

Mass vs. Weight

READ


What is the difference between mass and weight?

| mass | weight |
|--|--|
| <ul style="list-style-type: none"> Mass is a measure of the amount of matter in an object. Mass is not related to gravity. The mass of an object does not change when it is moved from one place to another. Mass is commonly measured in grams or kilograms. | <ul style="list-style-type: none"> Weight is a measure of the gravitational force between two objects. The weight of an object does change when the amount of gravitational force changes, as when an object is moved from Earth to the moon. Weight is commonly measured in newtons or pounds. |

Weightlessness: When a diver dives off of a 10-meter diving board, she is in free-fall. If the diver jumped off of the board with a scale attached to her feet, the scale would read zero even though she is under the influence of gravity. She is “weightless” because her feet have nothing to push against. Similarly, astronauts and everything inside a space shuttle seem to be weightless because they are in constant free fall. The space shuttle moves at high speed, therefore, its constant fall toward Earth results in an orbit around the planet.

EXAMPLES

- On Earth’s surface, the force of gravity acting on one kilogram is 2.22 pounds. So, if an object has a mass of 3.63 kilograms, the force of gravity acting on that mass on *Earth* will be:

$$3.63 \text{ kg} \times \frac{2.22 \text{ pounds}}{\text{kg}} = 8.06 \text{ pounds}$$

- On the moon’s surface, the force of gravity is about 0.370 pounds per kilogram. The same object, if it traveled to the moon, would have a mass of 3.63 kilograms, but her weight would be just 1.33 pounds.

$$3.63 \text{ kg} \times \frac{0.370 \text{ pounds}}{\text{kg}} = 1.33 \text{ pounds}$$

PRACTICE

- What is the weight (in pounds) of a 7.0-kilogram bowling ball on Earth’s surface?
- What is the weight of a 7.0-kilogram bowling ball on the surface of the moon?
- What is the mass of a 7.0-kilogram bowling ball on the surface of the moon?
- Describe what would happen to the spring in a bathroom scale if you were on the moon when you stepped on it. How is this different from stepping on the scale on Earth?
- Would a balance function correctly on the moon? Why or why not?
- Activity:** Take a bathroom scale into an elevator. Step on the scale.
 - What happens to the reading on the scale as the elevator begins to move upward? to move downward?
 - What happens to the reading on the scale when the elevator stops moving?
 - Why does your weight appear to change, even though you never left Earth’s gravity?

Astronomical Units

READ

Talking and writing about distances in our solar system can be cumbersome. The Sun and Neptune are on average 4,500,000,000 (or four billion, five hundred million) kilometers apart. Earth's average distance from the Sun is 150,000,000 (one hundred fifty million) kilometers. It can be difficult to keep track of all the zeroes in such large numbers. And it's not easy to compare numbers that large.

Astronomers often switch to astronomical units (abbreviated AU) when describing distances in our solar system. One astronomical unit is 150,000,000 km—the same as the distance from Earth to the Sun.

Neptune is 30 AU from the Sun. Not only is 30 an easier number to work with than 4,500,000,000; but using astronomical units allows us to see immediately that Neptune is 30 times as far from the Sun as Earth.

In this skill sheet, you will practice working with astronomical units.

EXAMPLE

- Jupiter is 778 million kilometers from the Sun, on average. Find this distance in astronomical units.

Solution: Divide 778 million km by 150 million km: $778,000,000 \div 150,000,000 = 5.19$ AU

- The average distance from Mars to the Sun is 1.52 AU. Find this distance in kilometers.

Solution: Multiply 1.52 AU by 150 million km: $1.52 \times 150,000,000 = 228,000,000$ km

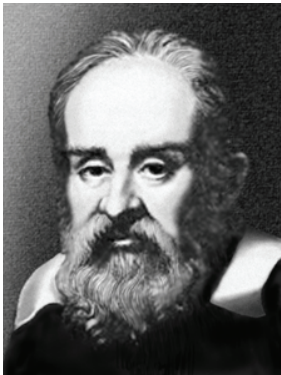
PRACTICE

1. The average distance from Saturn to the Sun is 1.43 billion kilometers. Find this distance in astronomical units.
2. The average distance from Venus to the Sun is 108 million kilometers. Find this distance in astronomical units.
3. Mercury's average distance from the Sun is 0.387 astronomical units. How far is this in kilometers?
4. The average distance from Uranus to the Sun is 19.13 astronomical units. How far is this in kilometers?
5. Is the distance from Earth to the moon more or less than one astronomical unit? How do you know?
6. Which planet is almost 20 times as far away from the Sun as Earth?
7. Which planet is less than half as far away from the Sun as Earth?
8. Which planet is almost twice as far from the Sun as Jupiter?
9. An unmanned spacecraft launched from Earth has traveled 10 astronomical units in the direction away from the Sun. It most recently passed through the orbit of which planet?
10. An unmanned spacecraft launched from Earth has traveled 0.5 astronomical units toward the Sun. Has it passed through the orbit of Venus yet?

Galileo Galilei

Galileo Galilei was a mathematician, scientist, inventor, and astronomer. His observations led to advances in our understanding of pendulum motion and free fall. He invented a thermometer, water pump, military compass, and microscope. He refined a Dutch invention, the telescope, and used it to revolutionize our understanding of the solar system.

An incurable mathematician



Galileo Galilei was born in Pisa, Italy, on February 15, 1564. His father, a musician and wool trader, hoped his son would find a more profitable career. He sent Galileo to a monastery school at age 11 to prepare for medical school. After four years there, Galileo decided to become a monk.

The eldest of seven children, he had sisters who would need dowries in order to marry, and his father had planned on Galileo's support. His father decided to take Galileo out of the monastery school.

Two years later, he enrolled as a medical student at the University of Pisa, though his interests were mathematics and natural philosophy. Galileo did not really want to pursue medical studies. Eventually, his father agreed to let him study mathematics.

Seeing through the ordinary

Galileo was extremely curious. At 20, he found himself watching a lamp swinging from a cathedral ceiling. He used his pulse like a stopwatch and discovered that the lamp's long and short swings took the same amount of time. He wrote about this in an early paper titled "On Motion." Years later, he drew up plans for an invention, a pendulum clock, based on this discovery.

Inventions and experiments

Galileo started teaching at the University of Padua in 1592 and stayed for 18 years. He invented a simple thermometer, a water pump, and a compass for accurately aiming cannonballs. He also performed experiments with falling objects, using an inclined plane to slow the object's motion so it could be more accurately timed. Through these experiments, he realized that all objects fall at the same rate unless acted on by another force.

Crafting better telescopes

In 1609, Galileo heard that a Dutch eyeglass maker had invented an instrument that made things appear larger. Soon he had created his own 10-powered telescope. The senate in Venice was impressed with its potential military uses, and in a year, Galileo had refined his invention to a 30-powered telescope.

Star gazing

Using his powerful telescope, Galileo's curiosity now turned skyward. He discovered craters on the moon, sunspots, Jupiter's four largest moons, and the phases of Venus. His observations led him to conclude that Earth could not possibly be the center of the universe, as had been commonly accepted since the time of the Greek astronomer Ptolemy in the second century.

