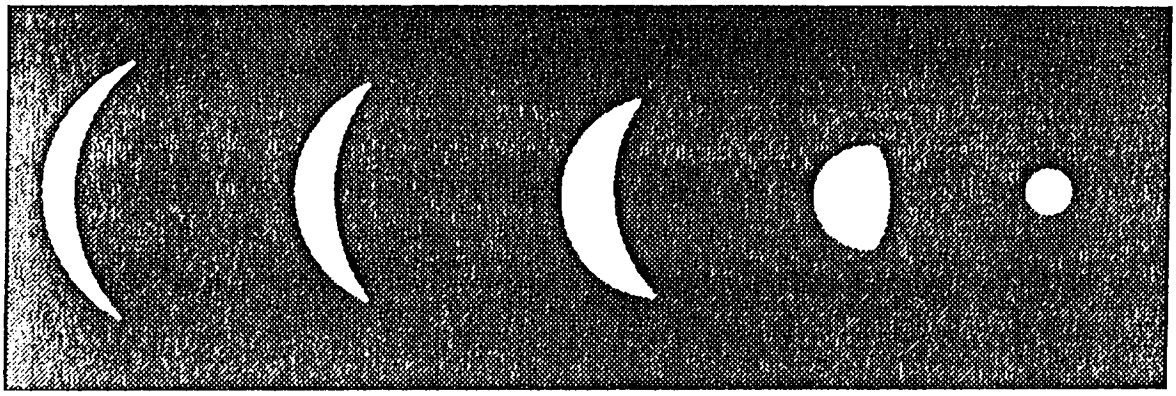
5.27 *If the Moon were at First Quarter tonight, when would it next be at First Quarter?*

5.28 *How long does it take for the Moon to make one orbit of the Earth?*

5.29 Study the pictures of the Moon's phases from the beginning of this activity. Does the Moon always keep the same face pointed at the Earth?

5.30 If you were standing in the center of the face of the Moon, would you see the Earth rise and set?

5.31 The picture below shows how Venus would appear through a telescope on the Earth on five different dates. When the "full" Venus was photographed, it was seen in the sky very close to the Sun. Venus was also seen very near the Sun in the sky when the thin crescent photos were taken. The fact that Venus undergoes phases was first observed by the Italian astronomer Galileo. He claimed that the phases meant Venus orbited the Sun, not the Earth. The Moon also has phases and goes around the Earth. Why would Galileo believe these observations to be a proof that Venus goes around the Sun?



EXTENSIONS

1. There have been at least two TV programs with names referring to the Moon: "The Honeymooners" and "Moonlighting". What are the origins of the words "honeymoon" and "moonlighting"? (The words existed long before the shows.) List other words and phrases that refer to the Moon and try to determine their origins. Why do you think "moon" turns up so often in our daily language?

2. With the help of another student, move the styrofoam ball in a circle around the 200-watt bulb so that it is about 2/3 as far from the bulb as you are. (If you are 3 meters from the bulb, keep the ball at 2 meters.) This setup is a model of the motion of Venus as seen from the Earth. (Question 5.31)
   a) Draw the sequence of phases that you would see if the ball were to move counterclockwise around the bulb.
   b) How does Venus' phase sequence compare to the Moon's phase sequence?

3. Discuss the phases that Jupiter undergoes as seen from the Earth. (Try setting up a ball and bulb model to work out your answer.) Hint: The distance of Jupiter from the Earth varies from 4 to 6 times the Earth's distance from the Sun.

4. a) Diagram the positions of the Moon, the Sun and the Earth for a lunar eclipse.
   b) In what phase is the Moon during a lunar eclipse?
   c) Why do we not see a lunar eclipse once every month?
   d) Find the date for the next partial and total lunar eclipse for your area.

5. a) Diagram the positions of the Moon, the Sun and the Earth for a solar eclipse.
   b) In what phase is the Moon during a solar eclipse?
   c) Why do we not see a solar eclipse once every month?
   d) Find the date for the next partial and total solar eclipse for your area.

Making Scale Models of Earth, Moon, and Sun*

PURPOSE

To build scale models of the size and distance relationships of the Earth, Moon and Sun to help you understand how the distances between those objects are related to their sizes.

WHAT DO YOU THINK?

Write the answers to the questions and/or problems in the spaces provided.

Your teacher has drawn a circle to represent the Sun at one end of the blackboard. You, along with each of your classmates, should draw another circle on the board to represent the Earth. Try to draw it to the same scale as the Sun. In other words, if the teacher's circle were really the size of the Sun, what size would the Earth be?

