Galileo and Newton

Physical Sciences
Broward College
Prepared for AST 1002
Horizons in Astronomy

What were the observations that caused the revision of physics?

- The observations of phases of other planets.
- The observation of moons around other planets.
- The observations of inertia, free fall.
- The observations of central seeking forces.
- The observation of binary stars.

Who was Galileo Galilei?

- 1564-1642 A.D.
- Was the first to use a spyglass for a telescope, *Siderius Nuncius*
- Taught school in Padua, Italy

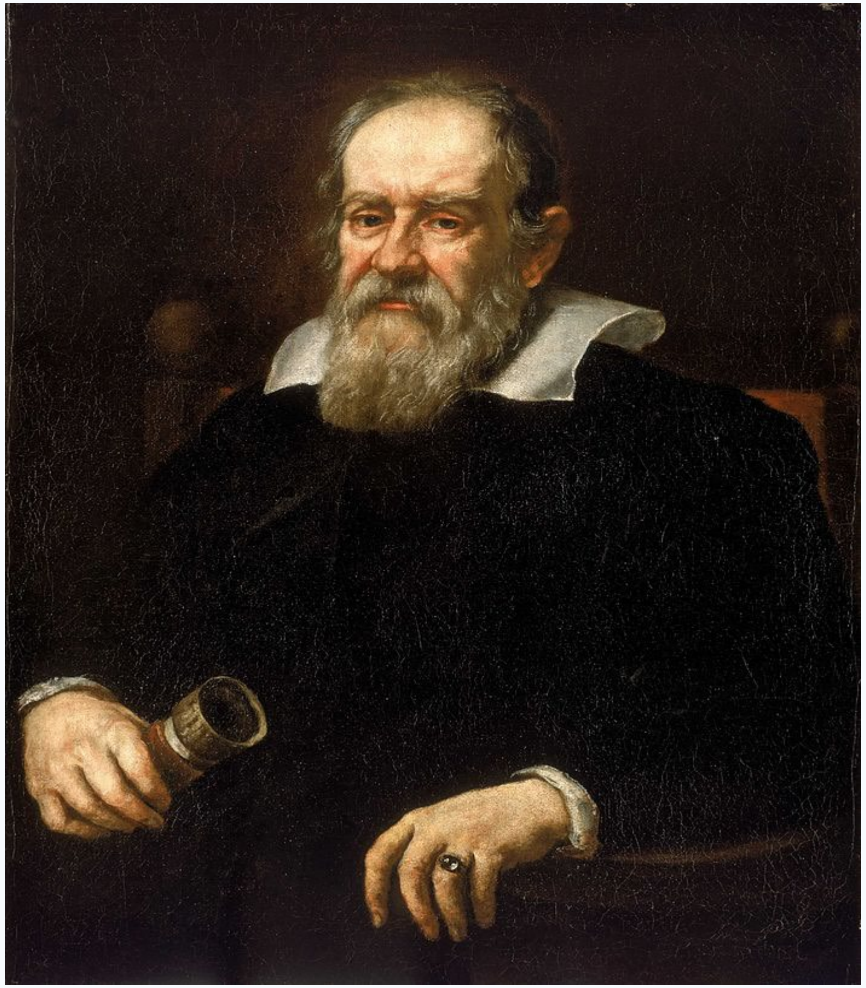


Figure 1. Galileo Galilei (Wiki)

Galileo’s Observations

- Spyglasses used for 300 years before Galileo.
- In 1609, Galileo constructed his first telescope
- Galileo observed mountains on the moon, moons around Jupiter, and stars with the telescope.
- In 1613, Galileo observed Venus had phases.

Dialogue of Two Chief World Systems: 1623

- A debate of the Copernican system versus the Ptolemaic system
- Galileo had political enemies due to his belief in the Copernican system.
- Galileo had an audience with the Pope which he used as the model for his Ptolemaic debater
- Galileo was placed under house arrest in 1633.
- The book was restricted until 1835.

What science did Galileo create?

