# Planets, Stars, and Galaxies

Chapter 2 & 3

Based on slides from Dr. Lauren Woolsey

1

## Review from last class

2

2

**Clicker Question:**

Which of the following statements is *false*?

a) When I push my car out of a ditch, my car is pushing back on me by the same amount, even if I am successful.
b) When dropped, hammer and a feather fall at the same rate on the moon.
c) The orbit of the Earth will be unaffected by the Sun changing in size as it ages.
d) A satellite in a circular orbit around the Earth is in uniform motion (no acceleration).
e) none of the above

3

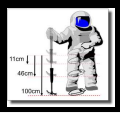
3

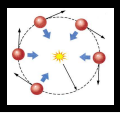
**Clicker Question:**

Imagine we've discovered a planet orbiting another star at 1 AU every 6 months. The planet has a moon that orbits the planet at the same distance as our Moon, but it takes 2 months. What can we infer about this planet?

a) It is more massive than Earth.
b) It is less massive than Earth.
c) It has the same mass as Earth.
d) We cannot answer the question without knowing the mass of the star.
e) We cannot answer the question without knowing the mass of the moon

$$m\frac{v^2}{r} = \frac{GMm}{r^2} \Rightarrow v = \sqrt{\frac{GM}{r}}$$



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## Newton's Law and Gravity

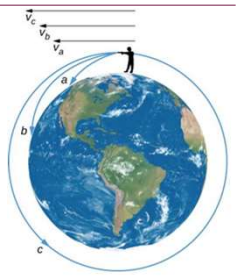
5

To be able to orbit something, we need the speed to be fast enough.

*Too slow*: object falls back to Earth

*Too fast*: object escapes Earth's gravity.

*Just right*: object is on a closed orbit. This "just right" speed for Earth is 17,500 miles per hour (8 km/s)!




Ch. 3.5

5

## Escape Velocity and Conservation of Energy

6

In orbital mechanics, objects also have an energy related to it's orbit. This is due to the fact that Energy is **conserved**.

There are two types of energy:

kinetic (relate to speed) $K = \frac{1}{2}mv^2$

**gravitational energy (related to position)** $U = -\frac{Gm}{r}$

**The energy is negative because it acts as a potential well**

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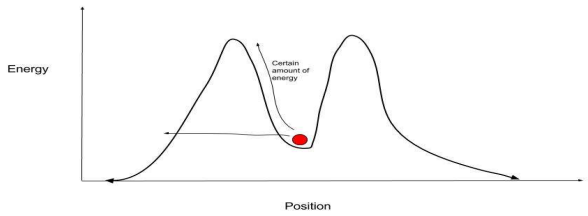
## Potential Well

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## Escape Velocity

8

- "Escaping the potential well" means having the speed necessary to escape the gravitational influence of the central body. When this happens, the total energy in Zero.

$$E = K + U$$

$$E = \frac{Gm}{r} - \frac{1}{2}mv_{esc}^2 = 0$$

$$\frac{Gm}{r} = \frac{1}{2}mv_{esc}^2$$

$$v_{esc}^2 = \frac{2Gm}{r} \rightarrow v_{esc} = \sqrt{\frac{2Gm}{r}}$$

8

## Conservation of Energy

2 In Fig. 8-22, a small, initially stationary block is released on a frictionless ramp at a height of 3.0 m. Hill heights along the ramp are as shown. The hills have identical circular tops, and the block does not fly off any hill. (a) Which hill is the first the block cannot cross?

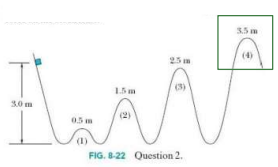


FIG. 8-22 Question 2.

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## Newton's Law and Gravity

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Newton's theories were published in 1688 ("Principia"). His Universal Law of Gravity combined with the Laws of Motion explain all three of Kepler's Laws of planetary motion.

These laws represent the "perfection" of the Copernican model. All planetary motions are explained with one equation, **gravity**. Geocentrism is finally wiped-out.

***Can Newton's ideas be tested further?***

Ch. 3.5

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## Newton's Law and Gravity

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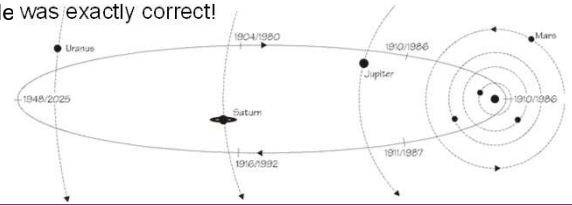
Edmund Halley tracked part of the orbit of a comet, and predicted when it would return using Newton's laws of motion. He was exactly correct!




Ch. 3.5

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## Newton's Law and Gravity

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The planet Uranus discovered in 1781 by William Herschel. However, Uranus did not move according to predictions made with Newton's laws.

The inconsistencies could be explained by another massive object that was pulling on Uranus's orbit. Using Newton's laws of motion, a new planet was predicted to exist further from the Sun than Uranus. Neptune was found in 1845, less than 1° away from its predicted position!

Newton's laws are not only **testable and verifiable,** they are **fruitful**. The discovery of Neptune is one the great stories of the scientific method. "If I have seen farther than other men, it is because I stood upon the shoulders of giants."

