**TOSS-UP**

1) Physics – *Multiple Choice* In lasers, a population inversion is commonly created through which of the following processes?

W) Stimulated emission
X) Spontaneous emission
Y) Radiation trapping
Z) Optical pumping

ANSWER: Z) OPTICAL PUMPING

**BONUS**

1) Physics – *Short Answer* Order the following 3 spectral lines for the hydrogen atom in terms of increasing wavelength of photons emitted: 1) Balmer-alpha; 2) Lyman-alpha; 3) Paschen-alpha.

ANSWER: 2, 1, 3

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

2) Biology – *Multiple Choice* During which of the following phases of the cell cycle do separase enzymes act?

W) G1 phase
X) S phase
Y) G2 phase
Z) M phase

ANSWER: Z) M PHASE

**BONUS**

2) Biology – *Short Answer* Identify all of the following three statements that are true concerning monocots: 1) They do not possess true root systems; 2) Their pollen grains contain two apertures; 3) The number of floral parts they possess is divisible by 3.

ANSWER: 3 ONLY
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

3) Chemistry – *Multiple Choice* A single bond formed between carbon and which of the following elements is the LEAST polar?

W) Hydrogen
X) Nitrogen
Y) Fluorine
Z) Chlorine

ANSWER: W) HYDROGEN

**BONUS**

3) Chemistry – *Short Answer* Considering only the valence shell, how many bonding electrons are found in diatomic oxygen?

ANSWER: 8

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

4) Earth and Space – *Multiple Choice* Bauxite is composed of a mix of oxides and hydroxides of which of the following elements?

W) Iron
X) Aluminum
Y) Magnesium
Z) Titanium

ANSWER: X) ALUMINUM

**BONUS**

4) Earth and Space – *Short Answer* Order the following four Galilean moons in terms of increasing average density: 1) Io; 2) Europa; 3) Ganymede; 4) Callisto.

ANSWER: 4, 3, 2, 1
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

5) Biology – *Multiple Choice* Which of the following ecosystems would exhibit the highest diversity?

W) A river experiencing high disturbance
X) A river experiencing intermediate disturbance
Y) A river experiencing low disturbance
Z) A river experiencing no disturbance

ANSWER: X) A RIVER EXPERIENCING INTERMEDIATE DISTURBANCE

**BONUS**

5) Biology – *Short Answer* Identify all of the following three scenarios that could result in Klinefelter's syndrome: 1) Normal egg is fertilized by a sperm with one X and one Y chromosome; 2) Normal egg is fertilized by a sperm with two X chromosomes; 3) Uniparental disomy occurs in the Y chromosome.

ANSWER: 1 ONLY

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

6) Energy – *Short Answer* Scientists at Pacific Northwest National Lab have been studying specific catalysts that increase the reaction rate of the hydrodeoxygenation of lignin-derived oxygenates to arenes. In which type of plant ground tissue is lignin primarily found?

ANSWER: SCLERENCHYMA

**BONUS**

6) Energy – *Short Answer* Researchers at Lawrence Livermore National Lab have been studying oxime compounds that can pass the blood-brain barrier and counteract the effects of nerve agents. These nerve agents prevent the breakdown of what neurotransmitter?

ANSWER: ACETYLCHOLINE
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

7) Math – *Short Answer* What is the circumradius of a right triangle with legs of 3 and 4?

ANSWER: 2.5

**BONUS**

7) Math – *Short Answer* How many nonnegative integers *n* less than 243 have no digit equal to 2 in their base 3 representation?

ANSWER: 32

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

8) Chemistry – *Short Answer* Intersystem crossing occurs when a system in a singlet state undergoes a radiationless transition to a triplet state. After a molecule is excited and then undergoes intersystem crossing, it must use what process in order to relax to its ground state?

ANSWER: PHOSPHORESCENCE (DO NOT ACCEPT: FLUORESCENCE)

**BONUS**

8) Chemistry – *Multiple Choice* In diatomic oxygen, a pi bonding orbital results from the parallel overlap of two 2p orbitals. Which of the following statements is correct regarding the nodal structure of this pi bonding orbital?

W) It contains one node parallel to the internuclear axis and one node perpendicular to the internuclear axis
X) It contains one node parallel to the internuclear axis and zero nodes perpendicular to the internuclear axis
Y) It contains zero nodes parallel to the internuclear axis and one node perpendicular to the internuclear axis
Z) It contains zero nodes parallel to the internuclear axis and zero nodes perpendicular to the internuclear axis

ANSWER: X) IT CONTAINS ONE NODE PARALLEL TO THE INTERNUCLEAR AXIS AND ZERO NODES PERPENDICULAR TO THE INTERNUCLEAR AXIS
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

9) Energy – *Short Answer* Scientists at Pacific Northwest National Lab have been categorizing and mapping recent alluvial sediments based on their metamorphic grades and river hydrodynamics. Order the following three metamorphic rocks in increasing temperature of formation: 1) Phyllite; 2) Slate; 3) Migmatite.

