

# The Shoulders of Giants

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Copernicus to Newton





Isaac Newton

The Shoulders of Giants

- **speed** — rate of change in position
- **velocity** — speed in a particular direction
- **acceleration** — rate of change in velocity
- **linear momentum** — product of mass and velocity ( $p = mv$ )
- **angular momentum** — product of mass, velocity and radial position ( $l = mvr$ )

# Newton's Laws of Motion

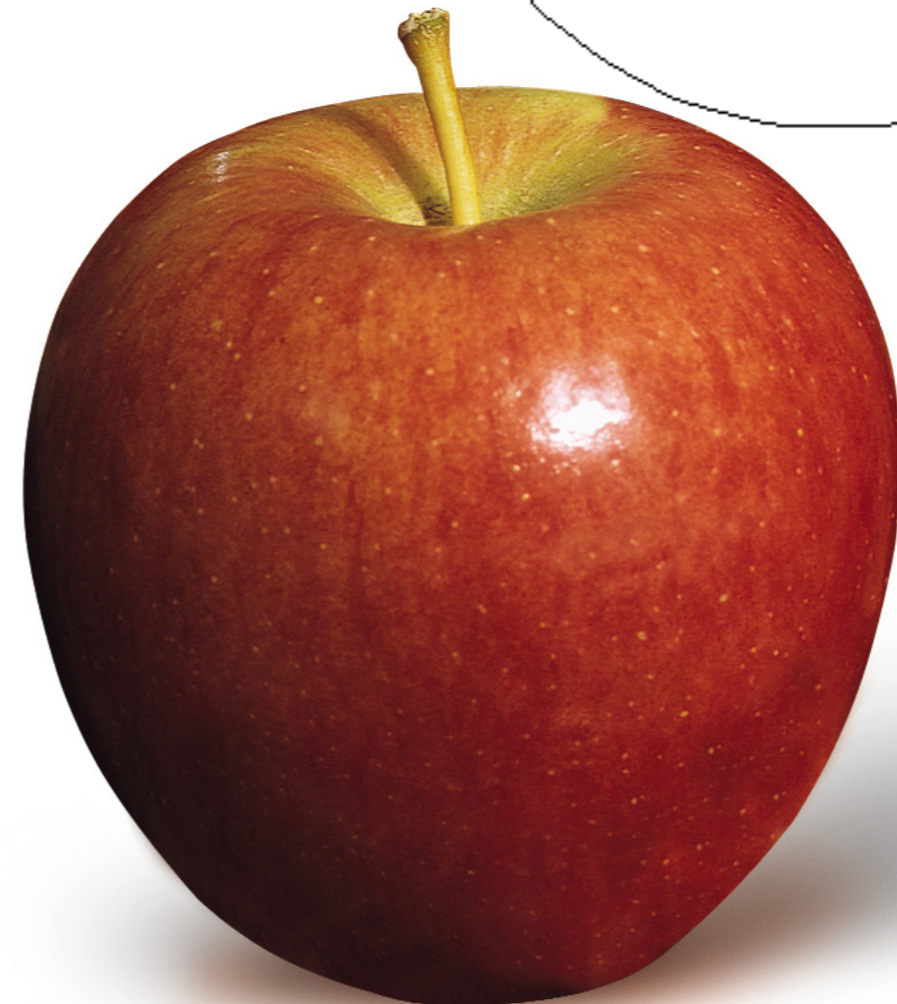
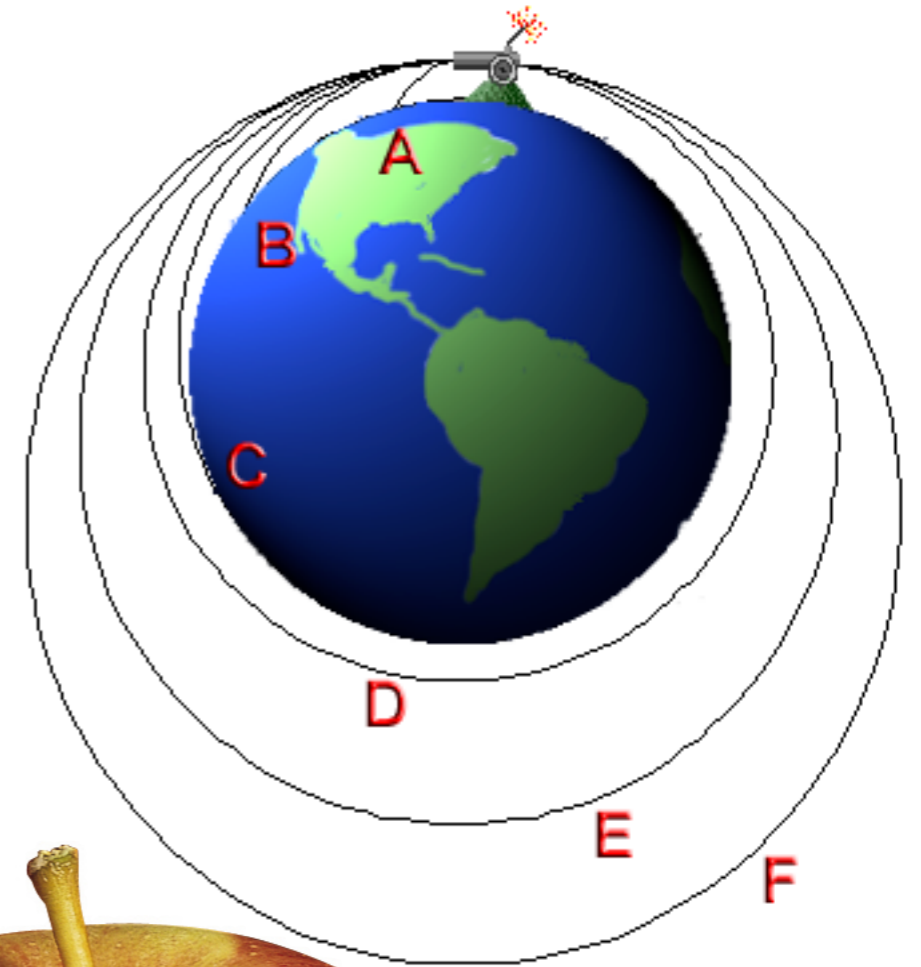
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- Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.
- The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.
- To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