12.1 How many times bigger than the Earth's diameter do you think the Sun's diameter is?

Now repeat the exercise, this time for the relationship between the Earth and the Moon, instead of for the Sun and the Earth. Your teacher has drawn a circle to represent the Earth. Draw a circle to represent your best guess of the size of the Moon compared to the Earth.

12.2 How many times bigger than the Moon's diameter is the Earth's diameter?

MATERIALS

an assortment of different size spheres
1 meter stick
1 classroom Earth globe (12 or 16 inch diameter)

PROCEDURE

Write the answers to the questions and/or problems in the spaces provided.
Show your math and box your answers, labeling answers with proper units of measurement.

1. Take one sphere from the box of spheres provided by your teacher. Your classmates will do the same so that each of you will have a different size sphere. Look around the room and find a partner whose sphere is adequately large or adequately small so the two spheres together would represent a scale model of the Earth and the Moon.

2. When you have found a partner, move your spheres apart until they are the distance you think the Earth and Moon would be if they were the size of the spheres. If you are having difficulty, read the following example.

EXAMPLE 12.1
The Earth is about 12,800 km in diameter. The Moon is about 3,500 km in diameter. Therefore, the Earth's diameter is nearly four times the diameter of the Moon. Thus, if your Moon-sphere is 12 cm in diameter, the Earth-sphere should be 48 cm in diameter. The Earth-Moon distance averages about 400,000 km. Therefore, it would take about 115 Moon-sized spheres, or about 1500 cm (15 m or about 50 ft), to fill the distance between the Earth and the Moon.

* Reproduced with permission from Project STAR, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138.

12.3 Measure the diameters of the objects you used for the Earth and Moon. List them below.

Earth = ______________ *cm* *Moon* = ______________ *cm*

3. Given your Earth globe, find a sphere that represents the size of the Moon at that same scale.

4. Place the Moon at the proper scale distance from the globe.

12.4 Measure the diameters of the Earth globe and the object you used to represent the Moon. Show the calculations you made to find the proper scale distance between them.

Earth = ______________ *cm*

Moon = ______________ *cm*

Distance = ______________ *cm*

5. Use the classroom Earth globe to answer the following questions.

12.5 At the scale of the globe, what is the diameter of the Moon?

12.6 At the scale of the globe, what is the distance from the Earth to the Moon?

12.7 The Space Shuttle orbits at a distance of about 480 kilometers (300 miles) above the Earth's surface. How far is this orbit above the surface of the globe?

12.8 Some satellites, such as some of those used for telephone and television communications, must always stay directly above the same spot on the Earth. If a satellite can be placed in a circular orbit at an altitude of 36,000 kilometers (22,300 miles) above the Earth's equator it will complete one full orbit in 24 hours. In this way the satellite appears to stay over the same spot on the Earth's surface, thus being called a "geostationary" satellite. How far from the globe's surface are these geostationary satellites?

12.9 Compare the distances of the shuttle and the geosynchronmous satellite from the Earth to the distance of the Moon from the Earth.

To begin to get a sense of the distance from the Earth to the Sun, you will need the following information:

The Earth's diameter is about 12,800 km (7,930 mi).

The Moon is about 3,500 km (2,200 mi) in diameter and orbits the Earth at an average distance of 400,000 km (240,000 mi).

The average distance from the Earth to the Sun during a year is 150,000,000 km (93,000,000 mi).

The Sun's diameter is about 1,400,000 km (875,000 mi).

12.10 How many times larger is the diameter of the Sun than the diameter of the Earth?

12.11 How many solar diameters would fit between the Sun and the Earth?

6. Choose two spheres, one as a scale representation of the Earth, and the other as a scale representation of the Sun. Measure their diameters.

   12.12 Given the diameters of the spheres you chose for the Earth and the Sun, how far apart must they be for the distance between them to be at the same scale. Show your calculations.

   Earth = ________ cm Sun = ________ cm Distance = ________ cm

7. Move your spheres to the correct scale distance apart. If your classroom is not large enough, move out into the hallway or out to the school yard (with your teacher's permission).

   In the previous questions, you knew the sizes of the Sun, Earth and Moon and tried to calculate their distances from each other. You can also calculate their *sizes* if you start by knowing their distances.

EXAMPLE 12.2

If your classroom is 15 m long (about 50 feet), how large would an Earth-sphere and a Sun-sphere have to be if the model Sun were to be placed at one end of the room and the model Earth placed at the other?