Ch. 3.6

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## Chapter 4: Earth, Moon, and Sky



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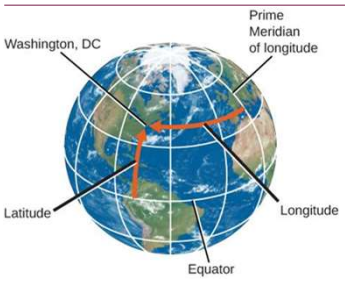
## Coordinates on Earth




On Earth, we can give a precise location by using **latitude** and **longitude**.

Latitude has a physically meaningful **zero point**: the Earth's **equator**.

Latitude is measured in **degrees**.

Ch. 4.1

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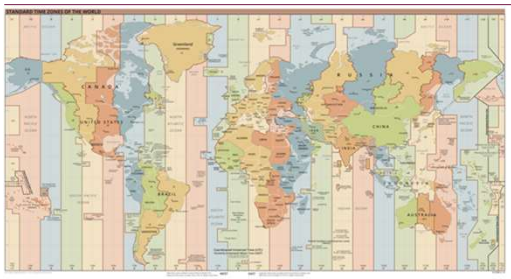
## Coordinates on Earth



**Time zones** across the Earth are a bit like lines of longitude.

They are based on average sunrise and sunset times.

*Image Link, Credit: TimeZonesBoy - US Central Intelligence Agency,* Ch. 4.1

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## Coordinates on the Sky

"Up-Down" Direction:

- Earth's **Latitude**: in degrees, relative to Earth's *Equator*
- Sky's **Declination** (Dec): in **degrees**, relative to the *Celestial Equator*.

"Left-Right" Direction:

- Earth's **Longitude**: in degrees (and time zones), relative to an arbitrary starting point called the *Prime Meridian*.
- Sky's **Right Ascension** (R.A.): in **hours**, relative to an arbitrary starting point called the *Vernal Equinox*.

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## Coordinates on the Sky

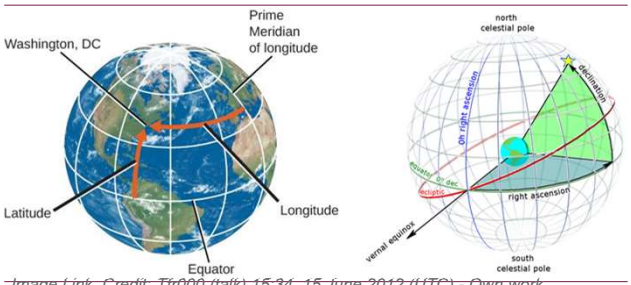


*Image Link, Credit: Tfr000 (talk) 15:34, 15 June 2012 (UTC) - Own work, CC BY-SA 3.0*

Ch. 4.1

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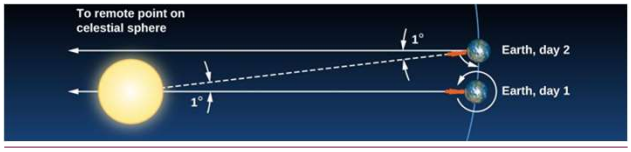
## Keeping Time: Solar vs Sidereal Day

The Sun and stars both appear to move nearly the same way over the course of a day, but there is a 4-minute difference.

**Solar day**: one rotation, facing the Sun to facing the Sun. 24 hr
**Sidereal day**: one rotation with respect to distant stars. 23 hr 56 min




Ch. 4.3

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**I will explain this on the board…**

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**The Calendar**

*Pause-and-Think Open Question:*

**Of the following lengths of time in the list below, which are based primarily on astronomical cycles and motions?**

- **Day**
- **Week**
- **Month**
- **Year**
- **Century**

Ch. 4.4

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**The Calendar**

**<u>One day</u>**: based the rotation of the **Earth** (i.e. the solar day, not the sidereal day) Astronomical value: 1.0000 days

**<u>One month</u>**: based on the orbit of the **Moon** around the Earth. Astronomical value: 29.5306 days

**<u>One year</u>**: based on the orbit of the Earth around the **Sun**. Astronomical value: 365.2422 days

Our calendar is right to ~1 day in 3300 years with leap years.

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## Ancient Calendars

Many cultures built methods of tracking time. Stonehenge was built between approximately 3000 BCE and 1500 BCE.

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## Ancient Calendars

At Stonehenge, the heelstone aligns with sunrise at summer solstice, and different stones mark sunset on the summer solstice, as well as sunrise and sunset on the winter solstice.

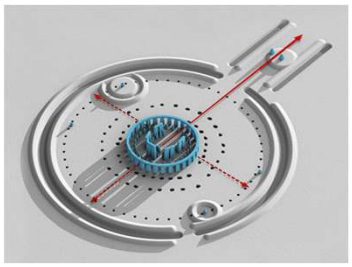

*Image Link, Credit: Joseph Lertola, Public Domain*

Ch. 4.4

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## Ancient Calendars

The Maya in Central America focused on counting days, but not on fitting the lunar month or solar year in their calendar.

