**­Teacher Answer Key**

**Pi in the Sky 8**

**Sample Science**

NASA’s OSIRIS-REx mission was designed to travel to an asteroid called Bennu and bring a small sample back to Earth for further study. To achieve its mission, the spacecraft needed to make contact with 26 cm2 of asteroid Bennu’s surface and collect millimeter-size particles using its "contact-pad samplers." These are 1.5-centimeter diameter circular pads of Velcro-like stainless steel. There are 24 pads on the mechanism designed to collect the samples.

**How many pads needed to make contact with Bennu's surface to meet the mission requirement?**

**If all 24 pads contacted Bennu, how much asteroid surface area would the contact pads sample?**

Learn More: [nasa.gov/osiris-rex](https://www.nasa.gov/osiris-rex)

**Answer**

*How many pads needed to make contact with Bennu's surface to meet the mission requirement?*

1. Compute the area of each sample pad.

A = πr2

π(0.75 cm)2 ~ 1.8 cm2

1. Divide the mission requirement for contact with Bennu's surface by the area of the sample pad.

 26 cm2 ÷ (1.8 cm2 /pad) ~ **15 pads**

*If all 24 pads contacted Bennu, how much asteroid surface area would the contact pads sample?*

1. Multiply the number of pads by the surface area contacted by one pad.

 24 pads \* (1.8 cm2 /pad) ~ **43 cm2**

**Whirling Wonder**

Joining the Perseverance rover on Mars is a small helicopter named Ingenuity[.](https://mars.nasa.gov/technology/helicopter/) With twin counter-rotating blades spanning 1.2 meters, Ingenuity is a test of new technology and is designed to achieve the first powered flight on another world.

Despite Mars having less gravity than Earth, the atmosphere on the Red Planet is much thinner than it is here on our home planet. This makes it challenging to lift off the ground on Mars. To generate enough lift for Ingenuity, engineers determined that the helicopter's blades needed to rotate at approximately 250 radians per second on Mars.

**How fast – in rotations per minute – do Ingenuity’s blades spin?**

**How does that compare to a typical helicopter on Earth with blades that spin at 500 rotations per minute?**

Learn more:

mars.nasa.gov/mars2020

**Answer**

*How fast – in rotations per minute – do Ingenuity’s blades spin?*

1. Convert radians to rotations per minute (1 rotation = 2π radians).

(250 rad/sec)\*(60 sec/1 min)\*(1rotation/2π radians) ~ **2,400 rpm**

*How does that compare to a typical helicopter on Earth?*

1. Divide Ingenuity rotations per minute by Earth helicopter rotations per minute.

2,400 rpm / 500 rpm = 4.8

Ingenuity's blades spin ~ **5 times faster**

**Signal Solution**

As more and more data are collected and transmitted through space, NASA needs new technologies to communicate faster and more efficiently with its spacecraft. One such technology is called Deep Space Optical Communications, or DSOC, which uses near-infrared light instead of radio waves to transmit a signal. This allows us to use a higher frequency (shorter wavelength), so more data can be transmitted per second.

The twin Voyager spacecraft launched in 1977 use a 12.5 Watt transmitter paired with a parabolic reflector that creates a circular radio signal with a diameter roughly 0.5 degrees wide. A DSOC system would use a 4 Watt transmitter on a flight laser transceiver, producing a light signal with a diameter of 0.0009 degrees.

If Voyager and a DSOC-equipped spacecraft were both placed 124 AU from Earth (where 1 AU = 150,000,000 km) what fraction of each original wattage would be received by a 70 meter antenna back on Earth?

By what factor is DSOC more effective?

Learn more: [go.nasa.gov/2Lnrv8o](https://go.nasa.gov/2Lnrv8o)

**Answer**

*What fraction of Voyager's original signal is received by a 70 meter antenna on Earth?*

1. Convert astronomical units to meters.

124 AU \* (150,000,000 km / 1 AU) \* (1,000 m / 1 km) ~ 1.86 \*1013 m

1. Find the radius of the beam at Earth using tangent and the distance between Earth and Voyager.

tan 0.25° ~ x / 1.86 \* 1013 m-> 8.12\*1010 m

1. Find the ratio of the antenna area (radius of 35 m) to the signal area.

π(35 m)2 / π (8.12\*1010 m)2 ~ 1.9\*10-19

1. Find the ratio of received signal versus the sent signal.

1.9\*10-19 \* 12.5 W ~ **2.3\*10-18 W or 1.8\*10-20%**

*What fraction of the signal from a DSOC-equipped spacecraft is received?*

1. Follow the same process as above with the values for the DSOC-equipped spacecraft.

124 AU \* (150,000,000 km / 1 AU) \* (1,000 m / 1 km) ~ 1.86 \*1013 m

tan 0.00045° ~ x/1.86 \*1013 m-> 1.46\*108 m

π(35m)2 / π(1.46\*108 m)2 ~ 5.7\*10-14

5.7\*10-14 \* 4 W ~ **2.3\*10-13 W or 5.8\*10-14%**

*By what factor is DSOC more effective?*

1. Divide the received wattage of the DSOC spacecraft's signal by that of Voyager's.

2.3\*10-13 / 2.3\*10-18 = **105 or 100,000 times more effective**

**Force Field**

Every day, Earth is showered in radiation from the Sun. The Sun also emits charged particles almost entirely in the form of ionized hydrogen and helium. These ions travel at speeds of about 400 km per second but rarely reach Earth's surface. That’s because they are deflected by Earth’s magnetic field due to the Lorentz force, given by the equation: F = qvBsinθ where F = force (N), q = charge of the particle in coulombs (C), v = velocity of the particle in meters per second (m/s), B = the magnetic flux density of Earth’s magnetic field in teslas (T) and θ in radians.

The charged particles can't cross Earth's magnetic field, so they follow it to Earth's North and South poles. The resulting concentration of charged particles is what creates auroras.

If Earth’s magnetic flux density is 60µT, what force would a hydrogen ion observe at π/4 radians from the equator? What about at the North Pole (π/2 radians)?

Does the relative magnetic field agree or disagree with what you’d expect about the location of auroras?

Learn more:

go.nasa.gov/3sEvxct

**Answer**

*What force does a hydrogen ion at π/4 radians from the equator observe? What about at π/2 radians from the North Pole?*

1. *Convert microteslas to teslas and kilometers per second to meters per second.*

*60µT = 6\*10-5 T*

*400 k/s = 4*\**105 m/s*

1. *Enter the known values into the Lorentz force equation and compute.*

F = (1.602\*10-19 C) \* (4\*105 m/s) \* (6\*10-5 T)\* sin (π/4)

F ~ **3\*10-18 N**

F = (1.602\*10-19 C) \* (4\*105 m/s) \* (6\*10-5 T)\* sin (π/2)

F ~ **4\*10-18 N**

*Does the relative magnetic field agree or disagree with what you’d expect about the location of auroras?*

1. ***Agrees.*** *A larger Lorentz force occurs at the North Pole where the formation of auroras is more common.*