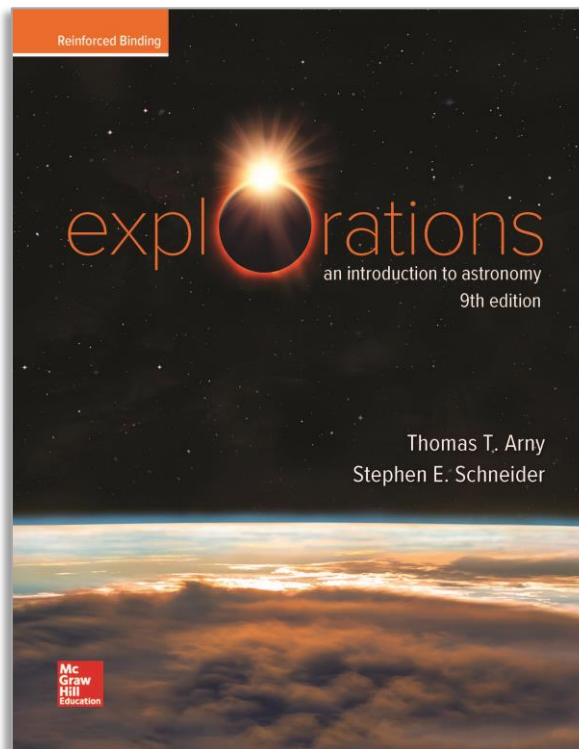
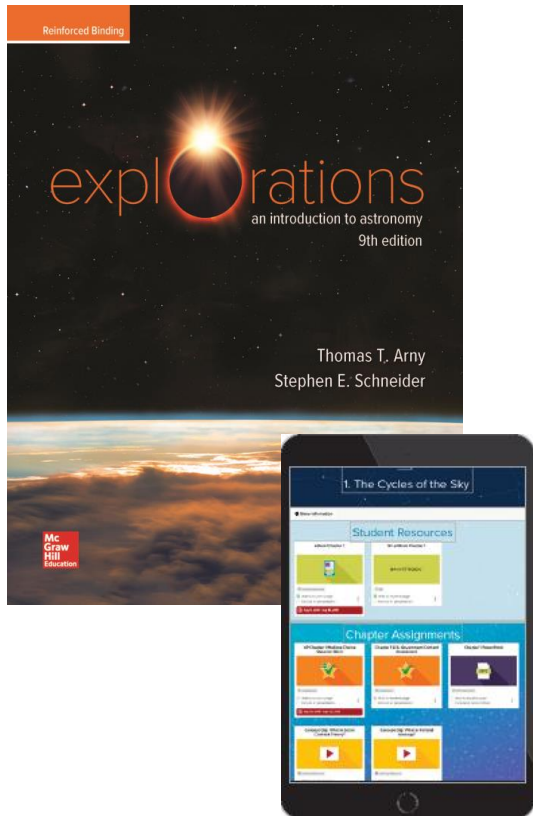


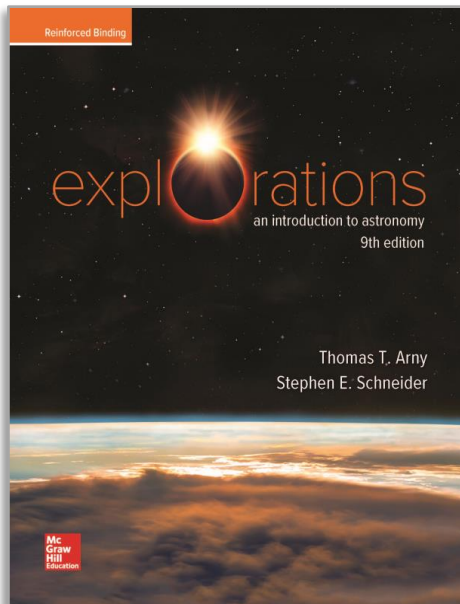
Explorations: An Introduction to Astronomy

Army, 9th Ed





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Stonehenge was built more than 4000 years ago in England. The huge stones are aligned to mark the seasonal rising and setting points of the Sun on the horizon. ©iStock Images/Getty Images

THE CYCLES OF THE SKY

LEARNING OBJECTIVES

Upon completing this chapter you should be able to:

- Describe the motions of the Sun, Moon, and stars as they rise along the eastern horizon, move across the sky, and set along the western horizon.
- Recognize the kinds of fixed patterns of stars called constellations.
- Explain why different constellations are visible at different times of the year.

- Relate the tilt of Earth's axis to the apparent daily path of the Sun in the sky.
- Explain why the tilt of Earth's axis causes changes in temperature on Earth at different parts of the year.
- Describe where, and how frequently, the Sun is straight overhead.

