Participants' Names: ___________________________ & __________________________

STAR FLEET ACADEMY'S
"AST 501: Advanced Planetary Observations"
A GRADUATE LEVEL SEMINAR

Launched from Cape Kennedy a mere 16.7 hours ago our shuttlecraft approaches Star Fleet Academy's first Orbital Classroom Observatory, or OCO. Short, pulsating bursts issued from its retro-rockets slowing our approach to the Primary Module. A barely audible thud followed by a short series of dampening vibrations culminates a safe rendezvous. My heart throbs uncontrollably as the hatch slides open, revealing a short cylindrical passageway leading directly to the interior of the observatory … our home away from home for the next nine months.

As a child, I often lay in bed gazing at the unbroken, seasonal procession of stars, endlessly gliding past my window. Never in my wildest dreams had I ever imagined a day when I would be silently floating among the stars high above Earth's atmosphere.

Hastily, you and I release the straps that have bound us to our seats. A simple push propels me toward the main cabin. This is my chance to apply **[1. a. Newton's First Law, b. Newton's Second Law, c. Newton's Third Law d. all of Newton's Laws]** of Motion using my own body as the mass receiving the action. You, my assistant in this adventure, immediately follow. Our curiosities beckon as we float toward a small porthole. We are fully aware that our first assignment aboard the OCO will provide many exciting moments. The sights unfolding before us …bright points of light scattered randomly against a canvass of darkness … overwhelm us. Unlike the stars of our child-hood memories, these do not appear to twinkle because we are now **[2]**.

Shaking my head as if awakening from a dream, I suddenly remember the purpose for our being here. In two short days another shuttle will dock bringing our first group of five graduate students for a ten-day seminar aboard this amazing facility. Ten days is a very short period of time to complete all the requirements I listed in the syllabus when I first proposed this course to NASA. You and I must begin planning immediately.

As our giant, orbiting observatory slowly rotates, we catch our first glimpse of Earth's only natural satellite, the Moon, coming into view. "Lunar phases," I utter excitedly. "What a great place to start!" The small sliver of reflected sunlight on its eastern limb is now a **[3. a. waning; b. waxing] [4. a. gibbous; b. crescent; c. quarter]**. When our students begin their first classes three days from now, half its visible surface will be shining brightly in what is known as its first **[5]** phase. As days pass, more of its surface will gradually brighten as it becomes a **[6. a. waning; b. waxing]** gibbous.

Finally, the entire near side will be aglow with reflected sunlight. The Moon will then be in its **[7. a. new; b. full]** phase.

The Moon's surface appears much closer and brighter when viewed aboard the OCO compared to our observations from Earth's surface. I select "Low Power" and the porthole transforms into a viewing screen. Peering through the viewing screen reveals a world even more intriguing than I had anticipated. I immediately spot craters numbering in the hundreds. A few have **[8]**, appearing as lines radiating outward from their centers. Craters bearing these features are relatively **[9. a. younger; b. older]** than those without them. These radiating lines were created by debris blasted outward as **[10. a. meteors, b. meteorites, c. meteoroids]** that once moved in different orbits within our solar system impacted the lunar surface.

Moving the telescope slightly to the left brings the entire sphere of the Moon into view. I concentrate upon the mare, or sea, in the upper left quadrant. "This is Mare Imbrium, the largest of the Moon's fourteen maria. As an introduction to the Moon from space, I will ask my students to determine the distance across the diameter of this sea measuring from upper left to lower right where the margins of the sea are most distinct. Their answers may vary somewhat from the actual value as that part of the lunar surface will be tipped slightly to our view from the OCO."

Photo: Courtesy of NASA

Tossing a quick glance your way, I suggest you calculate the approximate distance across Mare Imbrium while I continue my observations of the lunar surface.

With a reminder that we see only half the Moon's approximate circumference of 10,927 km, along with instructions that you will find a small ruler and a photo of the near side of the Moon in the instructor's pack, you go to work. You measure the distance across Mare Imbrium to be approximately 19 mm and the distance across the Moon's surface to be approximately 84 mm. Moments later you state the approximate diameter of this mare as being **[11]** kilometers.

