LIFEPAC®

SCIENCE

STUDENT BOOK

9th Grade | Unit 7

Alpha Omega
PUBLICATIONS

SCIENCE 907
Astronomy

LIFEPAC Test is located in the center of the booklet. Please remove before starting the unit.

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Alpha Omega PUBLICATIONS

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Astronomy

Introduction

Man has always been fascinated by the universe. Astronomy is the science that studies the composition, motions, positions, dimensions, and destinies of the planets, stars, and other heavenly bodies in our universe. Man has known or conjectured about our solar system for many years through mathematical computations, telescopic observation, and just plain imagination. Scientists have made startling new discoveries as a direct result of recent space probes. In exploring its vastness, beauty, and orderliness, he is increasingly awed by his Creator. Furthermore, space exploration represents the ultimate challenge in testing man's faith, ingenuity, courage, and resourcefulness.

Many historians cite man's landing on the moon as the greatest single scientific event, surpassing even the discovery of nuclear fission. The lunar landing represented the collective contributions of thousands of scientists, engineers, craftsmen, and executives (not to slight the millions of taxpayers). However, we look to the astronomer as the single most important expert in space feats of such magnitude.

In this LIFEPAC® you will be introduced to some very basic facts concerning our solar system. You will also be exposed to the laws of motion that provide the basis for an orderly universe. Astronomical instrumentation will be reviewed so that you will gain some familiarity with its purpose, capabilities, and limitations. And finally, you will study recent and planned space missions to extend further your knowledge of the universe.

Objectives

Read these objectives. The objectives tell you what you will be able to do when you have successfully completed this LIFEPAC. When you have finished this LIFEPAC, you should be able to:

1. Use scientific notation as an aid to comprehending the magnitudes involved in astronomical measurements.
2. Name and define the celestial bodies comprising the universe.
3. Position the major planets in our solar system both in actual mean distance and using Bode's Law.
4. Define an astronomical unit and employ it in various numerical conversions.
5. Define a light-year and compute its magnitude.
6. Name and position major constellations in the Northern Hemisphere and the Southern Hemisphere.
7. Classify stars by their apparent brightness.
8. Calculate the relationship between apparent magnitude and brightness in stars.
9. Calculate the distance to the stars.
10. Determine the degree of brightness admitted in a telescope.
11. Identify the main types of optical telescopes and describe their characteristics.
12. Describe focal length and calculate its effect upon a telescope's magnifying power.
13. List the critical technical developments in telescopes.
14. Classify the newer types of nonoptical telescopes.
15. List the requirements for a successful earth satellite launching.
16. Describe the gravitational and centrifugal forces that act upon a satellite in orbit.
17. Classify satellites by the principal function performed.
18. Identify various space explorations and list their findings and/or purposes.

Survey the LIFEPAC. Ask yourself some questions about this study and write your questions here.

1. THE UNIVERSE

The starting place in our study of astronomy is with the universe, which is composed of **stars**, **planets**, **dwarf planets**, **nebulae**, **satellites**, **planetoids**, **meteoroids**, and **comets**. The universe contains many **galaxies**, one of which is our own **Milky Way**. A single star, known as the sun, and its revolving planets, satellites, comets, planetoids, and meteoroids comprise the solar system. From its sun earth receives the fundamental energy that is essential to maintaining life.

SECTION OBJECTIVES

Review these objectives. When you have completed this section, you should be able to:

1. Use scientific notation as an aid to comprehending the magnitudes involved in astronomical measurements.
2. Name and define the celestial bodies comprising the universe.
3. Position the major planets in our solar system both in actual mean distance and using Bode's Law.
4. Define an astronomical unit and employ it in various numerical conversions.
5. Define a light-year and compute its magnitude.
6. Name and position major constellations in the Northern Hemisphere and the Southern Hemisphere.
7. Classify stars by their apparent brightness.
8. Calculate the relationship between apparent brightness and magnitude in stars.
9. Calculate the distance to the stars.

VOCABULARY

Study these words to enhance your learning success in this section.

comets (kom' its). Luminous spheres with taillike cylinders that appear from time to time as arcs in the sky.

dwarf planet (dwôrf plan' it). A celestial body that orbits the sun and is large enough to assume a nearly round shape, but that does not clear the neighborhood around its orbit and is not a satellite of a planet.

ellipse (e lips'). An oval-shaped geometric figure.

elliptical (e lip' ti cl). Having the shape of an oval.

galaxy (gal' uk sē). Group of millions or billions of stars, gas, and dust held together by the force of gravity.

light-year (līt' yir). The distance a beam of light travels in one year.

meteoroids (me' tē u roids). Normally very small solid objects that traverse space and usually are burned up before reaching earth. The light generated by meteoroids entering the earth's atmosphere leads observers to call them "shooting stars."

