Laws for Gravitational Force

by

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P3.6B Predict how the gravitational force between objects changes when the distance between them changes.

P3.6e Draw arrows (vectors) to represent how the direction and magnitude of a force changes on an object in an elliptical orbit.

Items:

1) Kepler's Laws of Planetary Motions.

2) Kepler's 3rd Law of Motion and Newton's Inverse Square Law of Gravity.

3) Einstein and Nature of Gravity.

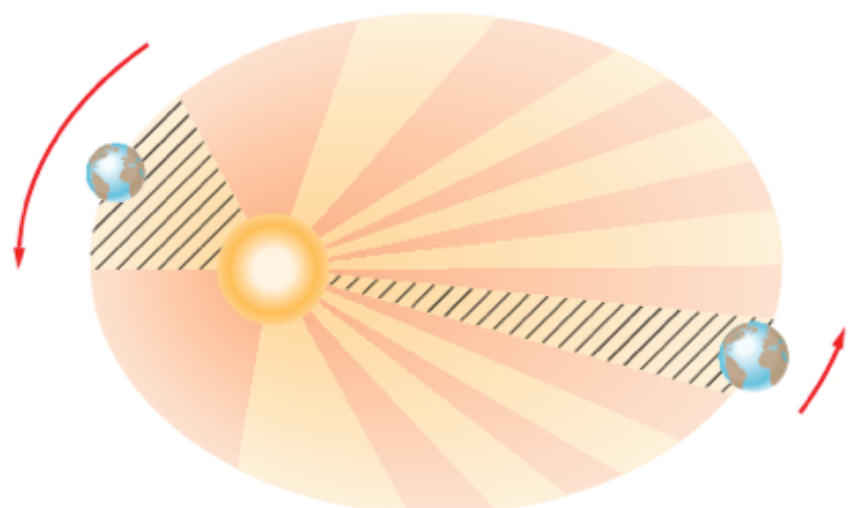
Johannes Kepler (1571-1630)

A German Scientist

Kepler's Laws of Planetary Motion

Kepler's First Law: The paths of the planets are ellipses, with the sun at one focus.

Kepler's Second Law: An imaginary line from the sun to a planet sweeps out equal areas in equal times. So, the planets move faster when they are closer to the sun and slower when they are farther away from the sun as illustrated in the picture below.



Newton's Inverse Square Law for Gravity

Based on Kepler's 3rd Law of planetary Motion, Newton derived the theory that the force of gravity (gravitational force, F) on an object depends on the distance from the Earth, decreasing as the distance increases.

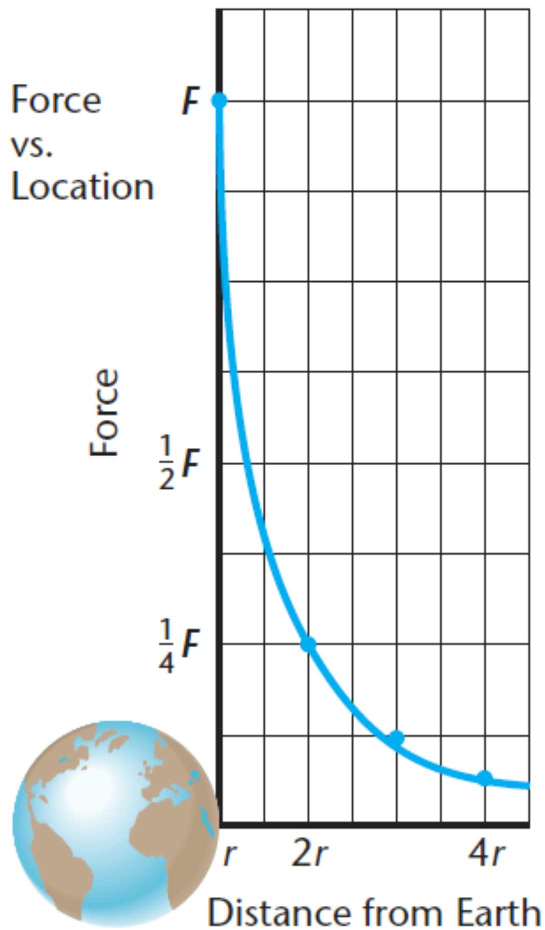
The change of gravitational force with distance follows the inverse square law. The gravitational force (F) depends inversely on the square of the distance of the object from the Earth's center. The formula is given below.

Inverse Square Law for Gravitational Force
$F_1/F_2 = (d_2)^2 / (d_1)^2$

F_1 : The gravitational force when the object is at distance d_1

F_2 : The gravitational force when the object is at distance d_2

The figure below shows that when the distance from the Earth increases, the gravitational force of attraction decreases. F is proportional to $1/r^2$



Example 1: *Gravity on a Rocket*

The force of gravity on a rocket 10000 km from the center of the Earth is 900 Newton . What will the force of gravity on the rocket be when it is 30000 km from the center of the Earth?