Instead, Galileo was convinced that Polish astronomer Nicolaus Copernicus (1473-1543) must have been right: The sun is at the center of the universe and the planets revolve around it.

House arrest

The Roman Catholic Church held that Ptolemy's theory was truth and Copernican theory was heresy. Galileo had been told by the Inquisition in 1616 to abandon Copernican theory and stop pursuing these ideas.

Despite these threats, in February 1632, he published his ideas in the form of a conversation between two characters. He made the one representing Ptolemy's view seem foolish, while the other, who argued Copernicus's theory, seemed wise.

This angered the church, whose permission was needed for publishing books. Galileo was called to Rome before the Inquisition. He was given a formal threat of torture and so he abandoned his ideas that promoted Copernican theory. He was sentenced to house arrest, and lived until his death in 1642 watched over by Inquisition guards.

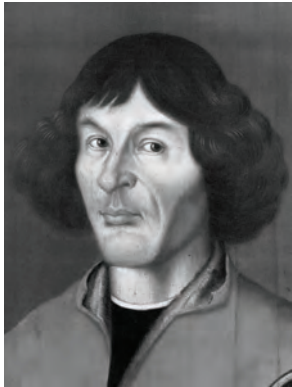
Reading reflection

1. What scientific information was presented in Galileo's paper "On Motion"?
2. **Research** one of Galileo's inventions and draw a diagram showing how it worked.
3. How were Galileo's views about the position of Earth in the universe supportive of Copernicus's ideas?
4. Imagine you could travel back in time to January 1632 to meet with Galileo just before he publishes his "Dialogue Concerning the Two Chief World Systems." What would you say to him?
5. In your opinion, which of Galileo's ideas or inventions had the biggest impact on history? Why?

Nicolaus Copernicus

Nicolaus Copernicus was a church official, mathematician, and influential astronomer. His revolutionary theory of a heliocentric (sun-centered) universe became the foundation of modern-day astronomy.

Wealth, education, and religion



Nicolaus Copernicus was born on February 19, 1473 in Torun, Poland. Copernicus' father was a successful copper merchant. His mother also came from wealth. Being from a privileged family, young Copernicus had the luxury of learning about art, literature, and science.

When Copernicus was only 10 years old, his father died. Copernicus went to live with his uncle, Lucas Watzenrode, a prominent Catholic Church official who became bishop of Varmia (now part of modern-day Poland) in 1489. The bishop was generous with his money and provided Copernicus with an education from the best universities.

From church official to astronomer

Copernicus lived during the height of the Renaissance period when men from a higher social class were expected to receive well-rounded educations. In 1491, Copernicus attended the University of Krakow where he studied mathematics and astronomy. After four years of study, his uncle appointed Copernicus a church administrator. Copernicus used his church wages to help pay for additional education.

In January 1497, Copernicus left for Italy to study medicine and law at the University of Bologna. Copernicus' passion for astronomy grew under the influence of his mathematics professor, Domenico Maria de Novara. Copernicus lived in his professor's home where they spent hours discussing astronomy.

In 1500, Copernicus lectured on astronomy in Rome. A year later, he studied medicine at the University of Padua. In 1503, Copernicus received a doctorate in canon (church) law from the University of Ferrara.

Observations with his bare eyes

After his studies in Italy, Copernicus returned to Poland to live in his uncle's palace. He resumed his church duties, practiced medicine, and studied

astronomy. Copernicus examined the sky from a palace tower. He made his observations without any equipment. In the late 1500s, the astronomer Galileo used a telescope and confirmed Copernicus' ideas.

A heliocentric universe

In the 1500s, most astronomers believed that Earth was motionless and the center of the universe. They also thought that all celestial bodies moved around Earth in complicated patterns. The Greek astronomer Ptolemy proposed this geocentric theory more than 1000 years earlier.

However, Copernicus believed that the universe was heliocentric (sun-centered), with all of the planets revolving around the sun. He explained that Earth rotates daily on its axis and revolves yearly around the sun. He also suggested that Earth wobbles like a top as it rotates.

Copernicus' theory led to a new ordering of the planets. In addition, it explained why the planets farther from the sun sometimes appear to move backward (retrograde motion), while the planets closest to the sun always seem to move in one direction. This retrograde motion is due to Earth moving faster around the sun than the planets farther away.

Copernicus was reluctant to publish his theory and spent years rechecking his data. Between 1507 and 1515, Copernicus circulated his heliocentric principles to only a few astronomers. A young German mathematics professor, George Rheticus, was fascinated with Copernicus' theory. The professor encouraged Copernicus to publish his ideas. Finally, Copernicus published *The Revolutions of the Heavenly Orbs* near his death in 1543.

Years later, several astronomers (including Galileo) embraced Copernicus' sun-centered theory. However, they suffered much persecution by the church for believing such ideas. At the time, church law held great influence over science and dictated a geocentric universe. It wasn't until the eighteenth century that Copernicus' heliocentric principles were completely accepted.

Reading reflection

1. How did Copernicus' privileged background help him become knowledgeable in so many areas of study?
2. Which people influenced Copernicus in his work as a church official and an astronomer?
3. How did Copernicus make his observations of the sky?
4. What did astronomers believe of the universe prior to the sixteenth century?
5. Describe Copernicus' revolutionary heliocentric theory of the universe.
6. Why did so many astronomers face persecution by the church for their beliefs in a heliocentric universe?
7. **Research:** Using the library or Internet, find out which organizations developed the Copernicus Satellite (OAO-3) and why it was used.

Johannes Kepler

Johannes Kepler was a mathematician who studied astronomy. He lived at the same time as two other famous astronomers, Tycho Brahe and Galileo Galilei. Kepler is recognized today for his use of mathematics to solve problems in astronomy. Kepler explained that the orbit of Mars and other planets is an ellipse. In his most famous books he defended the sun-centered universe and his three laws of planetary motion.

Early years in Germany



Johannes Kepler was born December 27, 1571, in Weil der Stadt, Wurttemberg, Germany, now called the “Gate to the Black Forest.” He was the oldest of six children in a poor family. As a child he lived and worked in an inn run by his mother’s family. He was sickly, nearsighted, and suffered from smallpox at a young age. Despite his

physical condition, he was a bright student.

The first school Kepler attended was a convent school in Adelberg monastery. Kepler’s original plan was to study to become a Lutheran minister. In 1589, Kepler received a scholarship to attend the University of Tubingen. There he spent three years studying mathematics, philosophy, and theology. His interest in math led him to take a mathematics teaching position at the Academy in Graz. There he began teaching and studying astronomy.

Influenced by Copernicus

At Tubingen, Kepler’s professor, Michael Mastlin, introduced Kepler to Copernican astronomy. Nicholas Copernicus (1473-1543), had published a revolutionary theory in, “On the Revolutions of Heavenly Bodies.” Copernicus’ theory stated that the sun was the center of the solar system. Earth and the planets rotated around the sun in circular orbits. At the time most people believed that Earth was the center of the universe.

