TOSS-UP

1) MATH *Short Answer* What law states that the union of two sets is equal to the sum of the sets without their intersection?

ANSWER: PRINCIPLE OF INCLUSION-EXCLUSION (ACCEPT: PIE)

BONUS

1) MATH *Short Answer* Six boys and two girls line up to take a group picture. In the picture, all six boys must be next to each other. Furthermore, two of the boys are identical twins and therefore indistinguishable. If the line is randomly arranged, what is the probability that the arrangement is valid?

ANSWER: 3/28

TOSS-UP

2) PHYSICS *Multiple Choice* What law states that the entropy of an isolated system may never decrease?

W) Hess's Law
X) First Law of Thermodynamics
Y) Second Law of Thermodynamics
Z) Rayleigh-Jeans Law

ANSWER: Y) SECOND LAW OF THERMODYNAMICS

BONUS

2) PHYSICS *Short Answer* A system whose entropy is constant but is not in a state of equilibrium must be undergoing what type of process?

ANSWER: REVERSIBLE

TOSS-UP

3) CHEMISTRY *Short Answer* What equation is most commonly used to calculate the effect of temperature change on the vapor pressure of a substance?

ANSWER: CLAUSIUS-CLAPEYRON EQUATION

BONUS

3) CHEMISTRY *Multiple Choice* Which of the following liquids is not correctly matched with its vapor pressure at 25 degrees C?

W) water, 1000 torr
X) mercury, 0.0017 torr
Y) ethanol, 58.9 torr
Z) ethane, 7095 torr

ANSWER: W

TOSS-UP

4) BIOLOGY *Multiple Choice* Which of the following groups of plants belong to the class of monocots?

W) beans
X) seagrass
Y) cacti
Z) peanuts

ANSWER: X) SEAGRASS

BONUS

4) BIOLOGY *Short Answer* List all of the following statements that are true about hormones:

I) Insulin signals the breakdown of stored glucose in the liver
II) HGH stimulates the release of cortisol
III) ADH signals the kidneys to reabsorb water
IV) Glucagon signals the uptake of glucose into the cell

ANSWER: III only

TOSS-UP

5) EARTH AND SPACE *Multiple Choice* Which of the following is not a silicate?

W) Quartz
X) Olivine
Y) Mica
Z) Dolomite

ANSWER: Z) DOLOMITE

BONUS

5) EARTH AND SPACE *Short Answer* Silicate minerals are classified into seven main groups based on the shape of the silicate cation. Name all of the following which would be classified as having a chain structure:

I) Quartz
II) Mica
III) Amphibole

ANSWER: III ONLY

TOSS-UP

6) MATH *Short Answer* Evaluate the limit of $(x^2+5x+6)/(x^2+4x+3)$ as x approaches -3.

ANSWER: 1/2

BONUS

6) MATH *Short Answer* What is the maximum number of intersection points between 8 circles?

ANSWER: 56

TOSS-UP

7) PHYSICS *Short Answer* To 3 significant figures, compute the acceleration due to gravity at the surface of a planet with a mass half that of the Earth and a radius half as large.

ANSWER: -19.6

BONUS

7) PHYSICS *Short Answer* Name all of the four fundamental forces which feature a monotonically increasing potential.

ANSWER: GRAVITY AND ELECTROMAGNETISM

TOSS-UP

8) CHEMISTRY *Multiple Choice* Steven is conducting a chemistry experiment. However, his only available solvent is benzene, in which sodium chloride is not soluble. Which of the following classes of reagents would help Steven dissolve sodium chloride in benzene?

W) lactones
X) benzene derivatives

Y) crown ethers
Z) organic acids

ANSWER: Y) CROWN ETHERS

BONUS

8) CHEMISTRY *Multiple Choice* Steven, as mentioned previously, wants to dissolve sodium chloride in benzene.Which of the following crown ethers best accomplishes this goal?

W) 12-crown-4
X) 15-crown-5
Y) 18-crown-6
Z) dibenzo-18-crown-6

ANSWER: X

TOSS-UP

9) BIOLOGY *Short Answer* What type of innate immune cell is responsible for killing tumor cells and cells infected by viruses?

ANSWER: NATURAL KILLER CELL

BONUS

9) BIOLOGY *Short Answer* Which of the following cells can be found in the central nervous system?

I) astrocytes
II) macroglia
III) ependymal cells
IV) microglia

ANSWER: I, III, IV

TOSS-UP

10) EARTH AND SPACE *Short Answer* Name all of the following 4 properties that are necessary for a planet to have a significant magnetic field.

I) A short rotation period
II) A metallic core
III) A short orbital period
IV) A molten interior

ANSWER: I and IV

BONUS

10) EARTH AND SPACE *Short Answer* The dust tail of a comet is pushed from the comet by what entity?

ANSWER: SOLAR WIND

TOSS-UP

11) MATH *Short Answer* Compute the derivative of f(x) = e^(2x^2).

ANSWER: e^(2x^2)*4x

BONUS

11) MATH *Short Answer* Find the area of a triangle with side lengths 13, 14, and 15.

ANSWER: 84

TOSS-UP

12) PHYSICS *Multiple Choice* In which of the following does Ampere's circuital law NOT apply?

W) Infinitely long straight wire
X) Finite length straight wire
Y) Simple closed loop circuit
Z) Circuit containing a solenoid

ANSWER: X) FINITE LENGTH STRAIGHT WIRE

BONUS

12) PHYSICS *Short Answer* In magnetostatics, the Biot-Savart Law can be used as a generalization of Ampere's circuital law, expressing contributions to the strength of the magnetic field over infinitesimally small changes in what physical quantity?