*All these calendars require astronomy!*

Ch. 4.4

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## Ancient Calendars

The Pre-Incas of in Peruvian Andes built an amazing Solar Observatory

It tracks with precision the position of the Sunrise, and it is also designed to track the stars

Werner Forman/Universal Images Group/Getty Images

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## Chapter 4: Earth, Moon, and Sky



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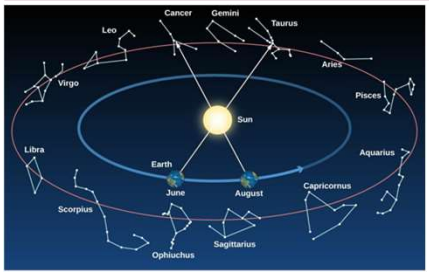
## Seasons Through the Year




Each year, the Sun appears in several constellations, changing our view of the night sky.

We experience various **seasons**, too. Why?

Ch. 4.2

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## Seasons Through the Year

*Pause-and-Think MC Question:*

**Based on your understanding before this class, what causes the different seasons on Earth?**

1) Variation in the distance between the Earth and the Sun
2) Changes in how much energy the Sun emits
3) Tilt of the Earth's axis of rotation
4) None of the above

Ch. 4.2

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## Seasons Through the Year

When we name seasons, we refer to the weather.

If it is Winter here, what season is it in Australia?

*Image Link, Credit: Planet Science, NESTA; Cleared for Educational Use*

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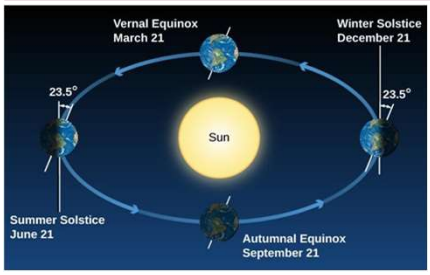
## Seasons Through the Year




Although some of you may have noted that the Earth's tilt is responsible, the key is ***how*** the tilt matters. There are two ways.

Ch. 4.2

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## Seasons Through the Year

There are two main reasons it is hot in summer and cold in winter. Both have to do with the Earth's tilt.

1. Sunlight is **more direct during summer**. It is hotter when the Sun is "angled higher" and sunlight is more direct.
2. We have **more hours of daylight in the summer**, and less hours of daylight in the winter. If there are more hours of heating, the temperature can stay higher in summer.

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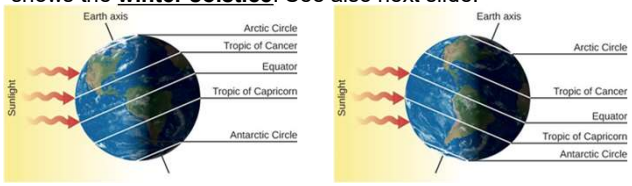
## Seasons: Direct and Indirect Sunlight

The first main reason is based on how direct or indirect the sunlight is. One image shows the **summer solstice**, the other shows the **winter solstice**. See also next slide.

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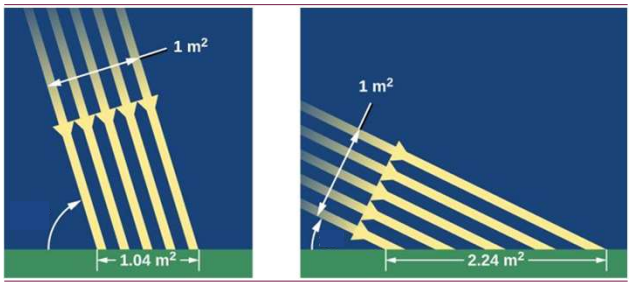
## Seasons: Direct and Indirect Sunlight

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## Seasons: Direct and Indirect Sunlight

Here's a local example of how the small difference in temperature between direct sunlight and shadow can affect whether snow on the ground melts or not.

A practical aspect of this effect involves which side of the mountain ski slopes are built!

*Images of GRCC Campus, credit: Lauren Woolsey, CC BY-SA 4.0*

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## Seasons: Length of the Day

The second main reason for seasonal variation is that we have different numbers of hours of daylight throughout year. This is because the location of sunrise and sunset changes during the year; it is not always perfectly East and West.

If you struggle to visualize the changes of the Sun's path throughout the year after this topic, I recommend this site: ccnmtl.github.io/astro-simulations/sun-motion-simulator/

Ch. 4.2

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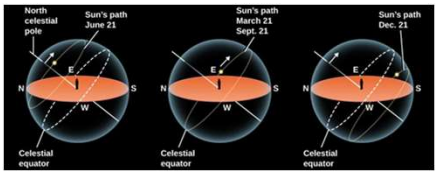
## Seasons: Length of the Day

There are special dates shown below, called solstices and equinoxes. These represent special points during the year. The solstices are the most extreme paths the Sun can take.

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## Seasons: Path of the Sun

**When does a vertical flagpole not cast a shadow in Panama City?**

A) every day at noon
B) every day at the time when the Sun is highest in the sky
C) when the Sun is highest in the sky, some day in the Northen Hemisphere summer
D) when the Sun is highest in the sky, some day in the Northen Hemisphere winter

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## Seasons: Path of the Sun

*Pause-and-Think Open Question:*

**Describe the Sun's path on January 1st. Consider these:**

- In what compass direction does it rise?
- In what compass direction does it set?
- Will it be getting higher or lower in the sky at noon over the next week?
- How will the amount of sunlight change in the next week?

