22. Describe the major developments in our understanding of Uranus, from ground-based observations to the Voyagers.

23. Discuss Miranda's appearance and explain why it is so surprising.

24. Describe the major developments in our understanding of Neptune, from ground-based observations to the Voyagers.

25. Compare Triton in size and surface with other major moons, like Ganymede and Titan.

26. **True or false?** Jupiter, Saturn, Uranus, and Neptune all have complete (but in some cases clumpy) rings.

27. **True or false?** Through a telescope on Earth, we can sometimes see Jupiter and Saturn in their crescent phases, just as the Moon is sometimes a crescent.

28. **True or false?** Saturn's rings are at such a large distance from the planet that it was difficult or impossible for the sparse material to coalesce into a moon.

29. **True or false?** From Earth, Saturn's rings appear "edge-on" only once per Saturn's orbital period.

30. **True or false?** Jupiter's mass is larger than the combined mass of all other planets in the Solar System. (by 2.5x)

31. **True or false?** There are more moons than planets in the Solar System. (193)

**32. True or false?** The rings of Uranus are kept narrow by the presence of adjacent small moons that gravitationally confine the particles to the rings.

**33. True or false?** The rings of Uranus were discovered from Earth when Uranus passed between us and a star.

**34. True or false?** Uranus has extreme seasons because its rotation axis is nearly in its orbital plane.

**35. True or false?** Tidal forces from Jupiter heat its large moons Io and Europa, leading to extensive volcanism on Io and an icy slush beneath Europa's surface.

**36. True or false?** The existence of Neptune was correctly predicted after astronomers noted that Uranus's observed and expected positions in the sky differed. (Mathmatically)

**37. Multiple choice:** The low average densities of Jupiter and Saturn compared with Earth suggest that **(a)** they are hollow; **(b)** their gravitational attraction has squeezed material out of their cores; **(c)** they consist mostly of water; **(d)** they contain large quantities of light elements, such as hydrogen and helium; or **(e)** volcanic eruptions have ejected all the iron that was originally in their cores.

**38. Multiple choice:** Jovian planets have rings because **(a)** their thick gaseous atmospheres would disintegrate any small rock that enters them; **(b)** there is too much material to have fit into the ball of each planet; **(c)** tidal forces prevent the material in rings from forming into moons; **(d)** jovian planets

rotate very rapidly, and some material near the equator of these planets was flung outward, forming the rings; or **(e)** tidal forces cause volcanic eruptions on some moons and part of this material subsequently escaped the gravity of the moons, forming the rings.

**39. Multiple choice:** Which one of the following statements about the jovian planets is *false*? **(a)** They generally have the thickest atmospheres of all planets in the Solar System. **(b)** They are the most massive of all the planets in the Solar System since they are mainly composed of heavy elements like iron. **(c)** Despite their size, they rotate about their axis very rapidly, in less than 24 hours. **(d)** They have many moons, probably due to their large gravitational fields. **(e)** They are the largest of all planets in the Solar System, with diameters up to nearly the diameter of the Sun.

**40. Multiple choice:** The rings of Uranus were discovered by accident, during observations of its **(a)** phases, **(b)** occultation of a star, **(c)** rotation period, **(d)** transit across the Sun's disk, or **(e)** moons.

**41. Multiple choice:** Which one of the following statements about the giant planets in our Solar System is *true*? **(a)** Neptune and Uranus appear greenish blue because they are covered by a liquid water ocean. **(b)** Of the four giant planets, only Saturn and Uranus have rings. **(c)** Jupiter's volume is roughly 10 times Earth's volume. **(d)** The giant planets consist mostly of hydrogen and helium, similar to the Sun. **(e)**

Saturn's rings rotate as a solid body, like a bicycle wheel and its spokes; all particles have the same orbital period.

**42. Multiple choice:** Jupiter and Saturn radiate more energy than they receive from the Sun. The most likely source of this excess energy is **(a)** gravitational contraction or settling, **(b)** hydrogen fusion, **(c)** chemical reactions, **(d)** radioactive decay, or **(e)** the magnetic fields of these planets.

**43. Multiple choice:** Which of the following characteristics describe terrestrial planets relative to jovian planets in the Solar System? Terrestrial planets (I) are smaller, (II) have shorter day/night cycles, (III) are denser. **(a)** I only. **(b)** I and II. **(c)** I and III. **(d)** II and III. **(e)** I, II, and III.

**44. Multiple choice:** Jupiter's moon Io has more than 100 active volcanoes on its surface. Which statement best describes the reason for this? **(a)** Io is still cooling from the initial heat of its formation. **(b)** Motion of Io's tectonic plates causes volcanoes just as they do on Earth. **(c)** Hydrothermal vents produce Io's large ice volcanoes. **(d)** A process similar to Earth's tides causes Io to heat up and form volcanoes. **(e)** Impacts from falling asteroids cause the formation of lava flows on Io.

**†45 Multiple choice:** Uranus has an axial tilt of about 98° and an orbital period of about 84 years. Its *northern* hemisphere experienced one of its summer solstices in June 1944. Which one of the following dates gives the best

approximation for the nearest time at which telescopes on Earth could have next seen Uranus's *southern* pole? **(a)** December 1944. **(b)** 1965. **(c)** 1986. **(d)** 2028. **(e)** Because of Uranus's axial tilt, telescopes on Earth can *never* see Uranus's southern pole.

**46. Fill in the blank:** The distance from a planet within which it is not possible to form a moon through gravitational attraction between particles is called the Roche limit □

**47. Fill in the blank:** The Cassini spacecraft dropped a probe into Titan's atmosphere in late 2004.

**48. Fill in the blank:** Perhaps the most likely moons of the Solar System on which life could have developed are Saturn's moon _____ and Jupiter's moon Europa, given their warm interior and partially melted water ice.

**49. Fill in the blank:** The magnetic fields of Uranus and Neptune are strange, with tilted axes offset from the planet centers.

**50. Fill in the blank:** Small moons that keep the material in narrow rings from spreading apart are called Shepherd satellites. †This question requires a numerical solution.