- The study of Mechanics
- Motion
  - Speed
    - Distance/time (v=d/t)
    - Instantaneous versus Average
  - Velocity
  - Acceleration
    - Change of velocity/time (a=v/t)
    - Acceleration versus Deceleration

Velocity and Distance

$$v = \frac{d}{t}$$

$$vt = \frac{d}{\cancel{t}}\cancel{t}$$

$$d = vt$$

Velocity of a Car

- What is the velocity of a car that travels 50 meters north in 3 seconds?

$$d = 50\,\text{meters}$$

$$t = 3\,\text{seconds}$$

$$v = \frac{d}{t}$$

$$v = \frac{50m}{3s} = 16.67\, m/s\ North$$

Distance of a Car

- What distance does a car traveling on the Autobahn at 120 km/hr travel in 3 hours?

$$v = 120\,km / hour$$

$$t = 3\,hours$$

$$d = vt$$

$$d = \left(\frac{120km}{hour} \right) 3\,hours = 360\,km$$

Acceleration and Distance

$$v_f - v_i = at$$

$$\frac{v_f - v_i}{t} = a$$

$$v_f^2 - v_i^2 = 2da$$

$$\frac{v_f^2 - v_i^2}{2a} = d$$

Acceleration of a Car

- What is the acceleration of a car that starts out at rest and speeds up to 6 m/s in 60 seconds?

$$v_f = 6 m/s$$

$$v_i = 0 m/s$$

$$t = 60 s$$

$$a = \frac{v_f - v_i}{t} = \frac{6 m/s - 0 m/s}{60 s}$$

$$a = 0.1 m/s^2$$

Distance of a Car

- What is the distance travels in the time period in the above period?

$$v_f = 6 m/s$$
$$v_i = 0 m/s$$
$$a = 0.1 m/s^2$$
$$d = \frac{v_f^2 - v_i^2}{2a} = \frac{(6 m/s)^2 - (0 m/s)^2}{2(0.1 m/s^2)}$$

$$d = \frac{36 m^2/s^2}{0.2 m/s^2}$$
$$d = 180 m$$

Aristotle’s Views

- Two spheres
  - Sphere of Perfection: Planets, Stars, and Universe
  - Sphere of Change: Earth
- Natural versus Forced Motion in the Sphere of Change
  - Natural Motion: Earth, air, fire, and water
  - Forced Motion: Required force by people
- Could not explain interaction at a distance

Horizontal versus Vertical Motion

- Vertical
  - Leaning Tower of Pisa
  - Free fall
  - Galileo versus Aristotle
    - Constant versus Accelerating objects
- Horizontal
  - Inclined Planes
  - Rolling Balls
  - Inertia
- Compound
  - The combination of vertical and horizontal motion
  - The steeper the angle of the inclined plane the faster the movement; this was behavior mimicked planetary movement around the Sun.

