DOUBLE ELIMINATION 8

TOSS-UP

1) Math - *Short Answer* What is the expected sum of a randomly chosen non-empty subset of $\{1,2,3,4\}$ **[the set 1, 2, 3, 4]**?

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

BONUS

1) Math - *Short Answer* A function $F(x,y) = (x^3y, 2x-3y)$ **[F of x comma y equals x cubed y comma two x minus three y]** has gradient function $g(x,y) = (P(x,y), Q(x,y))$. What is the value of $\frac{\partial P}{\partial y} - \frac{\partial Q}{\partial x}$ **[partial P partial y minus partial Q partial x]**?

ANSWER: 0

TOSS-UP

2) Earth and Space - *Multiple Choice* Which of the following best explains why deep confined aquifers sometimes exhibit unusually high hydraulic heads relative to local topography?

W) Fossil groundwater retains pressure from past recharge conditions
X) Influx of deep magmatic fluids increases pressure over time
Y) Water leaks downward from overlying aquifers due to excessive pumping
Z) Compressibility of aquitard clays causes hydraulic rebound

ANSWER: W) Fossil groundwater retains pressure from past recharge conditions

BONUS

2) Earth and Space - *Short Answer* Identify all of the following three processes that would likely result in crystal zoning: 1) Melt differentiation; 2) Infusion of new magma; 3) Infusion of volatiles.

ANSWER: 1 and 2

TOSS-UP

3) Chemistry - *Short Answer* In order to synthesize polymers of 1-alkenes like LDPE or HDPE, a special catalyst needs to be used in order to control the stereochemical outcome of the monomer sidechains. What is the name of this class of catalysts?

ANSWER: Ziegler-Natta catalysts

BONUS

3) Chemistry - *Short Answer* In crystal field theory, identify all of the following three properties that will affect the splitting energy of a complex: 1) Strength of field ligand; 2) Oxidation state of metal; 3) Nuclear spin of metal.

ANSWER: 1 and 2

TOSS-UP

4) Biology - *Multiple Choice* Edwin is investigating the glyoxylate cycle by radioactively labeling the carbons of certain citric acid intermediates. To ensure he can track the transformation of all intermediates within the glyoxylate cycle, which of the following compounds should he most likely avoid labeling?

W) Citrate
X) Malate
Y) Succinate
Z) Oxaloacetate

ANSWER: Y) Succinate

BONUS

4) Biology - *Short Answer* In a male fruit fly, nondisjunction of the sex chromosomes occurs during meiosis II, leading to the production of an abnormal gamete. When the abnormal gamete undergoes fertilization with a regular female gamete, the result is a male offspring. Identify all of the following four genotypes that this offspring can possess: 1) X0 **[X-oh]**; 2) Y0 **[Y-oh]**; 3) XYY; 4) XXY.

ANSWER: 1 and 3

TOSS-UP

5) Energy - *Multiple Choice* Researchers in the Surface Processes Lab at Stanford recently analyzed a sand grain sample containing markers of erosion from both sand dunes and glacial activity during the same time period. Which of the following geologic periods is this sample most likely from?

W) Cambrian
X) Cryogenian
Y) Ediacaran
Z) Permian

ANSWER: X) Cryogenian

BONUS

5) Energy - *Short Answer* Scientists in the Baxter Lab at Stanford are studying transmembrane beta barrels in bacterial cells. Identify all of the following 3 amino acids one would expect to find on the inside of a beta barrel: 1) Threonine; 2) Phenylalanine; 3) Proline.

ANSWER: 1 and 3

TOSS-UP

6) Math - *Short Answer* Identify all of the following three statements that must be true of an invertible $n \times n$ matrix: 1) It has rank less than n; 2) Its columns are linearly independent; 3) All its eigenvalues are nonzero.

ANSWER: 2 and 3

BONUS

6) Math - *Multiple Choice* Let A be the 2×2 matrix $\begin{bmatrix} 2 & 0 \\ 2 & 5 \end{bmatrix}$ **[first row 2 0, second row 2 5]**. Which of the following best describes the shape of the set Ax where x varies over the square $[0,1] \times [0,1]$ **[0 1 cross 0 1]**?

W) Line
X) Square
Y) Rectangle
Z) Parallelogram

ANSWER: Z) Parallelogram

TOSS-UP

7) Physics - *Multiple Choice* A spherical planet of radius R and constant density has gravitational acceleration g on its surface. A straight tunnel is dug between the poles of the planet and an object is dropped into the hole at the North Pole. Neglecting friction and air resistance, how long will it take for the object to emerge at the South Pole?

