DOCUMENT RESUME

ED 059 032 SE 004 165

TITLE	NASA Facts, Weightlessness.
INSTITUTION	National Aeronautics and Space Administration, Washington, D.C.
PUB DATE	67
NOTE	4p.
AVAILABLE FROM	Publications Distribution, National Aeronautics and Space Administration, Washington, D.C. 20546 (Free to teachers)
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Aerospace Education; Aerospace Technology; Force; General Science; Instructional Materials; Physical Sciences; Reading Materials; *Secondary School Science
IDENTIFIERS	NASA; *Space Sciences

ABSTRACT

Weightlessness and how it can be artificially produced is described in this pamphlet written for junior high school students. The pamphlet is one of the NASA Facts Science Series (each of which consists of four pages) and is designed to fit in the standard size three-ring notebook. Review questions, suggested activities, and references are included. (PR)

NASA FACTS

AN EDUCATIONAL PUBLICATION OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

S-5/ 8-67

SCIENCE SERIES
JR. HIGH SCHOOL;
PHYSICS

Weightlessness

An astronaut in orbit around the earth is said to be in a state of weightlessness, also called zero gravity or zero g.

The condition called "weightlessness" may also be experienced, briefly, in familiar circumstances on the ground. One example is illustrated in the sketch of a boy on a bicycle, first in a normal gravity condition and then in an "apparent weightless condition."

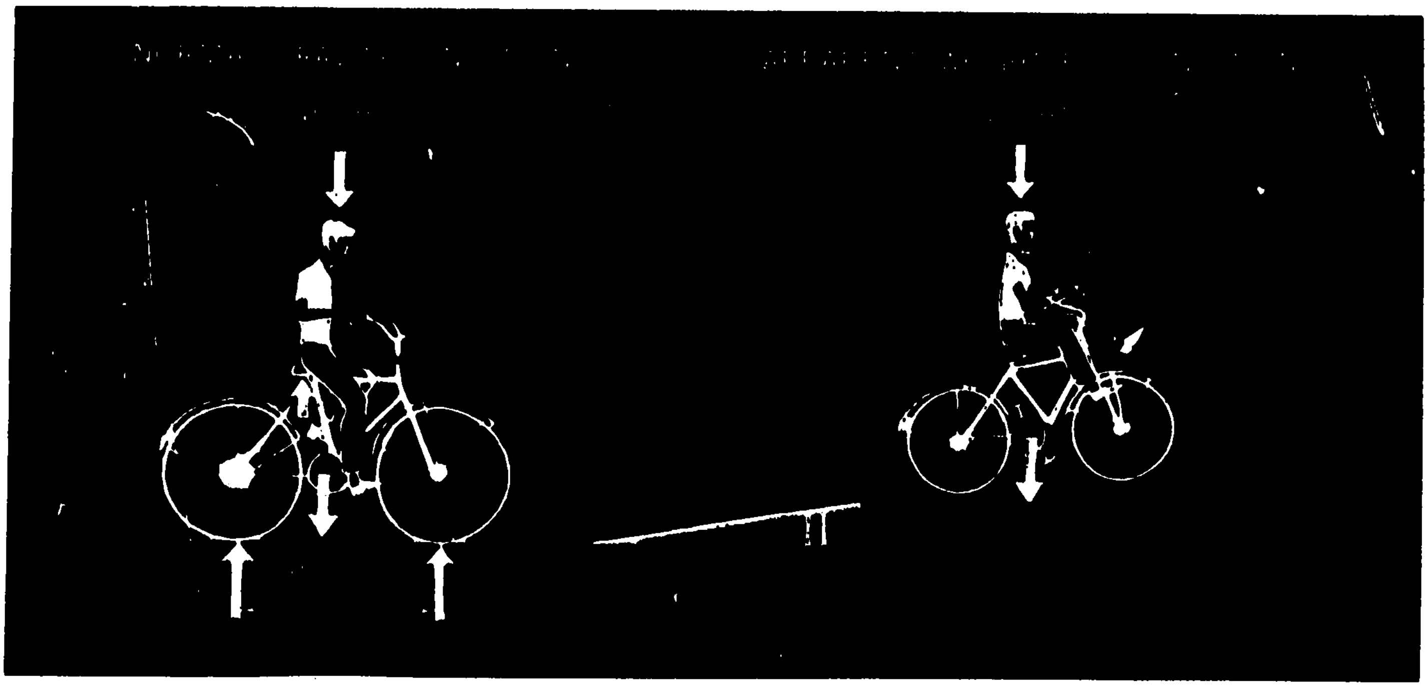
In a playground swing, when you reach the highest position and hang there for a split second before descending, the sensation is that of apparent weightlessness. A pole vaulter seems to be weightless at the top of his leap.

