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Education

π IN THE SKY 8

Answer Key

Force Field

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

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

   $60\mu T = 6 \cdot 10^{-5}\ T$

   $400\ km/s = 4 \cdot 10^{5}\ m/s$

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

   $F = (1.602 \cdot 10^{-19}\ C) \cdot (4 \cdot 10^{5}\ m/s) \cdot (6 \cdot 10^{-5}\ T) \cdot \sin(\pi/4)$

   $F \approx 3 \cdot 10^{-18}\ N$

   $F = (1.602 \cdot 10^{-19}\ C) \cdot (4 \cdot 10^{5}\ m/s) \cdot (6 \cdot 10^{-5}\ T) \cdot \sin(\pi/2)$

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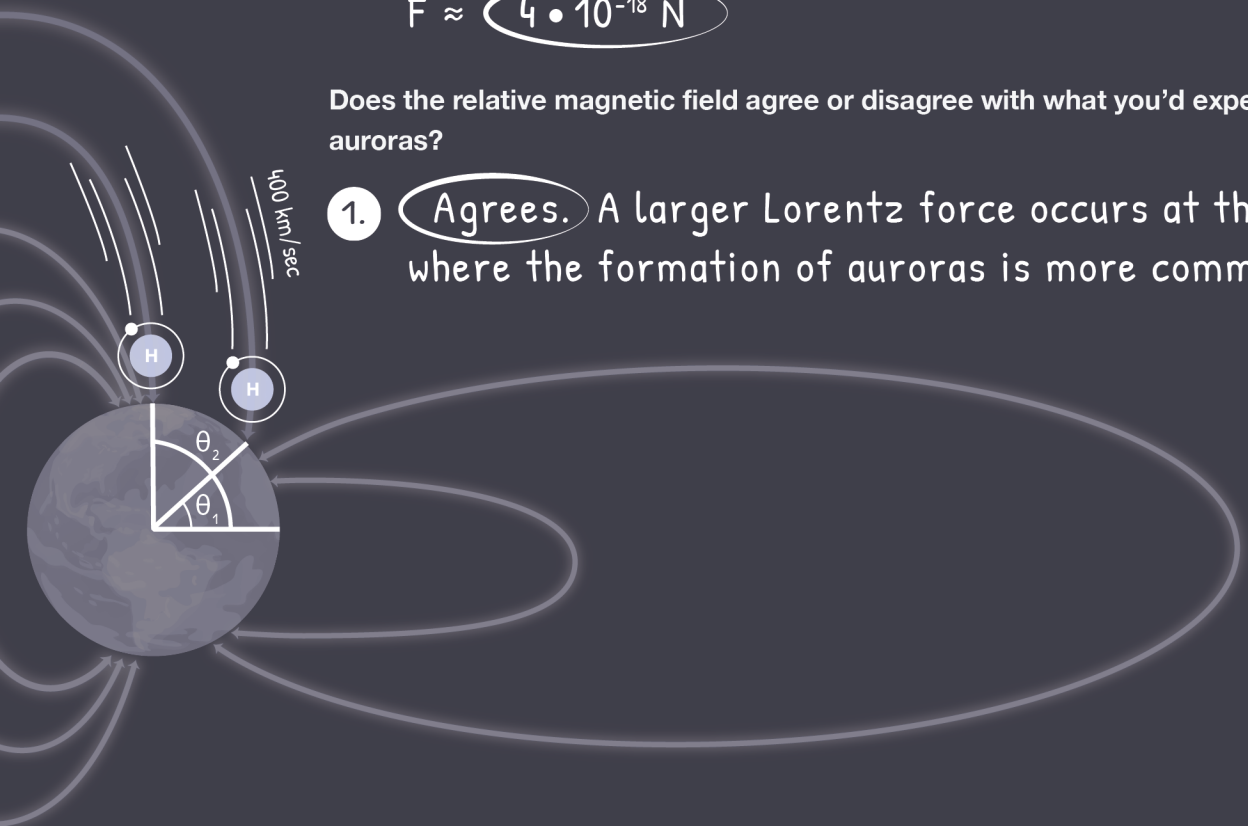
Does the relative magnetic field agree or disagree with what you'd expect about the location of auroras?