You calculated in Question 12.11 that it would take about 107 Sun diameters to fit in the space between the Sun and the Earth. (This is called a *scale factor.*) 15 m (1500 cm) divided by 109 (the scale factor) equals about 14 cm. Thus, a sphere would have to be 14 cm in diameter to represent the Sun.

EXAMPLE 12.3

You can complete a similar calculation to estimate the size of a sphere chosen to represent the Earth. In Question 12.10 you determined that it takes about 107 Earth diameters to fit into the diameter of the Sun. You then calculated that the model Sun would have to be 14 cm in diameter if it were located 15 m from a model Earth. Because the real Sun is 107 times larger in diameter than the Earth, we will have to divide 14 cm by 107 to calculate how large our model Earth would be in the same classroom. The answer is about 0.1 cm (or 1 mm), or roughly the size of the head of a pin!

7. Measure the length of your classroom, and let this length represent the distance between the Earth and the Sun.

12.13 The scale Earth-Sun Distance = _______________ cm

12.14 Following the example given above, calculate how large the Sun and the Earth would have to be to establish a scale model of the two objects in your classroom.

Model Sun diameter= _______________ cm

Model Earth diameter= _______________ cm

12.15 Follow the same reasoning to estimate how far the Moon would be from the Earth in your scale model.

12.16 List some common objects roughly the size of your model Sun and model Earth. (For example would a softball be about the size of your model Sun?)

Part V

References and Resources

Spinoffs From Space*

From the exploration of space, technological advances have been made that have applications beyond their original intended use. These indirect benefits can be as common as the cushioning in your atheletic shoes. Nearly 30,000 spinoffs can be credited to the space programs. Just a few of them are:

- Polarizing lens material for sunglasses
- Scratch-resistant lens coating for plastic eyeglasses
- Cordless drills and handheld vacuum cleaners
- Home Insulation
- Reflecting windows
- A reading machine for the blind
- Magnetic resonance imaging
- A voice-controlled wheelchair
- A tissue stimulator that provides relief from pain
- A joystick for automobiles for the handicapped
- The Nitinoy alloy (made of nickel and titanium) used for braces
- Computer software that simulates the behavior of materials
- A fine mesh used in safety nets for technicians
- High-volume, high-speed pumps to boost fuel flow
- A miniature laser that can tunnel into a clogged artery

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* Excerpted from *Spinoffs*, Nasa.

Readings, Materials, Maps, Slides, Films, and Software*

GENERAL READING FOR INSTRUCTORS

The following books are non-mathematical treatments of some of the specialized topics in astronomy and would provide the instructor with a greater depth of understanding of those topics.

Thursday's Universe, Bartusiak, Marcia (1986): Time Books, 777 Duke St., Alexandria, VA 223114.

Contact with the Stars: The Search for Extraterrestrial Life, Breuer, Reinhard (1982): W. H. Freeman & Co., 41 Madison Ave., 37th Floor, New York, NY 10010.

In Darkness Born: The Story of Star Formation, Cohen, M. (1988): Cambridge University Press, 32 E. 57th St., New York, NY 10022..

Astronomy from Space, Cornell, J. & Gorenstein, P. (1983): MIT Press, Cambridge, MA 02138.

The Red Limit (2nd ed.), Ferris, Timothy (1983): Quill Publishers, 105 Madison Ave., New York, NY 10016. This book provides a warm, human story about the investigation of the large-scale properties of the universe.

Solar System, Frazier, Kenneth (1985): Time-Life Books, 777 Duke St., Alexandria, VA 22314. This is an excellent color-illustrated book.

Moons and Planets (2nd ed.), Hartmann, W. (1984): Wadsworth, Inc., 10 Davis Drive, Belmont, CA 94002.

The New Astronomy, Henbest, N. & Marten, M. (1983): (Address above.) This book is particularly valuable for its view of the universe as seen in other than the visible part of the electromagnetic spectrum.

Observing the Universe, Henbest, N. & Marten, M. (1984): B. Blackwell Limited, 108 Cowley Rd., Oxford OX4 IJF, England. This easy-to-read reference provides a comprehensive look at the tools that make modern astronomy possible, including information on HEAO, IRAS, etc.

Psuedoscience and the Paranormal: A Critical Examination of the Evidence, Hines, T. (1988): Prometheous Books, Buffalo, NY. A "must read" book for teachers who confront the issue of astrology as a "science".

