Kepler’s Laws—8 Sept

• The discovery of the laws of motion, the first science.
  – De Revolutionibus Orbium Coelestium, Copernicus, 1543
  – Astronomia Nova, Kepler, 1609
  – Philosophiae Naturalis Principia Mathematica, Newton, 1687
• How Kepler figured out the path of Mars from Tyco’s observations. Discovery of his three laws.

Kepler Solves Mars Orbit

• Kepler’s Astronomia Nova, 1609, in Sleepwalkers, by A. Koestler.
• Kepler describes the orbit: “The conclusion is simply that the planet’s path is not a circle—it curves inward on both sides and outward again at opposite ends. Such a curve is called an oval. The orbit is not a circle, but an oval figure.” —Ch. 44
• “What happened to me confirms the old proverb: a bitch in a hurry produces blind pups… But simply I could not think of any other means of imposing an oval path on the planets. When these ideas fell upon me, I had already celebrated my new triumph over Mars without being disturbed by the question whether the figures tally or not.” —Ch. 45

Kepler discovers Kepler’s First Law of Planetary Motion

• “… I was wondering why and how a sickle of just that thickness (0.00429) came into being. While this thought was driving me around, while I was considering again and again… that my apparent triumph over Mars has been in vain, I stumbled entirely by chance on the secant of the angle 5° 18’, which is the measure of the greatest optical elongation. When I realized that this secant equals 1.00429, I felt as if I had been awakened from a sleep…” —Ch. 45 (a year’s work later)

• Reading assignment has changed: Read the handout.
• Maximum number of point on Hwk 1 is 28.
Kepler’s First Law of Planetary Motion 1605

• The path of a planet is an ellipse.
  – Ellipse is figure for which D1+D2 does not change
  – The sun is at one focus.
  – Eccentricity = (dist between foci)/(major axis)
• Modern extension
  – The path of an object controlled by the sun’s gravity is an ellipse, parabola, or hyperbola.
  – The sun is at one focus.

Kepler’s Second Law 1602

• The line joining the planet and the sun sweeps out equal areas in equal amounts of time
  – Planet moves slowly when it is far from sun
  – Planet moves rapidly when close to sun

Third Law 1618

• The size and periods of the planetary orbits are related by
  \[ P^2 = a^3 \]
  – where \( P \) is the period in years and
  – \( a \) is the half of the major axis in astronomical units

Questions concerning Kepler’s Laws

• A planet’s path is an ellipse with the sun at one focus.
• A planet “sweeps” out the same area in an equal amount of time.
• The planets’ periods \( P \) and semi-major axes \( a \) are related by
  \[ P^2 = a^3 \]
• A planet, which has an almost circular orbit, and a comet, which has a highly elliptical orbit, have the same periods. Draw their orbits on a single picture.
  1. Grading: sun’s position
  2. Grading: lengths of major axes.
Questions concerning Kepler’s Laws

- A planet’s path is an ellipse with the sun at one focus.
- A planet “sweeps” out the same area in an equal amount of time.
- The planets’ periods $P$ and semi-major axes $a$ are related by $P^2 = a^3$.

- A planet, which has an almost circular orbit, and a comet, which has a highly elliptical orbit, have the same periods. Draw their orbits on a single picture.

1. Grading: sun’s position
   A. Centered for comet
   B. Offset for comet

2. Grading: lengths of major axes.
   A. Same for both
   B. Different

   A. Same for both
   B. Different