Copernican theory intrigued Kepler and he wrote a defense of it in 1596, *Mysterium Cosmographicum*. Although Kepler’s original defense was flawed, it was read by several other famous European astronomers of the time, Tycho Brahe (1546-1601) and Galileo Galilei (1546-1642).

Kepler published many books in which he explained how vision, optics, and telescopes work. His most famous work, though, dealt with planetary motion.

Working with Tycho Brahe

In 1600, Brahe invited Kepler to join him. Brahe, a Danish astronomer, was studying in Prague, Czechoslovakia. Every night for years Brahe recorded planetary motion without a telescope from his observatory. Brahe asked Kepler to figure out a scientific explanation for the motion of Mars. Less than two years later, Brahe died. Kepler was awarded Brahe’s position as Imperial Mathematician. He inherited Brahe’s collection of planetary observations to use to write mathematical descriptions of planetary motion.

Kepler’s Laws of Planetary Motion

Kepler discovered that Mars’ orbit was an ellipse, not a circle, as Copernicus had thought. Kepler published his first two laws of planetary motion in *Astronomia Nova* in 1609. The first law of planetary motion stated that planets orbit the sun in an elliptical orbit with the sun in one of the foci. The second law, the law of areas, said that planets speed up as their orbit is closest to the sun, and slow down as planets move away from the sun. Kepler published a third law, called the harmonic law, in 1619. The third law shows how a planet’s distance from the sun is related to the amount of time it takes to revolve around the sun. His work influenced Isaac Newton’s later work on gravity. Kepler’s calculations were done before calculus was invented!

Other scientific discoveries

Kepler sent his book in 1609 to Galileo. Galileo’s theories did not agree with Kepler’s ideas and the two scientists never worked together. Despite his accomplishments, when Kepler died at age 59, he was poor and on his way to collect an old debt. It would take close to a century for his work to gain the recognition it deserved.

Reading reflection

1. Why was Copernicus' idea of the sun at the center of the solar system considered revolutionary?
2. Explain how Brahe helped Kepler make important discoveries in astronomy.
3. How was Kepler's approach to astronomy different than Brahe's and Galileo's?
4. Kepler discovered that Mars and other planets traveled in an ellipse around the sun. Does this agree with Copernicus' theory?
5. Describe Kepler's three laws of planetary motion.
6. Kepler observed a supernova in 1604. It challenged the way people at the time thought about the universe because people did not know the universe could change. When people have to change their beliefs about something because scientific evidence says otherwise, that is called a "paradigm shift." Find three examples in the text of scientific discoveries that led to a "paradigm shift."

Water on Mars



NASA's Exploration Rover Mission is an exciting effort to determine whether or not life ever arose on Mars. In pursuit of this aim, NASA has landed rovers on the planet that are capable of looking for clues in the rocks and soil.

In this project, you will:

- (1) Learn why evidence for life depends on finding evidence for water on Mars, and
- (2) Learn about one of the tools the rover uses to detect water on Mars.



Part 1: Why does water indicate life?

1. Visit the Mars Rover Project Site on-line at <http://marsrovers.jpl.nasa.gov/home/index.html>. Additionally, a link to the project site is found at www.nasa.gov. Become familiar with this web site.
2. How many rovers are on Mars? What are the names of the rovers?
3. What do we know at this time about the existence of water on Mars?
4. Why is finding water so important to the NASA scientists?
5. What do we know at this time about the existence of life on Mars?
6. Write a short essay that explains why water is necessary for life.
7. **Extension:** With your class have a discussion about whether or not it is worthwhile to search for the existence of life on other planets. What are the pros for this kind of exploration? What are the cons?

Part 2: Tools for detecting water

1. At the Mars Rover Project Site, find out what tools on the rovers are used to find evidence of water on Mars. Read about all the tools and select one to study.
2. Write a paragraph describing how this tool works and where it is located on the rover.
3. What data is collected by the tool?
4. Write a paragraph explaining how the collected data helps provide evidence for whether or not there is water on Mars.

Note to student: If you have trouble understanding what your tool does and why, ask an expert. Experts who may be able to help you include geologists, meteorologists, and other scientists. You can find an expert by going to the web site of a university near where you live. Usually, these web sites provide the email address or phone number of scientists. If you do contact an expert, be respectful of that person's time. Your teacher can help you determine what you would like to ask the expert and the best way to ask for advice.

5. By yourself or with a group prepare a presentation about the tool you studied. Ideas for presentations include: (1) making a poster with colorful graphics and written descriptions, (2) making a model of the tool, or (3) presentation in PowerPoint® format.

Touring the Solar System

READ



What would a tour of our solar system be like? How long would it take? How much food would you have to bring? In this skill sheet, you will calculate the travel distances and times for a tour of the solar system. Your mode of transportation will be a space vehicle travelling at 250 meters per second or 570 miles per hour.

Part 1: Planets on the tour

Starting from Earth, the tour itinerary is: **Earth to Mars to Saturn to Neptune to Venus and then back to Earth**. The distances between each planet on the tour are provided in Table 1. The space vehicle travels at 250 meters per second or 900 kilometers per hour. Using this rate and the speed formula, find out how long it will take to travel each leg of the itinerary. An example for how to calculate how many hours it will take to travel from Earth to Mars is provided below. For the table, calculate the time in days and years as well.

EXAMPLE



- How many days will it take to travel from Earth to Mars? The distance from Earth to Mars is 78 million kilometers.

Solution:

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

$$\text{time to travel from Earth to Mars} = \frac{78 \text{ million km}}{900 \frac{\text{km}}{\text{hour}}}$$

$$\text{time to travel from Earth to Mars} = 86,666 \text{ hours}$$

$$86,666 \text{ hours} \times \frac{1 \text{ day}}{24 \text{ hours}} = 3,611 \text{ days}$$

PRACTICE



Table 1: Solar System Trip

| Legs of the trip | Distance traveled for each leg (km) | Hours traveled | Days traveled | Years traveled |
|-------------------|-------------------------------------|----------------|---------------|----------------|
| Earth to Mars | 78,000,000 | | | |
| Mars to Saturn | 1,202,000,000 | | | |
| Saturn to Neptune | 3,070,000,000 | | | |
| Neptune to Venus | 4,392,000,000 | | | |
| Venus to Earth | 42,000,000 | | | |

Part 2: Provisions for the trip

A trip through the solar system is a science fiction fantasy. Answer the following questions as if such a journey were possible.

1. It is recommended that a person drink eight glasses of water each day. To keep yourself hydrated on your trip. How many glasses of water would you need to drink on the leg from Earth to Mars?
2. An average person needs 2,000 food calories per day. How many food calories will you need for the leg of the journey from Neptune to Venus?
3. Proteins and carbohydrates provide 4 calories per gram. Fat provides 9 calories per gram. Given this information, would it be more efficient to pack the plane full of foods that are high in fat or high in protein for the journey? Explain your answer.
4. You decide that you want to celebrate Thanksgiving each year of your travel. How many frozen turkeys will you need for the entire journey?

Part 3: Planning your trip for each planet

Section 17.2 of your student text presents a table that lists the properties of the nine planets. Use this table to answer the following questions.

