# *Using the Moon as a Tool for Discovery Oriented Learning*

R. Hays Cummins, Interdisciplinary Studies

Miami University

New! Search This SITE



---

The Earth-Moon system was recorded by NASA's NearEarth Asteroid Rendezvous (NEAR) spacecraft on1/29/98.
From Astronomy Picture of the Day

## ABSTRACT

**Portions of this work are from the article**: Cummins, R.H., Ritger, S.D., and C.A. Myers. 1992. *Using the moon as a tool for discovery-oriented learning.* Journal of Geological Education. 40(2):142-146.

To excite students about the scientific approach to viewing the natural world, we use laboratory exercises that rely on personal observation, data collection, interpretation, and model development. In this laboratory exercise, which is suitable for introductory earth science courses, students are asked to (1) test the hypothesis that the moon revolves east to west around the earth, (2) determine, by lunar observation, approximately how many degrees the moon revolves per night, and (3) develop a scale model of the earth-sun-moon system with which students demonstrate the phases of the moon. Although this exercise can be frustrating for students at first, we have found that, given time, carefully managed discussion, and the opportunity to interact with others in the laboratory group, most students develop a good understanding of the earth-sun-moon system and, more importantly, benefit by arriving at the knowledge through self-directed and group-assisted observation and reasoning. We believe self-discovery is the most important component of this process. Advantages to using the moon include its familiarity (which makes it easier to generate student interest), its accessibility (assuming cooperative weather), and the relative ease with which required astronomical measurements can be made.

*Picture taken by Nancy Teague and Jodi Forester, Junior Seminar, Interdisciplinary Studies*

The Moon lab is used in Geol 499/599: Tropical Marine Ecology of San Salvador, Bahamas & Florida Keys and WCP 121: From the Universe to the Duck Pond: Exploring Patterns & Processes in Natural Systems to illustrate the importance of careful observation, the use of models to understand the natural world & the testing of a variety of hypotheses.

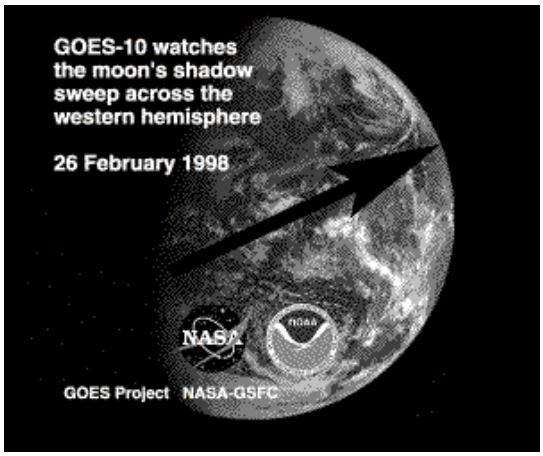
## A Common Experience

Several years ago, I (Cummins) taught introductory geology to a class of about 50 students in a traditional geology department. Most were fulfilling a science requirement. As in many introductory science courses, I lectured three times each week and taught a two-hour laboratory. I did not go out of my way, other than an occasional query to the class, to raise questions in students' minds because I was intent on covering the material, which seemed indisputable anyway.

As in most introductory physical geology courses, we spent class time discussing origins of the universe and our solar system. Besides discussing the Big Bang theory, we covered the geologic characteristics of the inner and outer planets as well as earth-moon geometry as it relates to the phases of the moon. I used an illuminated orbiter planetarium (sun, earth, and moon) to demonstrate the phases of the moon, the proper earth- moon alignment for lunar and solar eclipses, and changes in seasons over the course of a year. Without doubt, many students easily followed my explanations while watching the demonstration. I was satisfied with this effort at first. However, I later regretted missing a golden opportunity to have had the students become active participants in the scientific method rather than passive listeners and observers of my demonstration.

Although I lectured with care and received good evaluations, my students were treated as if they were "empty vessels" waiting to be filled with the knowledge of a resident expert. Uncertainty and skepticism were not part of much of the course because it was "top-heavy" with facts. I covered necessary information. I wonder, though, what value those students place on this earth science course three years after they took it. Because I was so content-driven, students did not learn much about the scientific process. I know my experience is not atypical; is it so amazing that many students are bored and uninterested in science?

