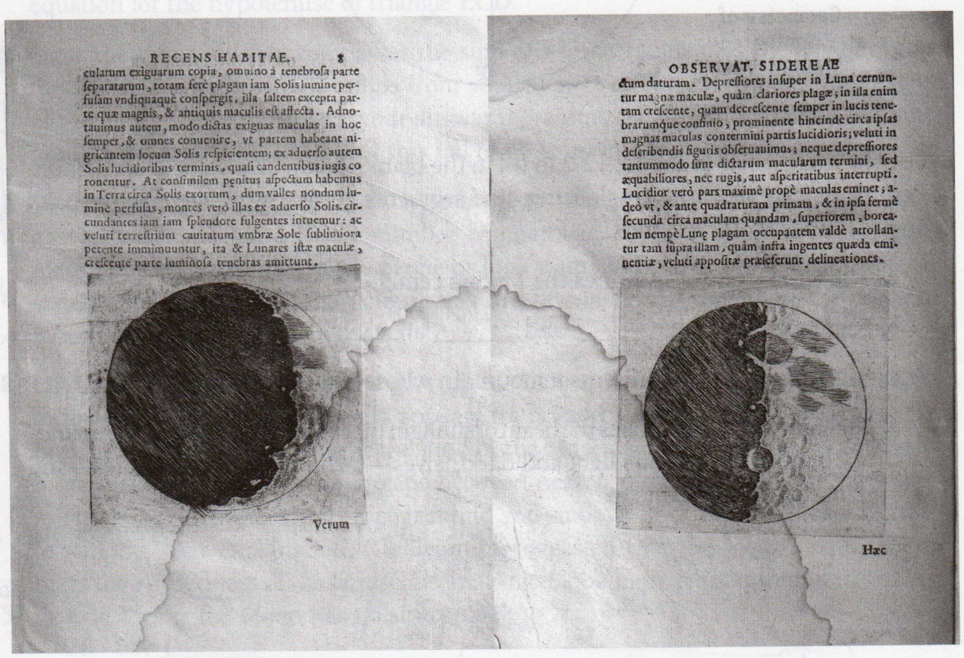
ACTIVITY 12

Galileo Measures a Mountain—On the Moon!

In 1610, Italian astronomer Galileo Galilei created a sensation with the publication of *The Starry Messenger*, an account of his many celestial discoveries with the telescope. Among his observations was a survey of features on the surface of the Moon. He believed that the Moon was another world, like Earth, even comparing mountainous lunar regions to similar landscapes in his native Europe.

One sight in particular captured Galileo's attention, as he relates in his book and its accompanying sketches (**Figure 12-1**):

> *[Not] only are the boundaries of light and shadow in the Moon seen to be uneven and sinuous, but—and this produces still greater astonishment—there appear very many bright points within the darkened portion of the Moon, altogether divided and broken off from the illuminated tract.... Now, is it not the case on the Earth before sunrise, that while the level plain is still in shadow, the peaks of the most lofty mountains are illuminated by the Sun's rays?*



RECENS HABITAE. 8

cularum exiguarum copia, omnino à tenebroſa parte ſeparatarum, totam ferè plagam iam Solis lumine perfuſam vndiquaquè conſpergit, illa ſaltem excepta parte quæ magnis, & antiquis maculis eſt affecta. Adnotauimus autem, modo dictas exiguas maculas in hoc ſemper, & omnes conuenire, vt partem habeant nigricantem locum Solis reſpicientem; ex aduerſo autem Solis lucidioribus terminis, quaſi candentibus iugis coronentur. At conſimilem penitus aſpectum habemus in Terra circa Solis exortum, dum valles nondum luminè perfuſas, montes verò illas ex aduerſo Solis circundantes iam iam ſplendore fulgentes intuemur: ac veluti terreſtrium cauitatum vmbræ Sole ſubliniora petente imminuuntur, ita & Lunares iſtæ maculæ, creſcentè parte luminoſa tenebras amittunt.

Verum

OBSERVAT. SIDEREAE

ctum daturam. Depreſſiores inſuper in Luna cernuntur magnæ maculæ, quàm clariores plagæ; in illa enim tam creſcente, quam decreſcente ſemper in lucis tenebrarumque confinio, prominente hincindè circa ipſas magnas maculas contermini partis lucidioris; veluti in deſcribendis figuris obſeruauimus; neque depreſſiores tantummodo ſunt dictarum macularum termini, ſed æquabiliores, nec rugis, aut aſperitatibus interrupti. Lucidior verò pars maximè propè maculas eminet; adeò vt, & ante quadraturam primam, & in ipſa fermè ſecunda circa maculam quandam, ſuperiorem, borealem nempè Lunę plagam occupantem valdè attollantur tam ſupra illam, quàm infra ingentes quæda eminentiæ, veluti appoſitæ præſeferunt delineationes.

Hæc

Figure 12-1 Galileo's sketches of the Moon.

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In other words, Galileo believed he saw mountain peaks in the dark portion of the Moon that were so tall that their tops were illuminated by the Sun. In this activity, you will follow Galileo's own simple geometric method to estimate the height of these lunar mountains.

