Reminders

1. No Online Quiz this Week
2. Read Chapter 5
Midterm Results

- Mean: 75%
- Median: 76%
- Standard Deviation: 10%
Lecture 14 – Galileo and Newton’s Laws
Clicker Question

Which properties of light changes in a refractive medium?

(a) wavelength
(b) wavelength and speed
(c) frequency, speed, and wavelength
(d) speed
(e) nothing changes
Copernicus’ Ideas were revolutionary because:

(a) The earth is not the center of the universe
(b) The earth goes around the sun
(c) We are not special
(d) all of the above
Kepler’s Laws

(a) Explain the motion of the planets
(b) Explain the motion of the moon
(c) Explain the motion of all orbiting bodies
(d) all of the above
Galileo
Achievements

- Published *Sidereius Nuncius* in 1609
- Discovered that the moon had mountains and therefore wasn’t *perfect*
- Discovered that Jupiter had 4 moons orbiting it: The so-called Galilean Satellites: Io, Europa, Calisto, Ganymede
- Discovered that Venus has phases like the moon: Can’t be explained in geocentric system
Moons of Jupiter
Phases of Venus

Ptolemaic universe

Copernican universe

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Wrote *Dialog Dei Due Massimi Sistemi* (Dialogue concerning the Two Chief World Systems). The death knell for Ptolemy’s system.

Sentenced to house arrest by Inquisition. Pardoned in 1979! *E pur si muove* (Still it moves)

Started new science of *mechanics* current view very different from that of Aristotle
Distance to the Stars I

Ptolemy
The scale of the planetary spacing is set by the earth-moon distance of $60R_⊕$ and then everything is spaced so the epicycles just miss each other. This works out to the earth-sun distance of $1200R_⊕$ found by Aristarchus from the “timing” of the half moon. The stars are just outside Saturn’s orbit.
Distance to the Stars II

- Copernicus
  He fudges to keep the earth-sun at $1200R_{⊕}$. Things are spaced so the epicycles just clear each other, but things are tighter now because the epicycles are smaller. The stars must be at an immense distance to explain the lack of parallax.
Tycho Observes that stars have diameters of \( \sim 2 \) arcminutes. To avoid having parallax of a similar amount the brightest biggest stars would have to be as big as earth’s orbit. This leads him to a stationary earth.
Galileo
The telescope makes planets bigger, i.e., they have resolved disks of a few tens of arcseconds. But stars are smaller, down to the limit of his optics (a few arcseconds?). This demolishes Tycho’s objection, and the stars can be at enormous distances as Copernicus wants.
Newton (1642-1727)

- Arguably, greatest scientist who ever lived
  “If I have seen farther than other men, it is because I stood on the shoulders of giants.”
- Contributions in many branches of mathematics, physics, and astronomy
- Published *Principia* in 1687
Newton
Newton’s Laws

Newton’s Three Laws of Motion

1. A body continues at rest or in a state of uniform motion unless acted on by a force

   \[ F = ma \]

2. For every action there is an equal and opposite reaction
Newton’s Law of Universal Gravitation I

- Law of Gravity — Inverse square law
  \[ F = -\frac{Gm_1m_2}{r^2} \]
- Can *derive* Kepler’s laws from Newton’s Laws
- Explains why objects fall toward center of the earth (see Aristotle)
Newton’s Law of Universal Gravitation II

- Explains why planets orbit sun and why moons orbit planets
- Can be used to make and test predictions
Newton’s Laws

Newton’s Three Laws of Motion

1. A body continues at rest or in a state of uniform motion unless acted on by a force.

2. \[ F = ma \]

3. For every action there is an equal and opposite reaction.
Uniform Circular Motion

- Motion toward Earth
- Curved path of moon’s orbit
- Straight line motion of the moon

Earth
Circular Velocity

A satellite above Earth’s atmosphere feels no friction and will fall around Earth indefinitely.

The velocity needed to stay in a circular orbit is called the **circular velocity**. Just above Earth’s atmosphere, circular velocity is 7700 m/s or about 17,400 miles per hour, and the orbital period is about 90 minutes.

At a distance of 42,250 km (26,260 miles) from Earth’s center, a satellite orbits with a period of 24 hours.

Earth satellites eventually fall back to Earth if they orbit too low and experience friction with the upper atmosphere.

Log into AceAstronomy and select this chapter to see Active Figure “Newton’s Cannon” and fire your own version of Newton’s cannon.
When the string cuts through the bagel, the bagel will:

(a) Move outward due to the centrifugal force
(b) Move in a straight line, since there is no longer a force
(c) Move in a random direction
(d) Hit someone in the head
Escape Velocity

If the cannonball travels as fast as escape velocity, the velocity needed to leave a body, it will enter an open orbit. An open orbit does not return the cannonball to Earth. It will escape.

A cannonball with a velocity greater than escape velocity will follow a hyperbola and escape from Earth.

A cannonball with escape velocity will follow a parabola and escape.

As described by Kepler's Second Law, an object in an elliptical orbit has its lowest velocity when it is farthest from Earth (apogee), and its highest velocity when it is closest to Earth (perigee). Perigee must be above Earth's atmosphere, or friction will rob the satellite of energy and it will eventually fall back to Earth.