24 CHAPTER 1 The Cycles of the Sky

ASTRONOMY by the numbers

THE ANGLE OF THE SUN AT NOON

The angle of the Sun above the horizon at noon is almost never straight overhead, contrary to common belief. The only place the Sun ever passes straight overhead is in the tropics (between latitudes 23.5° South and 23.5° North), and this happens on only one or two days each year.

Because the celestial sphere's equator and poles lie directly above Earth's equator and poles, an observer's zenith is as far north or south of the celestial equator as the observer's latitude is north or south of Earth's equator. This tells you where the noon Sun will be on the equinoxes, when the Sun is on the celestial equator.

For example, consider Phoenix, Arizona, at latitude 33.5° North. At noon on the equinoxes, the Sun is 33.5° south of the zenith. Because the zenith is by definition 90° above the horizon, this means the Sun is 56.5° above the horizon. And the Sun is never straight overhead.

On the summer solstice in Phoenix, the Sun is 23.5° north of the celestial equator, so it is only 10° from the zenith, or $80^\circ (= 90^\circ - 10^\circ)$ above the horizon. On the other hand, at the winter solstice, the Sun is 23.5° south of the celestial equator, so it is now 57° south of the zenith ($33.5^\circ + 23.5^\circ$), or only 33° above the horizon.

24 CHAPTER 1 The Cycles of the Sky

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- Recognize the kinds of fixed patterns of stars called constellations.
- Explain why different constellations are visible at different times of the year.
- Define the cycles of the Sun, Moon, and stars that are the basis for the day, month, and year.
- Describe how and why the shape of the lit portion of the Moon seen from Earth changes during the month.

- Relate the tilt of Earth's axis to the apparent daily path of the Sun in the sky.
- Explain why the tilt of Earth's axis causes changes in temperature on Earth at different parts of the year.
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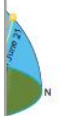


FIGURE 1.15

The path of the Sun in the sky differs depending on your latitude. At the North Pole, the Sun never sets for six months but gradually spirals up from the horizon from the vernal equinox to the summer solstice, then spirals back down to the horizon at the autumnal equinox before it disappears for six months. At the equator, the Sun rises straight upward from the horizon, but reaches the zenith only on the equinoxes. At 23.5° South, the Sun reaches the zenith at noon only on December 21, the start of summer in the Southern Hemisphere.

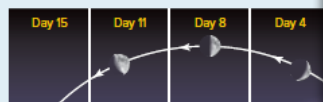
EXTENDING our reach

OBSERVING THE MOON

When the Moon is full, it lies approximately opposite to where the Sun lies, but when the Moon is a thin crescent, it lies in nearly the same direction as the Sun (see the middle of fig. 1.20). These connections between the Moon's phase and its position with respect to the Sun are the key to understanding when the Moon is visible from Earth.

Because the full moon is approximately opposite the Sun, it rises above the eastern horizon at about the time that the Sun sets below the western horizon. Likewise, the full moon sets at about the time the Sun rises. Therefore, the full moon is visible all night and highest in the sky near midnight.

On the other hand, the crescent moon is not visible during most of the night. Because it lies in nearly the same direction as the Sun, once the Sun is well below the horizon, the crescent moon must be below the horizon too. Moreover, the crescent moon is hard to see



Neutrino detectors are constructed deep underground or underwater to shield them from the many other kinds of particles besides neutrinos that constantly bombard Earth. For example, protons, electrons, and a variety of other subatomic particles constantly shower our planet. These particles, traveling at nearly the speed of light, are called **cosmic rays** and are thought to be particles blasted across space when a massive star explodes. Most cosmic rays penetrate only a short distance into Earth; so if a detector is located deep underground, nearly all the cosmic rays are filtered out. Neutrinos, however, are unfazed by a mere mile of solid ground: on the average they could travel through a light-year of lead!

When astronomers first tried to detect solar neutrinos in the 1960s, they found only one-third the expected number coming from the Sun. At first it was assumed that the detectors were simply not working as well as expected, but over decades of efforts

SCIENCE at work

SOLVING THE SOLAR NEUTRINO PUZZLE

In the 1960s American scientist Raymond Davis designed and built the first detector that successfully measured neutrinos emitted by the Sun. After the factor of three discrepancy in solar neutrino counts was discovered, Davis worked for two decades improving the detector and measurements and searching for any errors, but could find none. Astronomers proposed a wide variety of ideas to explain the discrepancy. Might the Sun's interior be much different from what we thought? Was our understanding of the nuclear reactions taking place in the Sun incomplete? Was the Sun undergoing a change in its core that did not yet show up in its light output? Each of these possibilities was carefully examined and eventually dismissed. Another idea surfaced: neutrinos might have properties that had not yet been discovered that affected their detectability in Davis's detector.

