Jet Propulsion Laboratory
California Institute of Technology | Education

# π IN THE SKY 9

## Answer Key

### Lunar Logic

**How much area does one of Lunar Flashlight's lasers cover in a single pulse?**

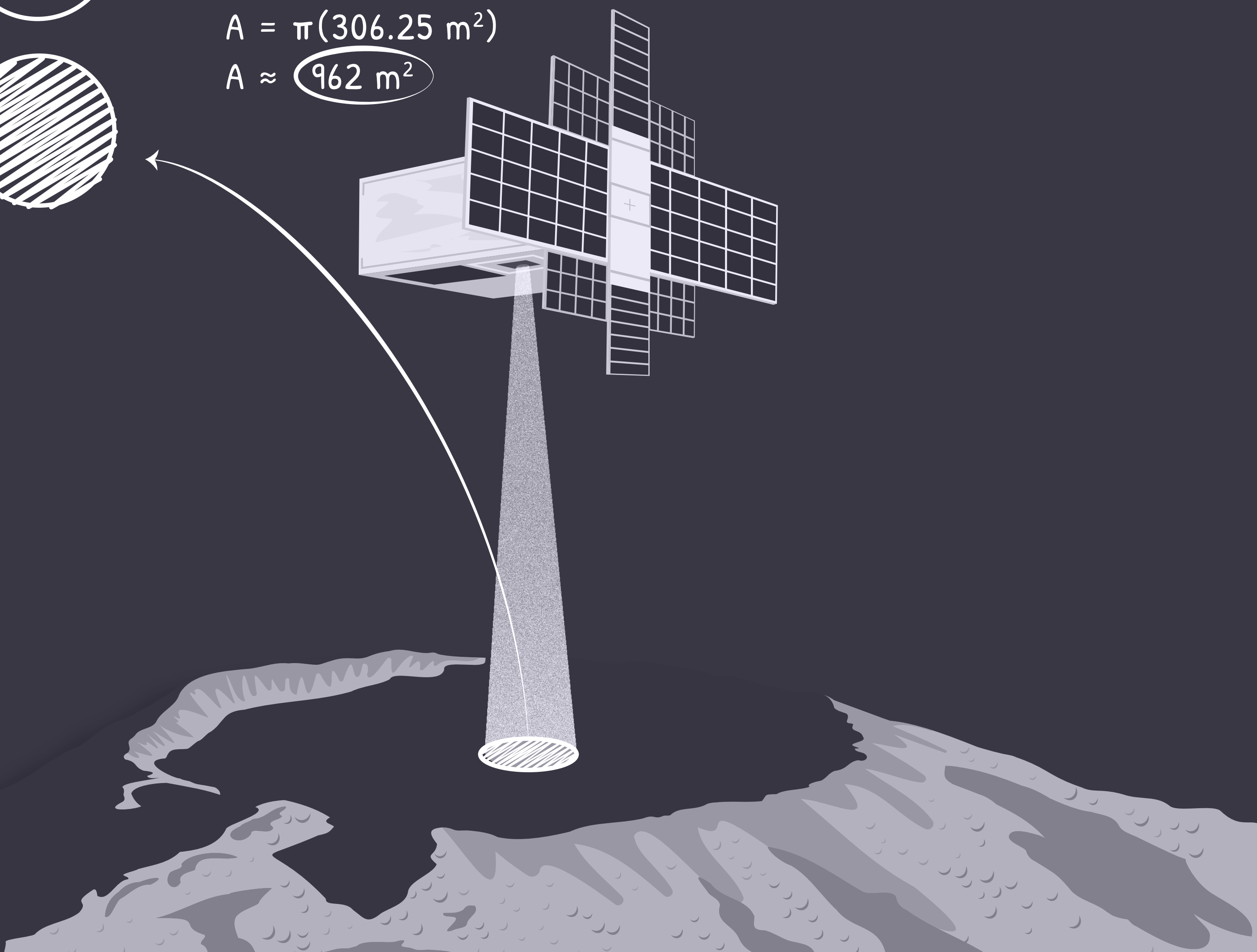
**1.** **Use the formula for area of a circle to calculate the area covered by a laser pulse.**

$A = \pi r^2$

$A = \pi(17.5\text{m})^2$

$A = \pi(306.25\ \text{m}^2)$

$A \approx \boxed{962\ \text{m}^2}$



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### Core Conundrum

**What is the density of Mars' core?**

1. **Convert km to cm.**

   $1{,}830 \text{ km} \bullet (100{,}000 \text{ cm} / 1 \text{ km}) = 183{,}000{,}000 \text{ cm} = 1.83 \bullet 10^{8} \text{ cm}$

2. **Calculate the volume of Mars' core.**

   $V = 4/3\pi r^3$

   $V = 4/3\pi(1.83 \bullet 10^{8} \text{ cm})^3$

   $V \approx 4/3\pi(6.13 \bullet 10^{24} \text{ cm})$

   $V \approx 2.57 \bullet 10^{25} \text{ cm}^3$

3. **Convert kg to g.**

   $(1.54 \bullet 10^{23} \text{ kg}) \bullet (1{,}000 \text{ g} / 1 \text{ kg}) = 1.54 \bullet 10^{26} \text{ g}$

4. **Divide the mass of Mars' core by its volume.**

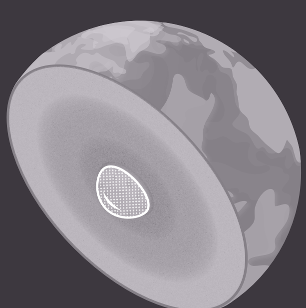
   $(1.54 \bullet 10^{26} \text{ g}) / (2.57 \bullet 10^{25} \text{ cm}^3) \approx 5.99 \text{ g/cm}^3$

**How does that compare to the density of Earth's core?**

Mars' core is less dense.

