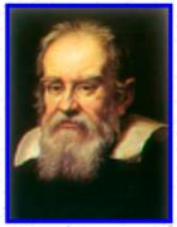
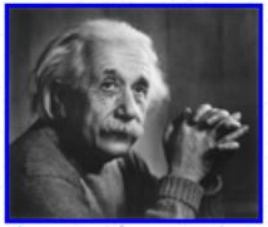
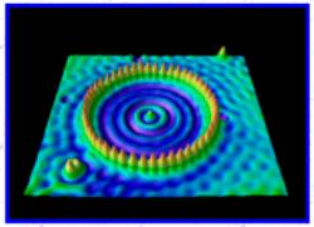
Physics 106
Concepts of Physics




Professor Frank Zimmermann
fmz@physics.rutgers.edu

Course Info: On Canvas

Grading - Section 01:

- Homework: 35%
- Labs: 15%
- I-clickers: 15%
- Final Exam 35%

Grading - Section H1 (honors):

- Homework: 30%
- Labs: 15%
- I-clickers: 15%
- Final Exam 35%
- Term paper 5%

iClicker: We will use iClicker for polling during the lectures. You can either use the physical remote, or the iclicker web app on your laptop, or the mobile app on your phone. Detailed instructions are here.

Homework:

- The solutions will be available right after the submission deadline.
- For this reason, there will be **NO LATE HOMEWORK ACCEPTED!**
- Homework is only accepted by uploading to Canvas. Do not email me homework.
- **Homework Guidelines**

Labs:

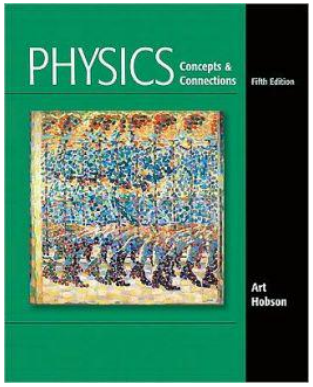
- There will be four simple labs that you will do over the semester.
- You will write lab reports according to the **Lab Guidelines** and upload them to Canvas.

Term Paper - Section H1 only:

- Students in the honors section H1 submit a 4-5 page term paper at the end of the term.
- Detailed instructions in **Assignments**.

Academic Integrity

- Students are expected to maintain the highest level of academic integrity.
- You should be familiar with the university policy on academic integrity .
- Violations will be reported and enforced according to this policy.
- Use of external sources to obtain solutions to homework assignments or exams is cheating and a violation of the University Academic Integrity policy.
- Cheating in the course may result in penalties ranging from a zero on an assignment to an F for the course, or expulsion from the University.
- Posting of homework assignments, exams, recorded lectures, or other lecture materials to external sites without the permission of the instructor is a violation of copyright and constitutes a facilitation of dishonesty, which may result in the same penalties as explicit cheating.



Textbook (optional):
Art Hobson, Physics Concepts & Connections

Free textbook: OpenStax College Physics (online)

Let’s test the iclickers!

A. I have the iclicker app on my phone.
B. I have the iclicker web app on my computer.
C. I will use the iclicker remote.
D. Iclicker what?

Course Syllabus

Jump to Today | Edit

Note: The syllabus may change slightly throughout the year.

Week of	Topic	Reading Assignment
Jan 18	Stars, atoms and the nature of things	Hobson Chapters 1 and 2
Jan 25	How things move	Hobson Chapter 3
Feb 1	Newton's laws of motion	Hobson Chapter 4
Feb 8	Gravity and astrophysics	Hobson Chapter 5
Feb 15	Energy	Hobson Chapter 6
Feb 22	Thermodynamics	Hobson Chapter 7
March 1	Electromagnetism	Hobson Chapter 8
March 8	Waves and Light	Hobson Chapter 9
March 15	*Spring break - no class*	
March 22	Special Theory of Relativity	Hobson Chapter 10
March 29	Cosmology	Hobson Chapter 11
Apr 5	The quantum idea	Hobson Chapter 12
Apr 12	The quantum universe	Hobson Chapter 13
Apr 19	Nuclear physics, fission, fusion	Hobson Chapters 14 and 15
Apr 26	Energy: fossil fuels, nuclear energy, renewables	Hobson Chapters 15 and 16
May 3	Elementary particles	Hobson Chapter 17

What is science?

