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Last Name First Name

ASTR 2020, Fall 2020
Professor Jack Burns
Exam #3
November 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. The *Cassini* mission to Saturn consists of
   a. an orbiter that orbits Saturn and a probe that descended to the surface of Titan.
   b. a large spacecraft that flew by Saturn on its way to other planets.
   c. an orbiter that orbits Saturn and a probe that descended into Saturn's atmosphere.
   d. a spacecraft that orbits Saturn and a sample return mission that landed on Titan, scooped up a surface sample, and will return it to Earth.

Cassini was an example of a billion-dollar class mission that was a combination of an orbiter (around Saturn) and a lander that descended through the thick clouds of the moon Titan and landed on the surface. The lander sent images back of the surface and showed pools of liquid methane/ethane. The orbiter mapped Saturn's clouds, probed its composition, and measured its gravity and magnetic field.

2. In what way is Venus most similar to Earth?
   a. Both planets are nearly the same size.
   b. Both planets have very similar atmospheres.
   c. Both planets have similar surface geology.
   d. Both planets have warm days and cool nights.

Venus is 95% of the radius of Earth so is virtually identical. But, the atmospheres are markedly different – Venus is carbon dioxide whereas Earth is mostly nitrogen and oxygen. Surfaces are different with water on Earth and carbon mostly in the rocks. The temperatures on the two planets are very different with Venus having virtually the same temperature during the day and at night due to the severe Greenhouse Effect.

3. Why was it advantageous for the *Voyager* mission to consist of flybys rather than orbiters?
    a. Spacecraft making flybys can return to Earth more quickly than orbiters.
    b. Each individual spacecraft was able to visit more than one planet.
    c. It was easier for data to be radioed back to Earth with flybys than orbiters.
    d. Flyby spacecraft can get closer to a planet than an orbiting spacecraft.

Voyager used gravitational slingshots to visit four planets – Jupiter, Saturn, Uranus, and Neptune due to the fortuitous alignment of the planets. Flybys allow quick sampling of multiple planets whereas an orbiter generally permits longer study but for only one planet.

4. The *lithosphere* of a planet is the layer that consists of
    a. material above the crust.
    b. material between the crust and the mantle.
    c. the rigid rocky material of the crust and uppermost portion of the mantle.
    d. the softer rocky material of the mantle.
    e. the lava that comes out of volcanoes.

A lithosphere is the rigid, outermost shell of a terrestrial-type planet or natural satellite, that is defined by its rigid mechanical properties. It is composed of the crust and the portion of the upper mantle that behaves elastically on time scales of thousands of years or greater. On Earth, it facilitates plate tectonics.

5. Which internal energy source is the most important in continuing to heat the terrestrial planets today?
    a. accretion
    b. differentiation
    c. radioactivity
    d. tidal heating
    e. all of the above

For terrestrial planets, the source of heating initially comes from accretion – converting kinetic energy via collisions into heat. Gradually, the planets cool via radiation. But, over time, the process by which Earth makes heat is driven by radioactive decay. It involves the disintegration of natural radioactive elements inside Earth – like uranium, for example. Uranium is a special kind of element because when it decays (transforms from one element to another), heat is produced. It's this heat that keeps Earth from cooling off completely.

6. How have we been able to construct detailed maps of surface features on Venus?
    a. by studying Venus from Earth with powerful telescopes
    b. by studying Venus with powerful optical telescopes on spacecraft that were sent to orbit Venus
    c. by making computer models of geological processes on Venus
    d. by using radar from spacecraft that were sent to orbit Venus
    e. by landing spacecraft on the surface for close-up study

The thick atmosphere of Venus makes it impossible to image the surface using optical or infrared wavelengths. Only radar (radio waves) can penetrate the clouds. Radar measures both topological features and radar reflections are sensitive to composition.

7. Which of the following statements about the greenhouse effect is *true*?
    a. Without the naturally occurring greenhouse effect, Earth would be too cold to have liquid oceans.
    b. A weak greenhouse effect operates on Mars.
    c. The burning of fossil fuels increases the greenhouse effect on Earth because of the release of carbon dioxide.
    d. One result of an increased greenhouse effect on Earth may be an increased number of severe storms.
    e. All of the above are true.

All of these are true. (a) On Earth, the Greenhouse Effect moderates extremes of temperatures and allows liquid water to exist on the surface. (b)The carbon dioxide atmosphere of Mars produces a mild Greenhouse Effect that makes the surface slightly warmer than it would otherwise be. (c)Fossil fuels produce Greenhouse gases, like carbon dioxide and methane, which impact climate change on Earth. (d)And, increasing the Greenhouse Effect on Earth leads to more severe weather according to atmospheric computer models.

8. Which of the following is a technology that NASA does ***NOT*** need to develop in preparation for future human expeditions to Mars?
    a. Improvements in propulsion and energy storage using, for example, advanced solar electric propulsion.
    b. A new spacecraft "capsule" design with a vastly improved heat shield.
    c. Better crew protection from solar and galactic radiation.
    d. Improvements in resource mining and utilization to help astronauts to "live off the land".
    e. Better understanding of bone loss in micro-gravity environments.

