SESSION ELEVEN: THE OUTER PLANETS

CAN YOU ANSWER THE FOLLOWING QUESTIONS/STATEMENTS ABOUT THE OUTER PLANETS, JUPITER, SATURN, URANUS, NEPTUNE, AND DWARF PLANET PLUTO?

JUPITER

1. The two basic elements from which the planet Jupiter is composed are ________________ and _________________. This also applies to Saturn, but to a lesser extent for Uranus and Neptune.

2. When observing Jupiter and its colorful markings with a telescope, or simply viewing the planet in a photograph, it is actually Jupiter's ________________ that we are seeing. Saturn, Uranus, and Neptune also fit this characteristic.

3. Jupiter has zebra-like markings over much of its "surface." Lighter stripes are called ________________, while darker bands are referred to as ________________. This banded structure is less distinct on Saturn, almost nonexistent on Uranus, but still present on Neptune.

4. The darker bands in the Jovian cloud tops represent areas where the atmosphere is _____________, while the lighter stripes are regions where the atmosphere is ________________. This certainly applies for Saturn and for the lighter features on Neptune.

5. The colors which are observed on Jupiter may represent phase changes or chemical reactions which are occurring at different levels in the Jovian atmosphere. These colors signify different ________________ zones.

6. The brown belts of Jupiter are COOLER/WARMER (circle one) than the white zones.

7. Major wind patterns experienced on a planet are a function of that planet's heat budget and ________________ speed. The Earth has three major wind zones while Venus has only one. Jupiter has MORE WIND ZONES/LESS WIND ZONES (circle one) than Earth because of its ________________ rotation.

8. On Jupiter, Saturn, and Neptune, areas of atmospheric motion in opposite directions are often found in close proximity to one another. This creates regions of ________________ which may promote hurricane-type activity. The Galileo probe, which descended into Jupiter's atmosphere on December 7, 1995, detected strong consistent winds of about 330 mph and intense turbulence. It also went through areas of extreme cold and heat before being crushed by the Jovian atmosphere.

9. Jupiter contains hurricanes of all sizes in the form of ovals, both large and small. The largest of these is called the **_________________________**. The size of the hurricane features on Jupiter may be related to their intensity and their longevity. The atmospheres of Saturn, Neptune, and the Earth are also conducive to the organization of these types of storm systems.

10. The Great Red Spot lies in a zonal region south of the Jovian equator. The atmosphere in this region is **_______________** and spreading outward. Because of the Coriolis effect, the air which moves toward the equator is deflected towards the RIGHT/LEFT (circle one), while air moving southward is deflected toward the RIGHT/LEFT (circle one). This sets up a **_________________** wind circulation (Hint: think of direction with respect to a clock face) within the Red Spot which was predicted before the first ***Pioneer*** flyby missions in 1973-4 and the two ***Voyager*** spacecraft in 1977.

11. Since air at the base of the Great Red Spot is converging and rising, this feature can be considered to be a HIGH/LOW (circle one) pressure system.

12. The Red Spot changes it position in longitude, but does not change it location in latitude. This is due to the strong **C_______________** effect generated within the belts and the zones of Jupiter which does not allow the spot to migrate in a northerly or southerly direction.

13. Jupiter's meteorology is driven **externally by the absorption of radiation from the sun, just like the Earth's weather patterns** or **internally from the leftover heat of accretion produced when the planet was first formed.** Draw a line through the incorrect phrase which is in bold type.

14. Because of its distance, Jupiter would be expected to radiate MORE/LESS (circle one) energy than it receives from the sun. The same can be said for Saturn, Uranus, and Neptune.

15. Jupiter is not to be considered a star in the making because its mass is about **_______________** times too small to initiate thermonuclear fusion in its core.

16. Describe two characteristics about the Jovian world that are star-like in nature.

    a. **____**
    b. **____**

17. Jupiter is considered to be a liquid planet because it has an extensive atmosphere and no solid **________________**. Although Jupiter is often called the largest of the gas giant planets, it has an extensive liquid mantle. Its atmosphere is about 600 miles (1000 km) in thickness and the pressures at the lower levels of the atmosphere compress the gasses into a liquid state.

