Jet Propulsion Laboratory
California Institute of Technology

Answer Key

π 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.

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

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

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

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

Epic Eclipse

What is the approximate surface area of Earth that will be covered by the disk 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.

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

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

2. Use properties of similar triangles to find the radius of the shadow on Earth.

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

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

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

$$r \approx 55.45\ km$$

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

$$A = \pi r^2$$

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

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.

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

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

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

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

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

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

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.

$$6.46\ days \cdot 22.5\ orbits = 145.35\ days$$

145.35 days from April 23, 2017 = 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 the temperature range (295 K) to find the inner radius of TRAPPIST-1's habitable zone.

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

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

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

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

Which of TRAPPIST-1's planets are 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.

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

$$a_{TRAPPIST\text{-}1b}^3 = (1.06198\text{x}10^{19}\ \tfrac{m^3}{s^2})\left(\frac{130{,}539.237984\ sec}{2\pi}\right)^2 \approx 4.58394\text{x}10^{27}\ m^3$$

$$a_{TRAPPIST\text{-}1b} \approx 1{,}661{,}165{,}569\ m \approx 0.011104\ AU$$

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

→ $a_{TRAPPIST\text{-}1d} \approx 0.021426\ AU$
$a_{TRAPPIST\text{-}1e} \approx 0.028153\ AU$
$a_{TRAPPIST\text{-}1f} \approx 0.037045\ AU$

$a_{TRAPPIST\text{-}1g} \approx 0.045065\ AU$
$a_{TRAPPIST\text{-}1h} \approx 0.06\ AU$