Science is all about **understanding nature:**

- We start with **observations** (or experiments).
- The observations are the **"scientific facts".**
- To make sense of the observations, we come up with **ideas/guesses/tentative conclusions** that might explain the observations.
- First, we don't know if these ideas make any sense: They might be true, or not.
- Such ideas are called **hypotheses**. (Plural of hypothesis)
- Typically, scientific hypotheses allow us to make **predictions**, which we can test with further observations/experiments.
- Hypotheses that are disproven by experiment must be discarded.
- On the other hand, the more predictions are actually **confirmed by experiments**, the greater our confidence and **level of conviction** in the validity of the idea/hypothesis.
- When the level of conviction is sufficiently great, the hypothesis becomes a **scientific principle**, or even a "**law of nature**".
- However, it can never become a fact. That's reserved for observations.

Scientific Theory

- A framework of a number of related ideas, definitions, scientific principles, and laws of nature, which helps us understand nature, is called a "**scientific theory**".
- Calling something theory makes not judgement about our level of conviction in the validity of the theory.
- A "theory" can be firmly grounded in experiment (high level of conviction), or it could be highly speculative.
- To judge the level of conviction, one must look at the **evidence**.
- The theories taught in college are typically the ones that have withstood the test of many attempts to disprove ("falsify") them. They agree with a large body of observations, giving us a very **high level of conviction** of their validity.
- Examples: Theory of Gravitation, Theory of Evolution, Big Bang Theory.
- The usage of the word "theory" is thus different from everyday life, where the utterance "it's just a theory" typically refers to an idea that is highly speculative. In fact, the statement "It's **just** a theory" makes absolutely no sense in science!

Smoke Ring Demo

Reasons to study science

- Expanded awareness of the universe
- Problems of modern society and their solutions
- Understanding everyday technology

Science and modern life

- Energy
- Transportation
- Information
- Medicine
- Communication
- Military
- Agriculture
- Climate
- Space exploration
- ….

What is Physics?