Ch. 4.2

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## Seasons Through the Year

In summary, there are two reasons why the Sun's changing altitude causes the seasons that you should understand:

- The angle at which the sunlight hits the ground determines its effectiveness in heating the ground, which in turn heats the atmosphere.
- The duration of daylight changes during the year.

*Long summer days allow the Sun to efficiently heat the ground for roughly 15 hours. Short winter days allow only 9 hours for Sun to heat ground inefficiently.*

Ch. 4.2

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## Seasons Through the Year

**Both** of these effects are due to the **tilt of the Earth's rotational axis** with respect to its orbit around the Sun a.k.a. the ecliptic. Biggest takeaway: seasons are **NOT** caused by a changing distance between the Sun and the Earth.

***Supplemental Workbooks***

- Lecture Tutorials for Introductory Astronomy, by Prather, Slater, et al:
  "Path of the Sun"
- Learning Astronomy by Doing Astronomy, by Palen and Larson:
  "Activity 3: Where on Earth are You?"

Ch. 4.2

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## Chapter 4: Earth, Moon, and Sky



*Image: "school" is licensed under CC0 1.0*

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## Chapter 4: Earth, Moon, and Sky

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## Introduction to Moon Phases

*Pause-and-Think MC Question:*

Based on your understanding before this class, what causes the moon to have different phases?

A. Clouds in the Earth's atmosphere

B. Earth's shadow covers different parts of the Moon at different times

C. The brightness of the moon changes based on its height in the sky

D. Our view of the half-illuminated moon changes throughout its orbit

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## Phases of the Moon: Goals

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By the end of this set of videos, I want you to feel **confident** answering the following questions when you see the actual Moon in the sky:

- What is the name of the current phase I am seeing?
- What will the Moon look like in a few days?
- Based on the Moon's location in the sky, what time is it?

We will start with a set of common misconceptions, then build up our vocabulary of new terms.

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## The Dark Side of the Moon?

Misconception #1: There's a "Dark Side" of the Moon

Let's break this down:

- What lights up the moon?
- What does dark mean?
- Does the illuminated side change or stay the same?



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Image Link (and alternate link), Credit: NASA; "Earthrise" by William Anders, Apollo 8, 1968

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## Phases of the Moon: The Dark Side?

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Half of the Earth is always lit up ("day") and half of it is dark ("night"). **This is true on the Moon, too.**

The dark side of the Earth change every 24 hours as it rotates on its axis. ***So, what about the Moon?***

Image Link (and alternate link), Credit: NASA; "Earthrise" by William Anders, Apollo 8, 1968 Ch. 4.5

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## Phases of the Moon: The Dark Side?

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"Phases of the Moon" by UCL Mathematical & Physical Sciences is licensed under CC BY 2.0 Ch. 4.5

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## The Far Side of the Moon?

Misconception #2: The Moon Doesn't Rotate

Let's break this down:

- Earth spins every 24 hours. Does Moon spin on its axis?
- How does it keep one side always facing us?

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## Phases of the Moon: A Brief Recap

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What we've determined so far:

- Moon is always half illuminated by **reflected sunlight**.
- The Moon half that is lit up changes over the course of the lunar cycle (i.e. there's **no single "dark side"**).
- The Moon spins on its own axis once for each orbit around Earth! This means there ***is* a single "far side"** of the Moon.

This last point is not a coincidence, it's due to **tidal locking**!

Ch. 4.5

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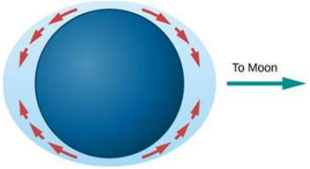
## Tidal Locking and the Earth-Moon System

The Moon is **tidally locked** to the Earth, but there's still variation in what face it shows.




*Moon Libration by Tom Ruen based on NASA data is released to the Public Domain (CC 0)*

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## Tides: A Brief Discussion

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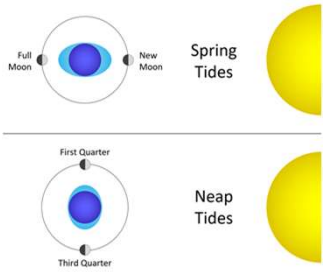
Tides are strongest at **New Moon** and **Full moon**.

Tides are weakest (least extreme) at **Quarter Moons**.

We don't need to remember these terms Spring or Neap tides for our curriculum.



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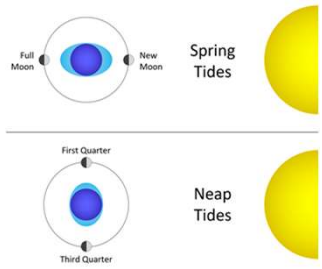
## Tidal Locking and the Earth-Moon System

Tides change intensity based on moon phase, which is interesting but not key to our curriculum.

More relevant: tidal locking isn't done: Earth is slowing down its rotation and the Moon is moving farther away!



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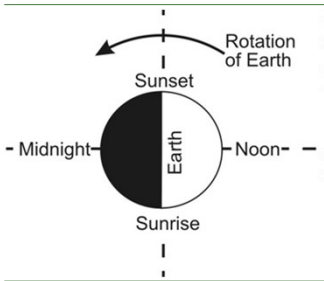
## Times for Moonrise and Moonset




We will often imagine sunlight coming in from the right side of our page, lighting up the side of the Earth and Moon facing that direction.

