International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 9 Sep. 2022, pp: 708-711 www.ijaem.net ISSN: 2395-5252

Artificial Gravity And Its Implications

Dr. K.S.S. Raja Sekhar,
JL in Physics, Government Junior College, Gollaprolu, Kakinada District, Andhra Pradesh, India

Date of Submission: 07-09-2022 Date of Acceptance: 17-09-2022

ABSTRACT: Artificial gravity has been one of the interesting topics in modern physics. Let's take the step deeper and look at some of the physics, both known and experimental, that physicists are analyzing this very moment to improve future space technology. In this article let us discuss how the artificial gravity differs from normal gravity, different ways to create artificial gravity and its implications.

I. INTRODUCTION

Artificial gravity is the creation of an inertial force that simulates the effects of a gravitational force, usually by rotation.Artificial gravity, or rotational gravity, is thus the appearance of a centrifugal force in a rotating frame of reference , as opposed to the force experienced in linear acceleration, which by the equivalence principle is indistinguishable from gravity. In a more general sense, "artificial gravity" may also refer to the effect of linear acceleration, e.g. by means of a rocket engine.

Rotational simulated gravity has been used in simulations to help astronauts train for extreme conditions.Rotational simulated gravity has been proposed as a solution in human spaceflight to the adverse health effects caused by prolonged weightlessness. However, there are no current practical outer space applications of artificial gravity for humans due to concerns about the size and cost of a spacecraft necessary to produce a useful centripetal force comparable to the gravitational field strength on Earth (g) Scientists are concerned about the effect of such a system on the inner ear of the occupants. The concern is that using centripetal force to create artificial gravity will cause disturbances in the inner ear leading to nausea and disorientation. The adverse effects may prove intolerable for the occupants.

Differences from normal gravity

From the perspective of people rotating with the habitat, artificial gravity by rotation behaves similarly to normal gravity but with the following differences, which can be mitigated by increasing the radius of a space station.

- Unlike real gravity, the apparent centrifugal force felt by observers in the habitat pushes radially outward from the axis, and the centrifugal force is directly proportional to the distance from the axis of the habitat. With a small radius of rotation, a standing person's head would feel significantly less gravity than their feet.[1] Likewise, passengers who move in a space station experience changes in apparent weight in different parts of the body.
- The Coriolis Effect gives an apparent force that acts on objects that are moving relative to a rotating reference frame. This apparent force acts at right angles to the motion and the rotation axis and tends to curve the motion in the opposite sense to the habitat's spin. If an astronaut inside a rotating artificial gravity environment moves towards or away from the axis of rotation, they will feel a force pushing them in or against the direction of spin. These forces act on the semicircular canals of the inner ear and can cause dizziness. Lengthening the period of rotation (lower spin rate) reduces the Coriolis force and its effects. It is generally believed that at 2 rpm or less, no adverse effects from the Coriolis forces will occur, although humans have been shown to adapt to rates as high as 23 rpm.
- Changes in the rotation axis or rate of a spin would cause a disturbance in the artificial gravity field and stimulate the semicircular canals. Thus, the rotation of a space station would need to be adequately stabilized, and any operations to deliberately change the rotation would need to be done slowly enough as to be imperceptible.

WAYS TO CREATE ARTIFICIAL GRAVITY

---->Constant linear acceleration and centrifugal force are two ways to create artificial gravity.

Using linear acceleration:

This is one of the methods of generating artificial gravity, by using the thrust from a spacecraft's engines to create the illusion of being under a gravitational pull. A spacecraft under constant acceleration in a straight line would have the appearance of a gravitational pull in the direction opposite of the acceleration, as the thrust from the engines would cause the spacecraft to "push" itself up into the objects and persons inside of the vessel, thus creating the feeling of weight. This is because of Newton's third law: the weight that one would feel standing in a linearly accelerating spacecraft would not be a true gravitational pull, but simply the reaction of oneself pushing against the craft's hull as it pushes back. Similarly, objects that would otherwise be free-floating within the spacecraft if it were not accelerating would "fall" towards the engines when it started accelerating, as a consequence of Newton's first law: the floating object would remain at rest, while the spacecraft would accelerate towards it, and appear to an observer within that the object was "falling".

To emulate artificial gravity on Earth, spacecraft using linear acceleration gravity may be built similar to a skyscraper, with its engines as the bottom "floor". If the spacecraft were to accelerate at the rate of 1 g—Earth's gravitational pull—the individuals inside would be pressed into the hull at the same force, and thus be able to walk and behave as if they were on Earth.