ANSWER: 2, 1, 3

**BONUS**

9) Energy – *Short Answer* Scientists at Brookhaven National Lab are studying how the Jahn-Teller effect increases voltage limits in manganese-based oxides. Identify all of the following 3 molecular geometries that will undergo Jahn-Teller distortion: 1) Linear; 2) Tetrahedral, 3) Octahedral.

ANSWER: 2 AND 3

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

10) Math – *Short Answer* What is the determinant of the 2 by 2 matrix with first row 5 and –4 and second row –3 and –2?

ANSWER: –22

**BONUS**

10) Math – *Short Answer* A group of six friends want to arrange themselves so that the distance between any two of them is exactly six feet. What is the minimum number of dimensions in which this is possible?

ANSWER: 5
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

11) Earth and Space – *Multiple Choice* Although the Bayer designation α ***[alpha]*** usually denotes the brightest star in a constellation, the β ***[beta]*** designation may sometimes be brighter. In which of the following constellations is the β star brighter than the α star?

W) Cassiopeia
X) Taurus
Y) Lyrae
Z) Orion

ANSWER: Z) ORION

**BONUS**

11) Earth and Space – *Multiple Choice* Which of the following statements regarding doublet earthquakes is NOT true?

W) They generally originate from the same hypocenter
X) They have nearly identical waveforms
Y) They are caused by asperities ***[ass-PEAR-ih-tees]*** impeding the direction of fault slip
Z) Their magnitudes are often between 2 and 3 units apart on the Richter scale

ANSWER: Z) THEIR MAGNITUDES ARE OFTEN BETWEEN 2 AND 3 UNITS APART ON THE RICHTER SCALE

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

12) Physics – *Short Answer* A binary star system consists of a 2 solar mass and a 3 solar mass star mutually orbiting each other at a constant distance of 1 AU. In AU, how far is the center of mass of the system from the 2 solar mass star?

ANSWER: 0.6 (ACCEPT: 3/5)

**BONUS**

12) Physics – *Short Answer* A uniform electric field of $-2\mathbf{i} + 4\mathbf{j} + 5\mathbf{k}$ volts per meter is present throughout a region of space. If the electric potential at the origin is given to be 0, calculate the electric potential in volts at the point $(2, -3, 4)$.

ANSWER: –4
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

13) Energy – *Multiple Choice* Researchers at Los Alamos National Lab are studying microhabitats in grassland ecosystems. A relatively new, but important concept in this field is the theory of island biogeography. Which of the following statements regarding island biogeography is false?

W) Biogeographic islands do not necessarily have to be surrounded by water
X) Biogeographic islands may be formed from the fragmentation of habitat by human development
Y) Biogeographic island species often change in size, becoming larger or smaller, in response to land and resource constraints
Z) Smaller biogeographic islands often have much greater species diversity than larger islands

ANSWER: Z) SMALLER BIOGEOGRAPHIC ISLANDS OFTEN HAVE MUCH GREATER SPECIES DIVERSITY THAN LARGER ISLANDS

**BONUS**

13) Energy – *Multiple Choice* Researchers at Lawrence Berkeley National Lab have been evaluating the effects of missing values and mixed data types on sociodemographic sequence clustering using t-distributed stochastic neighbor embedding, or t-SNE ***[tee-snee]***. For which of the following tasks would t-SNE most likely be utilized?

W) Logistic regression
X) Reinforcement learning
Y) Anomaly detection
Z) Data visualization

ANSWER: Z) DATA VISUALIZATION

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

14) Biology – *Short Answer* Which group of enzymes are responsible for lymphocyte VDJ diversity?

ANSWER: RECOMBINASES

**BONUS**

14) Biology – *Short Answer* Chondrichthyans ***[con-DRIC-thee-uns]*** contain skeletons made of which kind of connective tissue?

ANSWER: CARTILAGE
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

15) Chemistry – *Multiple Choice* Valence electrons in which of the following elements experience the greatest effective nuclear charge?

W) Helium
X) Neon
Y) Oxygen
Z) Sodium

ANSWER: X) NEON

**BONUS**

15) Chemistry – *Short Answer* Another group is attached to carbon 3 of chlorocyclohexane, forming a trans compound. Identify all of the following 3 groups that, when attached, would cause the equilibrium to favor the chloro substituent in the axial position: 1) methyl, 2) n-butyl, 3) t-butyl.

ANSWER: ALL

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

16) Earth and Space – *Multiple Choice* What type of stellar object is present at the center of the Ring Nebula, a famous planetary nebula in the Lyra constellation?

W) Black hole
X) Neutron star
Y) White dwarf
Z) Brown dwarf

ANSWER: Y) WHITE DWARF

**BONUS**

16) Earth and Space – *Short Answer* Consider a large sea stack located twenty meters from the shore, which causes waves to refract in such a way where there is significant deposition within a strip connecting the sea stack to land. Given enough time, what depositional coastal feature will form that joins the sea stack back to shore?

