

Answer Key

PI IN THE SKY 4

Pi is a handy tool for exploring the solar system and beyond. Did you make any stellar discoveries using pi? Check your answers below and find out!

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Crater Curiosity

Using the circularity ratio formula, determine which of the Mars craters would have the butterfly ejecta pattern.

- 1 Use the formula to find the circularity ratio of Aveiro crater.

$$\frac{4\pi A}{p^2} = \frac{4\pi(67 \text{ km}^2)}{(30 \text{ km})^2} \approx 0.94$$

- 2 Use the formula to find the circularity ratio of the unnamed crater.

$$\frac{4\pi A}{p^2} = \frac{4\pi(32 \text{ km}^2)}{(21 \text{ km})^2} \approx 0.91 \Rightarrow p = 21 \text{ km}$$

- 3 Determine which of the circularity ratios is below 0.925 (which suggests that the object that formed the crater struck at an angle below 20 degrees and created a butterfly ejecta pattern).

Unnamed Crater

AVEIRO CRATER (area) = 67 km²
p (perimeter) = 30 km

CRATER CURIOSITY

Craters form when an object hits the surface of a planet or other body. The impact creates a round impression surrounded by material, called ejecta, that gets blasted out of the crater. Scientists study ejecta because it contains clues about what's below a planet's surface. When an object hits Mars at an angle under 20 degrees, the crater is less circular and the ejecta settles in a butterfly shape. Some areas around the crater contain no blast material. Finding craters that formed this way can help scientists understand how meteor impacts change the surface of a planet. To do this, they measure a crater's circularity ratio. Craters formed at an angle under 20 degrees and created a butterfly ejecta pattern.

Using the circularity ratio formula, $\frac{4\pi A}{p^2}$, determine which of the craters shown here would have the butterfly ejecta pattern.

LEARN MORE ABOUT MARS CRATERS
bit.ly/marscraters

Epic Eclipse

What is the approximate surface area of Earth that will be covered by the disc of the moon's shadow at any one time during the eclipse?

- 1 Find the length of the portion of the moon's shadow that is blocked by Earth.

$$377,700 \text{ km} - 372,027 \text{ km} = 5,673 \text{ km}$$

$$5,673 \text{ km} + 6,378 \text{ km} = 12,051 \text{ km}$$

- 2 Use similar triangles (full shadow : shadow blocked by Earth) to find the radius of the shadow on Earth.

$$\frac{1,738 \text{ km}}{377,700 \text{ km}} = \frac{r}{12,051 \text{ km}}$$

$$(r \cdot 377,700 \text{ km}) = (1,738 \text{ km} \cdot 12,051 \text{ km})$$

$$(r \cdot 377,700 \text{ km}) = (1,738 \text{ km} \cdot 12,051 \text{ km})$$

$$\frac{377,700 \text{ km}}{377,700 \text{ km}}$$

$$r \approx 55.45 \text{ km}$$

- 3 Use the shadow's radius to find its area.

$$A = \pi r^2$$

$$A = \pi(55.45 \text{ km})^2 \approx 9,659 \text{ km}^2$$

Finale Fanfare

Approximately how many days will each of Cassini's 22 grand finale orbits take?

- 1 Convert the periapsis and apoapsis to meters and find the semi-major axis of Cassini's orbit.

$$a_{sc}^3 = \frac{(63,022,000 \text{ m} + 1,274,828,000 \text{ m})}{2} = (668,925,000 \text{ m})^3$$

- 2 Use Kepler's third law to find the orbital period for Cassini's grand finale orbits.

$$a_{sc}^3 = \mu_{cb} \left(\frac{T_{sc}}{2\pi} \right)^2$$

$$(668,925,000 \text{ m})^3 = 3.7931187 \cdot 10^{16} \frac{\text{m}^3}{\text{s}^2} \cdot \left(\frac{T_{sc}}{2\pi} \right)^2$$

$$T_{sc}^2 = \frac{(668,925,000 \text{ m})^3 \cdot (2\pi)^2}{3.7931187 \cdot 10^{16} \frac{\text{m}^3}{\text{s}^2}}$$

$$T_{sc} \approx 558,146 \text{ seconds} \approx 6.46 \text{ days}$$

Approximately what day will Cassini dive into Saturn's atmosphere?

