Inner Space Diver

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1. What is gravity?

It is a natural phenomenon by which physical bodies attract with a force proportional to their mass. Gravitation is most familiar as the agent that gives weight to objects with mass and causes them to fall to the ground when dropped. Gravitation causes dispersed matter to coalesce, and coalesced matter to remain intact, thus accounting for the existence of the Earth, the Sun and most of the macroscopic objects in the universe.

Gravitation is responsible for keeping the Earth and the other planets in their orbits around the Sun; for keeping the Moon in it's orbit around the Earth; for the formation of tides; natural convection, by which fluid flow occurs under the influence of a density gradient and gravity; for heating the interiors of forming stars and planets to very high temperatures; and for various other phenomena observed on Earth.

Early experiments began with Galileo Galilei in the sixteenth century dropping balls from the Tower of Pisa showing that gravitation accelerates all objects at the same speed regardless of size. In 1687 English mathematician Sir Issac Newton published Principia which hypothesizes the inverse-square law of universal gravitation. In his own words, “I deduced that the force which keeps the planets in their orbs must [be] reciprocally as the squares of their distances from the centers about which they revolve and thereby compared the force requisite to keep the Moon in her orb with the force of gravity at the surface of the earth and found them answer pretty nearly”. Newton's theory enjoyed its greatest triumph when it was use to predict the existence of the planet Neptune based on motions of Uranus that could not be accounted for by the actions of the other planets.

2. What is zero gravity or weightlessness?

Weightlessness or zero gravity is the condition that exists for an object or person when they experience little or no acceleration except the acceleration that defines their inertial trajectory or the trajectory of pure free fall. The definition and use of 'weightlessness' are difficult. Weight means the force exerted by gravity, weightless means the absence of such forces and weightlessness formally means the condition of zero gravitational force. If objects are far from a star, planet , moon or other such massive body,so that they experience very little gravitational interaction with them, they would approach the condition of zero gravity. If they are close to a massive object, but are freely accelerating towards the mass by gravitational acceleration only, they are in free fall and are weightless. Physically, they both follow Newton's first law of motion which describes linear motion. Such a situation, except for microgravity effects and the inhomogeneity of the gravitational field, cannot be distinguished from weightlessness due to the absence of gravity from a body nearby.

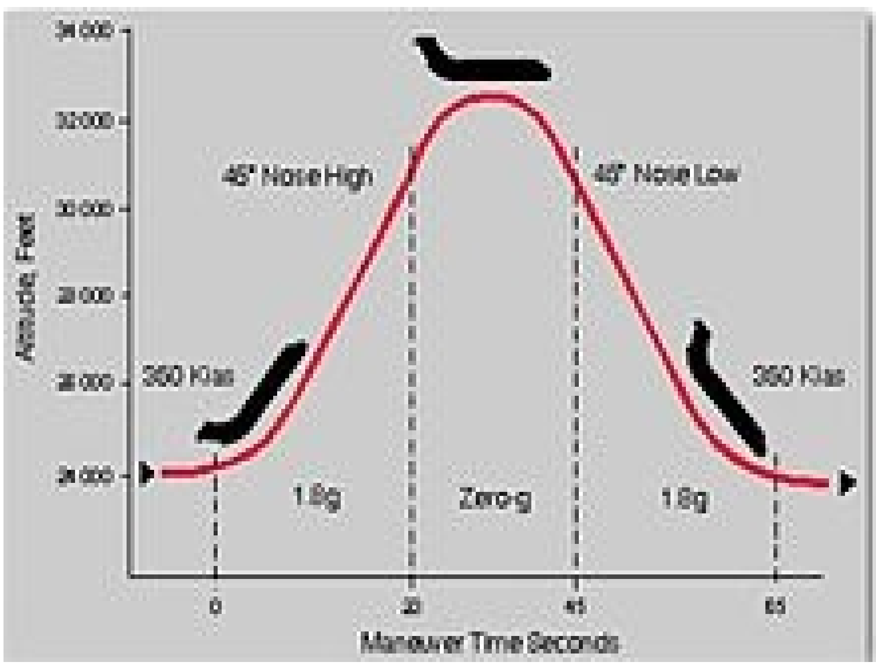
As an example, an accelerated free fall trajectory results in the weightlessness of objects in a falling elevator. The same type of accelerated free fall trajectory causes weightlessness of objects in orbit about the Earth. Such objects are in free fall toward the Earth, as in the falling elevator, but they do not strike the Earth because their forward speed is such that the curved surface of the Earth drops downward and away from the object as fast as the object falls toward the Earth. An astronaut inside an orbiting vehicle has the experience of weightlessness because the action and acceleration due to gravity by itself does not cause a sensation of weight, and all of the other types of forces that do cause such sensations (such as mechanical pushes from the floor or other surfaces that cause g-force acceleration) are absent.

