1. The age of the Earth is about  
   a. 4.5 million years  
   c. 600 thousand years  
   e. **4.5 billion years**  
   b. 600 million years  
   d. over 10 billion years

2. The earliest evidence of life occurs in rocks that are about  
   a. 4000 years old  
   c. 25 million years old  
   e. 100,000 years old  
   b. 500 million years old  
   d. 3.5 billion years old

3. The Earth’s mantle consists of  
   a. solid iron-nickel alloy  
   c. **solid silicate rock**  
   e. layered sedimentary rocks  
   b. liquid silicate rock  
   d. liquid iron-nickel alloy

4. The average depth of the oceans is about:  
   a. 150 meters  
   c. 10 kilometers  
   e. 4000 feet  
   b. **3800 meters**  
   d. 135 feet

5. In the absence of light, oceanographers use __________ to image the ocean floor  
   a. radar  
   c. sound waves  
   e. none of the above  
   b. lasers  
   d. both b and c

6. Which of the following techniques can be used to investigate the nature of rocks beneath the seafloor:  
   a. side-scan sonar  
   c. radar  
   e. none of the above  
   b. **seismic reflection and refraction**  
   d. both a and c

7. The theory of continental drift, condemned by some as “Utter damned rot”, but which later evolved into modern plate tectonic theory was introduced in 1915 by  
   a. Charles Darwin  
   c. Joyce Brothers  
   e. J. Tuzo Wilson  
   b. Alfred Wegener  
   d. Robert Ballard

8. If two theories explain a set of phenomena equally well, the one that is accepted is  
   a. the simplest one  
   c. the oldest one  
   e. the most mathematically complex one  
   b. the newest one  
   d. the one receiving the most votes

9. Ultimately, what drives the motion of lithospheric plates is  
   a. convection in the mantle  
   c. differential heating of the Earth’s surface by the Sun  
   e. expansion of the Earth  
   b. gravitational forces of the Sun and Moon  
   d. earthquakes
10. When the Moon and Sun are aligned with the Earth you will get
   a. neap tides
   b. spring tides
   c. semi-diurnal tides
   d. mixed tides
   e. all of the above.

11. The hydrogen bond that forms between water molecules
   a. results from sharing of electrons between hydrogen and oxygen
   b. results from the electrostatic attraction between partial charges on adjacent molecules
   c. occurs when a hydrogen atom donates an electron to a neighboring oxygen
   d. is an example of a covalent bond
   e. none of these

12. Melting beneath mid-ocean ridges occurs because
   a. water released from subducting lithosphere decreases the melting point of the overlying mantle
   b. friction produced by the convective motion of the mantle heats the rock to its melting point
   c. the melting point of mantle rock decreases with pressure, so that rising hot mantle eventually reaches its melting point – a process known as decompression melting
   d. mantle beneath mid-ocean ridges have particularly high concentrations of radioactive elements, which eventually heat it to its melting point
   e. none of the above

13. Although they vary, typical rates of sea floor spreading are in the range of
   a. 1 to 5 millimeters per hour
   b. 1 to 10 km per year
   c. about a meter per year
   d. a few centimeters per year
   e. 10 to 20 meters per year

14. The melting in subduction zones producing volcanoes such as Mt. St. Helens is due to
   a. water released from subducting lithosphere decreases the melting point of the overlying mantle
   b. friction produced by the convective motion of the mantle heats the rock to its melting point
   c. the melting point of mantle rock decreases with pressure, so that rising hot mantle eventually reaches its melting point – a process known as decompression melting
   d. mantle beneath mid-ocean ridges have particularly high concentrations of radioactive elements, which eventually heat it to its melting point
   e. none of the above

15. Going away from a mid-ocean ridge,
   a. the age of the ocean floor increases
   b. lithosphere thickens
   c. heat flow decreases
   d. water depth increases
   e. all of the above

16. “Island chains” that are parallel to the direction of lithospheric plate motion, such as the Hawaiian Islands, result from
   a. thrust faulting that sometimes occurs on fracture zones
   b. foundering of continental crustal fragments
   c. melting associated with downwelling convection currents
   d. mantle plumes that rise from the deep mantle and undergo decompression melting close to the surface
   e. none of the above
17. An example of a transform plate boundary is
   a. The Hawaiian Island chain
   b. The Marianas Islands
   c. The Mid-Atlantic Ridge
   d. New Zealand’s Great Alpine Fault
   e. The west coast of South America