This form of artificial gravity is desirable because it could functionally create the illusion of a gravity field that is uniform and unidirectional throughout a spacecraft, without the need for large, spinning rings, whose fields may not be uniform, not unidirectional with respect to the spacecraft, and require constant rotation. This would also have the advantage of relatively high speed: a spaceship accelerating at 1 g(9.8 m/s^2) for the first half of the journey, and then decelerating for the other half, could reach Mars within a few days. Similarly, a hypothetical space travel using constant acceleration of 1 g for one year would reach relativistic speeds and allow for a round trip to the nearest star, Proxima Centauri. As such, low-impulse but long-term linear acceleration has been proposed for various interplanetary missions. For instance even heavy (100 ton) cargo payloads to Mars could be transported to Mars in 27 months and retain approximately 55 percent of the LEO vehicle mass upon arrival into a Mars orbit, providing a low-gravity gradient to the spacecraft during the entire journey.

This form of gravity is not without challenges, however. At present, the only practical engines that could propel a vessel fast enough to reach speeds comparable to Earth's gravitational pull require chemical reaction rockets, which expel reaction mass to achieve thrust, and thus the acceleration could only last for as long as a vessel had fuel. The vessel would also need to be constantly accelerating and at a constant speed to maintain the gravitational effect, and thus would not have gravity while stationary, and could experience significant swings in g-forces if the vessel were to accelerate above or below 1 g. Further, for point-to-point journeys, such as Earth-Mars transits, vessels would need to constantly accelerate for half the journey, turn off their engines, perform a 180° flip, reactivate their engines, and then begin decelerating towards the target destination, requiring everything inside the vessel to experience weightlessness and possibly be secured down for the duration of the flip.

A propulsion system with a very high specific impulse (that is, good efficiency in the use of reaction mass that must be carried along and used for propulsion on the journey) could accelerate more slowly producing useful levels of artificial gravity for long periods of time. A variety of electric propulsion systems provide examples. Two examples of this long-duration, low-thrust, high-impulse propulsion that have either been practically used on spacecraft or are planned in for near-term in-space use are Hall effect thrusters and Variable Specific Impulse Magneto plasma Rockets (VASIMR). Both provide very high specific impulse but relatively low thrust, compared to the more typical chemical reaction rockets. They are thus ideally suited for long-duration firings which would provide limited amounts of, but long-term, milli-g levels of artificial gravity in spacecraft.

In a number of science fiction plots, acceleration is used to produce artificial Gravity for interstellar spacecraft, propelled by as yet theoretical or hypothetical means.

This effect of linear acceleration is well understood, and is routinely used for 0 g cryogenic fluid management for post-launch (subsequent) in-space firings of upper stage rockets.

Roller coasters, especially launched roller coasters or those that rely on electromagnetic propulsion, can provide linear acceleration "gravity", and so can relatively high acceleration vehicles, such as sports cars. Linear acceleration can be used to provide air-time on roller coasters and other thrill rides.

Using centrifugal force

A better way to create artificial gravity is to use the effect of centrifugal force, which is an outward force caused by an object being made to follow a curved path instead of a straight line.

If the spaceship was in a large, circular or donut shape that was rotating at a certain rate, the crew on the inside could feel the centrifugal force as artificial gravity. The equation for the rate of rotation is:

$\Omega = 9.55\sqrt{(g/r)}$

Where

- Ω is the rate of rotation in revolutions per minute (rpm)
- g is the acceleration due to gravity (9.8 m/s^2 or 32 ft/s^2)
- r is the radius of the spaceship donut in meters or feet

Human spaceflight

The Gemini 11 mission attempted to produce artificial gravity by rotating the capsule around the Agena Target Vehicle to which it was attached by a 36-meter tether. They were able to generate a small amount of artificial gravity, about 0.00015 g, by firing their side thrusters to slowly rotate the combined craft like a slow-motion pair of bolas. The resultant force was too small to be felt by either astronaut, but objects were observed moving towards the "floor" of the capsule.

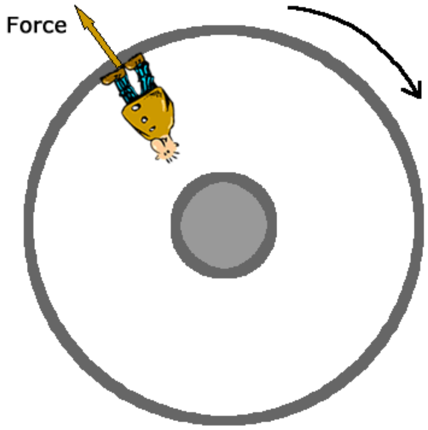
Health benefits

Artificial gravity has been suggested as a solution to various health risks associated with spaceflight. In 1964, the Soviet space program believed that a human could not survive more than 14 days in space for fear that the heart and blood vessels would be unable to adapt to the weightless conditions. This fear was eventually discovered to be unfounded as spaceflights have now lasted up to 437 consecutive days, with missions aboard the International Space Station commonly lasting 6 months. However, the question of human safety in space did launch an investigation into the physical effects of prolonged exposure to weightlessness. In June 1991, a Spacelab Life Sciences 1 flight performed 18 experiments on two men and two women over a period of nine days. In an environment without gravity, it was concluded that the response of white blood cells and muscle mass decreased. Additionally, within the first 24 hours spent in a weightless environment, blood volume decreased by 10%. Long weightless periods can cause brain swelling and eyesight problems. Upon return to earth, the effects of prolonged weightlessness continue to affect the human body as fluids pool back to the lower body, the heart rate rises, a drop in blood pressure occurs and there is a reduced tolerance for exercise.