Milky Way Galaxy (mil' kē' wā gal' uk sē). The cloudy band of light across the sky that contains our solar system and all stars that we can see with the unaided eye.

nebulae (neb' yu lē). Vast clouds composed of dust and gas, made visible by the light of stars.

panoptic (pan op' tik). Commanding a full view; seeing everything at once.

parallax (par' u laks). Apparent shift of position of an object with respect to its background due to a shift in position of the observer.

parsec (pär' sek). A unit of stellar distance.

planetoids (plan' u toids). Small, irregularly shaped solid bodies, revolving about the sun (also refered to as asteroids or minor planets).

planets (plan' its). Large, solid, approximately spherical masses, the most famous of which is earth, which revolve around our sun.

satellites (sat'u līts). Moons that revolve around the major planets. While the earth has only one moon, Jupiter has sixty-seven.

stars (stärs). Large globes of intensely heated gas, generating their own light.

Note: *All vocabulary words in this LIFEPAC appear in* **boldface** *print the first time they are used. If you are not sure of the meaning when you are reading, study the definitions given.*

Pronunciation Key: h**a**t, **ā**ge, c**ã**re, f**ä**r; l**e**t, **ē**qual, t**ė**rm; **i**t, **ī**ce; h**o**t, **ō**pen, **ô**rder; **oi**l; **ou**t; c**u**p, p**u̇**t, r**ü**le; **ch**ild; lo**ng**; **th**in; /ŦH/ for **th**en; /zh/ for mea**s**ure; /u/ represents /a/ in **a**bout, /e/ in tak**e**n, /i/ in penc**i**l, /o/ in lem**o**n, and /u/ in circ**u**s.

EXTENT OF THE UNIVERSE

Astronomers have adopted the distance of the earth from the sun—93,000,000 miles—as an astronomical unit (A.U.). To better appreciate the vastness of the universe, let us further reduce 1 A.U. to be comparable to a distance of 1 foot. With such a dimension, all the **planets** in our solar system could be contained in a ring measuring about 80 feet across at its diameter. The nearest known star to our sun is 270,000 A.U. away. Using the same conversion scale, then, its distance would be about 50 miles from the center of the ring. The **Milky Way Galaxy** is huge. If you were in a spaceship that could travel 186,000 miles (299,800 kilometers) in one second, it would take 100,000 years to travel from one side of the Milky Way to the other. When you recall that the Milky Way is just one of many **galaxies** in the universe, you can begin to comprehend how fantastically vast the universe must be and how great is the Creator who made the vast universe (Psalm 8:3), numbers the stars, and calls them all by name (Psalm 147:4).

Our solar system. Our solar system is composed of the sun, of course, eight major planets, and one or more dwarf planets. Their names and distances from the sun are shown in Figure 1. Note, however, what is meant by the statement that the distances given in A.U. are mean actual distances. Planets orbit around the sun in **elliptical** curves. Thus, the distances are approximate, since an **ellipse** is composed of a major axis and a minor axis. The mean actual distance is, therefore, the average distances of the two elliptical axes formed by the planets in their orbits about the sun.

Celestial Body	Mean Actual Distance from Sun	
	Astronomical Unit	1 A.U. = 1 ft.
Sun	0	0
Mercury	.4	4.8″
Venus	.7	8.4″
Earth	1	1′
Mars	1.5	18″
Jupiter	5.2	5′2″
Saturn	9.6	9′7″
Uranus	19.2	19′2″
Neptune	30.2	30′2″
Dwarf Planet Pluto	40.6	40′7″

Figure 1 | Planetary Distances

Bode's Law. Although the distances in Figure 1 have been computed accurately with scientific precision, some two hundred years ago an astronomer named Bode developed a mathematical relationship for the distances of the then known planets from the sun, which has been popularized as Bode's Law. His law uses as a basis the following numbers in sequence: 0, 3, 6, 12, 24, etc. To each number in sequence is added the number 4, giving 4, 7, 10, 16, 28, and so forth respectively. Divide these numbers by 10 and the results (.4, .7, 1.0, 1.6, 2.8, etc.) give the approximate radii of the planetary orbits in A.U. When Bode derived this relationship, the existence of Mercury, Venus, Earth, Mars, Jupiter, and Saturn was known. A gap stood between Mars and Jupiter, the Bode number being 2.8. No known planet exists at this distance from the sun. The actual distances for Mercury, Venus, Earth, Mars, Jupiter, and Saturn are so close to Bode's numbers that his "law" became accepted as indicating a precise mathematical relationship in the solar system.

