DOUBLE ELIMINATION 9

TOSS-UP

1) Physics - *Short Answer* A rusty spring with equilibrium length 10 centimeters is stretched to a length of 12 centimeters and released. During the resulting motion, the spring never shortens to less than 10 centimeters, instead decaying straight back to equilibrium. Identify all of the following three properties that could describe the spring's damping: 1) Underdamped; 2) Critically damped; 3) Overdamped.

ANSWER: 2 and 3

BONUS

1) Physics - *Short Answer* A general Lorentz transformation can be represented by a 4×4 matrix. How many degrees of freedom do these transformations have?

ANSWER: 6

TOSS-UP

2) Energy - *Multiple Choice* Scientists at Stanford's Arrillaga Center for Sports and Recreation are studying skeletal muscle metabolism during high-intensity exercise. Which of the following myosin subtypes would be dominant in the legs of elite sprinters?

W) 1A
X) 1B
Y) 2A
Z) 2X

ANSWER: Z) 2X

BONUS

2) Energy - *Multiple Choice* Researchers at the Woods Institute at Stanford recently predicted that climate change would reduce the amount of Saharan dust that travels over the Atlantic Ocean. What effect would this change have on average sea surface temperature and hurricane formation in the Atlantic, respectively?

W) Increase, increase
X) Increase, decrease
Y) Decrease, increase
Z) Decrease, decrease

ANSWER: W) Increase, increase

TOSS-UP

3) Chemistry - *Short Answer* The complex ion $[Co(CN)_6]^{4-}$ is a low-spin octahedral complex with a central cobalt ion in a d^7 electron configuration. Despite being a low-spin complex, it is labile and undergoes rapid ligand substitution. What effect commonly associated with axial bond distortion best explains this phenomenon?

ANSWER: Jahn-Teller effect

BONUS

3) Chemistry - *Short Answer* There is exactly one pair of enantiomers with chemical formula C3H6O. What is the specific name for the functional group that these enantiomers share?

ANSWER: Epoxide

TOSS-UP

4) Biology - *Short Answer* High auxin levels are required for the development of leaf primordia. What family of proteins is responsible for the polar transport of auxin by exporting it from L1-layer cells into young primordia?

ANSWER: PIN proteins

BONUS

4) Biology - *Short Answer* A hypothetical virus has RNA-dependent RNA polymerases in its capsid prior to infection. According to the Baltimore classification scheme, identify all of the following three groups in which this virus might belong to: 1) Group IV; 2) Group V; 3) Group VI.

ANSWER: 2 only

TOSS-UP

5) Physics - *Multiple Choice* Consider a particle of mass m in a quantum harmonic oscillator potential in 3 dimensions with frequency ω. Which of the following is the energy and degeneracy, respectively, of the ground state?

W) 0, 0
X) $\frac{3}{2}\hbar\omega$, 1
Y) $\frac{3}{2}\hbar\omega$, 3
Z) $3\hbar\omega$, 1

ANSWER: X) $\frac{3}{2}\hbar\omega$, 1

BONUS

5) Physics - *Short Answer* 12 identical one-ohm resistors are arranged in a cube. What is the combined resistance between two points on opposite sides of the long diagonal, in ohms?

ANSWER: $\frac{5}{6}$

TOSS-UP

6) Math - *Multiple Choice* Let z be a complex number with real part between 0 and 1. Which of the following best describes the region of possible values for e^z?

W) Half-plane
X) Sector
Y) Disk
Z) Annulus

ANSWER: Z) Annulus

BONUS

6) Math - *Short Answer* What is the area of the largest equilateral triangle that can be inscribed in a square with side length 1?

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

TOSS-UP

7) Energy - *Short Answer* Researchers at Stanford's TomKat Center for Sustainable Energy are manufacturing thin films for use as battery electrolytes. What type of crystal growth involves the formation of crystalline thin film layers from a specific substrate?

ANSWER: Epitaxy

BONUS

7) Energy - *Short Answer* Scientists at the Geballe Laboratory for Advanced Materials at Stanford University are studying cellular-automaton methods for quantum error correction in the noisy toric code. On a 2×2 toric lattice, there are 8 physical qubits that encode 2 logical qubits. What is the ratio of the dimensions of the physical to the logical Hilbert space?

