M01 Our Place in the Universe
Due: 5:00pm on Monday, September 12, 2011

Note: To understand how points are awarded, read your instructor's Grading Policy.

Key Concept: Our Cosmic Origins

Description: Students rank a list of events in the history of the universe, based on when they occurred, that have helped make possible our existence today. Follow-up questions help students associate the events with an absolute time scale using the "cosmic calendar."

Learning Goal: To understand the order and approximate timing of major cosmic events that have made it possible for us to be here today.

Part A  Ranking Task
Consider the indicated events in the history of the universe that have helped make human life possible. Rank the events based on when they occurred, from longest ago to most recent. To rank items as equivalent, overlap them.

Hint A.1  What makes us think there was a Big Bang?
The key discovery that led to the idea of the Big Bang was that __________.

ANSWER:  
○ stars are born from clouds of gas and dust
○ our Milky Way Galaxy is only one of many galaxies in the universe
○ the universe is expanding

The Big Bang is essentially defined as the moment when universal expansion began.

Hint A.2  Where do elements such as carbon and oxygen come from?
Essentially all chemical elements heavier than hydrogen and helium, including carbon and oxygen, were made __________.

ANSWER:  
○ by the Sun
○ in the Big Bang
○ by nuclear fusion in massive stars

Only hydrogen and helium (and a trace of lithium) were present in the very early universe. Other elements were made by nuclear fusion in massive stars, or in the explosions that accompany the deaths of these stars. By the time our solar system was born, about 2 percent of the original hydrogen and helium had been transformed into heavier elements.

Hint A.3  When did nuclear fusion begin in the Sun?
The Sun began to shine as a full-fledged star when nuclear fusion began inside of it, which was __________.
Our entire solar system, including the Sun and all the planets, formed at about the same time from a cloud of interstellar gas and dust.

**Hint A.4 Did dinosaurs live with people?**

You've probably seen cartoons showing dinosaurs bothering people (or vice versa). This idea is ________.

**ANSWER:**

- unreasonable, because dinosaurs died out before people existed
- plausible but unlikely, because dinosaurs lived on different continents than people
- reasonable, because the last dinosaurs died out after the first humans appeared

The last dinosaurs went extinct about 65 million years ago, which was more than 60 million years before the earliest humans arose on Earth.

**Part B**

According to current scientific estimates, when did the Big Bang occur?

**Hint B.1 Is there another way of asking when the Big Bang occurred?**

The time at which the Big Bang occurred can also be considered ________.

**ANSWER:**

- the time when the dinosaurs went extinct
- the birth of our solar system
- the birth of our universe

In other words, the current estimated age of the universe tells us how long ago the Big Bang occurred.
Scientists estimate the age of the universe by measuring the expansion rate, from which they can determine how long it has taken the universe to reach its current size. Current estimates put this age at about 14 billion years.

In the rest of this activity, we will consider the timing of events using a type of time line known as the “cosmic calendar.” Originally developed by Carl Sagan, the cosmic calendar compresses the history of the universe into a single year, with the Big Bang occurring at the first instant of January 1 and the present being the stroke of midnight on December 31.

Part C

On the cosmic calendar, which compresses the history of the universe into a single year, about when did Earth form?

How long does each month represent on this cosmic calendar?

Given that the cosmic calendar compresses the history of the universe into a single year, how much time does one month on the calendar represent?

The cosmic calendar compresses the 14-billion-year history of the universe into 1 year, which means that each month represents about 1/12 of 14 billion years, or about 1.2 billion years.

The age of Earth

Careful measurements (with a technique called radiometric dating, which you can read about in your textbook) indicate that our entire solar system, including Earth, was born about 4 ½ billion years ago.

The cosmic calendar compresses the 14-billion-year history of the universe into 1 year, which means that each month represents about 1.2 billion years. The solar system’s age of 4 ½ billion years therefore puts its birth in early September.
Part D

On the cosmic calendar, which compresses the history of the universe into a single year, about when did life arise on Earth?

**Hint D.1 How long does each month represent on this cosmic calendar?**

Given that the cosmic calendar compresses the history of the universe into a single year, how much time does one month on the calendar represent?

**ANSWER:**
- about 1 million years
- about 1.2 billion years
- about 14 billion years

The cosmic calendar compresses the 14-billion-year history of the universe into 1 year, which means that each month represents about 1/12 of 14 billion years, or about 1.2 billion years.

**Hint D.2 How long does each day represent on the cosmic calendar?**

Given that the cosmic calendar compresses the history of the universe into a single year, how much time does one day on the calendar represent?

**ANSWER:**
- about 1 million years
- about 40 million years
- about 1.2 billion years

The cosmic calendar compresses the 14-billion-year history of the universe into 1 year, which means that each day represents about 1/365 of 14 billion years, or about 40 million years.

**Hint D.3 Estimated time when early life arose on Earth**

Scientists currently estimate that the earliest life on Earth appeared somewhere between about 3 ½ and 4 billion years ago, or within the first 1 billion years after Earth first formed.

**ANSWER:**
- in late January
- in mid-August
- in September
- in mid-December
- just a few hours before midnight on December 31

From Part C, Earth formed in early September on the cosmic calendar. Life apparently arose on Earth within less than a billion years after that, which means it was still in September (because each month on the cosmic calendar represents about 1.2 billion years).

Part E

On the cosmic calendar, which compresses the history of the universe into a single year, about when did early humans first walk on Earth?
Hint E.1  How long does each day represent on the cosmic calendar?

Given that the cosmic calendar compresses the history of the universe into a single year, how much time does one day on the calendar represent?

ANSWER:
- about 1 million years
- about 40 million years
- about 1.2 billion years

The cosmic calendar compresses the 14-billion-year history of the universe into 1 year, which means that each day represents about 1/365 of 14 billion years, or about 40 million years.

Hint E.2  Estimated age of the earliest human fossils

According to modern techniques for dating fossils, early humans arose within the past 3 to 5 million years.

ANSWER:
- in June
- in September
- in mid-December
- on December 30
- just a few hours before midnight on December 31

The cosmic calendar compresses the 14-billion-year history of the universe into 1 year, which means that each day represents about 1/365 of 14 billion years, or about 40 million years. Early humans arose just a few million years ago, which therefore means just a few hours before the present moment (the stroke of midnight on December 31) on the cosmic calendar.

Sorting Task: Astronomical Objects

Description: Students sort objects as being either single objects or collections of astronomical objects including stars, planets, galaxies, and clusters.

Part A

Some of the objects listed following are generally considered to be single (individual) astronomical objects; others are thought of as collections of many individual astronomical objects. Match these to the appropriate category.

Hint A.1  Single astronomical objects

Single astronomical objects cannot easily be subdivided into smaller astronomical objects. The Sun, for example, is a single astronomical object.

Hint A.2  Collections of astronomical objects

Many astronomical objects exist in groups. A star system is a collection of astronomical objects because it is made of a group of stars that are gravitationally bound together.

Hint A.3  Which object has the largest number of stars?
Which of the following contains more stars than the others?

**Answer:**
- solar system
- galaxy
- supercluster

A supercluster is a "cluster of galaxy clusters," in which each cluster contains numerous galaxies, and each galaxy contains hundreds of millions to billions of star systems.

**Answer:**

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**Vocabulary in Context: Describing Motions in the Universe**

**Description:** Vocabulary in context exercise on basic motions in the universe including Earth, the Sun, and the Milky Way Galaxy.

**Part A**

Match the words in the left-hand column to the appropriate blank in the sentences in the right-hand column. Use each word only once.