Around the same time particle physicists were proposing that suggested the existence of three kinds of neutrinos, not just one. This seemed promising because the first neutrino detectors could detect only one of

the three kinds, thus perhaps explaining why only one-third the expected number were observed. However, the kind of neutrino Davis's experiment could detect was the same kind that was produced by the nuclear reactions in the Sun, so most particle physicists were skeptical that the factor of three was anything more than a coincidence. A revised model of neutrinos was developed that suggested these elusive particles could change into each other if they were not the massless particles they had been previously believed to be. With this new hypothesis about the nature of neutrinos, in the 1980s scientists began building a new generation of neutrino detectors that could detect all three varieties. The Japanese scientist Masatoshi Koshiba headed the Kamiokande group whose work first demonstrated that the new detectors agreed perfectly with the predictions of the solar theory, thereby also establishing the new model of neutrinos, including the fact that they have a mass. In 2002 Davis and the Koshiba received a Nobel Prize for their work.

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sunset. This crescent moon is visible in the sky near sunrise and not be visible in the sky near sunset.

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Reinforced Binding

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an introduction to astronomy
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Thomas T. Arny
Stephen E. Schneider

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34 CHAPTER 1 The Cycles of the Sky

SUMMARY

The night sky looks like a giant dome, which we model as part of a *celestial sphere*. Star patterns on the celestial sphere are called constellations. According to this model, stars rise in the east and set in the west as the celestial sphere rotates around Earth. This apparent motion is actually caused by Earth's spin.

The Sun's glare hides the stars behind it. However, as Earth orbits the Sun, the Sun changes its position with respect to the stars, making different constellations visible at different times of year. The path that the Sun follows around the celestial sphere is called the ecliptic, and the 12 constellations close to the ecliptic are called the zodiac.

The ecliptic is tipped at an angle of 23.5° to the celestial equator because Earth's rotation axis is tipped by that amount with respect to its orbit. The solstices and equinoxes mark when the Sun reaches its maximum angle from the celestial equator and when it crosses the equator, respectively. These dates define the onsets of the seasons.

Earth's spin keeps its rotation axis pointing in nearly a fixed direction as we orbit the Sun. Because the axis is

tipped, the Sun shines more directly on the Northern Hemisphere for half the year and on the Southern Hemisphere for the other half of the year. This Sun's light and warmth creates the seasons.

Ancient peoples built monuments to trace the motions of the Sun through the sky. The position of the Moon, with respect to the position of the Sun, changes every 29.5 days. The Moon's orbit around Earth is at a small angle to the ecliptic, there are lunar eclipses, and the Moon's shadow covers only a narrow path across Earth. The dates close to when the orbital planes of the Moon and Earth cross are called eclipse seasons, which gradually shift as the orientation of the Moon's orbit changes over time.

Because of the small size of the full moon can be completely in Earth's shadow during a lunar eclipse, but during a solar eclipse the Moon's shadow covers only a narrow path across Earth. The dates close to when the orbital planes of the Moon and Earth cross are called eclipse seasons, which gradually shift as the orientation of the Moon's orbit changes over time.

Circling in the northern sky is the well-known Big Dipper, part of the constellation Ursa Major. The Big Dipper is not a constellation, but just an asterism—a star grouping. It is similar to the early asterism looking north from mid-March through can help you find the North Star, and you can find several other intriguing objects in the sky.



LOOKING UP #2

34 CHAPTER 1 The Cycles of the Sky

SUMMARY

The night sky looks like a giant dome, which we model as part of a *celestial sphere*. Star patterns on the celestial sphere are called constellations. According to this model, stars rise in the east and set in the west as the celestial sphere rotates around Earth. This apparent motion is actually caused by Earth's spin. The Sun's glare hides the stars behind it. However, as Earth orbits the Sun, the Sun changes its position with respect to the stars, making different constellations visible at different times of year. The path that the Sun follows around the celestial sphere is called the ecliptic, and the 12 constellations close to the ecliptic are called the zodiac.

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QUESTIONS FOR REVIEW

- (1.1) What is the celestial sphere? What are the celestial equator and the ecliptic?
- (1.1) What is the difference between rotation and revolution?
- (1.1/1.2) What is a constellation, and what is special about the zodiac constellations?
- (1.2) What causes the seasons?
- (1.3) What causes the Moon's phases?
- (1.3) How long does it take the Moon to go through a cycle of phases?
- (1.4) What is the difference between lunar and solar eclipses?
- (1.4) Why aren't there eclipses each month?

