DOUBLE ELIMINATION 5

TOSS-UP

1) Chemistry - *Short Answer* How many vibrational degrees of freedom does a molecule of ozone have?

ANSWER: 3

BONUS

1) Chemistry - *Short Answer* The equilibrium constant of the Haber-Bosch process at temperature T using partial pressures can be calculated with the law of mass action. By what factor must this value be scaled to obtain its corresponding equilibrium constant using concentrations?

ANSWER: $(RT)^2$ **[the quantity RT squared]**

TOSS-UP

2) Earth and Space - *Multiple Choice* David and Aashray are trying to discover exoplanets in a nearby galaxy. They use a method that is able to locate nearby stars and can determine planetary radius but cannot determine mass. Which of the following is likely the method of exoplanet detection used by the duo?

W) Radial velocity
X) Transit
Y) Microlensing
Z) Direct imaging

ANSWER: X) Transit

BONUS

2) Earth and Space - *Short Answer* Identify all of the following three statements that are true regarding spiral galaxies: 1) Flocculent **[FLAH-kyoo-luhnt]** galaxies often contain self-sustaining star formation zones; 2) Orbital velocity decreases farther from the center of a spiral galaxy; 3) Spiral galaxies are the most common type of galaxy in the universe.

ANSWER: 1 and 3

TOSS-UP

3) Energy - *Multiple Choice* Researchers in the Gratta group at Stanford are using Mossbauer spectroscopy to search for new fundamental interactions in physics. Mossbauer spectroscopy is typically used to precisely measure the absorption of light in which of the following regions of the electromagnetic spectrum?

W) Gamma ray
X) X-ray
Y) Infrared
Z) Microwave

ANSWER: W) Gamma ray

BONUS

3) Energy - *Short Answer* Scientists in Stanford's Organismal Biology Lab are studying the bioenergetics of nitrogenous waste excretion. Identify all of the following three statements regarding nitrogenous waste excretion that are true: 1) Certain animals can excrete multiple types of nitrogenous waste; 2) Aquatic animals are more likely to excrete ammonia than terrestrial animals; 3) Uric acid is the most energetically favorable form of nitrogenous waste to produce.

ANSWER: 1 and 2

TOSS-UP

4) Physics - *Multiple Choice* Suppose a container of volume $2V$ is partitioned into two equal sections of volume V. One of the partitions is filled with n moles of gas A, and the other partition contains a vacuum. The partition is then removed so that the gas expands irreversibly into the entire container. Which of the following best describes the entropy increase of the system?

W) Independent of n and V
X) Independent of n but dependent on V
Y) Dependent on n but independent of V
Z) Dependent on both n and V

ANSWER: Y) Dependent on n but independent of V

BONUS

4) Physics - *Multiple Choice* Two parallel square conducting plates with area A and separation d, where $A \gg d^2$ **[A is much greater than d squared]**, are placed in a vacuum such that its capacitance is C_0 **[C nought]**. The two plates have fixed voltages with potential difference ΔV **[delta V]**. An insulating slab with area A, thickness d, and relative permittivity ε **[epsilon]** is slowly inserted in between the plates. Which of the following best describes the force on the slab as a function of x, the distance inserted?

W) Constant
X) Linear
Y) Quadratic
Z) Exponential decay

ANSWER: W) Constant

TOSS-UP

5) Math - *Short Answer* Including the ”empty” rotation, how many ways are there to rotate a tetrahedron so that the vertices end up in a permutation of their original positions?

ANSWER: 12

BONUS

5) Math - *Short Answer* Patricia inflates a perfectly spherical balloon at a constant rate of 6 meters cubed per second. When the radius of the balloon is 2 meters, what is the instantaneous rate of surface area increase, in meters squared per second?

ANSWER: 6

TOSS-UP

6) Chemistry - *Short Answer* A carboxylic acid derivative has the general molecular formula RCOX where X is a functional group. Order the following three carboxylic derivatives by increasing double bond character in the C-X bond: 1) Acid chloride; 2) Amide; 3) Ester.

ANSWER: 1, 3, 2

BONUS

6) Chemistry - *Multiple Choice* Which of the following correctly identifies the lowest unoccupied molecular orbital in the protonation of the double bond when propene **[PROH-peen]** reacts with HBr?

W) Pi bonding
X) Pi antibonding
Y) Sigma bonding
Z) Sigma antibonding

ANSWER: Z) Sigma antibonding

TOSS-UP

7) Biology - *Multiple Choice* In the Bohr shift, hemoglobin binds oxygen molecules most tightly under which of the following temperature and pH conditions?

W) High temperature, low pH
X) Low temperature, low pH
Y) High temperature, high pH
Z) Low temperature, high pH

ANSWER: Z) Low temperature, high pH

BONUS

7) Biology - *Short Answer* Genes A, B, C, and D are arranged in alphabetical order on the same chromosome from the 5' **[5 prime]** to 3' end. A and B are 1000 kilobases apart, B and C are 200 kilobases apart, and C and D are 600 kilobases apart. Identify all of the following three statements about crossing over that must be true: 1) Recombination is more likely to happen between A and B than between B and C; 2) Recombination is more likely to hapen between A and B than between B and D; 3) Recombination is more likely to happen between B and D than between C and D.