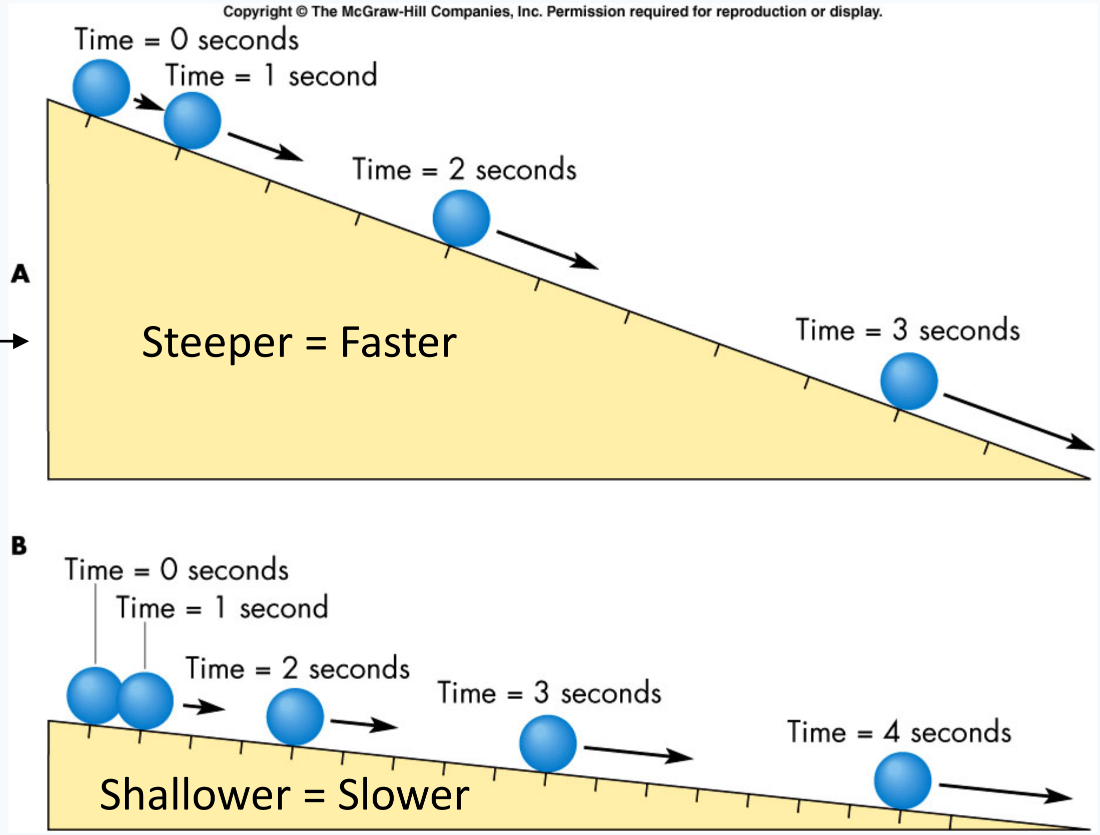


Figure 2. Two Inclined Planes (Fix, 2004)

Vertical Motion Explained

$$v_i = 0\, m/s$$

$$v_f = v$$

$$v = at \qquad\qquad v^2 = 2da$$

$$v^2 = a^2t^2 \rightarrow a^2t^2 = 2da$$

Now we solve for d

$$d = \frac{a^2t^2}{2a} = \frac{at^2}{2}$$

Height of a Building

- What is the height of a building from which a ball is dropped and takes 15 seconds to fall to the ground?

$$t = 15\, s$$

$$a = g = 9.8\, m/s^2$$

$$d = \frac{at^2}{2} = \frac{9.8\, m/s^2 (15\, s)^2}{2}$$

$$d = 1{,}103\, meters$$

Who was Isaac Newton?

- 1642 – 1727 A.D.
- Born December 25, 1642 on Woolsthorp Farm
- At 18, attended Trinity College, Cambridge

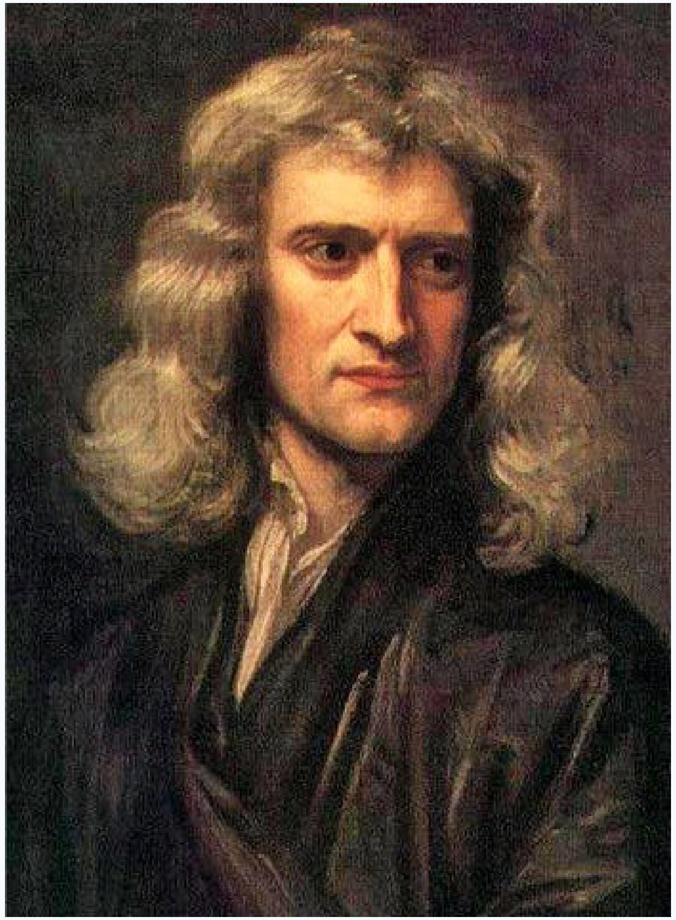


Figure 3. Isaac Newton (Wiki)

Work at Woolsthorp

- In 1655, Newton returned to Woolsthorp due to the bubonic plague.
- During his time at Woolsthorp, Newton sought a central seeking force.
- Newton observed an apple falling and compared it to the moon’s motion around the Earth.

