CHAPTER 2 THE WATER PLANET

Objectives

1. To acquire an appreciation for the physical and chemical processes that led to the formation of the solar system and the location of Earth in this system.
2. To understand the difference between time, as judged in human perspectives and the concept of deep time, or geologic time, along with a better perspective of the antiquity of Earth.
3. To become acquainted with the shape and size of Earth.
4. To learn how one might accurately divide the surface of our planet into a grid system for location and precise navigation.
5. To familiarize ourselves with the properties of our planet, and the existence of free surface water.

Key Concepts

Major Concept (I)

Observational data have provided increasing evidence that the universe originated about 13.7 billion years ago in an event called the Big Bang.

Related or supporting concepts:

- Our current understanding of the universe comes from many different types of observations using instruments that detect different wavelengths of energy across the electromagnetic spectrum.
- Scientists believe that all matter and energy in the universe was originally concentrated in an extremely hot, dense singularity smaller than an atom.
- The universe is thought to have originated in a cataclysmic explosion of this singularity, commonly called the Big Bang, roughly 13.7 billion years ago.
- One second after the Big Bang the temperature of the universe was roughly 10 billion K (room temperature is about 300 K). The universe consisted mostly of elementary particles, light, and other forms of radiation that were too energetic to combine into atoms.
- One hundred seconds after the Big Bang the temperature had cooled to about 1 billion K and the nuclei of hydrogen, deuterium, helium, and lithium began to form.
- Eventually, when the temperature had dropped to a few thousands of degrees K, electrons and nuclei started to combine to form atoms.
- The universe has a distinct structure:
    a. On a scale there are individual stars.
    b. Galaxies are composed of clumps of stars.
    c. Galaxies are preferentially found in groups called clusters.
    d. Individual clusters tend to group in long, string-like or wall-like structures called superclusters.
- Astronomical distances are typically measured in light-years, the distance light travels in one year. A light year is equal to 9.46×10^{12} km (5.87×10^{12} mi).
- Our Sun is one of about 200 billion that comprise the Milky Way galaxy.
- The Milky Way is shaped like a flattened disk 1000 light-years thick and 100,000 light-years in diameter.
- There are probably between 10 and 100 billion galaxies in the universe.
- A single cluster may contain thousand of galaxies and have dimensions of 1 to 30 million light-years.
- The largest superclusters can contain tens of thousands of galaxies and may be as much as 500 million light-years across.

Major Concept (II)

There is strong evidence that there may be extraterrestrial oceans in our solar system.

Related or supporting concepts:

- Two of Jupiter's moons, Europa and Callisto, may have oceans beneath their ice covered surfaces.
- Heat generated by tidal friction due to Jupiter's strong tidal force may make liquid oceans on Europa and Callisto possible.
- Magnetic measurements made by the Galileo spacecraft indicate that both Europa and Callisto consist partly of strongly conducting material (such as water with a high concentration of dissolved ions).
- Europa's water may have a high concentration of magnesium sulfate.
- A proposed model for Europa includes a surface ice layer 15 km (10 mi) thick covering a 100 km (62 mi) deep ocean.
- A proposed model for Callisto includes a surface ice layer 100 km (62 mi) thick covering a shallow 10 km (6.2 mi) deep ocean.
- Mars may have once had an ocean covering parts of its northern hemisphere.
- Our current understanding of the universe comes from many different types of observations using instruments that detect different wavelengths of energy across the electromagnetic spectrum.

Major Concept (III)

Modern theories attribute the beginning of our solar system to the collapse of a rotating interstellar cloud of gas and dust about 4.6 billion years ago.

Related or supporting concepts:

- The first stars were composed of hydrogen. Atomic fusion in the stars produced helium. Continued atomic reactions in these stars produced the other elements.
- Gravitational collapse of the rotating interstellar cloud, or nebula, that led to the formation of our solar system produced our Sun, nine planets and numerous satellites.
- This rotation may have started from a shock wave due to a nearby exploding star or supernova.
- The nine planets can be subdivided into two groups as a result of the temperature and gravitational distributions away from the Sun. These two groups are the four inner terrestrial planets rich in metals and rocky materials (heavy elements) and the five outer planets composed mostly of frozen gases (light elements).

Major Concept (IV)

Earth formed originally from cold matter but events occurred that raised Earth’s temperature and started processes that erased its earliest history and resulted in its present form.