From these initial experiences, three of us teaching in the School of Interdisciplinary Studies at Miami University developed a lab exercise that (1) directly involves students in better understanding the phases of the moon--a phenomenon that many people assume they understand, and more importantly, (2) emphasizes the importance of active participation and the use of careful observation in the scientific method, so that students can practice science rather than just hear about it.




A **fantastic** GOES 10 satellite loop (animated gif) of the Feb. 26, 1998 Solar Eclipse! (From GOES Hot Stuff.)

## The Moon Discovery Laboratory

The moon is an excellent object of study for a process-oriented, earth science lab (Johnston, 1967; Dexter, 1968). It is a celestial object with which we are all familiar. Countless legends are associated with its phases, including, but not restricted to, werewolves, romance, and (if you stretch it) bizarre behavior such as adolescent "mooning" activities. Calendars in many cultures are based upon its cycles. The ancient Babylonians based their calendar on the cycles of the moon. The Jewish and Moslem religions currently use a lunar calendar to measure the passage of months and years. Each lunar month begins with the appearance of a new moon. Ever wonder why the date of the Christian Easter holiday varies from year to year? Interestingly, the Easter holiday is always the first Sunday after the full moon which happens upon or after March 21.

Most people have heard the terms harvest moon, new moon, and blue moon, yet few have an understanding of what these terms mean. The movie *A Private Universe*, which we often show in conjunction with this lab, shows recent Ivy League graduates unable to explain the basis of seasons or why there are phases of the moon.

The moon is of great scientific importance. Oceanographers model earth- moon-sun gravitational interactions to predict tides. Jastrow (1990) referred to the moon as a "Roseta Stone" because the moon provides us a glimpse of the history of our solar system. It is instructive to contrast the geology of our dynamic, rapidly weathering, plate tectonic driven earth with that of our comparatively static, unweathered, solid to the core companion. The moon has also often been cited as an example of the importance of extraterrestrial impact in our solar system's history (Marvin, 1986). Craters over 100 km in diameter on the moon attest to the numerous catastrophic collisions in the past. These can be compared with the hypothesized extraterrestrial impact on earth that may have caused the end Cretaceous mass extinction.

Because the moon is so familiar to us, it can be extremely useful in emphasizing the importance of careful observation--even the most familiar phenomena may require investigation to yield better understanding. Its use as a teaching tool in the earth sciences is very effective, in part, because the lessons learned by students (hypothesis testing or the power of observation, for example) are much more powerful when familiar objects are examined with new attention.

## The Lab Project

To begin, we engage the class in a discussion of important lunar terms and concepts. These include synodic month,

sidereal period, conjunction, opposition, earth-moon system, common center of mass, perigee, apogee, lunar and solar eclipses, orbital plane, occulation, declination, maria, highlands, and lunar phases (new moon, first quarter, full moon, and third quarter).


From Prof. Arnold V. Lesikar, Physics Dept., St. Cloud State University. This is an AMAZING Astronomy website!

## Some Important Lunar Terms

**Sidereal Month**-The time it takes for the moon to complete one full orbit of the earth, measured with *respect to the stars*. This interval is the moon's true orbital period, ~ 27.3 days.

**Synodic Month**-The time it takes for the moon to complete one cycle of phases, i.e. new moon to new moon, or full moon to full moon ~ 29.5 days.

Why is the synodic month about 2 days longer than the sidereal month?

-As the moon is revolving around the earth, the earth is also revolving around the sun. The earth has completed about 1/12 of it's orbit around the sun in one lunar month.Therefore, the moon must travel slightly further than 360 degrees to get from one full moon to the next.

**Opposition-** That time during the moon's orbit when the earth is located between the moon on one side and the sun's rays on the other.

**Conjunction**- That time during the moon's orbit when the moon is located between the earth and sun. Sun-Moon-Earth line up.

**Quadratures-** That time during the moon's orbit when the sun, earth, and moon are positioned such that the moon, earth, and sun form a 90angle with one another.