1. On which planet would there be the most opportunities to visit a moon?
2. Which planets would require high-tech clothing to endure high temperatures? Which planets would require high-tech clothing to endure cold temperatures?
3. Which planet has the longest day?
4. Which has the shortest day?
5. On which planet would you have the most weight? How much would you weigh in newtons?
6. On which planet would you have the least weight? How much would you weigh in newtons? Use proportions to answer this question.
7. Which planet would take the longest time to travel around?
8. Which planet would require your spaceship to orbit with the fastest orbital speed? Explain your answer.

Benjamin Banneker

Benjamin Banneker was a farmer, naturalist, civil rights advocate, self-taught mathematician, astronomer and surveyor who published his detailed astronomical calculations in popular almanacs. He was appointed by President George Washington as one of three surveyors of the territory that became Washington D.C.

Early times



Benjamin Banneker was born in rural Maryland in 1731. His family was part of a population of about two hundred free black men and women in Baltimore county. They owned a small farm where they grew tobacco and vegetables, earning a comfortable living.

A mathematician builds a clock

Benjamin's grandmother taught him to read, and he briefly attended a Quaker school near his home. Benjamin enjoyed school and was especially fond of solving mathematical riddles and puzzles.

When he was 22, Benjamin borrowed a pocket watch, took it apart, and made detailed sketches of its inner workings. Then he carved a large-scale wooden model of each piece, fashioned a homemade spring, and built his own clock that kept accurate time for over 50 years.

A keen observer of the night sky

As a young adult, Benjamin designed an irrigation system that kept his family farm prosperous even in dry years. The Bannekers sold their produce at a nearby store owned by a Quaker family, the Ellicotts. There, Benjamin became friends with George Ellicott, who loaned him books about astronomy and mathematics.

Banneker was soon recording detailed observations of the night sky. He performed complicated calculations to predict the positions of planets and the timing of eclipses.

From 1791 to 1797, Banneker published his astronomical calculations along with weather and tide predictions, literature, and commentaries in six almanacs. The almanacs were widely read in Maryland, Delaware, Pennsylvania, and Virginia, bringing Banneker a measure of fame.

A keen observer of nature

Banneker was also a keen observer of the natural world and is believed to be the first person to document the cycle of the 17-year cicada, an insect that exists in the larval stage underground for 17 years, and then emerges to live for just a few weeks as a loud buzzing adult.

Banneker writes Thomas Jefferson

Banneker sent a copy of his first almanac to then-Secretary of State Thomas Jefferson, along with a letter challenging Jefferson's ownership of slaves as inconsistent with his assertion in the Declaration of Independence that "all men are created equal."

Jefferson sent a letter thanking Banneker for the almanac, saying that he sent it onto the Academy of Sciences of Paris as proof of the intellectual capabilities of Banneker's race.

Although Jefferson's letter stated that he "ardently wishes to see a good system commenced for raising the condition both of [our black brethren's] body and mind," regrettably, he never freed his own slaves.

Designing Washington D.C.

In 1791, George Ellicott's cousin Andrew Ellicott asked him to serve as an astronomer in a large surveying project. George Ellicott suggested that he hire Benjamin Banneker instead.

Banneker left his farm in the care of relatives and traveled to Washington, where he became one of three surveyors appointed by President George Washington to assist in the layout of the District of Columbia.

After his role in the project was complete, Banneker returned to his Maryland farm, where he died in 1806. Banneker Overlook Park, in Washington D.C., commemorates his role in the surveying project. In 1980, the U.S. Postal Service issued a stamp in Banneker's honor.

Reading reflection

1. Benjamin Banneker built a working clock that lasted 50 years. Why would his understanding of mathematics have been helpful in building the clock?
2. Identify one of Banneker's personal strengths. Justify your answer with examples from the reading.
3. Benjamin Banneker lived from 1731 to 1806. During his lifetime, he advocated equal rights for all people. Find out the date for each of the following "equal rights" events:
 - (a) the Emancipation Proclamation
 - (b) the end of the Civil War
 - (c) women gain the right to vote
 - (d) the desegregation of public schools (due to the Supreme Court case, Brown vs. the Board of Education).
4. Name three of Benjamin Banneker's lifetime accomplishments.
5. What do you think motivated Banneker during his lifetime? What are some possible reasons that he was persistent in his scientific work?
6. **Research:** Find a mathematical puzzle written by Banneker. Try to solve it with your class.

Measuring the Moon's Diameter



In this skill sheet you will explore how to measure the moon's diameter using simple tools and calculations.

Materials

Here are the materials you will need to measure the moon's diameter:

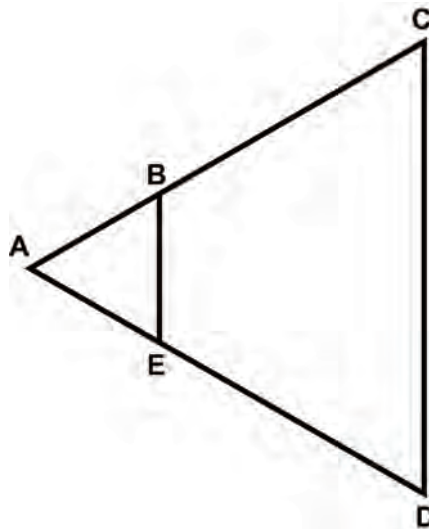
- A 3-meter piece of string
- A metric tape measure
- A small metric ruler
- Tape
- Scissors
- Marker
- One-centimeter semi-circle card (Cut out from the bottom of the last page)



Proportions and Geometry

The method you will use to measure the moon's diameter depends on the properties of similar triangles. The following exercise demonstrates these properties.

Below is a large triangle. A line drawn from one side to the other of the large triangle results in a smaller triangle inside the larger one. The ends of each line are labeled with letters.



1. Make the following measurements of the lines on the triangle:

Distance AC: _____ cm

Distance AD: _____ cm

Distance AB: _____ cm

Distance AE: _____ cm

Distance BE: _____ cm

Distance CD: _____ cm

2. How is the distance from AB related to AC?
3. How is the distance from BE related to CD?
4. Based on your measurements and your answers to questions (2) and (3), come up with a statement that explains the properties of similar triangles.

Finding the diameter of the moon

Now, you are ready to use your supplies to find the diameter of the moon. Follow these steps carefully and answer the questions as you go.

1. Locate a place where you can see the moon from a window. This is possible at night or early in the morning.
2. Use scissors to carefully cut out the semi-circle card found on the next page.
3. Tape this card to the window when you can see the full (or gibbous) moon through the window.
4. Tape one end of the 3-meter piece of string to the card directly underneath the semi-circle.
5. Now, slowly move backward from the window while holding on to the string. Watch your step! As you move backward, pay attention to the moon. You want to move back far enough so that the bottom half of the moon “sits” in the semi-circle cutout. You want the semi-circle to be the same size as the lower half to the moon.
6. When the lower half of the moon is the same size as the semi-circle cut out, stop moving backward and hold the string up to the side of one of your eyes. Have a friend carefully mark the string at this distance.
7. Now, measure the distance from the window to the mark on the string to the nearest millimeter. Convert this distance to meters. Write the string distance in Table 1.