It's a general convention we will try to stick to regularly. Let's discuss the time labels.



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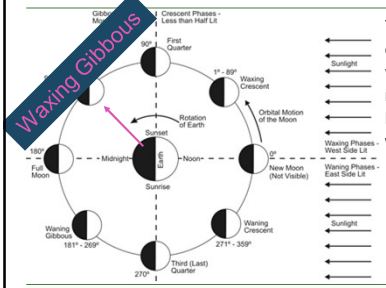
## Times for Moonrise and Moonset




This reference diagram has a lot of detail. Try drawing a simpler version, labeling phases not by memory, but by thinking how the Moon look from Earth and when we could see the phase.

*Diagram provided by William Millar for educational purposes* 55

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## Times for Moonrise and Moonset

Remember that these are smooth and consistent changes!


*Cycles of Time Diagram by Lauren Woolsey is licensed under CC BY-SA 4.0* 56

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## Predicting the Future

October 17th, 2015 at 7:00 pm

*Pause-and-Think Open Questions:*

- What is this phase name?
- I took these photos in Italy. What phase would you have seen here in Michigan on that same date?
- Can you see any phases of the moon during the day?

*Photographs of Moon by Lauren Woolsey are licensed under CC BY 4.0* 57

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## Predicting the Future

October 23rd, 2015 at 5:00 pm

This is a **waxing gibbous** moon, and it's the same phase around the whole globe.

You can see the Moon during the day, it's just less obvious.

October



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## Predicting Time and Location

*Pause-and-Think MC Question(s):*

Where would you look to see a first quarter moon as it rises?

1) Directly overhead
2) On the eastern horizon
3) On the western horizon
4) In the southern sky

***Where would you look to see the Sun at that time?***

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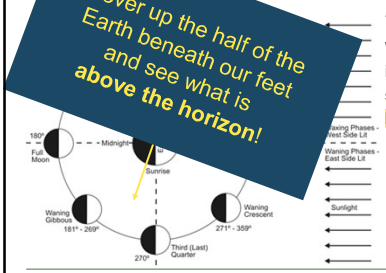
## P…me and Location




*Pause-and-Think Open Question:*

What are all the phases we'd see if we looked for the moon every single day of the month an hour before sunrise?



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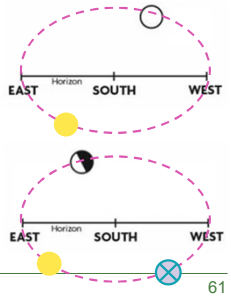
## Predicting Time and Location

Let's practice how to estimate the time of day from the Moon's position.

1. Draw the whole path of the Moon and Sun through the sky.
2. Based on how lit up the Moon is, where must the Sun be?
3. Based on the Sun's location, what would the approximate time be?

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## Predicting Phases of the Moon

To wrap up, consider this photo we saw in Section 2.1 and answer:

- What "Earth phase" is shown in this photo?
- What Moon phase would Earth observe?

*Earthrise by William Anders, Apollo 8, 1968 / NASA is released to the Public Domain (CC 0)*

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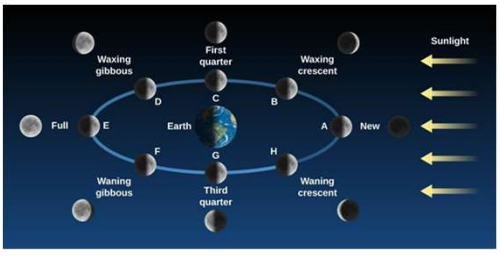
## Vocabulary for Phases of the Moon

Here are the terms we need to add to our vocabulary:

- **Full**
- **New**
- **Quarter**
- **Crescent**
- **Gibbous**
- **Waxing**
- **Waning**

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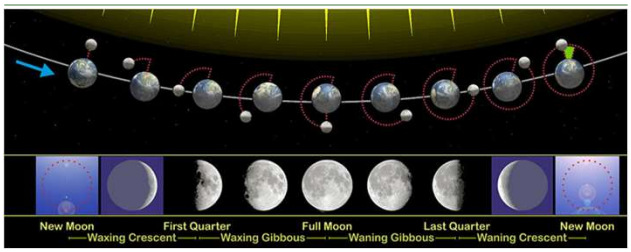
## Vocabulary for Phases of the Moon




The cycle takes 29.5 days - let's call that four weeks.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## Vocabulary for Phases of the Moon

We will focus on the order and length of phases in the next section. I will also have a Moon Phase Deeper Look Video to help.

Helpful resources to explore:

- Khan Academy Moon Phases
- Lunar Phase Simulator *(UNL)*
- Lunar Phase Simulator *(CCNMTL)*



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## Chapter 4: Earth, Moon, and Sky

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## The Cause of Moon Phases

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*Pause-and-Think MC Question:*

**Which best describes why the Moon goes through phases?**

1) Earth's shadow falls on different parts of the Moon at different times.
2) We see only part of the lit-up half of the Moon depending on its position relative to Earth and the Sun.
3) The sunlight reflected from Earth lights up the Moon but is less effective when the Moon is lower in the sky than when it is higher.
4) Earth's clouds cover portions of the Moon at various times resulting in the changing phases that we see.

