**TOSS UP**

1. MATH *Short Answer* Pablo walks 4 miles north, 6 miles east, and then 2 miles north again. In simplest form, how many miles is he from his starting point?

ANSWER: 6

**BONUS**

1. MATH *Short Answer* Evaluate ***the limit as x approaches infinity of x times the quantity negative 1 plus e to the 1 over x***.

ANSWER: 1

**TOSS UP**

2. CHEMISTRY *Multiple Choice* Which of the following is NOT a characteristic of amines?

W) A fully protonated amine is called an ammonium ion

X) Amines can function as Brønsted bases

Y) The VSEPR geometry of the nitrogen atom is trigonal planar

Z) Amines can be a hydrogen bond acceptor

ANSWER: Y) The VSEPR geometry of the nitrogen atom is trigonal planar

**BONUS**

2. CHEMISTRY *Multiple Choice* Of the following elements in their monatomic gaseous states, which has the lowest electron affinity?

W) Boron  
X) Carbon  
Y) Nitrogen  
Z) Oxygen  
  
ANSWER: Y) NITROGEN

**TOSS UP**

3. EARTH AND SPACE *Short Answer*  Indicate, by name or number, all of the following three statements that are TRUE of supernovas.

1. Type IA spectra contain an ionized silicon line at 615.0 nm;

2. Type II spectra contain no hydrogen lines;

3. Luminosity generated by Type IA supernovae after their explosion comes from the radioactive decay of Nickel and Cobalt-56 isotopes.

ANSWER: 1 AND 3

**BONUS**

3. EARTH AND SPACE *Multiple Choice* In an ophiolite ***[OF-ee-uh-lyt]*** sequence, what part of the spreading ridge environment does the peridotite ***[PER-i-doh-tyt]*** layer represent?

W) The upper crust

X) The ocean floor

Y) The upper mantle

Z) The magma chamber

ANSWER: Y) The upper mantle

**TOSS UP**

4. BIOLOGY *Multiple Choice* Which of the following cells are found in the stomach and are responsible for the secretion of intrinsic factor which is responsible for the absorption of vitamin B12?

W) Parietal

X) Chief

Y) G

Z) Mesangial

ANSWER: W) parietal

**BONUS**

4. BIOLOGY *Short Answer* By number, identify all of the following four couplets, vitamins and their respective deficiency conditions, that are correctly matched:

1. ascorbic acid and scurvy;

2. tocopherol ***[toh-KOF-uh-rol]*** and peripheral ***[puh-RIF-er-uhl]*** neuropathy;

3. thiamine ***[THY-uh-min]*** and beriberi;

4. niacin and Ricketts. ***[NY-uh-sin].***

ANSWER: 1, 2, AND 3 (ACCEPT: ALL BUT 4)

**TOSS-UP**

5. PHYSICS  *Multiple Choice* The weak force has the diameter of 1/10 of a proton, whereas the electromagnetic force is said to have infinite range. Which of the following statements correctly explains why this occurs?

W) The coupling constant of the weak force is one hundred thousand times smaller than the fine-structure constant.

X) The bosons of the weak interaction are of spin 2, whereas the photon has spin 1.

Y) The weak interaction violates the conservation of strangeness and charm

Z) The gauge bosons of the weak force have nonzero rest masses.

ANSWER: Z) THE GAUGE BOSONS OF THE WEAK FORCE HAVE NONZERO REST MASSES

**BONUS**

5. PHYSICS *Short Answer* Indicate all of the following three statements concerning the particle-in-a-box model that are TRUE:

1. The energy levels of the box are evenly spaced;

2. The ground state energy increases with increasing box length;

3. The energy is independent of the mass of the particles.

ANSWER: NONE OF THEM

**TOSS-UP**

6. ENERGY *Short Answer*  What compound, which is formed along with fatty acids from the saponification reaction of fat esters, is the major byproduct in the reaction that forms biofuels?

ANSWER: GLYCEROL

**BONUS**

6. ENERGY *Short Answer* Identify all of the following three statements that are true regarding spent fuel rods:

1. Most of the mass in a spent fuel rod is uranium-238;

2. Spent fuel rods are generally stored in water as they cool;

3. The major compound found in spent fuel rods is uranium hexafluoride.

ANSWER: 1 AND 2

**TOSS-UP**

7. MATH *Multiple Choice* The sum of the digits of a number is equal to 1.11 times some power of 10. Which of the following primes must be a factor of this number?