The idea that gravity does not exists in outer space is wrong. At 250 miles above the surface of the earth, gravity is at 88.8% of surface strength. When the gravitational force is opposed by an equal and opposite inertial force, a weightless state is produced. The inertial force in a spaceship is a centrifugal force created by the spaceship orbiting the earth.

Other examples are such systems as planets, centrifuges, spinning buckets, and rotating space stations. Therefore objects inside a spacecraft appear to float in a state called zero gravity. Some amusement rides make use of centrifugal forces. For instance, a Graviton's spin forces riders against a wall and allows riders to be elevated above the machine's floor in defiance of Earth's gravity.

Astronaut Marsha Ivins experiencing weightlessness during the STS-98 mission

Astronaut Clayton Anderson watches as a water bubble floats in front of him on the Discovery during the STS-131 mission.



Reduced weight in aircraft - Zero gravity flight maneuver.

Airplanes have been used since 1959 to provide a nearly weightless environment in which to train astronauts, conduct research and film motion pictures. Such airplanes are frequently referred to by the name “Vomit Comet”.

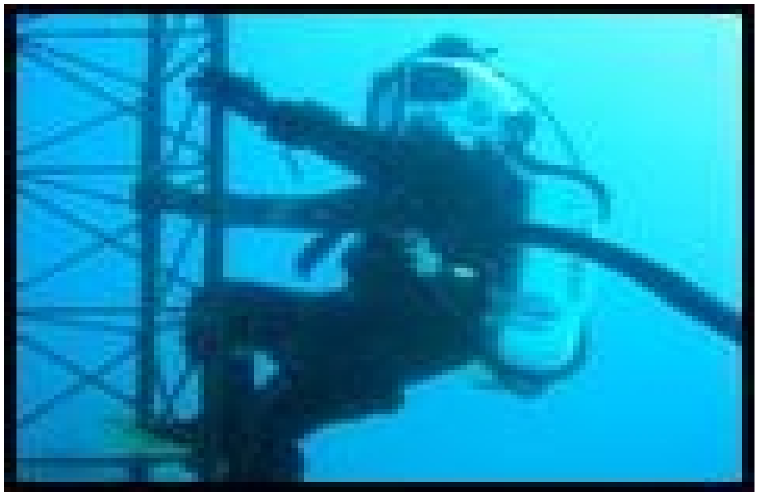
To create a weightless environment , the aircraft flies in a six mile long parabolic arc , first climbing then entering a powered dive. During the arc, the propulsion and steering of the aircraft are controlled such that the drag (air resistance) is canceled out , leaving the plane to behave as if it would if it were free-falling in a vacuum. During this period , the plane's occupants experience about 25 seconds of weightlessness, before experiencing about 25 seconds of 2 g acceleration (twice their normal weight) during the pull out from the parabola. A typical flight lasts around two hours during which fifty parabolas are flown. Some amusement park rides also create brief moments of free fall, as will jumping on trampoline.