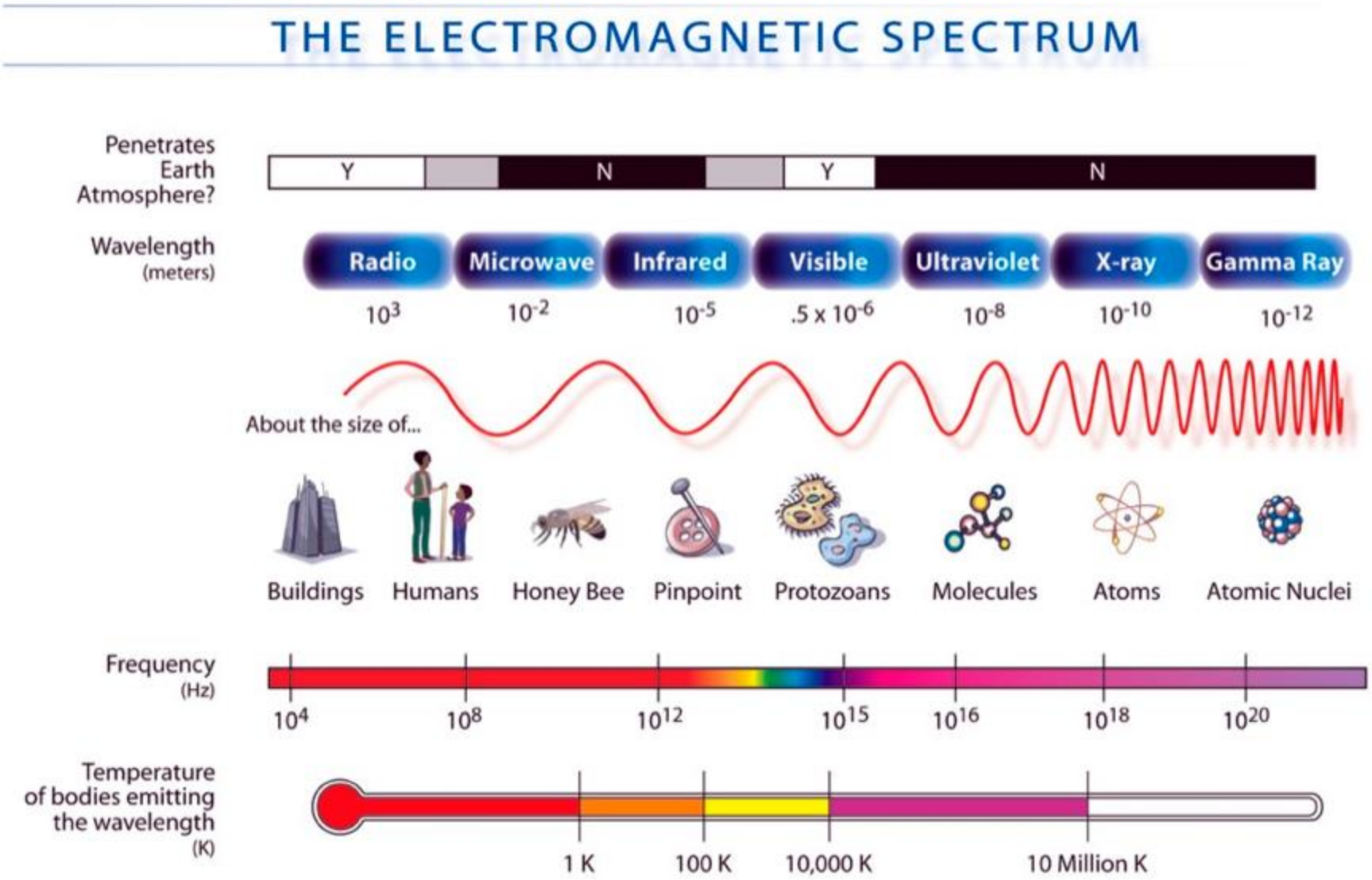
Aspects of physics: Universality

- We try to find theories that explain a broad range of phenomena
  - Geology: rocks
  - Biology: frogs
  - Astronomy: stars
  - Physics: What behaviors do rocks, frogs, and stars have in common?

Aspects of physics: Universality

- What laws of mechanics govern everyday objects (baseballs, trucks, …)?
- What laws of mechanics govern planets and stars? (Newton 1687)
- What laws of mechanics govern atoms and molecules? (Einstein 1905)

Aspects of physics: Universality



Aspects of physics: Simplicity

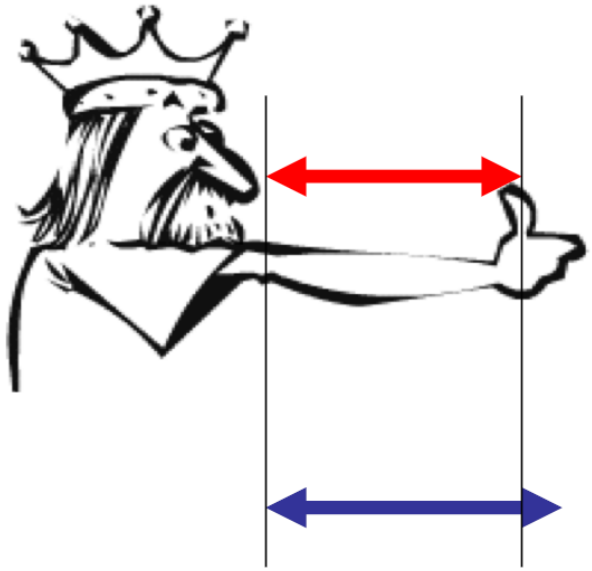
- Physical laws are often formulated for idealized phenomena and models
- When a system gets too complicated, the physics approach may no longer be useful
  - Need biology, chemistry, engineering, etc.
- Physicists looks for **simple** rules underlying complex behavior

Aspects of physics: Measurement

Mostly we measure

- Space
- Time
- Matter

Measuring Space



1 yard = 3 feet (English)

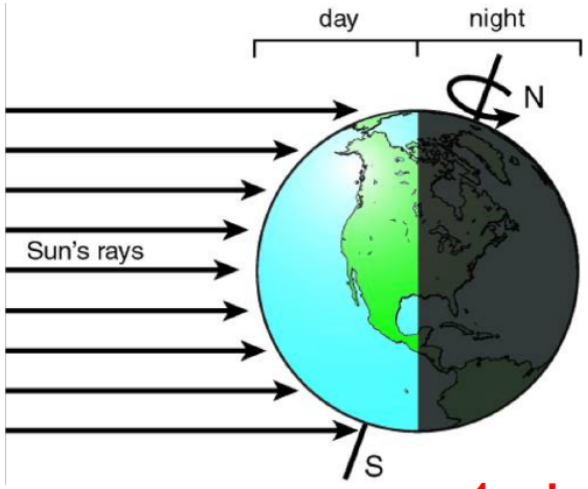
1 meter (metric)

$$1 \text{ meter} = \frac{1}{10{,}000{,}000} \text{ of pole-to-equator distance}$$

