Unit 1

Earth’s Role as a Body in Space
Lesson 1

Earth’s Position and Movement Through Space
(You Are Here ➔)
Earth’s Position in Space

What is Earth’s position within the hierarchy of the universe?
A. Earth’s Position in the Universe

1. Earth’s Position in the universe…
   • Earth ➔
   • Solar System (3rd planet from Sun) ➔
   • Milky Way Galaxy (the Orion Arm) ➔
   • Universe!

http://www.atlasoftheuniverse.com/
Earth’s Motion through Space

How is Earth’s motion related to the origin of the galaxy and its solar system?
The Origin of Our Expanding Universe

a. The Big Bang Theory
   – The theory that the universe began as a point and has been expanding ever since

Notice how the 3 yellow galaxies in each model are moving apart?
### The Big Bang Theory

**1.** The cosmos goes through a superfast "inflation," expanding from the size of an atom to that of a grapefruit in a tiny fraction of a second.

**2.** Post-inflation, the universe is a seething, hot soup of electrons, quarks and other particles.

**3.** A rapidly cooling cosmos permits quarks to clump into protons and neutrons.

**4.** Still too hot to form into atoms, charged electrons and protons prevent light from shining; the universe is a superhot fog.

**5.** Electrons combine with protons and neutrons to form atoms, mostly hydrogen and helium. Light can finally shine.

**6.** Gravity makes hydrogen and helium gas coalesce to form the giant clouds that will become galaxies: smaller clumps of gas collapse to form the first stars.

**7.** As galaxies cluster together under gravity, the first stars die and spew heavy elements into space; these will eventually form into new stars and planets.

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**NOTE:** The numbers in cosmology are so great and the numbers in subatomic physics are so small that it is often necessary to express them in exponential form. Ten multiplied by itself, or 100, is written as $10^2$. One thousand is written as $10^3$. Similarly, one-tenth is $10^{-1}$, and one-hundredth is $10^{-2}$.

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**Source:** The Birth of the Universe; The Kingfisher Young People's Book of Space

**TIME Graphic by Ed Gabel**
b. Astronomers hypothesize that the galaxy began as…
   - A rotating, spherical cloud in space …
   - Our solar system continues to orbit the center of the Milky Way because… it developed in the plane of the disk around the nuclear bulge (in the center)
The Milky Way

http://www.atlasoftheuniverse.com/
The Milky Way

The Origin of the Solar System

c. Our solar system began when...

- ...a rotating, interstellar cloud - a nebula - collapsed (as a result of gravity) to form the Sun and planets

Earth orbits the Sun because...

- ... it was located outside the center of the spinning nebula
The Eagle Nebula

A solar nebula is...
A disk of dust and gas that can form a star

Star formation has NEVER been observed! (just hypothesized!)
Lesson 2

Kepler’s Laws and Earth’s Orbit
Think About It…

How would Earth be different if its orbit was more oval than circular?
Focus Question

How do Kepler’s laws describe Earth’s orbit?
3. Kepler’s Laws (Introduction)…

Johannes Kepler, working with data painstakingly collected by Tycho Brahe (from 1576-1601) without the aid of a telescope, developed three laws which described the motion of the planets across the sky.


Unless otherwise noted, the info on the slides on Kepler’s laws was taken from the following website: http://hyperphysics.phy-astr.gsu.edu/hbase/kepler.html
a. Kepler’s First Law...

a. The **Law of Orbits**: All planets move in elliptical orbits, with the sun at one focus.

i. An **ellipse** is ... an oval shape centered on two points instead of a single point.

ii. The **orbital period** of a planet is ... the length of time it takes for it to travel a complete orbit around the sun. *(a year!)*
Background... Orbit Eccentricity

- The eccentricity of an ellipse can be defined as the ratio of the distance between the foci to the major axis of the ellipse. The more eccentric an orbit, the more of an oval it is.
- The eccentricity is zero for a circle.
- Of the planetary orbits, only Pluto has a large eccentricity.

http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=175
Examples of Ellipse Eccentricity