W) 2

X) 3

Y) 5

Z) 7

ANSWER: 3

**BONUS**

7. MATH *Short Answer* Consider a sphere whose radius is increasing at a rate of 2 centimeters per second. What is the instantaneous rate of change of volume in cubic centimeters per second when the radius is 3 centimeters?

ANSWER: 72 π

**TOSS-UP**

8. CHEMISTRY *Multiple Choice* How many neighboring atoms are attached to each metal atom in a face-centered cubic lattice?

W) 6

X) 8

Y) 10

Z) 12

ANSWER: Z) 12

**BONUS**

8. CHEMISTRY *Short Answer* Identify, respectively, the substances generated when using the following three industrial processes:

1. Bessemer process;

2. Otswald process;

3. Mond process.

ANSWER: 1) BESSEMER = Steel, 2) OTSWALD = nitric acid, 3) MOND = nickel

**TOSS UP**

9. EARTH AND SPACE *Short Answer* Give, by name or number, all of the following three statements that are true of the large-scale mass-energy distribution in the universe.

1. Summed together, baryonic and dark matter comprise 96% of the mass-energy;

2. At the time of the big-bang, dark energy played less of a role than it does now;

3. Gravitational lensing can be used to detect dark matter distribution in globular clusters.

ANSWER: 2 AND 3

**BONUS**

9. EARTH AND SPACE *Short Answer* In 1983, due to grains of rocks discovered in Australia, the age of the Earth was determined to be approximately 4.6 billion years. Which mineral was used to help determine this age?

ANSWER: ZIRCON

**TOSS UP**

10. BIOLOGY *Multiple Choice* Which of the following drugs is not matched correctly to its function?

W) Synthetic vasopressin and suppressing urine output

X) Taxol and arresting mitosis

Y) Aspirin and inhibiting nociceptors

Z) Propranolol and inhibiting beta-adrenergic receptors

ANSWER: Y) ASPIRIN AND INHIBITING NOCICEPTORS

**BONUS**

10. BIOLOGY *Short Answer* Identify all of the following three processes that are downstream results of insulin signaling:

1. Upregulating glucose uptake;

2. Upregulating gluconeogenesis;

3. Upregulating glycogenesis.

ANSWER: 1 AND 3

**TOSS-UP**

11. PHYSICS *Multiple Choice* Ten 100 ohm resistors are connected in series to a 15 volt battery. How much energy in joules is dissipated in this circuit in 60 seconds?

W) 0.225

X) 13.5

Y) 27.0

Z) 75

ANSWER: X) 13.5

**BONUS**

11. PHYSICS *Short Answer* Consider an RL circuit with a voltage source of 50 volts, a resistor with resistance 10 ohms, and a 20 millihenry inductor. The voltage source is turned on at time *t* = 0. What is the energy, in joules to the nearest hundredth, stored by the inductor at *t* = ∞?

ANSWER: 0.25 (ACCEPT: 0.25 J)

**TOSS-UP**

12. ENERGY *Multiple Choice*  Which of the following is NOT true regarding biofuels?

W) Biodiesel is as biodegradable as sugar

X) Burning ethanol produces a lower amount of energy per unit volume than gasoline

Y) Biodiesel can only be burned via the Otto cycle

Z) The most common biogas is methane

ANSWER: Y) BIODIESEL CAN ONLY BE BURNED VIA THE OTTO CYCLE

**BONUS**

12. ENERGY *Short Answer* What nanoscale semiconductor particles, which confine electrons, have bulk properties, like color, that depend on particle size?

ANSWER: QUANTUM DOTS

**TOSS UP**

13. MATH *Multiple Choice* Which of the following describes the solutions to the equation 𝑎𝑥2 + 𝑏𝑥 + 𝑐 = 0 if *b =* 0 and the product of *a* and *c* is positive?

W) Positive real

X) Negative real

Y) Pure imaginary

Z) Complex

ANSWER: Y) PURE IMAGINARY

**BONUS**

13. MATH *Short Answer* If *x* is a positive real number that grows without bound, then what value does log3 (18*x* – 10) – log3 (2*x* + 3) approach?