Measuring Time

Babylonian system:

- 1 day = 24 hours
- 1 hour = 60 minutes
- 1 minute = 60 seconds



1 day

Measuring Time

1 year = 1 earth orbit

= 365 days 6 hrs 9 min 9.8 sec

Most years are 365 days…

1 month = 1 moon orbit

= 29 days 12 hrs 44 min 2.9 sec

Month is appox. 4 phases of moon, 7 days each

Measuring matter (mass)

1 kilogram = 1 kg = 1,000 g

= hunk of metal (France)

[But...
https://www.npr.org/2018/11/13/666310991/say-au-revoir-to-that-hunk-of-metal-in-france-that-has-defined-the-kilogram]

A 1-kg brick is 1 kg of mass whether it is on the earth or the moon

It weighs ~2.2 pounds on the earth

It weighs ~0.3 pounds on the moon

(Weight is the force of gravity on an object)

Aspects of physics: Measurement

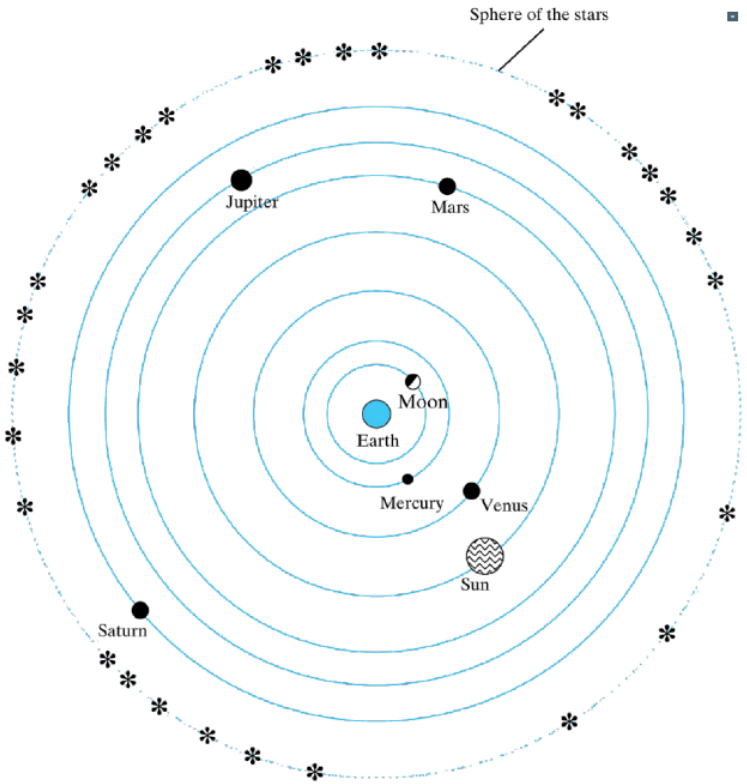
Scientific notation (powers of 10)