NASA's KC-135A plane ascending for a zero gravity maneuver

3. Neutral Buoyancy

Neutral buoyancy is a condition in which a physical body's mass equals the mass it displaces in a surrounding medium. This offsets the force of gravity that would otherwise cause the object to sink. An object that has neutral buoyancy will neither sink nor rise. The mathematician Archimedes in his 212 BC treatise 'On Floating Bodies' discovered much of how buoyancy works . In his research, Archimedes discovered that an object is buoyed up by a force equal to the weight of the water displaced by the object. In other words, an inflatable boat that displaces 100 pounds (45 kilograms) of water is buoyed up by that same weight of support. An object that floats in the water is known as being *positively* buoyant. An object that sinks to the bottom is *negatively* buoyant, while an object that hovers at the same level in the water is *neutrally* buoyant.

Weightlessness can be simulated by creating neutral buoyancy. NASA uses neutral buoyancy extensively to prepare for extra-vehicular activity (EVA) at it's Neutral Buoyancy Laboratory. Neutral buoyancy is not identical to weightlessness. Gravity still acts on all objects in a neutral buoyancy tank. Thus, astronauts in neutral buoyancy training still feel their full body weight within their spacesuits although the weight is well-distributed, similar to force on a human body in a water bed, or when simply floating in water. The suit and astronaut together are under no net force, as for any object that is floating, or supported in water, such as a scuba diver at neutral buoyancy. Water also produces drag, which is not present in vacuum.



(13 October 2004) --- Equipped in an EX14 suit, a NEEMO-7 crew member climbs a structure during a session of extravehicular activities (EVA) near the National Oceanic and Atmospheric Administration's (NOAA) Aquarius Underwater Laboratory, located off the coast of Key Largo, Florida, for the NASA Extreme Environment Mission Operations (NEEMO) project.

(11 October 2004) --- Equipped with SCUBA gear, the NEEMO-7 crew members leave the Aquarius habitat to begin a two-hour underwater extravehicular activity (EVA). Pictured are astronaut/aquanaut Robert B. Thirsk, commander representing the Canada Space Agency; astronaut/aquanauts Michael R. Barratt and Catherine G. (Cady) Coleman, both mission specialists; and Dr. Craig McKinley of the Centre for Minimal Access Surgery at St. Joseph's Healthcare Hamilton, Ontario.

(13 October 2004)---Equipped in a EX-14 suit a NEEMO-7 crew member works with a scuba equipped diver.

4. Working underwater and in space

Working underwater is a lot like working in outer space, which is why NASA used pools and ocean environments to train astronauts. Like the environment of space, the undersea world is a hostile, alien place for humans to live. In commercial diving the diver is tethered to someone on the surface. The tether often contains an umbilical cord providing air and communications. Astronauts are also tethered to the object they are working on and connected to air supply and communications. The bulky suits astronauts use to protect them from outer space are much like dry suits cold water divers use. Cold water divers wear bulky gloves, boots and full face masks for protection both thermal and toxic, just as astronauts protect protect themselves from the vacuum of space, micrometeorites and radiation. Rebreathers used in diving are very similar to the air packs space walkers use. All these similarities make training underwater invaluable for astronauts.

Both divers and astronauts are at risk for decompression sickness. Depressurization causes inert gases which were dissolved under higher pressure, to come out of physical solution and form gas bubbles within the body. These bubbles produce the symptoms of decompression sickness. On ascent from a dive, inert gas comes out of solution in a process called off gassing. Under normal conditions, most off gassing occurs by gas exchange in the lungs. If inert gas comes out of solution too quickly to allow out gassing in the lungs, then bubbles may form in the blood or within the solid tissues of the body. The space shuttle is a sealed environment, and when in orbit, astronauts breathe an oxygen/nitrogen (20% / 80%) mixture at a pressure of 14.7 psi, just as we do at sea level. Astronauts aboard the International Space Station preparing for extra-vehicular activity (EVA) "camp out" at low atmospheric pressure, 10.2 psi , spending eight sleeping hours in the Quest airlock chamber before their spacewalk. During the EVA they breathe 100% oxygen in their spacesuits, which operate at 4.3 psi.