Related or supporting concepts:

- Heat was generated by the following processes: the collision of particles, the increase in internal pressure caused by collapse and compression of these particles, and through the decay of radioactive elements.
- Heating led to differentiation of Earth and the migration of molten iron and nickel downwards to form the core and lighter elements upwards where they could solidify and form the crust.
- Earth’s oceans and atmosphere are probably both by-products of this heating and differentiation.
- The early atmosphere was very different from our present atmosphere and probably contained very little free oxygen.

Major Concept (V)

The age of Earth is thought to be between 4.5 and 4.6 billion years.

Related or supporting concepts:

- Early estimates of the age of Earth include:
    a. In the 17th century Archbishop Ussher of Ireland calculated the beginning of Earth to be 9:00 A.M., October 26, 4004 B.C. by counting the generations in the Bible,

   b. In 1897, the physicist Lord Kelvin dated Earth at 20–40 million years based on the cooling rate of magma, and
   c. In 1899, the physicist John Joly dated Earth at 100 million years based on the time it would take rivers to bring enough salt to the ocean to give it its present salinity.
- Radioactive isotopes will decay to form different isotopes at a predictable rate. The time it takes for half of the atoms of an isotope to decay from one element to another is known as its half-life. The half-life of each isotope is characteristic and constant.
- The constant decay rates of radioactive elements of materials such as uranium or thorium provide a relatively accurate means of dating even very long stretches of geologic time.
- The ages obtained from different decay series can be checked and compared with one another to give scientists more confidence about the ages.
- In 1905, Ernest Rutherford and Bertrum Boltwood used radioactive decay to date rock and mineral samples 500 million years old.
- In 1907, Boltwood calculated an age of 1.64 billion years for a mineral sample rich in uranium.
- Processes on Earth have been active since the beginning and have radically altered the surface so that the original surface rocks no longer exist. The oldest minerals that have been found on Earth are between 4.1 and 4.2 billion years old, providing a minimum age for Earth.
- The accepted age of Earth is based on dating objects, such as meteorites, in the solar system believed to have formed at the same time as the planets but are not geologically active. Several dating methods on multiple meteorites have resulted in ages of about 4.5 billion years.

Major Concept (VI)

Geological time is often difficult to grasp because of how long it is compared to all of human history (to say nothing of the incredibly brief time span of a single human life).

Related or supporting concepts:

- The subdivision of geological time and the record of important events is called the Geologic Time Scale. This is outlined in table 2.2 in the text.
- Just as we divide time into segments like years, months, and days to identify both duration and some sense of position, we divide geologic time as well. The longest division is called an eon. Eons are divided into eras, eras are divided into periods, and periods into epochs.
- The eras, in order of most distant past to most recent time, are:
   a. Precambrian,
   b. Paleozoic (ancient life),
   c. Mesozoic (middle life, or the Age of Reptiles), and
   d. Cenozoic (recent life, or the Age of Mammals).
- The divisions of geologic time were originally decided upon on the basis of the appearance and disappearance of specific fossils.
- The development of radiometric dating techniques allowed geologists to assign absolute dates to the different time divisions.
- An atom of a radioactive isotope has an unstable nucleus that decays and emits one or more particles plus energy.
- The time over which one-half of the atoms of a radioactive isotope decay is known as the isotope's half-life. The half-life of a particular isotope is constant and characteristic of that isotope.
- Because of the difficulty we typically have in comprehending time spans as great as billions of years, it is often easier to imagine that Earth is much younger, say tens of years old, and then consider what major events occurred in that period of time. Suppose, for example, that rather than Earth being 4.6 billion years old, it is only 46 years old. Then we can recognize the following important events in this order:
   a. 46 years ago Earth formed
   b. The first 3 years of the planet's history have not been preserved in the record.
   c. The earliest history is preserved in rocks found in Canada, Africa and Greenland that formed 43 years ago.
   d. Sometime between 35 and 38 years ago the first primitive living cells of bacteria appeared.