18. Deep sea “red clays” get their red color from
   a. iron oxide that they absorb from seawater
   b. iron already present in their structure is oxidized
   c. they consist of the shells of red-tide-causing planktonic dinoflagellates
   d. cobalt absorbed from seawater
   e. none of the above

19. In the late 1960’s, scientists initiated an ambitious program to test the theory of plate tectonics by
   a. measuring sea-level changes using satellite altimetry
   b. measuring the speed of sound in water over long distances
   c. drilling into the ocean floor
   d. imaging the Earth with seismic tomography
   e. measuring rates of plate motion using GPS

20. Evidence from ocean sediments of an asteroid impact 65 million years ago that ended the reign of dinosaurs includes
   a. soot (bits of charcoal)
   b. anomalously high concentrations of iridium
   c. shocked quartz crystals
   d. all of the above
   e. none of the above

21. $^{18}\text{O}$ differs from $^{16}\text{O}$ in that
   a. $^{18}\text{O}$ is radioactive whereas $^{16}\text{O}$ is not
   b. $^{18}\text{O}$ has 2 more electrons than $^{16}\text{O}$
   c. $^{18}\text{O}$ has 2 extra protons and electrons
   d. $^{18}\text{O}$ has 2 more protons than $^{16}\text{O}$
   e. $^{18}\text{O}$ has 2 more neutrons than $^{16}\text{O}$.

22. A wave with a wavelength of 200 m would behave as a deep-water wave provided the water depth was greater than
   a. 200 m
   b. 100 m
   c. 10 m
   d. 400 m
   e. none of the above

23. A common type of siliceous ooze consists of the shells of:
   a. coccolithophorids
   b. foraminifera
   c. pteropods
   d. copepods
   e. none of the above

24. According to Darwin’s theory of the origin of coral atolls, atolls form as
   a. corals of a reef that originally fringed an island continue to grow as the island sinks
   b. chemosynthetic bacteria provide an energy source in the absence of light
   c. a large volcanic explosion blasts away the center of the island, leaving only a ring-shaped caldera
   d. an asteroid impact produces a crater surrounded by an uplifted ring
   e. global warming caused sealevel to rise
25. The geologic features of the Finger Lakes region, particularly its deep valleys, provided support for Louis Agassiz’s theory of
   a. the greenhouse effect
   b. Ice Ages
   c. plate tectonics
   d. an asteroid impact at the K-T boundary
   e. evolution

26. According to the theory originally proposed by Milutin Milankovitch and now widely accepted, the primary cause of the Ice Ages is
   a. variations in the Earth’s orbit and rotation
   b. movement of lithospheric plates
   c. changes in the rate of radioactive heating of the Earth’s interior
   d. changes in solar luminosity
   e. changes in concentrations of greenhouse gases

27. The average salinity of seawater is about
   a. 3.5‰
   b. 35%
   c. 2.3%
   d. 35‰
   e. 25 ppm

28. The ratio of oxygen-18 to oxygen-16 (or the \( \delta^{18}O \)) in marine sediments is useful because
   a. it is a useful measure of the past biological productivity in the ocean
   b. it is a useful indicator of paleotemperatures and paleoclimatic conditions
   c. it provides a means of estimating age
   d. decreases with a constant half-life
   e. none of the above

29. Waves approaching the shore become shallow water waves when depth is less than
   a. twice the wavelength
   b. \( 1/20 \) the wavelength
   c. one half the wavelength
   d. \( 1/100 \) the wavelength
   e. none of the above

30. Which of the following is not among the unusual and unique properties of water
   a. it has the highest heat capacity of all substances except liquid ammonia
   b. it has the highest latent heat of fusion of all substances except liquid ammonia
   c. it dissolves more substances and in more quantity than any other liquid
   d. it has the highest latent heat of evaporation of all substances
   e. it readily transmits UV radiation

11. Compared to active continental margins, passive continental margins:
   a. are wider and more likely to have earthquakes and volcanoes
   b. are narrower and more likely to have earthquakes and volcanoes
   c. have more frequent turbidity current events
   d. are narrower and less likely to have earthquakes and volcanoes
   e. are wider and less likely to have earthquakes and volcanoes

32. In a 3-step process in which ice at 0°C is first melted, then the water temperature raised to 100°C and finally that water converted to steam, a total of 720 calories/gram is needed. Of this, the energy required to convert water to steam requires
   a. the most energy of the 3 steps
   b. exactly 100 calories per gram
   c. the least energy of the 3 steps
   d. less than 100 calories per gram
   e. exactly equal to the energy required to convert ice to water
33. Water that is alkaline has
   a. a high pH and an excess of OH\(^-\) over H\(^+\)  b. a lot of O\(_2\) dissolved in it.
   c. a low pH and an excess of OH\(^-\) over H\(^+\)  d. a low pH and an excess of H\(^+\) over OH\(^-\)
   e. a high pH and an excess of H\(^+\) over OH\(^-\)