Table 1: Finding the moon's diameter data

| | |
|---------------------------------|----------------------|
| Semi-circle diameter | 0.01 meter |
| String distance | |
| Diameter of the moon | ??? |
| Distance from Earth to the moon | 384, 400, 000 meters |

Finding the moon's diameter

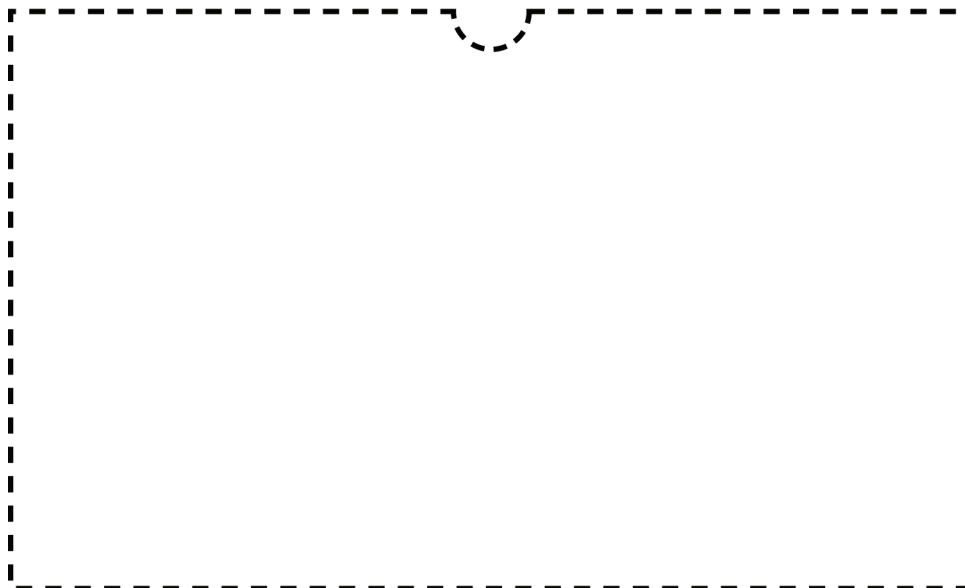
1. You have three out of four measurements in Table 1. The only measurement you need is the moon's diameter. You can find the moon's diameter using proportions. Which calculation will help you?

| | |
|--|--|
| <p>a.</p> $\frac{\text{semi-circle diameter}}{\text{moon diameter}} = \frac{\text{distance to semi-circle}}{\text{distance from Earth to the moon}}$ | <p>b.</p> $\frac{\text{semi-circle diameter}}{\text{distance to semi-circle}} = \frac{\text{moon diameter}}{\text{distance from Earth to the moon}}$ |
| <p>c.</p> $\frac{\text{moon diameter}}{\text{semi-circle diameter}} = \frac{\text{distance to semi-circle}}{\text{distance from Earth to the moon}}$ | <p>d.</p> $\frac{\text{moon diameter}}{\text{semi-circle diameter}} = \frac{\text{distance from Earth to the moon}}{\text{distance to semi-circle}}$ |

2. Use the proportion that you selected in question (1) to calculate the moon's diameter.
3. How is performing this calculation like the exercise you did in part 2?

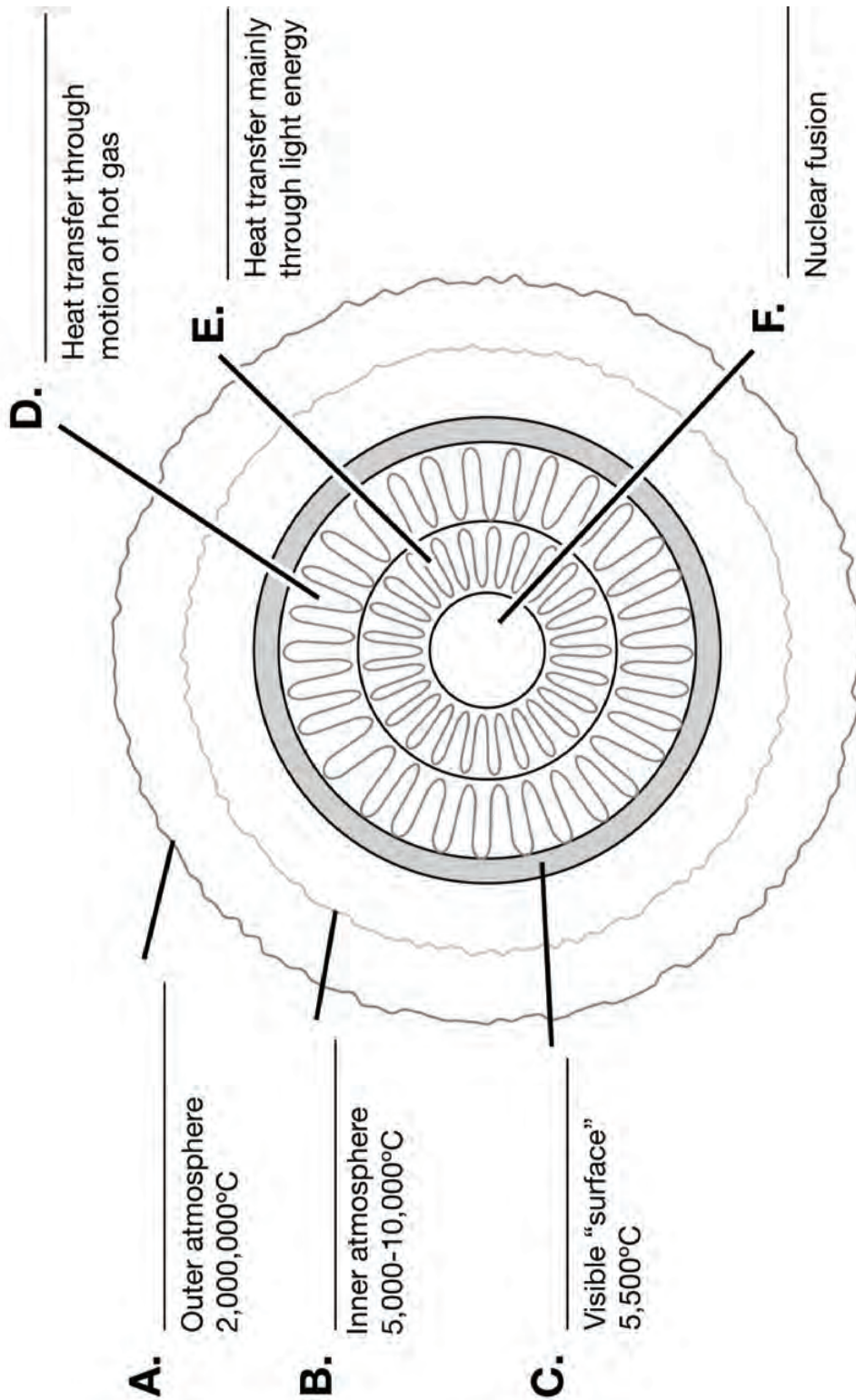
Semi-Circle Card:

Diameter = 1 cm



Semi-circle card
(cut out along dotted lines)

The Sun: A Cross-Section



Arthur Walker

Arthur Walker pioneered several new space-based research tools that brought about significant changes in our understanding of the sun and its corona. He was instrumental in the recruitment and retention of minority students at Stanford University, and he advised the United States Congress on physical science policy issues.

