Year 12 Science: Planetary systems: formation, orbits and exoplanets

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Why did the solar nebula flatten into a disc as it collapsed?

2. Why could water ice exist as a solid beyond the frost line but not close to the Sun?

3. Jupiter is 5.204 AU from the Sun. Use $T^2 = a^3$ to find its period in years.

4. A star dims by 1% during a transit. What is the planet's radius as a fraction of the star's?

5. Give two pieces of evidence that Phobos may be a captured asteroid.

Exam-style question: TRAPPIST-1

TRAPPIST-1 is a small, cool red dwarf about 40 light-years away with seven Earth-sized planets. They were found by the transit method.

6. Describe a protoplanetary disc.

7. Explain how rocky planets like these form from the disc, referring to changes in temperature.

8. Explain how the transit method detected these planets.

9. Explain why the habitable zone of TRAPPIST-1 is much closer to its star than the Sun's habitable zone is to the Sun.

10. Earth's Moon has rock very like Earth's mantle but a tiny iron core. Explain how this evidence supports the collision theory and rules out capture.

Fix the mistake

11. Correct this statement: "There is no gravity in space, so planets just keep moving."

12. Correct this statement: "The gas giants are big because they are further from the Sun's gravity."

13. Correct this statement: "Earth's Moon was captured as it flew past."

14. Correct this statement: "The habitable zone is the same distance from every star."

Answer key (for parents and tutors)

1. Why did the solar nebula flatten into a disc as it collapsed?
   As it shrank it spun faster, and the spin flattened it into a rotating disc.
2. Why could water ice exist as a solid beyond the frost line but not close to the Sun?
   Beyond the frost line the disc was cold enough for water to freeze; near the Sun it was too hot, so water stayed as gas.
3. Jupiter is 5.204 AU from the Sun. Use $T^2 = a^3$ to find its period in years.
   $T^2 = 5.204^3 = 140.9$, so $T = \sqrt{140.9} = 11.87$ years.
4. A star dims by 1% during a transit. What is the planet's radius as a fraction of the star's?
   $(r \div R)^2 = 0.01$, so $r \div R = \sqrt{0.01} = 0.1$, a tenth of the star's radius.
5. Give two pieces of evidence that Phobos may be a captured asteroid.
   It is small and lumpy, and it is made of dark carbon-rich rock like many asteroids.
6. Describe a protoplanetary disc.
   A flat, spinning disc of gas and dust around a newly formed star, which is the raw material for planets and moons (Achieved).
7. Explain how rocky planets like these form from the disc, referring to changes in temperature.
   Achieved: dust grains stick together and grow into planets. Merit: close to the star it is hot, so only rock and metal condense; grains collide and stick into planetesimals, which attract each other by gravity and grow into protoplanets. Excellence: collisions turn kinetic energy into heat, so young planets melt, iron sinks to make a core and lighter rock a mantle; as the disc and planets cool, solid crusts form, giving small, dense rocky planets.
8. Explain how the transit method detected these planets.
   Achieved: the star gets dimmer when a planet passes in front. Merit: the planet blocks a small fraction of the star's light, giving a regular dip; the time between dips gives the period. Excellence: the depth of the dip, (planet radius ÷ star radius)², gives the planet's size, so Earth-sized planets give small dips, easier to detect around a small star; repeated dips at fixed intervals confirm each planet.
9. Explain why the habitable zone of TRAPPIST-1 is much closer to its star than the Sun's habitable zone is to the Sun.
   Merit: a red dwarf is cool and much less luminous than the Sun, so it gives out less energy each second. Excellence: the energy reaching a planet falls with the square of distance, so to receive enough energy for liquid water a planet must orbit much closer to a dim star; the zone is also narrower.
10. Earth's Moon has rock very like Earth's mantle but a tiny iron core. Explain how this evidence supports the collision theory and rules out capture.
    Merit: the matching rock means the Moon is made from Earth's material, which a captured body from elsewhere would not be. Excellence: a giant impact blasted out mantle rock, which is low in iron, so the Moon has a small core; capture cannot explain the matching composition, and co-accretion would give the Moon Earth's large iron share.
11. Correct this statement: "There is no gravity in space, so planets just keep moving."
    The Sun's gravity pulls every planet towards it; that pull is what keeps bending its path into an orbit.
12. Correct this statement: "The gas giants are big because they are further from the Sun's gravity."
    They are big because ices could freeze in the cold outer disc, giving cores large enough to pull in gas.
13. Correct this statement: "Earth's Moon was captured as it flew past."
    Its rock matches Earth's mantle and it has little iron, which fits a giant impact, not capture.
14. Correct this statement: "The habitable zone is the same distance from every star."
    It depends on the star's luminosity: further out for hot bright stars, very close in for red dwarfs.