34. Seawater reaches its maximum density at
   a. 0˚C  b. 4˚C  d. it freezes before reaching its maximum density
   c. 32˚C  e. 100˚C

35. Divergent plate boundaries are usually associated with
   a. fracture zones  b. mid-ocean ridges
   c. volcanic island arcs  d. hot spots
   e. none of the above.

36. Conservative properties of seawater are those properties that
   a. change only at the surface of the ocean  b. are endorsed by the Republican Party
   c. change only through biological processes  d. never changes in the ocean
   e. both a and d

37. The appearance of diurnal, semidiurnal and mixed tides at different location on the earth is largely a result of
   a. the sun and moon pulling on the earth at 90˚ to each other twice a month (i.e., during first and last quarter moons)
   b. the moon revolving around the earth once every 24 h and 50 minutes
   c. the moon revolves around the earth at a declination of 28 degrees
   d. earth rotating around the sun every 365.25 days
   e. the gravitational force exerted by the Sun on the ocean surface is about half that exerted by the Moon

38. The concentration of an element or ion that exhibits a nutrient type distribution will
   a. exhibit a mid-depth minimum  b. be lower in coastal waters than the open ocean
   c. be higher in surface waters than in deep water  d. have a constant ratio to the concentration of other nutrients
   e. none of the above.

39. The tube worm Riftia, the vent clam Calyptogena, and the vent mussel Bathymodiolus all have which of the following in common:
   a. all are members of the phylum Mollusca  b. all are members of the phylum Vestimentifera
   c. all have no digestive track  d. all contain symbiotic chemosynthetic bacteria
   e. none of the above.

40. When Lavosier said that the oceans are the “rinings of the Earth”, he meant
   a. it rains a lot in the ocean  b. all rain runs to the sea
   c. salts dissolved in the ocean are weathering products of the land carried to the sea by rivers  d. hydrothermal vents provide most of the salt dissolved in the sea
   e. none of the above
41. The energy represented by the *latent heat of evaporation* of $H_2O$ is being used mainly to
   a. raise the temperature of the vapor
   b. raise the temperature of liquid water
   c. break hydrogen bonds
   d. increase the energy of individual molecules
   e. dissociate hydrogen and oxygen

42. Hydrothermal fluids are capable of dissolving large amounts of metals because
   a. they are alkaline and oxidizing (rich in $O_2$)
   b. they are acidic and reducing (poor in $O_2$)
   c. they are rich in magnesium
   d. they are oxidizing (rich in $O_2$) and hot
   e. they have greatly reduced salinity compared to seawater

43. Which of the following is *not* a reason scientists are interested in hydrothermal systems
   a. Many of the copper and zinc deposits we currently mine were produced in similar environments
   b. It is possible, and some think likely, that life originated in similar environments
   c. *They are significant factor in the thermal budget of the oceans and in thermohaline circulation*
   d. They are a factor in controlling the composition of seawater, e.g., as a sink for magnesium
   e. both c and d

44. Which of the following materials is ultimately derived from marine evaporite sediments
   a. copper used for wiring in houses
   b. salt used to keep roads ice-free.
   c. gypsum used to make plaster and sheetrock
   d. limestone used to make cement
   e. both b and c

45. By dividing the amount of sodium in the oceans by the yearly rate at which it is delivered to the oceans, we can calculate
   a. its atomic weight
   b. its mean concentration in the ocean
   c. **its residence time in the ocean**
   d. its half-life
   e. none of the above

46. At the Carbonate Compensation Depth (CCD):
   a. carbonate sediment **dissolves exactly as fast as it is accumulating**
   b. calcium carbonate begins to dissolve rapidly
   c. the depth below which seawater is undersaturated with calcium carbonate
   d. the depth below which seawater is saturated with calcium carbonate
   e. none of these

47. The speed of intermediate water waves depends on
   a. the wavelength
   b. water depth
   c. the wave height
   d. both $a$ and $c$
   e. **both a and b**

48. The chemical reaction $CaAl_2Si_2O_8 + 3H_2O \rightarrow Al_2SiO_5(OH)_4 + Ca^{2+} + 2OH^-$ represents the process of?
   a. chemosynthesis
   b. **chemical weathering**
   c. photosynthesis
   d. hydrothermal precipitation
   e. none of the above

