Easily digestible Aerospace Principles revealed for K-12 Students and Educators. These lessons will be sent on a bi-weekly basis and allow grade-level focused learning. - AIAA STEM K-12 Committee

ORBITAL DYNAMICS

On earth, if you are moving along behind somebody and want to catch up, you speed up some. In orbit around a massive body, it does not work that way.

GRADES K-2

Smaller circles have smaller circumferences than larger circles. While this is blindingly obvious to adults, it may be fun and informative to illustrate this to younger children. If you have access to an open field, you can have the students go out and stand in a circle facing outwards. This represents the Earth. (The students can certainly look around to see what is happening.) Have one student stand an arm's length from the "Earth" (this is the Space Station) and another student stand significantly farther away (say, 10-20 feet, representing a satellite in higher orbit)). Then have the two students walk around the circle as the Space Station and satellite orbit the earth. If the Space Station student wants to run, this is also fine; satellites in lower orbits move faster than satellites in higher orbits. Show the students how the student moving in the smaller circle finishes going around before the student moving in the larger circle.

GRADES 3-5

Objects that are in orbit around the earth move faster the closer they are to the earth. The Space Station, which is in low earth orbit about 205 miles up from the surface of the earth, moves at a speed of 4.79 miles per second and takes 92 minutes and 41 seconds to make a single orbit. (You may want to give the speed in terms of how many seconds it would take to go from the school to various nearby locations.) A weather satellite in geosynchronous orbit 22,236 miles above the surface of the earth, travels at 1.91 miles per second and takes 23 hours, 56 minutes, and 4 seconds (one sidereal day) to make a single orbit. The moon, to give an extreme example, is about 235,000 miles above the surface of the earth (239,000 miles from the earth's center), moves at an average speed of 0.65 miles per second, and takes 27 days and 8 hours to finish an orbit.

Thus an object in a lower orbit not only has less distance to travel to get around the earth, it moves more quickly in that orbit.

GRADES 3-5 (CONTINUED)

You may want to review the circumference of each orbit and calculate from it and the orbital period what the speed is and show that it matches what is given. Don't forget to include the radius of the earth at its equator. For example, the radius of the geosynchronous orbit is 22,236 miles plus the earth's radius of 3,963 miles, or 26,199 miles. The circumference of this orbit is two times pi times the radius, or 164,613 miles. The orbital period is 23 hours, 56 minutes, and 4 seconds, which converts into 86,164 seconds. Dividing the circumference by the period gives 1.9105 miles per second for the orbital speed.

GRADES 6-8

After reviewing that objects in lower orbits travel faster than objects in higher orbits, consider two objects that share the same orbit, one behind the other. Because they are in the same orbit, they are traveling at the same speed and the one stays behind the other. If the follower object speeds up a little, it will push itself into a higher orbit. (In fact, the follower object's orbit will become slightly elliptical, with the low point (perigee) at the place where it did the speeding up and the high point (apogee) on the opposite side of the earth. The average radius of this elliptical orbit, which is what counts when calculating the orbital period, will be larger than the radius of the circular orbit that the follower object was in.) When it is in the higher orbit, it will take longer to orbit the earth and so the follower object will fall farther behind the leader object. Conversely, if the follower object were to slow down slightly, it would fall into a slightly lower orbit (actually an elliptical orbit with its apogee touching the original orbit but its average radius smaller than that of the original orbit) than the leader object and would thus catch up with the leader object. Thus while in orbit, speeding up causes a satellite to fall farther behind while slowing down causes a satellite to move ahead. It is very counterintuitive.

GRADES 9-12

After reviewing the Grades 3-5 notes about objects in lower orbits moving faster than objects in higher orbits and the Grades 6-8 explanation about how speeding up will actually cause an object to fall behind in orbit, consider two objects in the same orbit going around a much larger primary body. If the objects are massive enough that each one's gravity pulls on the other one, they engage in a sort of orbital "dance." As the gravity of the leader object (call it Object A) pulls on the follower object (which we will call Object B), Object B will speed up slightly, move into a slightly higher orbit, and fall behind. At the same time, the Object B's gravity pulls on Object A, causing Object A to slow down, drop into a slightly lower orbit, and move ahead. The two objects will move away from each other as they circle around the primary body. Eventually, Object A will get far enough ahead that it has gone all the way around the primary body (relative to Object B—both objects have orbited the primary body many times by this point) and is now behind Object B. The roles of leader and follower are now reversed; Object A is now the follower and Object B is now the leader.

This configuration actually happens between two moons of Saturn called Janus and Epimetheus. Wikipedia describes this in some detail:

https://en.wikipedia.org/wiki/Epimetheus_(moon)#Orbital_relationship_between_Epimetheus_and_Janus

There is an asteroid named Cruithne which has a similar interaction with the Earth, although they do not share an orbit. (Cruithne's orbit is very elliptical and extends from inside Mercury's orbit to outside Mars' orbit.) Cruithne moves around the sun once per year, just as Earth does, and approaches the Earth relatively closely at one position in that orbit. (The closest approach is about 7.5 million miles, so there is no danger of a collision.) Relative to the Earth, the orbit of Cruithne looks like a large kidney bean. Over a period of 770 years, Cruithne's approach to Earth changes from being just ahead of Earth to being just behind Earth and back again, causing the kidney bean shape of its orbit (relative to Earth) to move slowly around the sun from behind the earth to the opposite side of the sun to ahead of the earth and back. You can find details here:

https://en.wikipedia.org/wiki/3753_Cruithne