

EEPS 1710 Notes

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Contents

1	The Sky - Lecture 2 (8/27/2025)	2
2	The Earth - Lecture 3-4 (9/3/2025 - 9/8/2025)	3
2.1	Shape of Objects	3
2.2	Earth Structure	3
3	The Moon - Lecture 5 (9/10/2025)	4
4	The Sun	5
5	Earth, Moon, and Sun	5
6	Telescopes	6
7	Mercury	6
8	The Planets (Summarized)	7

1 The Sky - Lecture 2 (8/27/2025)

- **Def.** Apparent magnitude - How bright an object is on Earth. The more negative the number is, the brighter it is
- Below are the apparent magnitude of some objects. You don't need to memorize these, but know roughly where things are

Apparent Magnitude	Object	Apparent Magnitude	Object
-27	Sun	2	Polaris, Mars (min.)
-13	Full Moon	5	Vesta (max.), Uranus (max.)
-5	Venus	6	Typical limit of naked eye
-3	Jupiter (max.), Mars (max.)	7	Ceres (max.)
-2	Mercury (max.)	8	Neptune (max.)
-1	Sirius	10	Typical binoculars
0	Vega, Saturn (max.)	14	Pluto (max.)

- Most planets are white / yellow, except Mars (red), Uranus (white, light blue), Neptune (blue)
- The colder a star is, the redder it is. The hotter a star is, the bluer it is
- Planets do not emit light. They reflect it.
- Stars move across the sky but maintain fixed positions because the Earth is rotating
- There is a north celestial pole (visible in northern hemisphere) and south celestial pole (visible in southern hemisphere)
- Everything rises in the East and sets in the West
- **Def.** Celestial sphere - Imagine all the stars / planets are on the surface of a sphere and the Earth is a concentric sphere within the celestial sphere
- People thought the celestial sphere spinned around the Earth for 2000 years. However, it is the Earth that rotates
- Non-fixed objects in the celestial sphere
 - Comets/meteors (often move in straight lines, not circles)
 - Planets (move in circles but gradually will not follow the same path)
- Seven Classical Planets (visible to the naked eye)
 - Sun
 - Moon
 - Mercury
 - Venus
 - Mars
 - Jupiter
 - Saturn
- **Def.** Depth-motion Parallax - Things close appear to move faster than things far away (think about hills in the distance when you're driving vs. the corn)
- For this reason, people incorrectly ordered the planets for millenia
- **Def.** Geocentric Model - Theory that the Earth is at the center of the universe and all celestial bodies orbit the Earth
- **Def.** Heliocentric Model - Theory that the objects in our solar system orbit the sun
- The Geocentric model was disproven by studying Mars in retrograde (it didn't have a fixed position in the sky)
- Additionally, Venus has faces, which are produced by light reflecting off of Venus

Equatorial Coordinate System

- Imagine the Earth is a concentric sphere within the celestial sphere
- Let the North and South Poles point to the north and south celestial pole, respectively
- **Def.** Right ascensions - Arcs on the celestial sphere that go from North to South
- **Def.** Declinations - Arcs on the celestial sphere that go from East to West

2 The Earth - Lecture 3-4 (9/3/2025 - 9/8/2025)

Horizontal Coordinate System

- Imagine you are standing outside and there is a line, called a zenith going straight up through your body
- The coordinate of an object is determined by the angle between the ground and the object, altitude, and the angle between north and the object, azimuth.
- **NOTE:** This system is not absolute, because the zenith depends on where you are on Earth

Proof the Earth is Round

- Well of Syene
- Ships “sink” over the horizon

2.1 Shape of Objects

- Large objects are spherical because gravity forces this shapes
- Smaller objects are usually not spherical because of this
- The transition between spherical and non-spherical objects is a few hundred km
- Earth’s surface has two types of regions (continents and oceans)
- The distribution of elevation is bimodal (one peak is just above sea level and the other is the ocean floor)
- The continental rock “floats” over the oceanic rock, because the continental rock is granite, which is less dense than the oceanic rock, basalt.
- Earth is on the rocky planet that has a bimodal elevation distribution because the other planets are built out of one rock

2.2 Earth Structure

1. Crust - Thin, rocky outer layer (10-15km)
 2. Mantle - Hot rock. Same consistency as room temp butter
 3. Outer core - liquid nickel and iron
 4. Inner core - Solid nickel and iron
- We know this by observing volcanoes, earthquakes, meteorites, drilling
 - Volcanoes - We observe the rocks that come out. This tells us about the composition of the mantle/core
 - Earthquakes - We observe body waves (P-waves and S-waves)
 - * P-waves - Earthquake waves that shift Earth forward and backward
 - * S-waves - Earthquake waves that shift the Earth up and down
 - Seismogram - A machine that measures the Earth’s horizontal movement
 - Seismograph - The graph generated by the Seismogram
 - When earthquakes happen, we observe the P-wave, then the S-wave, then the surface waves
 - Initially, the Earth’s entire core was liquid, however, it’s been cooling
 - We know the Earth was a liquid core because of size of the shadow zone in earthquakes

