Current Events in this Class

Homework 2 available, due this Wednesday

Quiz 1 will be handed back Wednesday

Today’s topics:

- Apparent motions of the planets (chapter 2)
- Kepler’s laws of planetary motion (chapter 3)
- Newton’s laws of motion (chapter 4), to be continued
Apparent Motions of the Planets

Generally along the ecliptic

Variable rate; can change direction
Mercury and Venus move back and forth from one side of the Sun to the other, always close to the Sun in the sky.
Therefore, morning (before dawn) or evening (after sunset) “stars”
Mars, Jupiter, and Saturn (also Uranus and Neptune, but they are not naked-eye)

Generally move from W to E along ecliptic

Of these, Mars moves fastest; others slower in order

Can attain any angular distance from Sun, $0^\circ$ to $360^\circ$

*Opposition* refers to planet being $180^\circ$ from Sun
Retrograde motion near opposition

- The term “retrograde” generally means “backwards”
- The Sun’s W to E motion on the ecliptic represents “forward”

Animation of Jupiter and Saturn in retrograde motion in fall 2000
Observer’s view of sky with stars in same place each night
The point of view of the hypothetical distant observer
Planets in order from Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune

This view of the organization of the solar system was the contribution of Copernicus

Summarize: the apparent motions of the planets are caused by a combination of the motions of the planets themselves around the Sun and the motion of the Earth

See Figure 2.27

Animation from "Voyager Sky Gazer"
Kepler’s Laws of Planetary Motion

First: what is meant by a law, called in full a physical law

- Description of what happens in nature under specified conditions, according to experience

- Written in such a way as to be always correct

- Correctly predicts future events under similar conditions

Kepler’s laws describe the planets’ motions as an observer located far from the ecliptic plane would see them

More detailed than Copernicus’s description

They are →
1. The orbit of each planet is an ellipse with the Sun at one focus
• The other focus is empty
• For the major planets, the ellipses are very nearly circular
• This means that the planets’ distances from the Sun change slightly during the course of their orbital motion
2. Each planet moves faster when closer to the Sun and slower when farther away [the actual law specifies the change in speed more precisely]
3. Planets with small orbits (closer to Sun) move faster than planets with big orbits do.
• The actual law relates the time to go around once (the period of the orbit) to each planet’s distance from the Sun

• Compare Earth and Mars, for example. If they moved at the same speed, Earth would take less time than Mars to go around the Sun because Earth’s orbit is smaller in circumference.

• Kepler’s 3rd Law implies: But the time needed for Earth to go around the sun is disproportionately short, so its speed in its orbit must be greater.
Kepler’s laws can also be worded so they apply to objects other than the Sun and planets.

Above, the wording of the 2nd and 3rd laws is simplified, in keeping with the non-mathematical nature of this course.
Motion

Our goal: understand orbital motion in general

Newton’s laws explain Kepler’s laws in terms of the behavior of all moving objects

Basic definitions

Position
**Speed** Rate of change of position, without regard to direction (see speedometer)

**Velocity** Rate of change of position; incorporates direction (see compass)

After a left turn, car’s velocity has changed even if its speed has not
**Acceleration** Rate of change of velocity: speed and/or direction

Your car speeds up: forward acceleration

![Diagram showing acceleration and velocity arrows](image)
Car slows down: backward acceleration

Note: car continues to move forward.
Car driving around a circular track at constant speed
The car’s acceleration is always directed toward the center of the circle while its velocity is directed along the circle.
**Force** An identifiable, physical mechanism that can act on an object and tend to cause acceleration

- Example: *friction*, a contact force that opposes motion, causing moving objects to slow down

**Mass** Alternative definitions

- An object’s resistance to acceleration or its *inertia* (official definition)
- Quantity of matter contained in an object; in detail, the total mass of all the protons, neutrons, and electrons in the object (more user-friendly definition)
Example: a car.

- Its mass is *not* the same as its volume.

- If the car were squashed flat with no material lost, its mass would be unchanged.
Newton’s Laws of Motion

1. In the absence of an applied net force, an object moves at constant velocity.

Note: two equal and opposite forces acting on an object simultaneously will have no net effect, therefore will cause no acceleration.
2. A force applied to an object causes the object to undergo an acceleration that is
(a) in the same direction as the force
(b) proportional to the force
(c) inversely proportional to the object’s mass
This means that

• If you push on an object, the object will move in the direction in which you push, provided no other force acts on it.

• The stronger the push, the greater the object’s acceleration.

• In order to bring about a given acceleration, it takes a stronger push on a large mass than on a small mass.
3. If agent $A$ exerts a force on agent $B$, then $B$ also exerts an equal and opposite force on $A$ (law of action and reaction).

Reaction force exerted by object back on you

Force (your push)

Object