e. 23 years ago (half the age of the planet) photosynthesis began producing oxygen. Most of this oxygen combined with iron in the early oceans and did not enter the atmosphere.
f. 15 years ago enough oxygen had accumulated in the atmosphere to allow the growth of complex cells that require oxygen. It took about 11 years more for oxygen to reach its present concentration in the atmosphere.
g. 7 years ago the first invertebrates (animals without backbones) appeared.
h. 5 years ago the first vertebrates (animals with backbones), primitive fish, and corals appeared.
i. 3 years 8.5 months ago the first sharks swam in the oceans.
j. 3 years 3.5 months ago reptiles could be found on land.
k. 2 years 6 months ago a massive extinction killed 96% of all life.
l. 2 years 3 months 10 days ago the dinosaurs appeared.
m. 2 years 2 months 15 days ago the first mammals developed.
n. roughly 2 years ago a second extinction killed over half of the species on Earth, leaving mostly dinosaurs on land.
o. 18.5 months ago birds first flew in the air.
p. about 14 months ago the first flowering plants appeared.
q. 237 days ago a third major extinction killed off the dinosaurs and many other species.
r. 211 days ago the mammals, birds, and insects are the dominant land animals.
s. a little less than 6 days ago our first human ancestors appeared.
t. about 30 minutes ago modern humans began recorded civilization.
u. 1 minute ago the Industrial Revolution began.

Major Concept (VII) *Natural time periods are produced by the rotation of Earth on an inclined axis in its orbit around the Sun.*

Related or supporting concepts:

- A year is the time required for Earth to complete one orbit around the Sun. This is 365.25 days.
- Seasonal changes are caused by the tilt of Earth's rotational axis 23.5 degrees from the vertical. When the Earth is at its furthest point from the Sun, the Northern Hemisphere is tilted towards the Sun and it experiences summer, while the Southern Hemisphere is in winter. Conversely, at its closest approach to the Sun, the Southern Hemisphere is tilted towards the Sun and is in summer while the Northern Hemisphere is in winter.
- The length of day and night changes throughout the year.
- The longest daylight period in the Northern Hemisphere occurs on the summer solstice when the Sun reaches its maximum height in the sky at 23.5 degrees above the equator at the Tropic of Cancer. This happens on or about June 22. On this day the Sun never sets above the Arctic Circle and it never rises above the Antarctic Circle.
- The days have equal period of sunlight and darkness when the Sun is directly above the equator. This happens on the autumnal equinox, on or about September 23, and the vernal equinox, on or about March 21.
- The shortest length of daylight occurs at the winter solstice when the Sun is 23.5 degrees below the equator at the Tropic of Capricorn. This happens on or about December 21. The Sun does not rise during the day above the Arctic Circle and it never sets during the day above the Antarctic Circle.
- These natural cycles, or seasons, are illustrated in figure 2.6.
- All living organisms respond to these natural cycles.

Major Concept (VIII) *The rotation of Earth, together with gravitational forces have shaped it into an oblate spheroid, flattened at the poles and bulging at the equator.*

Related or supporting concepts:

- The average radius of Earth is 6371 km (3959 mi). The polar radius is 6357 km (3950 mi) and the equatorial radius is 6378 km (3963 mi); see figure 2.7.
- This slight deformation indicates that the Earth is not rigid but responds in more of a plastic manner to

large, long-term forces.
- The unequal distribution of continents and oceans makes Earth slightly pear-shaped.
- From our perspective there are large changes in elevation from the tallest mountains to the deepest ocean. These changes are actually very small compared to the size of Earth. Consequently, the surface of Earth is really quite smooth, similar to a basketball or an orange if it were scaled down to that size.

Major Concept (IX) *In order to locate ourselves on the surface of a sphere we need a reference (or location) system.*

Related or supporting concepts:
- A grid of reference lines on Earth's surface allows us to accurately determine our position relative to these lines. These reference lines define two numbers called latitude and longitude that uniquely specify a given point.
- Lines of latitude are termed parallels because they are parallel to the equator and to each other. Latitude is an angular measure of how far a point is either north or south of the equator.
- Latitude varies from +90° at the North Pole to 0° at the equator to -90° at the South Pole.
- Parallels form circles of decreasing radius with increasing distance from the equator (see fig. 2.8).
- Lines of longitude are called meridians and are formed by constructing great circles around the globe that pass through both poles and are perpendicular to the equator (see fig. 2.9). Longitude is an angular measure of how far a point is either east or west of the zero degree meridian that passes through Greenwich, England (known as the prime meridian).
- Longitude may be measured all the way around the globe starting at the prime meridian and traveling east (in which case longitude varies from 0° to 360°), or it may be measured from the prime meridian to half way around Earth both east and west (in which case it varies from 0° to -180° west and 0° to +180° east). Note that -180° west and +180° east are the same meridian and 0° to 360° are both the prime meridian.
- The international date line corresponds roughly with the 180 degree longitude meridian.

