

Answer Sheet

Total Points: 183 points

Section A: Multiple Choice (20 pts). One point per question.

1. D	2. A	3. B	4. D	5. C	6. B	7. E	8. D	9. A	10. E
11. B	12. A	13. C	14. C	15. E	16. D	17. B	18. C	19. B	20. D

Section B: Image-focused Analysis (75 pts)

1.

a.

Europa (1 pt).

b.

Lineae (1 pt), which are composed of water ice (1 pt).

c.

The features were formed by eruptions of warm ice (1 pt),

d.

The lineae indicate habitability since they imply the existence of a sub-surface water ocean through water-ice eruptions (3 pts)

e.

Europa has an iron core (1 pt), a rocky mantle (1 pt), and an ocean of salty water (1 pt), under a thin shell of ice on the surface (1 pt).

f.

Juno (1 pt) in 2022 (1 pt). Image J (1 pt).

g.

Image B is a higher contrast version of Image A

h.

Junocam (1 pt), most appropriate as it is the only visible imager on the spacecraft. (2 pts)

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- i.

This object receives thermal energy from tidal heating (2 pts) and from the radioactive decay of elements within the body (2 pts).
 - j.

Image I (1 pt)
 - k.

Plumes (2 pts)
 - l.

Water ice (2 pts)
 - m.

Proving the existence of plumes implies that a water ocean exists under the surface (2 pts) , which would improve the habitability of Europa significantly (1 pt)
- 2.
- a.

101955 Bennu (1 pt)
 - b.

1999 RQ36 (1 pt)
 - c.

OSIRIS-REx (1 pt), MapCam (1 pt)
 - d.

The Thermal Emission Spectrometer (OTES) (1 pt) and the OSIRIS-REx Visible and InfraRed Spectrometer (OVIRS) (1 pt). Accept just the acronyms.
 - e.

A large collision (1 pt) with a carbon-rich asteroid (1 pt) broke it apart into fragments, one of the pieces being Bennu (1 pt).
 - f.

The Yarkovsky effect (1 pt)
 - g.

It works when sunlight hits an asteroid (1 pt), and the asteroid re-radiates a portion of the light (1 pt), causing a small thrust (1 pt). It applies to small

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meteors and asteroids (1 pt).

h.

It likely formed in the asteroid belt (1 pt)

i.

Image M (1 pt)

j.

67P/Churyumov–Gerasimenko (1 pt), Rosetta (1 pt)

k.

Electrons (1 pt) from the photoionization of water molecules (2 pts), break down
ices on the surface (1 pt).

l.

Glycine (2 pts).

m.

The density is much less than that of Earth and is less than the density of water.
(2 pts)

3.

a.

Enceladus (1 pt)

b.

Ring E (2 pts)

c.

The northern polar region (2 pts)

d.

Cassini (1 pt)

e.

Ali Baba (1 pt) and Aladdin (1 pt) (Any order acceptable)

f.

Dione (1 pt)

g.

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Tidal heating (1 pt)

h.

Dione injects orbital energy into Enceladus (1 pt) which is radiated by tidal forces (1 pt) to further heat the moon (1 pt).

i.

The hydrothermal activity allows for nutrients important for life to form (1 pt) and hydrothermal activity may support microorganisms. (2 pts)

Section C: Theory (88 pts)

1.

a.

The energy balance of a planet is the ratio of incoming energy to outgoing energy. (2 pts) The energy comes from both the host star (1 pt) and energy radiated by the planet itself (1 pt).

b.

A positive energy balance is when there is more incoming energy than outgoing energy (1 pt). A negative energy balance is when there is more outgoing energy than incoming energy to the planet (1 pt). A neutral energy balance is where there is an even amount of incoming and outgoing radiation (1 pt). A neutral energy balance is the most suitable for a planet to be habitable (2 pts).

c.

All three are neutral (3 pts)

d.

1 point for work, 2 points for the correct answer 4.

e.

1 point for work, 2 points for correct answer 300 W/m^2

f.

Planet B has a more similar flux to Earth (1 pt), and planet B is more likely within the habitable zone to the star. (2 pts)

g.

1 point for the graph having a y-intercept of $y=1$, 1 point for the point (1,0.5)

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labeled. 2 points for the point (2, 0.25) labeled. 2 points for the graph having the general shape shown below: $(1/(2^x))$:



2. Kepler's laws

a.

Kepler's first law. (1 pt) Kepler's third law. (1 pt)

b.

Constant angular momentum. (2 pts)

c.

4 types. (2 pts)

d.

2 points for showing work, 3 points for the correct answer $\frac{1}{4}$.

e.

2 points for work, 2 points for the correct answer, 2×10^8 seconds.

3. Proteins

a.

Protein denaturing. (1 pt)

b.

Protein denaturing destroys the hydrogen bonds that hold the protein together. (2 pts)

c.

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Life cannot form at temperatures that are too hot (1 pt). Venus and Mercury are thus excluded from having carbon-based life. (2 pts)

d.

Cooking. (2 pts)

4. Transits

a.

Transit depth is the ratio of the area of the planet to the area of the star. (3 pts)

b.

The ratio is squared since the area of a circle is proportional to r^2 . (2 pts)
It represents the area (1 pt).

c.

It could be used to decompose a complex signal into the individual signals of each exoplanet that orbits in the system (2 pts), which can determine the number of planets (1 pt) and their relative masses. (1 pt)

d.

The system has two planets (1 pt), x, y, and z represent the transits of the planets, with z being the transit of both planets together (3 pt), y being the transit of the larger planet alone (1 pt), and x being the transit of just the smallest planet. (1 pt)

5. Spectra

a.

The gases defined are dense gasses (1 pt), thin and hot gasses (1 pt), and thin and cool gasses (1 pt)

b.

A thin cool gas (1 pt), since planetary atmospheres produce absorption lines (2 pts)

c.

Oxygen gas (2 pts), and O_2 (1 point for O, 2 points with a subscript).

d.

Life (1 pt), since oxygen is a byproduct of chemical reactions that sustain life (1

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pt), and is unstable in an atmosphere by itself without a regular source to replenish it (1 pt)

e.

Photosynthesis (2 pts)

f.

No (1 pt). The feature could come from interstellar gas in between the planet and the observer. (3 pts)

g.

A space telescope (1 pt), since ground-based telescopes have interference from the oxygen in the atmosphere. (2 pts)