Not to be discouraged



Arthur Walker was born in Cleveland in 1936. His father was a lawyer and his mother a social worker. When he was 5, the family moved to New York. Arthur was an excellent student and his mother encouraged him to take the entrance exam for the Bronx High School of Science.

Arthur passed the exam, but when he entered school a faculty member told him that the prospects for a black scientist in the United States were bleak.

Rather than allow him to become dissuaded from his aspirations, Arthur's mother visited the school and told them that her son would pursue whatever course of study he wished.

Making his mark in space

Walker went on to earn a bachelor's degree in physics, with honors, from Case Institute of Technology in Cleveland and, by 1962, his master's and doctorate from the University of Illinois.

Next, he spent three years' active duty with the Air Force, where he designed a rocket probe and satellite experiment to measure **radiation** that affects satellite operation. This work sparked Walker's lifelong interest in developing new space-based research tools.

After completing his military service, Walker worked with other scientists to develop the first X-ray **spectrometer** used aboard a satellite. This device helped determine the temperature and composition of the sun's corona and provided new information about how matter and radiation interact in **plasma**.

Snapshots of the sun

In 1974, Walker joined the faculty at Stanford University. There he pioneered the use of a new multilayer mirror technology in space observations. The mirrors selectively reflected **X rays** of certain wavelengths, and enabled Walker to obtain the first high-resolution images showing different temperature regions of the solar atmosphere.

Walker then worked to develop telescopes using the multilayer mirror technology, and launched them into space on rockets. The telescopes produced detailed photos of the sun and its corona. One of the pictures was featured on the cover of the journal *Science* in September 1988.



A model for student scientists

Walker was a mentor to many graduate students, including Sally Ride, who went on to become the first American woman in space. He worked to recruit and retain minority applicants to Stanford's natural and mathematical science programs. Walker was instrumental in helping Stanford University graduate more black doctoral physicists than any university in the United States.

At work in other orbits

Public service was important to Walker, who served on several committees of the National Aeronautics and Space Administration (NASA), National Science Foundation, and National Academy of Science, working to develop policy recommendations for Congress. He was also appointed to the presidential commission that investigated the 1986 space shuttle Challenger accident.

Walker died of cancer in April 2001.

Reading reflection

1. Use your textbook, an Internet search engine, or a dictionary to find the definition of each word in bold type. Write down the meaning of each word. Be sure to credit your source.
2. What have you learned about pursuing goals from Arthur Walker's biography?
3. Why is a spectrometer a useful device for measuring the temperature and composition of something like the sun's corona?
4. **Research:** Use a library or the Internet to find one of Walker's revolutionary photos of the sun and its corona. Present the image to your class.
5. **Research:** Use a library or the Internet to find more about the commission that investigated the explosion of the space shuttle Challenger in 1986. Summarize the commission's findings and recommendations in two or three paragraphs.

Scientific Notation

READ


A number like 5,100,000 (5 million, 100 thousand) can take a long time to write, and an even longer time to read. Because they frequently encounter very large numbers like this one, scientists developed a shorthand method for writing these types of numbers. This method is called scientific notation. A number is written in scientific notation when it is written as the product of two factors, where the first factor is a number that is greater than or equal to 1, but less than 10, and the second factor is an integer (whole, not a fraction or decimal) power of 10.

$$5,100,000 = \underbrace{5.1}_{\text{Number between 1 and 10}} \times 10^{\underbrace{6}_{\text{Power of 10}}}$$

EXAMPLES

Rewrite large numbers (given in scientific notation) in standard form

- Express 6.26×10^6 in standard form.

Solution:

Move the decimal point (in 6.26) 6 places to the right. The exponent of the “10” is 6, giving us the number of places to move the decimal.

$$6.26 \times 10^6 = \underbrace{6.2.6.0.0.0.0.}_{\substack{\text{move decimal six} \\ \text{places to the right}}} = 6,260,000$$

Rewrite large numbers (given in standard form) in scientific notation

- Express 6,020,000,000 in scientific notation.

Solution:

You need to rewrite this number so that it fits into the form:

$$\underline{\hspace{2cm}}.\underline{\hspace{2cm}} \times 10^{\underline{\hspace{1cm}}}$$

Place the decimal point in 6 0 2 so that the number is greater than or equal to one but less than ten. This gives the first factor (6.02). To get from 6.02 to 6,020,000,000 the decimal point has to move 9 places to the right, so the power of ten is 9.

$$6,020,000,000 = 6.02 \times 10^9$$

PRACTICE 

1. Rewrite each number (given in scientific notation) into standard form.
 - a. 1.222×10^5
 - b. 9.01×10^7
 - c. 3.6×10^3
 - d. 7.003×10^2
 - e. 5.2722×10^4

2. Rewrite each number (given in standard form) into scientific notation: _____ $\times 10^{\text{---}}$
 - a. 4,051,000
 - b. 1,300,000,000
 - c. 1,003,000
 - d. 16,020
 - e. 9,999,900,000,000

Understanding Light Years

How far is it from Los Angeles to New York? Pretty far, but it can still be measured in miles or kilometers. How far is it from Earth to the Sun? It's about one hundred forty-nine million, six hundred thousand kilometers (149,600,000, or 1.496×10^8 km). Because this number is so large, and many other distances in space are even larger, scientists developed bigger units in order to measure them. An Astronomical Unit (AU) is 1.496×10^8 km (the distance from Earth to the sun). This unit is usually used to measure distances within our solar system. To measure longer distances (like the distance between Earth and stars and other galaxies), the light year (ly) is used. A light year is the distance that light travels through space in one year, or 9.468×10^{12} km.

EXAMPLES

1. Converting light years (ly) to kilometers (km)

Earth's closest star (Proxima Centauri) is about 4.22 light years away. How far is this in kilometers?

Explanation/Answer: Multiply the number of kilometers in one light year (9.468×10^{12} km/ly) by the number of light years given (in this case, 4.22 ly).

$$\frac{(9.468 \times 10^{12}) \text{ km}}{1 \text{ ly}} \times 4.22 \text{ ly} \approx 3.995 \times 10^{13} \text{ km}$$

2. Converting kilometers to light years

Polaris (the North Star) is about 4.07124×10^{15} km from the earth. How far is this in light years?

Explanation/Answer: Divide the number of kilometers (in this case, 4.07124×10^{15} km) by the number of kilometers in one light year (9.468×10^{12} km/ly).

$$4.07124 \times 10^{15} \text{ km} \div \frac{9.468 \times 10^{12} \text{ km}}{1 \text{ ly}} = \frac{4.07124 \times 10^{15} \text{ km}}{1} \times \frac{1 \text{ ly}}{9.468 \times 10^{12} \text{ km}} \approx 430 \text{ light years}$$

PRACTICE

Convert each number of light years to kilometers.