I still remember my favorite astronomy professor's first laboratory assignment. We discovered that a crater formed by the impact of a space rock is ten times the rock's diameter and nearly twice its diameter in depth. "What a great idea! I'll have my students calculate the diameter and depth of an imaginary impact crater. Suppose that a rock weighing one kilogram and measuring ten centimeters in diameter impacts the lunar surface. Complete those calculations for me. Would you?"

"That's simple. The diameter of the crater would be about **[12]** centimeters and the depth would be about **[13]** centimeters. Am I correct?"

"We might even consider reversing this procedure with an example of a crater 250 centimeters in diameter. It's quite likely that such a crater could be created by an impacting rock approximately **[14]** centimeters in diameter and a depth of **[15]** centimeters.

"You've taken enough classes from me to know that I love sharing nearly everything I have ever learned about the Moon. Do you remember Clementine, the military satellite that detected the largest known impact basin in the entire solar system right on the surface of our very own Moon and the very first traces of water as well?"

"Not really. Should I?"

"Well, the water was in the form of ice. It was found beneath the Moon's **[16. a. poles, b. near side, c. equator, d. far side]**. Some of the Moon's original water still exists in that area of the Moon because **[17]**."

As I continue my observations, I am amazed to discover that in less than a single day I can actually observe the **[18]**, or boundary between the illuminated and dark portions of the Moon, slowly sweep across the moon's craters, seas and mountains.

A sudden glow within our cabin alerts us that the Sun is about to reappear on the viewing screen as it automatically darkens to protect our eyes. Due to our being in orbit about the Earth, it's been just ninety minutes since we last saw the Sun. "We may now begin our solar studies," I hear my leader suggest.

"This time, I will review the facts you taught my class about our star, the Sun," you proclaim. "I will, that is, if you don't mind."

"Not at all. Go right ahead."

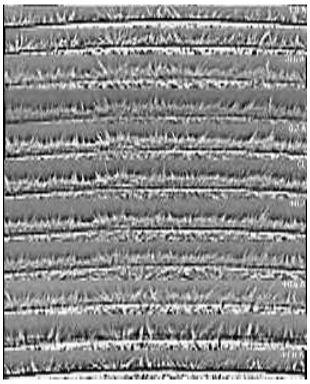
Our porthole is a technically advanced "Eye to the Heavens." With a touch of a finger we can view the Sun in visible light, ultraviolet, X-ray or Hydrogen α. We can even create an artificial solar eclipse.

I continue, "The Sun is Earth's life-sustaining star, a glowing ball of gas held together by **[19]** and powered by nuclear **[20. a. fusion; b. fission]**. Its surface – the part of the Sun that emits the radiation we see – is called the **[21. a. chromosphere, b. photosphere, c. corona].** This thin layer is responsible for its well-defined outer edge.

"Pairs of darkened, nearly circular areas, within this solar layer are called **[22]**. Scientists have studied these darkened areas carefully and now know that they are highly magnetic in nature. This magnetic force blocks the normal convective flow of hot gasses, resulting in **[23. a. cooler, b. hotter]** temperatures and a darkened appearance within these areas.

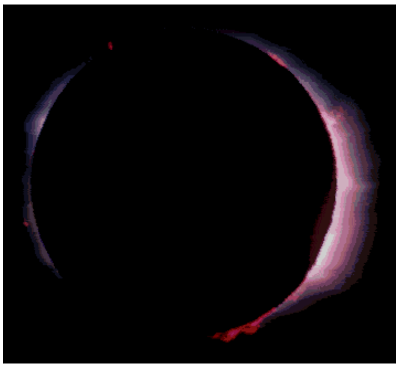
"The regions surrounding many of these dark spots are very active. Looping arcs, called **[24. a. prominences, b. helmet streamers, c. coronal mass ejections]** are formed as gasses are ejected outward and almost immediately plunge back to the surface. Even more explosive events, called solar flares, sometimes flash across the surface of the Sun, blasting particles deep into space.

“Lying above the hot, dense surface is a thin, cooler atmospheric layer called the **[25. a. photosphere, b. chromosphere. c. corona]**. Our Hydrogen Alpha image reveals



short-lived, narrow jets of gas called spicules sprouting upward from this layer. Their darkened appearance is a result of relatively cooler temperatures.

