Last Name First Name

ASTR 2020, Fall 2020
Professor Jack Burns
Exam #2
October 23, 2020

INSTRUCTIONS: Closed books, one page (2 sides) of notes allowed, calculators may be used, ***strictly individual effort***. WRITE your name on this page BEFORE you begin the exam.

The exam consists of 10 multiple choice questions worth 4 points each, and 4 short answer questions worth 15 points each. *Please allocate your time accordingly among these parts of the exam.*

Multiple Choice. In questions 1-10, choose the best answer (2 pts). Then explain your reasoning in 1-2 complete sentences (2 pts). A correct answer and correct explanation is worth a total of 4 pts.

1. Which of the following is not true about NASA's Commercial Crew program?
    a. It is a partnership with two companies, Boeing and SpaceX.
    b. NASA does not own nor operate the commercial crew vehicles.
    c. It is a public-private partnership with NASA buying seats from companies to fly their astronauts to the ISS.
    d. The commercial crew companies are permitted to fly only NASA astronauts to the ISS.
    e. All of the above are true

The commercial crew program is a new model for NASA. It is a public-private partnership in which companies share risks with NASA, but they design, build, and operate the crew vehicle and launch. NASA provides guidance and requirements on the spacecraft. NASA buys services, which in this case are seats on the crew vehicle. NASA is only one customer, allowing the companies to sell seats on launches to other space agencies or private companies or private individuals.

2. How much greater is the light-collecting area of a 12-meter telescope than that of a 4-meter telescope?
    a. Three times
    b. Four times
    c. Six times
    d. Nine times
    e. There is no difference.

Light-collecting area is proportional to the square of the telescope mirror diameter. So, the ratio of the light-collecting area for a 12-meter vs. a 4-m is $(12/4)^2 = 9$.

3. Suppose you want to determine the chemical composition of a distant planet or star. Which of the following will be most useful to have?
    a. high angular resolution
    b. high turbulence
    c. a radio telescope
    d. high spectral resolution

The chemical composition of an astronomical object can be determined from its spectrum. With a high resolution spectrum, you can determine the exact positioning of the spectral lines and separate one element from another.

4. What is the main difference in hardware used by Project Apollo versus Project Artemis?
    a. Apollo did not have a lunar orbiting space station whereas Artemis will have the Lunar Gateway.
    b. Apollo was launched by the Saturn V rocket whereas the Artemis crew will use a new commercial crew launch vehicle.
    c. Artemis will arrive at the Moon after only one day whereas Apollo took three days to travel from the Earth to the Moon.
    d. Apollo's Saturn V used liquid oxygen-hydrogen propellent where the Artemis Space Launch System uses solar electric propulsion.

The Lunar Gateway, in a high elliptical orbit above the poles of the Moon, is a new component of Artemis that wasn't used by Apollo. The Gateway will allow the Orion crew module to dock and for astronauts to transfer to a lander and then on to the surface. The other three answers are all untrue. For example, in (b) Artemis is being launched by Orion not by a commercial crew vehicle. In (c), it is wrong because Artemis will also take at least 3 days to get to the Moon. In (d), this is wrong because the SLS uses regular liquid propulsion whereas the Gateway using electric propulsion.

5. Why does the Moon have a layer of "powdery soil" on its surface?
    a. Recent, large impacts shattered lunar rock to make this soil.
    b. It is made by the same processes that make powdery sand on Earth.
    c. It is the result of countless tiny impacts by small particles striking the Moon.
    d. It exists because the Moon accreted from powdery material after a giant impact blasted Earth.
    e. It formed during an earlier time when the Moon had an atmosphere and liquid water on the surface.

The fine-grained "regolith" on the surface of the Moon is the result of millions of years of bombardment by asteroid debris and solar wind material striking the lunar surface. The tiny impacts carry a lot of kinetic energy which then breaks up rocks into powdery soil.

6. What do we mean by the period of *late heavy bombardment* in the context of the history of our solar system?
    a. the first few hundred million years after the planets formed, which is when most impact craters were formed
    b. the time before planetesimals finished accreting into planets, during which many growing planetesimals must have shattered in collisions
    c. the time during which heavy elements condensed into rock and metal in the solar nebula
    d. the when the proto-Earth was struck by a Mars-sized asteroid
    e. the period about 65 million years ago when an impact is thought to have led to the extinction of the dinosaurs

Several hundred million years after the solar system formed, comet and asteroid material from the outer reaches of the solar system entered the inner solar system, bombarding the Moon and Earth. It created most of the impact basins seen on the Moon which were subsequently filled in with volcanic lava to become maria. The Earth is believed to have experienced a similar number of impacts but these craters have been eroded by wind and rain over billions of years.

7. Which of the following statement about the farside of the Moon is not true?
    a. It has distinctly different geological features than the nearside including fewer maria regions.
    b. It has mountains or highlands on the farside of the Moon that are much younger than those on the nearside.
    c. It is an ideal location for a low frequency radio telescope to study the first stars and galaxies in the early Universe.
    d. It possesses the oldest impact crater, the South Pole Aitken Basin, which was formed near the time life first developed on the Earth.
    e. There are permanently shadowed craters near the poles on the farside that contain water ice.