ANSWER: 2

**TOSS UP**

14. CHEMISTRY *Multiple Choice* Which of the following statements fully describes the products of a reaction that involves achiral ***[ay-KY-ruhl]*** reagents, achiral reactants, and achiral solvents?

W) The products cannot be chiral ***[KY-ruhl]***

X) The products can be chiral, but they must only consist of one enantiomer ***[i-NAN-tee-uh- mer]***

Y) The products can be chiral and can be enriched in one enantiomer over another

Z) The products can be chiral, but must be a racemic mixture ***[ray-SEE-mik]***

ANSWER: Z) THE PRODUCTS CAN BE CHIRAL, BUT MUST BE A RACEMIC MIXTURE

**BONUS**

14. CHEMISTRY *Short* Answer For an ideal gas obeying the Maxwell-Boltzmann distribution, at a given temperature, rank the following three from lowest to highest:

1. mode particulate speed;

2. mean particulate speed;

3. root mean square particulate speed.

ANSWER: 1, 2, 3 (ACCEPT: MODE PARTICULATE SPEED, MEAN PARTICULATE SPEED, ROOT MEAN SQUARE PARTICULATE SPEED, IN THAT ORDER)

**TOSS UP**

15. EARTH AND SPACE *Multiple Choice* In the Chesapeake Bay, which of the following is true of the vertical distribution of dissolved oxygen?

W) It decreases with depth

X) It increases with depth

Y) It remains constant with depth

Z) Varies unpredictably with depth

ANSWER: W) IT DECREASES WITH DEPTH

**BONUS**

15. EARTH AND SPACE *Multiple Choice* Which of the following measurements would indicate that the mean temperature of the Earth had decreased?

W) Global increase in the oxygen-18 to oxygen-16 ratio in ice cores

X) Global increase in tree ring thicknesses corresponding to that time period

Y) Global increase in degree of unsaturation of biologically-derived alkenones

Z) Global decrease in relative abundance of spruce pollen compared to grass pollen

ANSWER: W) GLOBAL INCREASE IN OXYGEN-18 to OXYGEN-16 RATIO IN ICE CORES

**TOSS UP**

16. BIOLOGY *Short Answer* A botanist discovers a new land plant with a dominant sporophyte, contains chlorophylls *a* and *b*, and has cell walls made of cellulose. Identify all of the following three pieces of information that would be helpful in assigning this plant to a phylum:

1. Whether or not the plant releases spores;

2. Whether or not the plant possesses seeds;

3. Whether or not the plant produces flowers.

ANSWER: 2 AND 3

**BONUS**

16. BIOLOGY *Short Answer* In isolation, beta sheets are generally not found acting as transmembrane regions of proteins. However, when several beta sheets are organized to form a closed structure, they can be found acting as transmembrane channels. What is the name of this large organization of beta sheets, which is found in GFP?

ANSWER: BETA BARREL

**TOSS-UP**

17. PHYSICS  *Multiple Choice* Which of the following statements concerning orbits in a two-body gravitational system is NOT TRUE?

W) Orbits that have eccentricities greater than 1 are hyperbolas

X) Hyperbolic orbits have negative energy

Y) The potential energy for a circular orbit is equal to the negative 2 times the kinetic energy

Z) All such orbits occur in a single plane

ANSWER: X) HYPERBOLIC ORBITS HAVE NEGATIVE ENERGY

**BONUS**

17. PHYSICS *Short Answer* An electron is moving in a magnetic field. The field is described by *B* = 2.5*i* + 2*j*, and the electron's velocity is given by *j* + 2*k*. Assuming that the charge of a proton is 1, what is the vector that describes the force on the electron as it moves through the magnetic field?

ANSWER: 4i – 5j + 2.5k (ACCEPT: (4, -5, 2.5))

**TOSS-UP**

18. ENERGY *Short Answer*  Steam reforming is a cost-effective process to produce what fuel?

ANSWER: HYDROGEN (ACCEPT: SYNGAS)

**BONUS**

18. ENERGY *Short Answer* To the nearest 10 percent, what is the fraction of light received from the Sun that the Earth absorbs?