Major Concept (X) *Charts and maps are used to show Earth's three-dimensional surface on a flat, or two-dimensional, surface.*

Related or supporting concepts:
- Any chart or map results in some amount of distortion of Earth's true surface. The trick is to choose the type of map that gives the least distortion for the specific purpose you have in mind.
- Maps are made by projecting the features of Earth onto some type of surface, generally either a cylinder, a cone, or a plane tangent to the surface of Earth at some point. You can see each of these cases in figure 2.11.
- Maps that show lines of equal elevation or depth are referred to as contour maps. Contour maps of the ocean floor are bathymetric maps, while contour maps of land regions are topographic maps.
- Color or shading can be added to illustrate topographic changes. These are called physiographic maps.

Major Concept (XI) *Latitude and longitude have historically been measured in two different ways. Latitude is determined by astronomical measurements while longitude requires an accurate knowledge of time.*

Related or supporting concepts:
- Latitude is equivalent to the angle of elevation above the horizon of the North Star, Polaris, in the Northern Hemisphere or the constellation, the Southern Cross, in the Southern Hemisphere.
- Earth rotates completely through 360 degrees relative to the Sun every 24 hours on the average. This is the same as a rotation of 15 degrees of longitude per hour (see fig. 2.16). Consequently, we can convert differences in time between two locations on Earth to the equivalent differences in longitude.

To calculate the longitude of some location we need to know the difference between local time at that spot and the time at Greenwich, England (also known as Zulu, Greenwich Mean, or Universal Time). In the past this was accomplished by bringing along a clock set to Greenwich Mean Time that could be compared to local time. Local time could always be determined accurately by waiting for the Sun to reach its highest point in the sky, at which time it would be local noon.

- Earth's surface is divided into 24 time zones that are generally 15 degrees longitude wide (see fig. 2.17).

Major Concept (XII) *Modern navigational techniques use electronic aids that include radar, radio broadcast, and satellite methods. These allow us to determine position in any kind of weather and at any time of day with tremendous accuracy.*

Related or supporting concepts:

- There are three principal systems used in modern navigation:
    a. radar : "**ra**dio **d**etecting **a**nd **r**anging,"
    b. loran : "**lo**ng-**ra**nge **n**avigation," and
    c. satellite navigation : GPS or "**G**lobal **P**ositioning **S**ystem"
- Radar systems emit bursts of energy that travel outward and then return after reflecting off distant objects. By carefully measuring the travel time of the reflected energy you can determine distance quite accurately. Radar is only useful when you are close enough to land for signals to be reflected back to the vessel.
- Loran systems utilized fixed stations that transmit radio waves at specific frequencies. A loran receiver on board a ship can detect these transmissions. The difference in arrival time of the signals from pairs of stations is a measure of distance from the stations. Unlike radar, loran can be used far from land as long as the vessel is within receiving distance of loran stations. In addition, loran units can be interfaced with computers to automatically calculate latitude and longitude and to determine the ship's course to some pre-determined location.
- The most accurate location system is the U.S. Navstar Global Positioning System (GPS). A series of satellites broadcast radio signals that will allow GPS receivers to be located in three dimensions within a few meters using commercial receivers and a few centimeters using military receivers (fig. 2.18).
- GPS navigation permits the determination of accurate location in any kind of weather and any time of day.

Major Concept (XIII) *Earth is unique among the planets because its surface temperature and composition allow water to exist as a gas, liquid, and solid.*

Related or supporting concepts:

- Water can exist in all three phases on Earth because of the moderate, and nearly constant, temperature of the surface.
- The stable, moderate temperature of the surface is due to the nearly circular orbit of Earth around the Sun and the rotation of the planet.
- 71% of Earth's surface is covered by oceanic water while the remaining 29% is dry land.
- If Earth was a perfectly smooth ball the oceans would cover the globe to a depth of 2646 meters (ocean sphere depth). Adding all of the remaining water from the land and the atmosphere would increase this depth by 75 meters to 2721 meters (total water sphere depth).
- Nearly all of the water on the planet (approximately 97%) is either ocean water or sea ice. Look over table 2.3.