Table 1-3 | The Metric Prefixes

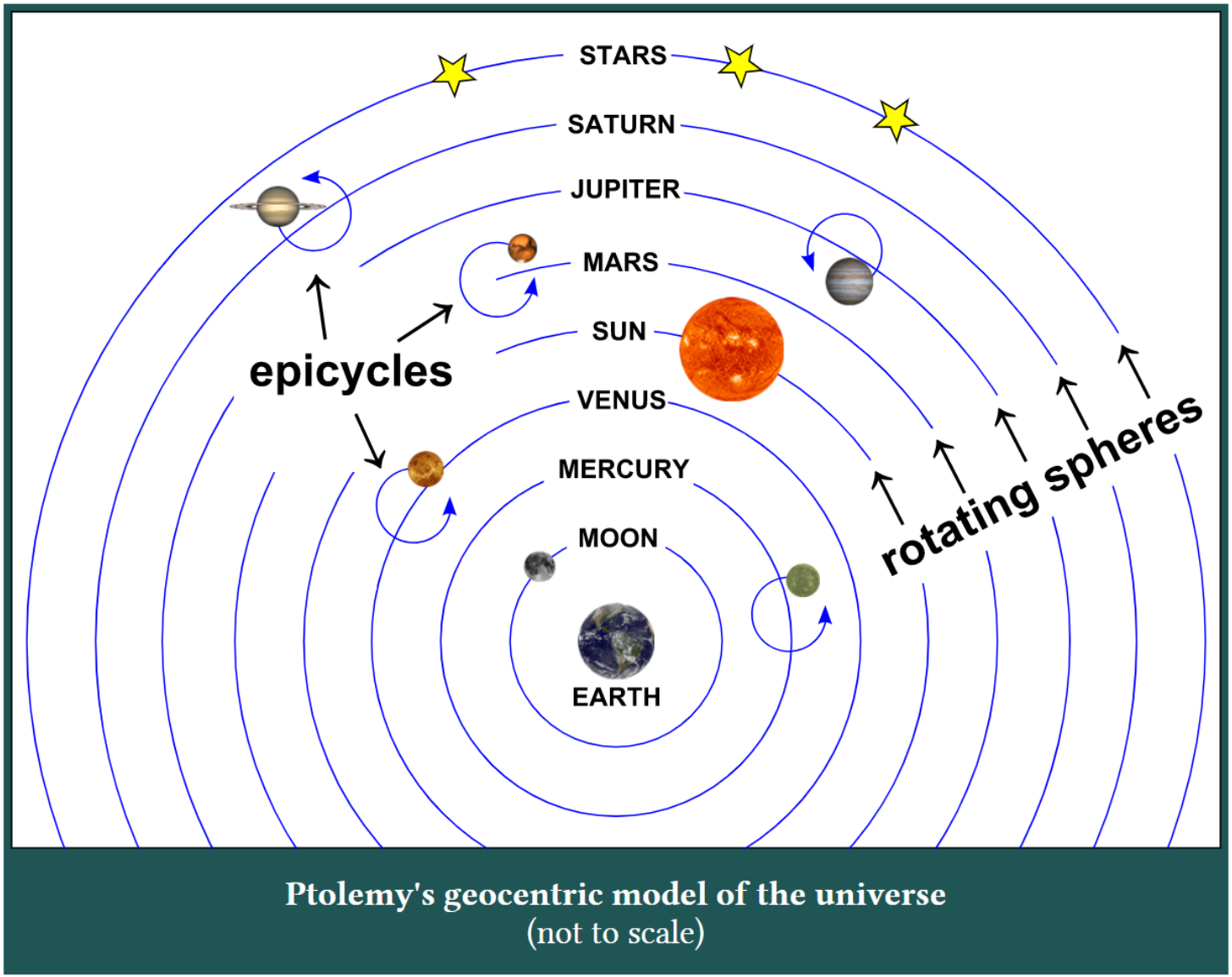
Prefix	Symbol		Value	
tera	T	trillion	10^{12}	1,000,000,000,000
giga	G	billion	10^{9}	1,000,000,000
mega	M	million	10^{6}	1,000,000
kilo	k	thousand	10^{3}	1,000
	one		10^{0}	1
centi	c	hundredth	10^{-2}	0.01
milli	m	thousandth	10^{-3}	0.001
micro	μ	millionth	10^{-6}	0.000 001
nano	n	billionth	10^{-9}	0.000 000 001
pico	p	trillionth	10^{-12}	0.000 000 000 001
femto	f	quadrillionth	10^{-15}	0.000 000 000 000 001

Geocentric Model of Universe

- The ancient Greeks described the universe as a series of concentric spherical shells, with the Earth at the center.
- Each shell contained one object – Sun, Moon, planet – and the stars were fixed to the outermost shell.



