

17. Discuss the significance of the collision of Comet Shoemaker–Levy 9 with Jupiter, and subsequent comet collisions.
18. What is the relation of meteoroids and asteroids?
19. What, physically, is a “shooting star”?
20. Why don't most meteoroids reach Earth's surface?
21. Explain the process by which a meteor shower occurs.
22. Why might some meteor showers last only a day while others can last several weeks?
23. Why are meteorites important in our study of the Solar System?
24. Compare the sizes and surfaces of asteroids with the moons of the planets.
25. How might the study of the apparent brightness of a star during an occultation by an asteroid tell us whether the asteroid has an atmosphere?
26. Why is the study of certain types of asteroids important for understanding our long-term survival on Earth?
27. What have the Galileo, NEAR Shoemaker, Deep Space 1, Deep Impact, Rosetta, and Dawn spacecraft found out about comets and asteroids?
28. ~~True~~ or false? Comets are made of mostly rocky material from the asteroid belt. ✓
29. True or false? The asteroid belt is inside the Sun's Roche limit and thus could not overcome the Sun's tidal forces to form a planet.
30. True or false? The time interval when a specific comet's tail is long is much less than the time interval when that comet's tail is short.
31. True or false? The asteroid belt was probably produced when two large, fully formed terrestrial planets collided with and shattered each other.
32. True or false? The retrograde motion of Pluto can be attributed to the relatively high eccentricity of its orbit around the Sun, as compared to normal planets.
33. True or false? Periodic comets generally grow brighter each time they appear, since they gradually accumulate more material from the outer parts of

the Solar System.

34. True or false? Most meteor showers occur when a random comet or asteroid enters Earth's atmosphere and then breaks up into many pieces.

35. True or false? Most of the Kuiper-belt objects are between the orbits of Neptune and the Oort cloud.

36. True or false? A "shooting star" or "falling star" is not a star at all, but rather a rock or chunk of ice from space that enters Earth's atmosphere at a high speed and burns up due to the sudden compression of air (friction).

37. True or false? The peculiar distribution of certain types of Kuiper-belt objects suggests the gravitational influence of a very distant, massive "Planet Nine" that astronomers are now trying to find.

38. True or false? The Giotto spacecraft observations of Comet Halley showed the evaporating gas and dust to come out of fissures in the comet's dark crust, creating jets.

39. Multiple choice: Most known comets do not reappear in our sky very often because (a) comets are not gravitationally bound to our Solar System; (b) comets burn quite rapidly, using up all their fuel within a few decades; (c) the orbits of comets are highly eccentric and their semimajor axes are large; (d) most comets only pass close to the Sun two or three times, and then they disintegrate; or (e) it is impossible to tell when most comets will return close to the Sun.

40. Multiple choice: Pluto (a) is about as large as the planet Mercury; (b) has no moons; (c) has a density intermediate between that of the terrestrial planets and the giant planets; (d) has a nearly circular orbit around the Sun, owing to its interactions with other objects in its vicinity; or (e) is massive enough to substantially affect the orbit of Uranus, which led to its discovery.

41. Multiple choice: Which one of the following statements is *true*? (a) There is still no direct evidence that a comet or asteroid impact helped cause the Cretaceous–Paleogene (i.e., Cretaceous–Tertiary) extinction during which the dinosaurs perished because no matching crater has yet been found. (b) The collision of Comet Shoemaker–Levy 9 with Jupiter dramatically illustrated the

amount of energy that can be released when an asteroid or comet hits a planet. (c) In principle, nothing can be done to prevent collisions of asteroids with Earth, so we might as well not worry about them too much. (d) Comets are like icy asteroids in composition, but they come primarily from regions beyond Neptune's orbit such as the Kuiper belt and the Oort cloud. (e) Meteor showers are produced when a cluster of stars falls through Earth's atmosphere.

42. Multiple choice: Which one of the following statements about the main asteroid belt is *true*? (a) The main asteroid belt is probably debris that would have formed a planet had Jupiter not prevented it. (b) The mass of all the asteroids together is roughly that of Earth. (c) The iron/nickel asteroids are the most common kind. (d) There is no evidence that the material from which many asteroids formed was ever part of one or more larger bodies that could have experienced differentiation. (e) All asteroids appear to be quite solid objects, rather than collections of smaller rocks held together by gravity.

†43. Multiple choice: Suppose you discover a comet having an orbital period of 1000 years around our Sun. Roughly what is its semimajor axis? (a) 10 au. (b) 32 au. (c) 10^2 au. (d) $10^{4.5}$ au. (e) 10^6 au.

44. Multiple choice: Which one of the following best describes the reason Pluto was demoted from being a genuine planet and promoted to the status of "dwarf planet"? (a) It orbits its center of mass with its main moon, Charon. (b) It is too small and is thus not quite spherical. (c) Its orbit sometimes brings it closer to the Sun than Neptune. (d) Its orbit is far more inclined than those of the other planets. (e) It has not cleared most other objects from its neighborhood.

†45. Multiple choice: Pluto has an orbital period of roughly 250 years. In 1989 Pluto was closer to the Sun than Neptune was. During which one of the following years will Pluto have the highest orbital speed? (a) 2015. (b) 2051. (c) 2114. (d) 2176. (e) 2239.

46. Multiple choice: If an asteroid with a diameter of 30 km were to collide with Earth, it would probably (a) burn up in the atmosphere before reaching the ground; (b) only crush a car, if one happened to be at the point of impact; (c) devastate an area no larger than 30 km in diameter; (d) create a crater more than 300 km in diameter, but have little or no effect on the rest of Earth and its

inhabitants; or (e) bring an end to human civilization, or at least destroy much of the human race.

47. Fill in the blank: Pluto is a large member of the Kuiper belt, and thus is no longer considered to be a genuine planet.

48. Fill in the blank: A meteoroid that has landed on the surface of a planet or a moon is called a meteorite.

49. Fill in the blank: When Earth passes through the orbit of an old, disintegrating comet, a Meteor showers can occur.

50. Fill in the blank: A thin layer of unusually high levels of the element Iridium in the strata of Earth's crust deposited 66 million years ago provides evidence for the impact theory of the Cretaceous-Tertiary (Cretaceous-Paleogene) extinction.

51. Fill in the blank: It is now generally thought that billions, or even trillions, of tail-less comets surround the Solar System in a spherical shell nearly one light-year in radius called the Oort Comet cloud. †This question requires a numerical solution.

Topics for Discussion

1. Now that many objects, some of them quite large, have been discovered in the Kuiper belt, do you think Pluto should still be called a planet?
2. Do you worry about asteroid or comet collisions with Earth? What could be done to save life on Earth if an asteroid were discovered sufficiently far in advance of the collision?
3. Some scientists have suggested that the dinosaurs were about to become extinct anyway, without an asteroid or comet collision, owing to changes in Earth's climate and other reasons such as massive volcanic eruptions. If so, does this detract from the impact theory, in view of evidence that $\frac{3}{4}$ of all species perished within a relatively short time period and a large crater having the right age has been found?