W) $\frac{\pi}{\sqrt{gR}}$
X) $\pi\sqrt{\frac{g}{R}}$
Y) $\pi\sqrt{\frac{R}{g}}$
Z) $\pi\sqrt{gR}$

ANSWER: Y) $\pi\sqrt{\frac{R}{g}}$

BONUS

7) Physics - *Multiple Choice* A sinusoidal standing wave defined by $\sin(kx)\cos(\omega t)$ **[sine of k x times cosine of omega t]** is excited on a string, which is fixed on both ends. Which of the following sets of functions correctly describes the oscillation of potential and kinetic energy, respectively?

W) $\cos(\omega t)$, $\cos(\omega t)$
X) $\cos^2(\omega t)$, $\cos^2(\omega t)$
Y) $\cos(\omega t)$, $\sin(\omega t)$
Z) $\cos^2(\omega t)$, $\sin^2(\omega t)$

ANSWER: Z) $\cos^2(\omega t)$, $\sin^2(\omega t)$

TOSS-UP

8) Chemistry - *Multiple Choice* Which of the following reactions would be most suitable for reducing the ketone group of a molecule that contains other functional groups sensitive to both strong acidic and basic conditions?

W) Clemmensen reduction
X) Wolff–Kishner reduction
Y) Mozingo reduction
Z) Birch reduction

ANSWER: Y) Mozingo reduction

BONUS

8) Chemistry - *Short Answer* Order the following three dienophiles from least to most reactive in a Diels-Alder reaction: 1) Methyl acrylate, 2) Maleic anhydride, 3) 1,4-benzoquinone.

ANSWER: 1, 2, 3

TOSS-UP

9) Energy - *Multiple Choice* Scientists in the Fisher group at Stanford are studying quantum magnetism in spin dimer **[DIE-mer]** compounds. Consider a spin dimer which consists of a pair of spin-1 particles. Which of the following is NOT possible for the total spin state of the system, in terms of total spin s with z-component m?

W) $s = 0$ and $m = 0$
X) $s = 1$ and $m = 1$
Y) $s = 1$ and $m = 2$
Z) $s = 2$ and $m = -2$

ANSWER: Y) $s = 1$ and $m = 2$

BONUS

9) Energy - *Short Answer* Researchers in the Kavli Institute at Stanford are using the Sunyaev-Zeldovich effect to search for new galaxies. Identify all of the following three quantities that, when increased, would make the Sunyaev-Zeldovich effect more detectable: 1) Mean galaxy rotation rate; 2) Mean galaxy temperature; 3) Mean photon energy.

ANSWER: 1 and 2

TOSS-UP

10) Earth and Space - *Short Answer* Fractures on the surface of Europa are colored slightly red in contrast to its bright icy crust. What group of organic compounds is thought to be responsible for this reddish color, which is seen on many outer solar system bodies?

ANSWER: Tholins

BONUS

10) Earth and Space - *Short Answer* Following the first dredge-up of low- to intermediate-mass red giant stars, what two elements primarily compose the star's core?

ANSWER: Helium and nitrogen

TOSS-UP

11) Biology - *Multiple Choice* At the current point in the cardiac cycle, the ventricular pressure is greater than atrial pressure, and aortic pressure is greater than ventricular pressure. If pressure is increasing in the ventricles, what stage of the cardiac cycle is being represented?

W) Ventricular filling
X) Ventricular ejection
Y) Isovolumetric relaxation
Z) Isovolumetric contraction

ANSWER: Z) Isovolumetric contraction

BONUS

11) Biology - *Multiple Choice* Phosphoenolpyruvate to pyruvate is an irreversible step, so in gluconeogenesis, oxaloacetate is required as an intermediate in the eventual conversion of pyruvate to PEP. What cofactor is required for oxaloacetate formation?

W) Thiamine
X) Riboflavin
Y) Niacin
Z) Biotin

ANSWER: Z) Biotin

TOSS-UP

12) Physics - *Multiple Choice* Which of the following differential equations most accurately describes the electrostatic potential of a configuration of charges?

W) Laplace's equation
X) Poisson's equation
Y) Helmholtz equation
Z) Wave equation

ANSWER: X) Poisson's equation

BONUS

12) Physics - *Short Answer* Above the Curie temperature T_C, the magnetic susceptibility of a ferromagnet is governed by the Curie-Weiss law, which has critical exponent $\gamma = 1$. What is the ratio of the susceptibility at temperature $2T_C$ to the susceptibility at temperature $3T_C$?

ANSWER: 2

TOSS-UP

13) Chemistry - *Multiple Choice* To determine the composition of a metal's surface, a scientist analyzes the energy of electrons emitted due to the transfer of energy from relaxation events within the metal. Which of the following techniques is the scientist using?

W) Auger electron spectroscopy
X) Energy-dispersive X-ray spectroscopy
Y) Inductively coupled plasma atomic emission spectroscopy
Z) Positron emission tomography

ANSWER: W) Auger electron spectroscopy

BONUS

13) Chemistry - *Short Answer* 2-methyl-2-butene undergoes allylic bromination. How many possible monobrominated products can be formed, including stereoisomers?