- 1 Multiply the orbital period by the number of orbits until Cassini's dive into Saturn.

$$6.46 \text{ days} \cdot 22.5 \text{ orbits} = 145.35 \text{ days}$$

$$145.35 \text{ days from April 23, 2017} = \text{Sept. 15, 2017}$$

Habitable Hunt

What are the inner and outer radii (r), in AU, of TRAPPIST-1's habitable zone?

- 1 Use the formula and the high end of TRAPPIST-1 temperature range to find the inner radius of its habitable zone.

$$r_{inner} = \sqrt{\frac{(1-A)L}{16\pi\sigma T^4}} = \sqrt{\frac{(1-0.3) \cdot (2.0097 \times 10^{23} \text{ W})}{16\pi(5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}) \cdot (295 \text{ K})^4}}$$

$$r_{inner} \approx 2,552,960,826 \text{ m} \approx 2,552,960.826 \text{ km} \approx 0.017 \text{ AU}$$

- 2 Repeat Step 1 using the low end of the temperature range (192 K) for TRAPPIST-1 to find the outer radius of the habitable zone ...

$$r_{outer} \approx 6,026,785,371 \text{ m} \approx 6,026,785.371 \text{ km} \approx 0.040 \text{ AU}$$

Which of TRAPPIST-1's planets is in the habitable zone?

- 1 Convert the orbital periods (T_p) to seconds and use Kepler's third law to find the semi-major axis (a_p) of each planet's orbit to determine which are in the star's habitable zone.

$$a_{TRAPPIST-1b}^3 = \left(\frac{T_{TRAPPIST-1b}}{2\pi} \right)^2 = \left(\frac{T_{TRAPPIST-1b}}{2\pi} \right)^2 a_{TRAPPIST-1b} \approx 0.011104 \text{ AU}$$

$$a_{TRAPPIST-1c} \approx 0.015209 \text{ AU}$$

$$a_{TRAPPIST-1d} \approx 0.021426 \text{ AU}$$

$$a_{TRAPPIST-1e} \approx 0.028153 \text{ AU}$$

$$a_{TRAPPIST-1f} \approx 0.037045 \text{ AU}$$

$$a_{TRAPPIST-1g} \approx 0.045065 \text{ AU}$$

$$a_{TRAPPIST-1h} \approx 0.06 \text{ AU}$$

FINALE FANFARE

In 2017, after more than 12 years at Saturn, the Cassini mission will come to an end with a final flyby of Saturn. Scientists are planning to use the gravity of Saturn's moon Titan to alter its trajectory and fly into the gap between Saturn and its rings. The mission operators have planned a daring series of orbits that will take Cassini closer to Saturn than ever before. Cassini will use the gravity of Saturn's moon Titan to alter its trajectory and fly into the gap between Saturn and its rings. The mission all begins with a flyby of Titan on April 23, 2017. Then, Cassini will fly by Saturn on a new orbital path. The first apoapsis is on April 23. Then, Cassini will complete 22 elliptical orbits with an average periapsis altitude of 63,022 km and an average apoapsis altitude of 1,274,828 km. A final flyby of Titan will place Cassini on a half-orbit trajectory for Saturn impact.

Use Kepler's third law below to find approximately how many days each orbit will take. Approximately what day will Cassini dive into Saturn's atmosphere?

LEARN MORE ABOUT CASSINI
bit.ly/cassini

TRAPPIST-1 SYSTEM

L (star luminosity) = 2.0097x10²³ watts

μ_{cb} (gravitational parameter) = 3.7931187x10¹⁶ m³/s²

σ (Stefan-Boltzmann constant) = 5.67x10⁻⁸ Wm⁻²K⁻⁴

T_{high} (temperature) = 192-295 K

A_{planet} (albedo) = 0.3

T_{low} (temperature) = 192-295 K

T_{high} (temperature) = 192-295 K

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