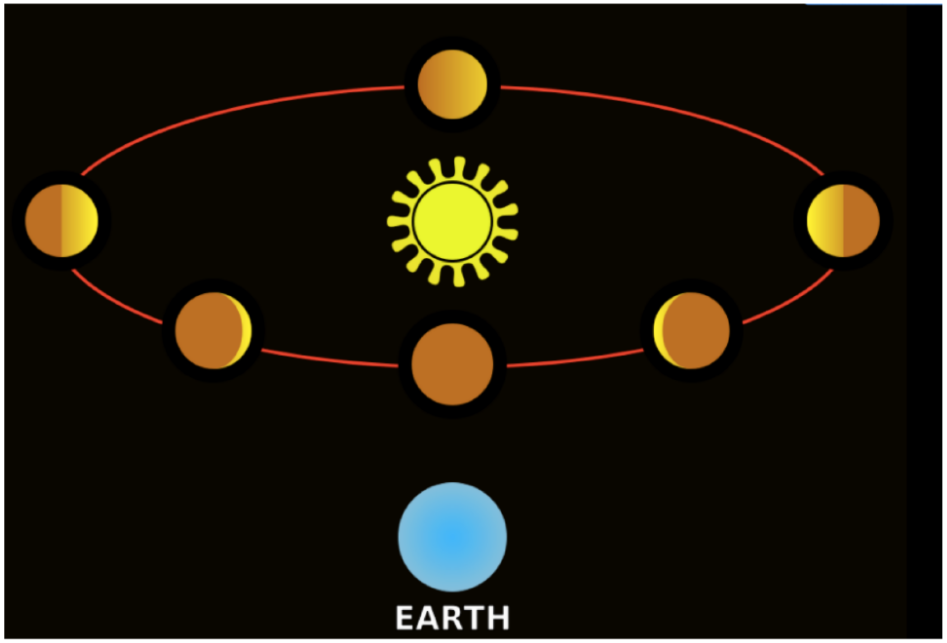
Ptolemy's Geocentric Picture



Ptolemy's geocentric model of the universe
(not to scale)

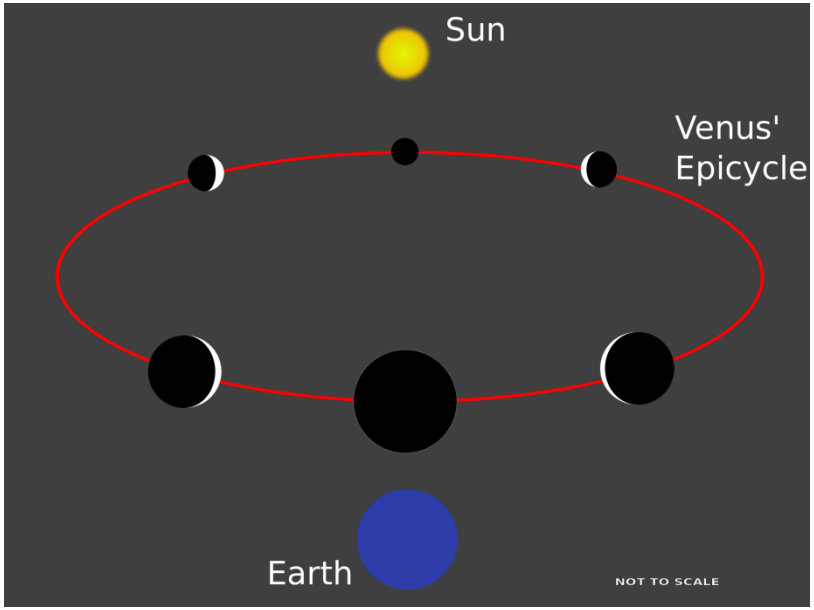
Copernicus: Heliocentric Model of Universe

