http://www.physics.smu.edu/pseudo

IF YOU ARE JUST JOINING THIS CLASS...

PLEASE COME TO THE FRONT OF THE CLASS AND SEE PROF. COTTON.

http://www.physics.smu.edu/pseudo

"Any sufficiently advanced technology is indistinguishable from magic."
--Arthur C. Clarke, "Profiles of The Future", 1961 (Clarke's third law)
English physicist & science fiction author (1917 – 2008)

"The Bible shows the way to go to heaven, not the way the heavens go."
--Galileo Galilei

"By denying scientific principles, one may maintain any paradox."
--Galileo Galilei

Induction and Deduction

Supplementary Material for CFB3333/PHY3333

Professors John Cotton and Stephen Sekula

January 25, 2012

Based on the following information on the web:

http://www.physics.smu.edu/pseudo/Induct/

The Scientific Method
A Brief Review

- Observation of a phenomenon
- Formulation of an hypothesis
  - this proposition must be testable by experiment, either for the purpose of being disproven or confirmed
  - an hypothesis can (almost) never be proven. It can only live to predict another day, perhaps eventually being elevated to theory, law, or fact status.
- Performance of experiment
  - the experiment will refute the hypothesis, confirm it, or be inconclusive
    - any one of these (especially the third) warrants performing more experiments
  - a good scientist reports the results REGARDLESS of the outcome

http://www.physics.smu.edu/pseudo

The Scientific Method
A Brief Review

- Observation of a phenomenon
  - what kind of observations?
  - how reliable are the observations?
- Formulation of an hypothesis
  - how does one begin to form a causal explanation for the phenomenon?
  - what evidence is used to generate the hypothesis?
  - how reliable is the evidence?
- Performance of experiment
  - what means are available for testing different properties or ideas?
  - how does one setup a reliable experiment?
  - how does one gather information from the experiment?

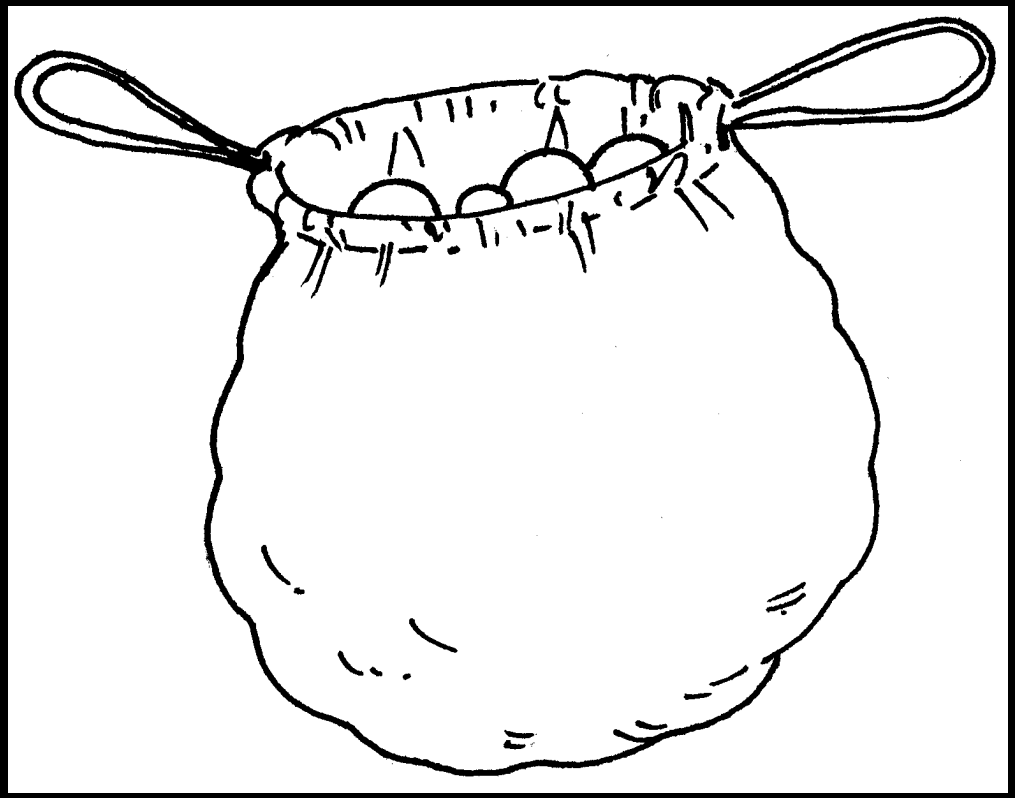
Induction

- The creative part of science
  - make a specific observation and from that state a general hypothesis (make generalizations based on specific observations)