- **Hint A.1 What an orbit is**
  An orbit is the path of one object around another due to gravity.

- **Hint A.2 What the Milky Way Galaxy is**
  The Milky Way Galaxy is a collection of more than 100 billion stars, including our Sun, which are all bound together by gravity.

- **Hint A.3 What the universe is**
  The universe is the sum total of all matter and energy.

- **Hint A.4 What the Local Group is**
  The Local Group is a group of a few dozen galaxies to which the Milky Way Galaxy belongs.

- **Hint A.5 What the solar system is**
  Our solar system consists of the Sun and all the objects that orbit it.
**Problem 1.25**

**Description:** Choose the best answer. (a) Which of the following correctly lists our "cosmic address" from small to large?

Choose the best answer.

**Part A**

Which of the following correctly lists our "cosmic address" from small to large?

**ANSWER:**
- Earth, solar system, Milky Way Galaxy, Local Group, Local Supercluster, universe;
- Earth, solar system, Local Group, Local Supercluster, Milky Way Galaxy, universe;
- Earth, Milky Way Galaxy, solar system, Local Group, Local Supercluster, universe.

**Problem 1.26**

**Description:** Choose the best answer. (a) When we say the universe is expanding, we mean that:

Choose the best answer.

**Part A**

When we say the universe is **expanding**, we mean that:

**ANSWER:**
- Everything in the universe is growing in size.
- The average distance between galaxies is growing with time.
- The universe is getting older.
Problem 1.44

**Description:** Just as a light-year is the distance that light can travel in 1 year, we define a light-second as the distance that light can travel in 1 second, a light-minute as the distance that light can travel in 1 minute, and so on. Calculate the distance represented by each of the following:

**Part A**

1 light-second in kilometers

**Express your answer using two significant figures.**

\[
1 \text{ light-second} = 3.0 \times 10^5 \text{ km}
\]

**Part B**

1 light-second in miles;

**Express your answer using two significant figures.**

\[
1 \text{ light-second} = 1.9 \times 10^5 \text{ mi}
\]

**Part C**

1 light-minute in kilometers;

**Express your answer using two significant figures.**

\[
1 \text{ light-minute} = 1.8 \times 10^7 \text{ km}
\]

**Part D**

1 light-minute in miles;

**Express your answer using two significant figures.**

\[
1 \text{ light-minute} = 1.1 \times 10^7 \text{ mi}
\]

**Part E**

1 light-hour in kilometers

**Express your answer using two significant figures.**
**Part F**

1 light-hour in miles

Express your answer using two significant figures.

ANSWER:

\[ 1 \text{ light-hour} = 6.7 \times 10^8 \text{ mi} \]

**Part G**

1 light-day in kilometers

Express your answer using two significant figures.

ANSWER:

\[ 1 \text{ light-day} = 2.6 \times 10^{10} \text{ km} \]

**Part H**

1 light-day in miles

Express your answer using two significant figures.

ANSWER:

\[ 1 \text{ light-day} = 1.6 \times 10^{10} \text{ mi} \]

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**Ranking Task: Astronomical Distances and Light-Travel Time**

**Description:** Students are asked to rank various astronomical objects by distance, by light-travel time, and by how much they have aged since they emitted the light we are seeing right now.

**Learning Goal:** To understand how astronomical distances relate to light-travel times and to how objects have aged since their light left on its way to Earth.

**Part A**

Shown here are astronomical objects located at different distances from Earth. Rank the objects based on their distances from Earth, from farthest to nearest.

**Hint A.1** What is Alpha Centauri?

Alpha Centauri is ________.

ANSWER: another name for our Sun
the nearest star (or star system) besides our Sun, about 4 light-years away
the nearest large galaxy to the Milky Way Galaxy, about 2.5 million light-years away

Alpha Centauri is the nearest star besides our Sun. (The Alpha Centauri system actually has three stars, but it is the brightest one that we see with the naked eye.) It is a little over 4 light-years away, which is close when compared to the size of our Milky Way Galaxy.

Hint A.2  What is the Orion Nebula?
The Orion Nebula is __________.

ANSWER:
- a cloud of gas located between Jupiter and Neptune
- a star-forming cloud located far outside our solar system
- a giant cloud of gas and young stars located far outside the Milky Way Galaxy

The Orion Nebula is a cloud of gas and dust in which new stars are forming. It is located about 1,500 light-years away, which is relatively nearby compared to the 100,000 light-year diameter of our Milky Way Galaxy.

Hint A.3  How big is the Milky Way Galaxy?
The disk of the Milky Way Galaxy is approximately __________ in diameter.

ANSWER:
- 1 light-year
- 1000 light-years
- 100,000 light-years
- 2.5 million light-years

The diameter of the disk of the Milky Way Galaxy is approximately 100,000 light-years. Our solar system is located a little more than halfway out from the center of the galaxy to the edge of the disk.

Hint A.4  How far away is the Andromeda Galaxy?
The distance to the Andromeda Galaxy is approximately __________.

ANSWER:
- 1 light-year
- 1000 light-years
- 100,000 light-years
- 2.5 million light-years

The distance to the Andromeda Galaxy is approximately 2.5 million light-years, or about 25 times the diameter of the Milky Way Galaxy.

Hint A.5  How far away is the center of the Milky Way Galaxy?
The distance between the center of the Milky Way Galaxy and our solar system is approximately _________.

ANSWER:
- 2800 light-years
- 28,000 light-years
- 2.8 million light-years

The diameter of the disk of the Milky Way Galaxy is approximately 100,000 light-years, so its radius is about 50,000 light-years. Our solar system is located a little more than halfway out from the center of the galaxy to the edge of the disk, which means a little more than half of the 50,000 light-year radius.

Considering again the objects you ranked by distance in Part A. Suppose each object emitted a burst of light right now. Rank the objects from left to right based on the amount of time it would take this light to reach Earth, from longest time to shortest time.

Hint B.1 How long does it take light to travel great distances?

If you want to calculate how long it takes light to travel from some distant object to Earth, the one thing you need to know is _________.

ANSWER:
- the age of the object
- the distance to the object
- the name of the object
- the mass of the object

Although light travels very fast, distances in space are so huge that even light takes substantial time to cross them. The farther away an object is located, the longer it will take its light to reach us.
Notice that light from more distant objects takes a longer time to travel to Earth. Now continue to Part C to be sure you understand the implications for what we actually see in the night sky.

Part C

Look once more at the objects you ranked in Parts A and B. This time, rank the objects from left to right based on how much they have aged since they emitted the light we see today, from greatest to least.

Hint C.1  How do you determine how much an object has aged since its light left?

If you want to calculate how much an object has aged since its light left on its way to Earth, the one thing you need to know is __________.

ANSWER:  
- the age of the object when its light left
- the age of the object right now
- the age of the object both when the light left and right now
- the light-travel time to the object

If you know the light-travel time to an object, then you know how long ago the light was emitted and how much the object has aged. For example, if an object is 10 light-years away, then the light we see today must have left the object 10 years ago, which means the object has aged 10 years since the light left.

Hint C.2  When did light leave a star 10 light-years away?

Tonight, you observe a star located 10 light-years away. When did the light you see tonight leave the star?

ANSWER:  
- yesterday
- 10 years ago
- cannot be determined from information given

The star has aged 10 years since the light that you see left it.

As you found in Part B, light from more distant objects takes a longer time to travel to Earth. This
means that we see more distant objects as they were longer ago. For example, if an object is 10 light-years away, then we see it as it was 10 years ago, but if it is 20 light-years away, we see it as it was 20 years ago. In other words, more distant objects have aged more since their light left on its way to Earth.