Copernican prediction regarding phases of Venus

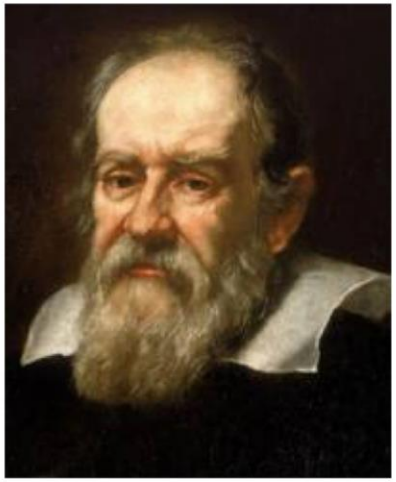


Prediction: All phases are possible

Ptolemy's Geocentric Model

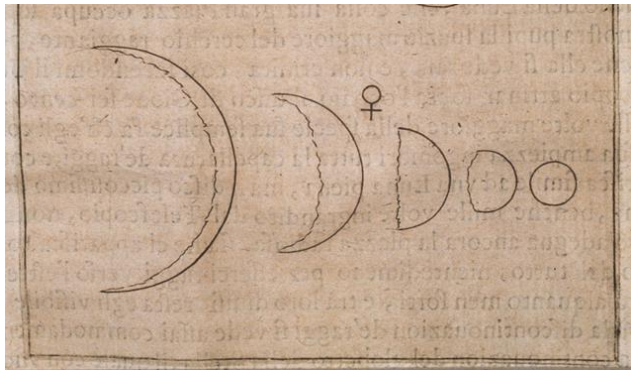


Prediction: Only crescent phases visible



Galileo Galilei, 1564-1642

- 1608: Telescope invented in Netherlands (Lippershey)
- 1609: Galileo built and improved telescope



Observes phases of Venus

Galileo and the Moon

- The moon has mountains and craters!
- More like earth!
- The moon is not perfect!

Galileo and Jupiter

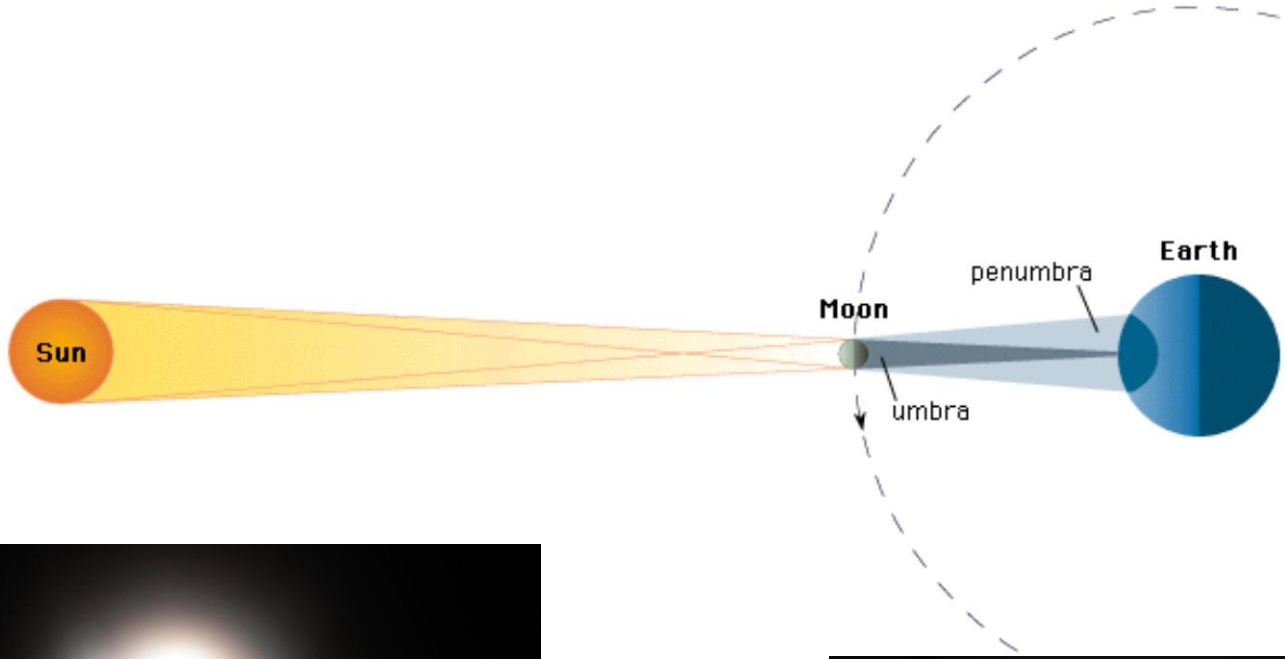
In 1610 Galileo discovered four “stars” that move back and forth across Jupiter. He concluded that they are four moons that orbit Jupiter’s much as our Moon orbits the Earth.