# Falling Bodies

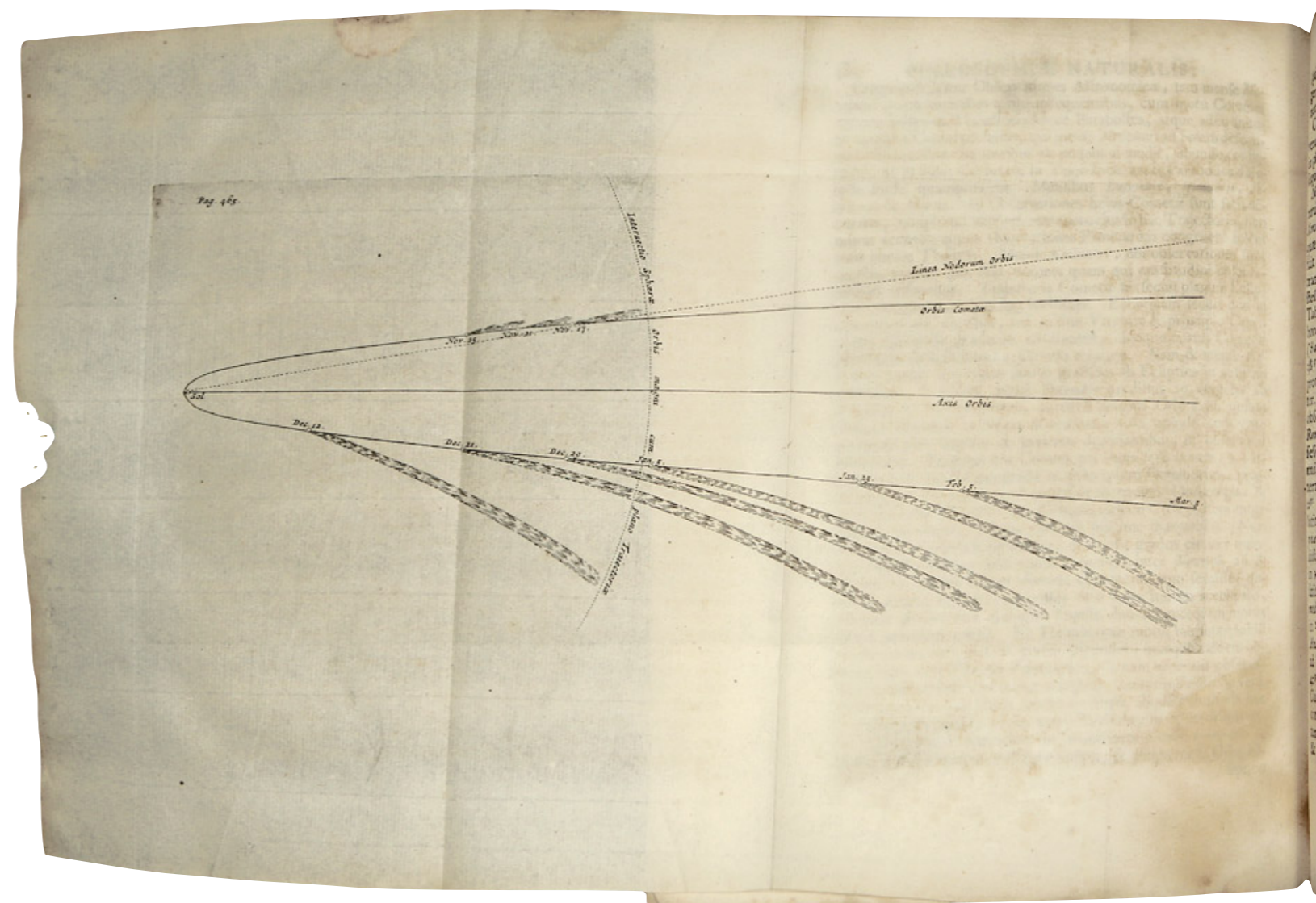
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