Major Concept (XIV) *The constant movement of water from one reservoir to another is referred to as the hydrologic cycle (fig. 2.19).*

Related or supporting concepts:

- A reservoir is simply a location where water can be stored, such as the oceans, lakes and rivers, in the ground, glaciers, and the atmosphere.

- While water is constantly entering and leaving each different type of reservoir, there is a net removal of ocean water by evaporation to the atmosphere, a net gain of water on land by precipitation from the atmosphere, and an eventual return of water to the oceans by runoff and groundwater flow.
- Water is also released to the atmosphere by plants in a process called transpiration and ice can be converted directly to water vapor in a process called sublimation.
- The average time that water spends in any one reservoir is called the residence time of that reservoir. Reservoirs that hold large volumes of water, like the oceans, have residence times that are measured in thousands of years while reservoirs that hold small amounts of water have residence times that may be measured in days or weeks. This concept of residence time is critical in our management of water supplies.

Major Concept (XV) *Land and water are not uniformly distributed on Earth's surface.*

Related or supporting concepts:

- About 70% of the landmasses are located in the Northern Hemisphere. The Southern Hemisphere is primarily covered with water (see fig. 2.21).
- There is only one band of latitude on the globe in which there is more land than water. This occurs between 45°N and 70°N (see fig. 2.22).
- Earth's seawater is divided into four oceans (three major ocean basins, the Pacific, the Atlantic, and the Indian; and a fourth small ocean, the Arctic) and a number of smaller adjacent seas (see table 2.4 and fig. 2.23).
- The Pacific has the largest surface area, volume, and greatest mean depth.
- The Atlantic is the shallowest of the three major oceans and has the largest number of adjacent shallow seas.
- The Indian Ocean has the smallest surface area but its mean depth is nearly as great as that of the Pacific.
- The Arctic is the smallest and shallowest of the four oceans.
- Another way of looking at the global distribution of land elevations and oceanic depths is to construct a hypsographic curve, a graph of depth or elevation versus surface area. In looking at the hypsographic curve given in figure 2.24 you may note that roughly 80% of the land surface is below an elevation of 2000 meters, while 80% of the sea floor is at a depth greater than 2000 meters.
- Small changes in sea level can have a large effect on the relative surface areas of land and water.

Matching Key Terms with Major Concepts

At the end of the chapter in the textbook is a list of key terms. You should be able to match each of these with one of the previously listed major concepts. To test your ability, try to match the following key terms with the number (I–XV) of the appropriate major concept identified in this section:

galaxy	electromagnetic spectrum	cluster
light-year	supercluster	nebula
solar system	heavy elements	light elements
differentiation	heating	isotope
half-life	era	period
epoch	Tropic of Cancer	solstice
equinox	oblate spheroid	deformable
latitude	longitude	projection
contour	Greenwich Mean Time	Zulu time
chronometer	radar	loran
sphere depth	hydrologic cycle	residence time
hypsographic curve	radiometric dating	great circle
topography	bathymetry	zenith

Test Your Recall

Answer the following questions to test your understanding

FILL IN THE BLANK

1. The four planets closest to the Sun are smaller in ________________________ and _______________ .
2. Heating and differentiation in the early Earth led to the migration of molten iron and nickel _____________________ to form the __________________.
3. The time over which one-half of the atoms of an ____________________ will decay from one element to another is called its ____________________________.
4. The principal subdivisions of geologic time are the __________________.
5. Earth is ________________________ on its axis of rotation.
6. The rotation of Earth causes it to bulge at the _________________________.
7. Lines of latitude are called _________________________ and lines of longitude are called _________________________.
8. Charts showing ocean depths are called ___________________________ maps.
9. The rotation of Earth allows us to use differences in ___________________ to measure longitude.
10. The constant movement of water through a number of different reservoirs is called the ___________________________ cycle.
11. The Sun and its nine planets are called the ___________________ _____________________.
12. An _____________________ of a radioactive isotope has an unstable nucleus.
13. The ___________________________ of each isotope is characteristic and constant.
14. The record of events in the history of Earth used by geologists is called the ___________________________ ___________________ scale.
15. The longest period of daylight, and the beginning of summer in the Northern Hemisphere, is called the __________________________ _______________________.
16. To determine our position on a curved Earth we use a __________________ of reference lines.
17. The ____________________ degree longitude line is known as the prime meridian.
18. Lines connecting points of similar elevation are called ________________________ lines.
19. To estimate latitude, early navigators measured the elevation of the ____________________ ____________________ above the horizon.
20. Earth is unique in our solar system as it has _______________ ___________________ on its surface.

