Announcements

Isaac Newton (1642 – 1727) was one of the brilliant circle in the early days of the Royal Society in London. He was a great friend of Halley, who sponsored the publication of “The Principia”, the foundation of all mechanics.

Newton’s 3 Laws of Motion:

1. A body at rest (or in uniform motion) stays at rest (or in uniform motion) unless acted on by a force. \( \text{a} = 0 \) of \( \text{F} = 0 \)
2. \( \text{F} = \text{ma} \), or \( \text{a} = \frac{\text{F}}{\text{m}} \) The acceleration is directly proportional to the impressed force and inversely proportional to the mass.
3. To every action there is an equal and opposite reaction.

Example: the baseball bat exerts no greater force on the baseball than the ball does back on the bat, but being of less mass, the baseball experiences a greater acceleration.

The Babson Institute in Wellesley, MA has Newton’s original library, books, etc. As a shrine to I. Newton (Babson made a killing in the stock market just before the crash by applying Newton’s Laws (inappropriately!) to the stock market.)

In addition we have to have the “source” of the force in order to apply these laws. For gravity there’s Newton’s Law of Universal Gravitation:

\[
\text{F} = \frac{\text{Gm}_1\text{m}_2}{\text{r}^2}
\]

where \( \text{m}_1 \) and \( \text{m}_2 \) are the two masses, \( \text{r} \) is their separation, \( \text{G} \) is the Gravitational constant and \( \text{F} \) is the force felt by each. Mass \( \text{m}_1 \) exerts a force \( \text{F} \) on \( \text{m}_2 \) equal and opposite to the force exerted by \( \text{m}_2 \) on \( \text{m}_1 \). Note this is an inverse square law; move \( \text{m}_1 \) twice as far from \( \text{m}_2 \) and the force felt by each is then multiplied by a factor of 1/4 . The famous Cavendish experiment measured the value of \( \text{G} \) in the lab by measuring the deflection of pendulum by a huge lead mass; this experiment was called “weighing the earth” because the force per unit mass at the earth’s surface is

\[
\text{g} = \frac{\text{Gm}_1}{\text{r}^2}
\]

so now one can calculate \( \text{m}_x \).

to derive the above, Newton applied local concepts of gravity at earth’s surface to the moon, also “falling” under the same force of gravity only diluted by \( 1/\text{r}^2 \).

There are two immediate consequences of the above:

1. Objects fall independent of their weight, viz \( \text{g} = \frac{\text{Gm}_1}{\text{r}^2} \) proportional only to earth’s mass and independent of the mass of the falling object. (For 1000’s of years people had believed differently, starting with Aristotle’s teachings.) Application of this idea enables us to weigh the planets, by measuring how much they accelerate a space probe or when the planet has a moon, by measuring the motions of the moon.
2. All of Kepler’s laws fall out simply by using Newton’s laws plus the law of gravity. For example, for an earth orbiting the sun, \( F = mEms/r^2 = m\cdot v^2/r = (m_x/x)(2\pi r/T)^2 \) where \( T \) is the orbital period, \( v \) the velocity and \( v^2/r \) the requisite centripetal acceleration. By simplifying one sees that for planets orbiting the sun, \( r^3 \sim T^2 \) or the harmonic law, where the proportionality constant is the mass being orbited \( m_x \).

Going back to consequence 1 above, local gravity for a planet is proportional to the planet’s mass divided by its radius squared. If we note that, e.g. for the terrestrials (where the densities are all about the same ~ 5 gm/cc) \( m \sim r^3 \), then local gravity.
\[
g \sim r
\]

So for tiny Mercury and the moon, \( g \) is just not big enough to retain any atmospheric gasses at all, and Mars just barely keeps \( \text{CO}_2 \) and \( \text{HO}_2 \).

We will now do a brief tour of the planets, starting with earth, which is the planet of extremes: fluid metallic core with fairly rapid rotation (which explains the strong magnetic field: both ingredients are necessary); active crust with earthquakes, volcanoes; third generation atmosphere (first primordial, second outgassed, third evolved under solar radiation and biological pressure).

There are four developmental stages which characterize terrestrial planets:

1. Differentiation – as planets form heavy metals sink to core leaving lighter elements floating in crust.
2. Cratering as remnants of original nebular batter down
3. Flooding of basins (as planet is heated from within by radioactive elements) by lava and later by water when it’s cooler
4. Surface evolution and weathering for 3.5 billion years. Should emphasize again that the first 3 stage occurred in the first billion years of the solar system.

1. Wind + rain