**Apogee-** The moon's orbit around the earth is an ellipse. During apogee, the moon is at it's greatest distance (about 405,800 km) from the earth.

**Perigee-** During perigee, the moon is at it's closest distance to the earth (about 375,200 km). Check out this amazing comparison of apparent size differences of the moon at perigee and apogee. The full moon on Dec. 22, 1999 , was "a full-perigee-solstice moon, reaching its full phase and perigee (the closest point in its orbit) on the solstice, the first day of northern hemisphere winter." From Astronomy Picture of the Day

**Spring Tide-** A tide which results in the greatest range between high and low tide. How frequently do spring tides occur each month?During which phase(s) does/do spring tides occur? Why?

**Neap Tide**- A tide which results in the least tidal range between high and low tide. How frequently do neap tides occur each month? During which phase (s) does/do neap tides occur? Why?

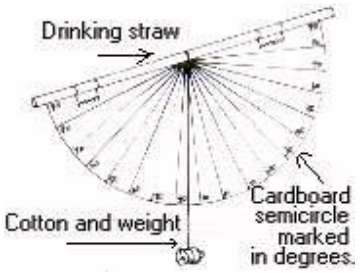
**Gibbous**- Designating the moon when it is in a phase between half moon and full moon and the curves forming its outline are convex.

---

The lab should be scheduled to coincide with phases of the moon convenient for viewing; first quarter thru full moon works well. To whet appetites, we have a night of telescopic observation of the moon. Even small aperture telescopes do a wonderful job of interesting students in lunar features. We usually scan the lunar highlands and search out prominent craters such as Copernicus and Kepler. We discuss lunar geology and examine impact features in detail. Students work in groups of four.

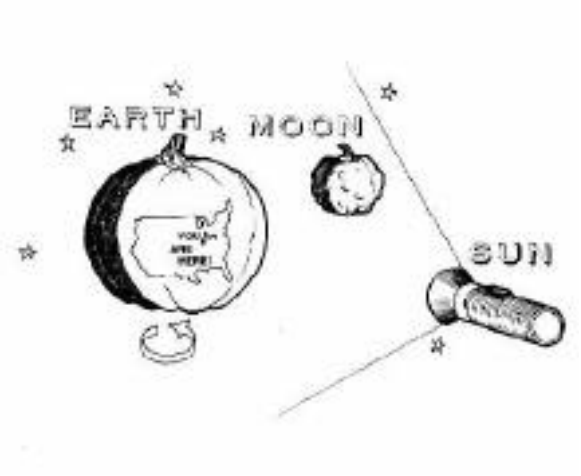
## Hypothesis Test-Exercise 1

In the first experiment, which requires a protractor, straw, and tape (to make an astrolabe), students test a hypothesis by observing the earth-sun-moon system and collecting the appropriate data.




We ask the following question: Given that the earth-moon system orbits a common center of mass resulting in a new moon, first quarter, full moon, and third quarter in the course of one lunar month, test the following hypothesis: "As viewed from a pre-defined location of your choice, the moon, during the course of your observations, revolves east to west around the earth." You are asked to observe the moon on consecutive nights and (a) derive a test for the hypothesis of lunar motion and (b) derive a method of determining the number of degrees the moon revolves around the earth in one day. **Hint:** This is not as simple as it may seem!

## Earth-Sun-Moon Model-Exercise 2



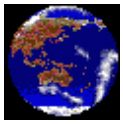

**The earth-sun-moon model. A map & a flag are used as frames of reference on a rotating earth. The student-generated vision of the world has Oxford, Ohio as its center.**

The second exercise requires a flashlight, a pumpkin (or equivalent), and a squash (or approximate equivalents), which students use to develop a model that demonstrates the phases of the moon. Models are used to better understand the world around us. Models of atoms, our solar system, and chemical compounds, for instance, help us to see and imagine possibilities that would otherwise be inacessible. To gain a more profound impact using this earth-sun-moon model, it is important to generate a model to scale, at least at first. If your model were to scale, would you be able to continue with your understanding of the earth-moon system? Or, might you have to make some compromises to continue?