- 6 light years
- 4.5×10^6 light years
- 4×10^{-3} light years

Convert each number of kilometers to light years.

- 5.06×10^{16} km
- 11 km
- 11,003,000,000,000 km

Solve each problem using what you have learned.

7. The second brightest star in the sky (after Sirius) is Canopus. This yellow-white supergiant is about 1.13616×10^{16} kilometers away. How far away is it in light years?
8. Regulus (one of the stars in the constellation Leo the Lion) is about 350 times brighter than the sun. It is 85 light years away from the earth. How far is this in kilometers?
9. The distance from earth to Pluto is about 28.61 AU from the earth. Remember that an AU = 1.496×10^8 km. How many kilometers is it from Pluto to the earth?
10. If you were to travel in a straight line from Los Angeles to New York City, you would travel 3,940 kilometers. How far is this in AU's?
11. Challenge: How many AU's are equivalent to one light year?

Calculating Luminosity

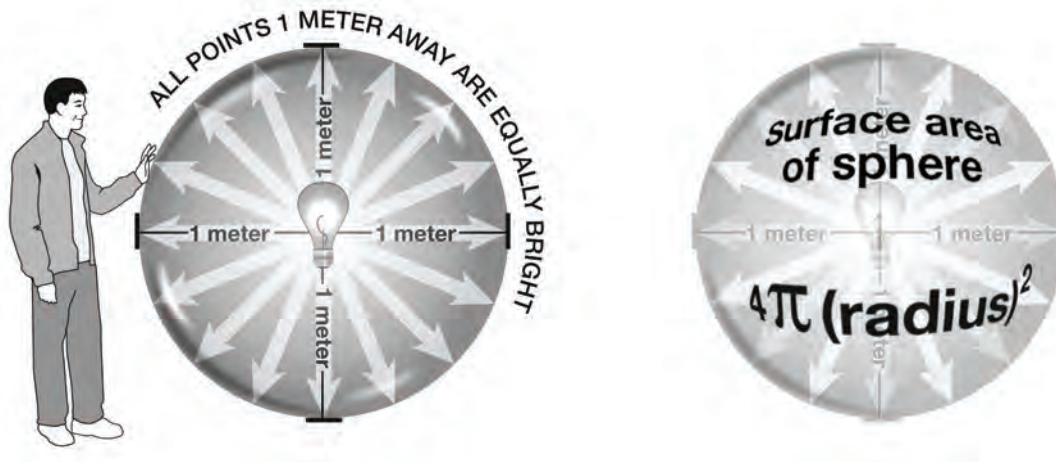
READ


You have learned that in order to understand stars, astronomers want to know their luminosity. *Luminosity* describes how much light is coming from the star each second. Luminosity can be measured in watts (W).

Measuring the luminosity of something as far away as a star is difficult to do. However, we can measure its brightness. *Brightness* describes the amount of the star's light that reaches a square meter of Earth each second. Brightness is measured in watts/square meter (W/m^2).

The brightness of a star depends on its luminosity and its distance from Earth. A star, like a light bulb, radiates light in all directions. Imagine that you are standing one meter away from an ordinary 100-watt incandescent light bulb. These light bulbs are about ten percent efficient. That means only ten percent of the 100 watts of electrical power is used to produce light. The rest is wasted as heat. So the luminosity of the bulb is about ten percent of 100 watts, or around 10 watts.

The brightness of this bulb is the same at all points one meter away from the bulb. All those points together form a sphere with a radius of one meter, surrounding the bulb.



If you want to find the brightness of that bulb, you take the luminosity (10 watts) and divide it by the amount of surface area it has to cover—the surface area of the sphere. So, the formula for brightness is:

$$\text{brightness} = \frac{\text{luminosity}}{\text{surface area of sphere}} = \frac{\text{luminosity}}{4\pi(\text{radius})^2}$$

The brightness of the bulb at a distance of one meter is:

$$\frac{10 \text{ watts}}{4\pi(1 \text{ meter})^2} = \frac{10 \text{ watts}}{12.6 \text{ meter}^2} = 0.79 \text{ W}/\text{m}^2$$

Notice that the radius in the equation is the same as the distance from the bulb to the point at which we're measuring brightness. If you were standing 10 meters away from the bulb, you would use 10 for the radius in the equation. The surface area of your sphere would be $4\pi(100)$ or 1,256 square meters! The same 10 watts of light energy is now spread over a much larger surface. Each square meter receives just 0.008 watts of light energy. Can you see why distance has such a huge impact on brightness?

If we know the brightness and the distance, we can calculate luminosity by rearranging the equation:

$$\text{luminosity} = \text{brightness} \times \text{surface area of sphere} = \text{brightness} \times 4\pi(\text{distance})^2$$

This is the same formula that astronomers use to calculate the luminosity of stars.

EXAMPLE

You are standing 5 meters away from another incandescent light bulb. Using a light-meter, you measure its brightness at that distance to be $0.019 \text{ watts/meter}^2$. Calculate the luminosity of the bulb. Assuming this bulb is also about ten percent efficient, estimate how much electric power it uses (this is the wattage printed on the bulb).

Step 1: Plug the known values into the formula:

$$\text{luminosity} = \frac{0.019 \text{ watts}}{\text{meter}^2} \times \frac{4\pi(5 \text{ meters})^2}{1}$$

Step 2: Solve for luminosity:

$$\text{luminosity} = 0.019 \times 100\pi \text{ watts} = 6 \text{ watts}$$

Step 3: If the bulb is only about ten percent efficient, the electric power used must be about ten times the luminosity. The bulb must use about $10 \times 6 \text{ watts}$, or 60 watts, of electric power.

PRACTICE

1. Ten meters away from a flood lamp, you measure its brightness to be 0.024 W/m^2 . What is the luminosity of the flood lamp? What is the electrical power rating listed on the bulb, assuming it is ten percent efficient?
2. You hold your light-meter a distance of one meter from the light bulb in your refrigerator. You measure the brightness to be 0.079 W/m^2 . What is the luminosity of this light bulb? What is its power rating, assuming it is ten percent efficient?
3. **Challenge:** Finding the luminosity of the sun.

You can use the same formula to calculate the luminosity of the sun.

Astronomers have measured the average brightness of the sun at the top of Earth's atmosphere to be $1,370 \text{ W/m}^2$. This quantity is known as the *solar constant*.

We also know that the distance from Earth to the sun is 150 billion meters (or 1.5×10^{11} meters).

What is the luminosity of the sun?

Hints:

1. You may wish to rewrite the solar constant as $1.370 \times 10^3 \text{ W/m}^2$.
2. $(10^{11})^2$ is the same as $10^{11} \times 10^{11}$. To find the product, add the exponents.
3. Don't forget to find the square of 1.5!

Edwin Hubble

Edwin Hubble was an accomplished academic that many astronomers credit with “discovering the universe.”

A good student and even better athlete



Edwin Hubble was born on November 29, 1889, in Marshfield, Missouri. His family moved to Chicago when he was ten years old.

