The night sky, and the Earth-Moon-Sun system
• [http://people.physics.tamu.edu/quadri/astr101_fall16/](http://people.physics.tamu.edu/quadri/astr101_fall16/)

• Homework extension to Thursday

• Access the homework site (“Pearson Mastering Astronomy”) through eCampus

• First create an account on Mastering Astronomy using the access code that came with your textbook (a separate code is available for purchase)

• You also have the option of getting a temporary 14-day license; that way you can enter the real access code whenever you get it
What does it look like, to us, when we look up at the night sky?
The celestial sphere

Imagine the stars as points of light fixed on a large rotating sphere surrounding the Earth.
The celestial sphere

The part of the sphere that you can see will depend on your **latitude** (i.e. how far north or south you are of the equator)
The celestial sphere

During daytime the stars are still there — they’re just completely outshone by the sun
The celestial sphere

The sun is also on the sphere — but it’s position isn’t quite fixed. It moves slightly slower than the rest of the sphere

- A **solar day** is the amount of time it takes the sun to make a full rotation around the Earth. 24 hours
- A **sidereal day** is the amount of time it take for the celestial sphere to make a full rotation around the Earth (*sidereal* comes from the latin word for *star*, so it’s a “star day”). 23 hours, 56 minutes
The celestial sphere

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After one year, the sun has slipped behind by one full rotation, so it is back where it started.
The celestial sphere

Not only does the sun slowly slip behind the celestial sphere, it also gradually moves up and down on the sphere over the course of a year.
The celestial sphere

At **summer solstice**, the path of the sun is highest on the sky. This is the longest day of the year.
The celestial sphere

At winter solstice, the path of the sun is lowest on the sky. This is the shortest day of the year.
The celestial sphere

At **spring equinox** and **the fall equinox**, the path of the sun is in between — and it rises due east, and sets due west.
The celestial sphere

• The zodiac refers to the set of constellations that lie on the Sun’s path across the celestial sphere. Your star sign refers to the constellation that the Sun was nearest to when you were born.
The celestial sphere — the planets

- The five other planets nearest the Sun are visible to the naked eye. They also are not completely fixed to the celestial sphere.
The celestial sphere — the planets

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- The planets occasionally undergo retrograde motion
The celestial sphere — the planets

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- The planets occasionally undergo retrograde motion.
- The word “planet” comes from the ancient Greek for “wandering star”.
Polaris, the north star
The Sun’s positions at the summer and winter solstices
https://www.youtube.com/watch?v=xOCCSegL8ic
https://www.youtube.com/watch?v=ZZcafg-meJA
The heliocentric model

• https://www.youtube.com/watch?v=_QcgDiF1a14
The heliocentric model

The plane of the Earth’s orbit is called the **ecliptic**
The Earth’s axis of rotation is not perpendicular to the ecliptic — there is a $23^\circ$ axis tilt. This means that the **equator** is also tilted at $23^\circ$ from the ecliptic.

The axis of rotation points in the same direction (approximately towards Polaris) throughout the Earth’s orbit.
But the axis does wobble over time — we call this **precession**. It takes 26,000 years for the Earth’s axis to precess all the way around. This means that the axis won’t point towards Polaris forever!
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Solar vs. sidereal day

One full rotation means you are again pointing in the original direction...

...but you need a bit of extra rotation to point again at the Sun.
The Moon

• When we see the Moon (and all of the planets), what we are seeing is reflected light from the Sun. They don’t produce their own light!

• The phases of the Moon (full, half, crescent…) depends on the part of the illuminated face of the Moon that we can see
• 02_MoonriseSetVsPhase.htm
• Lunar_Nav.swf
The Moon — synchronous rotation
The Moon — synchronous rotation

a If you do not rotate while walking around the model, you will not always face it.

b You will face the model at all times only if you rotate exactly once during each orbit.
The next homework and reading assignments due before class on Tuesday

• Read chapter 3
• There are different types of problems, activities, and tutorials. When you load up the assignment you can see how much each one is worth.
• The first tutorial is labeled as “practice” which means it isn’t graded, so you can get familiar with the interface.
• The tutorials launch in pop-up windows