### Ranking Task: Looking Back in Space and Time

**Description:** Students rank a set of galaxies according to light-travel time, then use this idea to infer the age of the universe at the time the galaxies emitted the light we receive from them today.

**Learning Goal:** To understand how astronomers learn about the history of the universe by studying galaxies at different distances from Earth.

#### Part A

Shown here are six galaxies, each labeled with its approximate distance from Earth. Rank the galaxies from left to right based on the amount of time it has taken their light to travel to Earth, from the longest time to the shortest time.

**Hint A.1 How do distances tell you the time required for light to reach Earth?**

The Andromeda Galaxy is located about 2.5 million light-years away. How long does its light take to reach us?

**ANSWER:**
- It depends on how fast the light travels.
- 2.5 million years
- 2.5 million light-years

Distances in light-years correspond directly to light-travel times.

**ANSWER:**

In fact, distances in light-years correspond directly to light-travel times. For example, light takes 100 million years to reach us from a galaxy that is 100 million light-years away. This fact has important implications to the study of the evolution of the universe, as you’ll see in Part B.

#### Part B

Consider again the galaxies you ranked in Part A. This time, rank them from left to right based on the age of the universe at the time these galaxies emitted the light we receive from them today, from oldest (closest to today) to youngest (furthest back in time).

**Hint B.1 How old is the universe?**
What is the best estimate for the age of the universe?

**ANSWER:**
- 14 million years
- 4 1/2 billion years
- 14 billion years

This age is based on studies of the rate of expansion of the universe. Now, think about a galaxy located, say, 12 billion light-years away. Compared to its age today, was the universe young or old when light left that galaxy on its way to Earth?

**Hint B.2 How do you get an age for the universe from an object’s distance?**

Suppose a galaxy is located 10 billion light-years away. Given that the universe is now about 14 billion years old, how old was the universe at the time when the galaxy emitted the light we see today?

**ANSWER:**
- 10 billion years
- 14 billion years
- 4 billion years

If a galaxy is 10 billion light-years away, it means its light left 10 billion years ago. Therefore, the universe was only 4 billion years old at the time.

**ANSWER:**

By looking to objects at a variety of distances, we can actually see what the universe was like at different ages. This fact helps astronomers to reconstruct the history of the universe.

**Problem 1.28**

**Description:** Choose the best answer. (a) Could we see a galaxy that is 20 billion light-years away?

Choose the best answer.

**Part A**

Could we see a galaxy that is 20 billion light-years away?

**ANSWER:**
- Yes, if we had a big enough telescope.
- No, because it would be beyond the bounds of our observable universe.
- No, because a galaxy could not possibly be that far away.
Problem 1.29

Description: Choose the best answer. (a) The star Betelgeuse is about 425 light-years away. If it explodes tonight:

Choose the best answer.

Part A

The star Betelgeuse is about 425 light-years away. If it explodes tonight:

ANSWER:

- We'll know because it will be brighter than the full Moon in the sky.
- We'll know because debris from the explosion will rain down on us from space.
- We won't know about it until 425 years from now.

Problem 1.30

Description: Choose the best answer. (a) If we represent the solar system on a scale that allows us to walk from the Sun to Pluto in a few minutes, then:

Choose the best answer.

Part A

If we represent the solar system on a scale that allows us to walk from the Sun to Pluto in a few minutes, then:

ANSWER:

- the planets would be the size of basketballs and the nearest stars would be a few miles away.
- the planets would all be marble size or smaller and the nearest stars would be thousands of miles away.
- the planets would be microscopic and the stars would be light-years away.

Problem 1.31

Description: Choose the best answer. (a) The total number of stars in the observable universe is roughly equivalent to:

Choose the best answer.

Part A

The total number of stars in the observable universe is roughly equivalent to:

ANSWER:

- the number of grains of sand on all the beaches on Earth.
- the number of grains of sand on Miami Beach.
Problem 1.32

**Description:** Choose the best answer. (a) The age of our solar system is about:...

Choose the best answer.

**Part A**
The age of our solar system is about:

**ANSWER:**
- one-third of the age of the universe.
- three-fourths of the age of the universe.
- two billion years less than the age of the universe.

Problem 1.34

**Description:** Choose the best answer. (a) The fact that nearly all galaxies are moving away from us, with more distant ones moving faster, helped us to conclude that:...

Choose the best answer.

**Part A**
The fact that nearly all galaxies are moving away from us, with more distant ones moving faster, helped us to conclude that:

**ANSWER:**
- The universe is expanding.
- Galaxies repel each other like magnets.
- Our galaxy lies near the center of the universe.

Problem 1.45

**Description:** (a) How long does it take light to travel from the Moon to Earth? (b) How long does it take light to travel from the Sun to Earth?

**Part A**
How long does it take light to travel from the Moon to Earth?

**ANSWER:** $1.28 \text{ s}$

**Part B**
How long does it take light to travel from the Sun to Earth?

ANSWER: \[ 499 \text{ s} \]

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Problem 1.46

**Description:** Photos of Saturn and photos of galaxies can look so similar that children often think the photos show similar objects. In reality, a galaxy is far larger than any planet. (a) About how many times larger is the diameter of the Milky Way Galaxy than ...

Photos of Saturn and photos of galaxies can look so similar that children often think the photos show similar objects. In reality, a galaxy is far larger than any planet.

**Part A**

About how many times larger is the diameter of the Milky Way Galaxy than the diameter of Saturn's rings? (Data: Saturn's rings are about 270,000 km in diameter; the Milky Way is 100,000 light-years in diameter.)

**Express your answer using two significant figures.**

ANSWER: \[ 3.5 \times 10^{12} \]

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Problem 1.47

**Description:** Imagine that you could drive your car at a constant speed of \( v \) km/hr (\( v_2 \)), even across oceans and in space. (a) How long would it take to drive around Earth's equator? (Hint: Use Earth's circumference of about 40000 km.) Hint:... (b) How long...

Imagine that you could drive your car at a constant speed of 200 km/hr (124 mi/hr), even across oceans and in space.

**Part A**

How long would it take to drive around Earth's equator? (Hint: Use Earth's circumference of about 40000 km.)

ANSWER: \[ \frac{40000}{24v} \text{ days} \]

**Part B**

How long would it take to drive from the Sun to Earth?

ANSWER: \[ \frac{149600000}{365 \cdot 24v} \text{ years} \]
Part C
How long would it take to drive from the Sun to Pluto? (Hint: You can find Pluto’s distance in Appendix E in the textbook.)

\[
\text{ANSWER: } \frac{5916 \times 10^6}{365 \times 24 \times v_1} \text{ years}
\]

Part D
How long would it take to drive to Alpha Centauri (4.4 light-years away)?

Express your answer using two significant figures.

\[
\text{ANSWER: } \frac{4.4 \times 4.6 \times 10^6}{365 \times 24 \times v_1} \text{ million years}
\]

Key Concept: The Expanding Universe

**Description:** This tutorial uses the raisin cake analogy to help students understand what we mean by an expanding universe and how Hubble’s observations led to the conclusion that we live in an expanding universe.

**Learning Goal:** To understand what we mean by an expanding universe and how we know that the universe is expanding.
Introduction. The idea that we live in an expanding universe is fundamental to much of modern astronomy. But we can't actually see the universe growing larger, so how do we know that it really is expanding? This tutorial should help you understand the evidence.

Part A
Which of the following statements best describes what astronomers mean when they say that the universe is expanding?