ANSWER: 64

TOSS-UP

8) Earth and Space - *Short Answer* What term describes the phenomenon where downgoing oceanic crust at a subduction zone is thrust onto an adjacent tectonic plate?

ANSWER: Obduction

BONUS

8) Earth and Space - *Multiple Choice* Which of the following best explains how rock fins develop?

W) Fins form as tectonic activity leads to vertical fracturing of rock layers
X) Fins form as decreasing pressure peels away concentric layers of rock from an igneous intrusion
Y) Fins form as water infiltrates joints in rock and erodes them further
Z) Fins form as lava from volcanic eruptions cools in thin sheets

ANSWER: Y) Fins form as water infiltrates joints in rock and erodes them further

TOSS-UP

9) Chemistry - *Multiple Choice* In a redox titration with Fe^{2+} to Fe3+ and Ce^{4+} to Ce3+ in acidic solution, which of the following statements is true at the equivalence point?

W) The concentration of Fe2+ and Ce4+ will be equal
X) The cell potential at the equivalence point is the average of the two standard reduction potentials of the half reactions
Y) The cell potential will be zero
Z) The cell potential equals the potential of the reference electrode used in the titration

ANSWER: X) The cell potential at the equivalence point is the average of the two standard reduction potentials of the half reactions

BONUS

9) Chemistry - *Multiple Choice* The Zimmerman-Traxler transition state in aldol reactions predicts which of the following stereochemical outcomes?

W) The Z isomer enolate results in anti addition and the E isomer enolate results in syn addition
X) The Z isomer enolate results in anti addition and the E isomer enolate results in anti addition
Y) The Z isomer enolate results in syn addition and the E isomer enolate results in anti addition
Z) The reaction produces a racemic mixture for Z and E isomers

ANSWER: Y) The Z isomer enolate results in syn addition and the E isomer enolate results in anti addition

TOSS-UP

10) Math - *Short Answer* Let $f(n) = \frac{n+1}{4}$. What is the smallest integer value of n for which $f(f(n))$ is a positive integer?

ANSWER: 11

BONUS

10) Math - *Multiple Choice* Which of the following describes the locus of points in the complex plane satisfying $|z-3-3i| = |z+3+3i|$ **[the magnitude of the quantity z minus 3 minus 3i equals the magnitude of the quantity z plus 3 plus 3i]**?

W) The real axis
X) The imaginary axis
Y) The line passing through the origin and $1+i$
Z) The line passing through the origin and $1-i$

ANSWER: Z) The line passing through the origin and $1-i$

TOSS-UP

11) Biology - *Short Answer* Identify all of the following three groups that are paraphyletic: 1) Reptilia; 2) Zygomycota; 3) Osteichthyes.

ANSWER: 1 and 2

BONUS

11) Biology - *Short Answer* An accumulation of misfolded proteins in the ER leads to mass retrotranslocation and subsequent protein degradation. Order the following three enzymes that the misfolded protein comes in contact with from first to last leading up to proteasome degradation: 1) E3 ligase; 2) Disulfide isomerase; 3) Ubiquitin.

ANSWER: 2, 1, 3

TOSS-UP

12) Earth and Space - *Multiple Choice* A binary star system consists of a visible red giant and a massive but very dark companion oriented such that the two stars never obscure each other. This binary system most likely falls under which of the following classifications?

W) Astrometric binary
X) Eclipsing binary
Y) Spectroscopic binary
Z) Visual binary

ANSWER: Y) Spectroscopic binary

BONUS

12) Earth and Space - *Multiple Choice* Which of the following statements regarding Seyfert **[READ: see-fert]** galaxies is false?

W) Both Type I and Type II Seyferts are considered radio-quiet
X) Type II Seyferts contain large radio lobes that extend beyond the galaxy
Y) Type I Seyferts have broader emission lines than Type II Seyferts
Z) Both Type I and Type II Seyferts lack visible accretionary disks

ANSWER: X) Type II Seyferts contain large radio lobes that extend beyond the galaxy

TOSS-UP

13) Chemistry - *Short Answer* Identify all of the following three cations that will cause a sodium alginate solution to polymerize by cross-linking: 1) Na^+; 2) Mg_2^+; 3) Ca_2^+.