“Touching the screen right here creates an artificial **[26]** blocking out the bright solar disk. Under these conditions the extremely hot **[27]** completely enveloping the Sun and extending outward for millions of miles becomes visible. A constant stream of escaping solar particles collectively called the **[28]** escape through large holes in this layer of the Sun’s atmosphere. Those particles that reach the Earth follow the Earth’s magnetic field to create beautiful polar displays called **[29]**.”



“Very well done, my worthy assistant. I will assign this lecture to be your responsibility.”

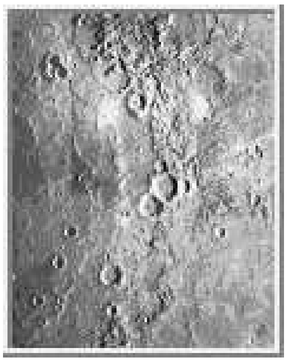
“Let’s keep our viewing window in the eclipse mode just a bit longer and increase its magnification by a factor of ten. In just a moment we should be able to spot Mercury, the fastest **[30. A. rotating, b. revolving]** planet in our solar system.”

"There it is! Just above the solar sphere! Can we increase the magnification just a tad more to get a better view of Mercury's surface features?

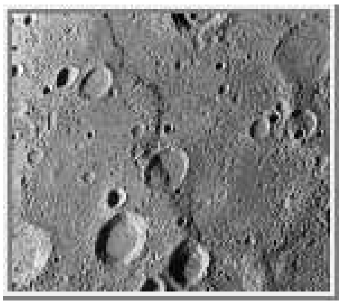
"Wow! What a view!"

"The crater walls aren't nearly as high as those on the Moon. And the ejected materials appear to have landed much closer to the impact sites. That must mean that Mercury's surface gravity is **[31. a. less than, b. nearly the same as, c. greater than]** the Moon's surface gravity.

"The large, flat areas we saw on the Moon, **called [32. a. craters, b. maria, c. highlands]**, seem nowhere to be seen. And there seems to be **[33. a. fewer, b. about the same number of, c. more]** craters per given area on Mercury than on the near side of the Moon.



"I'm certain the entire surface of Mercury must have been heavily cratered millions of years ago. Those intercrater plains had to have formed late in the geologic history of the planet. Some planetary geologists believe the older craters were **[34. a. worn down by erosion, b. covered by lava flows, c. flattened by gravitational forces]**.



"Mercury is about to enter the bright sphere of the solar disk, so take a final look. See that long, cliff-like structure. That's a scarp. Nothing like this is found on the Moon's surface. Notice that the scarp crosses several craters. This indicates that whatever produced the scarp must have occurred **[35. a. before, b. during, c. after]** those craters were formed.

"Next stop …Venus! Venus orbits between Earth and the Sun. When it is farthest from Earth, an alignment known as **[36. a. inferior, b. superior]** conjunction, Venus is in its **[37. a. full, b. quarter, c. new]** phase. Venus is brightest when **it's [38. a. closest to Earth, b. farthest from Earth, c. somewhere between its closest and most distant point]**.

"Viewing Venus through the optical wavelength setting, we see only a blurred, white-yellow disk with just a hint of cloud circulation. Let's see whether that view changes when we switch to the ultraviolet.

"The contrast is much better now because something within the atmosphere itself absorbs the high-frequency radiation of the ultraviolet. Do you see how swiftly the clouds in the upper atmosphere are moving? The upper atmospheric layers rotate in about four days, **[39. a. much faster than, b. about the same as, c. much slower than]** the planet's rotational rate.

"Studies of the atmospheric gasses indicate that the clouds surrounding Venus are composed of **[40. a. hydrochloric, b. citric, c. sulfuric]** acid, the same type of corrosive acid found in car batteries. Venus's **[41. a. high, b. moderate, c. low]** planet-wide surface temperatures are a result of this thick, dense cloud cover.

"Let's see if we can trick our graduate students. Planetary astronomers define "north" and "south" for individual members of the solar system on the condition that planets always rotate from west to east. The ecliptic plane is a large, imaginary area lying within the oval-shaped path of the Sun relative to the stars on the celestial sphere over the course of one year. With this definition, Venus's retrograde, or opposite, spin means that this planet's north pole lies **[42. a. above, b. on, c. below]** the ecliptic plane."

"We've been at this task for hours. Could we please get ready for a cozy eight-hour sleep, after all we've spent most of our time since launch taking nothing but short cat naps?"