Hint A.1 How big is the observable universe?
The size of the observable universe depends on _________.

ANSWER:
- the power of our telescopes
- the number of galaxies we observe
- the age of the universe

For example, if the universe is 14 billion years old, then the observable universe extends to a radius of 14 billion light-years from us in all directions. This means that as the universe gets older, the observable universe gets larger in size. However, it does not necessarily mean that the universe or anything in it is growing with time.

Hint A.2 What is a galaxy?
A galaxy is best described as _________.

ANSWER:
- a star and the planets that orbit it
- a hot, glowing ball of gas that generates energy through nuclear fusion in its core
- a very large collection of stars held together by gravity

The key idea is that a galaxy is held together by gravity, which means that it does not expand with time.

ANSWER:
- The observable universe is growing larger in radius at a rate of one light-year per year.
- All objects in the universe, including Earth and everything on it, are gradually growing in size.
- The average distance between galaxies is increasing with time.
- The universe itself is not growing, but our knowledge of the universe is increasing with time.
- The average distance between stars in the Milky Way Galaxy is increasing with time.
Keep in mind that while the universe as a whole is expanding, individual galaxies (and gravitationally bound groups or clusters of galaxies) and their contents do not expand. That is why average distances between galaxies grow with time, but objects such as people, Earth, the solar system, and the Milky Way Galaxy are stable in size.

Edwin Hubble discovered two key observation facts: (1) Virtually every galaxy outside our Local Group is moving away from us. (2) The more distant the galaxy, the faster it is moving away. The raisin cake analogy shows how these two facts lead to the conclusion that the universe is expanding. Click “Play” to watch the animation; observe the motions of the raisins and note how the values in the table change as the cake expands.

**Part B**

Note that an observer located at the Local Raisin would see Raisins 1, 2, and 3 all move away from her during the animation. What would an observer located at Raisin 2 see?

**Hint B.1** How would an observer located at Raisin 2 describe her own motion?

As the raisin cake expands, an observer located at Raisin 2 would say that ________.

**ANSWER:**

- she is moving outward through the cake
- she is moving away from the Local Raisin
- she is staying in the same place

Observers located at any raisin would consider themselves stationary, and say that the other raisins are moving relative to them.

**Hint B.2** Does the distance between Raisin 1 and Raisin 2 change?

As the cake expands, the separation between Raisin 1 and Raisin 2 _____.

**ANSWER:**

- stays the same
- increases
- decreases

Now, consider how the observer located at Raisin 2 would describe the motion of Raisin 1 (or any other raisin) to account for this increasing distance.

**ANSWER:**

- Raisin 1 moves toward her while Raisin 3 moves away from her.
- Raisin 1 and Raisin 3 both move away from her.
- Raisin 1 moves away from her while Raisin 3 moves toward her.
- Raisin 1 and Raisin 3 both move toward her.

In fact, observers at any raisin would see all the other raisins moving away. Note also that the farther away a raisin is located from the observer, the faster it moves away — which is just what Hubble discovered for galaxies in the universe.

**Part C**
The table in the animation shows you the speeds of Raisins 1, 2, and 3 as measured from the Local Raisin. Suppose instead you measured speeds as seen from Raisin 2. An observer at Raisin 2 would measure __________.

**Hint C.1 How does speed depend on distance?**

Suppose two people start walking away from you. If they are both 10 meters away when they start walking and 30 meters away when they both stop at the same time, you can conclude that __________.

**ANSWER:**
- they are both walking at the same speed
- the first person is walking faster than the second
- both people are walking at a speed of 20 meters per hour

If two objects are equally far away from you, then they must either be stationary or traveling away from you at the same speed. Now look at the animation: Are there any raisins that always stay the same distance from Raisin 2? What can you conclude about their speeds?

**Hint C.2 How far does Raisin 1 travel?**

As viewed from Raisin 2, how far does Raisin 1 travel during the animation?

**ANSWER:**
- 1 centimeter
- 2 centimeters
- 3 centimeters

The separation between Raisins 1 and 2 increased from 1 centimeter to 3 centimeters during the animation, so an observer at Raisin 2 would see Raisin 1 move 2 centimeters during the hour of baking. What does this tell you about the speed of Raisin 1 as seen from Raisin 2?

**ANSWER:**
- Local Raisin speed = 4.0 cm/hr; Raisin 1 speed = 2.0 cm/hr; Raisin 3 speed = 4.0 cm/hr
- Local Raisin speed = 2.0 cm/hr; Raisin 1 speed = 4.0 cm/hr; Raisin 3 speed = 6.0 cm/hr
- Local Raisin speed = 6.0 cm/hr; Raisin 1 speed = 4.0 cm/hr; Raisin 3 speed = 2.0 cm/hr
- Local Raisin speed = 4.0 cm/hr; Raisin 1 speed = 2.0 cm/hr; Raisin 3 speed = 2.0 cm/hr
- Local Raisin speed = 2.0 cm/hr; Raisin 1 speed = 2.0 cm/hr; Raisin 3 speed = 2.0 cm/hr

Note that the observer at Raisin 2 sees essentially the same thing as the observer at the Local Raisin: The nearest raisins (Raisins 1 and 3 in this case) are moving away at 2 cm/hr and the next nearest (the Local Raisin in this case) is moving away at 4 cm/hr. If the cake were bigger, the pattern would continue. The key point is this: *It does not matter which raisin you observe from; in an expanding raisin cake — or an expanding universe — all observers see all other raisins (galaxies) moving away, with more distant raisins (galaxies) moving faster.*

---

Part D
The following statements describe ways in which the analogy might apply to the real universe. Which statements are correct?

**Hint D.1 What is the universe?**
The universe is best defined as __________.

**ANSWER:**
- the sum total of all matter, energy, space, and time
- the Milky Way Galaxy
- the collection of objects that we can see (with or without telescopes) in the night sky
- our solar system, including the Sun and the planets

Given that the universe by definition includes all space, is there any place that is “outside” the universe?

**Hint D.2 How does the temperature of the universe change with time?**
As the universe expands, its overall temperature _____.

**ANSWER:**
- decreases
- stays the same
- increases

The universe is thought to have started out extremely hot and dense in the event we call the Big Bang, and it has been cooling ever since.

**Check all that apply.**

**ANSWER:**
- An observer at any raisin sees more distant raisins moving away faster, just as an observer in any galaxy sees more distant galaxies moving away faster.
- The raisins stay roughly the same size as the cake expands, just as galaxies stay roughly the same size as the universe expands.
- Raisin 1 is near the center of the cake, just as our galaxy is near the center of the universe.
- The average distance increases with time both between raisins in the cake and between galaxies in the universe.
- The temperature starts low and ends high in both the raisin cake and the universe.
- Both the raisin cake and the universe have a well-defined inside and outside.

Like any scientific model, the raisin cake analogy has limitations, but it gives us a good overall picture of how the universe is expanding.

**Part E**

Based on what you've learned from the raisin cake analogy, what two properties of distant galaxies do astronomers have to measure to show that we live in an expanding universe?
Hint E.1  **Open this hint if you are stuck**

The key to answering Part E is to understand how someone living in the raisin cake could conclude that the cake is expanding. Look again at the animation and review Parts A through D. You’ll realize that if you lived in an expanding raisin cake, you’d see all other raisins moving away from yours, with more distant ones moving faster. So if you really did live in the raisin cake, what two things would you have to measure to conclude that more distant raisins are moving away from you faster? These are the same things we must measure for galaxies in order to conclude that we live in an expanding universe.