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The Book of the Moon, Hockey, Thomas A. (1986): Prentice Hall Press, One Gulf Western Plaza, New York, NY 10023. One of the best general level books about the moon.

Universe of Galaxies, Hodge, Paul (1984): W.H. Freeman & Co. (See address above.)

Coon Mountain Controversies, Hoyle, W.G (1987): University of Arizona Press, 130 Park Ave., N., Tucson, AZ 85719. This book discusses the early controversy concerning the origin of the Barringer Meteor Crater.

Black Holes and Warped Space Time, *Galaxies and Quasars*, *Planets and Moons*, and *Stars and Nebula*, Kaufmann, William: W.H. Freeman & Co. (Address given above.) These descriptive books could also serve as texts for short courses with advanced students.

The Supernova Story, Marschall, Laurence A. (1988: Plenum Publishing Corp., 233 Spring St., New York, NY 10013. This well acclaimed book, thought motivated by SN1987A places supernovae in a full astronomical context.

The New Solar System, O'Leary, Brian & Beatty, J.K. (eds) (1982): Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02138.

Man and Meteorites, Pejovic, Brian (1982): Sheridan House, 145 Palisade St., Dobbs Ferry, NY 10522.

Cosmic Horizons, Rowan-Robinson, Michael Wagoner, R. & Goldsmith, D. (1983): (Also from W.H. Freeman & Co.). This is a collections of articles on modern topics in astronomy.

Black Holes, Quasars, and the Universe (2nd ed.), Shipman, Harry L., (1980): Houghton Mifflin Co., 1 Beacon St., Boston, MA 02107.

The Invisible Universe Revealed, Verschuur, Gerrit L. (1987): Springer-Verlag New York, Inc., P.O. Box 2485, Secaucus, NJ 07094.

The Mystery of Comets, Whipple, Fred L. (1985): Smithsonian Institution Press, 475 L'Enfant Plaza, Rm. 2800, Washington, DC 20560.

GENERAL READING FOR STUDENTS

The books selected here are only some of the more recent books designed for a junior-high or senior high-school audience. They differ widely in topics and reading levels, but are all chosen for their recency of publication. Although some are familiar to the preparers of this resource booklet, no attempt has been made to review them all for accuracy.

The Moon and its Exploration, Apfel, Necia (1982): Franklin Watts, 387 Park Ave. S., New York, NY 10016.

The Planets in Our Solar System, Branley, Franklyn (1981): Thomas Crowell (Division of Harper-Row),10 E. 53rd St., New York, NY 10022.

The Comet Book, Chapman, R. & Brandt, J. (1984): Jones & Bartlett Publishers Inc., 20 Park Plaza, Bos'on, MA 02116.

The Greenhouse Effect, Gay, Kathlyn (1986): Franklin Watts. (Address above.)

Black Holes, Quasars & Other Mysteries of the Universe, Gibilisco, Stan (1984): TAB Books, Inc., Monterey Ave., Blue Ridge Summit, PA 17214.

Spacewarps, Gribben, John (1984): Delacorte Press, 1 Dag Hammarskjold Plaza, 245 E. 47th St., New York, NY 10017.

Comet Fever, Gropman, Donald & Mirvis, Kenneth (1985): Simon & Schuster, Inc.,1230 Ave. of the Americas, New York, NY 10522.

Recent Revolutions in Astronomy, Kelsey, Larry & Hoff, Darrel (1987): Franklin Watts. (See address above.)

Daytime Star, Mitton, Simon (1983): Charles Scribner's Sons, 597 Fifth Ave., Glenview, IL 60025.

Astronomy Today, Moche, Dina (1986): Random House, Inc., 201 E. 50th St., New York, NY 10022.

Sun, Moon and Planets, Myring, L. and Snowden, S. (1982): EDC Publishing, E. 55th Pl., Tulsa, OK 74146.

First Light: The Search for the Edge of the Universe, Preston, Richard (1987): Atlantic Monthly, NY.

The Young Astronomer's Handbook, Ridpath, I. (1984): Arco Publishing (Div. of Prentice-Hall), Englewood Cliffs, NJ 07632.

Volcanoes in Our Solar System, Taylor, G.J. (1983): Dodd, Mead & Co., 79 Madison Ave., New York, NY 10016.

