Orbital Motion

Orbital Motion

- What kind of force causes objects to move along a circular path?

  Centripetal Force!
- To determine the orbital speed of a mass that is orbiting around a larger central mass, we must first recognize that the centripetal force keeping it in orbit is actually the gravitational force, so…

Orbital Motion

$$F = G\frac{Mm}{r^2}$$

- *And…* $F_c = \frac{mv^2}{r}$
- *So it follows that:* $G\frac{Mm}{r^2} = \frac{mv^2}{r}$
- *The orbital speed of a satellite, therefore, can be determined by using:*

$$G\frac{M}{r} = v^2$$

Orbital Motion

- The previous example shows us how the orbital speed of a satellite depends on its orbital radius.
- The farther out a satellite is from Earth's surface, the slower it can go and still remain in orbit
- **How far out (what orbital radius) must a satellite have to remain in geosynchronous orbit?**

Kepler's laws of Planetary Motion

- **1st Law:** Planets move in ellipses around the sun, the sun being at one of the foci of each ellipse.
- **2nd Law:** The line from the sun to he planet sweeps out equal areas in equal times.
- **3rd Law:** The time taken to complete one full revolution is proportional to the 3/2 power of the mean distance from the sun.
  - *Or: the orbital period squared is directly proportional to the cube of the mean distance from the sun.*

Orbital Period, related to Kepler's third law of planetary motion…

- Assume a circular orbit…the average orbital speed is equal to the distance traveled by the planet or satellite in one orbital period:

  $v = \frac{d}{t}$ Which Means… $v = \frac{2\pi r}{T}$

- Using the relationship we previously deduced:

  $$G\frac{M}{r} = v^2$$

- We can relate Newton's law of gravitation to Kepler's 3rd law of planetary motion…

Newton's Law of Gravitation & Kepler's 3rd Law of Planetary Motion

- Known: $v = \frac{2\pi r}{T}$ $G\frac{M}{r} = v^2$
- Substitute:
- Solve:
- And we get the value of the proportionality constant for Kepler's 3rd law:

Weightlessness

- The forces that act on an astronaut (or anything else) in orbit in a spacecraft, some distance *r* from the center of the earth are:
  - His weight (gravitational force from Earth)
  - The normal force (N) from the "floor" of the spacecraft.
- What is the net force acting on the astronaut?

- $F_{net} = \frac{(GMm)}{r^2} - N = \frac{mv^2}{r}$
- $\frac{(GMm)}{r^2} - \frac{mv^2}{r} = N$

$N = (^m/_r)\{(^{GM}/_r) - (v^2)\}$

When we looked at Orbital motion, we showed that $(^{GM}/_r) = v^2$ …so our equation above mathematically shows that the Normal force that the astronaut feels is equal to **0 N…**

Therefore: "Weightlessness" implies not that there is no gravity, but rather that there is no reaction force exerting the upward force that we sense as our weight.