Natural sciences (physics, chemistry, biology, etc.) are inductive. Evidence is collected. The Scientific Method is applied. Start with specific results and try to guess the general rules. Hypotheses can only be disproved, never proved. If a hypothesis withstands repeated trials by many independent researchers, then confidence grows in the hypothesis. All hypotheses are tentative; any one could be overturned tomorrow, but very strong evidence is required to overthrow a "Law" or "Fact".

http://www.physics.smu.edu/pseudo

Example of Induction



Consider this “thought experiment”:

I have a bag of marbles. I randomly draw 20 marbles from the bag. All of the marbles I draw are white.

I can now make an inductive proposition:

HYPOTHESIS: all marbles in this bag are white. That explains why drawing 20 at random always yielded a white marble.

Further sampling is required to test the hypothesis. All it takes is one non-white marble to overturn my hypothesis, requiring me to amend it.

NOTE: in this thought experiment, we have a rare example of a case where the hypothesis can be absolutely proven: I can dump out all the remaining marbles and see if they are all white.

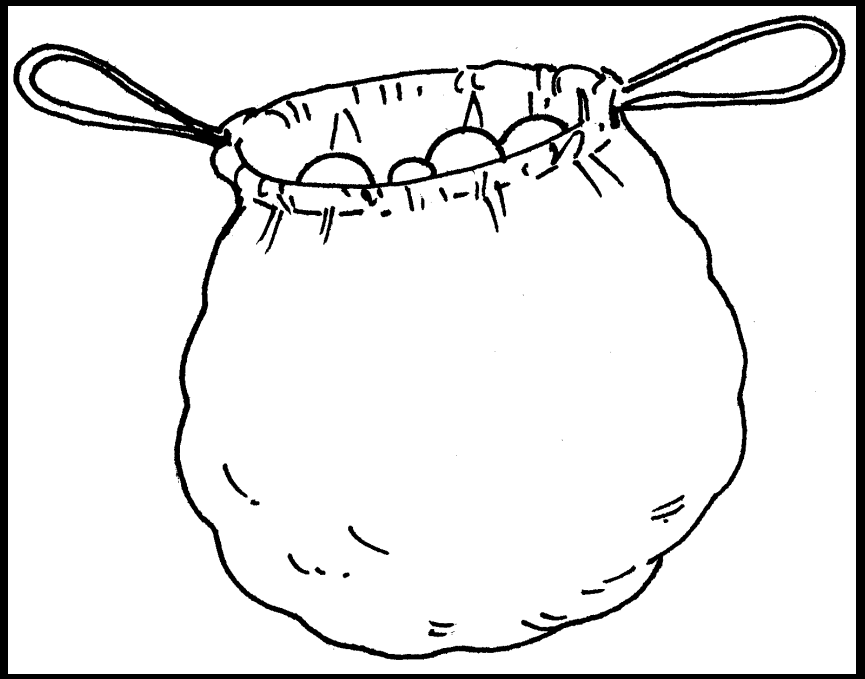
Deduction

- begin with a general rule and make specific predictions
  - conclusions follow from a set of premises or hypotheses

Mathematics is a good example of a deductive framework. Axioms (fundamental assumptions or propositions) are made. They are not tested; they are assumed to be true. Theorems (specific statements) are produced from the axioms.

If a set of axioms produces a theorem and also the NEGATION of the theorem, then the axioms are inconsistent and must be revised or replaced.