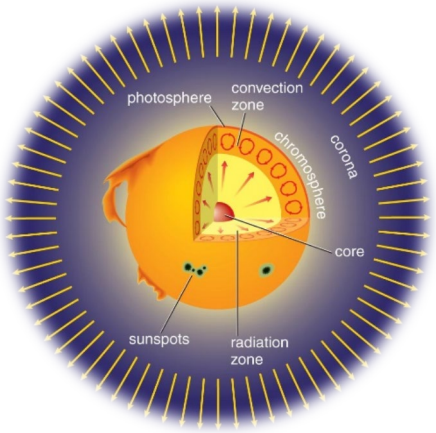
The nearside and the farside of the Moon are quite different. The farside has only a few maria whereas the nearside has many maria regions. We discussed in class placing a radio telescope on the farside because the farside always faces away from the Earth and is thus quiet. The South Pole Aitken Basin is a prime target for sample return because it is so old and deep. And, water ice has been discovered within craters at the poles by recent orbital missions. Only (b) is untrue because the mountains on the farside are older (not younger) than the maria on the nearside.

8. Why do sunspots appear dark in pictures of the Sun?
    a. They are too cold to emit any visible light.
    b. They actually are fairly bright but appear dark against the even brighter background of the surrounding Sun.
    c. They are holes in the solar surface through which we can see to deeper, darker layers of the Sun.
    d. They are tiny black holes, absorbing all light that hits them.
    e. They emit light in other wavelengths that we can't see.

Sunspots are cooler than the rest of the photosphere. Cooler objects emit less light than hotter objects. Thus, the sunspots emit less light than the rest of the photosphere.

9. From center outward, which of the following lists the "layers" of the Sun in the correct order?
    a. core, radiation zone, convection zone, corona, chromosphere, photosphere
    b. core, convection zone, radiation zone, corona, chromosphere, photosphere
    c. core, radiation zone, convection zone, photosphere, chromosphere, corona
    d. core, corona, radiation zone, convection zone, photosphere, chromosphere

The core is where nuclear reactions occur and heat is generated. Very high energy photons radiate away above the core. In the outer cooler layers, heat is transported by convection (like boiling water); we can see the tops of the convection cells via the mottled appearance of the photosphere. Above the photosphere is the thinner but hotter chromosphere.



10. What is the *solar wind*?
    a. the uppermost layer of the Sun, lying just above the corona
    b. the strong wind that blows sunspots around on the surface of the Sun
    c. the wind that causes huge arcs of gas to rise above the Sun's surface
    d. a stream of charged particles flowing outward from the surface of the Sun
    e. an upper atmospheric wind in the Earth's atmosphere caused by heating from a solar flare

The solar wind consists of high energy charged particles with velocity high enough to escape the Sun. It flows like a particle wind throughout the solar system. When the solar wind strikes the Earth's magnetosphere, some of these particles are trapped and create the Van Allen radiation belts.

Short Answer Questions 11-14: Please answer the following questions in a few cogent sentences. Be sure to write legibly. Also, use sketches, if helpful, in addition to the text. Please be brief. Literacy and clarity count! **Each short answer is worth 15 points.**

11. The angular resolution of a 10-meter telescope in space is about 0.01 arcsecond for visible light. Would you expect the angular resolution of a 20-meter space telescope observing visible light to be better than, equal to, or worse than 0.01 arcsecond? Explain.

The angular resolution depends upon the ratio of the wavelength to the diameter of the telescope mirror. In this case, the wavelengths for the two telescopes are the same (visible light) so only the ratio of the diameters comes into play. Since there is no atmosphere in space to blur the light, these space telescopes achieve their ideal resolution. The larger the mirror diameter, the better the resolution (the smaller the angular distance in arcseconds between two close objects that can be separated). In this case, the resolution of the 20-meter telescope is a factor of two better than the 10-meter telescope for an angular resolution of 0.01/2 = .005 arcsecond.

12. Why is the discovery of water ice in permanently shadowed craters at the lunar poles deemed a "game-changer" for space exploration? Describe several potential uses for water on the Moon.

Water on the Moon is extremely valuable. It can be used to drink by the astronauts and to grow food. Water is also excellent in shielding humans and electronics from radiation from the Sun. Water can be broken up into hydrogen and oxygen, cooled and reassembled as liquid rocket fuel which does not need to be transported from the Earth (savings via the rocket equation).

13. Solar Radiation.

a. Describe the effects of solar radiation on electronics on satellites and human astronauts in space.

Solar radiation can significantly damage unshielded electronics by flipping the 0 or 1 state on a digital integrated circuit board or with high enough kinetic energy even blowing a hole in the circuitry.

Solar radiation, in high enough dozes like that experienced near the Hiroshima bomb blast, can cause radiation poisoning and quick death. Smaller dozes of ionizing radiation can disrupt the DNA in cells and lead to cancer.

a. How might astronauts shield themselves from space radiation on the surface of the Moon? List at least one way that you think will be effective.

As noted above, water is a good shield from space radiation. A layer of 1 to 2 meters of water, mined from the Moon's poles, could effectively shield astronauts in a habitat on the lunar surface (and also serve as drinking water storage). Another possibility is to bury habitats beneath meters of lunar regolith (soil) or to establish lunar colonies in underground tunnels called lava tubes.

14. Describe how the Moon formed. Include in your discussion, the relationship with Earth, the age of the Moon, and evidence from core samples returned by the Apollo missions for this model.

During the formation of the Earth, a roughly Mars-sized proto-planet collided with Earth. This ripped up much of the outer layers of the early Earth. The debris both accreted back onto the Earth and coalesced to form the Moon. This happened roughly 30-50 million years into the formation of the solar system (4.5 billion years ago). Rock samples returned from the Moon by Apollo have compositions which, although similar, are not identical with Earth rocks. This fits with the proposed model due to the different formation locations of the proto-planet impactor and Earth.