ANSWER: 3 only (DO NOT ACCEPT: All)

TOSS-UP

8) Physics - *Short Answer* A scientist performs a double slit experiment with a single photon passing through the apparatus at a time. When the scientist attempts to determine which slit the photon passes through, the interference pattern disappears. This is an example of what type of quantum principle, which states that properties like the wave and particle nature of light cannot be observed simultaneously?

ANSWER: Complementarity

BONUS

8) Physics - *Short Answer* Identify all of the following three constants that are dimensionless: 1) Fine structure constant; 2) Strong coupling constant; 3) Planck constant.

ANSWER: 1 and 2

TOSS-UP

9) Earth and Space - *Multiple Choice* Assuming that the strata **[STRAT-uh]** in a region are approximately horizontal, in which of the following directions do stream knickpoints move over time?

W) Upstream
X) Downstream
Y) Vertically upwards
Z) Vertically downwards

ANSWER: W) Upstream

BONUS

9) Earth and Space - *Short Answer* Order the following three minerals from first to last to deposit in an evaporating lake: 1) Gypsum **[JIP-sum]**; 2) Halite; 3) Anhydrite.

ANSWER: 1, 3, 2

TOSS-UP

10) Math - *Multiple Choice* Herbert and Gerbert both pick an integer between 1 and 45 inclusive. Which of the following is closest to the probability that Herbert's number is at least triple Gerbert's?

W) 0.1
X) 0.2
Y) 0.3
Z) 0.4

ANSWER: X) 0.2

BONUS

10) Math - *Short Answer* A regular 12-gon T has side length 2. An inscribed 12-gon T' **[read as: T prime]** is created by connecting consecutive midpoints of sides of T. What is the area of the region contained in T but outside T'?

ANSWER: 3

TOSS-UP

11) Biology - *Short Answer* At lower population densities, a population experiences a significantly lower growth rate than the predicted logistic growth model. What effect, which explains that the mean individual fitness increases in higher population sizes due to increased cooperation, best explains this phenomenon?

ANSWER: Allee **[uh-LEE]** effect

BONUS

11) Biology - *Short Answer* Identify all of the following three essential elements that would likely be deficient in acidic soils: 1) Potassium; 2) Sulfur; 3) Calcium.

ANSWER: 1 and 3

TOSS-UP

12) Chemistry - *Short Answer* Identify all of the following three polymers that are formed from addition polymerization: 1) Cyanoacrylate; 2) Polystyrene; 3) Polyvinylchloride.

ANSWER: 2 and 3

BONUS

12) Chemistry - *Short Answer* Calculate the wavelength of the hydrogen spectral line emissions as the electron falls from the 4th energy level to the second, expressing your answer in terms of Rydbergs?

ANSWER: $\frac{16}{3R}$

TOSS-UP

13) Physics - *Short Answer* Rocks in oceanic crust can be used to determine the history of Earth's magnetic field because they retain some remnant magnetization from that time. This is an example of what property often seen in magnetic systems, which is defined as the dependence of a system's state on its history?

ANSWER: Hysteresis **[his-tur-EE-sis]**

BONUS

13) Physics - *Short Answer* Consider a wavefunction describing the spin of an electron. Identify all of the following three choices that are properly normalized wavefunctions: 1) $\left(\frac{1}{2}, \frac{1}{2}\right)$; 2) $\left(\frac{\sqrt{3}}{2}, \frac{i}{2}\right)$; 3) $\left(\frac{\sqrt{3}}{2} + \frac{i}{2}, 0\right)$.

ANSWER: 2 and 3

TOSS-UP

14) Energy - *Multiple Choice* Scientists in the Bertozzi Group at Stanford are studying how glycoproteins enable breast cancer cells to resist HER2-targeting **[her-two targeting]** therapies. What fibrous network of carbohydrates that covers the surface of cell membranes are they most likely investigating?

W) Spectrin cortex
X) Fibronectin
Y) Glycocalyx **[gly-koh-KAY-lix]**
Z) Caveolae **[cav-ee-OHL-ee]**

ANSWER: Y) Glycocalyx

BONUS

14) Energy - *Short Answer* Researchers in the Moler group at Stanford are mapping the strength of magnetization when a magnetic field is applied to a superconductor. What property, which equals the ratio of magnetization to the applied magnetic field intensity, are these researchers studying?

ANSWER: Magnetic susceptibility (ACCEPT: Susceptibility)

TOSS-UP

15) Math - *Short Answer* Compute $\log_{81} 243^{16}$ **[log base 81 of open parentheses 243 to the power of 16 close parentheses]**.

ANSWER: 20

BONUS

15) Math - *Short Answer* Oswald wants to make a sandwich with exactly 8 slices of meat. He has infinite slices of ham, salami, and turkey. Disregarding the ordering of slices, how many different sandwiches can he make?