ANSWER:  
- their distances and masses
- their distances and speeds
- their ages and distances
- their ages and masses

The analogy shows that if you lived in an expanding raisin cake, you’d see all other raisins moving away from yours, with more distant ones moving faster. This is exactly what we observe for galaxies outside our Local Group, which is why we conclude that we live in an expanding universe.

Part F

Today, the evidence that we live in an expanding universe is extremely strong, because astronomers have measured the motions of millions of galaxies. Nevertheless, in science, we must always remain open to the possibility that some future observation could call even our most strongly supported theories into question. Which of the following hypothetical observations would **not** be consistent with what we expect in an expanding universe?

**Hint F.1  What is a “hypothetical” observation?**

When we say that an observation is “hypothetical,” we mean that we are talking about __________.

ANSWER:  
- an observation that we have not yet made, but probably will in the future
- an observation that could not possibly be made
- an observation that we have not actually made

Some hypothetical observations are things that we are likely to observe or are very similar to things we have already observed, while others are things that we are very unlikely to observe.

ANSWER:  
- You discover a pair of distant galaxies that are colliding with one another.
- You discover an extremely distant galaxy that is moving away from us at 90% of the speed of light.
- You discover an extremely distant galaxy that is moving toward us.

In an expanding universe, extremely distant galaxies must be moving away from us, just as distant raisins in the raisin cake must be moving away. It would make no sense to find an extremely distant galaxy that was moving **toward** us, and such an observation would therefore cause us to question the very idea of an expanding universe.

**Process of Science: Observations vs. Explanations**
Description: This process of science activity helps students distinguish between observations (things we actually see or measure) and explanations (hypotheses that seek to explain what we observe), both with everyday ideas and with astronomical ideas.

Learning Goal: To understand the scientific distinction between what we actually observe and ways in which we attempt to explain what we observe.

Introduction. In science, it is important to be able to distinguish between an observation (something we actually see or measure) and an explanation (essentially a hypothesis that seeks to explain what we observe). This activity will help you understand this distinction, first with everyday ideas and then with astronomical ideas.

Part A
Consider each of the following statements that you might hear in everyday life. Classify each statement as either an observation or an explanation.

Hint A.1 Definition of an observation
Observations are things that we can directly see or measure. In that sense, observations are “facts” that can be wrong only if the observer made a mistake when conducting the observation (or, in rarer cases, if the observer is lying about what he or she observed). For example, if a medical examiner claims that your DNA was found in the cafeteria, then we can consider this an “observed fact” that must be true unless the medical examiner made a mistake when analyzing the DNA.

Hint A.2 Definition of an explanation
Explanations provide possible reasons for what we measure or observe. Explanations are not necessarily correct: Some explanations may be little more than guesses, while others may be based on well-verified scientific principles. Not all explanations can be verified. In general, explanations are not things that we can directly observe, but rather are things that we infer from observations.

Hint A.3 Does your appointment calendar explain where you are?
Suppose you use a calendar to keep track of your appointments and the calendar says that you had a doctor appointment last Thursday at noon. Which of the following statements must be true?

**ANSWER:**
- Anyone looking at your calendar can see that you had a doctor appointment last Thursday at noon.
- You were at your doctor appointment last Thursday at noon.
- Both statements above are true.

Anyone looking at your calendar can observe that it says you had the appointment as indicated, but the calendar does not tell us whether you actually attended the appointment. This same idea should help you categorize the statement about the defendant’s calendar in Part A.

**ANSWER:**

View
Be sure you understand all these everyday examples before you continue to the astronomical examples in Part B. For example, the statement “James is wearing a yellow shirt” is an observation because it is something you can see directly, while the statement “James wears a yellow shirt when his other shirts are dirty” is an explanation because it is an attempt to explain why James is wearing a yellow shirt.

Part B

Consider the following astronomical statements. Classify each statement as either an observation or an explanation.

Hint B.1  Andromeda Galaxy example of an observation

Observations are things that we can directly see or measure. In that sense, observations are “facts” that can be wrong only if the observer made a mistake when conducting the observation (or, in rarer cases, if the observer is lying about what he or she observed). For example, if an astronomer says that “the Andromeda Galaxy is 2.5 million light-years away,” then we can assume this claim is based on an actual measurement made by some established technique of distance measurement. This statement is therefore an “observation” that must be true unless the astronomer applied the distance measurement technique incorrectly or there is some unknown problem with the technique itself.

Hint B.2  Andromeda Galaxy example of an explanation

Explanations provide possible reasons for what we measure or observe. Explanations are not necessarily correct. Some explanations may be little more than guesses, while others may be based on well-verified scientific principles. Not all explanations can be verified. In general, explanations are not things that we can directly observe, but rather are things that we infer from observations. For example, if we say that "the Andromeda Galaxy was born from the collapse of a giant cloud of gas," this is clearly something we must infer, because we cannot observe what the galaxy looked like before it was born.

Hint B.3  Can we “observe” or measure something older than we are?

True or False: When scientists claim that our solar system formed 4 ½ billion years ago, this cannot be an observation because no one was alive at that time.

ANSWER:
- True
- False

It is possible to measure ages for things much older than we are. For example, you can use tree rings to measure the ages of trees that have been alive for hundreds or thousands of years. Similarly, scientists have developed techniques that allow them to measure the ages of our solar system and of other stars. These measurements are considered “observations” because they are things that anyone can in principle observe (measure) for themselves.

Hint B.4  What is the Big Bang?

Scientists claim that the universe began with the Big Bang because __________.

ANSWER:
- powerful telescopes allow us to see the Big Bang occurring
- we have measured the precise distance to the Big Bang
- the Big Bang theory explains many features of the universe, including the fact that the entire universe is expanding
The Big Bang theory explains many observations and measurements of the universe, including the observations that indicate that the universe is expanding. This fact should help you categorize at least one of the statements in Part B.

ANSWER:

The examples given here are fairly easy to classify, but the distinction between an observation and an explanation can sometimes be fuzzy. For example, the statement “Earth orbits the Sun” is something we now consider an observed fact, but in the past it would have been considered only one potential explanation for what we see in the sky (and an alternate explanation of “everything orbits Earth” was favored for thousands of years). Nevertheless, understanding the basic distinction between an observation and an explanation is very important in science.

Problem 1.33

Description: Choose the best answer. (a) An astronomical unit is:

Choose the best answer.

Part A

An astronomical unit is:

ANSWER:

- any planet's average distance from the Sun.
- Earth's average distance from the Sun.
- any large astronomical distance.

Chapter 01: Concept Quiz

Description: (a) Which of the following has your "cosmic address" in the correct order? (b) Using the ideas discussed in your textbook, in what sense are we "star stuff"? (c) How are galaxies important to our existence? (d) When we look at an object that is...

Part A

Which of the following has your "cosmic address" in the correct order?

Hint A.1

Review Section 1.1 of The Essential Cosmic Perspective in your textbook, and especially study Figure 1.1 in the textbook.
**ANSWER:**

- You, Earth, solar system, Local Group, Milky Way Galaxy, Local Supercluster, universe
- You, Earth, solar system, Milky Way Galaxy, Local Group, Local Supercluster, universe
- You, Earth, Milky Way Galaxy, solar system, Local Group, Local Supercluster, universe
- You, Earth, Local Group, Local Supercluster, solar system, Milky Way Galaxy, universe
- You, Earth, solar system, Local Group, Local Supercluster, Milky Way Galaxy, universe

Be sure to look at the relative scales, which are shown in Figure 1.1 in the textbook of *The Essential Cosmic Perspective*.