TRUE - FALSE

1. The planets all have approximately the same chemical composition since they formed from a single original gas cloud.
2. Heating of the planet has removed any record of the earliest history of the solid Earth.
3. The rotational axis of Earth is perpendicular to the plane of its orbit around the Sun.
4. Earth is deformed as a result of its rotation so it bulges at the poles and is flattened at the equator.
5. Contour lines on maps trace lines of equal elevation or depth.
6. You can determine your latitude by looking at the stars.

7. Roughly half of the surface of Earth is covered with water.
8. Residence times of water in different reservoirs can vary depending on the size of the reservoir.
9. Most of the land on Earth is in the Northern Hemisphere.
10. Small changes in the average depth of the oceans can result in large changes in the relative amount of land and water on the surface.
11. Our solar system is thought to be about 4.6 billion years old.
12. The planets closest to the Sun are generally smaller than those further away.
13. Earth's oceans and atmosphere probably formed from light gases and water trapped from an initial dust cloud by gravitational attraction.
14. The principal divisions of geologic time are the epochs.
15. Earth is an active planet and its original surface rocks no longer exist.
16. Earth completes one orbit around the Sun in exactly 365 days, hence the length of one year.
17. The Sun stands directly above the equator twice each year.
18. Despite the height of mountains and the depth of ocean trenches, the surface of Earth is quite smooth.
19. Meridians are parallel to each other.
20. The prime meridian runs through New York.

MULTIPLE CHOICE

1. The currently accepted age of Earth is based heavily on
    a. evidence from the earliest fossils.
    b. radiometric dating of the oldest known surface rocks.
    c. calculations of the length of time required for the oceans to achieve their salinity.
    d. dating of meteorites thought to have formed at roughly the same time as Earth.
2. The first dinosaurs appeared on Earth roughly ______ years ago.
    a. 50 million
    b. 135 million
    c. 225 million
    d. 345 million
3. Earth's axis of rotation is tilted at _____ degrees from the vertical.
    a. 23.5
    b. 45.0
    c. 30.5
    d. 15.0
4. The beginning of summer in the Southern Hemisphere is called the
    a. summer solstice.
    b. winter solstice.
    c. autumnal equinox.
    d. vernal equinox.
5. The moon orbits Earth in _____ days.
    a. 29.5
    b. 23.5
    c. 30
    d. 31
6. The international date line corresponds with
    a. the prime meridian.
    b. the Tropic of Capricorn.
    c. 180 degrees longitude.
    d. 90 degrees latitude.
7. One nautical mile is equivalent to
    a. 1 second of latitude.
    b. 1 minute of latitude.
    c. 1 degree of latitude.
    d. 1 land mile.
8. Ocean depths can be shown on a map by using
    a. contours.

b. isobaths.
c. color or shading.
d. all of the above.
e. none of the above.

9. Earth rotates through _____ degrees of _____ each hour.
a. 10, latitude
b. 15, longitude
c. 20, latitude
d. 10, longitude
e. 15, latitude

10. Water exists at Earth's surface in all three phases, liquid, solid, and gas, because of
a. the distance between Earth and the Sun.
b. the rate of rotation of Earth on its axis.
c. the presence of an atmosphere.
d. all of the above.
e. none of the above.

11. What percent of Earth's surface is covered with water?
a. 91
b. 71
c. 59
d. 45
e. 29

12. The reservoir that holds the largest volume of water is the
a. atmosphere.
b. glaciers and other land ice.
c. oceans and sea ice.
d. lakes and rivers.
e. groundwater.

13. The Pacific Ocean has the
a. largest surface area.
b. greatest mean depth.
c. largest volume.
d. all of the above.
e. none of the above.

14. The first land plants on Earth appeared
a. before the first reptiles.
b. after the first fish.
c. during the Paleozoic era.
d. during the Silurian period.
e. all of the above.

15. The early Earth probably did not have an atmosphere because
a. Earth spun too rapidly at first.
b. Earth was too small and its gravity too weak.
c. strong winds constantly blew it away.
d. a and c above.
e. a and b above.

