DOUBLE ELIMINATION 7

TOSS-UP

1) Biology - *Multiple Choice* Which of the following is not one of the functions of GTP hydrolysis in prokaryotic translation?

W) Improving the accuracy of tRNA-codon base pairing
X) Forming peptide bond between nascent peptide strand and next amino acid
Y) Translocating ribosome to the next codon on the mRNA
Z) Assembling the ribosomal complex onto mRNA

ANSWER: X) Forming peptide bond between nascent peptide strand and next amino acid

BONUS

1) Biology - *Short Answer* An Arabidopsis mutant is continuously undergoing the triple response. Identify all of the following three observations that would be true if the plant was a ctr mutant: 1) Removal of all functional ethylene receptors halts the triple response; 2) Introducing ethylene synthesis inhibitors halts the triple response; 3) When crossed with an ein mutant, the offspring would undergo triple response only under normal conditions.

ANSWER: None

TOSS-UP

2) Energy - *Multiple Choice* Researchers in the Pavone Lab at Stanford are designing binary decision processes for autonomous systems. Which of the following would be the most appropriate activation function for the output layer of a binary classification?

W) Linear
X) ReLU **[READ: ray-loo]**
Y) Tanh **[READ: tanch]**
Z) Sigmoid

ANSWER: Z) Sigmoid

BONUS

2) Energy - *Short Answer* Scientists at SLAC are modeling the behavior of electrons at energies near the Fermi level. Order the following three materials in terms of increasing distance between their Fermi level and conduction band: 1) N-type semiconductor; 2) P-type semiconductor; 3) Conductor.

ANSWER: 3, 1, 2

TOSS-UP

3) Math - *Short Answer* Anne starts at a point chosen uniformly from the perimeter of a unit equilateral triangle. She then chooses one of the two remaining sides and walks parallel to that side until she hits the perimeter again. What is the average distance Anne walks?

ANSWER: $\frac{1}{2}$

BONUS

3) Math - *Short Answer* Ben buys an empty banana farm for 10 million dollars. If the marginal cost of planting the k-th banana tree is $10k + 16$ dollars, then to the nearest hundred, how many banana trees should Ben plant to minimize the average cost per tree?

ANSWER: 1400

TOSS-UP

4) Chemistry - *Short Answer* The Mond process purifies nickel by combining an impure sample with what functional group, creating a gas that leaves solid impurities behind?

ANSWER: Carbonyl

BONUS

4) Chemistry - *Multiple Choice* Which of the following statements best summarizes the kinetic isotope effect?

W) The increased reaction rate of heavier isotopes due to their greater stability
X) Bonds involving heavier isotopes are stronger, making them easier to break during a chemical reaction
Y) Reaction rates between molecules containing lighter and heavier isotopes differ due to differences in zero-point vibrational energies
Z) The inability of isotopes to participate in chemical reactions due to differences in mass

ANSWER: Y) Reaction rates between molecules containing lighter and heavier isotopes differ due to differences in zero-point vibrational energies

TOSS-UP

5) Physics - *Multiple Choice* Which of the following quantities is considered a four-vector in special relativity?

W) Energy
X) Momentum
Y) Pressure
Z) Electric field

ANSWER: X) Momentum

BONUS

5) Physics - *Short Answer* What thermodynamic ensemble is most appropriate for describing a system where the total energy and number of particles is fixed?

ANSWER: Microcanonical

TOSS-UP

6) Energy - *Short Answer* Researchers in the Horne group at Stanford are modeling natural gas reservoirs in fractured rock. This modeling is difficult because real gases experience temperature changes when traveling through small openings. What effect accounts for this phenomenon?

ANSWER: Joule-Thomson effect

BONUS

6) Energy - *Multiple Choice* Scientists at Stanford's Geballe Lab are improving upon quantum mechanical simulators that utilize quantum dots. Which of the following compounds could be used to make quantum dots?

W) Copper hydride
X) Lead selenide
Y) Sodium iodide
Z) Ferronickel

ANSWER: X) Lead selenide

TOSS-UP

7) Earth and Space - *Multiple Choice* Which of the following best describes the primary driving mechanism of most massive pulsating stars?

W) Higher temperatures result in higher opacity
X) Higher temperatures result in lower opacity
Y) Higher radiation pressures result in higher opacity
Z) Higer radiation pressures result in lower opacity

ANSWER: W) Higher temperatures result in higher opacity

BONUS

7) Earth and Space - *Short Answer* Identify all of the following three core collapse mechanisms that commonly result in a remnant black hole: 1) Pair instability; 2) Photodisintegration; 3) Degenerate core electron capture.

ANSWER: 2 only

TOSS-UP

8) Math - *Short Answer* Lucas writes the numbers 2, 0, 2, and 5 on a board. He chooses 2 numbers, erases them, and writes their nonnegative difference. After doing this three times, there is a single number on the board. What is the minimum possible value of this final number?