The right-hand image in Figure 12-1 shows Galileo's sketch of the first-quarter Moon, with sunlight shining on it from the right. Several illuminated mountain peaks appear as white specks within the Moon's dark half. Now imagine rotating the Moon, as depicted here, around a horizontal axis until we see one of these illuminated peaks from the side. Then the Moon would appear as Galileo drew it in **Figure 12-2**, with the right-hand hemisphere in sunlight, the left-hand hemisphere in darkness. The base of the mountain is located at point **A** and the top at point **D**. Use your imagination or your pencil to fill in the form of the mountain itself. Figure 12-2 is a hypothetical "sideways" view of the Moon from somewhere in outer space. Our actual "face-on" viewpoint from Earth is indicated by the vertical arrow labeled "our view."

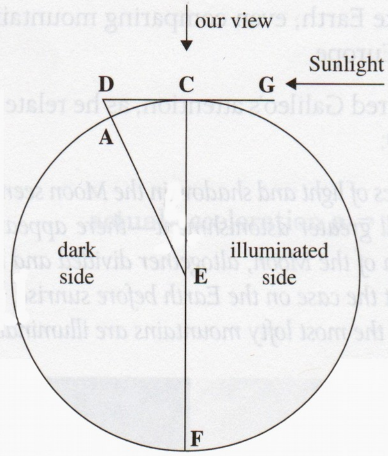

Figure 12-2
Geometry of an illuminated mountain.

1. Use the letter labels in Figure 12-2 to fill in the blanks below and on your worksheet. Points are indicated by a single letter, line segments always by a pair of letters, and angles always by three letters.

   a. The letter _______ indicates the Moon's center.

   b. Segments _______, _______, and _______ are each a radius of the Moon.

   c. Segment _______ represents a mountain whose top is at point **D**.

   d. Segment _______ indicates the beam of sunlight that touches, at point **C**, the boundary between the Moon's light and dark halves—technically, the *terminator*—and illuminates the mountain.

2. In Figure 12-2, Galileo found a right triangle of interest: triangle **ECD**. Again, use the letter labels in Galileo's diagram to fill in the blanks below regarding statements about triangle **ECD**.

a. Angle _______ is the right angle.

b. Side _______ is a lunar radius, about 1080 miles.

c. Side _______ is the distance from the terminator to the illuminated mountain peak, as seen from Earth.

d. Side _______ is the triangle's hypotenuse.

e. This hypotenuse encompasses the sum of two segments: another lunar radius, segment _______, plus the height of the mountain, segment _______.

3. In *The Starry Messenger*, Galileo wrote that the illuminated peaks appeared as far as $\frac{1}{20}$ of the Moon's diameter from the terminator. **(a)** Given that the Moon's diameter is 2160 miles, compute how far into the Moon's dark side these illuminated peaks were situated, according to Galileo. **(b)** To which side of the right triangle **ECD** does this answer correspond?

4. Galileo now applied the Pythagorean Theorem for right triangles: the square of the hypotenuse is equal to the sum of the squares of the sides, or $(\text{hypotenuse})^2 = (\text{side a})^2 + (\text{side b})^2$. Using your answers to Parts 2(b), 2(c) and 2(d), write down the Pythagorean Theorem for the right triangle **ECD**.

5. Using the numerical values from Parts 2(b) and 3, solve the Pythagorean Theorem equation for the hypotenuse of triangle **ECD**.

6. Since the hypotenuse encompasses the sum of a lunar radius plus the height of the mountain, subtract a lunar radius from your answer to Part 5 to obtain the height of the mountain itself. In fact, your answer represents the minimum height of lunar mountains; they must be *at least* this tall to poke up into the sunlight.

7. **(a)** Compare the height of lunar mountains to that of mountains on Earth. Your answer must include a direct number comparison. If you don't know how high mountains on Earth are, ask someone or look it up. **(b)** Do you agree with Galileo's stated conclusion that lunar mountains are *several times* taller than the highest mountains on Earth?

8. Having found that the Moon is so rugged, Galileo had to explain why the edge, or *limb*, of the Moon nonetheless appears round and smooth instead of jagged. He proposed that, when looking at the limb of the Moon, an observer sees successively more distant mountains in the gaps between nearer mountains. Explain how this might make the Moon's limb appear round and smooth. Feel free to sketch a picture to support your explanation. (Galileo also suggested that the Moon's atmosphere blurs the ruggedness of the landscape, making it look more regular than it is. In this he was wrong; the Moon has no atmosphere.)

NAME ______________________________

WORKSHEET ACTIVITY 12

Galileo Measures a Mountain—On the Moon!

For credit, you must show all your work.

1. **(a)** ________ **(b)** ________, ________, ________ **(c)** ________ **(d)** ________

2. **(a)** ________ **(b)** ________ **(c)** ________ **(d)** ________ **(e)** ________, ________

3. **(a)** ________ miles **(b)** ________

4. ____

5.

________ miles

6.

________ miles

7. (a) ______________________________

____

(b) ______________________________

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8. ______________________________

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