18. Jupiter's composition could be considered to be simply _______________. As internal pressures increase, this element is forced into a _______________ molecular phase (state of matter), and finally into a ________________ atomic phase before a possible silicate-iron core is reached in a location where temperatures are five times hotter than the sun's "surface."

19. Jupiter is characterized by a strong magnetic field because it _______________ very rapidly, and possesses a region where self-induced electric currents can be generated. This region is in Jupiter's ____________________ layer. The flow of electricity in a regimented fashion always produces a magnetic field. Saturn, Uranus, and Neptune also have extensive magnetic fields because of similar properties.

20. Jupiter's magnetic field is the most intense of all the planets. Because of this, it is less likely for the solar wind to penetrate the magnetosphere of Jupiter. Yet it is well-known that an abundance of charged particles whirl around the planet at tremendous speeds. This material (plasma) comes predominately from _______________ (element) rocketed high above the surface of the Jovian satellite, Io, by its extensive volcanic activity.

21. Jupiter possesses a ring which is VISIBLE/INVISIBLE (circle one) from Earth. Saturn, Uranus, and Neptune also are ringed planets.

22. This ring is composed of DUST/ICE (circle one) as compared to Saturn's rings which are composed of mainly DUST/ICE (circle one).

23. The material which populates Jupiter's ring comes from particles which are "sandblasted" from a small _______________ just on the outside of the Jovian ring system.

THE GALILEAN SATELLITES OF JUPITER

24. State two ways in which the inner and outer Galilean satellites imitate the terrestrial and Jovian planets of our solar system.

    a. ____
    b. ____

25. Because there are relationships between the inner and outer planets, and the inner and outer Galilean satellites, this is further proof that after accretion, Jupiter must have been very _______________ and possessed a much stronger magnetic field.

26. Each successive moon of the Galilean group is about twice as far from the planet as the preceding satellite. The gravitational tugs and pulls of Jupiter on these satellites and the satellites' gravitational attractions for each other have produced geological activity of a wide variety. The Galilean moons, given below, are listed in order of increasing distance from Jupiter. State what modifications have taken place or are taking place to the surfaces of these bodies.

Satellite		Geological Activity
a. Io	:	________________________________
b. Europa	:	________________________________
c. Ganymede	:	________________________________
d. Callisto	:	________________________________

27. There IS/IS NOT (circle one) a relationship between the distances of the Galilean moons from Jupiter and the geological activity present on their surfaces.

28. One key concept in understanding the extreme differences in the surface ages of Io and Callisto is attributable to the number of ____________________ each satellite possesses. Io's surface is considered to be NEW/OLD (circle one) while Callisto's surface is _______________ because ____.

29. The lack of high features, such as mountains or even hills on Europa, indicates that this satellite may have a fairly active and _______________ (thickness) crust. This is probably why Europa has such few impact craters on its surface.

30. The grooved terrain which is characteristic of Callisto may indicate that this satellite went through a period of ____________________ before the surface froze.

31. The differences in the brightness of various features on Ganymede and Callisto may also give an indication of the age of the terrain. It is considered that the older regions of these satellites possess a HIGHER/LOWER (circle one) reflectivity (albedo) because they have had more time to sweep up _______________.

SATURN

32. State three similarities between Jupiter and Saturn.

a. ____
b. ____
c. ____

33. If placed in a bathtub filled with water and large enough to accommodate its volume, Saturn would ________________. Therefore Saturn's density must be less than that of ________________.

34. One would not infer a substantial core of nickel-iron or even silicates at the center of the planet Saturn because its ____
____

35. Saturn, because of its smaller size, is internally WARMER/COOLER (circle one) than Jupiter. However, it radiates about 2.5 times more energy than it receives from the sun. This appears to be more energy than Jupiter, but remember Saturn is twice the distance of Jupiter from the sun, and therefore, only receives about one quarter the energy that reaches Jupiter.

36. An additional source of Saturn's internal heat supply could be the result of ________________ condensing in its atmosphere. This could be a major factor influencing why Saturn's weather is EXTERNALLY/INTERNALLY (circle one) driven.

37. Saturn shows the same zone and belt structure as seen on Jupiter, but on Saturn, the belts and zones are less easily distinguished. The upper atmosphere is slightly colder, causing the planet to be immersed in a frozen ammonia ________________.