For an understanding of weightlessness, it is necessary first to have in mind that the weight is a measure of the force exerted by the earth's gravity. If you weigh 150 pounds, it means the earth's pull upon your body is measured in a degree expressed by the value 150 pounds.

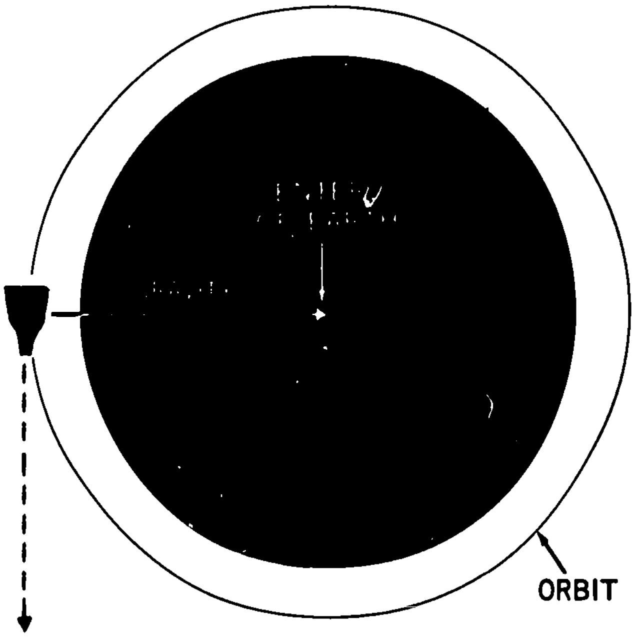
But in special circumstances such as those described above, it appears that you weigh nothing—even though the mass (the amount of matter) of your body has not changed, and the earth's gravity is still there. This is what is meant when weightlessness is defined as "apparent lack of gravitational pull."

Apparent is the key word in understanding this definition. Gravity is present, but its force is not reacted upon by physical contact between two objects.

As you stand on the floor, your body is attracted



Illustrated at left is a boy riding on his bicycle under normal circumstances of gravity. The boy's weight presses downward and the bicycle, supported by the ground, pushes upward with a force equal to his weight and supports him. At right is an illustration of the boy and the bicycle in a free fall after riding off the ramp. For a brief time, although the boy and the bicycle both have weight, the bicycle is not mechanically supported and is consequently not pushing upon the hoy; hence the boy experiences a brief weightlessness with respect to the bicycle.



Gravity and the motion of the spacecraft interact to hold the spacecraft in orbit, where it is weightless.

(pulled) by the earth, as a result of the earth's gravity. The sensation of being pulled downward toward the earth is experienced by certain body sensors and as pressure against the soles of your feet. If you were "weightless," there would be no such pressure. The astronaut, weightless in orbit, does not experience such pressure.

The unit of measurement for gravity is g, which represents the acceleration due to gravity, at the earth's surface.

Weightlessness is expressed by the term zero g, but this does not mean that the gravity of the earth has disappeared, or that the object which is in a weightless condition does not have mass. It means, rather, that the "weightless" object is subject not only to gravity, but also to some other effect, which balances the force of gravity, thus producing apparent lack of gravitational pull, hence, zero g.

In the case of the playground swing, you have velocity which has been acquired by pushing yourself into the upward arc, but the pull of the earth's gravity causes you to slow down. When you reach the top of the swing you are suspended momentarily, in apparent weightlessness, before you start back down.