THOUGHT QUESTIONS

- (1.1) If you were standing on Earth's equator, where would you look to see the north celestial pole? Could you see this pole from Australia?
- (1.1) Draw a sketch of Earth and a distant North Star, and show that your latitude is the angle of the north celestial pole above the northern horizon.
- (1.1) Can you think of an astronomical reason why the zodiac may have been divided into 12 signs rather than 8 or 16?
- (1.1) Draw sketches to show the angles setting stars would make relative to the horizon for someone watching at the equator, the north pole, and a midlatitude.
- (1.1/1.2) When it is winter in New York, what season is it in Australia, and in Paris? If you see Orion in the evening in New York, would you see it in the evening in Australia or Paris?
- (1.2) If the shape of Earth's orbit were unaltered but its rotation axis were shifted so that it had no tilt with respect to the orbit, how would the seasons be affected?
- (1.2) Why does the position of sunrise along the eastern horizon change during the year?

- (1.2) Why do we have time zones? Sketch and label a diagram to justify your answer.
- (1.3) Provide two or three pieces of evidence you could use to explain to someone that the Moon's phases are not caused by Earth's shadow.
- (1.3) If the Moon orbited Earth in the opposite direction, but everything else remained the same, how would the sidereal and solar months change (if at all)? Create a drawing like figure 1.19 representing this situation.

PROBLEMS

- (1.1) If Earth turns one full rotation in approximately 24 hours, how many degrees per hour does the sky turn?
- (1.2) From a latitude of 55° , what is the highest and lowest angle above the horizon of the noon Sun? What will the angle be on September 22?
- (1.3) Make a sketch to calculate what times the waxing crescent moon will rise and set. Indicate the observer's location and lines of sight to the Moon for these times.
- (1.3) Calculate how many degrees the Moon moves in its orbit in one day based on its 27.3 day period relative to the stars. Use this result and the answer to problem 1 to determine how much later the Moon rises each day.
- (1.3/1.4) The Moon crosses down through the ecliptic every 27.21222 days ("draconic period"). Its synodic period, the period of the phases, is 29.5306 days. Show that 242 draconic periods very nearly equals 223 synodic periods. How long is this in years? What does this suggest about eclipses and why? (This match of cycles is called the saros and was used by ancient astronomers to predict eclipses.)
- (1.4) Find how many hours it takes the Moon to move in its orbit a distance equal to Earth's diameter. (You will need to determine the speed of the Moon in its orbit. You can find values for the diameter of Earth and the radius and period of the Moon's orbit.)

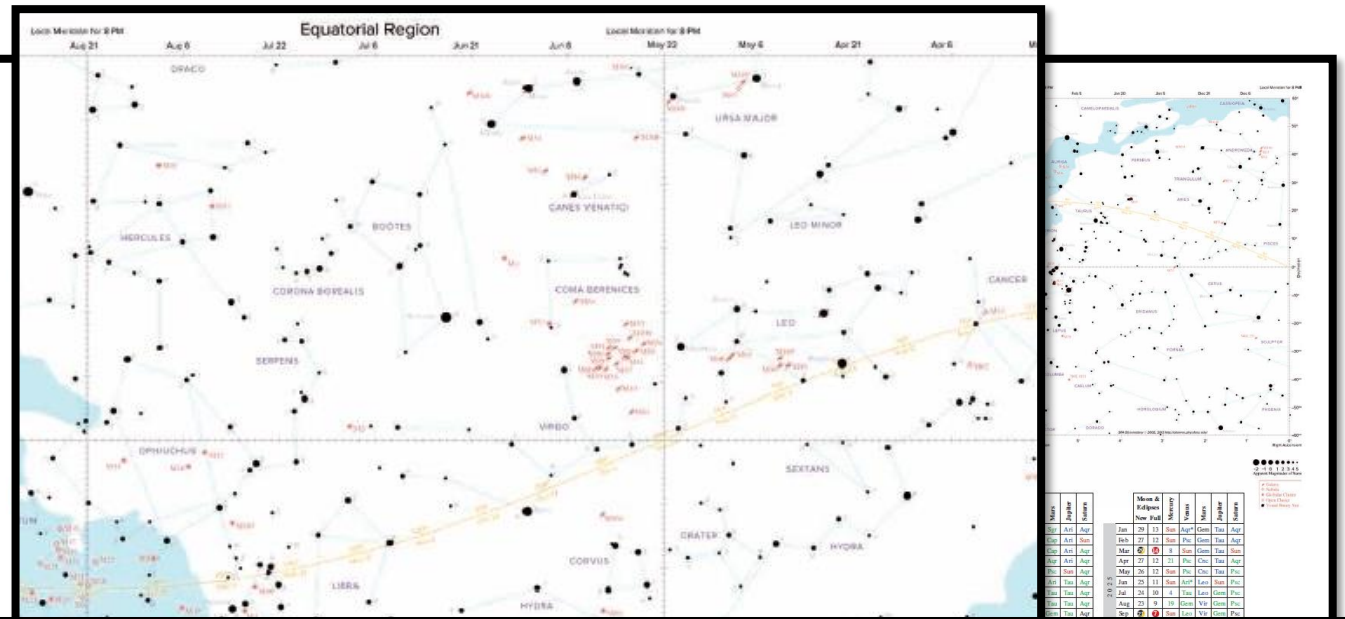
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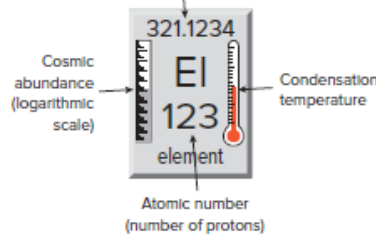
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9th edition