The Return to Trinity College

- Newton studied optics and created the reflecting telescope.
- Edmund Halley (1656)
  - Halley wanted to find an analytical solution for elliptical orbits
  - Halley pushed Newton to publish work because he wanted a model to predict when the comet bearing his name would return.
- Newton published the *Principia* in 1687, which contained his three laws of motion.

Newton’s First Law of Motion

- “Every object retains it state of uniform, straight-line motion unless acted up by an unbalanced force”
- Example: A car rolling forward.
- Inertia
- Mass

Professor Howard's Zero-G Ride

Click on the picture for video.

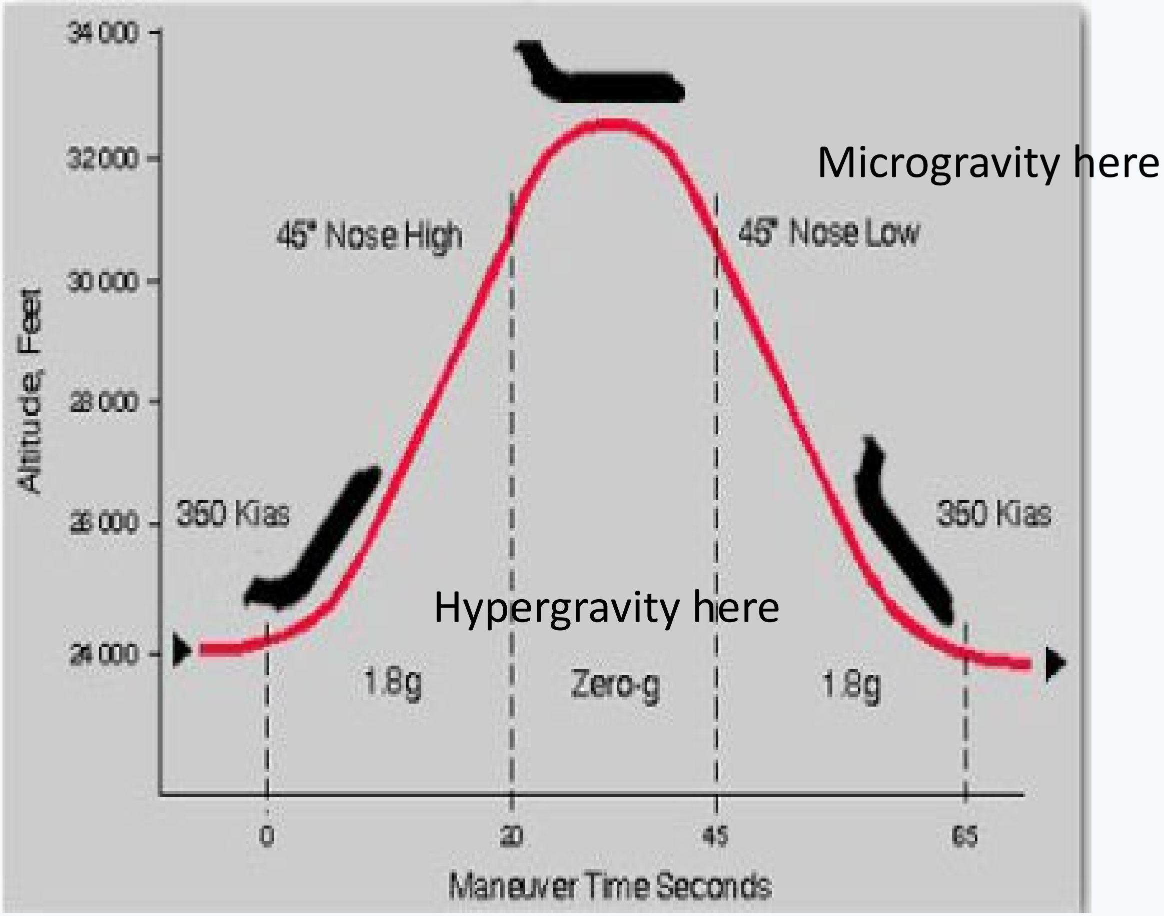


Figure 4. Microgravity Plane Profile (Wiki)

Newton’s Second Law of Motion

- “The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to the mass of the object”
- Example: Weight of an object.
- F = ma

Force of a Car

- The car from the above problem has a mass of 2,000 kg. What is its force traveling forward?

