Jet Propulsion Laboratory
California Institute of Technology | Education

π IN THE SKY 7

Answer Key

Mars Maneuver

What percentage of Curiosity's landing ellipse is Perseverance's landing ellipse?

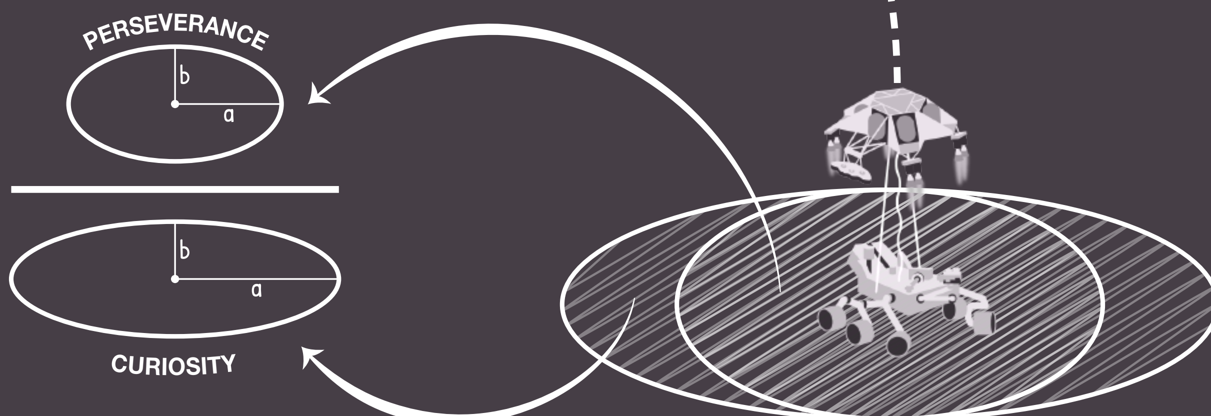
1. **Divide the area of Perseverance's landing ellipse by the area of Curiosity's landing ellipse, using the formula for the area of an ellipse. (Note: π cancels out π.)**

$$A_{ellipse} = \pi ab$$

$$(\pi \bullet 3.5 \bullet 6.5) \,/\, (\pi \bullet 3.5 \bullet 10) \Rightarrow (3.5 \bullet 6.5) \,/\, (3.5 \bullet 10) = 0.65$$

2. **Convert to a percentage.**

$$0.65 \bullet 100 = 65\%$$



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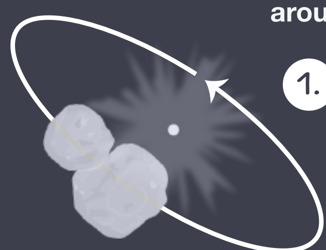
Answer Key

Cold Case

Learn a bit more about Arrokoth by calculating how long it takes the object to make one trip around the Sun.



1. **Using the formula for circumference, compute distance traveled by Arrokoth in one orbit.**

$$C = 2\pi r$$

$$C = 2\pi(6{,}600{,}000{,}000 \text{ km} + 150{,}000{,}000 \text{ km})$$

$$C = 2\pi(6{,}750{,}000{,}000 \text{ km}) \approx 42{,}411{,}500{,}823 \text{ km}$$

2. **Convert radius kilometers to meters, then compute Arrokoth's orbital velocity.**

$$V = \sqrt{\frac{GM_{Sun}}{r}}$$

$$V = \sqrt{\frac{(6.67\text{x}10^{-11}\ m^3kg^{-1}s^{-2}) \bullet (2\text{x}10^{30}\ kg)}{6.75 \text{ x } 10^{12}\ m}}$$

$$V \approx 4{,}446 \text{ m/s}$$

3. **Convert circumference kilometers to meters, then use d=rt compute the time it takes Arrokoth to complete one orbit.**

$$t \approx (42{,}411{,}500{,}823{,}000 \text{ m}) / (4{,}446 \text{ m/s}) \approx 9{,}539{,}248{,}948 \text{ s}$$

4. **Convert seconds to years.**

$$(9{,}539{,}248{,}948 \text{ s}) \bullet (1 \text{ min} / 60 \text{ s}) \bullet (1 \text{ hour} / 60 \text{ min}) \bullet$$
$$(1 \text{ day} / 24 \text{ hours}) \bullet (1 \text{ year} / 365 \text{ days}) \approx 300 \text{ years}$$