38. Because the "surface" gravity on Saturn is much weaker than Jupiter's "surface" gravity, the Saturnian atmosphere is DEEPER/MORE COMPRESSED (circle one) than the Jovian atmosphere. This would make it MORE/LESS (circle one) difficult to view cloud features below the cloud tops.

39. Saturn generates its own magnetic field which is second only to Jupiter's in intensity. This indicates that structurally, Saturn probably possesses a layer of _____________________, similar to Jupiter. Another reason which would support a strong magnetic field is Saturn's rapid _____________________.

40. Saturn's magnetosphere does not contain the quantity of charged particles which are found in the Jovian field. State two reasons why this phenomenon is explainable.
    a. ____
    b. ____

RINGS OF SATURN

41. Saturn's axial tilt is ________________ from the perpendicular to its orbital plane. As the planet revolves around the sun, the axis always points in the same ________________. The rings of Saturn are found in the ________________ plane of the planet.

42. When Saturn's axis is tipped towards or away from the Earth, we see the ring system EASILY/WITH DIFFICULTY (circle one). When observers view the rings in their own plane, they ____________________.

43. The last statement is an indication that the rings of Saturn are very ________________.

44. All of the major rings of Saturn are located within the ________________ limit. A satellite which approaches to within 2.44 times the radius of its primary will be ____.

45. State two mechanisms which could have created the rings of Saturn.

    a. ____
    b. ____

46. Give one convincing reason to support the fact that the rings around Saturn are not solid like the disk of a CD or record. Hint: Consider what happens to the orbital speeds and periods of revolution as planets get farther from the sun. This is called Keplerian motion. Then consider the same situation with respect to the rotational velocities of positions at increasing distances from the center of a disk rotating like a solid.

    ____
    ____

47. There are three classical rings which were first observed from the Earth, and later, confirmed by the ________________ and ________________ spacecraft which flew past the planet in 1979 (P11), 1980 (V1), and 1981 (V2).

48. These classical rings are called the ________________-ring, the ________________-ring, and the ________________-ring. An 1800 mile gap separates the ________________-ring from the ________________-ring, and is known as the ________________ division.

49. Flyby missions to Saturn established the D-ring, E-ring, F-ring, and the G-ring. Indicate their approximate locations with respect to the classical rings which were discovered with Earthbound telescopes.

    SATURN C B A

50. Orbital periods which are in certain whole number ratios to each other are called ________________ orbits.

51. The gravitational attraction of a moon for a band of ring particles which have orbits which are in certain whole number ratios to each other will tend to __________________________ ____. This is one explanation which has been put forth to understand the gaps in Saturn's ring system.

52. Normally, photography of the planets involves creating an image from sunlight which has been ________________ from an object. However, if the sun is in back of very small, micron-sized dust or ice particles, this material can be photographed in __________________ light. There are 1000 microns in a millimeter and 25.4 millimeters per inch.

53. Using both techniques of photography, as mentioned in the last statement, has allowed NASA scientists to interpret the **si**________________ and **de**________________ of the ring particles. Below, please capsulize this information with regard to Saturn's rings.

    a. A-ring: ____

    b. Cassini division: ____

    c. B-ring: ____

    d. C-ring through G-ring: ____

54. Due to the gravitational tugs and pulls of the planet and its moons, the rings of a planet over time should disperse outward and inward from their original boundaries. This does not happen with Saturn's ring system. The objects which stabilize the narrow F-ring and keep the A-ring from widening are called ________________ satellites.

55. In the case of the F-ring, where there are two moons, the satellite on the outside of the ring causes the ring particles to GAIN/LOSE (circle one) energy. This forces the ring material to move CLOSER/FARTHER (circle one) to/from the planet. Just the opposite is true for the inner moon of this duo.

56. Dust in the Saturnian ring system may become electrostatically charged from the plasma whirling inside the planet's magnetosphere. This dust is lifted several tens of meters above the ring plane to form the famous ________________ discovered by the ***Voyager*** probes. The period of revolution of the spokes is the same as the period of rotation of Saturn's _____________________. This gives another indication that this feature is magnetically influenced.

