The Earth

Question

How do we know the internal structure of the Earth?
Data Table

Regions to Investigate

The Interior

The Surface

The Atmosphere

The Magnetosphere
The Interior

Density

The density of surface rocks is 2.5 to 3.0 g/cm³. The average density of the planet is 5.5 g/cm³. Hence the interior must be very dense.
Seismic Waves

P waves – longitudinal, pressure waves
S waves – transverse waves
L waves – rolling

P Waves

P waves – Pressure waves
(Primary waves)
Faster of the Two Waves
Travels thru Solids & Liquids
S Waves

S waves – Transverse waves
(Secondary waves)
Slower of the Two Waves
Travels thru Solids ONLY

Earthquakes

Epicenter
Seismic Results
Seismic Results
### Structure

<table>
<thead>
<tr>
<th>Layer</th>
<th>Composition</th>
<th>Depth Range</th>
<th>Percentage</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner core</td>
<td>solid (iron, nickel)</td>
<td>0000 to 1200 km</td>
<td>19%</td>
<td>13 g/cm³</td>
</tr>
<tr>
<td>Outer core</td>
<td>liquid (iron, nickel)</td>
<td>1200 to 3500 km</td>
<td>55%</td>
<td>11 g/cm³</td>
</tr>
<tr>
<td>Mantle</td>
<td>ooze (iron, Mg, Si)</td>
<td>3500 to 6400 km</td>
<td>99%</td>
<td>4.5 g/cm³</td>
</tr>
<tr>
<td>Crust</td>
<td>ocean (basalt)</td>
<td>8 km thick</td>
<td></td>
<td>3.5 g/cm³</td>
</tr>
<tr>
<td></td>
<td>continental (granite)</td>
<td>20 to 70 km thick</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Excellent Homework Problem:

Calculate the Volumes and Masses of the Inner Core, the Outer Core, and the Mantle.

### Differentiation

![Diagram of Earth's structure](image.png)

- Iron
- Less dense matter
- Solid iron inner core
- Liquid iron outer core
- Mantle
- Crust
Temperature of the Interior

Why is the Earth’s Core Hot?

1. Heat left over from the formation of the Earth.
2. Gravitational pressure by tidal forces and the rotation of the Earth.
3. Radioactive decay of elements in the inner part of the Earth.
The Magnetosphere

Rotation axis
Geographic north pole
Magnetic north pole
Magnetic south pole
Geographic south pole

The Magnetosphere

Magnetopause
Shock wave
Magnetic field lines
Van Allen belts
Particle flow
Solar wind

10,000 km

100,000 km
What Generates the Magnetic Field?

There are two components necessary for a strong magnetic field:

1. There has to be fluid motion to generate the field. The Earth’s magnetic field is produced by the electric currents found in the liquid, outer core.

2. Rapid rotation is necessary. The Earth’s 24 hour rotation is slower than that of the Jovian planets, but nevertheless it is considered to be a rapid rotator.

Aurora
The Surface

Geologic Processes

**Endogenic** source is from internal activity (e.g., volcanism)

**Exogenic** source is from external processes (e.g., impacts)
Initial Evidence for Motion

Alfred Wegener, 1880 - 1930

Plate Tectonics

<table>
<thead>
<tr>
<th>Lithosphere</th>
<th>Asthenosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>mobile, top, crust</td>
<td>convective zone in the mantle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Continents</th>
<th>Granite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>Basalt</td>
</tr>
</tbody>
</table>
Plate Boundaries

The green dots indicate sites of major earthquake activity. These are the plate boundaries.

Breakup of the Supercontinent

a. 200 million years ago
b. 180 million years ago
c. Today
**Plate Interactions**

**Rift Zones**

Two plates get pushed apart.

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**Plate Interactions**

**Subduction Zones**

An oceanic plate is pushed under a continental plate.

Much of the Earth’s surface has been destroyed and recycled by this process.
Plate Interactions

Fault Zones
Two plates move along side of each other.

Plate Interactions

Mountain Building Zones
Two continental plates move into each other.
Three Types of Volcanoes

Shield

Eruptive

Flood Plain

Volcanoes – Shield

Caldera
Volcanoes – Shield Chains

Volcanoes – Eruptive
Volcanoes – Flood Plains
Oceans

Creation of the Oceans

The oceans were formed over the millennia from steam given off from the interior of the Earth by the action of volcanoes, and they acquired their salty composition by the continual weathering and leaching of the rocks through countless cycles of evaporation and precipitation.

This has resulted in the composition of sea water being 3.5% by weight of dissolved salts, a percentage that remains constant within very narrow limits throughout the world’s oceans.