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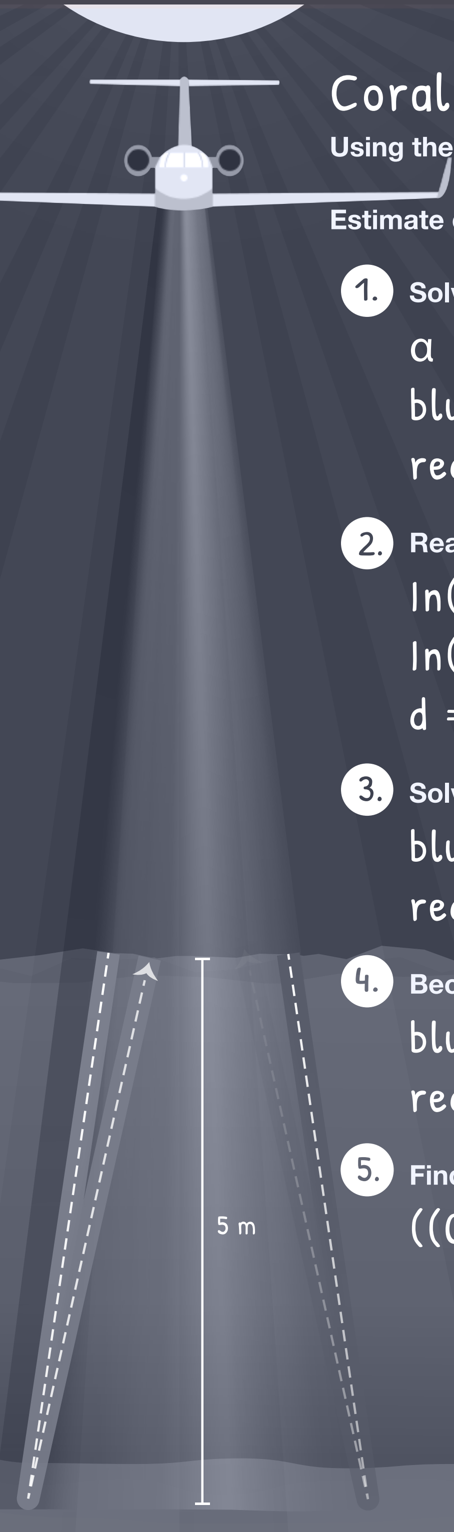

Coral Calculus

Using the absorption coefficient and Beer-Lambert law formulas, calculate the water's depth.

Estimate distance on the blue and red ends of the spectrum:

1. **Solve for the blue light and red light absorption coefficients.**

   $\alpha = (4\pi k) / \lambda$

   blue light: $\alpha = (4\pi \bullet 1.01\text{E-}09) / (0.00000045 \text{ m}) \approx 0.028/\text{m}$

   red light: $\alpha = (4\pi \bullet 1.60\text{E-}08) / (0.00000065 \text{ m}) \approx 0.309/\text{m}$

2. **Rearrange the Beer-Lambert law formula, $T = e^{(-\alpha \cdot d)}$, to solve for d.**

   $\ln(T) = \ln(e^{(-\alpha \cdot d)})$

   $\ln(T) = -\alpha \cdot d$

   $d = \ln(T) / (-\alpha)$

3. **Solve for d on the blue and red ends of the spectrum.**

   blue light: $d = \ln(0.76) / (-0.028) \approx 9.73 \text{ m}$

   red light: $d = \ln(0.045) / (-0.309) \approx 10.04 \text{ m}$

4. **Because light passes through the water twice, divide the total distances by 2.**

   blue light: $9.73 \text{ m}/2 \approx 4.87 \text{ m}$

   red light: $10.04 \text{ m}/2 \approx 5.02 \text{ m}$

5. **Find the weighted mean of the distances from both ends of the spectrum.**

   $((0.76 \bullet 4.87) + (0.045 \bullet 5.02)) / (0.76 + 0.045) \approx$ 5 m

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Planet Pinpointer

Given the angle of the disk's apparent size is 169 arcseconds, determine the actual distance across it using the formula for small angle approximation.

1. **Convert arcseconds to degrees.**

   $1 \text{ arcsec} = (1/3{,}600)^\circ$

   $169 \text{ arcsec} \bullet 1^\circ/3{,}600 \text{ arcsec} \approx 0.0469^\circ$

2. **Multiply degrees by π/180° to convert degrees to radians.**

   $0.0469^\circ \bullet (\pi \;/\; 180^\circ) \approx 0.000819 \text{ radians}$

3. **Use the formula for small angle approximation to find the distance across the Beta Pictoris debris disk.**

   $D = d\theta$

   $D = (6 \bullet 10^{14} \text{ km}) \bullet 0.000819 \approx$ 500 billion km