- The higher the density of the rock, the faster the wave is
- This allows us to determine the Earth's composition and temperature, because we can measure the speed of P and S waves and backtrack the earth's density
- We notice that earthquakes and volcanoes tend to happen more along these lines, which outline the tectonic boundaries
- Plate tectonics
 - The earth contains several plates (which are large pieces of crust)
 - These plates border each other and rub against each other, leading to earthquakes and volcanoes
 - Types of plate boundaries
 1. **Def.** Divergent Plate Boundary (Fault type: Normal) - Plates are moving away from each other
 2. **Def.** Transform Plate Boundary (Fault type: Strike-slip) - Plates are moving in opposite directions side to side
 3. **Def.** Convergent Plate Boundary (Fault type: Reverse or thrust) - One plate moves underneath another
 - Earthquakes can occur at any plate boundary
 - Volcanoes
 - * See slides / go to OH
 - * **Divergent boundary:** Forms because the plates are being pulled apart, exposing melted rock
 - * **Convergent boundary:** The subducting plate will move seawater underground, which lowers the melting point of rock, causing volcanoes to form
 - Note that an oceanic plate MUST collide into a continental plate. If two continental crusts have a convergent boundary, mountains rise, but no volcanoes

3 The Moon - Lecture 5 (9/10/2025)

- The moon's rotation period is the same as its orbital period. For this reason, the Moon spins on its axis once for every revolution around the Earth
- As the moon rotates, it wobbles, letting us see 55% of it
- Has a low-land area (Mare) and a higher area (highlands)
- Mare is lower & flatter. Made of cooled lava
- Highland is higher & bumpier. Made of plagioclases
- Mare is younger than the highlands
- Core is not in the center of the moon—rather it's closer to the Earth
- We believe this is true because of Earth's gravity pulling the core towards it
- This is why the near side has a mare and the other side doesn't
- Mare was formed later than the highland. We know this from
 1. Radioactive dating. Proves highland is about 4B years older than the mare
- We know about the moon's insides by recording moonquakes.
 - Done the same way we measure quakes on Earth (S-waves, P-waves)
 - The Apollo missions put seismometers on the moon.
- How did the moon form?
 - **Fission Theory:** The moon was spun out of the Earth ← wrong
 - **Capture Theory:** The moon was an asteroid that got captured by the Earth ← wrong because it has very similar material to the Earth
 - **Condensation Theory:** The Earth and moon were formed simultaneously as asteroids collided and combined with each other ← wrong
 - **Giant Impact Hypothesis:** Theia (hypothetical planet) smashed into the Earth, forming the moon.

- Composition
 - $M_{Moon} = \frac{1}{80} M_{Earth}$
 - $\rho_{Moon} = \frac{1}{2} \rho_{Earth}$

4 The Sun

- **Def.** Sun spots - Dark spots on the sun. These are regions that are cooler than the rest of the surface of the sun (4,500K instead of 5,800K)
- Discovered by Galileo, who stared at the sun using a telescope
- Galileo noticed that the sun spots moved and take about 1 month to rotate around the sun, which taught us the sun rotates.
- However, the rotation is not uniform. The closer you are to the equator, the faster it rotates (**differential rotation**).
- **Def.** Solar Granulation - The sun is made of corn kernel shaped bumps called **Granules**. Hot gas rises through the center and then falls at the sides of the kernels. This process is called **convection**.
- Each granule is massive (about the size of Texas).
- Convection is constantly happening through the Sun.
- Sunspots appear to form in 11-year cycles (over an 11 year period, there will be an increasing and then decreasing number of sunspots)
- Over this period, the sunspots will gradually start forming closer and closer to the equator due to magnetic activity
 - This is because the magnetic field lines in the sun get tangled due to differential rotation
 - At the ends of the magnetic field lines, there will be sunspots
- **Def.** Maunder Minimum - Between 1650 and 1700, there are no recorded sunspots. Scientists debate on if this is true or if nobody was recording sunspots during this time.
- The more sunspots there are, the brighter the sun is. This is because there are more photons being emitted.
- Sun layers (theory):
 1. Convection zone - Outermost layer where convection happens; $\rho = 1.4g/cm^3$
 2. Core - Innermost layer; hotter and denser than the radiation zone; this is where the energy and light the sun emits is generated; $\rho = 150g/cm^3$; temperature is 10M+ K
 3. Radiation zone - Hotter and denser than the convection zone; this is where the energy created by the core is released via radiation from fusion reactions (fusing two atoms to create a new one)
- The sun is red because the emission spectrum of hydrogen (what the sun is made of) is red.