The working pressure in the spacesuit is dropped to 4.3 psi - otherwise the spacesuits would balloon to be restrictive and uncomfortable to work in. This pressure differential is not as dramatic a change as diving 100 meters below the surface of the ocean, but enough to allow dissolved nitrogen to be released.

What is done to prevent or treat the bends in astronauts? To help the astronauts acclimate to the lower pressure in their suits they can prebreathe pure oxygen for hours prior to wearing the suit. In the event the astronaut does have a problem with the bends, the suit can be pressurized up to 8 psi over the cabin pressure, so the suit effectively becomes a mini-hyperbaric chamber to slow the release of nitrogen.

5. Similarities of water and space

Exposure to weightlessness has been demonstrated to have some negative effects on human health. Humans are well-adapted to the physical conditions at the surface of the Earth. In response to an extended period of weightlessness, various physiological systems begin to change and atrophy. Though these changes are usually temporary, long term health issues can result.

The first sensation experienced by three quarters of all astronauts in weightlessness is space sickness. It is a form of motion sickness that occurs when astronauts are free to move about in the weightless environment. Symptoms of space adaptation syndrome may include nausea, vomiting, anorexia, headache, malaise, drowsiness, lethargy, paleness and sweating. It is believed to be caused by sensory conflicts in the vestibular system - a collection of sensitive organs in the inner ear that maintain balance and orientation - and the visual system. This is the same as sea sickness.

In the long term more serious problems such as muscle atrophy and bone loss may develop in space. The condition affects all Astronauts regardless of how much time they spend in orbit. Even the rigorous work-out routine that astronauts aboard the International Space Station have to complete every day cannot prevent the loss of bone and muscles that microgravity causes. Upon returning to Earth, space fliers need to conduct a series of rehabilitation sessions.

Astronaut Michael Foale can be seen in the foreground exercising
on the International Space Station.

In commercial diving bone loss is a serious occupational hazard occurring in 50% of commercial Japanese divers, 65% of Hawaiian fishermen and 16% of commercial and caisson divers, with a definite relationship between length of time underwater and exposure to extreme depths. Scuba diving is associated with a 90% reduction in effective weight and with the loss of a weight-bearing effect on joints. These conditions are very similar to the continuous weightlessness that occurs in spaceflight and bed-rest, which are clearly associated with significant bone mass loss. Studies currently show recreational scuba diving does not influence bone loss.

An underwater habitat or space station has to meet the needs of human physiology and provide suitable environmental conditions for life support, and the one which is most critical is breathing air of suitable quality. Others concern the physical environment (pressure, light, temperature, humidity), chemical environment (drinking water, food, waste products, toxins) and the biological environment (hazardous sea creatures, microorganisms, fungi) and power generation.

Space stations were designed to keep the astronauts at 70 degrees Fahrenheit. Underwater habitats are kept in the 70's also. Crew members must be comfortable because they are busy during all their waking hours. Typically crew members spend twelve hours working, two hours exercising, two hours eating and preparing meals, and eight hours sleeping.

Despite the comforts of home, life in space or underwater in a habitat require acclimation. Once on board one has to adjust to the weightlessness, close living quarters and master new technologies necessary for carrying out routine daily activities. These three conditions, unique to space stations and underwater habitats (except weightlessness), mean the most basic and commonplace daily activities require vigorous attention, patience and coordination.

Sleep requirements in space are simplified by weightlessness. Designers of space stations can position astronauts to sleep in any position, vertically as well as horizontally. Aquanauts originally slept on water beds which doubled as an emergency water supply.