ANSWER: 70% (ACCEPT: ANY ANSWER BETWEEN 65% and 75%)

**TOSS-UP**

19. MATH *Short Answer* What is the last digit of the number 761 ?

ANSWER: 7

**BONUS**

19. MATH *Short Answer* To three decimal places, what is the square root of 1.012?

ANSWER: 1.006

**TOSS-UP**

20. CHEMISTRY *Short Answer* Indicate all of the following three compounds that have a dipole moment: 1. Xenon tetroxide; 2. Xenon tetrafluoride; 3. Xenon trioxide.

ANSWER: 3 ONLY

**BONUS**

20. CHEMISTRY *Multiple Choice* Which of the following statements is TRUE concerning the compressibility factor of a gas?

W) It is equal to zero for ideal gases

X) It is smaller than one at high pressures for most real gases

Y) It is smaller than one at low pressures for most real gases

Z) The compressibility factor of a van-der-Waals gas is constant with pressure

ANSWER: Y) IT IS SMALLER THAN ONE AT LOW PRESSURES FOR MOST REAL GASES

**TOSS UP**

21. EARTH AND SPACE *Short Answer* If the luminosity of the sun is L, what is the luminosity of a 4-solar mass main sequence star in terms of L, to the nearest integer multiple of L?

ANSWER: 128 L

**BONUS**

21. EARTH AND SPACE *Short Answer* Indicate all of the following three statements that are TRUE concerning variable stars: 1. Population I Cepheids are usually less massive than the sun; 2. W Virginis variables are generally metal-poor and old; 3. RR Lyrae variables generally have spectral types A or F.

ANSWER: 2 AND 3

**TOSS UP**

22. BIOLOGY *Short Answer* Indicate all of the following three compounds that would induce expression of the *lac* operon: 1) allolactose, 2) IPTG, 3) glucose.

ANSWER: 1 AND 2

**BONUS**

22. BIOLOGY *Short Answer* Indicate all of the following three statements that are true regarding the Krebs cycle:

1. The conversion of succinyl-CoA ***[SUHK-suh-nil]*** to succinate ***[SUHK-suh- nate]*** involves a substrate level phosphorylation ***[FOS-for-uh-lay-shuhn]***;

2. The conversion of citrate to isocitrate generates NADH;

3. The conversion of fumarate ***[FYOO-muh-rayt]*** to malate ***[MAH-late]*** generates NADH.

ANSWER: 1 ONLY

**TOSS-UP**

23. PHYSICS *Short Answer* What specific two-quark particle is responsible for mediating the strong interaction between nucleons?

ANSWER: PION (ACCEPT: PI MESON, PI-0 MESON)

**BONUS**

23. PHYSICS *Short Answer* Order the following three events from least to greatest in terms of their associated energy:

1. hydrogen electron transitions from n = 1 to n = 2;

2. ionization energy for hydrogen;

3. hydrogen electron transitions from n = 2 to n = 5.

ANSWER: 3, 1, 2

**TOSS-UP**

24. ENERGY *Short Answer* If the secondary side of a transformer has 300 loops, what is the secondary voltage in volts produced when the primary voltage applied is 100 volts using 60 loops?

ANSWER: 500 V (ACCEPT: 500)

**BONUS**

24. ENERGY *Multiple Choice*  Which of the following is NOT true regarding the nitrogenase enzyme?

W) The formation of ammonia from molecular hydrogen and nitrogen is exothermic

X) Nitrogenase contains an iron-containing cofactor

Y) Glutamine is used as the final nitrogen-sink in the reaction

Z) Ferrodoxin or flavodoxin act as oxidizing agents

ANSWER: Z) FERRODOXIN OR FLAVODOXIN ACT AS OXIDIZING AGENTS

**TOSS-UP**

25. MATH *Short Answer* Convert 103 in base 10 to base 7.

ANSWER: 205

**BONUS**

25. MATH *Multiple Choice* Which of the following numerical integration methods will result in an overestimation of the area under the graph of 𝑦 = x ***[y equals the square root of x]*** on the interval [0,1] ***[closed interval from 0 to 1]*** ?

W) Left Riemann sum

X) Trapezoidal rule

Y) Average of left and right Riemann sums

Z) Midpoint Riemann sum

ANSWER: Z) MIDPOINT RIEMANN SUM