ANSWER: 45

TOSS-UP

16) Earth and Space - *Multiple Choice* Which of the following supernovae types contains hydrogen in its spectra and displays a linear decrease in its light curve?

W) Type Ia **[one-A]**
X) Type Ib
Y) Type 2P
Z) Type 2L

ANSWER: Z) Type 2L

BONUS

16) Earth and Space - *Short Answer* Order the following three components of the interstellar medium in order of lowest to highest density: 1) H1 regions; 2) Coronal gas; 3) Molecular clouds

ANSWER: 2, 1, 3

TOSS-UP

17) Chemistry - *Short Answer* What compound is typically used in hydrogen-1 NMR as the reference standard for a chemical shift of 0 parts per million?

ANSWER: Tetramethylsilane **[tetra-methyl-PSY-lane]** (ACCEPT: TMS)

BONUS

17) Chemistry - *Short Answer* Order all of the following four benzoic acids by increasing pKa values: 1) p-nitrobenzoic acid; 2) p-bromobenzoic acid; 3) p-methoxybenzoic acid 4) p-methylbenzoic acid.

ANSWER: 1, 2, 4, 3

TOSS-UP

18) Biology - *Short Answer* Order the following three steps of Gram staining from earliest to latest: 1) Ethanol wash; 2) Safranin **[SAF-ruh-nin]** staining; 3) Crystal violet and iodine staining.

ANSWER: 3, 1, 2

BONUS

18) Biology - *Short Answer* Identify all of the following three algal species that reproduce through alternation of generations: 1) Brown algae; 2) Charophytes **[KAIR-oh-fights]**; 3) Chlorophytes.

ANSWER: 1 and 3

TOSS-UP

19) Physics - *Multiple Choice* When a material is heated beyond its Néel temperature, which of the following best describes the magnetic phase transition that occurs?

W) Ferromagnetic to antiferromagnetic
X) Antiferromagnetic to ferromagnetic
Y) Paramagnetic to antiferromagnetic
Z) Antiferromagnetic to paramagnetic

ANSWER: Z) Antiferromagnetic to paramagnetic

BONUS

19) Physics - *Multiple Choice* Consider a cyclical thermodynamic process, such as one seen in a heat engine, that can be illustrated as closed loops on T-S and P-V diagrams. Which of the following best describes how the area of the T-S loop compares to the area of the P-V loop?

W) Always greater
X) Always smaller
Y) Always equal
Z) Depends on the thermodynamic cycle

ANSWER: Y) Always equal

TOSS-UP

20) Energy - *Short Answer* Researchers at the Kavli Institute at Stanford are studying the early formation of galaxies. The researchers observed that during this period, galaxies should be too hot for their baryonic matter to be gravitationally bound. What massive structure surrounding the galaxy is thought to resolve this problem?

ANSWER: Dark matter halo (DO NOT ACCEPT: Halo)

BONUS

20) Energy - *Multiple Choice* Scientists at the SLAC-Stanford Battery Center are researching the properties of lithium-sulfur batteries, which have anodes made of lithium and cathodes made of the most common allotrope of sulfur, which typically takes on which of the following structures?

W) Cyclic
X) Linear
Y) Pentagonal bipyramidal
Z) Tetrahedral

ANSWER: W) Cyclic

TOSS-UP

21) Earth and Space - *Multiple Choice* Which of the following global atmospheric circulation patterns does La Niña strengthen?

W) Ferrel circulation
X) Walker circulation
Y) Subtropical jet stream
Z) Subpolar jet stream

ANSWER: X) Walker circulation

BONUS

21) Earth and Space - *Short Answer* Order the following three layers from the highest to lowest position in which they would be found in a regressive sequence: 1) Limestone; 2) Sandstone; 3) Mudstone.

ANSWER: 2, 3, 1

TOSS-UP

22) Math - *Short Answer* Identify all of the following three statements that are true of trees: 1) They have no cycles; 2) Removing any edge results in a disconnected graph; 3) There is a unique path between every pair of vertices.

ANSWER: All

BONUS

22) Math - *Short Answer* An elliptic curve consists of points (x,y) satisfying the equation $y^2 = x^3 + ax + b$. Given an elliptic curve with $a = -6$ and $b = 4$, what is the slope of the tangent line at the point $(0,2)$?

ANSWER: $-\frac{3}{2}$

TOSS-UP

23) Biology - *Short Answer* Identify all of the following three statements about parthenogenesis that are true: 1) Species that mainly reproduce via parthenogenesis have a high male-to-female ratio; 2) Parthenogenesis can result in diploid offspring; 3) Parthenogenesis introduces genetic variation into the population.

ANSWER: 2 only

BONUS

23) Biology - *Multiple Choice* Malonate **[MAL-uh-nate]** inhibits the conversion of succinate **[SUK-sin-ate]** to fumarate by mimicking succinate's structure. According to the Michaelis-Menten equation, the introduction of malonate would most directly alter which of the following parameters?

W) K_m
X) V_{max}
Y) Rate constant
Z) Activation energy

ANSWER: W) K_m