![Image of a tutorial window with a question about seasons and a set of icons for navigation.]
Review — the celestial sphere
Review — the celestial sphere
Review — the celestial sphere

People in both the northern and the southern hemisphere will see this horse constellation; but one hemisphere will see it upside down.
Neither the Sun, nor the Moon, nor the planets are fixed to the celestial sphere. In particular, the planets occasionally undergo retrograde motion.
Review — the path of the Sun across the sky
Review — the heliocentric model
Review — the phases of the Moon

Photos show phases as they appear in the Northern Hemisphere; turn the book upside down to see how the same phases appear from the Southern Hemisphere.
Eclipses

- **Lunar eclipse** — the Moon goes into the Earth’s shadow
- **Solar eclipse** — the Moon blocks out the sun, so (part of) the Earth is in the Moon’s shadow
Shadows

The **umbra** is a shadow where the light source is completely blocked. The **penumbra** is where it is only partially blocked.
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Eclipses — lunar eclipse

- **Total Lunar Eclipse**: Moon passes entirely through umbra.
- **Partial Lunar Eclipse**: Part of the Moon passes through umbra.
- **Penumbral Lunar Eclipse**: Moon passes through penumbra.
Eclipses — solar eclipse

A total solar eclipse occurs in the small central region.

A partial solar eclipse occurs in the lighter area surrounding the area of totality.

If the Moon’s umbral shadow does not reach Earth, an annular eclipse occurs in the small central region.

Total Solar Eclipse
Partial Solar Eclipse
Annular Solar Eclipse
Eclipses

If you see this, you are in the Moon’s umbra

If the Moon’s umbral shadow does not reach Earth, an annular eclipse occurs in the small central region.

In the Moon’s penumbra
An *annular solar eclipse* happens when the Moon is pretty far out in it’s orbit from the Earth, so it doesn’t block out the entire Sun. A *total solar eclipse* happens when the Moon is more nearby.
Eclipses — when do they occur?
Notice also that the plane of the Moon’s orbit is actually slightly tilted from the ecliptic. So the moon doesn’t usually pass directly in front (or behind) the Earth — it is a bit lower, or a bit higher.
Eclipses — when do they occur?
Eclipses — when do they occur?

So eclipses only occur when the moon is in front (or behind) the Earth and when the Moon is crossing the ecliptic. This only happens about twice a year.
The cause of the seasons
The cause of the seasons

When the light from the sun arrives almost perpendicular — i.e. the light is the most concentrated — you expect higher temperatures. This happens at summer solstice.
The cause of the seasons
The cause of the seasons

• When it’s summer in the northern hemisphere, it’s winter in the southern hemisphere

• The difference between the seasons is minimized near the equator, because the angle that the sunlight impacts the Earth doesn’t vary as much
The cause of the seasons

summer solstice (summer in the Northern hemisphere)

the spring and fall equinoxes (sometimes called the vernal and autumnal equinoxes)

winter solstice (winter in the Northern hemisphere)
The cause of the seasons

• But summer solstice is usually taken to make the *beginning* of summer, not the middle! And the same goes for winter solstice, and the fall and spring equinoxes.

• The reason is that it takes a while for the Earth to change temperature significantly. Even though the most sunlight is hitting it at summer solstice, the Earth doesn’t reach it’s highest temperature until somewhat later.
The cause of the seasons

• Question: what if the Earth’s axis wasn’t tilted? Would the temperature differences between the seasons be
  A. larger
  B. smaller
  C. the same
  D. there wouldn’t be seasons
The cause of the seasons

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  A. larger
  B: smaller
  C: the same
  D: there wouldn’t be seasons

Technically the answer is B. Each position on the Earth would get the same intensity of sunlight year-round, and the days would have the same length… but there would still be some seasonal variation, since the Earth’s orbit isn’t perfectly circular.
The heliocentric model — retrograde motion

Retrograde motion — the planets move across the celestial sphere, but occasionally they change directions for a while.
The heliocentric model — retrograde motion

b This diagram shows how the same idea applies to a planet. Follow the lines of sight from Earth to Mars in numerical order. Notice that Mars appears to move westward relative to the distant stars as Earth passes it by in its orbit (roughly from points 3 to 5).
The heliocentric model — retrograde motion

- mars_retrograde_motion.htm