6. Underwater and outer space communication systems

Sound cannot travel through the vacuum of space, but electromagnetic radiation and light can. Astronauts have devices in their helmets that transfer sound waves from their voice into radio waves and transmit it to ground stations or other astronauts in space. This is how your radio at home works. Radio waves are not sound waves, which can only travel in an elastic medium like air or water, but electromagnetic radiation analogous to visible light, and therefore can propagate through space. Lights' range in water is very limited, on the order of tens of meters, restricting its' operational usefulness underwater.

Sound is used to communicate underwater. Aquanauts not wearing a helmet can hear when sound is transmitted by a speaker. Full face masks can have speakers and microphones built in. Sound spreads in a series of pressure waves from point of origin and transfers energy from one point to another without necessarily transferring matter. Sound travels four times faster through water than air and will travel further. Sound waves travel on every line in three dimensions (spherical wave pattern) and at the same speed, unless interrupted by an obstacle.

7. Factors influencing sound in water

A consequence of the remarkable transmission of sound is that unwanted sounds are transmitted just as efficiently. One of the ultimate limitations to the use of underwater sound is the ability to detect a signal above the noise. In the ocean, there are four distinct categories of ambient sound: biological, oceanographic physical processes, seismic, and anthropogenic (caused or produced by humans) such as ocean traffic.

Temperature
Generally the environmental parameter that dominates acoustic processes in oceans is the temperature, because it varies both spatially and temporally. Solar heating of the upper ocean has one of the most important effects on sound propagation. As the temperature of the upper ocean increases, so does the sound speed. Winds mix the upper layer, giving rise to a layer of water of approximately constant temperature, below which is a region called the thermocline. Below that, most seawater reaches a constant temperature. All these layers depend on the season and the geographical location, and there is considerable local variation, depending on winds, cloud cover, atmospheric stability, and so on. Also speed of transmission will decrease with temperature drop.

Fading
As sound travels through the mass of water, energy is absorbed and converted into heat
Reflection: Sound that is transmitted inevitably finds something to scatter from in the water column as a sound wave spreads and encounters an obstacle, such as sea floor, reefs, wrecks, rocks etc. It bounces in the opposite direction creating rumble and echo.

Refraction
occurs when waves pass through different mediums of transmission such as thermoclines or schools of fish, creating an echo.

Interference
occurs when sound waves come from different sources (directions) and can magnify the energy or nullify it. Major ocean currents, such as the Gulf Stream and Kuroshio, have major effects on acoustics. The cold and warm eddies that are spun off from these currents are present in abundance and significantly affect acoustic propagation.

Shadow areas
poor reception or transmission typically in shallow water, where sound waves are affected by the surface as well as the sea floor, tides and fresh water mixing.

Area of silence
large masses like rocks, reefs or wrecks can block the signal between sender and receiver.

8. Benefits from NASA to scuba diving and the environment

The purpose of space flight is to provide significant contributions to the physical and mental needs of humanity on a national and global basis. Such contributions fall specifically in the areas of (1) Earth resources of food, forestry, atmospheric environment, energy, minerals, water, and marine life; (2) Earth and space sciences for research; (3) commercial materials processing, manufacturing in space, and public services. More general goals of space flight include expansion of knowledge; exploration of the unknown, providing a driving force for technology advancement and, hence, improved Earth-based productivity; development and occupation of new frontiers with access to extraterrestrial resources and unlimited energy; strengthening of national prestige, self-esteem, and security; and providing opportunity for international cooperation and understanding.

In June 2011, the Aquarius/SAC-D spacecraft was launched to study the world's oceans and their interactions with the earth's atmosphere and landmasses. After less than one month in operation, Aquarius produced the first map showing the varying degrees of salinity across the ocean's surface produced by NASA.

The Aquarius instrumentation is designed for the first global measurements of ocean salinity levels-indicators of evaporation, rainfall, soil moisture, ice melt, sea ice extent, and changing ocean currents. It will map the global oceans once every seven days for at least three years monitoring salinity levels by sensing microwave emissions from the water surface.