**Some beginning questions:** In your Earth-Sun-Moon system(using your model earth as your beginning frame of reference), if it were true to scale, what would be (1) the model flashlight diameter of the sun; (2) the diameter of the model moon? (3) What would be the distance between the model earth and sun? The model earth and moon? Ask students to make predictions **before** doing their calculations.

---

**Given:**



Actual diameter of the earth~12,756 km

Actual diameter of the moon: ~3476 km

Actual diameter of the sun~ 1,390,000 km

Average distance between the earth & moon~384,000 km

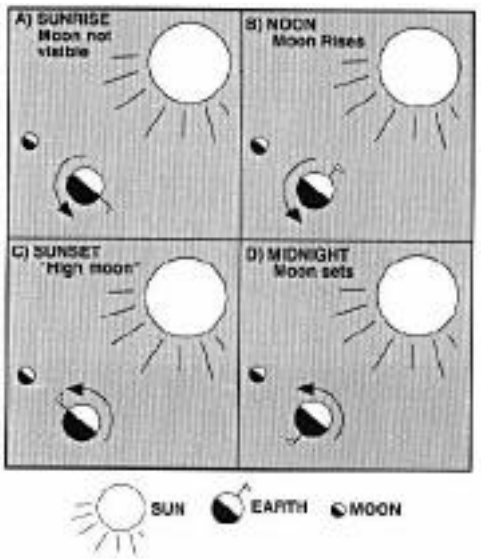
Average distance between the earth/sun~150,000,000 km

Go HERE: To pinpoint the exact time of: MOONRISE/MOONSET/PHASE for your location!

## Phases of the Moon

A Waxing Moon! 1/9/98

When attempting to understand why there are phases of the moon, always think in terms of the angular relationships between the arrangement of the earth, moon, and sun in space. As these angular relationships change, so do the phases.




**The flag marks the observer's location on earth. As the earth rotates, the field of view of an observer changes. During first-quarter, moonrise on the ?????? horizon takes place at about ??????? and moonset occurs on the ?????? horizon at ???????.**

Several Hours Later on 1/9/98

Another Waxing Moon at Sunset, 2/8/98

## Use your earth-sun-moon model to address these remaining questions:

Remember, a **frame of reference** on your "earth" model is very important!

- Which way does the model earth rotate? Label your earth-model horizions (N,S,E,W).
- Which horizon does the model sun rise? set?
- Which horizon does the moon rise? set?
- Does the moon revolve around the earth? If it does, which direction does the moon revolve?
- Does the moon rotate on its axis? If it does, why don't we ever see the far side of the moon from the earth's surface?
- What are the differences between a lunar and solar eclipse?
- Does a full moon in China occur within 24 hours of seeing the full moon in Oxford, Ohio?

Use the earth-sun-moon model to determine the direction that the earth rotates on its axis, approximate local times (sunrise, noon, sunset, and midnight) of moonrise, high moon, moonset, and times of visibility of the moon.

- **Table 1.** Complete this chart with times (sunrise, noon, sunset, and midnight) using the earth-sun-moon model.

| Phase | Moonrise | High Moon | Moonset | Times of Visibility |
|---|---|---|---|---|
| **New Moon** | ? | ? | ? | ? |
| **First Quarter** | ? | ? | ? | ? |
| **Full Moon** | ? | ? | ? | ? |
| **Third Quarter** | ? | ? | ? | ? |