ANSWER: TOMBOLO
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

17) Biology – *Short Answer* What bodily fluid do ependymal cells secrete?

ANSWER: CEREBROSPINAL FLUID (ACCEPT: CSF)

**BONUS**

17) Biology – *Multiple Choice* Which of the following agents would NOT be used in an SDS-PAGE?

W) Dithiothreitol
X) Beta mercaptoethanol
Y) Albumin blocking protein
Z) Tris-HCl buffer

ANSWER: Y) ALBUMIN BLOCKING PROTEIN

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

18) Physics – *Multiple Choice* In the Planck system of natural units, the Planck time is equal to the Planck length divided by what fundamental constant?

W) Gravitational constant
X) Speed of light
Y) Planck's constant
Z) Fine structure constant

ANSWER: X) SPEED OF LIGHT

**BONUS**

18) Physics – *Short Answer* A 120 gram mass is placed in between two springs with spring constants of 27 newtons per meter and 48 newtons per meter. The other ends of the springs are fixed to opposing walls. To two significant figures and in seconds, what is the period of the longitudinal oscillations of the mass?

ANSWER: 0.25
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

19) Math – *Short Answer* The point (9, 8) is rotated 90 degrees clockwise and then reflected across the line $y = x$. What are the coordinates of the final point?

ANSWER: (–9, 8)

**BONUS**

19) Math – *Short Answer* Alice and Bob each roll 2 dice. What is the probability that the difference of Alice's rolls equals the difference of Bob's rolls?

ANSWER: 16/81

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

20) Chemistry – *Short Answer* When hydrochloric acid is added to 1-butene, the major product formed is 2-chlorobutane. What rule predicts that 1-chlorobutane will not be formed in significant amounts?

ANSWER: MARKOVNIKOV'S RULE

**BONUS**

20) Chemistry – *Short Answer* An aqueous galvanic cell is constructed with a copper cathode and a zinc anode. The two electrodes are then connected by a solid, semipermeable salt bridge. Identify all of the following three statements that are correct regarding this cell: 1) Electrons flow towards the copper electrode; 2) Anions in the salt bridge migrate towards the copper electrode; 3) Zinc is oxidized as the cell discharges.

ANSWER: 1 AND 3
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

21) Physics – *Short Answer* A pipe is open at both ends and has a fundamental frequency of 17 Hz at a certain temperature. If the speed of sound is 340 m/s at the same temperature, what is the length of the pipe?

ANSWER: 10

**BONUS**

21) Physics – *Multiple Choice* Which of the following quantities is most likely greater in a strongly-coupled plasma than a weakly-coupled plasma?

W) Degree of ionization
X) Plasma parameter
Y) Strength of electrostatic forces
Z) Temperature

ANSWER: Y) STRENGTH OF ELECTROSTATIC FORCES

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

**TOSS-UP**

22) Math – *Short Answer* What is the area of the region bounded by the curves $y = x^9$ and $y = x^8$?

ANSWER: 1/90

**BONUS**

22) Math – *Short Answer* A positive integer has a base 16 representation of 143 ***[one-four-three]***. In base 10, what is the largest prime factor of this integer?

ANSWER: 19
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

## TOSS-UP

23) Earth and Space – *Short Answer* Identify all of the following three changes that can be applied to a parcel of freshwater at 2 degrees Celsius that will increase its density: 1) Mixing with an equal-volume parcel of saline water at 4 degrees Celsius; 2) Addition of sodium chloride; 3) Cooling down to 1 degrees Celsius.

ANSWER: 1 AND 2

## BONUS

23) Earth and Space – *Short Answer* To one significant figure and in light years, calculate the distance to a star with a parallax angle of 0.3 arcseconds.

ANSWER: 10

**jay's questions that we may or may not use in the future**

Bonus 10: Chem, Short Answer
Hydroboration-oxidation disobeys what rule for additions, which states that a group will be added to the more substituted carbon?
ANSWER: Markovnikov's rule

TU 15: Chem, Multiple Choice
Which of the following techniques would be best for determining chemical shift?
(W) Mass spectrometry
(X) Infrared spectroscopy
(Y) NMR spectroscopy
(Z) Chromatography
ANSWER: (Y) NMR spectroscopy

Bonus 15: Chem, Short Answer
In proton NMR, hydrogen atoms described by this term will cumulatively produce one signal. Hydrogen atoms described by this term can be either homotopic or enantiotopic.
ANSWER: chemically equivalent

TU 4: Chem, Multiple Choice
Which of the following molecular orbitals is antibonding?
(W) sigma
(X) sigma*
(Y) pi
(Z) delta
ANSWER: (X) sigma*

Bonus 5: Chem, Short Answer
What is the bond order of a molecule with two electrons in a sigma orbital, four electrons in pi orbitals, and one electron in a pi* orbital?
ANSWER: 5/2 [or 2.5]