However, with the discovery in 1781 of Uranus, the planet beyond Saturn, Bode's Law started to suffer deviations. Uranus is 19.2 A.U. from the sun. Using Bode's Law, Uranus should have been 19.6 A.U. away. You may think that estimate is not too far off, but what about Neptune, discovered in 1846? Its mean distance is 30.6 A.U., but Bode's Calculations would have placed it 38.8 A.U. With dwarf planet Pluto, Bode's Law really goes awry. Dwarf planet Pluto is actually half as far from the sun as Bode would have calculated.

Nonetheless, Bode's Law is useful in memorizing the distance of the six or seven planets (stretching a little with Uranus) and is of historical importance as it prevailed for some two hundred years.

Light-years as measurement. Even the A.U. is cumbersome when we talk about distances to other **stars** in the universe. The closest star to Earth not counting the sun, known as Alpha-Centauri, is 274,000 A.U. away. Consequently, astronomers have adopted the unit **light-year** to measure such distances. Light travels 186,000 miles in one second. To find one light-year, therefore, we set up the following equation:

$$\text{One light year} = 186{,}000 \text{ miles} \times 60 \text{ seconds} \times 60 \text{ minutes} \times 24 \text{ hours} \times 365 \text{ days}$$
$$= 6 \text{ million million or } 6 \text{ trillion miles} = 6 \times 10^{12} \text{ miles}$$

A light-year is about 63,000 A.U., so Alpha-Centauri is approximately 4.3 light-years distant.

Scientific notation. Scientists and engineers use a system of scientific notation to eliminate the number of zeros when working with very large or very small numbers. With scientific notation, numbers are written with two factors: a numeral between one and ten, and a power of ten (e.g. 4.31×10^3). The number of places and the direction the decimal point is moved determines the superscript.

The following table gives examples of the second factor:

- 1 thousand = 1,000 = 10^3
- 1 million = 1,000,000 = 10^6
- 1 billion = 1,000,000,000 = 10^9
- 1 trillion = 1,000,000,000,000 = 10^{12}
- 1 thousandth = 1/1000 = 10^{-3}
- 1 millionth = 1/1,000,000 = 10^{-6}
- 1 billionth = 1/1,000,000,000 = 10^{-9}
- 1 trillionth = 1/1,000,000,000,000 = 10^{-12}

Examples of scientific notation:

- 254 = 2.54×10^2
- 254,000 = 2.54×10^5
- 0.0254 = 2.54×10^{-2}

Write true or false.

1.1 ____________ The sun revolves around the earth.

1.2 ____________ Meteoroids are sometimes referred to as shooting stars.

1.3 ____________ Only one galaxy is in the universe.

Write the letter for the correct choice on each line.

1.4 A light-year is __________ .
a. the distance traveled by light in one year
b. equal to 186,000 miles
c. any year not called a leap year

1.5 The planet whose distance from the sun equals 1 A.U. is __________ .
a. Venus b. Earth c. Mars d. Jupiter

1.6 The eight major planets orbiting the sun move in elliptical curves at an average distance of approximately __________ A.U.
a. 1 b. 30 c. 8.5

Complete these activities.

1.7 Why was Bode's Law accepted as a good approximation of the major planets' distances from the sun?

____

____

____

1.8 Define an astronomical unit (A.U.).

____

____

1.9 Describe the procedure used in scientific notation.

____

____

____

1.10 Using the scale of 1 inch = 1 A.U., sketch our solar system showing the relative orbits of the eight major planets. Plotting the system on adding machine tape may be helpful.

TEACHER CHECK ____________ ____________
initials date

CONSTELLATIONS

All of us have gazed skyward and found pleasure in observing the panorama of twinkling stars on a clear night. Even without the aid of a telescope, the unaided eye can observe approximately 2,500 stars in either the Northern Hemisphere or the Southern Hemisphere. These bright stars are grouped into some eighty-eight constellations.

In this section we shall concern ourselves with only a few of the more prominent constellations.