Whitney's Star Finder, Whitney, C. (5th ed., 1988): Alfred A. Knopf, Inc., 201 E. 50th St., New York, NY 10016

MAPS AND ATLASES

Addresses given above for the Sky Publishing Co., AstroMedia, and the ASP are the sources for many of the following maps and atlases Another excellent source for atlases, catalogs and other astronomical publications is Willmann-Bell, Inc., P.O. Box 35025, Richmond, VA 23235. Write them to obtain a free catalog. We have restricted the entries here to the best quality products.

Atlas of the Heavens: A. Becvar. This set of 16 sky charts is printed white on black, showing stars to a magnitude limit of 7.75. A total of 35,000 objects are shown. A similar desk edition is sold at the same price with stars shown in black on a white background. ($6.50) (Available from Sky Publishing.)

Atlases: Borealis, Eclipticalis, and Australis: A. Becvar. These books are large format and contain fold-out maps. Each covers a different region of the sky. For northern-hemispheric observers, the Borealis (circumpolar) and Eclipticalis (ecliptic) regions would be all that are needed. A total of 320,000 stars are plotted to a limiting magnitude of 9, with colors used to denote different spectral classes. At $49.95 each, they are a rich source of information for discussion. (Available from Sky Publishing.)

The Edmund Mag 5 Star Atlas: This atlas comes highly recommended by teachers. It lists all stars to a magnitude of 5.0 down to 60 degrees south declination. It is one of the least expensive ($6.95) atlases on the market and its simplicity makes it ideal for student use. (Edmund Scientific Co., 101 E. Gloucester Pike, Barrington, NJ 08007)

Norton's Atlas (17th ed.): This atlas (which began in 1910) has had the greatest popularity of any beginning sky atlas. It contains 8,400 stars to 6.35 magnitude and 600 deep-sky objects. If you choose only one atlas for reference, this should be the one. ($29.95) (Available from Sky Publishing.)

Sky Atlas 2000.0, Tirion, Wil: The "2000.0" refers to the fact that this atlas shows stellar positions as they will be seen in the year 2000. It includes 43,000 stars to visual magnitude 8.0 and 2,500 deep-sky objects. A field edition (white stars on black) is printed on 27 13.5 x 18.5 inch charts unbound and sells for $15.95. A color edition is also available on white background for $34.95. (Available from Sky Publishing.)

SLIDE AND AUDIO TAPE SOURCES

In an instructional world where video tapes, 16-mm movies and video disks abound, the ordinary 35-mm slide still provides one of the least expensive and versatile audio-visual aids. In addition to ease of use, slide collections can be readily up-dated and re-sequenced as new information becomes available, or instructional patterns change. In addition to their use in a lecture-discussion mode, they can be used to promote inquiry and investigation. For example, a slide showing segments of the sun taken over a series of days can be used to elicit a discussion about possible models to explain why the sunspots appear in different positions on a succession of days. As another example, try projecting a slide of a typical open cluster and a typical globular cluster, and challenge your students to determine observational differences between these two objects. Informal tests of this technique by the editor of this booklet have produced lively and interesting discussions on a variety of topics.

The following distributors are only a few of the possible sources for astronomical slides. These distributors have the largest variety of slides available. Consult astronomy periodicals for additional sources.

The AAPT distributes some slide sets useful for astronomy instruction. These sets have been developed by teachers and the AAPT produces and distributes them. These sets include study guides.

The ASP is a major supplier of astronomical slides. They distribute slides from Palomar Observatory and NASA, and have assembled specialized sets of slides on a variety of topics including historical topics, world telescopes, comparisons of planet and satellite sizes, images of the universe as "seen" in radio and infrared wavelengths, and satellite images of the planets.

The Hansen Planetarium, 15 South State St., Salt Lake City, UT 84111, is a commercial distributor of a large variety of astronomical slides. In addition to slides, they also distribute posters, calendars and other materials useful for the classroom teacher. Write to them to obtain a free catalog.

The MMI Space Science Corporation is a major supplier of color slides, videocassettes, filmstrips, movies, manuals, and globes. Their current catalog contains eight pages of advertisements for slides alone. These are generally sold as sets of 10 to 40 slides each. Write to them at 2950 Wyman Parkway, PO Box 19907, Baltimore, MD 21211 for a free catalog.

NASA is a major producer of visual materials, including slides. It maintains a Resource Center for Educators at the Alabama Space and Rocket Center, Huntsville, Al 35807. Their slide catalog, called "Photography Index" does not show pictures of the slides, and subjects are identified with only a single line description. Teachers who have used their services report a very slow response time. Each of NASA's Resource Centers will allow visitors to copy any of their videotapes at no cost. Visitors must bring their own VHS blank tapes.