$$m = 2{,}000\,kg$$

$$a = 0.1\,m/s^2$$

$$F = ma = (2{,}000kg)(0.1m/s^2)$$

$$F = 200kgm/s^2 = 200\,N$$

Newton’s Third Law of Motion

- “Whenever two objects interact, the force exerted on one object is equal in size and opposite in direction to the force exerted on the other object”
- Example: Standing on the Floor
- $F_{AB} = F_{BA}$

Circular Motion

- Centripetal versus Centrifugal
  - Centripetal: A center seeking force.
  - Centrifugal: A psuedoforce to balance out centripetal.
- All circular motion inside
- $a_c = v^2/r$
- $F = mv^2/r$

Circular Motion of a Car

- A Daytona car that is the same mass of the car above is going on a track of 40 meters and at 30 m/s , what is its centripetal force?

$$m = 2{,}000\,kg$$

$$v = 30\,m/s$$

$$r = 40\,m$$

$$F = \frac{mv^2}{r} = \frac{(2{,}000kg)(30m/s)^2}{40m}$$

$$F = \frac{(2{,}000kg)(900m^2/s^2)}{40m}$$

$$F = 45{,}000kgm/s^2 = 45{,}000\,N$$

Newton's Law of Gravitation

- "Every object in the universe is attracted to every other object with a force that is directly proportional to the product of their masses"
- $F = \frac{GM_1M_2}{R^2}$
- $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$
- The gravitational field acts like all the gravity of a massive object comes from its center.

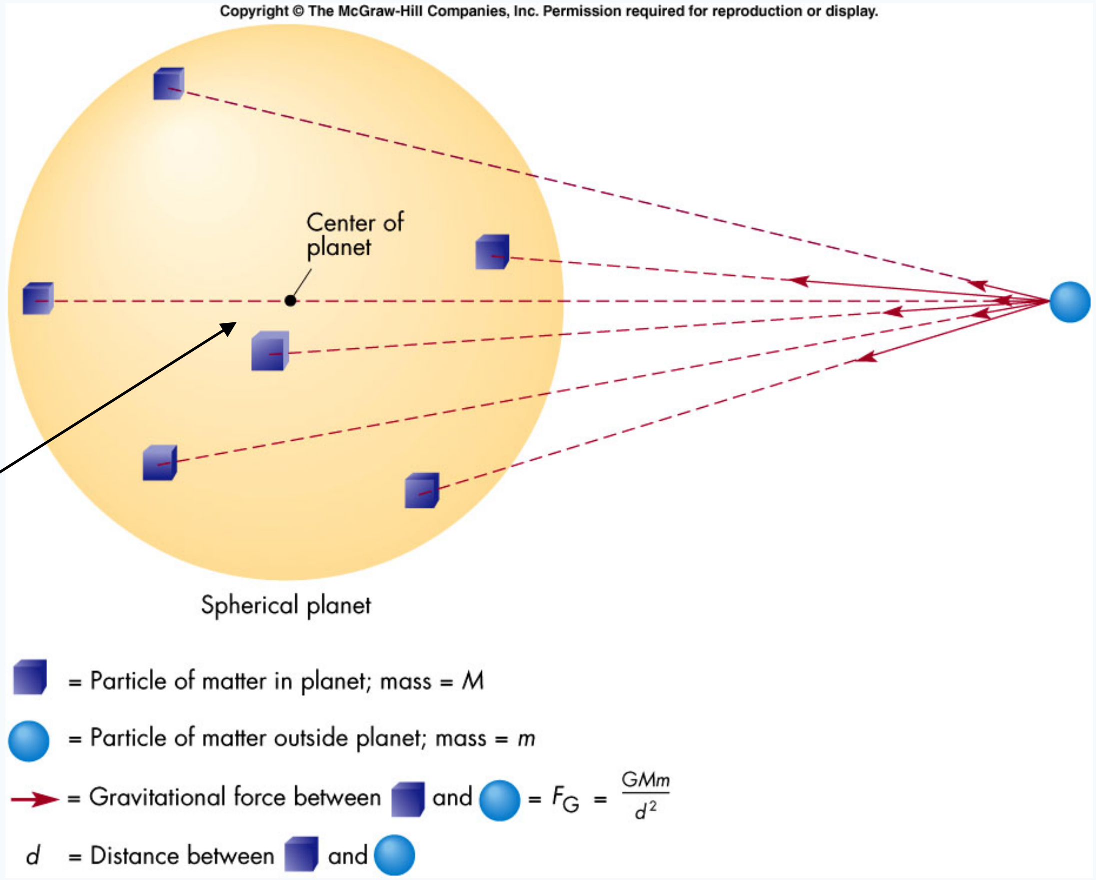


Figure 5. Gravity Interaction (Fix, 2004)