### Part B

**Using the ideas discussed in your textbook, in what sense are we "star stuff"?**

**Hint B.1**

See Section 1.1 of *The Essential Cosmic Perspective*.

**ANSWER:**

- Movie stars and other people are all made of the same stuff, so we all have the potential to be famous.
- The overall chemical composition of our bodies is about the same as that of stars.
- We could not survive without light from our star, the Sun.
- Nearly every atom from which we are made was once inside of a star.

According to present understanding, the early universe contained only the elements hydrogen and helium. All other elements - including carbon, oxygen, and other major ingredients of life - were produced by stars.

### Part C

**How are galaxies important to our existence?**

**Hint C.1**

See Section 1.1 of *The Essential Cosmic Perspective* in your textbook.

**ANSWER:**

- Galaxies recycle material from one generation of stars to the next, and without this recycling we could not exist.
- Without galaxies, the universe could not be expanding.
- Without galaxies, there could not have been a Big Bang.
- Deep in their centers, galaxies created the elements from which we are made.

Except for hydrogen, all the elements of life were produced by stars and scattered into space when the stars died. Without galactic recycling, these elements would have dispersed into the expanding
universe rather than being available to build planets and life around later generations of stars.

Part D
When we look at an object that is 1,000 light-years away we see it _________.

Hint D.1
Study Section 1.1 of *The Essential Cosmic Perspective*, and remember that a light-year is the distance in your textbook that light can travel in one year.

ANSWER:

- as it was 1,000 light-years ago
- as it is right now, but it appears 1,000 times dimmer
- looking just the same as our ancestors would have seen it 1,000 years ago
- as it was 1,000 years ago

It takes 1,000 years for light to travel 1,000 light-years, so we see the object as it was 1,000 years ago.

Part E
Suppose we look at two distant galaxies: Galaxy 1 is twice as far away as Galaxy 2. In that case _________.

Hint E.1
Study Section 1.1 of *The Essential Cosmic Perspective* in your textbook, and remember that the farther away we look in distance, the further back we look in time.

ANSWER:

- Galaxy 1 must be twice as big as Galaxy 2
- we are seeing Galaxy 1 as it looked at a *later* time in the history of the universe than Galaxy 2
- Galaxy 2 must be twice as old as Galaxy 1
- we are seeing Galaxy 1 as it looked at an *earlier* time in the history of the universe than Galaxy 2

Remember that the farther away we look in distance, the further back we look in time. Because Galaxy 1 is farther away, we are seeing it at a time further into the past, which means earlier in the history of the universe.

Part F
Suppose we make a scale model of our solar system, with the Sun the size of a grapefruit. Which of the following best describes what the planets would look like?

Hint F.1
This question makes use of the 1-to-10 billion scale from the Voyage model solar system described in Section 1.2 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:
The planets are all much smaller than the Sun. Four planets are located within
a few centimeters of the Sun, and four planets are located at distances ranging up to about a meter.

- The planets range in size from about the size of a marble to the size of a baseball. They are spread out over a region about the size of a football field.
- The planets are all much smaller than the Sun and are spread out evenly over a distance about the length of a large classroom.
- The planets are all much smaller than the Sun. Four planets are within about 20 meters of the Sun, while the rest planets are spread much farther apart.

You can see this idea clearly in the figures that relate to the Voyage model solar system in Section 1.2 of *The Essential Cosmic Perspective* in your textbook.

**Part G**

If you could count stars at a rate of about one per second, how long would it take to count all the stars in the Milky Way Galaxy?

**Hint G.1**

Study Section 1.2 of *The Essential Cosmic Perspective* in your textbook, and remember that there are at least 100 billion stars in the Milky Way Galaxy.

**ANSWER:**

- Several years
- Several weeks
- Several days
- Several thousand years

There are at least 100 billion stars in the Milky Way Galaxy, so it would take at least 100 billion seconds to count them — and 100 billion seconds is more than 3,000 years.

**Part H**

The total number of stars in the observable universe is about _________.

**Hint H.1**

Study Section 1.2 of *The Essential Cosmic Perspective* in your textbook, and remember that there are some 100 billion stars in a typical galaxy and some 100 billion galaxies in the observable universe.

**ANSWER:**

- the same as the number of atoms that make up the Earth
- the same as the number of grains of sand on all the beaches on Earth
- the same as the number of grains of sand in a school sandbox
- 100 billion

It's a remarkable fact. There are some $10^{11}$ (100 billion) stars in a typical galaxy and $10^{11}$ galaxies in the observable universe, making a total of some $10^{11} \times 10^{11} = 10^{22}$ stars — comparable to the total number of (dry) grains of sand on all beaches on Earth combined.

**Part I**
Where is our solar system located within the Milky Way Galaxy?

Hint I.1
The solar system's location is discussed and shown in Section 1.1 of The Essential Cosmic Perspective in your textbook.

ANSWER:
- Very near the center of the galaxy
- Roughly halfway between the center and the edge of the visible disk of the galaxy
- At the far edge of the galaxy's visible disk
- In the halo of the galaxy

The disk is about 100,000 light-years in diameter, which means about 50,000 light-years in radius. Therefore, the Sun's distance of about 28,000 light-years from the galactic center puts it a little over halfway out through the disk.

Part J
If we imagine the history of the universe compressed into one year, dinosaurs became extinct _________.

Hint J.1
Study the cosmic calendar in Section 1.2 of The Essential Cosmic Perspective in your textbook, and remember that the universe is about 14 billion years old in real time.

ANSWER:
- about an hour ago
- yesterday morning
- about 3 weeks ago
- about 6 months ago

Dinosaurs went extinct only about 65 million years ago in real time - which is indeed yesterday morning on a cosmic calendar that compresses the 14-billion-year history of the universe into one year.

Part K
Relative to the age of the universe, how old is our solar system?

Hint K.1
You can find the ages of the solar system and universe in Section 1.2 of The Essential Cosmic Perspective in your textbook.

ANSWER:
- It is about one-third the age of the universe.
- It is between about 5% and 10% as old as the universe.
- It is nearly the same age as the universe.
- It is about 1% as old as the universe.
The universe is about 14 billion years old and the solar system about 4.5 billion years ago, and 4.5 billion years is about one-third of 14 billion years.

Part L
How do the speeds at which we are moving with Earth's rotation and orbit compare to the speeds of more familiar objects?

Hint L.1
See Section 1.3 of The Essential Cosmic Perspective in your textbook.

ANSWER:
- Earth's rotation carries most people around the axis at about the speed of a commercial jet, and Earth's orbit carries us around the Sun at about the speed of a military jet.
- Earth's rotation carries most people around the axis at about the speed at which the Space Shuttle orbits Earth, and Earth's orbit carries us around the Sun at nearly the speed of light.
- Earth's rotation carries most people around the axis faster than a commercial jet travels, and Earth’s orbit carries us around the Sun faster than the Space Shuttle orbits Earth.
- Earth's rotation carries most people around the axis at about the speed of a car on the freeway, and Earth’s orbit carries us around the Sun at about the speed of a commercial jet.

It may seem surprising, but the speeds are indeed this high.

Part M
Why do the patterns of the stars in our sky look the same from year to year?

Hint M.1
Study Section 1.3 of The Essential Cosmic Perspective in your textbook.

ANSWER:
- Because the stars in the constellations are not moving.
- Because the stars in the constellations all move at the same speeds and in the same directions, so they don't change their relative positions.
- Because the stars in the constellations move so slowly — typically about the speed of a snail — that their motions are not noticeable.
- Because the stars in the constellations are so far away.