Example of Deduction #1



Consider this "thought experiment":

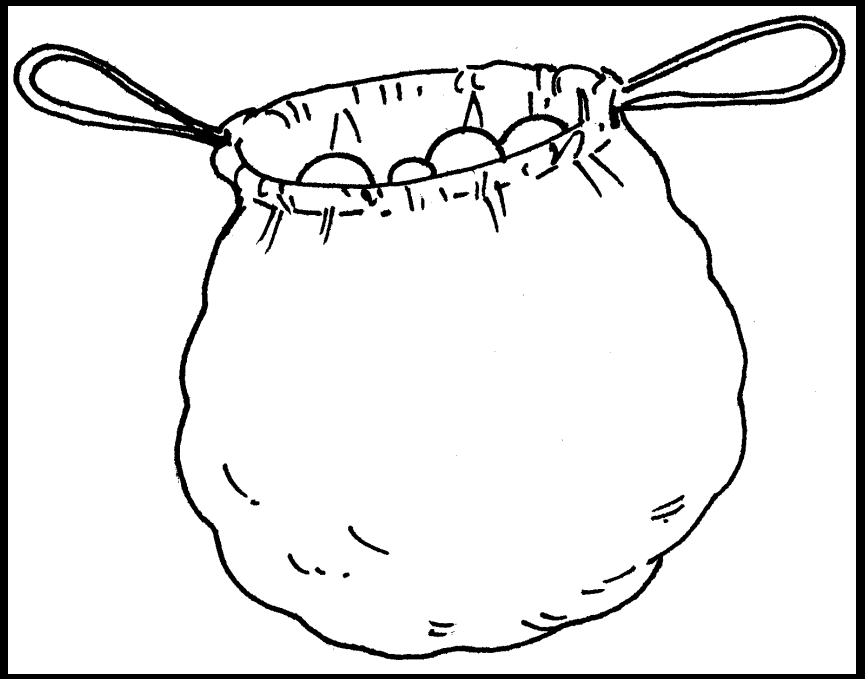
- We have a large bag of marbles
- All of the marbles in the bag are white
- I have a random sample of 20 marbles taken from the bag

Without looking at the 20 marbles, I can deduce that all of them are white.

This kind of reasoning is called "modus ponens," from Latin and meaning "the way that affirms by affirming." In a logical form, *modus ponens* can be framed as:

If P, then Q
P
Therefore, Q

Example of Deduction #2



Consider this other "thought experiment":

- We have a large bag of marbles
- All of the marbles in the bag are white
- I have a random sample of 20 marbles (I don't know if they are from the bag or not) that are multi-colored

I can deduce that the marbles in my sample of 20 are NOT from the bag of all-white marbles.

This kind of reasoning is called "modus tollens," from Latin and meaning "the way that denies by denying." In a logical form, *modus tollens* can be framed as:

If P, then Q
Not Q
Therefore, not P

http://www.physics.smu.edu/pseudo

DIFFERENT WAYS OF ARGUING

Aristotelian Method

(Aristotle: 384-322 B.C.)

Argument by authority: here is the way I see it, everybody listen!

Some things he said seem reasonable:

All Earthly objects tend to rest -- their natural state.
All celestial objects remain in circular motion forever.

But other things he said make no sense today:

"Males have more teeth than females in the case of men, sheep, goats, and swine; ..."
Aristotle online -- The History of Animals 350 BCE

Heavier objects fall faster than light ones, in proportion to their weight.

How about an experiment to test these arguments? Do they pass a self-consistency test?

If your theory is not self-consistent, or your theory disagrees with careful experiments, then your theory is wrong. It doesn't matter how beautiful the theory is; it's wrong.

Galilean Method

(Galileo Galilei: 1564-1642)

Argument by evidence: experiment is the only way to gather objective evidence, upon which argument should be based.

He greatly improved the telescope. He profited by selling his telescopes and designs to merchants. Thanks to his profits and the support of a wealthy patron, he was free to pursue fundamental research (research for the sake of learning). He was the first to observe moons orbiting Jupiter, to see the phases of Venus, to realize that the moon had mountains and craters, and to see sunspots.