Force between the Sun and Venus

$$M_{Sun} = 1.99 X 10^{30} kg$$

$$M_{Venus} = 4.870 \text{ X } 10^{24} \text{ kg}$$

$$\text{R(Distance)} = 1.082 \text{ X } 10^{11} \text{ m}$$

$$\text{F} = \frac{\text{GM}_{\text{Sun}} M_{Venus}}{R^2}$$

$$\text{F} = \frac{(6.67\text{X}10^{-11} Nm^2 / kg^2)(1.99 X 10^{30} kg)(4.87 X 10^{24} kg)}{(1.082 X 10^{11} m)^2}$$

$$F = 5.5 X 10^{22} \ N$$

Orbital Velocity

$$F_C = \frac{mv^2}{r}$$

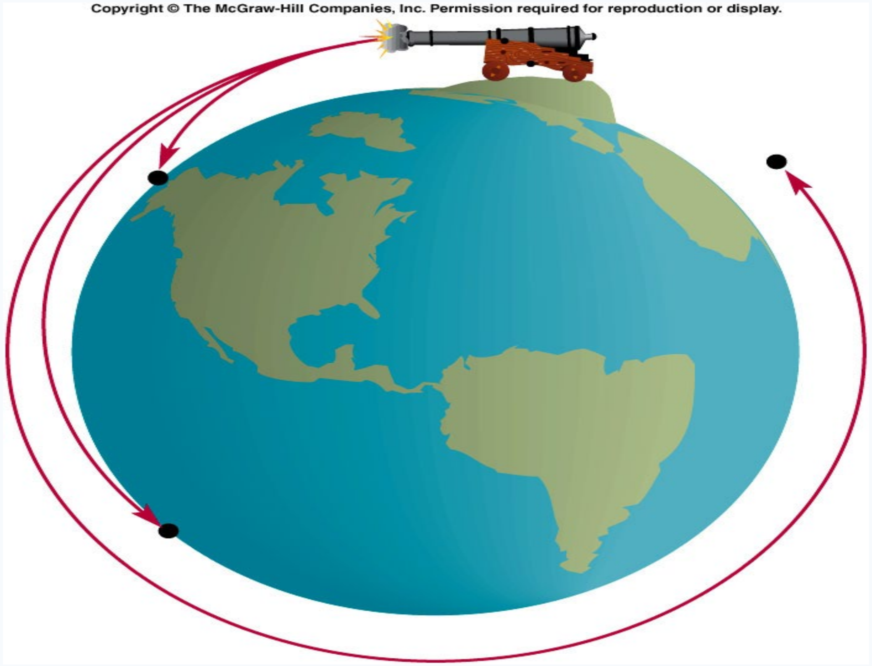
$$F_G = \frac{GMm}{r^2}$$

$$F_C = F_G$$

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$\sqrt{v^2} = \sqrt{\frac{GM}{r}}$$

$$v = \sqrt{\frac{GM}{r}}$$



An object orbits another object when its forward speed is faster than its falling speed.

Figure 6. Object Orbiting (Fix, 2004)

Velocity to Orbit Venus

$$M_{Venus} = 4.878X10^{24}\,kg$$

$$R_{Venus} = 6.052X10^{6}\,m$$

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{(6.67X10^{-11}\,Nm^{2}/kg^{2})(4.878X10^{24}\,kg)}{6.052X10^{6}\,m}}$$

$$v = 7{,}300\,m/s$$

Newton's Form of Kepler's Third Law

$$P^2 = \frac{4\pi^2 a^3}{G(M+m)}$$

Period of Venus

$$M = 1.99 X 10^{30} kg$$

$$m = 4.870 \text{ X } 10^{24} \text{ kg}$$

$$\text{R} = 1.082 \text{ X } 10^{11} \text{ m}$$

$$P^2 = \frac{4\pi^2 a^3}{G(m+M)}$$

$$P^2 = \frac{4\pi^2 (1.082 X 10^{11} m)^3}{(6.67 X 10^{-11} \, Nm^2 / kg^2)(4.870 \text{ X } 10^{24} \text{ kg} + 1.99 X 10^{30} kg)}$$

