# **Kepler's Laws**

I. The Law of Orbits: All planets move in elliptical orbits, with the sun at one focus.

**II. The Law of Areas:** A line that connects a planet to the sun sweeps out equal areas in equal times.



**III. The Law of Periods:** The square of the period of any planet is proportional to the cube of the semimajor axis of its orbit (i.e. the "bigger" radius of the ellipse):



### **Newton's Law of Gravity**

Two masses,  $m_1$  and  $m_2$ , experience gravitational attractive force to each other, that depends on distance between them, r:

$$F = -\frac{Gm_1m_2}{r^2}; \qquad G = 6.7 \times 10^{-11} \frac{m^3}{kg \cdot s^2}$$

G is called Gravitational Constant.

From Newton's Universal Gravity, one can derive Kepler's Laws. The easiest is to derive the Third Kepler's Law for the case of a circular orbit.

Consider a planet of mass **m** on a circular orbit of radius **R** around a star of mass **M**. Since its centripetal acceleration,  $a=v^2/R$ , is due to gravity, we obtain:  $\frac{GMm}{R^2} = ma = m\frac{v^2}{R}$ 

Here, speed  $v = 2\pi R/T$ , and therefore, Kepler was right!

$$T^2 = \frac{4\pi^2}{GM}R^3$$



## Homework

#### Problem 1

- a) By using Newton's law of gravity, find the gravitational acceleration on the surface of a planet with mass M and radius R. For doing this, consider an apple of mass m. Its weight is mg. But is also must be equal to Newton's gravitational force.
- b) Imagine that you discovered a planet with the same density as Earth, but its radius is twice as big. What will be the value of g on that planet?

#### Problem 2.

If we were living in a 2D world, the Newton's Gravity would have a slightly different form:

$$F = -\frac{G'Mm}{R}$$

Can you predict how would Kepler's Third Law change? Assume a circular orbit