North circumpolar stars. Figure 2 shows seven well-known constellations that are continuously in view in latitudes north of 40°, together with their patterns. These constellations are called north circumpolar constellations since they are continuously above the horizon and appear near the North Pole.

South circumpolar stars. In Figure 3 are shown some of the more prominent south circumpolar constellations. These constellations can be seen from the Southern Hemisphere, ideally, from Australia, South Africa, and South America.

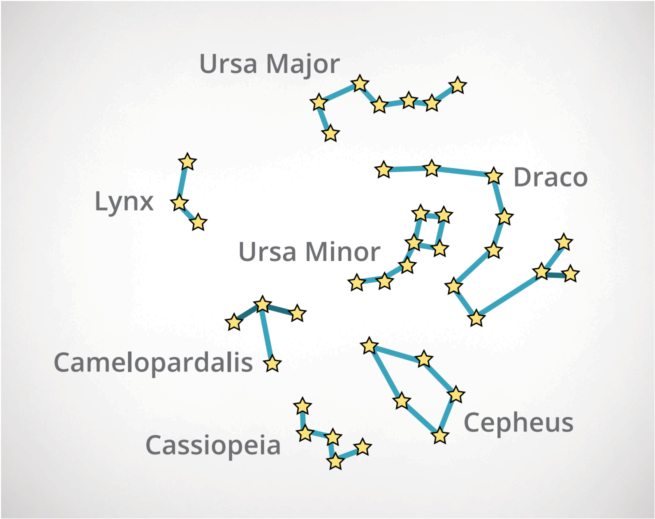


Figure 2 | Major Northern Hemisphere Constellations

Brightness of stars. Stars are classified according to their brightness. The ancient Greek astronomers developed this system according to their apparent brightness to the unaided eye. Six such classes were named. Twenty of the brightest stars were designated as stars of the first magnitude, the next fifty in degree of brightness were designated as stars of the

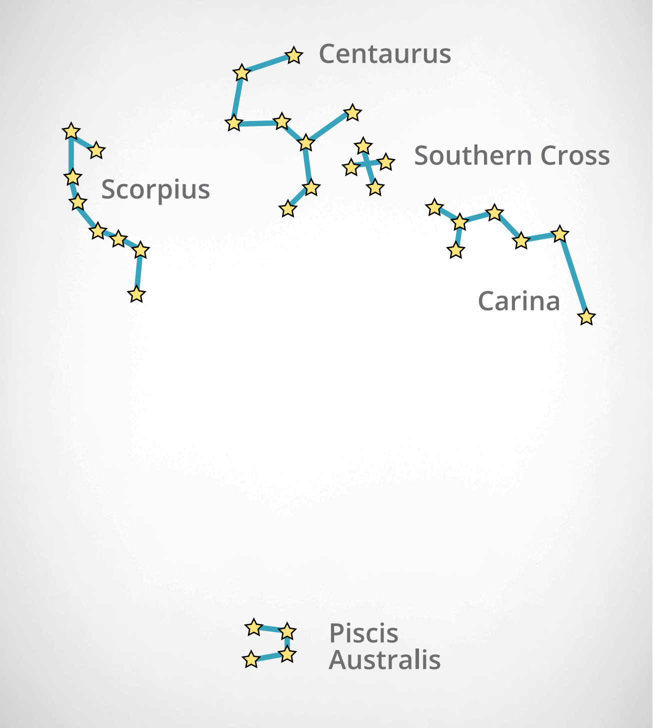


Figure 3 | South Circumpolar Stars

second magnitude, and so on. Six classes included all the stars that were barely visible to the unaided eye.

However, in the nineteenth century decimal division was introduced to provide a more precise classification to the apparent magnitude of stars. Thus, a star with a magnitude of 4.5 was considered to possess an apparent brightness halfway between that of a star of magnitude 4.0 and a star of magnitude 5.0.

Apparent magnitude and apparent brightness. The apparent magnitude is the brightness of a star as seen by the unaided eye. Scientists have found a law that relates apparent magnitude with apparent brightness or intensity. To the eye, if the apparent magnitude of a star increases by one unit, the brightness increases by 2.51 times. This can be written as:

Brightness ratio = $2.51^{\text{(difference in magnitude)}}$: 1, where the exponent of $2.51^{(x)}$ is equal to the difference in magnitude.