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## Phases of the Moon: New Terms

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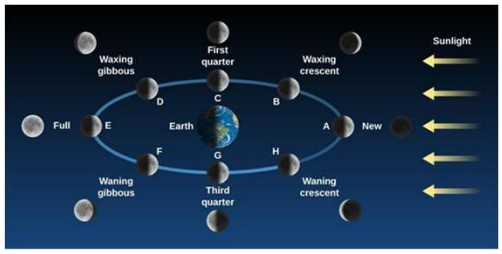
Here are all of the **terms** we need to learn for this topic:

- Full
- New
- Quarter
- Crescent
- Gibbous
- Waxing
- Waning

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## Phases of the Moon: Order and Length

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We have talked about ***why*** the moon has phases, but now we need to think about the order and length of those phases.

**Waxing**: becoming progressively *more* visibly illuminated.
**Waning**: becoming progressively less visibly illuminated.

External Websites for Simulations:

- https://astro.unl.edu/classaction/animations/lunarcycles/moonphases.html
- https://www.khanacademy.org/partner-content/nasa/measuringuniverse/spacemath1/pi/animate-phases-of-the-moon

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## Phases of the Moon: Order and Length

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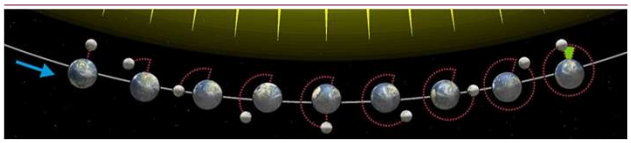

**Solar Month**: 29.5 days (also called Synodic period)
"New Moon to New Moon" period. This is 7.4 days for each quarter of the cycle, this is the length of time we care about.

**Sidereal Month**: 27.3 days (One orbit around the Earth)

*Image Link, Credit: Orion 8, CC BY-SA 3.0*

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## Phases of the Moon: Order and Length

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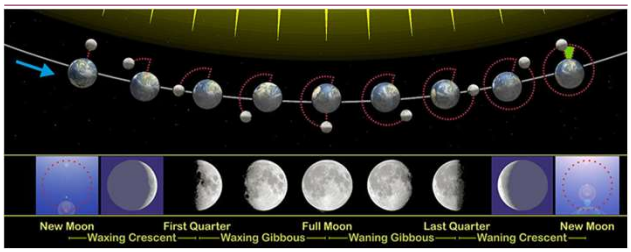


The crescent and gibbous phases each last about a week.

*Image Link, Credit: Orion 8, CC BY-SA 3.0*

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## Phases of the Moon: Predicting Time and Location

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| Moon Phase | Rise Time | Highest Point | Set Time |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

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## Phases of the Moon: Predicting Time and Location

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*Pause-and-Think MC Question(s):*

**Where would you look to see the full moon when it rises?**

1) Directly overhead
2) On the eastern horizon
3) On the western horizon
4) In the southern sky

**Where would you look to see the Sun at that time?**

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## Phases of the Moon: Predicting Time and Location

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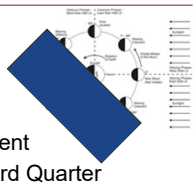
*Pause-and-Think MC Question:*



**Which set of Moon phases could be seen (above the horizon) at 3:00 PM?**

1) First Quarter, Full Moon, Waning Crescent
2) Waning Crescent, Waxing Gibbous, Third Quarter
3) Waxing Crescent, Waning Gibbous, Full Moon
4) Waxing Crescent, Waning Crescent, Waxing Gibbous

*Diagram provided by William Millar for these slides*

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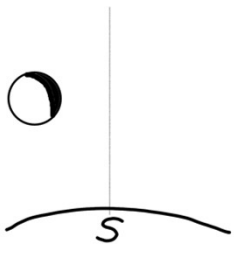
## Phases of the Moon: Predicting Time and Location

75

Let's consider how to estimate the time of day based on seeing the Moon in the sky. We'll face South.

The most important thing to remember is that our clocks are based on the location of the Sun, not the Moon. ***Where would the Sun be in the situation(s) shown?***

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## Phases Beyond the Moon!

76

To wrap up, I have a few questions to consider about this photo we saw earlier.

***What "Earth phase" is shown in this photo?***

***What Moon phase would people on Earth see?***

*Image Link (and alternate link), Credit: NASA; "Earthrise" by William Anders, Apollo 8, 1968*

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## Phases of the Moon: Summary

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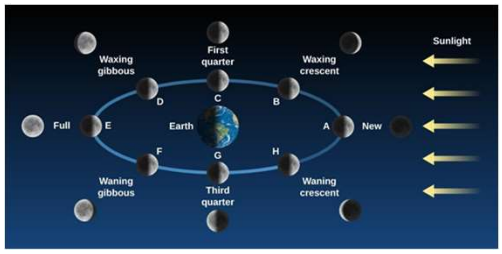
As a reminder, this is the diagram that shows all of the moon phases.

We will have a Deeper Look video where we draw it out from scratch.

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## Phases of the Moon: Summary

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We will have worksheets and activities to help us build up our ability to predict what the Moon will look like over a month of phases and to understand how to approximate the time of day if we see the Moon in the sky.