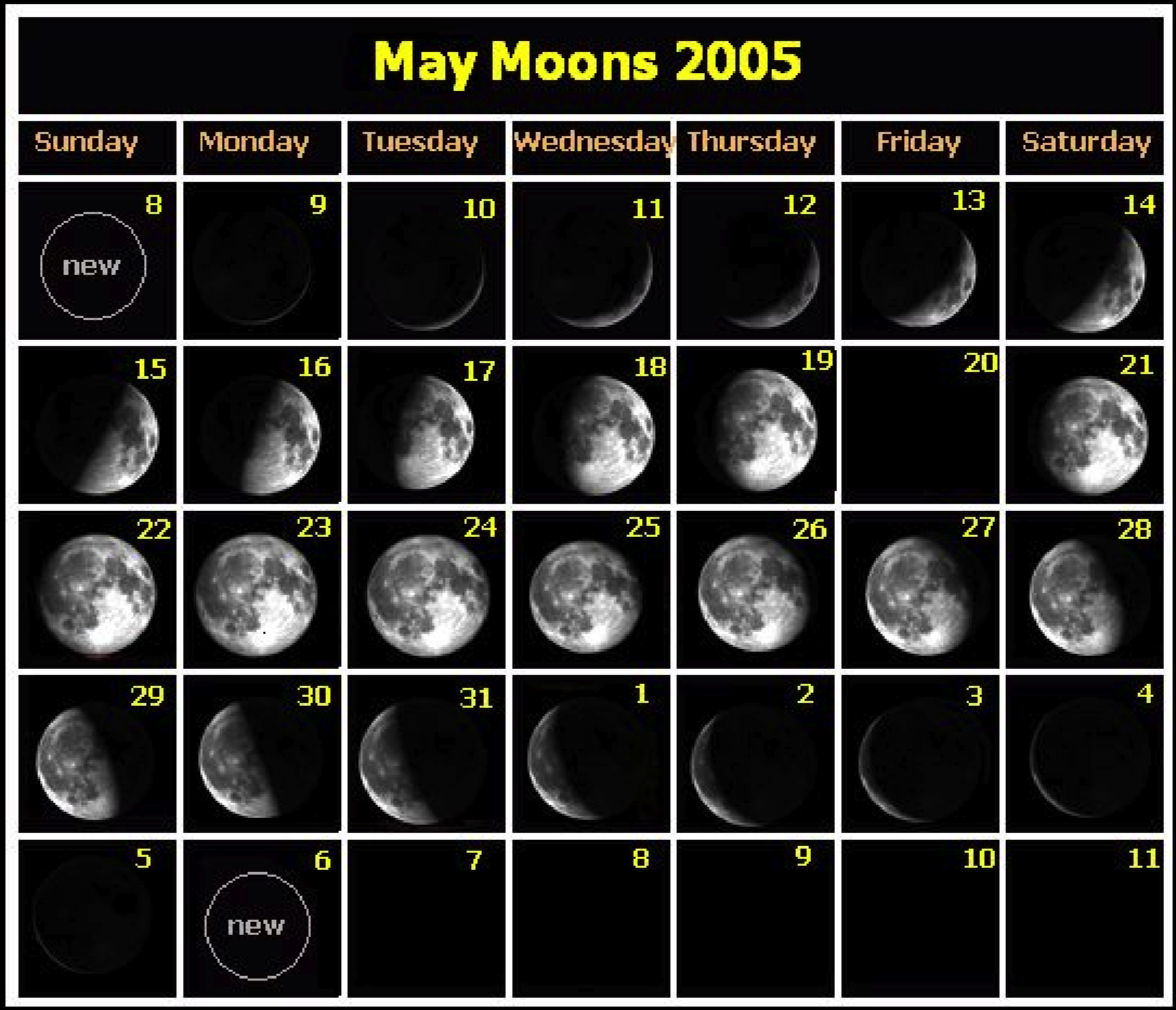
Based on these observations, he argued that the Earth cannot be at the center of the cosmos; rather, the Earth and other bodies orbited the Sun.