Today, the oceans cover 70% of the Earth’s surface.
Ocean Currents

Navigators have known for thousands of years that the oceans have variable winds and variable currents. However, it has only been during the last half-century that a reasonable picture has emerged of the patterns of ocean currents and their underlying causes.

(1) The major force setting up and maintaining the oceanic current system is that of the prevailing winds.

(2) The direction of the current flow is governed by
   (a) the winds and
   (b) the rotation of the Earth.

Surface Circulation

http://oceansjsu.com/105/exped_circulation/1.html
Oceanic Conveyor Belt of Heat
A conceptual model of global ocean circulation.

Tsunamis

Tsunamis are often no taller than normal wind waves, but they are much more dangerous.

1. Wind waves come and go without flooding higher areas.
2. Water flows in a circle.
3. Tsunamis run quickly over the land as a wall of water.
4. Even a tsunami that looks small can be dangerous.
5. Any time you feel a large earthquake, or see a disturbance in the ocean that might be a tsunami, head to high ground or inland.
The Atmosphere

Greenhouse Effect

1. Sunlight arrives at the Earth
2. 39% of sunlight is reflected by clouds and the surface
3. Sunlight that is not reflected is absorbed by surface, heating it
4. Heated surface emits infrared radiation
5. Some of infrared radiation is trapped by atmosphere, heating both atmosphere and surface
6. Remaining infrared radiation “leaks” into space

Albedo: Percent of sunlight that is reflected.
Theories of Formation

1. Was formed with the rest of the planet
2. Was released via volcanoes later
3. Was derived from impacts by comets

History of the Atmosphere

1. Original gases had the same composition as the solar nebula. The gases were at first trapped, but as the Earth heated and became molten, the gases were released from the rocks. The Earth’s gravity was too weak to retain free Hydrogen and Helium, but the Hydrogen combined with Oxygen to produce water (H₂O).

2. As the Earth cooled, the water vapor condensed into raindrops and fell to the surface, creating the oceans. (If the only atmospheric constituent was water, then the oceans would have frozen. Because this is not the case, there must have been other, greenhouse gases that kept the Earth warm.)
History of the Atmosphere

3. The other gas is carbon dioxide (CO₂), which must have been very abundant. Most of the CO₂ was not lost to space (it is too heavy), but it was removed from the atmosphere by the rain. Most of the Earth’s CO₂ is now trapped in ocean rocks. [Some CO₂ is returned to the atmosphere by subduction zones that melt the ocean rocks.]

4. Once plant life began and flourished, CO₂ was converted via photosynthesis into O₂. Later, animal life converted the O₂ back to CO₂.

Composition of the Atmosphere

<table>
<thead>
<tr>
<th>Gas</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N₂)</td>
<td>78.1</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>21.0</td>
</tr>
<tr>
<td>Argon (Ar)</td>
<td>0.93</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.03</td>
</tr>
<tr>
<td>Neon</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Temperature of the Atmosphere

Structure of the Atmosphere

1. Troposphere 00 - 10 km
2. Stratosphere 10 - 65 km
3. Mesosphere 65 - 85 km
4. Thermosphere 80 - 400 km
Wind Circulation Patterns

**Hadley cells** are circulation flows. The dominant circulation in our atmosphere consists of six convection cells. The poleward-equatorward flow is diverted into zonal flow by the **Coriolis effect**.

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Hurricanes

[Image: NOAA Hurricane Center]
Hurricanes

A tropical cyclone is a rapidly rotating storm system characterized by a low-pressure center, strong winds, and a spiral arrangement of thunderstorms that produce heavy rain.

Depending on its location and strength, a tropical cyclone is referred to by names such as

- hurricane, typhoon, tropical storm, cyclonic storm,
- tropical depression, and simply cyclone.

Hurricanes

The term “tropical” refers to the geographical origin of these systems, which form almost exclusively over tropical seas.

The term “cyclone” refers to their cyclonic nature, with wind blowing counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

The opposite direction of circulation is due to the Coriolis effect.
Hurricanes

Tropical cyclones typically form over large bodies of relatively warm water. They derive their energy from the evaporation of water from the ocean surface, which ultimately re-condenses into clouds and rain when moist air rises and cools to saturation.

The strong rotating winds of a tropical cyclone are a result of the (partial) conservation of angular momentum imparted by the Earth's rotation as air flows inwards toward the axis of rotation. Cyclones are between 100 and 4,000 km (62 and 2,485 mi) in diameter.
Weather and Climate

Weather – short term

Climate – long term

Causes for Climate Change

I. Internal Forcing Mechanisms
   Ocean variability
   Volcanism
   Plate tectonics
   Life & Human influences

II. External Forcing Mechanisms
   Orbital variations
   Solar output