MOONS OF SATURN

57. Saturn officially contains ________________ satellites, although more are suspected. To be officially listed as a moon, the ________________ of the satellite must be known well enough to predict the satellite's position accurately at some future time.

58. Most of the satellites of Saturn have bulk densities of approximately 1.3 gm/cm^3. This would lead one to suspect that these moons have compositions of varying quantities of ________________ and ________________. (Hint: Think general here. You are not looking for specific chemical compounds.)

59. The largest and most interesting satellite of Saturn is planet-sized _______________ which possesses an _______________ substantially thicker than our own. It is composed primarily of _______________.

60. On this large satellite, mentioned in the previous problem, NH_3, called _______________, is photodissociated by the _______________ radiation (specific type of EM energy) from the sun. The hydrogen diffuses into space because the gravity of this satellite is too weak to retain the gas. Left behind is the _______________ that has been accumulating over eons of time to composes the bulk of this satellite's atmosphere at a pressure twice that of Earth's ocean of air.

61. The interaction of sunlight with CH_4, _______________ (name the gas), induces chemical reactions that produce a variety of carbon-hydrogen compounds called _______________. These include ethane (C_2H_6), acetylene (C_2H_2), ethylene (C_2H_4), and propane (C_3H_8), which as aerosols gradually fall to the surface and coat the satellite. There will never be an "oil" crisis on this moon!

62. The temperature of Titan is also very cold, about -290° F (-180° C). This is near the triple point of methane which means that this compound can exist simultaneously as a _______________, a _______________, and a _______________. What very important substance is near its triple point on the planet Earth? _______________

63. This satellite of Saturn looks like the Death Star because of a large meteorite crater which nearly broke the moon apart. The name of this moon is _______________.

64. _______________ is the moon responsible for the Cassini Division which divides Saturn's A-ring from its B-ring.

65. This moon, named _______________, may have geysers on its surface which spurt water into space to form the torus of ice particles which is known as the _______________-ring.

66. _______________ has a light and a dark side to it. The leading hemisphere is almost black and may have become coated when it swept up dark carbonaceous material during Saturn's capture of its most distant satellite, Phoebe, which was probably an asteroid. Phoebe moves in a retrograde orbit.

URANUS

67. The planet Uranus was discovered by the German-English astronomer, William ________________, on March 13, 1781 while conducting a survey of the nighttime sky visible from England.

68. The axial tilt of Uranus is such that its poles almost lie in the _______________ plane of the solar system. The poles always point in the same _______________. Therefore, as Uranus revolves around the sun in its 84 year period, each pole and the equator is alternately exposed to seasons of high sun, lasting about _______________ years.

69. The masses of Jupiter and Saturn are significantly HIGHER/LOWER (circle one) than Uranus and Neptune, yet the densities of the two largest planets are MORE/LESS (circle one). This indicates that Uranus and Neptune are composed of materials which are HEAVIER/LIGHTER (circle one) than Jupiter and Saturn.

70. Images returned from the spacecraft _______________ showed that Uranus possessed A LARGE NUMBER OF/VIRTUALLY NO (circle one) features in its clouds. This served as an indicator that the atmosphere of Uranus is probably VERY DEEP/SHALLOW (circle one).

71. A method of measuring the internal rotational period of a planet, such as Uranus, is to determine the period of rotation of that planet's ____________________. This was accomplished for Uranus, and it was discovered that the rotational spin axis does not point in the same _______________ as the magnetic spin axis. Uranus' magnetic field is tilted some 60 degrees from its rotational axis and offset from the center of the planet by about 30 percent.

72. This discrepancy has lead some astronomers to surmise that early in the history of Uranus, it was probably ____
____

73. The density of Uranus' five "classical" satellites is approximately 1.5 gm/cm^3 indicating that they are composed of a mixture of _______________ and _______________. This IS/IS NOT (circle one) consistent with what one would expect at this distance from the sun.