Difference in Magnitude	Brightness Ratio
0.1	1.1:1
1.0	2.5:1
2.0	6.3:1
3.0	15.8:1
4.0	40:1
5.0	100:1
6.0	251:1
10.0	10,000:1
20.0	100,000,000:1
25.0	10,000,000,000:1

For example, if the magnitude difference between two stars is 4, the brightness ratio is:

$$(2.51)^{4}{:}1 = 40{:}1$$

Or, if the magnitude difference between two stars is 6, the brightness ratio is:

$$\begin{aligned}(2.51)^{6}{:}1 &= (2.51)^{2} \cdot (2.51)^{4}{:}1\\ &= (6.3) \cdot (40){:}1\\ &= 251{:}1\end{aligned}$$

Sirius has a magnitude difference with our sun of 25. This difference gives a brightness ratio of:

$$\begin{aligned}(2.51)^{25}{:}1 &= 10{,}000{,}000{,}000{:}1\\ &= 10^{10}{:}1\end{aligned}$$

Antares has an apparent magnitude of 1 compared to our sun with an apparent magnitude of -26.7. (Bright stars are given a negative magnitude number.) The difference in magnitude is (-26.7) - (1) = -27.7, or -28 rounded off. The brightness ratio is:

$$\begin{aligned}(2.51)^{28}{:}1 &= (2.51)^{25} \cdot (2.51)^{2} \cdot (2.51)^{1}{:}1\\ &= (10^{10}) \cdot (6.3) \cdot (2.51){:}1\\ &= (10^{10}) \cdot (15.8){:}1\\ &= 1.58 \times 10^{11}{:}1\end{aligned}$$

Therefore, our sun appears to be 1.58×10^{11} or 158,000,000,000 times brighter than Antares.

Distance of stars. To measure the distance to the stars, which are actually trillions of miles beyond earth's surface, astronomers use a technique known as **parallax**. Schematically, the technique works as shown in Figure 4.

The distance to the star is relative to its parallax angle, which is one-half the apparent change in its angular position during the 6-month period. Parallax angles are extremely small, being measured in seconds of an arc (1 sec = 1/3600 degree). One **parsec** (pc) is the distance to a star that corresponds to a parallax of one second of an arc ("). One parsec is equivalent to about 19 trillion miles, or 3.26 light-years.

The general formula to use, then, to compute the distance to any star from its measured parallax is this:

Star's distance in pc = 1/parallax(in seconds).

Let's take an example of a "close star." The measured parallax for Alpha-Centauri is 0.76". Applying the formula,

Alpha-Centauri distance = 1/0.76" = 1.3 pc, but 1 pc = 3.26 LY (light-years). Therefore, 1.3 pc = 4.2 LY corresponds to about 24.7 trillion miles.

Absolute magnitude. Thus far, we have been talking about the apparent magnitude of stars based upon their apparent brightness. Through a rather involved radiation law first developed by Stefan-Boltzman, which is beyond the scope of this LIFEPAC, astronomers can calculate the absolute magnitude of stars in space. By this method stars are known to be anywhere from one-tenth of the sun's radius (which is 432,000 miles) up to 400 times the sun's radius.

With these kinds of magnitudes, man is rightly awed by the vastness of the universe. As marvelous as man's journey to and from the moon was, in terms of what celestial bodies still remain for exploration the lunar journey is but a speck in God's **panoptic** survey of His universe.