(a)Current liquid propulsion is slow, taking 8.5 months to reach Mars. Efficient, constant-acceleration engines like, solar electric, could decrease the travel time but this needs to be made more efficient. (b) This is Orion which already has a tested capsule design with an advanced heat shield. (c) Radiation protection for astronauts is currently limited. Better protection from Coronal Mass Ejections and cosmic rays is needed. (d) We've never done any surface mining on the Moon or Earth so this technology needs to be developed. (e) There is no current remedy for bone loss in zero gravity, although exercise helps.

9. Which of the following statements about Titan is *not* true?
   a. It may have an ocean of liquid ethane/methane.
   b. Its atmosphere is mostly nitrogen.
   c. Its temperature is too cold for liquid water to exist.
   d. Its surface is hidden from view by its thick atmosphere.
   e. It is the coldest moon in the solar system.

Titan has a very thick atmosphere – the only moon in the solar system with an atmosphere – and can't be viewed from orbit with standard visible/IR cameras. It is cold on the surface, too cold for water to exist, but is not the coldest moon because the atmosphere moderates its temperature. There are lakes or seas of liquid ethane/methane. Surprisingly, the atmosphere is dominated by nitrogen, like the Earth.

10. In the asteroid impact theory of the extinction of the dinosaurs some 65 million years ago, the dinosaurs (and over half of all the other species on Earth at that time) died off largely because
    a. of injuries suffered from direct hits of pieces of the asteroid or comet.
    b. dust injected into the stratosphere from the impact absorbed visible light from the Sun, causing global temperatures to plummet.
    c. radiation from iridium in the asteroid caused the dinosaurs to die of cancer.
    d. the impact caused massive earthquakes and volcanic activity worldwide.
    e. dust settled on the leaves of plants, making them inedible, so the animals died of starvation.

This impact resulted in a kind of global cooling, the opposite of what is happening today due to the Greenhouse Effect. The asteroid impact produced massive fires which resulted in soot and dust rising in overwhelming quantities into the atmosphere. Dust reflects light from the Sun so this resulted in reducing the amount of heating of the surface, causing temperatures to drop. This cooling killed many plants, which was the principal source of food for many of the forms of life during this era.

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. Pick one of the planets or moons in the Solar System. Discuss how we have "explored" this planet or moon and what we have learned. Discuss the exploration tools for this object which might include telescopes, robotic spacecraft, and/or human missions.

Example (Mars): While we have observed Mars with Hubble, Mars is close enough that the main part of our exploration of Mars has been done with orbiting satellites and rovers. Orbiters such as the Mars Global Surveyor and the Mars Reconnaissance Orbiter have mapped out the surface of Mars. This led to the discovery of systems of dry riverbeds and evidence for a former northern ocean. Surface rovers such as Spirit, Opportunity, and Curiosity have studied the geology of Mars and the chemical composition of Martian rocks. Recently, the orbiter named MAVEN has been studying how Mars lost its atmosphere.

Example (Moon): Our Moon is the only object in our solar system to which we have sent human missions. The Apollo program led to the return of surface samples from the Moon. These samples contributed the giant impact theory of the formation of the Earth-Moon system. More recently, the Lunar Reconnaissance Orbiter has created a 3D map of the lunar surface. This map will be used to plan future landing missions.

12. Why did astronomers identify Pluto as a planet from its discovery? What scientific evidence led to its reclassification?

Pluto was a relatively bright object in the outer solar system, and not near the asteroid belt, so it was regarded as a planet when it was first discovered. But, from the very beginning, the reflected light from Pluto indicated that it was small and not like the gas giant planets that dominate the outer solar system. Spectra also indicated that it had a solid icy surface and a thin atmosphere. New evidence contradicting this classification included the discovery of the Kuiper Belt, in particular the discovery of other large Kuiper Belt objects. Multiple Kuiper Belt objects with similar sizes to Pluto have been found. Unlike the other planets in the solar system, Pluto does not have enough gravity to "clear its neighboring region of other objects" which is used as a definition of a planet.

13. Summarize the evidence suggesting that Mars once had flowing water.

Mars has what looks like dried-up riverbeds and impact craters that appear to have formed in mud; the *Mars Pathfinder* found rocks of many different types jumbled together, as would occur if there had once been a great flood in the region; some very old craters appear to have been eroded by rain. Orbital imaging reveals dozens of what appear to be dried river deltas that look surprisingly like those seen on Earth. These deltas on Earth are only formed by water which flows faster and cuts narrow channels compared to volcanic lava.

14. Earth and Venus both presumably had similar gases outgassed from their volcanoes. Briefly explain how their atmospheres ended up so different.

On Venus, water and carbon dioxide remained in the atmosphere. Over time, ultraviolet light split the water molecules and the hydrogen escaped to space. Thus, Venus has no more water today and an atmosphere thick with carbon dioxide. On Earth, water condensed to rain and eventually formed the oceans. Carbon dioxide was absorbed in the oceans and is now locked up in carbonate rocks. Thus, most of the water on Earth remains in the oceans, and most of the carbon dioxide is in rocks, leaving a much thinner atmosphere than that of Venus.