Chapter 3

Interior of the Earth

3.1 Quick Facts About Earth

- The third planet from the Sun and the fifth-largest planet.
- The only place we know of inhabited by living things.
- Length of days: 23.9 hours
- Length of year: 365.25 days
- Distance from Sun: 93,327,712 miles (150,196,428 km)
- The name Earth is at least 1,000 years old. It was taken from Old English and Germanic. Imply it means "the ground".

3.2 The Earth System

- Only the Earth currently has liquid water among the Solar System's planets.
- The Earth lies within the *habitable zone* – the distance from the Sun at which temperatures range between the boiling and freezing points of water.
  - On planets closer to the Sun than the habitable zone, all water evaporates.
  - On planets farther away, all water exists only as solid ice.
- Earth has the potential for life!

3.3 The Size of Earth

- Eratosthenes observed that if the Earth were spherical, the Sun's rays could not strike two distant locations at the same angle at the same time.

  - At noon in Syene (modern Aswan), the Sun was directly overhead and cast no shadow.
  - At the same time in Alexandria, about 5,000 stadia ($\approx$ 800 km) to the North, a vertical tower cast a shadow.
  - Eratosthenes measured the angle between the two and the Sun's rays to be 7.2°.
  - Since 7.2° is $\frac{1}{50}$ of a full circle, he concluded that the Earth's circumference must be 50 times the distance between the two cities and it is 250,000 stadia ($\approx 39,300$ km).
- *Very close to the modern accepted value (40,075.017 km)!*

3.4 Earth's Rotation

- Earth completes one rotation every *23.9 hours* and it takes *365.25 days* to complete one trip around the sun!
- Foucault proved that the Earth spins on its axis

3.4.1 Foucault's Pendulum Experiment

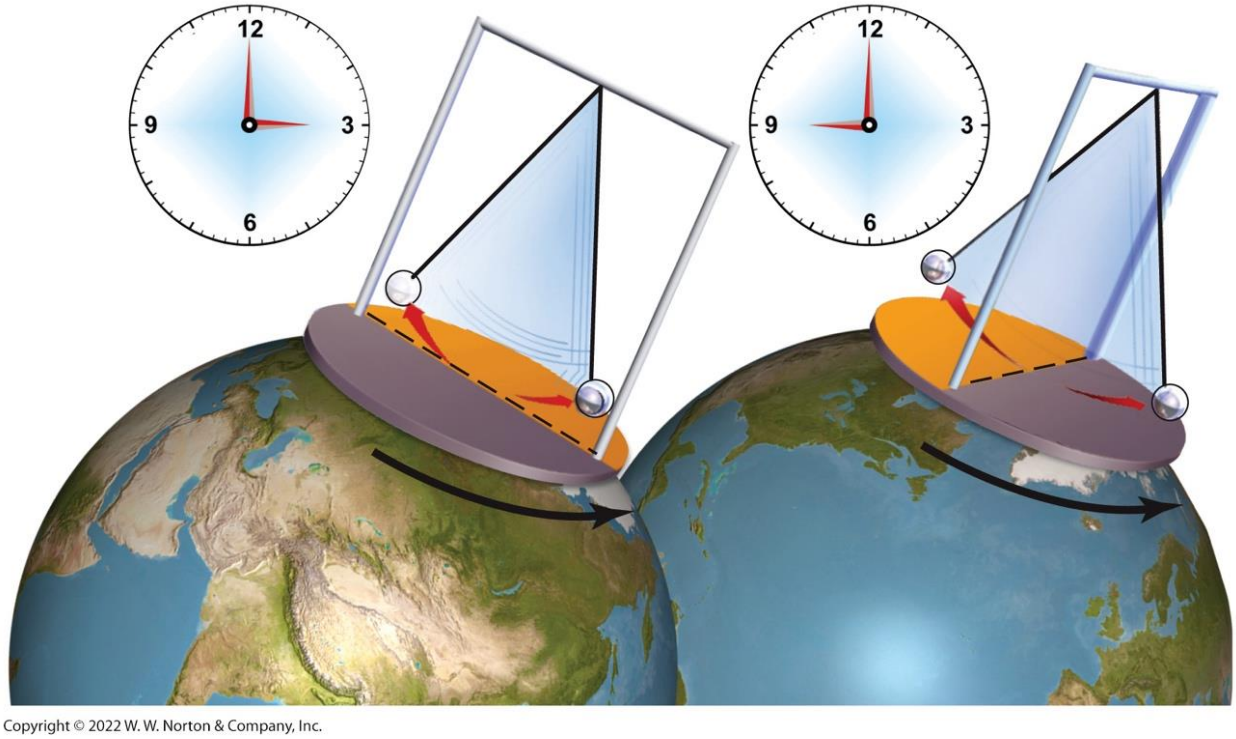

Figure 3.1: Foucault's Pendulum Experiment

- At Time 1 (left), the plane in which the pendulum swings is the same as the plane of its frame.

- At Time 2 (right), 6 hours later, the plan in which the pendulum swings is perpendicular to the plane of its frame.

3.4.2 Earth's Axis of Rotation

- Earth's axis of rotation is tilted 23.5° with respect to the plane of Earth's orbit around the Sun.
  - This tilt causes our yearly cycle of seasons.