ANSWER: 1

BONUS

8) Math - *Short Answer* Two positive real numbers have arithmetic mean 24 and harmonic mean 6. What is the geometric mean of the two numbers?

ANSWER: 12

TOSS-UP

9) Physics - *Multiple Choice* A spherical particle is moving through a viscous fluid. Which of the following best describes the dependence of the drag force on the speed v of the particle?

W) Always proportional to v
X) Always proportional to v^2
Y) Proportional to v for small Reynolds numbers and v^2 for large Reynolds numbers
Z) Proportional to v^2 for small Reynolds numbers and v for large Reynolds numbers

ANSWER: Y) Proportional to v for small Reynolds numbers and v^2 for large Reynolds numbers

BONUS

9) Physics - *Short Answer* For a fixed energy, chemical potential, and temperature, order the following three distributions in increasing order of the average occupancy of a non-empty state: 1) Maxwell-Boltzmann; 2) Bose-Einstein; 3) Fermi-Dirac.

ANSWER: 3, 1, 2

TOSS-UP

10) Biology - *Short Answer* During a hemorrhage, systemic vascular resistance increases as intracranial vasculature compresses from the mounting pressure. As a response, mean arterial pressure increases through systemic arteriole constriction, restoring blood flow in the brain. What is the name of this relation that correlates increased intercranial pressure with increased mean arterial pressure?

ANSWER: Cushing's phenomenon (ACCEPT: Cushing's [effect, response, reaction, or reflex]) (DO NOT ACCEPT: Cushing's syndrome, Cushing's disease)

BONUS

10) Biology - *Short Answer* Identify all of the following three statements that are true about cell division in dinoflagellates: 1) Miotic spindle forms within the nucleus; 2) The nuclear envelope breaks down during mitosis; 3) Microtubules attach to the kinetochores of chromosomes.

ANSWER: None

TOSS-UP

11) Chemistry - *Multiple Choice* Which of the following molecules has a carbon with the highest oxidation state?

W) Ethylene oxide
X) Methyl methanoate
Y) Acetylene
Z) Methanal

ANSWER: X) Methyl methanoate

BONUS

11) Chemistry - *Short Answer* Ignoring Hund's rule, what is the number of possible microstates for the first excited state of Be, with electron configuration 1s2 2s1 2p1?

ANSWER: 12

TOSS-UP

12) Earth and Space - *Short Answer* What term is given to a significant relationship between geographically distant weather events?

ANSWER: Teleconnection

BONUS

12) Earth and Space - *Short Answer* Assume that the dry adiabatic lapse rate is 10° C/km, the dew point lapse rate is 2° C/km, and the temperature of an unsaturated air parcel is 3.5° C above the dew point at ground level. In meters and to two significant figures, how high must the parcel rise for cloud formation to begin?

ANSWER: 440

TOSS-UP

13) Physics - *Multiple Choice* A prism with an n-sided regular polygon base is placed on a 30° incline on one of its n sides. What is the minimum value of n at which the prism will definitely tip over and begin rolling in the presence of gravity?

W) 5
X) 6
Y) 7
Z) 8

ANSWER: Y) 7

BONUS

13) Physics - *Short Answer* The rotational motion of a rigid body can be described by a symmetric 3-dimensional rank-2 moment of inertia tensor. What theorem in linear algebra guarantees that 3 perpendicular principal axes can always be found for any arbitrarily shaped rigid body?

ANSWER: Spectral theorem

TOSS-UP

14) Energy - *Multiple Choice* Researchers in the Radio Glaciology group at Stanford are mapping the presence of subglacial lakes beneath the Antarctic ice sheet. Which of the following best describes how temperature changes with depth in a large ice sheet?

W) Uniformly increases
X) Uniformly decreases
Y) Increases, then decreases
Z) Decreases, then increases

ANSWER: W) Uniformly increases

BONUS

14) Energy - *Short Answer* Researchers in the Dror Lab at Stanford are using machine learning to understand the spatial organization and dynamics of biomolecules. Geometric reasoning is usually best achieved using what type of neural network?

ANSWER: Graph neural network (ACCEPT: GNN)

TOSS-UP

15) Chemistry - *Multiple Choice* Which of the following best describes the mechanism of the Wittig reaction?

W) [2+2] cycloaddition
X) [4+2] cycloaddition
Y) [3+1] cycloaddition
Z) [3+3] cycloaddition

ANSWER: W) [2+2] cycloaddition

BONUS

15) Chemistry - *Short Answer* When an aryl diazonium salt is treated with fluoroboric acid, fluorobenzene forms. What is the name of this specific reaction?

ANSWER: Schiemann reaction

TOSS-UP

16) Biology - *Short Answer* Order the following three components of a desmosome junction by increasing distance from the center of the cell: 1) Keratin filaments; 2) Cadherin proteins; 3) Dense plaques.

ANSWER: 1, 3, 2

BONUS

16) Biology - *Short Answer* Identify all of the following four amino acids that can act as zwitterions at neutral pH: 1) Glycine; 2) Tryptophan; 3) Lysine; 4) Threonine.