Planetary orbit eccentricities

- Mercury: 0.206
- Venus: 0.0068
- Earth: 0.0167
- Mars: 0.0934
- Jupiter: 0.0485
- Saturn: 0.0556
- Uranus: 0.0472
- Neptune: 0.0086
- Pluto: 0.25
b. Kepler’s Second Law…

b. The **Law of Areas**: A line that connects a planet to the sun sweeps out equal areas in equal times.

i. Draw this!

ii. When the planet is closer to the sun, it moves faster, sweeping through a longer path in a given time. (to conserve angular momentum)

[Diagram of Kepler's Second Law]

http://www.mathacademy.com/pr/prime/articles/kepler/index.asp
In Other Words....

1\textsuperscript{st} Law
- Orbits of the planets are elliptical.
- An \textbf{ellipse} is an oval-shaped path.

2\textsuperscript{nd} Law
- Planets revolve faster when they are closer to the sun.
c. Kepler’s Third Law…

c. **The Law of Periods**: The square of the orbital period of any planet is proportional to the cube of the semimajor axis of its orbit.

i. \( P^2 = a^3 \) \((P = \text{orbital period} = \text{unit of time in Earth yrs}, \ a = \text{length of the semimajor axis})\)

ii. If you know the distance of a planet to the Sun, you would be able to figure out its… **orbital period**.
3rd Law

An orbital period is the time (in Earth years) it takes a planet to make one revolution around the sun.

The further the planet is from the sun, the longer the orbital period is.
4. Barycenter and Earth’s Orbit…

Barycenter is …the center of mass between a planet and the Sun.

a. The law of universal gravitation states that…
   – every pair of bodies in the universe attracts each other with a force
     • proportional to the product of their masses and
     • inversely proportional to the square of the distance between them.
4. Barycenter and Earth’s Orbit…

b. A planet, such as Earth, actually orbits…
   its barycenter with the Sun

c. The Sun orbits …
   the **barycenter of the solar system**. (It is NOT stationary in the sky as planets orbit it.)

d. Draw this!

See next slide.
Modeling Barycenter

– http://spaceplace.nasa.gov/barycenter/
Lesson 3

Earth’s Rotation
Day and Night
Earth’s Slightly Squashed Shape
Think About It…

How would Earth’s day be different if it did not rotate on its axis?
Focus Questions…
What causes the day and night cycle?
What motion and force causes Earth’s slightly squished shape?
5. Earth’s Rotation Causes Day and Night...

5. Day and night are caused by...
   - the rotation of Earth on its axis - spinning towards and away from the Sun.

a. Earth’s axis is...
   - the imaginary line that goes through the N and S poles.

b. We know that Earth is spinning on its axis because we see ...
   - the sun rise in the east & set in the west.
Think About It… Why are there 24 hours in a day?

Earth spins…
15 degrees each hour

There are 360 degrees in a circle (the circumference of Earth).

360 divided by 15 is 24 so there are 24 hours in a day!

http://huntingtonastro.wikispaces.com/file/view/earth-rotation.png/199559520/earth-rotation.png
Still Thinking About It…

The exact amount of time it takes Earth to spin one time on its axis is…

- 23.9345 hours (Write this in the margin!)

If an Earth day was 5832.5 hours long (like that of Venus!) then…

- It would take 243 days for Earth to spin one time on its axis!
- Our day and night would be much longer! (And it would get really hot and really cold!)
Sunrise and Sunset

c. What is actually happening when we see the Sun rise and set?

- At sunrise, we spin towards the Sun and see it “rise” and at sunset, we spin away from the Sun, we see it “set.”

d. Draw this concept!

http://curious.astro.cornell.edu/images/pathofsun_40deg.jpg
6. Earth’s Rotation Causes Its Slightly-squished Shape…

a. What motion causes Earth to take the shape of an oblate spheroid?  
**Earth’s rotation**

b. What force causes the Earth’s mass to move outward from its center at the equator as Earth rotates on its axis?  
**Centrifugal force**
Earth’s Rotation and Its Shape…

http://www.cleonis.nl/physics/phys256/equatorial_bulge.php
6. Earth’s Rotation Causes Its Slightly-squished Shape…

c. There is a slight bulging at the equator and a slight squishing at the poles.

d. This causes the circumference at the equator to be slightly larger than that of the poles.
Earth’s Rotation and Its Shape…

e. Draw this →

Notice the equatorial diameter is **42 km** more than the polar diameter!