ANSWER: LENGTH (ACCEPT POSITION, DO NOT ACCEPT CURRENT)

TOSS-UP

13) CHEMISTRY *Multiple Choice* In a metallic solid with a simple cubic structure, how many metal atoms are there per unit cell?

W) 1
X) 2
Y) 3
Z) 4

ANSWER: W) 1

BONUS

13) CHEMISTRY *Short Answer* What is the only metal to adopt a simple cubic crystal structure under standard conditions?

ANSWER: POLONIUM

TOSS-UP

14) BIOLOGY *Short Answer* Female birds possess what two chromosomes?

ANSWER: Z AND W

BONUS

14) BIOLOGY *Short Answer* Shannon entropy is a measure of what biological quantity?

ANSWER: DIVERSITY (ACCEPT BIODIVERSITY)

TOSS-UP

15) EARTH AND SPACE *Multiple Choice* Which of the following objects is one of the most luminous in the universe, releases radiation across the entire electromagnetic spectrum, and includes subclassifications such as quasars and blazars?

W) active galaxy nuclei
X) black hole
Y) white dwarf
Z) asymptotic giant branch star

ANSWER: W) ACTIVE GALAXY NUCLEI

BONUS

15) EARTH AND SPACE *Short Answer* What type of active galaxies are similar at first glance to normal spiral galaxies but have very high surface brightness and have very strong infrared emission?

ANSWER: SEYFERT GALAXY

TOSS-UP

16) MATH *Short Answer* Compute the 4-dimensional hyper-volume of a 4-dimensional hyper-cube with a side length of 6.

ANSWER: 1296

BONUS

16) MATH *Multiple Choice* Which of the following is not true about stereographic projection?

W) Stereographic projection preserves angles
X) Stereographic projection is a smooth mapping
Y) Stereographic projection is a bijection
Z) Stereographic projection is area-preserving

ANSWER: Z) STEREOGRAPHIC PROJECTION IS AREA-PRESERVING

TOSS-UP

17) PHYSICS *Short Answer* Which of the following forces are conservative?

I) Gravitational force
II) Frictional force
III) Spring Force
IV) Electrostatic force

ANSWER: I, III, and IV

BONUS

17) PHYSICS *Short Answer* When reading a gravitational energy versus distance curve, what does negative one times the slope of the graph at a point represent?

ANSWER: THE MAGNITUDE OF FORCE (accept reasonable equivalents)

TOSS-UP

18) CHEMISTRY *Short Answer* By name or number, arrange the following three ions in order of increasing ionic radius: Na^{+}, F^{-}, Al^{3+}

ANSWER: Al^{3+}, Na^{+}, F^{-} (3, 1, 2)

BONUS

18) CHEMISTRY *Multiple Choice* Identify which of the following is least accurate about atomic trends:

W) The lanthanides all have similar atomic radii
X) Oxygen is more electronegative than chlorine
Y) Noble gases have negative electron affinity
Z) The second ionization energy of lithium is less than that of beryllium

ANSWER: Z) The second ionization energy of lithium is less than that of beryllium

TOSS-UP

19) BIOLOGY *Short Answer* By name or number, Which of the following would decrease if primase was inhibited?

I) Leading strand production
II) Okazaki fragment production
III) DNA polymerase production

ANSWER: I and II only

BONUS

19) BIOLOGY *Short Answer* What type of RNA is most abundant in the cell?

ANSWER: rRNA

TOSS-UP

20) EARTH AND SPACE *Multiple Choice* What upper-air winds that travel parallel to the isobars that results when the Coriolis effect balances the pressure gradient force?

W) trade winds
X) geostrophic winds
Y) monsoons
Z) chinooks

ANSWER: X) GEOSTROPHIC WINDS

BONUS

20) EARTH AND SPACE *Short Answer* What form of air circulation causes air to rise near the equator and travels to the subtropical zone, which then flows back to the equator?

ANSWER: HADLEY CELL

TOSS-UP

21) PHYSICS *Short Answer* What term is used to describe the positions where a small object can be placed such that the gravitational pull of two large masses in orbital motion causes the small object to maintain its position relative to the other two?

ANSWER: LAGRANGIAN POINTS

BONUS

21) PHYSICS *Short Answer* What is the name that refers to an object located at the L_4 or L_5 points of an orbital system?

ANSWER: TROJANS

TOSS-UP

22) CHEMISTRY *Short Answer* If unsaturated aqueous solutions of silver (I) fluoride and lithium perchlorate are mixed and assuming that no reactants are limiting, which of the following substances would you expect to precipitate?

I) silver perchlorate
II) lithium fluoride
III) silver (I) fluoride
IV) lithium chlorate

ANSWER: II ONLY

BONUS

22) CHEMISTRY *Short Answer* Assuming that the solubility of sodium sulfate is 0.1 moles per liter at STP, compute the solubility product constant of sodium sulfate to the nearest thousandths.

ANSWER: 0.004

TOSS-UP

23) BIOLOGY *Multiple Choice* What type of cell-cell junction are composed of cadherins and are specialized for adhesion?

W) Gap junction
X) Tight junction
Y) Desmosome
Z) Plasmodesmata

ANSWER: Y) DESMOSOME

BONUS

23) BIOLOGY *Short Answer* Innexins form gap junctions in invertebrates. What proteins form gap junctions in vertebrates?

ANSWER: CONNEXINS