

Newton's Laws of Motion
Astronomy
Lesson 16

The Earth revolves around the sun in an elliptical orbit. The moon orbits the Earth in the same way. But what keeps the Earth and the moon in orbit? Why don't they just fly off into space? Or crash into each other?

The first person to answer these questions was the scientist Isaac Newton. Newton realized that there must be a force acting between Earth and the moon that kept the moon in orbit.

What is a force? [A force is a push or a pull]. When one object pushes or pulls on another, you say that the first object exerts a force on the second object.

In science, we represent forces by arrows. The direction of a force is represented by the direction of the arrow. The length of the arrow tells you the strength of the force – the longer the arrow, the greater the force.

Demonstration: Pull a chair across the floor of the room, then try to pull a chair across the room with a student sitting in it. Ask students: what's the difference? [the more mass the object has, the more it resists the change/force]. What is the scientific name for that resistance to change? [inertia]

Did the chair move on its own? [No] Someone had to push or pull it—in other words, exert a force on it. If the two forces are balanced, would the chair move? [No] If the forces were unbalanced, in other words, if I pushed harder on the chair than the inertia of the chair, would it move? [Yes] When the object is at rest, does it have a speed? [yes—but it's zero] When the object is moving, does it have a speed? [yes] What do we call that change from a speed of zero to a speed of something? [acceleration]

So, let's bring it back to my initial question: what keeps the Earth and the moon in orbit, preventing them from crashing or flying off away from each other?

If the sun and Earth are constantly pulling on one another because of gravity, why doesn't Earth fall into the sun? Why doesn't the moon crash into Earth? The fact that these collisions haven't happened means there must be some other factor we haven't yet taken into account.

Who can recall Newton's first two laws of motion from last night's reading? [First Law: Objects tend to stay at rest or move in a straight line at a constant speed unless acted upon by an outside force.]

Second Law: The force acting on a body is directly proportional to, and in the same direction as, its acceleration]

Newton's first law of motion is, essentially, the definition of inertia—the tendency of an object to resist a change in motion. The more mass an object has, the greater its inertia. An object with greater inertia is more difficult to start or stop.

Newton's second law tells us that the force (F) on an object is directly proportional to its acceleration, and that is dependent on its mass. So, the second law can be summed up as $F=ma$. Or, acceleration depends on the objects mass and on the net force acting on the object:

$$\text{Acceleration} = \frac{\text{Force}}{\text{Mass}}$$

[Newton's second law may be a bit more difficult for students to really grasp. I find the following demonstration useful: fill a large tub with sand. Drop a piece of balled paper into the tub and notice the impression that the paper makes. Then, drop a rock into the tub and notice the impression that the rock makes. The greater the mass, the greater the force of the impact, the greater the depression in the sand]

Orbital Motion: Why do Earth and the moon remain in their orbits? Newton concluded that two factors: inertia and gravity combine to keep the Earth in orbit around the sun and the moon in orbit around the earth. What exactly, is the force of gravity? 9.8 m/s^2 . Where have we seen that unit of measurement before, and what does it describe? [it's the acceleration]

The Earth's gravity keeps pulling the moon toward it, preventing the moon from moving in a straight line. At the same time, the moon keeps moving forward because of inertia. If not for Earth's gravity, the moon would shoot off into space in a straight line, and if not for the moon's inertia, the moon would collide with Earth due to the pull of Earth's gravity.

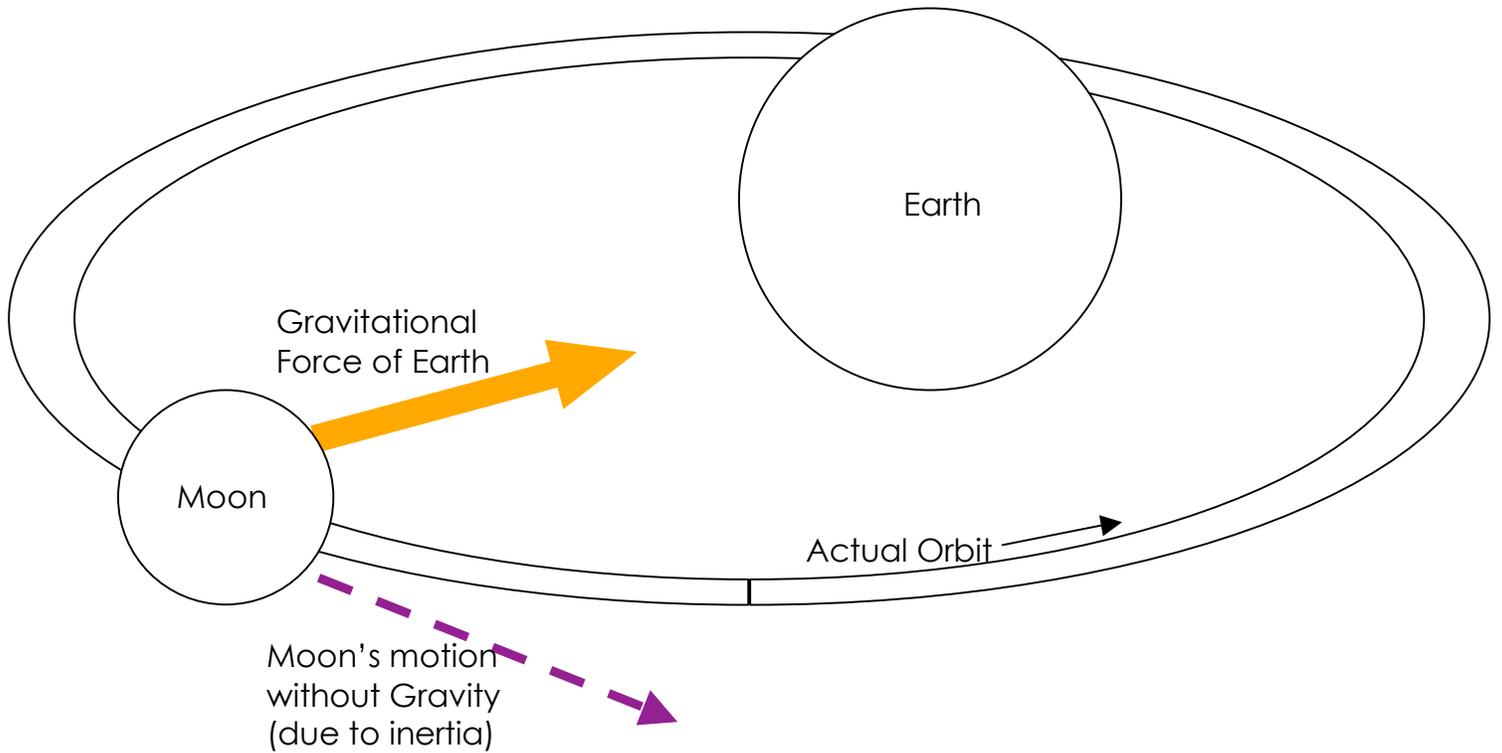


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[This is a great moment to perform a centripetal force demonstration and ask students to identify which object is the moon, Earth, forces, etc. I like to attach a tennis ball to a piece of yarn and swing it around my head. My head acts as the Earth, the yarn in the gravitational force from the Earth, the Moon is the tennis ball that orbits around me.]