Think About It…

During which month is Earth closest to the Sun?
Focus Question (and Answer!)…

7. What causes the seasons?
The tilt of the Earth on its axis as it revolves around (orbits) the Sun.
7. Earth’s Orbit and Seasons…

a. The **ecliptic** is…
   - …the plane on which Earth orbits around the Sun

7. Earth’s Orbit and Seasons…

b. The tilt of Earth’s axis relative to the ecliptic is 23.5 degrees.

Draw The Seasons!

Arctic Circle (66.5° N)
Tropic of Cancer (23.5° N)
Equator
Tropic of Capricorn (23.5° S)

Vernal Equinox
March 21–22
Incoming solar energy equal in both hemispheres

Summer Solstice
June 21–22
Incoming solar energy greatest in Northern Hemisphere

Orbit

Winter Solstice
December 21–22
Incoming solar energy greatest in Southern Hemisphere

Autumnal Equinox
September 22–23
Incoming solar energy equal in both hemispheres

23½°
7. Earth’s Orbit and the Seasons!

d. What causes summer in the northern and southern hemispheres?
   – when it is tilted toward the Sun during Earth’s orbit

d. What causes winter in the northern and southern hemispheres?
   – when it is tilted away from the Sun during Earth’s orbit
7. Earth’s Orbit and Seasons…

The seasons in the northern and southern hemispheres are opposite each other because...

– When one hemisphere is tilted towards the Sun, the other is tilted away from the Sun
Seasons...

f. Earth is closest to the Sun during our... Winter! (In January)
And farthest from the Sun during the Antarctic winter (which makes it tough on the penguins!)
Lesson 5

Changes in The Seasons – Precession and Nutation
Think About It…

What would happen to the average temperatures during our winter if Earth was tilted MORE on its axis?
Focus Question…

What circumstances can bring about a change in the seasons?
8. Precession

8. Precession is...
   – the wobble in Earth’s rotational axis.

a. One full cycle of precession takes...
   – 26,000 years!

b. The force that causes precession is...
   – the sideways pull of the Moon’s on the Earth. (See next slide)
The Moon’s orbit is tilted 5° which over time pulls on Earth…

http://earthsky.org/astronomy-essentials/what-is-the-ecliptic
8. Precession…

c. Our current north star is…
   – Polaris
   – In about 12,000 years, our new north star will be…
     • Vega
A New North Star and Our Seasons...

e.i. **Winters** in the N. hemisphere will be...
   – in June, July, and August
   – It will be colder here because Earth will be farthest from the Sun.

e.ii. **Summers** in the N. hemisphere will be...
   – in December, January, and February
   – It will be warmer here because Earth will be closest to the Sun.
A New North Star and Our Seasons...

d. Draw this!
9. Nutation...

Nutation is...

... a change in the angle of tilt of Earth’s axis

a. Present tilt of Earth’s axis is $23.5^\circ$.
b. The tilt can vary from $22.1^\circ$ to $24.5^\circ$. 
9. Nutation…

c.i. If the angle of tilt decreased…
there would be **less** of a temperature difference between seasons.

c.ii. If the angle of the tilt of Earth’s axis increased …
there would be **more** of a temperature difference between seasons.
d. Draw Nutation
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Lesson 6
Tides
Think About It… Tides Lesson

How would Earth’s oceans be affected if Earth did not have a moon?
Focus Question…

What forces and heavenly bodies cause the tides?
Tides...