3.5 Earth's Structure

- By the end of the 19th century, researchers realized that the Earth resembles a hard-boiled egg in that it had three principal layers.
  1. A not-so-dense crust (like an eggshell),
  2. A thicker and denser solid mantle in the middle (like an egg white),
  3. A very dense core (yolk).
- Earthquake (seismic) waves allowed geologists to refine the model of Earth's interior.
- Earth is composed of four main layers:
  - Inner core
  - Outer core
  - Mantle
  - Crust

3.5.1 Earth's Crust

- Outermost layer of the Earth
- Two types of crust:
  - Oceanic crust underlies the seafloor and is thinner (7-10 km) and denser.
  - Continental crust underlies continent and is thicker (25-70 km) and less dense.
- Earth's crust is comprised of, mostly, eight different elements. Of these, oxygen and silicon account for 74.3% by weight.

3.5.2 Earth's Mantle

- 2,820- to 2,890-km thick shell that surrounds the core.
- The mantle can be divided into two sublayers: upper mantle and lower mantle.
- Almost all of the mantle is solid rock, but the mantle at a great depth stays so hot that it is enough to flow (at a rate of less than 15 cm/year).
- The temperature of the mantle vary with location:
  - Warmer regions of mantle are less dense than adjacent cooler regions.
  - Warmer regions tend to flow upward, while cooler regions flow downward.
  - *The mantle undergoes very flow convection!*

3.5.3 Earth's Core

- The core is the densest layer - consists of iron alloy (> 80% iron mixed with nickel and lesser amounts of sulfur, oxygen, silicon, and other elements).
- Core is divided into two parts:
  - Outer core (2,890-5,155 km) consists of liquid iron alloy.
  - Inner core (5,155-6,371 (the center) km) consists of solid iron alloy.
  - Even though the inner core is hotter than the outer core, the inner core stays solid because it endures immense pressure.
- The iron alloy of the outer core can flow, and this flow generates the Earth's magnetic field.

3.5.4 Pressure and Temperature Inside the Earth

- Pressure increases with depth, and at the Earth's center, it is estimated to reach about 3,600,000 atm.
- Temperature also increases with depth, approaching 6,000°C at the core.
- The rate of temperature increase with depth is called the *geothermal gradient*.
  - 15-30°C/km in the upper part of crust.
  - At greater depth, less than 10°C/km.

3.6 Earth's Surface

- Dry land covers 30% of the surface.
- Water covers the remaining 70% of the surface, but most surface water contains salt and resides in the oceans.
- *Topography* shows variation in elevation on both the land surface and beneath the ocean.
- A *hypsometric curve* indicate the proportion of Earth's solid surface at different elevations.
  - Earth's surface is mostly continent (plains and shelf) or ocean floor.
  - Mountains and deep-sea trenches cover relatively little area.
  - Change in sea level would dramatically change the area of dry land.

3.7 Earth's Atmosphere

- The Earth is wrapped in a gaseous cloak called the atmosphere.
- This atmosphere is made of a mixture of gases that we call air.
  - Nitrogen (78%) and oxygen (21%) are the dominant.
  - Other gases include argon, carbon dioxide, neon, methane, ozone, carbon monoxide, and sulfur dioxide.
  - Air also contains variable amounts of water vapor at lower elevation.
- Other terrestrial planets have atmosphere, but mostly CO_2 gas.
- The density of the atmosphere increases closer to the Earth's surface, and atmospheric pressure decreases with elevation.
- However, temperature does not follow a simple decrease–it varies by layer.
  - Troposphere
  - Stratosphere
  - Mesosphere
  - Thermosphere
- All weather occurs in the *Troposphere*.

3.8 Earth Materials

- Of the 92 naturally occurring elements that make up the Earth, 91.2% of the Earth's mass consists of only 4: iron, oxygen, silicon, and magnesium.
- The elements of Earth materials bond together to form a great variety of materials that can be classified into several basic categories:

  Organic chemicals - A carbon-containing compound that occurs in living organisms.

  Minerals - A solid, natural substance in which atoms are arranged in an orderly pattern.

  Glass - A solid in which atoms are not arranged in an orderly pattern.

  Melts - A melt forms when solid materials become hot and transform into liquid.

  Rocks - A coherent aggregate of mineral crystals or grains, or a mass of natural glass.

  Grains - Either individual crystal within a rock or individual fragment derived from a once-larger mineral sample or rock body.

  Sediment - An accumulation of loose grains.

  Metals - A solid composed entirely of metal atoms.

  Volatiles - A material that can exist as a gas under the conditions found at the Earth's surface.

3.9 Earth's Magnetic Field

- Our planet's rapid rotation and molten nickel-iron core give rise to a magnetic field.
- Solar wind distorts the magnetic fields into a teardrop shape in space.
- The magnetic field deflects most solar-wind particles, serving as a first shield - Magnetosphere.
- The magnetic field is what causes compass needles to point to the North Pole regardless of which way you turn.
- The Earth's magnetic field behaves like a dipole, similar to an imaginary bar magnet inside the planet.
- Magnetic field lines flow into the magnetic south pole and emerge out of the magnetic north pole.