AEROSPACE PALACE ACADEMY, NIGERIA
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LESSON 30: EARTH’ S TEMPORARY MOONS

When we think of the solar system, we often picture vast celestial bodies moving slowly through space, following the same paths for billions of years. To some extent, this is true, but in reality there are many smaller space objects that make the solar system a much more dynamic place. For example, the Earth often captures small asteroids as it travels around the Sun; these asteroids orbit the Earth for a while and then leave. Usually these asteroids are about a meter in diameter and stay under the Earth’s gravitational control for a little less than a year. This phenomenon is just one example of how dynamic the Solar System is.

GRADES K-2

If you look up at the sky on a clear night, what is the first thing you are likely to see? The moon! The moon is the closest large space object to Earth and it has been a major part of the lives of humans for as long as we can tell. The moon is very small compared to Earth (if the Earth were hollow, then about 50 moons would fit inside), but compared to many other space objects it is quite big; there are many, many other pieces of rock and ice that move through our solar system. Perhaps you have heard the names for these: asteroids and comets. Asteroids and comets can be very big, but many of them are small. These space objects are not always in a regular orbit like the planets and sometimes they come flying by the Earth at tremendous speed. Other times, they float by more slowly, and sometimes they are moving slowly enough, and the Moon is in just the right place, that they start to orbit the Earth. The Moon has to be in the right place in its orbit relative to the asteroid, though, so this does not happen very often.

GRADES 3-5

Everyone knows the moon – it has captivated humans for thousands of years; we have written songs and poetry about it, studied it, and even sent astronauts to visit it. Perhaps you have heard of other moons in our solar system. Mars has two moons called Deimos and Phobos; Jupiter and Saturn, meanwhile, have dozens of moons including Ganymede, Europa, and Io (Jupiter) and Titan, Calypso, and Janus (Saturn). Just like the planets, many moons are named after figures from Greek and Roman mythology. Many of these moons look quite different from our moon. Some are quite big and have mountains, oceans, and weather patterns. Others are so small that they are really just large chunks of rock or piles of rubble which are stuck in a planet’s gravity field.

GRADES 3-5 (CONTINUED)

From time to time, Earth picks up one of these miniature moons: if a stray asteroid wanders too close, it can be captured by the gravitational pull of Earth and the moon.

A good way of imagining how this happens is to picture a large trampoline. If there is nothing on the trampoline, you can roll a ball from one side to the other without any problem. This is just like an asteroid moving through space when it is not in a strong gravitational field. However, what would happen if you were to stand in the middle of the trampoline? If you had a friend roll a ball across the trampoline, it might make it to the other side if it were going really quickly, or if your friend aimed it away from where you were standing. However, the ball would probably be pulled towards you and might even begin to circle around you. This is what happens with asteroids which pass near Earth – the combined gravity of Earth and the moon can "trap" objects into an orbit around Earth. (One difference between the ball on the trampoline and the asteroids out in space is that the ball is subject to friction while the asteroids are not. Thus friction will slow the ball down while the asteroid will pass right by unless geometry of the Earth, Moon, and asteroid are just right.) Often these asteroids will eventually break free; miniature moons like this might spend a few months or a year circling our planet before heading back out into the solar system.

GRADES 6-8

Astronomers have detected several asteroids with orbits controlled or strongly influenced by the Earth's gravity. The one mentioned in this lesson's primary reference, called "2006 RH120," circled the Earth only about three times before leaving Earth orbit less than a year after it was discovered. Another asteroid, "2016 HO3," has apparently orbited the Earth for almost a century and will evidently continue in Earth orbit for several hundred more years.

There are different categories of asteroid with respect to their orbiting the Earth. First, there are asteroids whose orbits have nothing to do with the Earth's orbit. Most asteroids fall into this group. Then there are asteroids which orbit the Sun but whose orbits interact with the Earth, either because they go around the Sun in exactly one year or because their orbital periods have some resonance with the Earth's orbit. The asteroid 3753 Cruithne is one of these. There are also some asteroids that follow the same orbit around the Sun that the Earth does, but are 60 degrees ahead of or behind the Earth in its orbit; these are called

GRADES 6-8 (CONTINUED)

"Earth Trojan" asteroids. There are asteroids which approach the Earth, are captured for several months, and leave, as 2006 RH120 did. Other "corkscrew asteroids" are captured for several years, decades, or even centuries. While it is physically possible for there to be asteroids that orbit the Earth permanently (similar to the smaller moons of Jupiter and Saturn), none have been found, although in April 2016 an object called "S509356" was found that may be one.

GRADES 9-12

If you look at the Earth's gravity by itself, you might conclude that "capturing" a moon is impossible. The total energy of an astronomical body is conserved. This energy is a combination of potential energy, which depends on its altitude, and kinetic energy, which depends on its speed.

In the Earth's gravitational field (which varies with altitude), the potential energy of a body with mass "*m*" is given by the formula

$$PE = -\frac{GMm}{R}$$

where "*PE*" is the potential energy of the body, "*G*" is the universal gravitational constant (6.67259×10^{-11} $m^3/Kg\text{-}s^2$), "*M*" is the mass of the Earth (5.792×10^{-24} Kg), and "*R*" is the distance of the body from the center of the Earth. It is customary to assign a potential energy of zero to a body infinitely far from the Earth and allow it to take negative values as the body approaches the Earth.

A body in a circular orbit around the Earth has its centrifugal force exactly balanced by the Earth's gravitational force:

$$\frac{mV^2}{R} = \frac{GMm}{R^2}$$

In this equation, "*V*" is the speed of the body in its orbit. We can calculate the kinetic energy "*KE*" of a body in a circular orbit in terms of the Earth's gravitational attraction:

$$KE = \frac{1}{2}mV^2 = \frac{GMm}{2R}$$

GRADES 9-12 (CONTINUED)

Adding the two forms of energy together gives the total energy "*E*" of the body:

$$E = PE + KE = -\frac{GMm}{R} + \frac{GMm}{2R} = -\frac{GMm}{2R} < 0$$

Thus the total energy of any body in orbit is less than the energy of that body infinitely far from the Earth. (It takes a lot of energy to put a rocket into orbit from the surface of the Earth because the rocket on the Earth's surface has a total energy that is even more negative.)

From this derivation, any asteroid that approaches the Earth from elsewhere in the Solar System will have enough energy to pass by and escape from the Earth's gravity. What allows the Earth to capture a temporary moon is the fact that it is not the only massive body in the area. The Earth's permanent Moon on its way around the Earth will also pull on the asteroid because of its gravity. If the Moon is behind the asteroid, its gravitational pull can slow down the asteroid enough that the asteroid no longer has enough energy to escape the Earth's gravity. If that happens, the asteroid will go into orbit around the Earth and become another "moon." At some later time, when the Moon is in front of the asteroid in its orbit around the Earth, its gravity may speed up the asteroid enough that it can escape the Earth's gravity and go back into orbit around the Sun.

Sixty Years Ago in the Space Race:

January 7, 1957: Aviation Week announced that the Navy had withdrawn from the Jupiter rocket project to pursue its own Polaris missile, leaving the Jupiter as an Army-only program.