10. Tides are caused by...
   – the gravitational attraction among Earth, the Moon, and the Sun. (Write next to Q #10.)

a. Tides are...
   – the periodic rise and fall of sea level.
   i. High tide...
      • Highest level to which the water rises
   ii. Low tide...
      • lowest level of the water
Tides: Bay of Fundy…

Low Tide

High Tide

http://www.amusingplanet.com/2012/03/tides-at-bay-of-fundy.html

http://www.srh.noaa.gov/jetstream/ocean/fundy_max.htm
The Cause of Tides...

b. What **motion** causes the tides?
   – Earth’s rotation on its axis

c. What **forces** causes the tides?
   – gravitational attraction of the Moon and the Sun that “pulls” ocean water toward them and centrifugal force that causes ocean water on the opposite side of Earth to swish away
   – These forces generate tidal bulges on opposite sides of Earth.

d. The times of tides vary each day as the moon orbits the Earth (every 28 days)
7e. Draw the Tides… (as seen from above)

Tide Simulation:
http://astro.unl.edu/classaction/animations/lunarcycles/tidesim.html
Lesson 7

The Sun’s Energy
Think About It…

Is it possible to make electricity by using the same process that powers the Sun?
Focus Question…

What process powers the Sun and what forms of Energy does that process produce?
A Little Bit About the Sun…

How many Earths could be lined up edge to edge to fit across the Sun?
– 109

The Sun makes up…
– 99% of the mass of the solar system!

A pair of dice with the density of the Sun…
– would weigh 2 pounds!

The solar interior is made of…
… plasma (one of the 4 states of matter)
The Sun’s atmosphere consists of…

– Photosphere…
  • the lowest layer
  • 400 km thick
  • Hot! (5800 K)
  • the visible surface of the Sun
The Sun’s atmosphere consists of…

- Chromosphere…
  - Above the photosphere
  - 2500 km thick
  - Very hot! (30,000 K)
The Sun’s atmosphere consists of...

- Corona...

  • Extends several million km from the top of the chromosphere
  • Very low density – only visible during an eclipse
  • Extremely hot! (1 to 2 million K)
11. Fusion (or Fission?)

a. Fusion is...
   - the combining of hydrogen atoms into a helium atom.
5. Fusion...

b. Fusion occurs...
   – in the stars! (our Sun)

c.a. During fusion, the two atoms that combine to form a helium atom are...
   – $^1H_1$ Deuterium
   – $^3H_1$ Tritium

   ![Diagram of fusion process]
5. Fusion…

c.b. The mass that is lost when two hydrogen nuclei combine to form helium …
   – … gets converted into energy

f. Albert Einstein’s theory of special relativity explains this!

Fusion and Electricity Production…

• “The power produced by a fusion reactor will be converted to electric energy or other goods like hydrogen or desalinised water.

• Neutrons produced in the D-T fusion process carry 4/5 of the energy.

• One or two fluids circulate in the blanket and in the diverter_FW to extract the energy and to provide stable operational temperature of the components.

• The fluids must flow at high velocity (often in conditions of turbulent flow) while structural materials, pipes, junctions must withstand neutron bombardment, corrosion/erosion, high operational temperature, high heat flux.”

• What??!!
Fusion and Electricity Production...
China claims fusion reactor test a success

Government hopes fusion provides clean, limitless energy source …

• “BEIJING - Scientists on Thursday carried out China's first successful test of an experimental fusion reactor, powered by the process that fuels the sun, a research institute spokeswoman said.

• China, the United States and other governments are pursuing fusion research in hopes that it could become a clean, potentially limitless energy source.

• Fusion produces little radioactive waste, unlike fission, which powers conventional nuclear reactors.”

updated 3:22 p.m. ET, Thurs., Sept. 28, 2006
11d. Fusion Reaction – Draw this!

Deuterium

Neutron

Tritium

Fusion

Helium
11. Fission (or Fusion?)

e. Fission is...

- The splitting of heavy atoms into smaller, lighter atoms
- We use this process to generate electricity in a nuclear power plant.
11. Fusion (or Combustion?)

f. Combustion is...