http://www.physics.smu.edu/pseudo

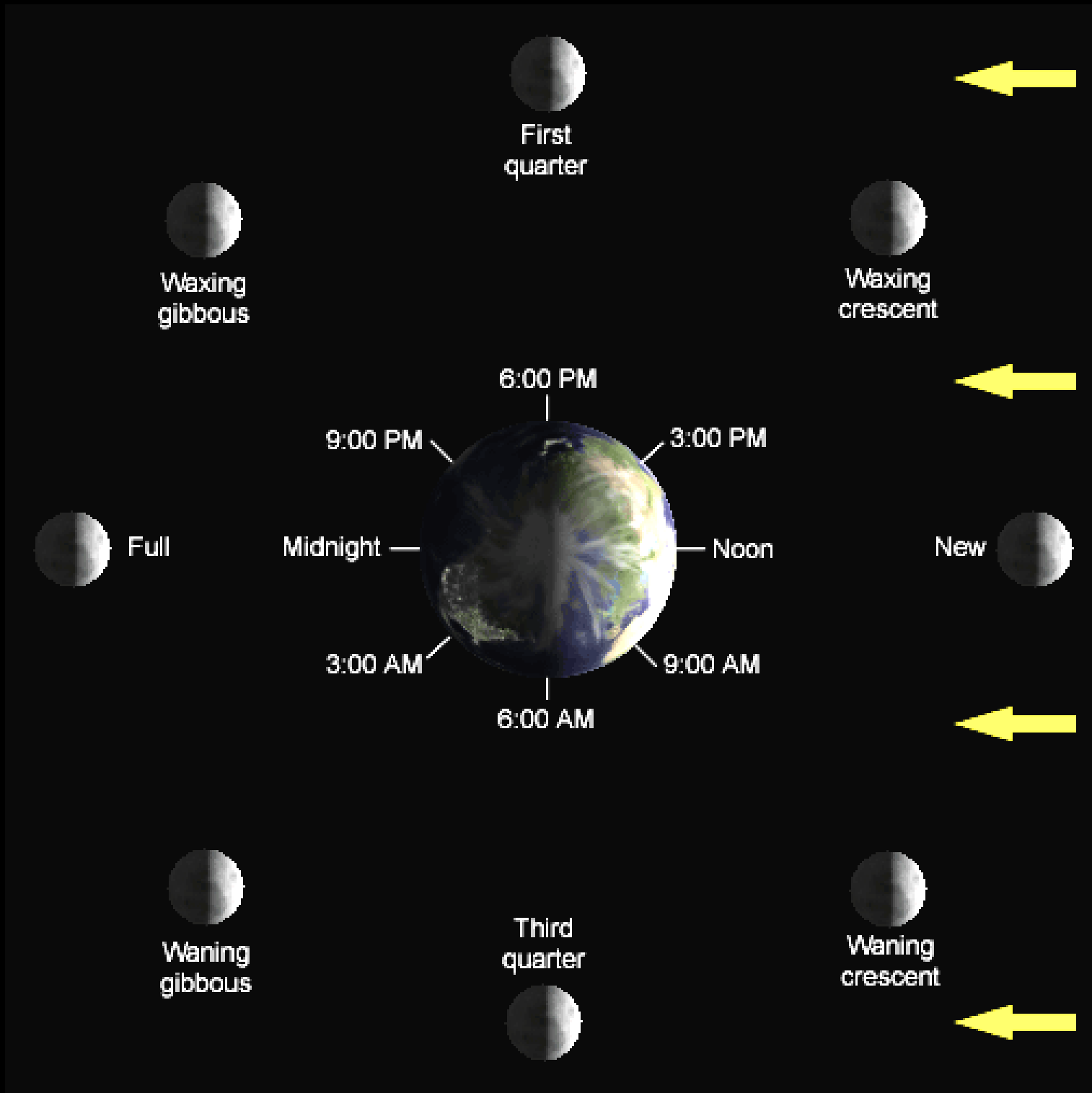
http://www.physics.smu.edu/pseudo

May Moons 2005

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
8 new	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4
5	6 new	7	8	9	10	11