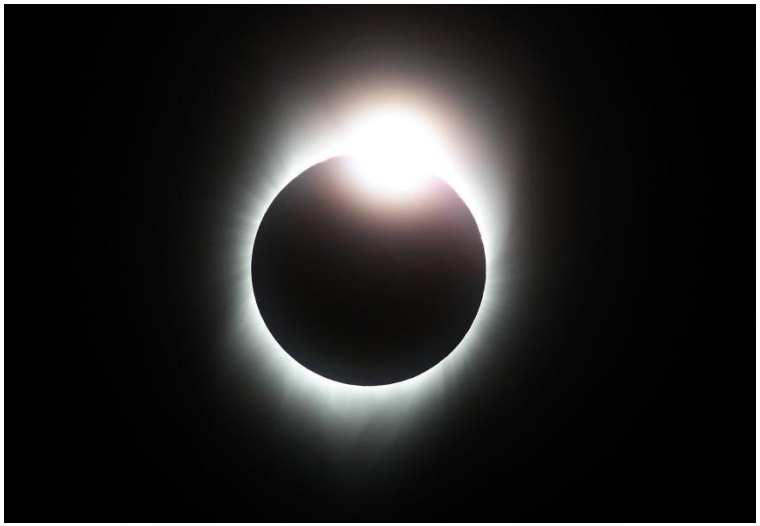
there were two stars, and a single one towards the west. . . . But when on January 8th, led by some fatality, I turned again to look at the same part of the heavens, I found a very different state of things, for there were three little stars all west of Jupiter, and nearer together than on the previous night.

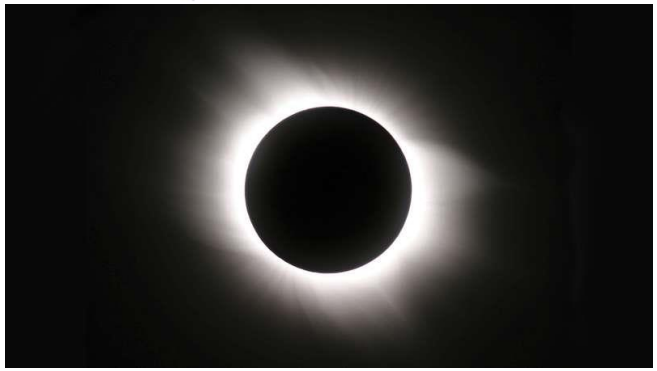
Thus Galileo decided that:

There are three stars in the heavens moving about Jupiter, as Venus and Mercury round the Sun.

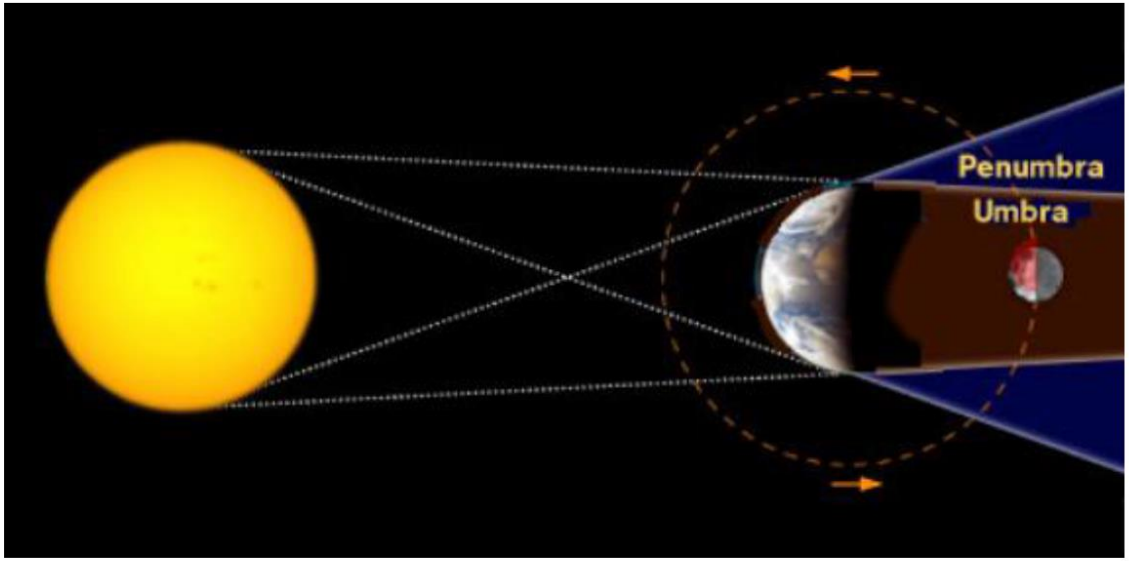
Solar Eclipse







Lunar Eclipse



Solar and Lunar Eclipse Demo

Scale of Solar System Demo