Tapes of the Night Sky is a set of two seasonal audio tapes with a book of transcripts, four specially designed star maps and a reading list. These tapes are designed to orient the beginning sky watcher. Available from the ASP for $16 for a two tape set. Recommended!

Tapes of the radio sounds of pulsars, solar storms and Jupiter radio activity are available from The National Radio Astronomy Observatory, Box 2, Green Bank, WV 24944. They will loan you a tape for copying at no charge. The pulsar signals are fascinating to students.

If you have access to a videodisc player, you may wish to investigate the astronomical video discs available from the Optical Data Corporation, 66 Hanover Road, Florham Park, NJ 07932. Titles include "Astronomy", "Voyager", "Apollo", "Shuttle", "Sun/Universe" and "Earth Science". The "Astronomy" disc contains 54,000 images which can be accessed as slides or shown as film clips. ($400.)

FILMS AND VIDEOCASSETTES

There is no one single film source that we can recommend. There are approximately 50 movie distributors which either sell or rent scientific films. A recent listing of distributors is given in *The Universe at Your Fingertips*. *The Universe in the Classroom* by Andrew Fraknoi (Freeman press) contains a detailed subject index of several hundred astronomy films available as of 1985. An older (1980) review of Films in the Sciences is available from the AAAS, 10th Floor, 1101 Vermont Ave. N.W., Washington, DC 20005 for $14. Their monthly publication, AAAS Science Books and Films also lists current films, filmstrips and books. This useful publication is available for a $20 a year subscription.

Astronomical films differ widely in content, accuracy and recency. Our best advice is to consult your local film sources and preview before use. We list here those films most commonly used by teachers. Contact the individual sources for current rental or purchase costs.

Film Series

Explorations in Space and Time by M.L. Meeks (1973, Houghton-Mifflin Co., 1 Beacon St., Boston, MA 02107). This is a series of eight computer-generated films. Each is about 8-10 minutes long, and the series is also available on silent film loops. Sample titles include: "Sirius and the White Dwarf", "The System Xi Ursa Majoris", "Planetary Motions and Kepler's Laws", and "Doppler Effect".

The well-known television series *Cosmos* is available on video tapes. This 13 part series was produced by Carl Sagan Productions and KCET-TV, Los Angeles. A film series is distributed by Random House, Inc., 201 E. 50th St., New York, NY 10022. This set of six half-hour films is accompanied by a reader and study guide.

Project Universe is a series of 30 video programs produced by the Coast Community Colleges, 11460 Warner Ave.., Fountain Valley, CA 92708. These 30 minute programs take a content approach to the topic of astronomy at a beginner's level. Narrated by Edwin Krupp, the series takes an inside-out look at the universe and includes a large number of interviews with astronomical experts in the field. Consult your local school district or educational learning agency to determine if copies are available for classroom use. The general content is recent and very useful for introductory instruction. It is also accompanied by a study guide keyed to Abell's *Realm of the Universe.*

Contact the Resource Center for Educators, Alabama Space and Rocket Center, Huntsville, Al 35807, for a current list of available NASA films. These are distributed at no cost, but our experience has been that it is difficult to obtain them at your desired scheduling times. Recently NASA has established a Central Operation of Resources for Educators. These centers distribute NASA video tapes, films and slides at modest cost. We have had excellent service with NASA CORE, Lorain County JVS, 15181 Route 58 S., Oberlin, OH 44074. Write for free catalog.

Individual Films

No attempt will be made here to preview a large number of astronomical films, but several are of high quality and have been found to be very useful for the high-school astronomy teacher, and will be noted here.

Introductory or overview

Powers of Ten. This brief 10-minute film takes the viewer from the smallest to the largest objects in the universe by powers-of-ten steps. In addition to giving the beginner a sense of scale of the universe, it is a visual lesson in scientific notation. The narration is done by the well-known astronomer, Phillip Morrison. (Pyramid Films, Box 1048, Santa Monica, CA 90406.)

Universe. A 28-minute color film, narrated by William Shatner, takes the viewer on a spectacular tour of the Universe. Its 1976 copyright makes it dated in a few places, but it is ideal for either a beginning look at the cosmos, or as a summary at the end of a course. This film is available from Screenscope, Suite 2000, 1022 Wilson Blvd, Arlington, VA 22209, and is also distributed by NASA.