***Supplemental Workbooks***

- Lecture Tutorials for Introductory Astronomy, by Prather, Slater, et al:
  "The Cause of Moon Phases" and "Predicting Moon Phases"
- Learning Astronomy by Doing Astronomy, by Palen and Larson:
  "Activity 4: Studying the Phases of the Moon"

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## Chapter 4: Earth, Moon, and Sky

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*Image: "school" is licensed under CC0 1.0*

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## Eclipses of the Sun and Moon

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Remember that initial *pause-and-think* question from Section 4.5: What causes the moon to have different phases?

1) Obstruction by the Sun's shadow
2) Obstruction by the Earth's shadow
3) **Various alignments of the Sun-Earth-Moon system**
4) Clouds in the Earth's atmosphere

For those who voted (2) originally, there certainly **is** an astronomical event that is caused by the obstruction by the Earth's shadow. That's our next topic.

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## Eclipses of the Sun and Moon

81

To understand eclipses, we need to start out with two points.

- **All the diagrams we've been seeing in the slides and textbooks are perfectly aligned, but that's not true.** We lose the third dimension in these diagrams.
- **All the diagrams we've been seeing in the slides and textbooks are not accurate to-scale models.** The Sun is about 400 times larger than the Moon. *By coincidence*, it is also about 400 times farther away.

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## Eclipse Requirements: Orbital Alignment

82

The Sun's apparent path through our sky is along the Ecliptic, and the Moon's path is ***almost*** along the ecliptic. Each month, there are two **nodes** where the Moon crosses the ecliptic plane. The nodes shift slowly over 18 years.

There are two types of eclipses, and both need the Moon to be at a **node** of its orbit. We call that time frame **eclipse season**.

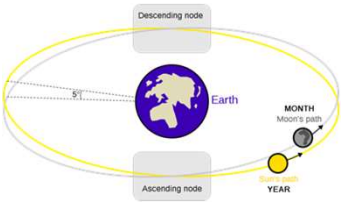


*Image Link, Credit: SuperManu, following work by Tom Ruen, Public Domain* Ch. 4.7

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## Eclipse Requirements: Angular Size

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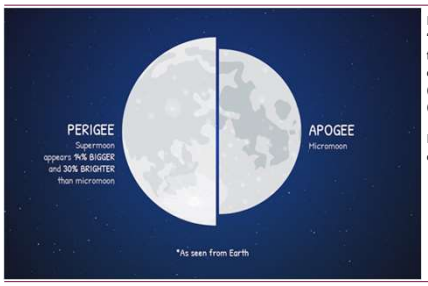


If you've ever heard the term "supermoon," you may be aware that the Moon's orbit is not circular. Sometimes it's closer (and bigger), sometimes it's farther (and smaller).

It isn't changing actual size, it is changing **angular size**.

*Image Link, Credit: NASA/JPL-Caltech* Ch. 4.7

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## Eclipse Requirements: Angular Size

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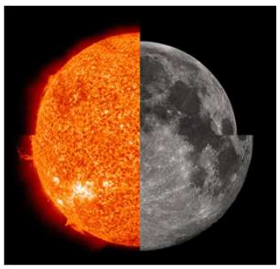

Because the ratio of physical sizes is similar to the ratio of their distances, the Moon and the Sun have a very similar **angular size** on our sky (0.5°).

This is pure coincidence, and it means that the Moon is often able to completely cover the Sun!

*Image Link, Credit: Tdadamemd, CC BY-SA 4.0* Ch. 4.7

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## Eclipse Requirements: Shadows

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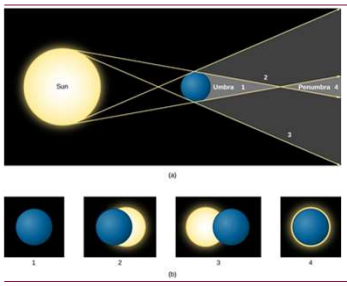


If illuminated by a light source, ***any object*** can cast a shadow. There will be a zone of partial shadow, the **Penumbra**, and a zone of full shadow, the **Umbra**. *Note: this diagram is not to scale.*

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## Solar Eclipses: Moon's Shadow

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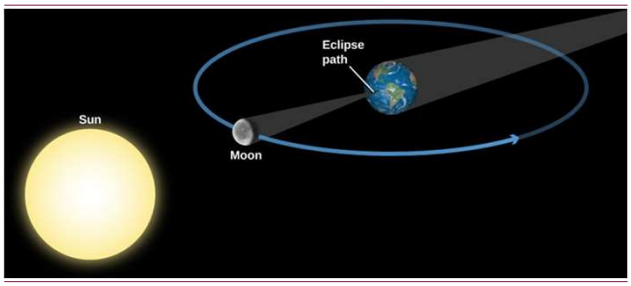


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## Solar Eclipses: Moon's Shadow

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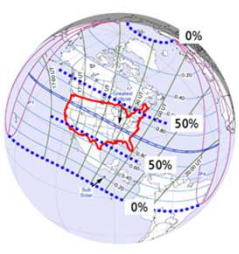
On August 21st, 2017, there was a total solar eclipse, visible from Oregon to South Carolina. I saw it from Gallatin, TN!

[View from Space]




*Eclipse Predictions by Fred Espenak, NASA GSFC Emeritus; Photo by S. Woolsey (CC BY 4.0)*

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## Solar Eclipses: Moon's Shadow

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Here are my pictures leading up to the eclipse. This part took over an hour, and is similar to what could be seen in GR.