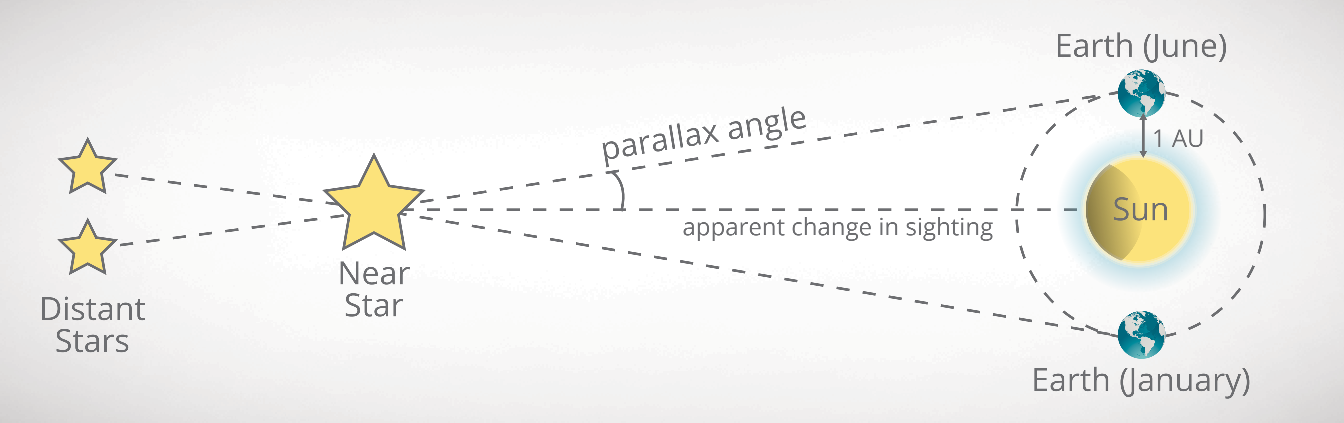


Figure 4 | Measuring Star Distance

Write true or false.

1.11 ____________ All major constellations can be viewed from the United States.

1.12 ____________ Greek astronomers classified stars according to their brightness into six classes.

1.13 ____________ Absolute magnitude and apparent magnitude are in reality the same thing.

Write the letter for the correct choice on the line.

1.14 Constellations that can be viewed at about 40° north latitude are__________ .
a. Northern stars
b. Polar stars
c. North circumpolar stars
d. North latitude stars

1.15 The constellation known as Scorpius appears__________ .
a. at the equator
b. at the North Pole
c. only in December
d. in the Southern Hemisphere

1.16 Apparent magnitudes of the brightest stars __________ .
a. have negative values
b. have values on the order of 10^{10} power
c. are greater than zero
d. are proportional to the square root of their distance to the sun

Answer these questions.

1.17 What is the relationship between the apparent magnitude of a star and its apparent brightness?

____

____

____

1.18 What is the approximate limit in apparent magnitude of a star which can be viewed with the unaided eye?

____

1.19 How do we describe the parallax technique for measuring the distance to the stars?

____

____

____

____

Complete these activities.

1.20 Identify the following constellations:

a. ______________________ b. ______________________ c. ______________________

1.21 Explain why the seemingly brightest stars have the smallest numbers on the apparent magnitude scale.

____

____

____

Perform the following calculations.

1.22

Given Star	Apparent Magnitude
Sirius	-1.5
Betelgeuse	+0.8
Find: Apparent brightness of both stars related to each other. (Hint: A graph of the data in the Difference of Magnitude chart may be helpful.)	

1.23

Given Star	Parallax
Alpha Draco	0.18″
Altair	0.20″
Find: the farther star and compute the difference in light-years.	

1.24 Convert 10 light-years to miles using scientific notation.

Review the material in this section in preparation for the Self Test. The Self Test will check your mastery of this particular section. The items missed on this Self Test will indicate specific areas where restudy is needed for mastery.

SELF TEST 1

Match these items (each answer, 2 points).

1.01 ________ astronomical unit
1.02 ________ planetoids
1.03 ________ parsec
1.04 ________ a million million
1.05 ________ major planet farthest from the sun

a. asteroids
b. 10^{12}
c. a billion
d. 93,000,000 miles
e. distance a beam of light travels in one year
f. a unit of stellar distance
g. Neptune
h. Alpha-Centauri

Complete these activities (each answer, 3 points).

1.06 The three closest major planets to Earth are
a. ____________________ , b. ____________________ , and c. ____________________ .

1.07 Using Bode's Law, which are the major planets that seem to be approximately correctly positioned with respect to their distances from the sun?

a. ____ b. ____
c. ____ d. ____
e. ____ f. ____

Perform the following numerical conversions (each answer, 3 points).

1.08 3 light-years = ____________________ miles
1.09 307.5 million miles = ____________________ A.U.
1.010 3 × 10-6 = ____________________
1.011 1 magnitude of apparent brightness = ____________________ brightness ratio
1.012 1 parsec = ____________________ degree(s)
1.013 6.52 LY = ____________________ pc

Name these constellations (each answer, 3 points).

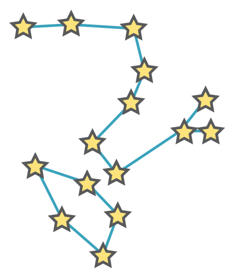
1.014 Label the north circumpolar constellations as they appear in the diagram.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

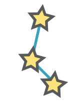


e. ______________________

f. ______________________

g. ______________________

h. ______________________



63/79 **SCORE** __________ **TEACHER** __________ __________

initials date

NOTES

SCI0907 – May '14 Printing
ISBN 978-0-86717-787-9
9 780867 177879

Alpha Omega
PUBLICATIONS

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