ANSWER: 2 and 3

BONUS

13) Chemistry - *Short Answer* Most SN1 reactions do not produce a purely racemic mixture because the inversion product is slightly favored. This is due to the fact that the leaving group anion is temporarily and loosely electrostatically associated with carbocation, which shields that side of the carbocation from nucleophilic attack. What concept explains this phenomenon?

ANSWER: Intimate ion pair (ACCEPT: ion pair)

TOSS-UP

14) Math - *Short Answer* A probability distribution is equal to zero everywhere except for where the absolute value of x is less than or equal to a, where it has a constant value. What name is given to the function defined as the limit of this distribution as a goes to zero?

ANSWER: Dirac delta function (ACCEPT: Delta function)

BONUS

14) Math - *Short Answer* Let z be a complex number that satisfies the equation $z^2+z+1=0$. Identify all of the following three values that are possible values of z^{10}: 1) 1; 2) $e^{2\pi i/3}$ **[e to the power of the quantity 2 pi i over 3]**; 3) $e^{4\pi i/3}$.

ANSWER: 2 and 3

TOSS-UP

15) Physics - *Multiple Choice* Which of the following best describes the functional form of the current-voltage characteristic of an ideal diode?

W) Linear passing through the origin
X) Linear with a nonzero y-intercept
Y) Exponential passing through the origin
Z) Exponential with a nonzero y-intercept

ANSWER: Y) Exponential passing through the origin

BONUS

15) Physics - *Short Answer* Assuming $c = 1$, what are the timelike and spacelike components, respectively, of the four-current density?

ANSWER: Charge density and current density

TOSS-UP

16) Energy - *Multiple Choice* Researchers in the Stanford Machine Learning Group are working on improving the practicality of machine learning algorithms. Which of the following techniques is most effective for preventing overfitting in a neural network?

W) Increasing learning rate
X) Adding new hidden layers
Y) Adding new activation functions
Z) Introducing dropout

ANSWER: Z) Introducing dropout

BONUS

16) Energy - *Short Answer* Researchers in the Kapitulnik group at Stanford are building a sensitive interferometer to detect rotation. Rather than using a mechanical gyroscope to prevent rotation, the most sensitive interferometers take advantage of what effect, which causes a phase difference in the output of the interferometer when rotation occurs?

ANSWER: Sagnac effect

TOSS-UP

17) Biology - *Short Answer* During an eccentric contraction, identify all of the following three regions of a sarcomere that would increase in length: 1) A band; 2) I band; 3) H zone.

ANSWER: 2 and 3

BONUS

17) Biology - *Short Answer* In a hypothetical organism, skin color is controlled by three genes following a polygenic inheritance pattern with a capital dark-skin allele for each gene and a lowercase light-skin allele for each gene. The dark-skin alleles of each gene increase skin pigmentation by the same set unit, and the light-skin allele decreases skin pigmentation by the same set unit. If two individuals with the genotype aaBbCc **[little a little a big B little b big C little c]** are mated, what is the probability that the offspring will have lighter skin than the parents?

ANSWER: $\frac{5}{16}$

TOSS-UP

18) Math - *Short Answer* Let $z = e^{5\pi i/3}$ **[e to the power of the quantity 5 pi i over 3]**. What is the complex conjugate of $-z$?

ANSWER: $e^{4\pi i/3}$ (ACCEPT: $e^{-2\pi i/3}$, $-\frac{1}{2} - \frac{\sqrt{3}}{2}i$)

BONUS

18) Math - *Short Answer* A 2x2 covariance matrix can be represented as an ellipse. Which of the following expressions correctly calculates the area of this ellipse in terms of the eigenvalues of the matrix, λ_1 **[lambda 1]** and λ_2 **[lambda 2]**?

