Astronomy 2020 – Space Astronomy & Exploration **Fall 2020**
Homework #4 Due: Oct. 21, 2020

In questions 1-3 below, choose the best answer. Then explain your reasoning in a few complete sentences. Why is your answer correct?

1. (2 pts.) Which of the following is always true about images captured with X-ray telescopes?
   a. They are always very pretty.
   b. They are always displayed with the highest possible angular resolution.
   c. They are always useful for seeing through things.
   d. They are always displayed in false color.
   e. They are always displayed with north pointing upward in the images.

X-rays cannot be seen by the human eye. So, to visualize structures observed by X-ray telescopes of objects like supernova remnants or galaxy clusters, astronomers color-code images whereby the colors often represent brightness or different wavelengths within the X-ray band.

2. (2 pts.) What is the *giant impact hypothesis* for the origin of the Moon?
   a. The Moon formed when two gigantic asteroids collided with one another.
   b. The Moon originally was about the same size as Earth, but a giant impact blasted most of it away so that it ended up much smaller than Earth.
   c. The Moon formed from material blasted out of the Earth's mantle and crust by the impact of a Mars-size object.
   d. The Moon formed just like Earth, from accretion in the solar nebula.

Apollo geological core samples brought back to Earth show that the Moon's composition is a hybrid between elemental abundances seen on Earth and those in asteroids. This combination of materials is best understood via the impact of a Mars-sized protoplanet or asteroid and a proto-Earth.

3. (2 pts.) Satellites in low-Earth orbits are more likely to crash to Earth when the sunspot cycle is near *solar maximum* because
   a. it is too dangerous to send the Space Shuttle to service satellites during solar maximum.
   b. Earth's upper atmosphere tends to expand during solar maximum, exerting drag on satellites in low orbits.
   c. of increased magnetic interference.
   d. they are more likely to have their electronics "fried" by a solar flare during solar maximum.

During the maximum in the solar cycle, the Sun emits more high energy particles (space radiation) which in turn heats the Earth's atmosphere. Heated gases expand and that's just what the Earth's atmosphere does. Denser gas in LEO creates a greater drag force which slows down satellites and causes them to spiral downward into the atmosphere and burn up or crash.

4. (3 pts.) What is the main visual difference between the lunar highlands and the lunar *maria*? What are the implications of this observation?

The lunar highlands are very heavily cratered and the lunar *maria* are generally smooth. (More specifically, the *maria* contain only 3 percent as many craters per unit area as the highlands.) The difference in the amount of craters shows that the *maria* formed after the highlands, at the end of the heavy bombardment phase of the solar system. Radiometric dating of rocks from the highlands and *maria* shows that the heavy bombardment phase lasted no longer than a few hundred million years.

5. (**6 pts**). The early Earth-Moon system after formation 4.5 billion years ago looked quite different than today. The Earth's rotation period was only 5 hours and the Moon was only 3.5 Earth radii away from Earth versus the 24 hour Earth rotation period and 60 Earth radii distance of the Moon from Earth today.
    a. How did this dramatic change occur?

This change is due to the conservation of angular momentum. The closed system of the Moon and Earth have a constant total angular momentum, however, angular momentum can be exchanged between the two. Early Earth had much more rotational angular momentum, rotating quickly and the Moon had less, with a smaller orbital radius. Earth has been giving the Moon angular momentum, causing the Moon to drift away and in turn, making Earth rotate more slowly on its axis.

    b. Using Newton's version of Kepler's Third Law, calculate the period of revolution of the Moon around the Earth when its orbital radius was only 3.5 Earth radii.

$$P = \frac{2\pi R^{3/2}}{\sqrt{GM_E}}$$

R = 3.5 Earth Radii = 3.5×6,378,000m = 22,323,000m
G = 6.67×10^{-11}
$M_E = 5.97 \times 10^{24}$kg

$$P = \frac{2\pi(22{,}323{,}000)^{3/2}}{\sqrt{(6.67x10^{-11})(5.97x10^{24})}} = 33293\ s = 9.25\ hours$$

6. (4 pts.) Compare and contrast the component pieces that were used for Project Apollo's Moon landings (rockets, crew vehicles, orbiting vehicles, landers) versus those planned NASA's Project Artemis.

- **Rocket**: For Apollo, it was the Saturn V with five liquid oxygen-hydrogen engines. For Artemis, it is the Space Launch System with similar liquid O-H engines plus two solid rocket boosters.
- **Crew Vehicle**: For Apollo, the command module seated three and was powered by fuel cells. For Orion, it seats 4 astronauts and is powered by solar energy. The Orion capsule is about 30% larger in volume, has touch screens, and modern avionics.

- **Lunar Gateway**: Artemis will have a lunar-orbiting space station at which to dock and transfer to the lunar lander. Apollo did not have such a component.
- **Lander:** The lunar lander for Apollo seated two astronauts with a descent engine and then ascent engine to return and dock directly with the command module. For Artemis, the lander will be larger, capable of carrying several metric tons to the surface and three astronauts. It, too, has descent and ascent components.

7. (6 pts). Let's do a little more exploration of the Sun's activity. Using your assigned reading, answer the following:
    a. What is the Sunspot cycle?

The sunspot cycle is a rise and decline of the average number of sunspots observable, which repeats every 11 years.

    b. How are variations in the numbers and sizes of Sunspots related to other activity on the Sun such as flares and Coronal Mass Ejections?

Flares and coronal mass ejections vary on the same cycle, with each occurring more frequently and more intensely when sunspots are more frequent and larger.

    c. Explain the role of magnetic fields in creating Sunspots and in keeping their temperatures lower than the surrounding photosphere.

This is because all of these phenomena depend on the activity of the magnetic field, whose variation is causing the cycle. Sunspots correspond to regions of higher concentrations of magnetic fields. These magnetic fields keep the temperature of that region of the photosphere lower by inhibiting convection. The lower temperatures mean that the area appears darker.

8. (4 pts). **Space Weather.** Describe how variations in Space Weather affect the following:
    a. Electronic components on GPS satellites orbiting the Earth.

If the ionosphere is disturbed, the radio signals used by GPS satellites can be distorted, leading to erroneous readings of position.

    b. Aircraft trajectories across the North Pole of the Earth.

Aircraft are required to maintain constant communication with the ground. Transmission at radio frequencies is particularly disturbed near the poles (more high energy particles are channeled along the magnetic fields which converge at the poles), making it difficult to guarantee the ability to communicate over an entire polar route during a space weather event.

    c. The U.S. power grid.

Space weather can induce electric fields in the Earth's crust, and in turn in the wiring of the US power grid. This can impair the grid's proper functioning, damage transformers, and cause blackouts.

    d. An astronaut in the Orion Crew Vehicle in cis-lunar space on its way to the Moon.

Outside of the protection provided by the Earth's magnetic field, the highly energetic charged particles associated with space weather would impact the spacecraft crew through the breaking

of DNA. Such a dose of radiation could be life- threatening, due to increased risk of cancer, damage to the central nervous system, and acute radiation syndrome.

9. (2 pts.) Why is it important to understand the Sun in order to understand the Earth's radiation belts and space weather?

Solar activity causes the responses in the near-Earth space environment that produce changes in the radiation belts, so an understanding of how the Sun changes is directly relevant to space weather.