Thomas T. Arny
Stephen E. Schneider



A Cosmic Periodic Table of the Elements

Atomic mass of most common
(or most stable) isotope



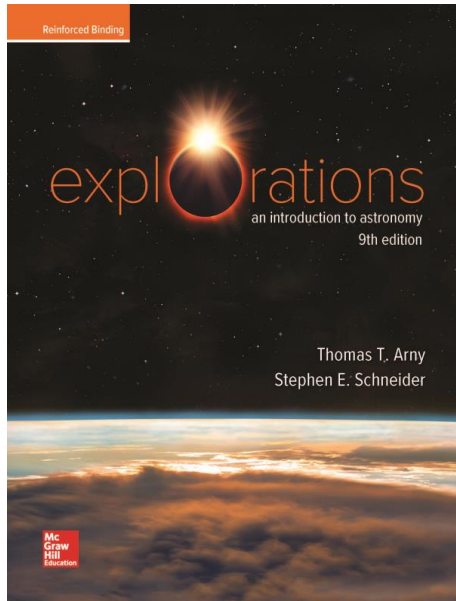
Sources of the Elements

- Big Bang**
 - Fusion during first 10 minutes
- Fission Processes**
 - Cosmic ray collision with heavier elements
 - Radioactively unstable
- Low-mass Stars**
 - Stellar wind/planetary nebula
 - Type Ia supernova
- High-mass Stars**
 - Type II supernova
 - Neutron star merger

11.0221 B 5 boron	12.0140 C 6 carbon	14.0194 N 7 nitrogen	16.0135 O 8 oxygen
27.0129 Al 13 aluminum	28.0095 Si 14 silicon	31.0098 P 15 phosphorus	32.0093 S 16 sulfur
69.0057 Ga 31 gallium	74.0072 Ge 32 germanium	75.0087 As 33 arsenic	80.0095 Se 34 selenium
132.9054 Sb 51 antimony	121.7571 Te 52 tellurium	127.603 I 53 iodine	126.905 Xe 54 xenon

A Cosmic Periodic

1.00794 H 1 hydrogen	7.0242 Li 3 lithium	9.0227 Be 4 beryllium	12.0107 C 6 carbon	14.00307 N 7 nitrogen	16.00013 O 8 oxygen
23.00399 Na 11 sodium	24.0026 Mg 12 magnesium	26.981538 Al 13 aluminum	28.08558 Si 14 silicon	30.973762 P 15 phosphorus	32.065047 S 16 sulfur
39.0983 K 19 potassium	40.078 Ca 20 calcium	44.955912 Sc 21 scandium	47.867 Ti 22 titanium	50.9415 V 23 vanadium	51.99616 Cr 24 chromium
55.93494 Mn 25 manganese	55.93894 Fe 26 iron	58.933195 Co 27 cobalt	58.933195 Ni 28 nickel	63.546 Cu 29 copper	64.558 Zn 30 zinc
69.923 Ga 31 gallium	72.630 Ge 32 germanium	74.9216 As 33 arsenic	75.92186 Se 34 selenium	78.96 Br 35 bromine	79.904 Kr 36 krypton
85.4678 Rb 37 rubidium	87.62 Sr 38 strontium	88.90584 Y 39 yttrium	90.9073 Zr 40 zirconium	91.224 Nb 41 niobium	92.90638 Mo 42 molybdenum
95.94 Tc 43 technetium	97.907 Ru 44 ruthenium	101.07 Rh 45 rhodium	102.9055 Pd 46 palladium	106.42 Ag 47 silver	107.8682 Cd 48 cadmium
112.407 In 49 indium	114.818 Sn 50 tin	118.710 Sb 51 antimony	121.757 Te 52 tellurium	127.603 I 53 iodine	126.905 Xe 54 xenon
132.905 Ba 56 barium	137.327 La 57 lanthanum	140.90765 Ce 58 cerium	140.90765 Pr 59 praseodymium	140.90765 Nd 60 neodymium	140.90765 Pm 61 promethium
140.90765 Sm 62 samarium	140.90765 Eu 63 europium	140.90765 Gd 64 gadolinium	140.90765 Tb 65 terbium	140.90765 Dy 66 dysprosium	140.90765 Ho 67 holmium
140.90765 Er 68 erbium	140.90765 Tm 69 thulium	140.90765 Yb 70 ytterbium	140.90765 Lu 71 lutetium	140.90765 Hf 72 hafnium	140.90765 Ta 73 tantalum
140.90765 W 74 tungsten	140.90765 Re 75 rhenium	140.90765 Os 76 osmium	140.90765 Ir 77 iridium	140.90765 Pt 78 platinum	140.90765 Au 79 gold
140.90765 Hg 80 mercury	140.90765 Tl 81 thallium	140.90765 Pb 82 lead	140.90765 Bi 83 bismuth	140.90765 Po 84 polonium	140.90765 At 85 astatine
140.90765 Rn 86 radon	140.90765 Fr 87 francium	140.90765 Ra 88 radium	140.90765 Ac 89 actinium	140.90765 Th 90 thorium	140.90765 Pa 91 protactinium
140.90765 U 92 uranium	140.90765 Np 93 neptunium	140.90765 Pu 94 plutonium	140.90765 Am 95 americium	140.90765 Cm 96 curium	140.90765 Bk 97 berkelium
140.90765 Cf 98 californium	140.90765 Es 99 einsteinium	140.90765 Fm 100 fermium	140.90765 Md 101 mendelevium	140.90765 No 102 nobelium	140.90765 Lr 103 lawrencium