ANSWER: 1, 2, and 4

TOSS-UP

17) Math - *Short Answer* A cyclops number is a number that when written in base 2, has an odd number of digits that are all 1s except for the center digit, which is 0. What is the base 10 value of the 4th smallest, positive cyclops number?

ANSWER: 495

BONUS

17) Math - *Short Answer* A particle is fired from the corner of a 1 by 2 rectangle into the rectangle, reflects perfectly upon hitting any of the four sides, and finally reaches a corner and stops. Identify all of the following three numbers that are possible values for the distance traveled by the particle: 1) $\sqrt{13}$; 2) $\sqrt{22}$; 3) $\sqrt{31}$.

ANSWER: 1 only

TOSS-UP

18) Earth and Space - *Multiple Choice* Which of the following star types would likely have the widest spectral absorption lines?

W) White dwarves
X) W Virginis stars
Y) Wolf-Rayet stars
Z) OH variable stars

ANSWER: X) W Virginis stars

BONUS

18) Earth and Space - *Short Answer* Large-scale structures across the universe often contain huge thin sheets of intergalactic gas. What characteristic absorption line series is observed through the detection of these gas sheets?

ANSWER: Lyman-Alpha Forest (DO NOT ACCEPT: Lyman)

TOSS-UP

19) Physics - *Short Answer* The Schrödinger equation of the hydrogen atom is the only one for the elements which is exactly solvable in quantum mechanics. Disregarding effects from fine structure, what is the degeneracy of the first excited energy level of hydrogen?

ANSWER: 8

BONUS

19) Physics - *Short Answer* Some examples of transport phenomena in thermodynamics are thermal conduction, which transports heat, and diffusion, which transports mass. What mechanical quantity is transported in viscosity?

ANSWER: Momentum

TOSS-UP

20) Chemistry - *Multiple Choice* In a redox titration of Fe^{2+} with MnO_4^- in acidic solution, why is no external indicator required?

W) Fe^{2+} changes color as it is oxidized
X) MnO_4^- acts as its own indicator
Y) The reaction endpoint is measured by a precipitate
Z) The reaction produces a gas at the endpoint

ANSWER: X) MnO4- acts as its own indicator

BONUS

20) Chemistry - *Short Answer* According to hard-soft acid-base theory, order the following four compounds from lowest to highest solubility in water. 1) $Ca(OH)_2$; 2) $Ca_3(PO_4)_2$; 3) $CaCO_3$.

ANSWER: 1, 3, 2

TOSS-UP

21) Biology - *Multiple Choice* The Sec residue **[S-E-C residue]** is formed during protein synthesis rather than post-translational modification. Which of the following best explains how this amino acid is added to the polypeptide chain during translation?

W) Modified serine-charged tRNA recognizes recoded start codon
X) Modified cysteine-charged tRNA recognizes recoded start codon
Y) Modified serine-charged tRNA recognizes recoded stop codon
Z) Modified cysteine-charged tRNA recognizes recoded stop codon

ANSWER: Y) Modified serine-charged tRNA recognizes recoded stop codon

BONUS

21) Biology - *Short Answer* A certain lipid molecule is currently located inside a chylomicron in a small intestine epithelial cell. Order the following four locations within the body from first to last in which the lipid molecule will likely encounter it: 1) Aorta; 2) Lacteals; 3) Liver; 4) Adipocyte.

ANSWER: 2, 1, 3, 4

TOSS-UP

22) Earth and Space - *Multiple Choice* Studies show that while Archean sediments from shallow-water environments are rare, their deep-water counterparts are more abundant. Which of the following rocks is most indicative of these deep-water environments?

W) Greenstone
X) Limestone
Y) Rock gypsum
Z) Chert

ANSWER: Z) Chert

BONUS

22) Earth and Space - *Multiple Choice* Which of the following is most accurate regarding atmospheric convergence and divergence?

W) Fast-moving air in troughs collides with slower-moving air in ridges, resulting in convergence aloft
X) Fast-moving air in troughs pulls away from slower-moving air in ridges, resulting in surface divergence
Y) Fast-moving air in ridges collides with slower-moving air in troughs, resulting in convergence aloft
Z) Fast-moving air in ridges pulls away from slower-moving air in troughs, resulting in surface divergence

ANSWER: Y) Fast-moving air in ridges collides with slow-moving air in troughs, resulting in convergence aloft

TOSS-UP

23) Math - *Short Answer* In regular hexagon $ABCDEF$, the length of AC is 6. What is the radius of the circumcircle of the hexagon?

ANSWER: $2\sqrt{3}$

BONUS

23) Math - *Short Answer* Identify all of the following three statements that are true of the roots of the polynomial $x^4 + 4x^3 + 6x^2 + 4x - 1$: 1) There are exactly 2 real roots; 2) All roots have absolute value at most 2; 3) Exactly one root has a positive real part.

ANSWER: 1 and 3