Hubble was an active, imaginative boy. He was an avid reader of science fiction. Jules Verne's adventure novels were among his favorite stories. Science fascinated Hubble, and he loved the way Verne

wove futuristic inventions and scientific content into stories that took the reader on voyages to some strange and exotic destinations.

Hubble was a very good student and also an excellent athlete. In 1906 he set an Illinois state record for the high jump, and in that same season he took seven first place medals and one third place medal in a single high school track meet.

Focus turns to academics

Hubble continued his athletic success by participating in basketball and boxing at the University of Chicago. Eventually though, his studies became his primary focus. Hubble graduated with a bachelors degree in Mathematics and **Astronomy** in 1910.

Hubble was selected as a Rhodes Scholar and spent the next three years at the University of Oxford, in England. Instead of continuing his studies in math and science, he decided to pursue a law degree. He completed the degree in 1913 and returned to the United States. He set up a law practice in Louisville, Kentucky. However, it was a short lived law career.

Returning to Astronomy

It took Hubble less than a year to become bored with his law practice, and he returned to the University of Chicago to study astronomy. He did much of his work at the Yerkes Observatory, and received his Ph.D. in astronomy in 1917.

Hubble joined the army at this time and served a tour of duty in World War I. He attained the rank of Major. When he returned in 1919, he was offered a job by

George Ellery Hale, the founder and director of Carnegie Institution's Mount Wilson Observatory, near Pasadena, California.

The best tool for the job

The timing could not have been better. The 100-inch Hooker telescope, the world's most powerful telescope at the time, had just been constructed. This telescope could easily focus images that were fuzzy, too dim, or too small to be seen clearly through other large telescopes.

The Hooker telescope enabled Hubble to make some astounding discoveries. Astronomers had believed that the many large fuzzy patches they saw through their powerful telescopes were huge gas clouds within our own Milky Way **galaxy**. They called these fuzzy patches “nebulae,” a Greek word meaning “cloud.”

Hubble's observations in 1923 and 1924 proved that while a few of these fuzzy objects were inside our galaxy, most were in fact entire galaxies themselves, not only separate from the Milky Way but millions of light years away. This greatly enlarged the accepted size of the universe, which many scientists at the time believed was limited to the Milky Way alone.

Another landmark discovery

Hubble also used **spectroscopy** to study galaxies. He observed that galaxies' spectral lines were shifting toward the red end of the spectrum, which meant they were moving away from each other. He showed that the farther away a galaxy was, the faster it was moving away from Earth. In 1929, Hubble and fellow astronomer Milton Humason announced that all observed galaxies are moving away from each other with a speed proportional to the distance between them. This became known as Hubble's Law, and it proved that the universe was expanding.

Albert Einstein visited Hubble and personally thanked him for this discovery, as it matched with Einstein's calculations, providing observable evidence confirming his predictions.

Hubble worked at the Wilson Observatory until his death in 1953. He is considered the father of modern **cosmology**. To honor him, scientists have named a space telescope, a crater on the moon, and an asteroid after him.

Reading reflection

1. Look up the definition of each boldface word in the article. Write down the definitions and be sure to credit your source.
2. **Research:** What is a Rhodes Scholarship?
3. **Research:** Why does a larger telescope allow astronomers to see more?
4. Imagine you knew Edwin Hubble. Describe how you think he may have felt when Albert Einstein came to visit and thank him for his discoveries.
5. **Research:** Before Hubble's discovery, people thought that the universe had always been about the same size. How did Hubble's discovery that the universe is currently expanding change scientific thought about the size of the universe *in the past*?

Henrietta Leavitt

Leavitt, although deaf, had a keen eye for observing the stars. Her ability to identify the magnitude of stars set the standard for determining a star's distance—hundreds or even millions of light years away.

Star struck



Photo courtesy of the American Association of Variable Star Observers

Henrietta Swan Leavitt was born on July 4, 1868 in Lancaster, Massachusetts. Henrietta's family lived in Cambridge, Massachusetts and later moved to Cleveland, Ohio. In Ohio, Leavitt attended Oberlin College for two years and was enrolled in the school's conservatory of music. She then moved back to Cambridge and attended

Radcliffe College, which was then known as the Society for the Collegiate Instruction of Women.

In her last year of college, Henrietta took an astronomy course—then began her fascination with and love for the stars. She graduated in 1892 and later became a volunteer research assistant working at the Harvard College Observatory.

Computing the stars

In the 1880s, Harvard College established a goal to catalog the stars. Edward Pickering, a former professor at the Massachusetts Institute of Technology, became director of the Harvard Observatory. Pickering was an authority in photographic photometry—determining a star's magnitude from a photograph. He wanted to gather information about the brightness and color of stars.

In order to complete this work, Pickering needed people to perform the tedious task of examining photographs of stars. Men typically did not perform this type of work, but women were hired and known as “computers.” Leavitt was hired at a rate of \$.30 per hour to complete this painstakingly detailed work.

Leavitt was not a healthy woman, struggling with complete hearing loss and other illnesses during college and throughout her career. Despite these setbacks, she became a super computer, devoting her life to studying the stars. She eventually became the head of the photographic stellar photometry department.

Leavitt catalogued variable stars that altered in brightness over the course of a few days, weeks, or even months. She studied Cepheid variable stars in the Magellanic Clouds, two galaxies near the Milky Way.

Leavitt examined photographic plates, comparing the same regions on several plates taken at different times. Stars that had changed in brightness would look different in size. Leavitt continued to examine plates, discovering nearly 2,000 new variable stars in the Magellanic Clouds.

Leavitt found an inverse relationship between a star's brightness cycle and its magnitude. A stronger star took longer to cycle between brightness and dimness. Therefore, brighter Cepheid stars took longer to rotate between brightness and dimness. In 1912, Leavitt had established the Period-Luminosity relation.

These stars, all located within the Magellanic Clouds, were roughly the same distance from the Earth. This rule provided astronomers with the ability to measure distances within and beyond our galaxy.

Astronomical findings

Leavitt's discovery had a tremendous impact on future research in the field of astronomy. Astronomers could now determine distances to galaxies and within the universe overall. Ejnar Hertzsprung was able to plot the distance of Cepheid stars. Harlow Shapley, using Leavitt's findings, was able to map the Milky Way and determine its size. Edwin Hubble applied her rule to establish the age of the Universe.

An unsung heroine

In 1925, the Swedish Academy of Sciences wished to nominate Leavitt for a Nobel Prize. However, she had died of cancer nearly four years earlier at the age of 53. The Nobel Prize must be given during a recipient's lifetime.

In addition to her discovery of numerous variable stars, Leavitt discovered four novas and developed the standard method for determining the magnitude of stars. An asteroid and crater on the moon are named in her honor.

Reading reflection

1. How did Henrietta Leavitt discover new variable stars?
2. What were Leavitt's two significant contributions to the field of astronomy?
3. **Research:** What is the name of the asteroid named in Leavitt's honor?
4. **Research:** When was the Harvard Observatory established and what does it do now?
5. **Research:** State three facts about each of these astronomers: Ejnar Hertzsprung, Harlow Shapley, and Edwin Hubble.
6. **Research:** What is the Nobel Prize?