- The burning of a fuel in the presence of oxygen to produce heat and light

http://reich-chemistry.wikispaces.com/M.Higgins+And+D.Lazerev+Reaction+Wiki
12. The Sun’s Energy…

a. Electromagnetic radiation consists of …
   – … electric and magnetic disturbances that travel through space as waves.

b. Electromagnetic radiation includes…
   – radio waves, microwaves, infrared energy, visible light, ultraviolet radiation, x-rays, and gamma rays

c. The electromagnetic spectrum…
   – Organizes the forms of EM energy

d. Electromagnetic energy…
   – … is classified by wavelength and…

e. … moves at the speed of light
The Electromagnetic Spectrum...

e. This is the dangerous side!

Absorption of The Sun’s Energy by the Earth...

f. Which gas in the atmosphere blocks harmful ultraviolet radiation from the sun?

  • Ozone (O₃)

http://mmedia.pl/ozone-layer-diagram-for-kids
13. Solar Wind and Earth’s Magnetic Field…

a. Solar wind is…
   – A supersonic plasma that flows outward from the corona at high speeds
   – It consists of charged particles or ions
   – Solar wind bathes each planet in a flood of high-energy particles. (Which isn’t very good for us!)

• Next slide…
Solar Wind

Artist Rendition of Solar Wind
Created by: K. Endo

Photo Courtesy of Prof. Yohsuke Kamide
National Geophysical Data Center
13. Solar Wind and Earth’s Magnetic Field…

b. Earth’s magnetic field protects us from the solar wind by…

– deflecting these particles and trapping them in two huge rings called the Van Allen belts

http://www.redorbit.com/education/reference_library/space_1/solar_system/2574610/van_allen_radiation_belt/
Earth’s Magnetic Field…

c. Draw this!
13. Solar Wind and Earth’s Magnetic Field...

d. The auroras are created when...
   – … high-energy particles in the Van Allen belts collide with gases in Earth’s atmosphere which give off light
   – See next slide…
The Auroras…

https://vimeo.com/21294655
Lesson 8

Energy For Earth...
Think About It…

What would happen to Earth if the Sun were turned off today?
Focus Question…

How does the Sun’s energy warm Earth’s surface and atmosphere?
14. Energy For Earth...

a. Radiation is ...

the transfer of energy through space by visible light, ultraviolet radiation, and other electromagnetic waves

http://virtualskies.arc.nasa.gov/weather/images/2b1.png
What Happens to the Sun’s Energy?

http://www.physicalgeography.net/fundamentals/images/cascade.GIF
14. Energy For Earth…

a.i. The Sun’s energy reaches Earth by the process of **radiation**.

a.ii. About **50 %** of the Sun’s energy is absorbed by Earth’s surface.

Differential Heating…

a.iv. Which heats up and cools down more slowly – water or land?
  – Water
  – This is called differential heating. (Circle this term on your lesson!)
  – This is what moderates the climate in coastal areas.
a. Radiation

- the transfer of energy through space by visible light, ultraviolet radiation, and other electromagnetic waves
- Earth’s surface is warmed by the sun’s rays

Energy for Earth...

b. Conduction is...
   the transfer of energy that occurs when molecules collide

i. The air molecules above Earth’s surface are warmed by the process of **conduction**.

ii. Energy moves from your hand to your desk. Why?
Energy for Earth...

c. Convection is...

- the transfer of energy by the flow of a heated substance

i. Warm air rises.

ii. When the warm air gets high enough, it cools and sinks.

iii. This creates a convection current.
Energy For Earth…

Copy the diagram your teacher draws on the board!
15. Energy for Photosynthesis...

a. During photosynthesis, solar energy is transformed into chemical energy.

b. This occurs in plants, algae and some bacteria.

c. For this to occur, there must be water, CO2, and sunlight.

d. In plants, this occurs in chloroplasts.

http://abhsscience.wikispaces.com/Photosynthesis+TD
https://www.youtube.com/watch?v=pE82qtKSSH4
Photosynthesis Rap.