The weightless state can be produced in an airplane for a brief period (thirty to forty seconds) by putting the craft into a flight path variously called a ballistic trajectory, a Keplerian trajectory or a parabolic arc (See sketch page 3). The pilot first noses down to increase speed, then turns the nose upward and directs it into an arc, as illustrated. During this brief period no lift is produced on the wings, the airplane is not supported by the air, and the occupants are not supported by the airplane. The result is zero gravity for the airplane and its occupants. The procedure is used to study weightlessness, and in the training of astronauts.

To achieve orbit, the spacecraft is pushed upward, then gradually pitched over from the vertical into a horizontal path, and its speed accelerated to the necessary rate by its launch vehicle. The spacecraft separates from the launch vehicle and goes into orbit.

The spacecraft now is traveling with a velocity which has been imparted by the launch vehicle. Gravity and the motion of the spacecraft interact to hold the spacecraft in orbit, where it is weightless. Gravity exerts centripetal force, tending to pull the spacecraft toward the center of the earth. (See sketch page 2).

The spacecraft, in motion, would go straight ahead (dotted arrow) if its direction were not altered by the force of gravity. (Newton's first law of motion: A body remains at rest or travels with constant velocity in a straight line unless acted upon by an external force.) At orbital speed for the altitude, the result is an orbital path for the spacecraft.

Orbital flight sometimes is explained by saying that the centripetal force of gravity, pulling inward toward the center of the earth, is balanced by "centrifugal force" exerted outward and creating a balance which converts the movement of the object into an orbit. This explanation is useful if it is realized that centrifugal force actually is the effect of inertia upon the moving body. It is not really a force; a better term is centrifugal effect.

Its movement may be described as falling toward the earth, but with the curved surface of the earth falling away from its path, so that it continues to fall around the earth. Later, the retrorockets will fire, reducing speed in orbit, and gravity will bring the craft back to earth.

But while it is in orbit it is weightless, and everything in the spacecraft also is weightless. Gravity produces the same change of direction on all objects within the spacecraft as it does on the spacecraft itself. They are motionless relative to each other and produce no push or pull on one another. The astronaut feels no pressure from his couch. Any objects in the cabin not securely fastened will "float." John Glenn released his camera in midair, and it remained there until he wanted it again and reached for it. Liquids do not fall, they float in large and small drops. Crumbs of food would float around in the spacecraft's controlled atmosphere and become an inconvenience, or even a hazard, so food for the astronauts is provided in special closed containers. Liquids are contained until taken into the mouth. Solid foods are bite-sized to avoid crumbs, or are in dehydrated form in plastic containers, to which water may be added, and then they may be squeezed into the mouth without letting anything into the cabin atmosphere. Once the food, or water, or other liquid, has been taken into the mouth, it can be swallowed normally; weightlessness does not interfere with this muscular process.

Anything which separates from the spacecraft is still in orbit, and still weightless. This was demonstrated during Gemini IV by Astronaut Edward H. White II in his experiment with EVA (extravehicular activity), and by other astronauts on subsequent flights. Wearing a space suit especially designed for the purpose, White emerged from Gemini IV and remained outside the spacecraft for more than 20 minutes. White's "walk in space" more precisely might be called floating in space, or maneuvering in space. At one point he attempted to walk on the outside surface of the spacecraft; to do so he had to pull on the tether which connected him to Gemini, to hold himself against the spacecraft. The pull on the tether replaced the pull of gravity which he would have had on earth. With this assistance, he found it possible to take three or four steps.

The astronauts all report that the sensation of weightlessness is a pleasant one. Astronaut White, during his time outside of Gemini IV, reported that there was no difficulty in sensing location and attitude. "I'm looking right down," he said, "and it looks like we're coming up on the coast of California, and I'm going in slow rotation to the right. There is absolutely no disorientation.

In the future of space exploration, when more and more work of more and more kinds will have to be accomplished in space—an example would be the assembly of large space vehicles in space by putting together components launched separately from earth—weightlessness poses a special problem in the use of tools.

In a state of weightlessness, when you put a wrench on a nut and turn, the result is not the same as it would be in normal circumstances. To make the nut turn, you need a firm base from which to exert the force which is to be transmitted through the wrench to the nut. Lacking this, you may turn instead of the nut, or both you and the nut may turn. So special tools are being developed which will provide the reaction required to exert force.