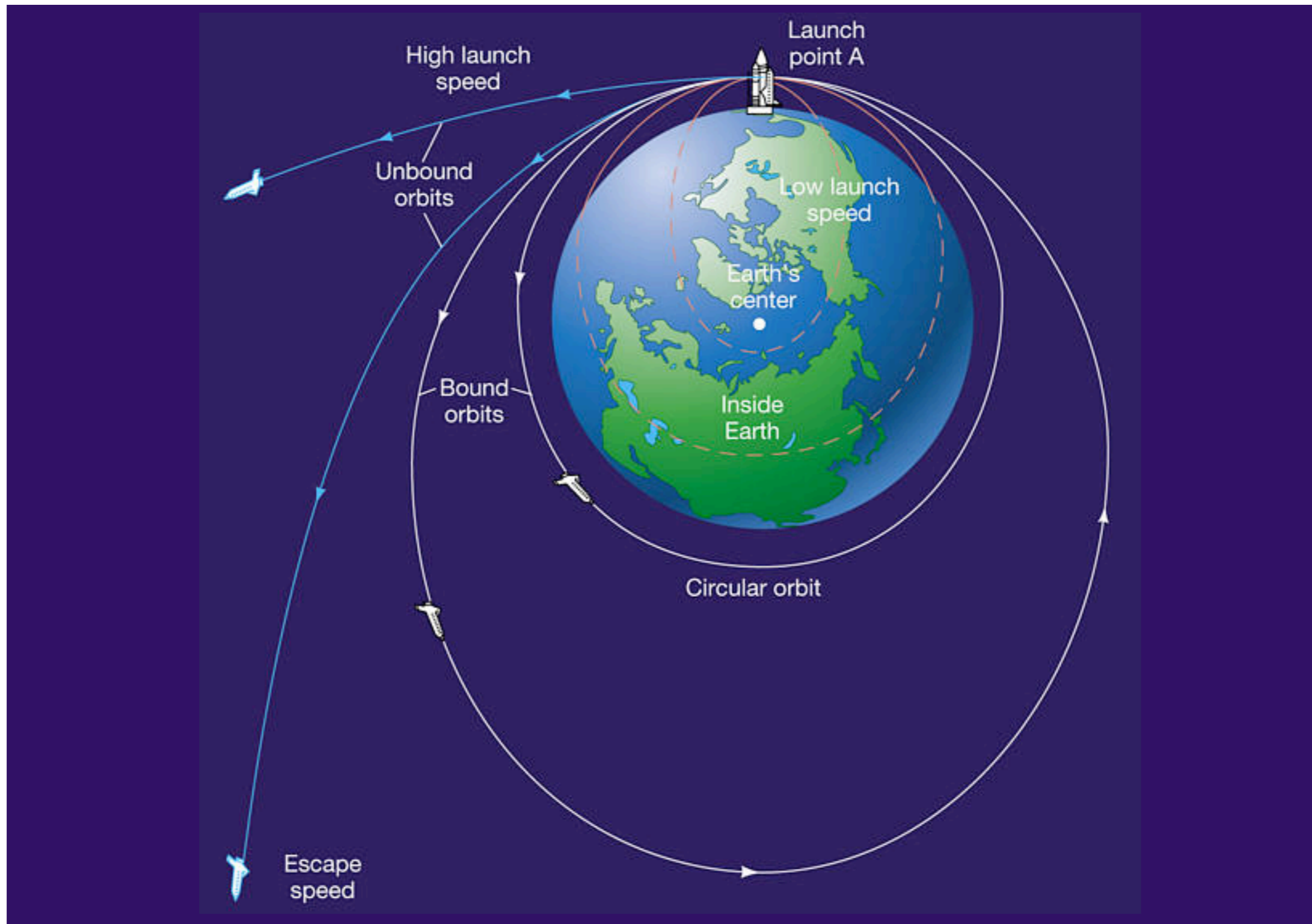
Unifying heavenly and earthly forces