Data Table			
d_1	d_2	F_1	F_2
10000 km	30000 km	900 N	?

We need to use the formula of the inverse square law of force;

$$F_1/F_2 = (d_2)^2 / (d_1)^2$$

$$900 / F_2 = (30000)^2 / (10000)^2$$

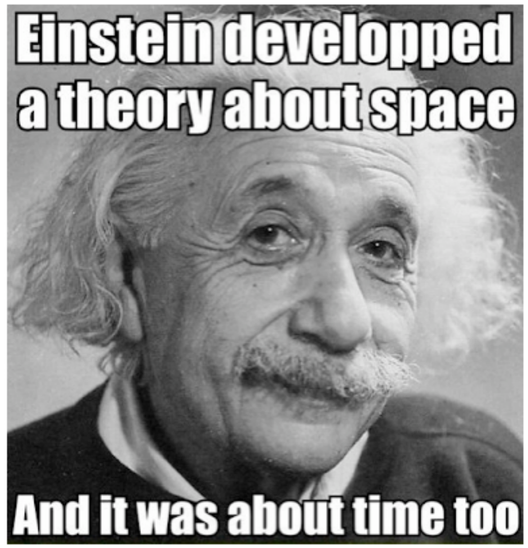
$$900 / F_2 = 9/1$$

$$900 / F_2 = 9$$

$$F_2 = 900 / 9 = 100 \text{ N}$$

When the distance increases to 30000 km from the center of the Earth, the force drops from 900 N to 100 N.

Einstein and Nature of Gravity



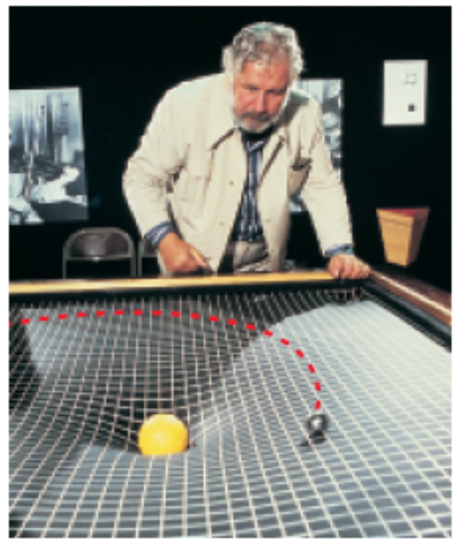
A German Scientist

(1879-1955)

Einstein proposed that gravity is not a force, but an effect of space itself. Einstein proposed that a mass changes the space around it and causes it to be curved. Therefore, when other moving masses passe close by, they follow this curvature and accelerate.

Scientists are still searching to understand gravity.

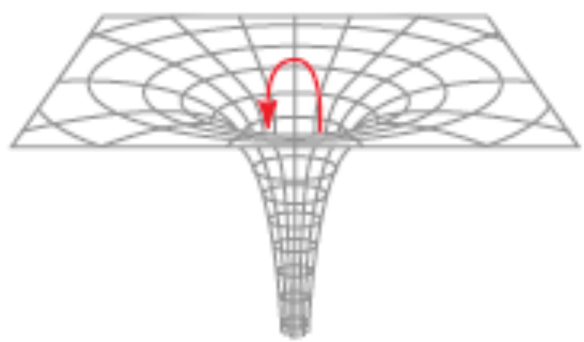
An experiment to picture this is shown in the figure below. In the picture, there is a two dimensional rubber sheet that represents the space. There are also two balls: a large yellow ball representing a massive object such as the sun and a small rolling gray ball representing a smaller moving object such as the Earth.



When the yellow ball (sun) was placed on the sheet (space), it curved it. So, the sun curved the space (sheet) around it and caused a little hole (curvature). The rolling gray marble represents the Earth. When the moving Earth passes close to the curvature of space made by the sun, it accelerates and follows an elliptical path.

Example 2: *The Supermassive Black Holes:*

Black holes are present in space. They are massive, dense objects with immense gravity. The black hole matter is 4.8 x 10^{39} kg, which is equivalent to 2.4 billion of our sun (2.0 x 10^{9} kg). They are located at the center of galaxy M87. They curve the space very deeply causing an immense gravity. No light ever escapes black holes. The immense gravity will totally bent back the light and return it.



References:

1) Humanic. (2013). www.physics.ohio-state.edu/~humanic/. In Thomas Humanic Brochure Page.

Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current*. *www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department:"We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

4) Zitzewitz, P. W. (1999). *Glencoe Physics Principles and Problems*. New York: McGraw-Hill Companies, Inc.

5) Schnick, W.J. (n.d.). *Calculus-based physics, A Free Physics Textbook*. Retrieved from http://www.anselm.edu/internet/physics/cbphysics/index.html

6) Nada H. Saab (Saab-Ismail), (2010-2013) Westwood Cyber High School, Physics.

7) Nada H. Saab (Saab-Ismail), (2009- 2014) Wayne RESA, Bilingual Department.