74. Probably the most interesting satellite of Uranus is _______________ which appears to have light and dark surface features “cemented” together in a rather weird angular pattern. This can be explained by the fact that this moon was probably broken ________________
____

75. The Uranian ring system was discovered by EARTH-BASED OBSERVATIONS/VOYAGER 2 FLYBY MISSION (circle one) in 1977.

76. Uranus' 11 rings are composed of _______________ materials which have a very HIGH/LOW albedo (circle one).

NEPTUNE

77. Neptune possesses a DEEP/SHALLOW (circle one) atmosphere which is probably divided into several layers.
    a. A high altitude hydrocarbon smog created from CH_4 (methane) that has been photodissociated by sunlight
    b. A methane cloud layer which is very reflective because it is frozen
    c. A lower cloud layer composed of hydrogen sulfide or ammonia

78. The layering of Neptune's atmosphere was revealed by clouds in the methane level which cast ________________ onto the lower level.

79. The composition of Neptune's atmosphere is about three quarters ________________ and about one quarter ________________. Methane contributes about one percent of this total.

80. Neptune possesses an anticyclonic (high pressure) feature known as the ________________. This region, as well as a small dark spot, and the Scooter are made visible by ________________ clouds which form when this gas cools and condenses as it is forced over these weather systems.

81. Just like Uranus, Neptune's ____________________ is tilted at a steep angle (48 degrees) to its rotational axis, and it is offset from the planet's ________________ by about 55 percent of Neptune's radius.

82. The four tenuous rings which Neptune possesses are all composed of ________________.
    a. Two are thin and brighter. The outer ring contains three arcs or concentrations of material.
    b. The two fainter rings are less dense but much broader.

83. Neptune possesses ________________ satellites. Two of these were discovered many years before ***Voyager 2*** flew past the planet. Of importance are:
    a. Triton: 1680 miles in diameter (2700 km) retrograde revolution
    b. Nereid: 210 miles in diameter (340 km) very eccentric orbit
    c. 1989N1: 250 miles in diameter (400 km) first observed, 1981

84. Triton, one of the major satellites of the solar system, is similar in size to dwarf planet ________________. It probably has a thin 100 mile (160 km) water-ice crust, a similarly thick slushy magma layer of water, methane, and ammonia, followed by a 1500 mile (2400 km) rocky core.

85. Triton is the only large body in the solar system with a retrograde orbit. It was probably a former small ____________________ object captured by Neptune.

86. In the south polar region of Triton, volcanic activity in the form of ________________ has been photographed. Sunlight may warm the transparent nitrogen ice in this region at depths of tens of feet (5-10 meters), causing pockets of liquid nitrogen and nitrogen gas to form under great pressure. These break through weak zones in the ice to spray jets of gas and ice skyward to heights of five miles (8 km). The thin atmosphere which is 70,000 times less dense than Earth’s atmosphere is created by the volcanic activity.

DWARF PLANET PLUTO

87. Pluto was discovered in 1930 by the American astronomer Clyde W. _______________.

88. State two reasons why Pluto does not fit into the category of an inner or an outer planet.

    a. ____
    b. ____

89. Compositionally, Pluto best represents some of the PLANETS/SATELLITES (circle one) of the outer solar system. However, based upon eccentricity of orbit (0.25) and orbital inclination (17 degrees), it appears as if Pluto could be a larger and more distant _______________ object.

90. Formally, Pluto was considered to have been an escaped satellite of _______________; but the discovery of Pluto's moon, _______________, and subsequently three additional satellites have made this theory impossible to accept.

91. The Pluto-Charon system represents the _______________ ratio of primary to secondary bodies in the solar system. The Earth-moon system comes in second.
    a. Diameter of Pluto: 1400 miles (2300 km)
    b. Diameter of Charon: 750 miles (1200 km)

92. The rotation of Pluto and the revolution of Charon are _______________ (locked), occurring once in every 6.39 days.

93. Pluto possesses a very tenuous _______________ (composition) atmosphere, about 100 times less dense than Triton.

NOTES

ANSWERS TO SESSION ELEVEN QUESTIONS

JUPITER

1. hydrogen, helium
2. cloud tops
3. zones, belts
4. descending, ascending
5. temperature
6. WARMER
7. rotational, MORE WIND ZONES, faster
8. shear
9. Great Red Spot
10. ascending, LEFT, RIGHT, counterclockwise
11. LOW (at high altitudes the GRS is a high pressure system)
12. Coriolis
13. run a line through "externally by the absorption of radiation from the sun 500 million miles away"
14. MORE
15. 70
16. a. Jupiter radiates more energy than it receives.
    b. Jupiter's chemical composition is virtually identical to that of stars like our sun.
    c. Jupiter's satellite system mimics the planetary system. There are distinct differences between the inner and outer Galilean moons.
17. surface
18. hydrogen, liquid, metallic (solid)
19. rotates, metallic or metallic hydrogen
20. (erupting) volcanoes
21. INVISIBLE
22. DUST, ICE
23. satellite

THE GALILEAN SATELLITES OF JUPITER

24. a. The density of the inner Galilean moons is higher than the outer Galilean satellites.
    b. The outer Galilean satellites are larger than the inner major satellites of Jupiter.
25. hot
26.