Although nearby stars move relative to us at typical speeds of tens to hundreds of thousands of kilometers per hour, they are so far away that it would take thousands of years for their motion to be noticeable to the eye.

Part N
Astronomers infer that the universe is expanding because distant galaxies all appear to _________.

Hint N.1
Study the raisin cake analogy to the universe in Section 1.3 of *The Essential Cosmic Perspective* in your textbook.

**ANSWER:**
- be made mostly of dark matter
- rotate rapidly
- be growing in size
- be moving away from us, with more distant ones moving faster

This was Hubble’s great discovery, from which we conclude that the universe must be expanding. If the idea is not completely clear to you, review the raisin cake analogy to the universe in Section 1.3 of *The Essential Cosmic Perspective* in your textbook.

**Part O**

Which statement about motion in the universe is *not* true?

**Hint O.1**
See Section 1.3 of *The Essential Cosmic Perspective* in your textbook.

**ANSWER:**
- The mysterious *dark matter* is the fastest-moving material in the universe.
- Except for a few nearby galaxies, all other galaxies are moving away from us.
- Some stars in the Milky Way Galaxy are moving toward us and others are moving away from us.
- Your speed of rotation around Earth’s axis is faster if you live near the equator than if you live near the North Pole.

This is the correct answer because the statement is *not* true. In fact, dark matter is thought to reside galaxies and clusters of galaxies, and hence moves with these galaxies and clusters; it does not move faster than them.

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**Chapter 01: Reading Quiz**

**Description:** (a) Which of the following is a general difference between a planet and a star? not... (b) Our solar system consists of _______. (c) A typical galaxy is a _______. (d) Which of the following best describes what we mean by the *universe...*

**Part A**

Which of the following is *not* a general difference between a planet and a star?

**Hint A.1**
Review the box with definitions of Basic Astronomical Objects in Section 1.1 of *The Essential Cosmic Perspective* in your textbook.

**ANSWER:**
- Planets are dimmer than stars.
- Planets orbit stars, while stars orbit the center of the galaxy.
Planets are smaller than stars.

- All planets are made of rock and all stars are made of gas.

Planets are not necessarily made of rock; they may be rocky, icy, or gaseous in composition.

Part B

Our solar system consists of _________.

Hint B.1

Review the definition of our solar system in Section 1.1 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:

- a few hundred billion stars, bound together by gravity
- the Sun and several nearby stars, as well as the planets and other objects that orbit these stars
- the Sun and the planets, and nothing else
- the Sun and all the objects that orbit it

The objects orbiting the Sun include the planets and their moons and countless small objects that include rocky asteroids and icy comets.

Part C

A typical galaxy is a _________.

Hint C.1

Review the definition of a galaxy in Section 1.1 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:

- relatively small, icy object orbiting a star
- large, glowing ball of gas powered by nuclear energy
- system consisting of one or a few stars orbited by planets, moons, and smaller objects
- nearby object orbiting a planet
- collection of a few hundred million to a trillion or more stars, bound together by gravity

Our own Milky Way Galaxy is relatively large, containing more than 100 billion stars.

Part D

Which of the following best describes what we mean by the universe?

Hint D.1

The term universe is discussed in Section 1.1 of *The Essential Cosmic Perspective* in your textbook.
The universe is another name for our Milky Way Galaxy.
The sum total of all matter and energy
A vast collection of stars that number as many as the grains of sand on all the beaches on Earth
All the galaxies in all the superclusters

In other words, the universe consists of all the galaxies and everything within and between them.

Part E
What do astronomers mean by the Big Bang?

Hint E.1
The basic idea of the Big Bang is discussed in Section 1.1 of The Essential Cosmic Perspective in your textbook.

ANSWER:
The event that marked the beginning of the expansion of the universe
The explosion of a massive star at the end of its life
The event that marked the birth of our solar system
A gigantic explosion that blew all the galaxies in the universe to smithereens

Based on careful study of the current expansion of the universe (and of the cosmic microwave background, which we'll discuss later in the book), the Big Bang occurred about 14 billion years ago.

Part F
What do we mean when we say that the universe is expanding?

Hint F.1
The basic idea of expansion is introduced in Section 1. of The Essential Cosmic Perspective; see also the raisin cake analogy for expansion in Section 1.3.

ANSWER:
Within galaxies, average distances between star systems are increasing with time.
Average distances between galaxies are increasing with time.
Everything in the universe is gradually growing in size.
The statement is not meant to be literal; rather, it means that our knowledge of the universe is growing.

Note that while distances between galaxies are increasing (on average), galaxies themselves are not expanding because they are held together by gravity. (Many clusters of galaxies are also held together by gravity and hence not expanding, which is why we say that average distances between galaxies are increasing with time.)

Part G
Based on observations of the universal expansion, the age of the universe is about _________.

http://session.masteringastronomy.com/myct/assignments?courseID=1012411
Hint G.1
Review the discussion of the Big Bang and expansion in Section 1.1 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:
- 14 trillion years
- 14 billion years
- 14,000 years
- 14 million years

In other words, current evidence suggests that the universe was born in the Big Bang about 14 billion years ago.

Part H
A television advertisement claiming that a product is light-years ahead of its time does not make sense because ________.

Hint H.1
Study Section 1.1 of *The Essential Cosmic Perspective* in your textbook, and remember that a light-year is about 10 trillion kilometers.

ANSWER:
- it doesn't specify the number of light-years
- light-years can only be used to talk about light
- a light-year is an astronomically large unit, so a product could not possibly be so advanced
- it uses "light-years" to talk about time, but a light-year is a unit of distance

You can see how the advertisement fails by remembering that a light-year is about 10 trillion kilometers or 6 trillion miles. The ad therefore implies that the product is "6 trillion miles ahead of its time," which clearly does not make sense.

Part I
The term *observable universe* refers to ________.

Hint I.1
The distinction between the observable universe and the entire universe is discussed in Section 1.1 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:
- that portion of the universe that we have so far photographed through telescopes
- the portion of the universe that can be seen by the naked eye
- that portion of the universe that we can see *in principle*, given the current age of the universe
- the portion of the universe that is not hidden from view by, for example, being below the horizon
The age of the universe limits how far we can see. For example, in a universe that is 14 billion years old, we cannot see objects located 15 billion light-years away, because their light has not yet had time enough to reach us.

Part J

On a scale in which the distance from Earth to the Sun is about 15 meters, the distance from Earth to the Moon is _________.

Hint J.1

This question makes use of the 1-to-10 billion scale from the Voyage model solar system described in Section 1.2 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:

- about 5 meters
- about 30 meters
- about 1 meter
- small enough to fit within your hand

Using a scale of 1 to 10 billion, Earth is about the size of a ballpoint and located about 15 meters from a grapefruit-size Sun, while the Moon (about one quarter the size of Earth) is a mere 4 centimeters (about an inch and a half) from Earth.

Part K

On a scale where the Sun is about the size of a grapefruit and the Earth is about 15 meters away, how far away are the nearest stars besides the Sun?

Hint K.1

This question makes use of the 1-to-10 billion scale from the Voyage model solar system described in Section 1.2 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:

- About the distance across the United States
- About the distance across 50 football fields
- About the distance across the state of Delaware
- 100 meters

Using a scale of 1 to 10 billion, on which Earth is about the size of a ballpoint and located about 15 meters from a grapefruit-size Sun, the distance to the nearest stars is more than 4,000 kilometers (about 2,500 miles).

Part L

The number of stars in the Milky Way Galaxy is approximately _________.