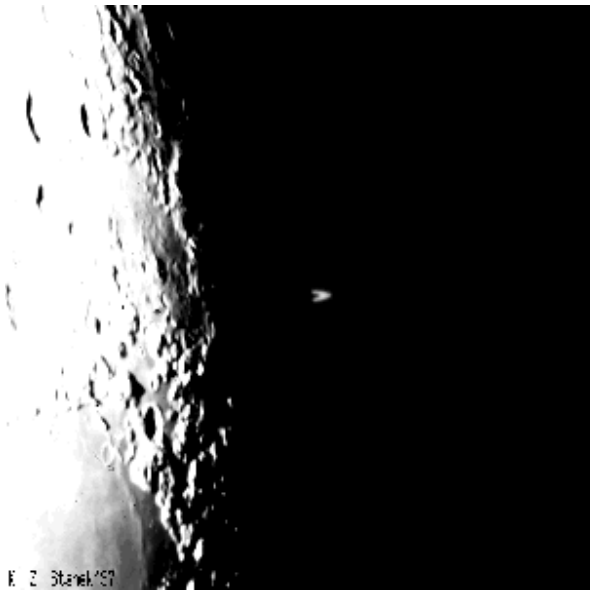
Now, using your model to guide you, can you explain why there are phases of the moon? If it all is just too much, visit the Astronomy Site of the Day for a wonderful diversion. The Phases of the Moon Site provides dates and phases of the moon for any month or year!

**Ever think about what a Full Moon Looks like from Beyond Planet Earth?** Check out this satellite perspective of a full moon over N America and Asia! (From GOES Hot Stuff.)

---

A brand new "new" moon, one day old, March 9, 1997. Cleveland National Forest, southern California. Photo by Emily Harrison and her buddy Sarah Bernhardt.

---



Many stargazers in the U. S. were able to watch a lovely lunar occultation early last Thursday morning (9/24/97) as a bright Moon passed in front of Saturn. Using a 1.2 meter reflector, astronomer Kris Stanek had an excellent view of this dream-like event from the Whipple Observatory atop Arizona's Mount Hopkins.This animated gif image was constructed by Wes Colley from 4 frames taken by Stanek at 35 second intervals as the ringed planet emerged from behind the Moon's dark limb. From Astronomy Site of the Day. Go here for more info on Ocullation Events.

## Some Wonderful Moon Links

- The "Moon" from *Views of the Solar System*
- The Picture List from *The Nine Planets*
- A **Monthly Calendar and Phases of the MoonTerrific!** From Prof. Arnold V. Lesikar, Physics Dept., St. Cloud State University
    - The "Age of a Phase of the Moon"
- Earth and Sky "Skywatching Center" Excellent Nightly Skywatching Tips!

As viewed from your location on earth, are the shadows moving in the right direction as the moon changes phase?

## Some Additional Questions:

1-Using your model, explain why LUNAR ECLIPSES occur only during full moon. If a full moon occurs every month, why don't we see lunar eclipses every month?

2- Using your model, explain why SOLAR ECLIPSES occur only during new moon. If a new moon occurs every month, why don't we see solar eclipses every month?

**Movies of the Sun & Moon!**

- Quicktime Movie:The last solar eclipse of 1999! This video from NASA covers all of the bases.
- A Quicktime Movie ~ 2 MB of the Suns Lower Corona-From the Stanford Solar Center. This site presents a collection of fun educational activities based on Solar Oscillations Investigation (SOI) and Solar and Heliospheric Observatory (SOHO) data. A Fantastic SITE!!
- Fred's Excellent Eclipse Movie Complete with the OO's and Ah's ~15MB! Quicktime!
- Eclipse MPEG Movie~1.5 MB Oct 24, 1995 by the Japanese Yohkoh ("Sunbeam") Soft X-ray Telescope (SXT) covering the period when the path of totality on the earth's surface was sweeping eastward from Myanmar across Thailand and Cambodia.
- Fred Espenak of NASA Goddard Space Flight Center caught this Earth-Based Imagery~925 K MPG of the Oct '95 Eclipse in India.
- Some absolutely wonderful Quicktime! Movies of the Apollo 11 Mission. From the High Energy Astrophysics Research Center Video Archives.
    - The Eagle has Landed at Tranquility Base!
    - President Nixon makes a historic phone call to the crew.
    - The Placing of the US flag on the lunar surface

3- How would the relationships between the period of rotation and revolution of the moon affect whether or not we see the "far side" from the earth's surface? Since we don't see the other side, what is your explanation? Use your model to generate an explanation.

4- What tests would you use to determine whether the moon formed from the same dust cloud as the earth, was fragmented from the proto-earth at some later date, was formed from a collision with an extraterrestrail object, or was an alien body captured by the earth as the satellite moved within the grasp of the earth's gravitational field? Can you find the most recent literature references on this topic?