3.6 MEASURING AN OBJECT'S MASS USING ORBITAL MOTION

Knowledge of orbital motion is important for more than just understanding the paths of astronomical objects. From the orbit's properties (such as size and orbital period), astronomers can deduce physical properties of the orbiting objects, such as their masses.

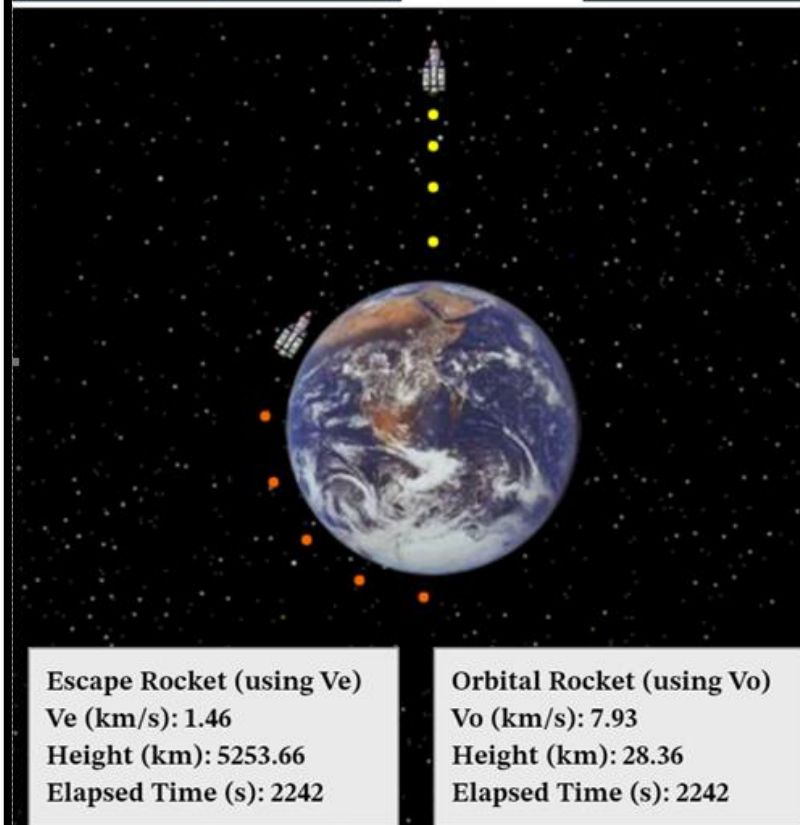
Newton drew upon Kepler's third law in deriving the law of gravity. Although

