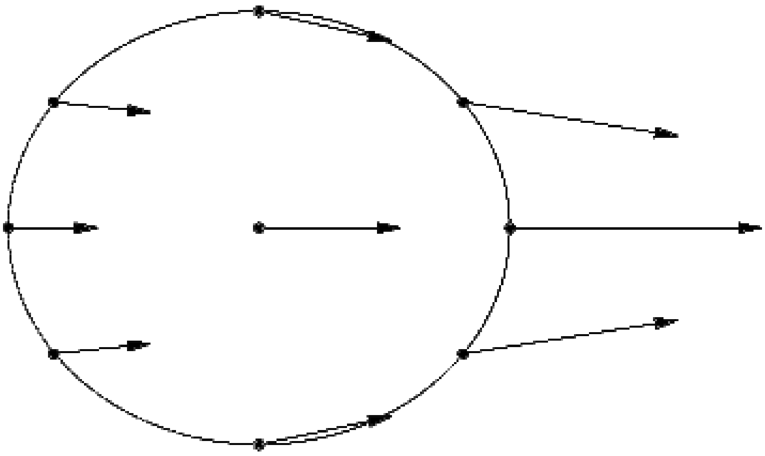
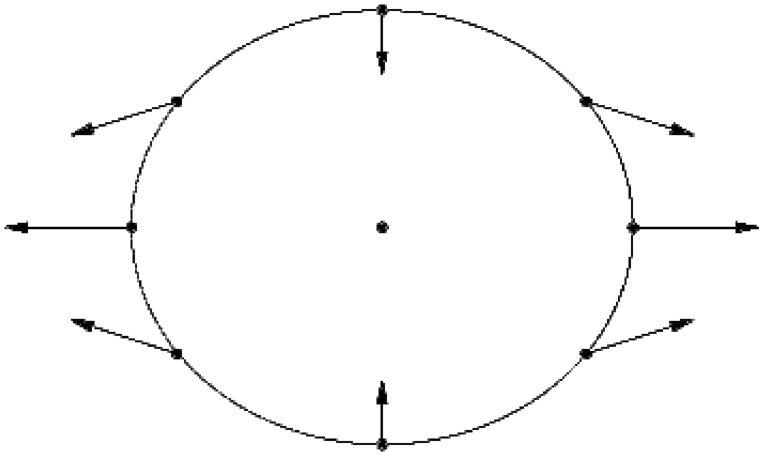
Gravitational Tides

Look closely at the **gravitational force** acting on a moon as it orbits its planet:



If we subtract the center of mass force, we see the **differential force** acting on it:



So gravity "**stretches**" and "**squashes**" a moon!

Let's look at this mathematically. The force of gravity is:

$$F = -\frac{GMm}{r^2}$$

So the **differential force** (also called the **tidal force**) across a distance dr is

$$dF = \left(\frac{dF}{dr}\right)dr = \frac{2GMm}{r^3}dr$$

Note that

- the tidal force is proportional to the mass of the primary (**M**)
- the tidal force is inversely proportional to the distance ***cubed***.

Note also that it works both ways -- the moon also stretches the planet!

Why is it called a tidal force?

What is stronger on the Earth, the tidal force from the moon or the tidal force from the Sun?

$$\frac{F_{tidal,moon}}{F_{tidal,sun}} = \left(\frac{M_{moon}}{M_{sun}}\right)\left(\frac{r_{sun}}{r_{moon}}\right)^3$$

$$= 2.2$$

So the moon exerts a stronger force, but the Sun's tidal force can be significant. Hence the concept of **spring tides** and **neap tides**:

- **Spring Tides:** Sun and Moon in alignment; tidal forces add. ***Big tides!***
- **Neap Tides:** Sun and Moon 90 degrees apart; tidal forces counteract. ***Small tides.***

Remember: Tides are not merely a water effect! The Earth's surface also has tidal bulges, about 10cm in height. And the moon has an even greater tidal bulge -- 20m high.

Thought experiment: What happens when you keep squeezing and stretching a piece of silly putty? What does this have to do with tides?