5- A laser beam fired to the moon from the earth's surface strikes a mirror (left by the Apollo astronauts for the purpose of studying changes in distance between the earth and moon) and is reflected back to the earth. Travel time is 2.562 seconds. How many kilometers away is the moon from the earth?

---

## Tides & Other Moon Links

And of course, there is the major discussion on **Ocean Tides** (This really cool site will present tidal predictions and graphs for many coastal locations in the US.) Go HERE for a question-answer WWW page on tides. I plan on adding more info about the tides on this web page, but that is for another day!

## Other Really Great Moon-Sun Links:

**US Naval Observatory- Astronomical Applications** computes, from fundamental astronomical reference data, the position, brightness, and other observable characteristics of celestial bodies, as well as the circumstances of astronomical phenomena.

- U.S Naval Observatory-Astronomical Applications
  - Sun and Moon Data for One Day
  - Upcoming & Recent Eclipses of the Sun and Moon
  - Sun or Moon Altitude/Azimuth Table for One Day
  - Earth's Seasons, Perihelion and Aphelion 1992-2005
  - Dates of Ash Wednesday and Easter Sunday
- Times of Rise and Set for Sun and Moon from the "Dome of the Sky"

**For the latest NASA News on the moon, visit The Lunar Prospector site.**

## Interested in Astronomy and Other Extraterrestrial Things?

The database has a very large number of links and descriptions of URLs on phylogeny, evolution, astronomy, tropical weather, ecology, and earth science. Just type in a few key words!

**Enter some key words to search by:**

**Find pages with** all **of these words and return** 10 **results.**

☐ Detailed Results ☐ Search Phonetically ☐ Begins With Searching

Search for key words found only in: ☐ URLs ☐ Titles ☐ Header

Search

Got Mac OS 8.5? Download Hays' Sherlock Plug-In

## Interested in the Weather?

| | | |
|---|---|---|
| **Weather Home Base**<br>A Complete Listing of "all things weather." Pretty Large Site. Can be slow to load. | **Radar Overview & Severe Weather**<br>See Where the Action is! | **Midwest Weather**<br>A Quick Look! |
| **Satellite Links**<br>A complete listing of satellite images and movies. Text based for fast downloads. | **Hurricanes & Tropical Weather**<br>The Atlantic season is will be here before you know it! | |
| **Satellite Downloads and Other Maps**<br>Real-time satellite movies automatically downloaded. Graphics Intensive! | **Just the Maps & Views!**<br>While far from complete, these downloaded views provide for a satisfying overview of North American Weather. | **"Text Only" Main Home Base**<br>A complete weather listing, non-graphics based. Not as interesting, but download time is much quicker! |


**| Return to Home Page |**

# Visit the "Treat of the Day"

**Liven up your day with the "Midwest Weather!"**

# Site Line-Up--Table of Contents

## Tropical Ecosystem Courses/Weather & Earth Science Resources

WEATHERSITES Go!

TROPICAL ECOSYSTEM COURSES and IMAGES Go!

TROPICAL ECOSYSTEMS FIELD COURSE PRESENTATIONS Go!

|**Earth Science Resources** | **Astronomy Links** | **Global Change** |

## Other Academic Courses, Student Research Feedback, Other Stuff

COURSE SYLLABII Go!

STUDENT RESEARCH PROJECTS AND FEEDBACK Go!

| Educational Philosophy | **Discovery Labs:** Moon, Geologic Time, Sun, Taxonomy, Frisbee | Project Dragonfly | Vita | Field Course Postings | Student Research Postings | Nature/Science Autobiography |

## Teaching Tools and Other Stuff

DISCOVERY LABS Go!

**Daily Necessities:** Macintosh Resources | Search Engines | Library Resources| Server Stats| Family Album | Add to Guestbook | View Guestbook | Wild Flowers in Miami's Natural Areas

 Any mail, comments or suggestions? You can **Add to my Guestbook** ,**View the Guestbook** or e-mail me privately at HaysC@muohio.edu.

**Thanks for stopping by!**

---