# Newton's Law of Universal Gravitation

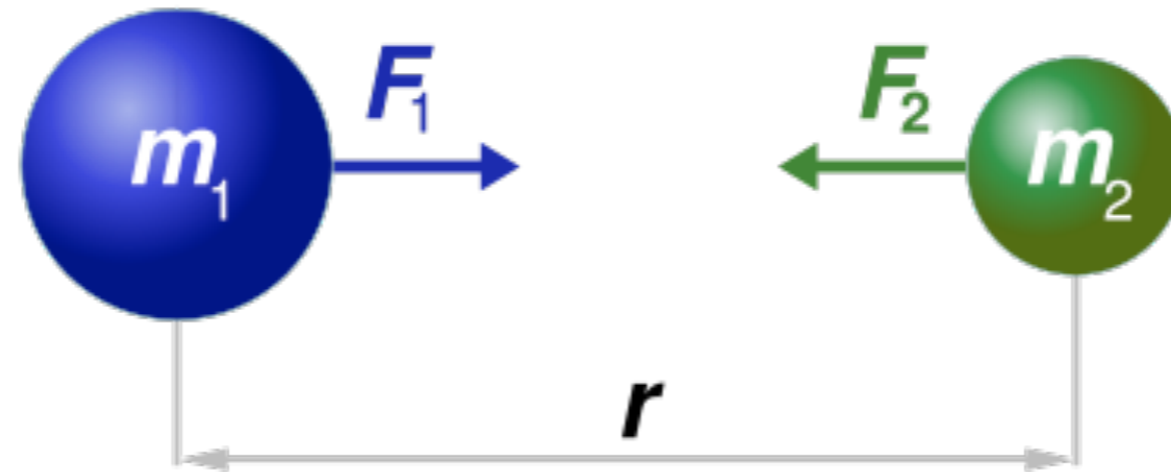
Every object in the universe attracts every other object along a line of the centers of the objects proportional to each object's mass, and inversely proportional to the square of the distance between the objects.





Orbital Dynamics

Apollonius' Conic Sections



$$F_1 = F_2 = G \frac{m_1 \times m_2}{r^2}$$

Universal Gravitation

Mutual action at a distance