Solar System

Comet. This 15-minute film distributed by the National Film Board of Canada is described by our teacher panel as "Excellent." It is available from the National Film Board of Canada, 16th Fl., 1251 Avenue of the Americas, New York, NY 10020.

Comets: Time Capsules of the Solar System. This 12-minute Walt Disney Educational Media film was made in 1981. It provides an overview of comets using excellent animation. (500 S. Buena Vista St., Santa Barbara, CA 91521.)

Jupiter Odyssey. NASA produced this film following the Pioneer 10 exploration of Jupiter. It was released in 1974 and is 28 minutes long. Unfortunately, NASA has not released a similar film following the Voyager missions.

Mars Minus Myth. A post-Viking examination of Mars, 22 minute film produced by Churchill Films, 662 N. Robertson Blvd., Los Angeles, CA 90069.

Mercury, Exploration of a Planet. Produced in 1976 following the exploration of Venus and Mercury by Mariner 10, this film uses both animation and photography to explore the two inner planets. (NASA)

One Small Step. This 59-minute NOVA production was released in 1978 and presents a comprehensive overview of the Apollo program. Available from Time-Life, 100 Eisenhower Dr., Paramus, NJ 07652.

Planet Mars. This 29-minute NASA film was produced in 1979 and describes the exploration of Mars, following completion of the Viking lander missions to the planet.

Resolution on Saturn. A 58-minute NOVA production produced in 1981 after Voyager I had encountered Saturn. It is available from Time-Life Films. Address given above.

The Solar System. This 28-minute film was made in 1982 following the Voyager I encounter with Saturn. Available from The International Film Bureau, 332 S. Michigan Ave., Chicago, IL 60604.

The Sun: Earth's Star. A 20-minute film, produced by the National Geographic Society in 1980, describes the Sun and the Earth's relationship to it. (17th and M Streets, N.W., Washington, DC 20036.

Sunspot Mystery. An excellent 30-minute NOVA film, released in 1979, explores the possible connection between sunspot cycles and terrestrial weather patterns. Available from Time-Life.

Stars

The Birth and Death of a Star. A 1974 film which describes the structure of stars, their origin, evolution and deaths. Available from Time-Life. Address given above.

The Crab Nebula. A 1972 Time-Life film presents the story of the Crab Nebula as a mystery story. It is an excellent film to incorporate in a discussion of supernovae, pulsars and neutron stars.

Galaxies and Beyond

A Whisper from Space. This 1979 release describes the discover of the three degree background radiation in a 57-minute NOVA film. It is available from Time-Life.

Beyond the Milky Way. A 1981 NOVA production, 57 minutes in length, this film is a fairly recent survey of extragalactic astronomy. Available from Time-Life.

Black Holes and Quasars. This 29-minute film was released in 1983. It is distributed by McGraw-Hill, 1221 Avenue of the Americas, New York, NY 10016.

Exploring the Milky Way. While this film was released in 1967, it is well enough done so that it still contains generally good material to explain the means used to explore the overall structure of our galaxy. It is 28 minutes long and available from Modern Learning Aids, Box 92912, Rochester, NY 14692.

Miscellaneous Topics

A Private Universe This videotape was produced by Project STAR to demonstrate that students hold serious misconceptions about the universe. It also demonstrates that conventional lecture-discussion teaching does not remove deep misconceptions. It is 18 minutes long and is available for rental or purchase from Pyramid Film & Video, Box 1048, Santa Monica, CA 90406

Search for Life. NOVA produced this excellent astronomically oriented film concerning the problems in the search for life. It includes a discussion of the Miller-Urey experiments, DNA and findings from the Murchison meteorite. It is 30 minutes long, was released in 1975, and is available from Time-Life.

The Observatories. Kitt Peak produced this film in 1982 showing the research tools used at Kitt Peak, Cerro Tololo, Sacramento Peak, the National Radio Astronomy Observatory and Arecibo. Available from: Kitt Peak National Observatory, Photo Dept., P.O. Box 4130, Tucson, AZ 85717.

Two films from the ***Ascent of Man*** series, narrated by Jacob Bronowski, are particularly Clockwork" reviews the contributions of Kepler, Newton and Einstein. These films are each 52 minutes long, were released in 1974, and are available from Time-Life

Quest for Contact. This recently-released tape on the search for extraterrestrial life. The program features Philip Morrison, Frank Drake, Carl Sagan, Bernard Oliver, Paul Horowitz and other scientists. Available from the ASP for $27.