W) $\pi\lambda_1\lambda_2$ **[pi lambda 1 lambda 2]**
X) $\pi\sqrt{\lambda_1\lambda_2}$ **[pi times the square root of the quantity lamda 1 lambda 2]**
Y) $\pi(\lambda_1^2+\lambda_2^2)$ **[pi times the quantity lambda 1 squared plus lambda 2 squared]**
Z) $\pi\sqrt{\lambda_1^2+\lambda_2^2}$ **[pi times the square root of the quantity lambda 1 squared plus lambda 2 squared]**

ANSWER: X) $\pi\sqrt{\lambda_1\lambda_2}$

TOSS-UP

19) Earth and Space - *Short Answer* What is the name of the orogeny that took place from the Late Cretaceous to the early Paleogene and was primarily responsible for the creation of the Rocky Mountains?

ANSWER: Laramide orogeny

BONUS

19) Earth and Space - *Multiple Choice* Which of the following best explains why mid-ocean ridge basalts, or MORBs, are typically depleted in incompatible elements?

W) MORBs originate from a deep, undifferentiated mantle source rich in volatiles and alkalis
X) The source region of MORBs has undergone previous melt extraction, removing incompatible elements
Y) MORBs crystallize at higher pressures, preventing incompatible elements from entering the melt phase
Z) The rapid ascent and cooling of MORB magmas prevent incompatible elements from fractionating into the melt

ANSWER: X) The source region of MORBs has undergone previous melt extraction, removing incompatible elements

TOSS-UP

20) Chemistry - *Multiple Choice* Which of the following reactions would increase the oxidation state of carbon by two?

W) Hydrogenation of an alkene
X) Keto to enol tautomerization
Y) Lithium aluminum hydride on an amide
Z) Pyridinium chlorochromate on a secondary alcohol

ANSWER: Z) Pyridinium chlorochromate on a secondary alcohol

BONUS

20) Chemistry - *Multiple Choice* How many stereoisomers of 1,3,5-trimethylcyclohexane are meso?

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

ANSWER: X) 2

TOSS-UP

21) Biology - *Short Answer* In a lab, there are two different species of bacteria named Species A and Species B. Species A has an ampicillin-resistant gene in its chromosome while Species B does not possess resistance. Identify all of the following three methods by which Species B can gain antibiotic resistance from Species A: 1) Forming a mating bridge with an F+ cell from Species A; 2) Being infected by a lambda bacteriophage produced by ruptured Species A bacterium; 3) Uptake of single-stranded DNA in the environment, originating from dead Species A cells.

ANSWER: 2 and 3

BONUS

21) Biology - *Short Answer* In the formation of triplex DNA, a protonated cytidine residue can base pair with the guanosine of an existing guanine-cytosine pair. What type of base pairing is exhibited in this interaction?

ANSWER: Hoogsteen pairing

TOSS-UP

22) Physics - *Multiple Choice* Consider an electron originally in the spin-up state in the $+z$ direction. A measurement of its spin is made in the x direction, where a spin of $+x$ is measured with probability p_1. Immediately afterward, a measurement of its spin is made in the z direction again, where a spin of $+z$ is measured with probability p_2. What are the values of p_1 and p_2, respectively?

W) $0, 1$
X) $\frac{1}{2}, 1$
Y) $\frac{1}{2}, \frac{1}{2}$
Z) $1, 1$

ANSWER: Y) $\frac{1}{2}, \frac{1}{2}$

BONUS

22) Physics - *Short Answer* The spin of an electron can be described by the Pauli matrices, a set of three 2×2 matrices. Identify all of the following three statements that are true of the Pauli matrices: 1) They contain only real entries; 2) They have only real eigenvalues; 3) They are symmetric.

ANSWER: 2 only

TOSS-UP

23) Earth and Space - *Short Answer* Between the crust and quark-gluon plasma of a neutron star, the nuclear attraction of neutrons and protons is thought to create a form of degenerate matter with several uniquely-shaped structures. What term is given to this theoretical type of matter?

ANSWER: Nuclear pasta

BONUS

23) Earth and Space - *Short Answer* One of the leading theories for dark matter depends on the existence of the axion. Identify all of the following three statements that are true regarding axions: 1) They can be converted into photons under strong magnetic fields; 2) They could be a solution to the strong CP problem; 3) Large numbers of them were likely created during the Big Bang.

ANSWER: ALL (ACCEPT: 1,2,3)