Hint L.1

You'll find the answer in both Sections 1.1 and 1.2 of *The Essential Cosmic Perspective*, and a discussion of the meaning of the answer in Section 1.2.
We generally say that there are more than 100 billion stars in the Milky Way Galaxy; we do not have a precise count, but the actual number is probably a few hundred billion.

Part M
An astronomical unit (AU) is _________.

Hint M.1
See Section 1.3 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:

- the average distance between any planet and the Sun
- any very large unit, such as a light-year
- the current distance between Earth and the Sun
- the average distance between Earth and the Sun

This distance is about 150 million kilometers. (More precisely, it is 149.6 million kilometers.)

Part N
What is the ecliptic plane?

Hint N.1
See Section 1.3 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:

- The plane of the Milky Way Galaxy
- The plane of Earth's equator
- The plane of Earth's orbit around the Sun
- The plane of the Sun's equator

All of the other planets orbit close to, but not exactly in, the ecliptic plane.

Part O
How long does it take the Earth to complete one orbit around the Sun?

Hint O.1
If you are unsure of the answer, you'll find it in Section 1.3 of *The Essential Cosmic Perspective* in your textbook.

ANSWER:

- One week
The time it takes Earth to orbit the Sun changes significantly from one orbit to the next.

Earth completes one orbit of the Sun each year.

Chapter 01: Visual Quiz

Description: (a) Each box in this figure represents a different level of structure in our universe. Each box is labeled with one of the numbers 1-5. Which box represents the Milky Way Galaxy? (b) What does this photograph show? (c) This painting represents the ...
You'll find this figure in Chapter 1 of *The Essential Cosmic Perspective*.

**ANSWER:**
1
2
3
4
5

Notice the clear disk and spiral structure of our Milky Way Galaxy.

**Part B**

What does this photograph show?

![Photograph of a galaxy]

**Hint B.1**

You'll find this photo in Chapter 1 of *The Essential Cosmic Perspective*.

**ANSWER:**
- It is a picture of our own Milky Way Galaxy.
- It is a picture of a young star in the process of being born.
- It is a picture of our own solar system.
- It is a picture of a cloud of gas known as the Orion Nebula.
- It is a picture of the Andromeda galaxy, located about 2.5 million light-years away.

Therefore, the light from this galaxy has traveled through space for about 2.5 million years to reach us.

**Part C**

This painting represents the Sun and planets of our solar system. What is NOT to scale in this painting?
Hint C.1
You'll find this figure in Chapter 1 of *The Essential Cosmic Perspective*.

**ANSWER:**

- The sizes of the planets are not correctly scaled compared to each other or the Sun.
- Neither distances nor sizes are correctly scaled.
- The distances between the planets are not shown to scale.
- Everything is correctly scaled, but the planets are shown in the wrong order from the Sun.
- The Sun is too big compared to the planets.

To see the distances shown correctly, study the Voyage scale model solar system described in Chapter 1 of *The Essential Cosmic Perspective*.

Part D

What is the significance of this photograph?

Hint D.1
You'll find this photo in Chapter 1 of *The Essential Cosmic Perspective*.

**ANSWER:**

- It was taken Jan. 1, 2000 to commemorate the turn of the millennium.
- It shows the first person ever to go into space.
- It shows a person standing on the most distant world ever visited by a human being.
- It shows the first person ever to land on Mars.

The photo shows astronaut Buzz Aldrin on the Moon in July, 1969. The Moon is the only other world yet visited by human beings.

Part E
Suppose we made a scale model of our Milky Way Galaxy in which the disk of the galaxy is the size of a football field. Which (if any) diagram below represents the Sun on the same scale?

**Hint E.1**

Study the scale of the universe in Section 1.2 of *The Essential Cosmic Perspective*. Also note that because a football field is about 100 meters long and our galaxy is about 100,000 light-years in diameter, scaling the galaxy to a football field means that 1 meter represents about 1,000 light-years, so 1 millimeter in your textbook represents 1 light-year, or about 10 trillion kilometers.

**ANSWER:**

- The Sun on this scale would be microscopic and too small to see on the screen.
- The Sun on this scale would be about 2 feet in diameter and too big to show on the screen.

Because a football field is about 100 meters long and our galaxy is about 100,000 light-years in diameter, scaling the galaxy to a football field means that 1 meter represents about 1,000 light-years, so 1 millimeter represents 1 light-year, or about 10 trillion (10\(^{13}\)) kilometers. The Sun's diameter of a little over 1 million (10\(^{6}\)) kilometers, therefore is only 1 ten millionth of a millimeter on this scale — which is about the size of a single atom!

**Part F**

These photos show two different astronomical objects. Which object is bigger, and by about how much?

**Hint F.1**

First figure out what types of objects the two photos show, then decide which is larger and by how much; it may help you to look at the scale factors given in Figure 1.1 in the textbook of *The Essential Cosmic Perspective*.
**ANSWER:**
- Object 2 is more than a trillion times as large as Object 1.
- Object 2 is approximately 1,000 times as large as Object 1.
- Object 1 is about 10 times as large as Object 2.
- Object 2 is about 10 times as large as Object 1.
- Both objects are about the same size.

Object 1 is the planet Saturn and Object 2 is an entire galaxy, and the diameter of a galaxy is indeed more than a trillion times the diameter of a planet like Saturn.

**Part G**

This diagram represents Earth's rotation and orbit. What do we call the flat blue plane shown in this diagram?

- the galactic plane
- Earth's axis
- the ecliptic plane
- an Astronomical Unit
- the solar plane

Notice that the ecliptic plane is the plane defined by Earth's orbit around the Sun.

**Part H**

Notice that Earth's axis is shown with an arrowhead in this diagram. What does the arrow point to?

(http://session.masteringastronomy.com/myct/assignments?courseID=1012411)
Hint H.1
You'll find this figure in Chapter 1 of *The Essential Cosmic Perspective*.

**ANSWER:**
- the Northern lights
- the Sun
- Polaris, the North Star
- the ecliptic plane
- the center of the Milky Way Galaxy

Indeed, Polaris is the North Star *because* Earth's rotation axis points very close to it.

### Part I

These diagrams show a raisin cake before it is put in the oven and again one hour later after it has expanded during baking. Suppose you lived in Raisin 3 (the raisin labeled "3"). What would you have noticed about Raisin 2 during baking?

**Hint I.1**
You'll find this figure in Chapter 1 of *The Essential Cosmic Perspective*.

**ANSWER:**
- Raisin 2 is moving away from you at a speed of 2 cm/hr.
- Raisin 2 is moving toward you at a speed of 2 cm/hr.
- Raisin 2 always stays in the same place, but gets bigger in size.
- Raisin 2 is moving away from you at a speed of 4 cm/hr.
- Raisin 2 is moving away from you at a speed of 6 cm/hr.

Notice that Raisin 2 begins 1 cm away from Raisin 3 and ends 3 cm away from Raisin 3. It therefore appears to move 2 cm from Raisin 3 during the hour, so someone on Raisin 3 will see Raisin 2 moving at 2 cm/hr.

### Part J
Nearly all of the objects that you can see in this photograph are:

**Hint J.1**

You'll find this photo, taken by the Hubble Space Telescope, on the opening page of Chapter 1 of *The Essential Cosmic Perspective*; look carefully at the structures in the photo to decide what they are.

**ANSWER:**

- stars
- planets
- galaxies
- Astronomical units

This photo is a portion of the Hubble Ultra Deep Field, which shows galaxies in one tiny region of the sky. Almost all the object in this photo are galaxies.

**Score Summary:**

Your score on this assignment is 0%.
You received 0 out of a possible total of 40 points.