16. The Sun stands directly above the equator at the
a. vernal equinox.
b. summer solstice.
c. winter solstice.
d. spring conjunction.
e. b and c above.

17. Meridians
a. are lines of longitude.
b. are great circles.

c. converge at the poles.
d. a and c above.
e. all of the above.

18. In the open ocean, modern navigation relies on
    a. radar.
    b. norad.
    c. satellite navigation.
    d. celestial navigation.
    e. sextant.
19. All of the water in Earth's rivers and lakes would cover a uniform sphere the size of the planet to a depth of
    a. 100 m.
    b. 50 m.
    c. 10 m.
    d. 1 m.
    e. 1 cm.
20. Earth is protected from extreme temperature changes by
    a. its distance from the Sun.
    b. its rate of rotation.
    c. the water in the oceans.
    d. a and c above.
    e. all of the above.

Visual Aids: Test Your Understanding of the Figures

1. Study figure 2.6 carefully. What is the direction of the tilt of Earth's axis in winter for the Northern Hemisphere? What is it during the summer? How can this be, if the axis itself does not change inclination?
2. Study figures 2.12 and 2.13. Are contour lines closer together or further apart on steep slopes?
3. On figure 2.17, locate where you live, and calculate how many hours of time difference exists from Greenwich, England.

Study Problems

City	**Latitude**	**Longitude**
Los Angeles, CA	33° 42' N	118° 15' W
Chicago, IL	41° 50' N	87° 38' W
New York, NY	40° 38' N	73° 50' W
Houston, TX	29° 44' N	95° 22' W
Miami, FL	25° 46' N	80° 14' W

1. Using the table above:
    a. Which city is farthest west? east? north? and south?
    b. How far south is Houston from Chicago in both nautical and statute miles?
    c. What is the time difference to the nearest minute between New York and Los Angeles?
2. Table 2.3 in the book lists the volume of water held in ocean water and sea ice. Figure 2.19 shows the volume of water that is evaporated from the oceans annually. If no water could return to the oceans, how many years would it take for them to completely evaporate?
3. Using figures for the surface area of the oceans from table 2.4 and the volume of water evaporated from the oceans annually, calculate the thickness in meters of the layer of water that is evaporated from the surface of the oceans each year.

Answer Key for Key Terms and Test Your Recall

KEY TERMS

galaxy(I)	electromagnetic spectrum(I)	cluster(I)
light-year(I)	supercluster(I)	nebula(III)
solar system (III)	heavy elements (III)	light elements (III)
differentiation (IV)	heating (IV)	isotope (V)
half-life (V)	era (VI)	period (VI)
epoch (VI)	Tropic of Cancer (VII)	solstice (VII)
equinox (VII)	oblate spheroid (VIII)	deformable (VIII)
latitude (IX)	longitude (IX)	projection (X)
contour (X)	Greenwich Mean Time (XI)	Zulu time (XI)
chronometer (XI)	radar (XII)	loran (XIII)
sphere depth (XIII)	hydrologic cycle (XIV)	residence time (XV)
hypsographic curve (XV)	radiometric dating (V)	great circle (IX)
topography (X)	bathymetry (X)	zenith (XI)

FILL IN THE BLANK

1. diameter, mass	2. downwards, core	3. isotope, half-life
4. eras	5. tilted	6. equator
7. parallels, meridians	8. bathymetric	9. time
10. hydrologic	11. solar system	12. atom
13. half-life	14. geologic time	15. summer solstice
16. grid	17. zero	18. contour
19. North Star	20. free water	

TRUE - FALSE

1.F 2.T 3.F 4.F 5.T 6.T 7.F 8.T 9.T 10.T 11.T 12.T 13.F 14.F 15.T 16.F 17.T 18.T 19.F 20.F

MULTIPLE CHOICE

1.d 2.c 3.a 4.b 5.a 6.c 7.b 8.d 9.b 10.d 11.b 12.c 13.d 14.e 15.b 16.a 17.e 18.c 19.d 20.e

STUDY PROBLEMS

1. a. Los Angeles, New York, Chicago, Miami
   b. 726 nautical miles, 835 statute miles
   c. 2 hours 58 minutes or 178 minutes
2. 4218.5 years
3. 0.884 meters, or roughly 1 meter