Escape Velocity and Orbital Velocity

Introduction

How To

Simulation



$$V_{\text{escape}} = \sqrt{\frac{2 \times 62.5 \times 1.00}{1.00}} = 11.2$$

$$V_{\text{orbit}} = \sqrt{\frac{62.5 \times 1.00}{1.00}} = 7.9$$

Fire

Reset

Initial Velocity: 7.9 km/sec



Planetary Mass: 1 Earth mass



Height Above Earth: 1.00 km

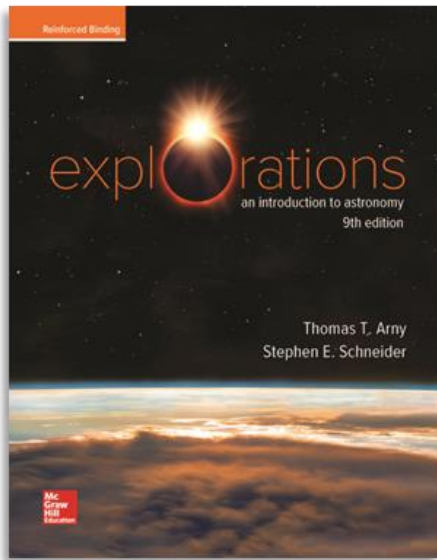


Planet

☒ Earth ☐ Mars ☐ Mercury ☐ Venus

Sound

☒ Escape Rocket ☐ Orbital Rocket ☐ Off

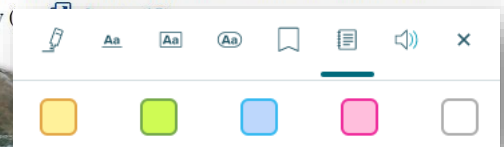


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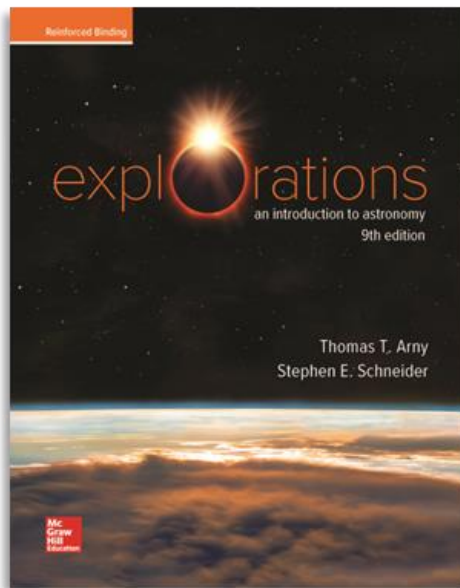
Environmental science helps us understand our remarkable planet

Imagine that you were an astronaut returning home after a trip to the moon or Mars. What a relief it would be, after the silent void of outer space, to return to this beautiful, bountiful planet ([fig. 1.3](#)). We live in an incredibly prolific and colorful world that is, as far as we know, unique in the universe. Compared with other planets in our solar system, temperatures on the earth are mild and relatively constant. Plentiful supplies of clean air, fresh water, and fertile soil are regenerated endlessly and spontaneously by biogeochemical cycles and biological communities (discussed in [chapters 2](#) and [3](#)). The value of these ecological services is almost incalculable, although economists estimate that they account for a substantial proportion of global economic activity (

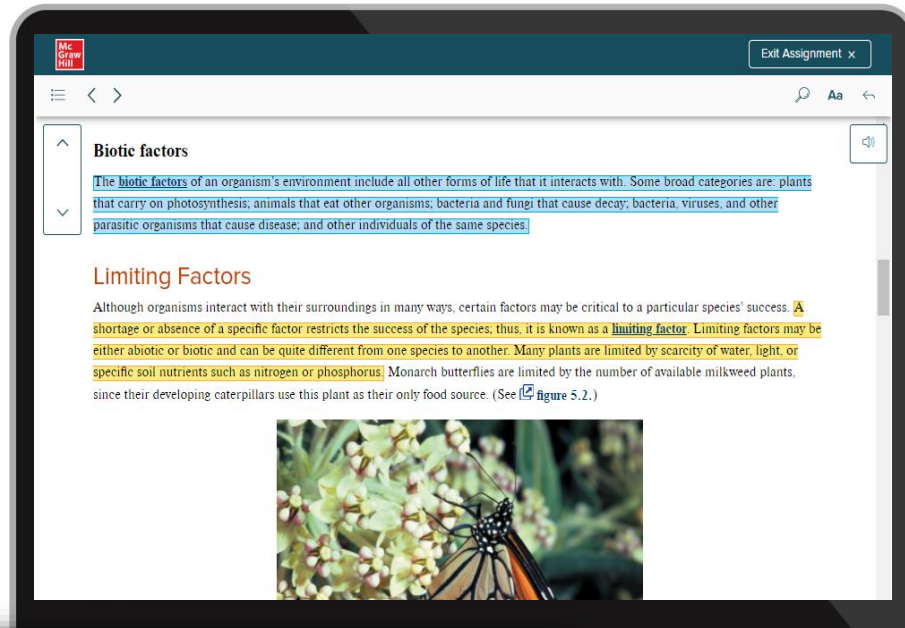


► **FIGURE 1.3** The life-sustaining ecosystems on which we all depend are unique in the universe, as far as we know.