Some of the possible effects of weightlessness in relation to living organisms are still in question, and are being studied primarily on man in the Manned Space Flight program. On animals, cells and plants, the effects of weightlessness are being studied in NASA's Biosatellite program scheduled to begin this year (1967). Biologists will send aloft living organisms ranging from bacteria to monkeys, with instruments to measure effects and transmit data to the ground. What effect will weightlessness have on the circulation of the animal's blood, on his central nervous system, the bones of the skeleton? The Biosatellite program will provide the answers.

The Biosatellite program also is concerned with the effects of radiation, and with the effects of removal from the earth's rotation, which includes the day-night cycle, responsible for the daily rhythm exhibited by most living organisms on earth.

Scientific study of weightlessness under controlled conditions on the ground is accomplished with "drop towers." The largest drop tower, or shaft, for these studies in the United States is the Zero Gravity Facility recently completed at NASA's Lewis Research Center, Cleveland, Ohio.

Basic structure of the Zero Gravity Facility is a shaft that extends 510 feet into the ground. The shaft is lined with an 18-inch-thick concrete casing 28 feet in diameter. Inside this is a welded steel vacuum chamber 20 feet in diameter.

Five seconds of weightlessness can be produced by releasing an experiment from the top of the shaft. The time is doubled when the experiment is

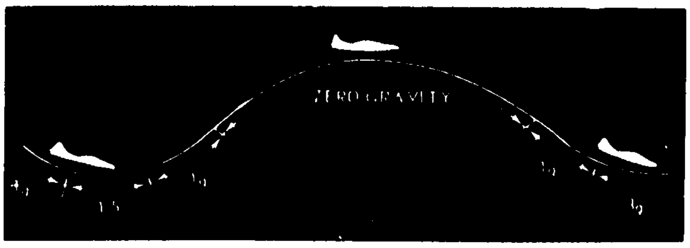
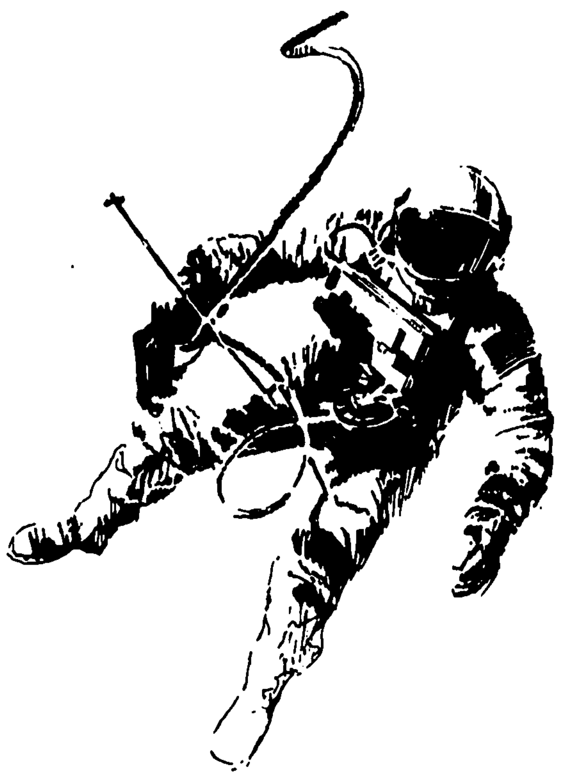


Diagram of an aircraft performing weightless flight. Following a power dive, the aircraft, nosing upward, coasts through a no-lift arc. During this period it is weightless. Astronauts in training float in the cabin experiencing a sensation of weightlessness.



projected upward from the bottom of the chamber by a high-pressure accelerator, since it is weightless on the journey upward, and again as it falls back to the bottom. A typical zero gravity experiment consists of a transparent tank containing test fluids. High-speed motion picture cameras record the fluid's behavior during zero g operation.

QUESTIONS:

1. When does man become weightless in space? Why?

2. What special measures are necessary in preparation of food for the weightless man in space?

ACTIVITY:

Tie a weight to a string. Hold the weight suspended, then swing it upward through a quarter of a circle. As the weight reaches its highest point, the string will become slack, and the weight is "weightless," like the occupant of the playground swing.

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For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 5 cents

U.S. GOVERNMENT PRINTING OFFICE : 1967 O—278-779