COMPUTER SOFTWARE

There are literally hundreds of computer programs produced for astronomy. Unfortunately, many are "drill and recall" types of programs which do not really exploit the full potential of the computer. Others are computer versions of handbooks and atlases. One program, highly recommended for classroom use, is the ***Astronomy Disk***. This disk requires user interaction and contains 16 educational programs on one disk. These include: "Spectral Types", "Double Stars, "Evolution of Stars", and similar topics. This disk is distributed by Prentice-Hall Publishers, Englewood Cliffs, NJ 07632 as well as the ASP.

The ASP also distributes three programs for sky simulation, one each for the Apple, IBM PC (and compatibles) and a new one titled MacStronomy for the Macintosh. These programs are: ***The Observatory, The Sky,*** and ***MacStronomy*** and all are given high recommendations by the ASP.

If you have access to the Incider magazine, an excellent article appeared in the June, 1987 issue on astronomy software for the Apple II computer. It lists the sky simulation programs, the calendar programs, eclipse and orrery programs, and games and simulations

The Astronomical Society of the Pacific has published an annotated listing of astronomical software. The list includes 89 different, commercially-available programs for the most popular microcomputers such as Apple, Macintosh, IBM, Commodore, Atari, TRS-80 and Hewlett-Packard. The software ranges from simple calculations to home planetarium and space-travel simulations. The listing also includes brief reviews of 13 introductory books and articles on astronomical computing.

Sources of Materials Used in This Issue

Activities in Planetary Geology for the Physical and Earth Sciences, NASA, EP-179,

French, B.M. *What's New on the Moon*, NASA.

Hartsfield and Norlem, *The History of Flight*, NASA, Lewis Research.

Hartisfield and Hartsfield, *Human Spaceflight*, NASA.

One, Two, Three and the Moon-America's Flight Program, NASA, EP-8.

Project STAR, Havard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, 02138.

Spinoffs, NASA.

The International of Associations for Science Education (ICASE)

AIMS

The International Council of Associations for Science Education (ICASE) was established in 1973 to extend and improve education in science and technology for all children and youth throughout the world by assisting member associations and institutions. It is particularly concerned to provide a means of communication among individual science teachers' associations and to foster co-operative efforts to improve science and technology education.

ACTIVITIES

ICASE activities include

- publishing a journal, Science Education International and other occasional publications
- issuing a Directory of Science Teacher Associations Worldwide
- diseminating information about activities of national and regional groups
- arranging regional activities in association with other organisations such as UNESCO
- promoting exchanges of science teaching personnel
- using its endeavours to promote research in science education

MEMBERSHIP

FULL MEMBERSHIP is available to

- National associations for the promotion of science education
- National associations for the promotion of education through separate disciplines
- Science education sections of national scientific associations or national educational associations

ASSOCIATE MEMBERSHIP is available to

- Sub-national groups concerned with science education
- Multi-national associations concerned with regional or international activities in science education

INSTITUTIONAL MEMBERSHIP is available to

- Science centres, science museums, science societies, faculties embracing science education of Universities or colleges, or other centres interested in science education

FOUNDATION MEMBERSHIP is available to

- Foundations or support groups with an interest in science education and science teachers' associations

COMPANY MEMBERSHIP is available to

- Companies and business endeavours with an interest in science education and science teachers' associations

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The following conference reports and books are available from the ICASE seretariat or from the ICASE treasurer. Please add 25% for postage and packing when ordering any books.

Specials rates are applicable for bulk orders.

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* Notes for Teachers - Halley's Comet	2.00	1.50
* Junior Secondary Science - Some Resource Notes	2.00	1.50
200th Anniversary of Man's First Flight - notes for Teachers (1983)	2.00	1.50
* Commemorative issue - Newton (1987)	6.00	4.50
Commemorative issue - Pasteur and Microbes (1988)	8.00	5.00
Commemorative issue - Apollo 11 (1990)	10.00	6.00
ICASE Yearbooks -		
* 1987 - Advances in Sc & Tech. Educ	5.00	3.50
* 1988 - What Research says to the Science Teacher	5.00	3.50
1989 - Sc Educ and Quality of Life (conference proceedings)	12.00	7.00
Primary Science -		
Report of Seminar held in Bangalore (19850	3.50	2.00
Integrated Science -		
Int Science Education Worldwide (Netherlands 1978)	2.00	1.50
Recent Trends in Int Science Worldwide (Australia 1989)	5.00	3.50
Science, Technology and Society -		
The Physics of Traffic Accident Investigation	5.00	3.50

* Out of Print