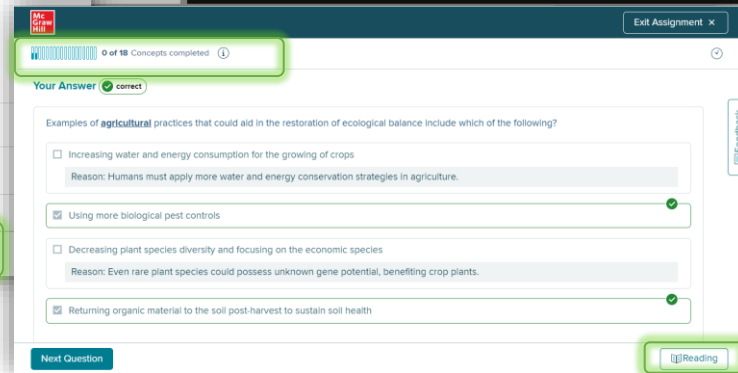
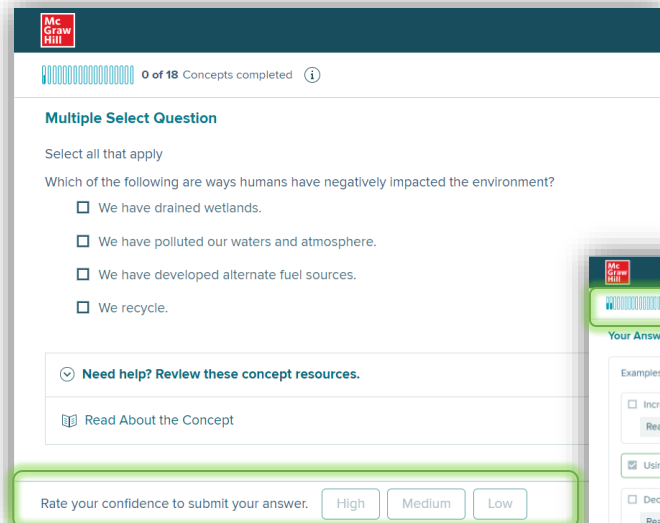
Source: Norman Kuring/NASA



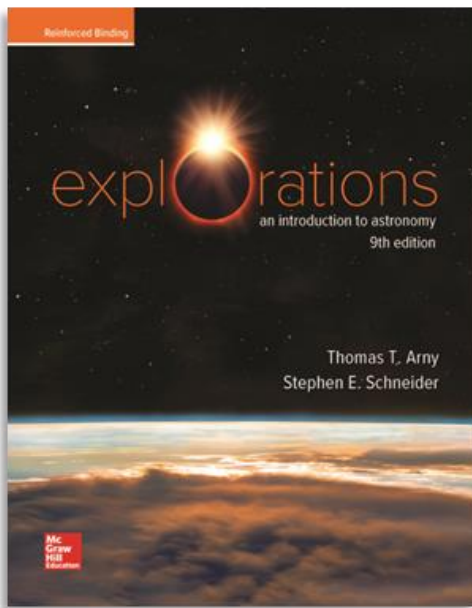
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Highlighted content adapts as students work through the practice sets.



Practice sets with instant feedback measure understanding and personalize the learning path based on student responses.



Adaptive SmartBook

Model 1: Flipped

SmartBook is
used to
preview
content

Model 2: Homework

SmartBook
Is assigned as
reinforcement

Model 3: Review

SmartBook is
assigned to
review as a
study tool

Model 4: Self-Pacing

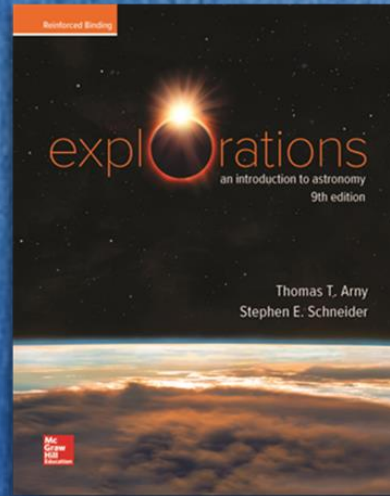
SmartBook is
assigned as a
tool to support
self-pacing

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Phone, iPad, Chromebook, or Tablet

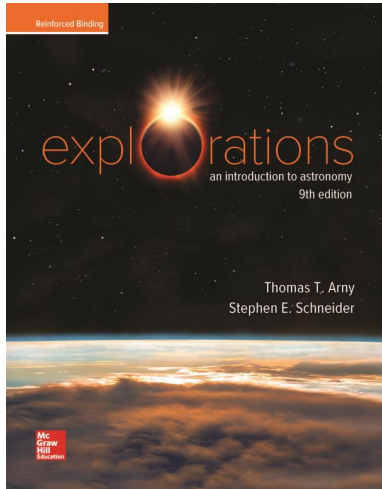


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