Artificial gravity, for its ability to stimulate the behavior of gravity on the human body, has been suggested as one of the most encompassing manners of combating the physical effects inherent with weightless environments. Other measures that have been suggested as symptomatic treatments include exercise, diet and penguin suits. However, criticism of those methods lies in the fact that they do not fully eliminate the health problems and require a variety of solutions to address all issues. Artificial gravity, in contrast, would remove the weightlessness inherent with space travel. By implementing artificial gravity, space travelers would never have to experience weightlessness or the associated side effects. Especially in a modern-day six-month journey to Mars, exposure to artificial gravity is suggested in either a continuous or intermittent form to prevent extreme debilitation to the astronauts during travel.

Special conditions and problems

The major requirement for the astronaut to experience artificial gravity in a rotating spacecraft is that he is fixed to the floor. This means that he would be moving in a circular path along with the rotation of the spacecraft. The centrifugal force would be acting on the astronaut, creating the artificial gravity effect.



Astronaut must be fixed to floor in rotating spaceship

However, if he jumped up off the floor, he would only have a linear velocity in the direction of rotation and would fall to the floor not necessarily upright.

If an astronaut was not initially in contact with the floor or walls, he would be floating within the area.

Shoes or skates

Special shoes might be needed to keep the astronaut in contact with the floor. Velcro grip shoes or magnetic shoes are a few ideas being considered.

An interesting idea is for the astronaut to use magnetic roller skates to navigate along an iron floor.

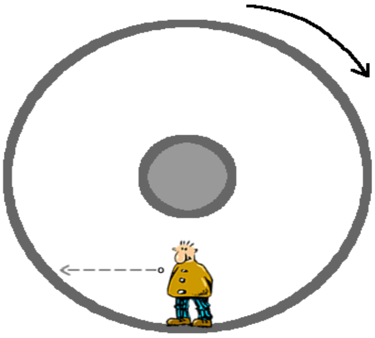
Direction of walking or skating

Walking or skating in the direction of rotation could slightly increase the feeling of gravity, while moving in the opposite direction would decrease that feeling. However, the effect would be negligible since the velocity would be small.

Dropping something

If an object was not in contact with the floor, it would float about. If it had some initial velocity, it would move in a straight line.

Suppose the astronaut would drop or let go of a pencil he was holding. Since it was no longer forced to move in a curved path, the pencil would simply moved forward in a straight line, according its initial velocity, when released.



Dropped object would move in straight line but appear to fall

However, since the floor of the spacecraft was curved, the pencil would move forward until it hit the curved floor. Although it was not pulled to the floor by artificial gravity, it would appear to do so to the astronaut.

II. CONCLUSION

Though some studies have the potential for determining a sound artificial gravity prescription, validation of these studies can only be performed in space. No human-rated centrifuges that have been built specifically to counteract cardiovascular and musculoskeletal deconditioning have flown in space to date. Some information could be gained from studies using animal models by comparing the potential differences between the effects of an artificial gravity prescription during centrifugation on Earth and in space. However, questions such as what are the impacts of centrifugation inside a space vehicle on the vibration level, motion sickness, or crew time need to be addressed by use of a human-rated centrifuge. The short-term effects of centrifugation could be assessed by studying changes in biomarkers or gene expressions. Any positive results from this space centrifuge would also provide the impetus for further ground-based research.

REFERENCES

[1]. Young, Laurence; Yajima, Kazuyoshi; Paloski, William, eds. (September 2009). ARTIFICIAL GRAVITY RESEARCH TO ENABLE HUMAN SPACE EXPLORATION

[2]. Larson, Carl Alfred (1969). Rotating Space Station Stabilization Criteria for Artificial Gravity

[3]. Davis, Bl; Cavanagh, Pr; Perry, Je (September 1994). "Locomotion in a rotating space station: a synthesis of new data with established concepts".

[4]. "Weightlessness Obstacle to Space Survival". The Science News-Letter. 86 (7): 103. April 4, 1964.

[5]. Arrott, A. P., Young, L. R., and Merfeld, D. M. (1990). Perception of linear acceleration in weightlessness. Aviat. Space Environ. Med. 61, 319–326.