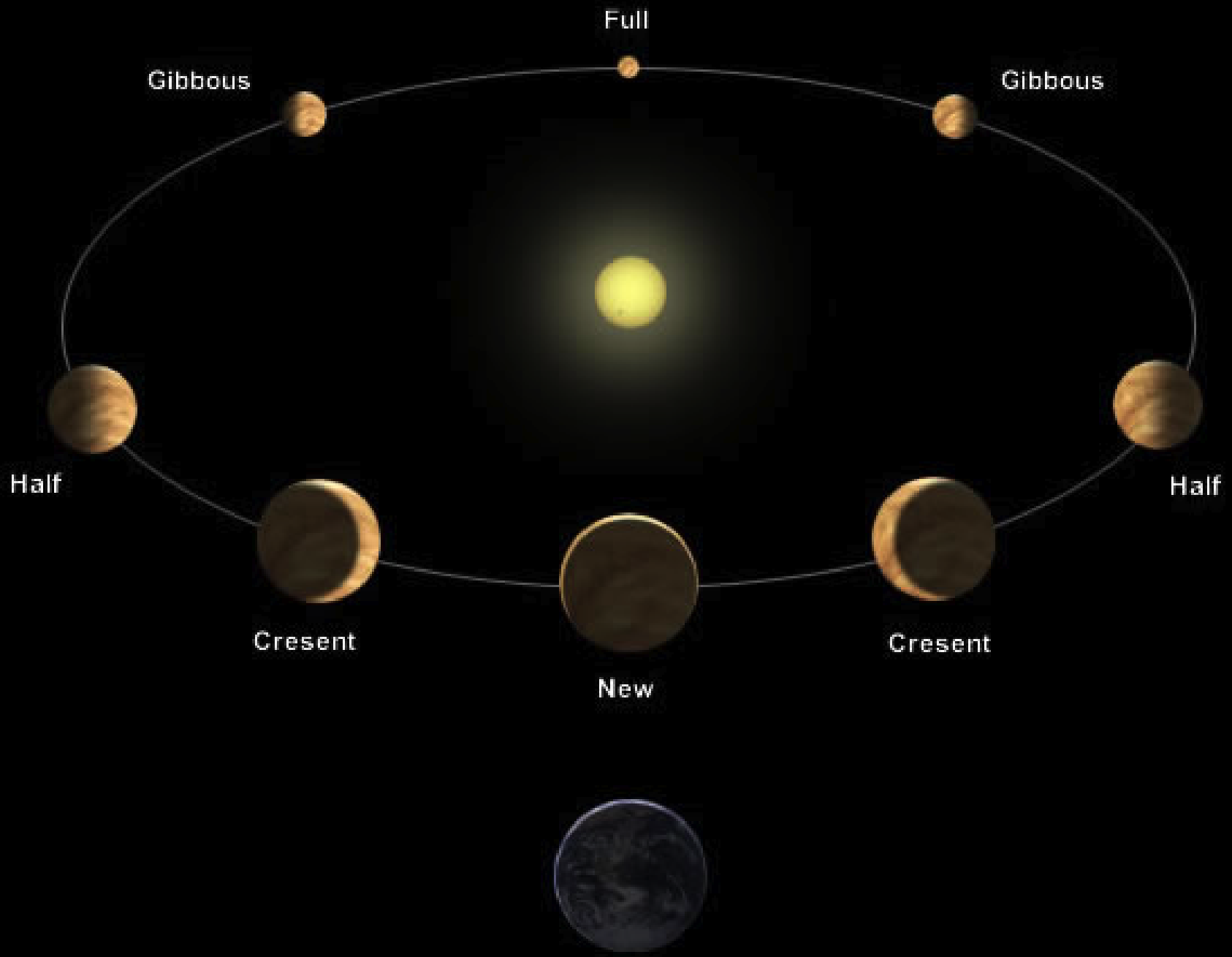
http://www.physics.smu.edu/pseudo



In a Geocentric Universe

- If Venus is between Earth and the Sun
  - the phases of Venus should only EVER be crescent or all dark (never fully lit)
- If Venus is beyond the Sun
  - the phases of Venus should only ever be crescent or all bright (fully lit, never fully dark)
- What did Galileo observe?
  - at first, he observed Venus to be small and fully lit
  - it went through crescent phases and grew larger in size, and later in the year was nearly fully dark
  - this could not be explained in the geocentric model of the solar system.

http://www.physics.smu.edu/pseudo



http://www.physics.smu.edu/pseudo

Galilean Method

(Galileo Galilei: 1564-1642)

Argument by evidence: experiment is the only way to gather objective evidence, upon which argument should be based.

Galileo's conclusion contradicted the widely held belief, based on “common sense” and Biblical scholarship, that the Earth was the center of the cosmos. For his arguments, and his publications, he was brought before the Inquisition and forced (on penalty of death) to recant his “opinion” and affirm the word of the Bible. He was placed under house arrest for the remainder of his life. Ironically, while under house arrest he revisited some old work he had abandoned and began to write down the laws of motion. These were formalized by Sir Isaac Newton, who was born in the same year Galileo died.

Galileo's major publication, containing all his data and arguments, was entitled “Dialogue on the Two Chief Systems of the World.” It was formally removed from the Vatican's banned books list in 1835. Pope John Paul II apologized for the “Galileo affair” in 1992, referring to it as a “tragic mutual incomprehension.”

http://www.physics.smu.edu/pseudo

Apollo 15 Mission (1971): http://www.youtube.com/watch?v=5C5_dOEyAfk