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



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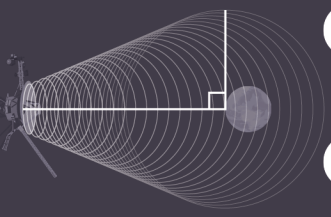
Answer Key

Signal Solution

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

1. **Convert astronomical units to meters.**

   $124\ AU \bullet (150{,}000{,}000\ km / 1\ AU) \bullet (1{,}000\ m / 1\ km) = 1.86 \bullet 10^{13}\ m$

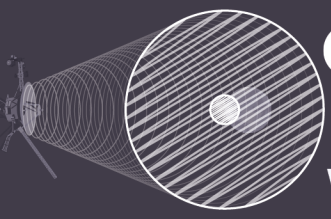


2. **Find the beam radius at Earth using tangent and the distance between Earth and Voyager.**

   $\tan 0.25^\circ \approx x / (1.86 \bullet 10^{13}\ m) \rightarrow 8.12 \bullet 10^{10}\ m$

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

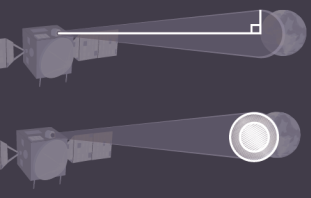
   $\pi(35\ m)^2 / \pi(8.12 \bullet 10^{10}\ m)^2 \approx 1.9 \bullet 10^{-19}$



4. **Find the ratio of received signal versus the sent signal.**

   $1.9 \bullet 10^{-19} \bullet 12.5\ W \approx$ $2.3 \bullet 10^{-18}\ W$ or $1.8 \bullet 10^{-20}\ \%$

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



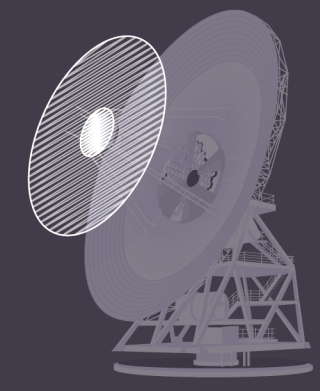
1. **Follow the same process as above with the values for the DSOC-equipped spacecraft.**

   $24\ AU \bullet (150{,}000{,}000\ km / 1\ AU) \bullet (1{,}000\ m / 1\ km) \approx 1.86 \bullet 10^{13}\ m$

   $\tan 0.00045^\circ \approx x / (1.86 \bullet 10^{13}\ m) \rightarrow 1.46 \bullet 10^{8}\ m$

   $\pi(35\ m)^2 / \pi(1.46 \bullet 10^{8}\ m)^2 \approx 5.7 \bullet 10^{-14}$

   $5.7 \bullet 10^{-14} \bullet 4\ W \approx$ $2.3 \bullet 10^{-13}\ W$ or $5.8 \bullet 10^{-14}\ \%$



By what factor is DSOC more effective?

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

   $2.3 \bullet 10^{-13} / 2.3 \bullet 10^{-18} =$ 10^5 or 100,000 times more effective

π IN THE SKY[8]

Answer Key

Whirling Wonder

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) • (1 rotation / 2π radians)

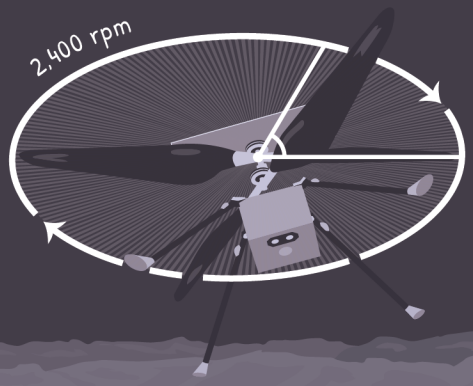
≈ 2,400 rpm

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



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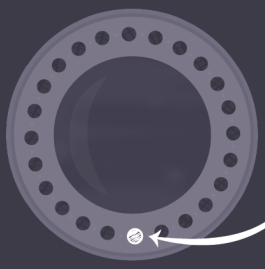
Answer Key

Sample Science



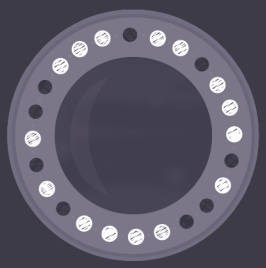
How many pads needed to make contact with Bennu's surface to meet the mission requirement?

1. **Compute the area of each sample pad.**

$A = \pi r^2$

$\pi(0.75\ \text{cm})^2 \approx 1.8\ \text{cm}^2$

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



$26\ \text{cm}^2 \div (1.8\ \text{cm}^2/\text{pad}) \approx$ 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.**

$24\ \text{pads} \bullet (1.8\ \text{cm}^2/\text{pad}) \approx$ 43 cm^2