$$\sqrt{P^2} = \sqrt{3.767 X 10^{14} s^2}$$

$$P = 1.941 X 10^7 s (1 year / 31{,}557{,}600 s)$$

$$P = 0.62 \, years$$

Results of Newtonian Physics

- Ability to calculate the center of mass.
- Discovery of Neptune
  - Adams: Theorized Neptune's existence
  - George Airy: Tried to observe
  - Urbain J. Leveri and Johann Galle: Discovers of Neptune
- Ability to model the motion of binary stars.
- We could find the escape velocity: the velocity need to escape the gravity of the planets. This allowed for inter-body travel in our Solar System.
- Confirmation of the results of Kepler and Copernicus.
  - All three men received 0.62 Earth years for the orbital period of Venus.

Results of Newtonian Physics -Orbital Elements

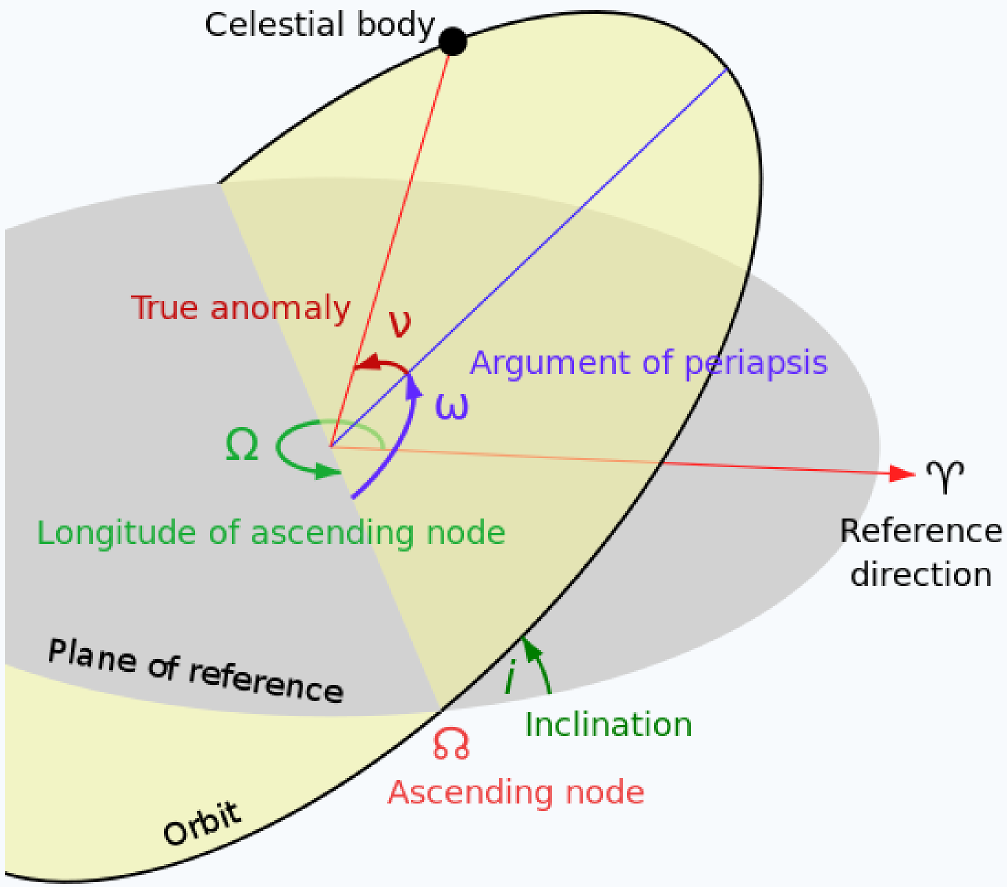


Figure 7. Orbital Elements (Wiki)

- The final outcome of Newtonian physics is that creation of orbital elements.
- The elements allowing the precise timing of where an object is with respect to periapsis, the point of closest approach.

Newton’s Cosmology

- Everything in perfect working order
- Planetary orbital procession not quite explained
  - “God resets everything”

Book/Course Image References

- Fix, J. D. (2004) *Astronomy: Journey to the Cosmic Frontier,* New York, New York, McGraw- Hill Higher Education.

Wiki Commons/Wikipedia Image References

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