**What does that tell us about the makeup of Mars' core?**

Mars' core is made of less dense material than Earth's core.



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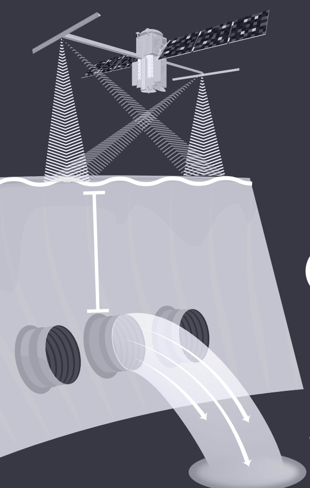


## Dam Deduction

**Compute the velocity of the powered outflow.**

1. **Plug in the values for the measured height of the reservoir (H) above the penstocks and acceleration of gravity constant (g), and compute.**

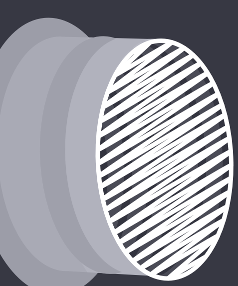
$$V = \sqrt{2gH} = \sqrt{2(9.8\ m/s^2)(100\ m)} = \sqrt{1{,}960\ m^2/s^2} \approx 44\ m/s$$

**What is the powered outflow if 1 penstock is open?**

1. **Compute the area of the penstock opening and multiply by the velocity.**

$$A = \pi r^2 = 3.14 \bullet (3.1\ m)^2 \approx 30\ m^2$$

$$\text{Powered outflow} \approx (30\ m^2)(44\ m/s) \approx 1{,}320\ m^3/s$$



**Is this a high or low percentage of the total outflow?**

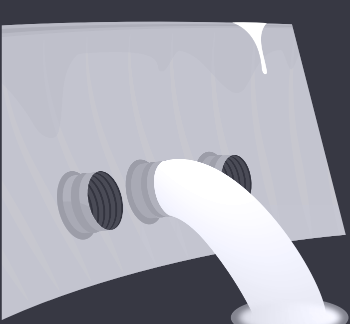
1. **Compute the ratio of powered outflow to total outflow.**

$$(1{,}320\ m^3/s)\ /\ (1{,}350\ m^3/s) \approx 98\%$$

a high percentage of total outflow

**What can this tell you about the potential environmental impacts?**

The potential for environmental impact is high.

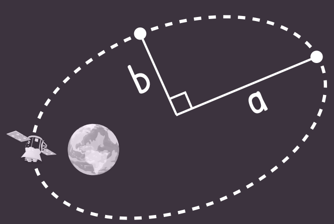


# π IN THE SKY 9

## Answer Key

### Telescope Tango

**How many kilometers would TESS need to travel to successfully transmit its data if its velocity stayed uniform?**

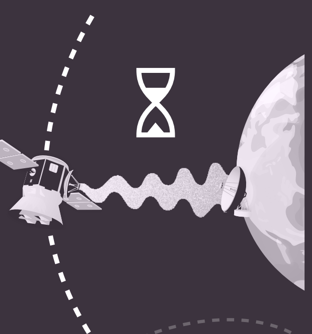



1. **Plug in the values for the semi-major axis (apogee axis/2) and the semi-minor axis (perigee axis/2) into the equation for the perimeter of an ellipse to find the total distance TESS travels throughout its orbit.**

$$P \approx \pi\left[3(a + b) - \sqrt{(3a + b)(a + 3b)}\right]$$

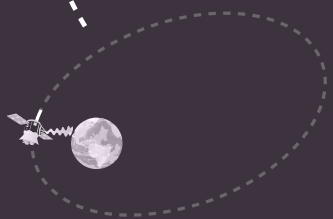
$$P \approx \pi\left[3(188{,}000\text{ km} + 54{,}200\text{ km}) - \sqrt{((3 \bullet 188{,}000\text{ km}) + 54{,}200\text{ km}) \bullet (188{,}000\text{ km} + (3 \bullet 54{,}200\text{ km}))}\right]$$

$$P \approx 820{,}100\text{ km}$$



2. **Divide the downlink time by the time it takes TESS to complete its orbit to find the percentage of the orbit spent sending data back to Earth.**

$$3\text{ hours} / (13.7\text{ days} \bullet 24\text{ hours}) \approx 0.9\%\text{ of perimeter}$$



3. **Multiply the percent of time transmitting by the total perimeter to get the distance covered in this time:**

$$0.009 \bullet 820{,}100\text{ km} \approx 7{,}380\text{ km}$$

**Note: There are many ways to solve this problem. One way is to use the Ramanujan approximation as shown above. However, calculus can also be used.**