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## Solar Eclipses: Total Eclipse

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At the point of totality, the Sun's **corona** becomes visible! In Gallatin, totality for the 2017 eclipse was only 160 seconds.

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## Solar Eclipses: Total Eclipse

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On April 8th, 2024 there will be another "Great American" Total Solar Eclipse that doesn't require a flight around the world to watch!

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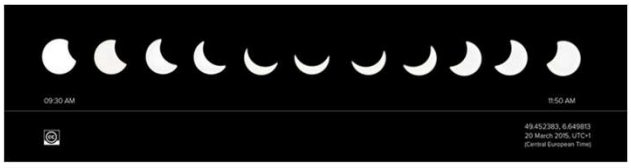
## Solar Eclipses: Partial Eclipse

91

If you are close to the path of a **total solar eclipse** but not quite lined up, just like Grand Rapids was in August 2017, then you might observe a **partial solar eclipse**.




*"solar eclipse from germany" by Fabian Lauer is licensed under CC BY 2.0* Ch. 4.7

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## Solar Eclipses: Partial Eclipse

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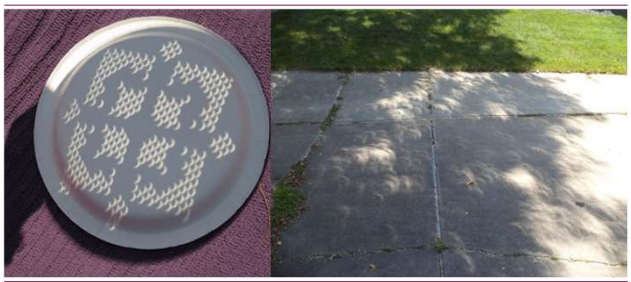

*Left: Dr. Lauren Woolsey (CC BY 4.0); Right: Brandon Blahnik (CC BY 2.0)* Ch. 4.7

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## Solar Eclipses: Annular Eclipse

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If the Moon can't fully block the Sun, there can be an **annular solar eclipse**. This composite image is from May 20, 2012 in Red Bluff, California.

We get this kind of eclipse if the moon is near the farthest point in its orbit when also at a node.

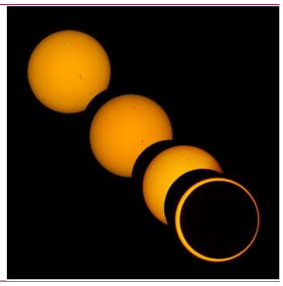

*Image Link, Credit: Brocken Inaglory - Own work, CC BY-SA 3.0* Ch. 4.7

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## Solar Eclipses: Summary

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There are **total, annular, and partial solar eclipses.**

Required Conditions:

- Must be an eclipse season. (*Nodes in right spot*)
- Observer must be in the narrow path of totality (or annularity), or near enough to see a partial eclipse.
- And the moon must be in the **New Moon** phase.

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## Lunar Eclipses: Earth's Shadow

95

There are three types of **lunar eclipses**.

1. **Penumbral** eclipses (we'll ignore these, not very exciting to non-astronomers)
2. **Partial** lunar eclipses
3. **Total** lunar eclipses

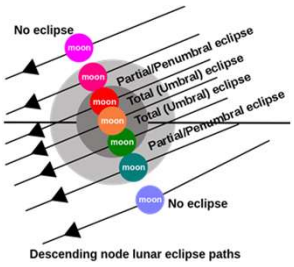


*Image Link*, Credit: MatthewZimmerman at English Wikipedia / Public domain

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## Lunar Eclipses: Earth's Shadow

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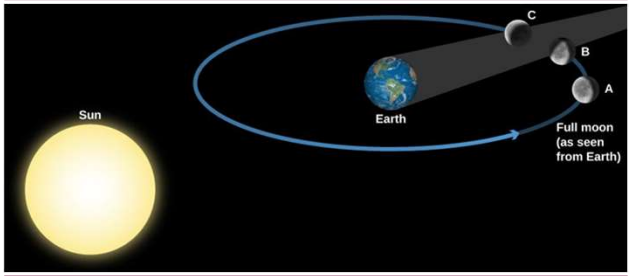


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## Lunar Eclipses: Earth's Shadow

97

The shape of the Moon during the hours of a Lunar Eclipse **does not match** the phase shapes.

*Composite by Ashwin Kumar and Single Shot in middle by osseous (both CC BY-SA 2.0)* Ch. 4.7

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## Lunar Eclipses: Summary

98

Because the Earth's shadow provides a large target, **total lunar eclipses** are slightly more common than **total solar eclipses**, since there's no chance the shadow is too small (as it is in annular solar eclipses).

Conditions for a **Lunar Eclipse**:

- Must be an eclipse season. (*Nodes*)
- Observer must be on night/evening side of Earth when the alignment occurs.
- And the moon **must be in the Full Moon phase**.

*Animation, Thomas Knoblauch, CC BY-SA 3.0* Ch. 4.7

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## Eclipses of the Sun and Moon

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Short (2-min) video from NASA that discusses eclipses and shows a nice animation of Moon's orbit and the shadows of the Moon and the Earth:

https://www.youtube.com/watch?v=INi5UFpales


*Original Tweet: Katie Mack, https://twitter.com/AstroKatie/status/518697246305439745?s=20* Ch. 4.7

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