	Satellite		Geological Activity
a.	Io	:	erupting volcanoes spraying sulfur and sulfur dioxide, no impact craters
b.	Europa	:	thin cracked crust which undergoes changes, liquid mantle, few impact craters
c.	Ganymede	:	grooved surface indicative of continental drift type activity in the distant past
d.	Callisto	:	crater saturated surface, perhaps it is not even completely differentiated

27. IS (the farther from the planet the less geological activity)
28. impact craters, NEW, old, it is completely crater saturated
29. thin
30. continental drift (plate tectonics or divergent plate boundaries)
31. LOWER

SATURN

32. a. similar compositions
    b. internally driven meteorology
    c. rapid rotations
    d. no solid surfaces
    e. extensive atmospheres
    f. liquid interiors
    g. strong magnetic fields
    h. numerous satellites
33. float, water
34. average density is so low
35. COOLER
36. helium, INTERNALLY
37. haze
38. DEEPER, MORE
39. metallic hydrogen, rotation
40. a. There is no volcanic action which is feeding matter into the Saturnian magnetosphere. Saturn's satellite, Enceladus, does possess active "water" geysers.
    b. The extensive ring system of Saturn absorbs the plasma.

RINGS OF SATURN

41. 27 degrees, direction, equatorial
42. EASILY, disappear
43. thin
44. Roche, be broken apart by tidal (gravitational) effects
45. a. A satellite got within the Roche limit and was broken apart (tidally disrupted).
    b. Material within the Roche limit was not able to accrete to form a satellite.
46. a. Ring particles closer to the planet have a shorter orbital period than ring particles which are farther away.
    b. Stars can be observed in back of Saturn's ring system.
47. ***Pioneer, Voyager***
48. A, B, C, A, B, Cassini
49. SATURN D C B A F G E x t e n d e d
50. resonating (resonate)
51. move the ring particles away from the resonance area creating a gap
52. reflected, scattered
53. size, density
    a. A-ring: medium size particles, medium density
    b. Cassini division: very fine and tenuous-- considered a gap very low density
    c. B-ring: largest particles and densest part of ring system
    d. C through G rings: very small particles, little material
54. shepherding
55. LOSE, CLOSER

56. spokes, magnetic field

MOONS OF SATURN

57. 62+, orbit
58. ice, rock
59. Titan's, atmosphere, nitrogen
60. ammonia, ultraviolet, nitrogen
61. methane, hydrocarbons
62. solid, liquid, gas, water
63. Mimas
64. Mimas
65. Enceladus, E
66. Iapetus

URANUS

67. Herschel
68. orbital, direction, 21
69. HIGHER, LESS, HEAVIER
70. ***Voyager 2***, VIRTUALLY NO, VERY DEEP
71. magnetic field, direction
72. struck by a very massive object
73. ice, rock, IS
74. Miranda, broken apart and reassembled several times during its early history
75. EARTH-BASED OBSERVATIONS
76. rocky (yard-sized), LOW

NEPTUNE

77. DEEP
78. shadows
79. hydrogen, helium
80. Great Dark Spot, methane
81. magnetic field, center
82. dust
83. 13
84. Pluto
85. Kuiper Belt
86. geysering

DWARF PLANET PLUTO

87. Tombaugh
88. a. Pluto is much smaller than any of the other planets.
    b. Pluto has the highest orbital eccentricity of any planet.
    c. Pluto has the highest orbital inclination of any planet.
    d. Pluto's composition is neither terrestrial or Jovian.
89. SATELLITES, Kuiper Belt
90. Neptune, Charon

91. smallest
92. synchronous
93. methane

April 18, 2012