"Okay, but let's observe one more planet before calling it a day. That planet is Mars, named for the Roman God of War due to its reddish appearance. Mars is at its largest and brightest **at [43. a. opposition, b. conjunction]** when Earth lies between it and the Sun.

"We are quite familiar with Earth as a planet, and we've carefully observed both Mercury and Venus. We can now use our knowledge and observations of these three planets and our Moon in an attempt to interpret our observations of Mars.

"Have you ever wondered why Olympus Mons is so tall in comparison to volcanoes on the other terrestrial planets? The heights of volcanoes are directly related to a planet's surface gravity. Since Martian volcanoes are so much taller, we can infer that the surface gravity on Mars is **[44. A. less than, b. nearly equal to, c. greater than]** the surface gravity on both Venus and Earth. Since the heights of the tallest volcanoes on Venus and Earth are roughly the same, we can infer that these two planets have very **[45. a. similar, b. different]** surface gravity."

"Now that we've compared volcanic craters found on several of the terrestrial planets, may we spend a few moments discussing impact craters?

"The appearance of impact craters located on planetary and lunar surfaces not yet visited by man or machine may provide valuable clues as to what may be found beneath the surface. Space rocks impacting upon the dry lunar surface eject blankets of dust, soil and boulders. Ejecta blankets surrounding impact craters on the Martian surface appear as if a liquid has splashed or flowed out of the crater during impact. This observation has raised hopes that **[46]** may be found beneath the Martian surface making it more practical for future explorers to colonize the Red Planet.

"The larger of the two Martian moons, Phobos, provides a very interesting phenomenon. Phobos orbits the planet in just 7 hours and 39 minutes, less time than a Martian day. To an observer on the Martian surface, Phobos would appear to move backward across the Martian sky. Because Phobos moves faster than an observer on the surface, it overtakes the planet's rotation. This causes the moon to rise in the **[47]** and set in the **[48]**, crossing the sky from horizon to horizon in a mere 5.5 hours. Deimos, the smaller and more distant of the two Martian moons, completes a single orbit in 30 hours and 18 minutes. Because Deimos requires more than a single Martian day to complete an orbit, its apparent motion, as viewed from the surface, is from **[49]** to **[50]**.

Because the two Martian moons are so different in composition from Mars itself, astronomers believe these moons may have once been **[51]** that were slowed and captured by the outer fringes of the early Martian atmosphere. Until the Mariner and Viking missions, the brightness of Mars itself and the close orbital distances made detailed observations of the moons impossible.

"Two of the most striking Martian features, as viewed from the OCO, are the polar caps and Valles Marineris. The polar caps are composed of **[52]** a substance that, on Mars, remains forever frozen and **[53]** that turns to ice at approximately -- 125° C. The Martian orbit is extremely eccentric taking it outward to a distance of 249 million kilometers and, one half a Martian year later, bringing it inward to 207 million kilometers. During mid-winter in the Southern hemisphere, the polar cap is approximately 4000 km across. During mid-winter in the Northern hemisphere, its polar cap is approximately 3000 km across. This data indicates that the **[54. a. southern, b. northern]** polar cap is experiencing the winter season when Mars is at its greatest distance from the Sun."

"How about asking a tough question like 'During which seasons is the Martian atmosphere at its densest? **[55]**' and 'Why?'" **[56]**

"The Martian canyon known as Valles Marineris is not really a canyon in the terrestrial sense because **[57]** played no part in its formation. Astronomers believe it is actually a giant crack created by crustal forces from deep within. Valles Marineris runs parallel to the Martian equator and nearly one-fifth of the distance around the equator. Calculate that distance so we can ask our graduate students to do it also."

"First I have to know the distance around the equator. The only value that comes close to what I need is Mars's equatorial radius of 3394 kilometers."

"That's even more challenging. Let's give them that value and the formula 2 pi r for determining the circumference of a circle if the radius is known."

"Since that was my idea, may I be excused from doing the calculations?"

"What do you think?"

"Okay. I'll get right on it."

Several minutes later I had the answer. "I found the approximate length of Valles Marineris to be **[58]** kilometers."

"I suppose our next lesson will introduce our graduate students to objects that lie beyond Mars?"

"You'll just have to wait and see! Won't you? Goodnight."