49. The chemical reaction: $CO_2 + H_2S + O_2 + H_2O \rightarrow [CH_2O] (carbohydrate) + H_2SO_4$
   represents the process of
   a. photosynthesis
   b. **chemosynthesis**
   c. chemical weathering
   d. carbonate precipitation
50. Cotidal lines depict
   a. regions that have co-dependent tides
   b. the wavelength of a tide
   c. **timing and location of tide wave crests**
   d. elevation of a tide wave
   e. constructive addition to two tide waves

51. Calcium carbonate becomes increasingly soluble with depth in the ocean because
   a. pH decreases with depth in the ocean
   b. its solubility increases with pressure
   c. it is attacked by bacteria as it sinks
   d. both b and c
   e. **both a and b**

52. Which of the following is not true of tsunamis
   a. They can be generated by submarine landslides
   b. their speed depends on water depth
   c. They have long periods and wavelengths
   d. One could occur in the Atlantic Ocean
   e. The leading phase is always negative, so that when they strike the shore, the water always recedes before it rises.

53. The “restoring force” for small capillary waves is
   a. there is no restoring force; they are free waves
   b. gravity
   c. the wind
   d. surface tension
   e. friction

54. Waves of a range of sizes generated by a storm will undergo **dispersion** in which
   a. waves sort themselves out by size as the large ones travel faster than the small ones
   b. the large waves “damp out” and disappear
   c. the small waves “damp out” and disappear
   d. water depth slows the small waves more than the big ones, so the small ones travel in a different direction than big ones
   e. dispersion does not occur until the waves reach shallow water

55. Which is not true of the Messinian Salinity Crisis
   a. it began about 5.9 million years ago
   b. it occurred when the Strait of Gibraltar closed and the Mediterranean Sea largely dried up
   c. salinity of the entire ocean decreased
   d. **it occurred at the Cretaceous-Tertiary Boundary when an asteroid struck the Earth cause most of the ocean to evaporate**
   e. It produced the evaporite deposits that underly much of the Mediterranean seafloor.

57. Of the various factors that limit primary biological productivity in the ocean, on the global scale the most important factor is
   a. temperature
   b. availability of light
   c. **availability of nutrients surface waters**
   d. availability of $O_2$
   e. exposure to UV radiation

58. Rotary tidal waves …
   a. rotate counter-clockwise in the northern hemisphere
   b. result, in part, from the effects of the Coriolis Force and obstruction of continents
   c. have tidal ranges that **decrease** away from their amphidromic point
   d. all of the above
   e. **both a and b**
59. The observations that provided persuasive support for Milankovitch’s theory of the ice ages were
a. recognition of glacial features in the Finger Lakes region
b. measurements demonstrating the increasing concentration of $\text{CO}_2$ in the atmosphere
c. confirmation that the Earth’s orbit about the Sun is elliptical
d. variations in oxygen isotope ratios in the shells of micro-organisms recovered from deep sea sediment
e. there is no persuasive evidence of Milankovitch’s theory

60. Even before the extensive exploration of the oceans that followed WWII, a number of observations supported the theory of plate tectonics. Which of the following was not one of these observations?
a. continents from both sides of the Atlantic seemed to fit together
b. the motion of Paleozoic glaciers made sense only if the continents were fit together
c. most earthquakes occurred in narrow zones
d. sediment thickness increased progressively with distance from mid-ocean ridges
e. the Earth’s magnetic pole appeared to move, and rocks from different continents defined different polar wander paths.

Part II True/False  Use answer a to indicate TRUE; b to indicate FALSE

61. b The inner core of the earth is liquid whereas the outer core is solid.

62. a Oceanic-type crust is more dense than continental-type crust.

63. a In pure water, the concentrations of the $\text{H}^+$ and $\text{OH}^-$ ions are both equal to $10^{-7}$.

64. a The ocean drilling project found vast deposits of salt beneath the Mediterranean seafloor.

65. a Biological precipitates, such as oozes, are important sinks for dissolved ions in seawater.

66. a Satellite altimetry can detect the presence of seamounts beneath the ocean surface.

67. a Tsunamis can be generated by volcanic eruptions.

68. b Neap tides are good times to go clam digging because more of the tidal flat will be exposed

69. a The speed of a “deep water wave” depends only on its wavelength

70. b Waves that travel through each other tend to cancel each other out and cease to exist on the far side of the passing zone.