Answer Key

Section A [40 points]

T/F [20 points]

1. T
2. T
3. F
4. F
5. T
6. T
7. F
8. T
9. F
10. F
11. T
12. F
13. T
14. T
15. F
16. T
17. T
18. F
19. T
20. T

Fill-in-the-blank [20 points]

21. Voyager 2
22. HR 8799
23. Neptune
24. Triton
25. Venus
26. Pluto
27. Io
28. Iapetus
29. TESS
30. Jupiter

Section B [72 points]

31. (2 points) 3, 12, 4, 18, 2
32. (2 points) 6, 3, 1, 11, 15
33. (a) (1 point) Venus
    (b) (1 point) 0
    (c) (1 point) Image 17
    (d) (2 points) A: Mantle; B: Crust
    (e) (1 point) D
    (f) (1 point) B
34. (a) (1 point) Image 9
    (b) (1 point) Cassini
    (c) (1 point) ISS-Narrow Angle
    (d) (1 point) Huygens
    (e) (1 point) Cassini Regio
35. (a) (1 point) Saturn
    (b) (1 point) Particles of water ice and rock
    (c) (1 point) Image 5
36. (a) (1 point) Image 6
    (b) (1 point) Cantaloupe Terrain
    (c) (2 points) Diapirism
37. (a) (1 point) K2
    (b) (2 points) Two reaction wheels failed, so it couldn't stay pointed at its targets over time.
    (c) (1 point) K2-33b
    (d) (3 points) Uranus; Mercury; Venus (in that order)
38. (a) (1 point) HR 8799
    (b) (1 point) Planets
    (c) (2 points) This is one of the first instances of exoplanet detection via direct imaging, which this image is an example of.
39. (a) (1 point) Neptune
    (b) (1 point) Voyager 2
    (c) (2 points) Location: interstellar space (or equivalent); Communication status: online, communicating with Earth
    (d) (1 point) A high-altitude cloud
    (e) (2 points) Voyager 2 is viewing it tangentially, and the sunlight is scattered back to space before it can be absorbed by the methane.
40. (a) (1 point) Image 18
    (b) (1 point) New Horizons
    (c) (1 point) Image 9
    (d) (1 point) D
    (e) (1 point) B
    (f) (2 points) An occultation is when an object passes in front of another object (in this case, Arrokoth passing in front of a star). Astronomers used Arrokoth's shadow to estimate its shape.
41. (a) (1 point) Image 14
    (b) (1 point) Jupiter and Io
    (c) (2 points) Image 3 and Image 11
    (d) (2 points) Solar panel efficiencies back then were not high enough to provide enough electricity without taking up an unreasonable amount of space/weight.
    (e) (2 points) It was directed to burn up in the atmosphere of Jupiter to prevent cross-contamination with the objects it was studying
42. (a) (1 point) Image 16
    (b) (1 point) Pluto
    (c) (1 point) Tombaugh Regio
    (d) (1 point) A
43. (a) (1 point) Transiting Exoplanet Survey Satellite (TESS)
    (b) (1 point) Image 10
    (c) (3 points) Possible answers include: large planet radius, low orbit inclination when viewed from earth, orbiting closer to parent star (recall that transit probability decreases for planets that orbit farther from their parent stars)
    (d) (5 points) Star B! Since it will have a much shorter orbital period, it is possible to obtain data for many of its transits, which will overcome the initially worse signal-to-noise ratio.
44. (a) (1 point) Io
    (b) (1 point) Image 3
    (c) (1 point) It is a plume [1], which releases sulfurous fallout that settles onto the surrounding rocky surface [1] in the distinct red ring around the volcano [1].

Section C [40 points]

45. (a) (1 point) Atmosphere

 (b) (8 points) The x-axis plots the temperature of the atmosphere [1], while the y-axis plots the corresponding pressure(s) of the atmosphere at that temperature [1]. Points on the y-axis are further delineated by subdivisions into atmospheric layers [1] marked off by their altitude [1]. In general, as altitude increases, temperature and pressure decrease [2] at variable rates [1]. Also, the concentration of certain chemical compounds varies by height/pressure/temperature [1].

 (c) (4 points) Different compounds will condense at different temperatures/pressures [1], so the altitudes they form at will be dictated by these variables [1]. In this case, H_2O ice condenses at significantly higher temperatures and lower pressures than CH_4 [1], meaning that the H_2O clouds are much lower in Uranus's atmosphere than those of CH_4 [1].

 (d) (3 points) Molecular hydrogen (H_2) [1] and helium [1] are absent, likely because they do not condense into cloud structures at these temperatures/pressures [1].

46. (a) (3 points) Semimajor axis, semiminor axis, orbital period (in that order)

 (b) (1 point) T would increase by a factor of $2^{3/2}$.

 (c) (1 point) The eccentricity of the orbit would increase.

 (d) (2 points) Greatest where it is nearest the star (left edge of ellipse) [1], least where it is farthest from the star (right edge of ellipse) [1].

 (e) (3 points) The faster θ changes, the greater the orbital velocity [1]. Therefore, the greatest rate of change in θ is at the point nearest the star [1], while the least rate of change in θ is at the farthest point from the star [1].

47. (a) (2 points) It requires a higher [1] specific energy to disperse an object than to shatter it. When you disperse an object, you have to do additional work (i.e., apply a force against the force of gravity trying to hold everything together) to "eject" parts of the impacted object at a velocity high enough that it won't all come back together. In the dispersed case, the total mechanical energy of the system is positive, while in the shattered case, it is still negative [1].

 (b) (6 points) The ability of small bodies to withstand impact without being disrupted depends upon the material strength of the object [3]. In general the material strength of bodies declines with increasing size, owing to the greater prevalence of defects that lead to cracks [3].

 (c) (6 points) Large bodies are held together primarily by gravitational forces [2]. As a result, Q_D^* must scale with (and exceed significantly, actually) the specific binding energy of the impacted object. [2] At a given density, the specific binding energy is proportional to the square of the radius of the impacted object. As a result, it follows that Q_D^* would also increase with size in this regime [2].