5 Earth, Moon, and Sun

- Crashcourse on what you *need* to know
- Sun
 - 3 layers: Core, radiative, and convective zones
 - Fusion only occurs in the core (how photons (which carry energy) are made)
 - Photons are radiated out of the core because radiation is the most efficient way to transmit energy
 - Hot and cold gas rise/sink via granules in the convective zone
 - Photosphere: physical surface of the sun, covered in granules
 - Some areas of the sun are disrupted by magnetic fields, which prevent convection from occurring, leading to colder zones, called sun spots
 - Sun spots form in 11 year cycles
 - Sun atmosphere contains two parts:

- * Chromosphere: low atmosphere. the part is red because the sun is made of hydrogen. it's red due to the emission spectrum.
- * We see the red due to Kirchhoff's Three Laws
- * Corona: high atmosphere: very thin. white because it is reflecting sunlight. only visible during solar eclipses
- *
- **Def.** Solar Winds: Stream of charged particles (protons and electrons) emitted from the Sun
- The Earth has a magnetic field due to its liquid iron core. Solar Wind is deflected by the magnetic field (either around the Earth or it goes into the poles)
- When charged particles go into the poles, this forms aurora borealis (North Lights) as particles hit the atmosphere
- **Missions:**
 - * Genesis Mission: Collected solar wind particles & returned to Earth. Crashed in the Utah desert, rendering most findings unusable
 - * Parker Solar Probe: Going to observe the Sun closer than any mission before. Uses a heat shield to help keep it cool. Launched in 2018.
- **Solar Eclipses:**
 - * Partial eclipse: Moon partially covers the sun
 - * Annular eclipse: Moon is on top of the sun but does not completely cover it
 - * Total eclipse: Moon completely blocks out the sun
 - * Solar eclipses happen about every 6 mo. because the Earth's orbit around the Sun and Moon's orbit around the Earth are both ecliptic & do not perfectly overlap.
 - * Eclipses only happen when the two overlap
- **The MOON**
 - * Supermoon: Big moon. When it's closest to the earth
 - * Blood moon: Occurs during lunar eclipse
 - * Blue moon: When there are two full moons in a calendar month

6 Telescopes

- **Def.** Telescope - A device that collects light and magnifies it
- **Def.** Aperture - The diameter of the telescope's mirror or lens. This determines how zoomed in the telescope is. The larger the aperture, the shorter away you can see things.
- On earth, you can only make telescopes to see visible light and radiowaves due to the atmosphere.
- **Def.** Radio Telescope - A telescope that collects radio waves. Mainly used to observe cold and dark objects (molecular clouds, interstellar dust)
- Arecibo Observatory - It was the largest radio telescope in the world. It was built in 1963 and collapsed in 2020.
- Green Bank Telescope - Another radio telescope. This can be moved, unlike Arecibo.
- **Def.** Thirty Meter Telescope - 30m telescope being constructed in Hawaii.
- **Def.** Extremely Large Telescope - 40m telescope in the Atacama Desert in Chile (almost done)
- **Def.** University of Hawaii 2.2m telescope - A telescope at the University of Hawaii.
- Telescopes were invented in Europe around 1600
- Review how lenses and refraction works in telescopes.

7 Mercury

- Mercury is the smallest planet in the solar system and closest to the Sun.

- One of the classical planets, known for a long time
- Very difficult to see with naked eye b/c it's very close to the Sun in the sky, very small, and farther from the Earth than Mars or Venus
- You only have 2 hours / day to see Mercury in the sky (around sunrise / sunset)
- Days & Years on Mercury
 - Mercurian Orbital Year: 88 Earth days
 - Mercurian Sidereal Day: 59 Earth days
 - Mercurian Solar Day: 176 Earth days
- We can use the Doppler Effect to determine a planet's rotational speed
 - If a planet is not rotating, when we send signals at it, they are reflected back to us at the same frequency.
 - If a planet is rotating, when we send signals at it, they are reflected back to us at a different frequency.
 - The part of the planet moving towards us will be reflected at a higher frequency, and the part of the planet moving away from us will be reflected at a lower frequency.

8 The Planets (Summarized)

- **Def.** Orbital Year - The time it takes for a planet to orbit the Sun
- **Def.** Sidereal Day - The time it takes for a planet to rotate once on its axis
- **Def.** Solar Day - The time it takes for a planet to rotate once on its axis and orbit the Sun
- All years / days are measured in Earth days / years
- Has virtually no atmosphere
- Mercury has intercrater plains (plains with lots of craters) and smooth plains (areas with fewer craters)
- We are not sure what these plains are made of. We suspect they are formed by the same rock because they have the same color.
- **Def.** Caloris Basin - Large basin (1/2 the size of the planet) which is 1550km in diameter. We suspect this is an impact basin.
- **Def.** Lobate Scarp - A large scar on the surface of a planet
- Mercury has lots of lobate scarps because Mercury's inside cooled rapidly. This caused the volume inside the planet to contract, creating rifts. It's kinda like how balloons wrinkle when they deflate.

Planet	Orbital Year	Sidereal Day	Solar Day	Subsolar Point	Sublunar Point	Axial Tilt
Mercury	88 days	59 days	176 days	427C	-173C	0.01 deg
Earth	365.25 days	1 day	1 day	15C	-15C	23.5 deg
Planet	Atmosphere Composition					
Mercury	H, He, O, Na, Mg, K, Ca, H ₂ O					
Earth	365.25 days					
1 day	1 day					
15C	-15C					
23.5 deg						