

Answer Key

PI IN THE SKY²

Guess what. You just calculated some of the same math problems that NASA scientists and engineers use to explore space. So ... you're basically an honorary rocket scientist. Just sayin'. Check below to see how the experts solved these stellar problems. Do your answers match up?

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Mars Marathon

- 1 Calculate the Opportunity rover's wheel circumference using the pi formula for circumference
 $2\pi r = \text{diameter} \cdot \pi$
 $25 \text{ cm} \cdot \pi$
- 2 Convert the wheel circumference (in cm) to kilometers
 $(25 \text{ cm} \cdot \pi) / 100,000$
- 3 Divide the marathon distance by the wheel circumference
 $42.195 \text{ km} / [(25 \text{ cm} \cdot \pi) / 100,000] \text{ km} \approx 53,724.3$

53,724.3 ROTATIONS

MARS MARATHON

The Mars Exploration Rover Opportunity has been driving on the Red Planet for more than 11 years -- not bad for a mission only planned to last for three months! Opportunity has already beat the off-Earth driving distance record of 39 kilometers and is approaching a marathon distance: 42,195 kilometers.

When Opportunity reaches the marathon goal, how many times will its 25-centimeter diameter wheels have rotated?

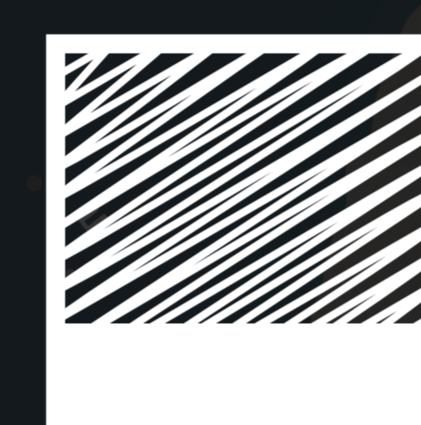
LEARN MORE ABOUT THE MISSION
mars.nasa.gov/mer

PIXEL PUZZLER

The Dawn spacecraft is orbiting Ceres -- a nearly spherical dwarf planet with an average radius of 475 kilometers -- in a perfectly circular polar orbit. While in orbit, Dawn will snap images of Ceres' surface to piece together a global map. From its lowest altitude orbit of 370 kilometers, Dawn's camera can see a patch of Ceres about 26 kilometers on a side.

Assuming no overlap in the images, how many photographs would Dawn have to take to fully map the surface of Ceres?

LEARN MORE ABOUT THE MISSION
dawn.jpl.nasa.gov



Pixel Puzzler

- 1 Calculate the surface area of Ceres using the pi formula for the surface area of a sphere
 $4\pi r^2 = 4\pi(475 \text{ km})^2 \approx 2,835,287 \text{ km}^2$
- 2 Find the surface area of a single image taken by the Dawn spacecraft
 $s^2 = 26 \text{ km} \cdot 26 \text{ km} = 676 \text{ km}^2$
- 3 Divide the surface area of Ceres by the surface area of the image
 $2,835,287 \text{ km}^2 / 676 \text{ km}^2 \approx 4,194.2$

4,195 IMAGES

Frozen Formula

- 1 Find the minimum and maximum radius of Europa minus its ice shell
 $\text{Min: } 1,561 \text{ km} - 30 \text{ km} = 1,531 \text{ km}$
 $\text{Max: } 1,561 \text{ km} - 2 \text{ km} = 1,559 \text{ km}$
- 2 Find the minimum and maximum radius of Europa's rocky interior by subtracting the ice thickness and ocean depth from the radius
 $\text{Min: } 1,561 \text{ km} - (2 \text{ km} + 100 \text{ km}) = 1,459 \text{ km}$
 $\text{Max: } 1,561 \text{ km} - (30 \text{ km} + 3.5 \text{ km}) = 1,527.5 \text{ km}$
- 3 Use the pi formula for the volume of a sphere ($\frac{4}{3}\pi r^3$) to find the minimum and maximum volume for Europa's ocean layer
 $\text{Min: } \frac{4}{3}\pi(1,531^3 - 1,527.5^3) \approx 102,857,290 \text{ km}^3$
 $\text{Max: } \frac{4}{3}\pi(1,559^3 - 1,459^3) \approx 2,862,511,574 \text{ km}^3$

102,857,290 km³ TO
2,862,511,574 km³

FROZEN FORMULA

Scientists have good reason to believe that Jupiter's moon Europa has a liquid ocean wedged between its ice shell and a rocky sea floor. Though it has a known radius of 1,561 kilometers slightly smaller than Earth's moon -- uncertainty exists about the exact thickness of Europa's ice shell and the depth of its ocean.

Assuming Europa's ice shell is between 2 and 30 kilometers thick and its ocean is between 3.5 and 100 kilometers deep, what is the minimum and maximum volume of its ocean?

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solarsystem.nasa.gov/europa

Hear Here

HEAR HERE

The twin Voyager spacecraft, which launched in 1977, are the most distant human-made objects in space. They are currently about 131 astronomical units away (one astronomical unit, AU, is equal to about 150,000,000 kilometers). The Voyager high-gain antenna, a circular parabolic reflector, transmits a circular signal about 0.25 degrees wide.

At the current distance, what fraction of the signal is received by the Deep Space Network antenna?

How many of the original 12.5 watts are received by the DSN antenna?

- 1 Find the radius of Voyager's signal at Earth using tangent and the distance between Earth and Voyager
 $\tan 0.25^\circ = \frac{X}{131 \text{ AU}}$
 $\tan 0.25^\circ = \frac{X}{131 \cdot (1.5 \cdot 10^8 \text{ km})}$
 $X = (1.965 \cdot 10^{10} \text{ km}) \cdot \tan 0.25^\circ \approx 8.574 \cdot 10^7 \text{ km}$
- 2 Convert kilometers to meters. Then use the pi formula for area of a circle (πr^2) to find the ratio of the area of the DSN antenna to the area of Voyager's signal at Earth
 $(8.574 \cdot 10^7 \text{ km}) \cdot 1,000 = 8.574 \cdot 10^{10} \text{ m}$
 $\frac{\pi(35 \text{ m})^2}{\pi(8.574 \cdot 10^{10} \text{ m})^2} = 1.7 \cdot 10^{-19}$
- 3 Multiply the fraction of the signal received at Earth by the original signal wattage sent from Voyager
 $(1.7 \cdot 10^{-19}) \cdot 12.5 \text{ watts} = 2.1 \cdot 10^{-18} \text{ watts}$

1.7 · 10⁻¹⁹

2.1 · 10⁻¹⁸ WATTS

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