ANSWER: 6

TOSS-UP

14) Math - *Multiple Choice* Which of the following expressions is equivalent to the natural logarithm of -1?

W) i
X) πi
Y) $-\pi i$
Z) $\ln \pi i$

ANSWER: X) πi

BONUS

14) Math - *Multiple Choice* A multivariate normal distribution is spherically symmetric. Its covariance matrix is best described as which of the following types of matrices?

W) Identity
X) Diagonal
Y) Negative semidefinite
Z) Singular

ANSWER: X) Diagonal

TOSS-UP

15) Biology - *Multiple Choice* CRISPR-Cas 9 is used to modify a certain gene to include a GFP-coding sequence at the end of it. Which of the following is not true about this process?

W) A double-stranded donor DNA containing the GFP-coding sequence is introduced into the cell
X) Nonhomologous end joining repairs the double-stranded break caused by Cas9
Y) TracrRNA is linked to crRNA to form the guide RNA
Z) A protospacer adjacent motif must be present upstream of the gene of interest for Cas9 to cleave the sequence

ANSWER: X) Nonhomologous end joining repairs the double-stranded break in DNA caused by Cas9

BONUS

15) Biology - *Short Answer* Identify all of the following three types of antibodies that can active the classical pathway of the complement system: 1) IgA; 2) IgG; 3) IgM.

ANSWER: 2 and 3

TOSS-UP

16) Earth and Space - *Multiple Choice* The shape of rising mantle plumes is analogous to that of a mushroom cloud at Earth's surface. This is because both features are described by which of the following physical phenomena?

W) Bennet-Diaz discordance
X) Rayleigh-Taylor instability
Y) Taylor-Couette instability
Z) Kelvin-Helmholtz instability

ANSWER: X) Rayleigh-Taylor instability

BONUS

16) Earth and Space - *Multiple Choice* Which of the following soil types has the greatest amount of water available for plants?

W) Clay loam
X) Silty loam
Y) Sand
Z) Clay

ANSWER: X) Silty loam

TOSS-UP

17) Chemistry - *Multiple Choice* Which of the following heterocyclic nitrogen-containing compounds is NOT aromatic?

W) Pyrrole
X) Pyrrolidine
Y) Pyridine
Z) Pyrimidine

ANSWER: X) Pyrrolidine

BONUS

17) Chemistry - *Multiple Choice* In a crystal lattice, the edge length of a cubic unit cell is a, and the radius of the constituent atoms is r. Which of the following is the correct relationship between a and r for a body-centered cubic structure?

W) $a = 2r$
X) $a = 4r$
Y) $a = 4r/\sqrt{2}$
Z) $a = 4r/\sqrt{3}$

ANSWER: Z) $a = 4r/\sqrt{3}$

TOSS-UP

18) Physics - *Multiple Choice* A dart is thrown with speed v from a point on flat ground. Neglecting air resistance, what shape describes the boundary of the locus of all points in three dimensions that can be hit by the dart?

W) Hemisphere
X) Ellipsoid
Y) Paraboloid
Z) Hyperboloid

ANSWER: Y) Paraboloid

BONUS

18) Physics - *Multiple Choice* A two-level system with energy states $+E$ and $-E$ is in thermal equilibrium at temperature T. Which of the following is the partition function of this system?

W) $2\cosh(\frac{E}{k_B T})$ **[READ: 2 cosh of the quantity E over k b times T]**
X) $2\sinh(\frac{E}{k_B T})$ **[READ: 2 sinch of the quantity E over k b times T]**
Y) $-2\sinh(\frac{E}{k_B T})$ **[READ: negative 2 sinch of the quantity E over k b times T]**
Z) $2\tanh(\frac{E}{k_B T})$ **[READ: 2 tanch of the quantity E over k b times T]**

ANSWER: W) $2\sinh(\frac{E}{k_B T})$

TOSS-UP

19) Math - *Multiple Choice* Chinese Santa needs to wrap 1 billion gifts for Chinese New Year, where the n-th gift is shaped like a cube with side length $1/n$. If he randomly picks a gift to wrap, the average amount of gift wrap he will need in square units is closest to which of the following?

W) 10^{-10}
X) 10^{-9}
Y) 10^{-8}
Z) 10^{-7}

ANSWER: Y) 10^{-8}

BONUS

19) Math - *Short Answer* Let X be a random real number drawn uniformly from 0 to 1. What is the probability that $-\lfloor \log_2 X \rfloor$ **[the floor of negative log base 2 of x]** is even?

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

TOSS-UP

20) Biology - *Short Answer* Two strains of yeast are growing in leucine-rich mediums. From prior testing, it has been concluded that both yeasts cannot synthesize the amino acid leucine. However, when an a **[A]** type haploid yeast cell mates with an alpha type haploid yeast cell of the other strain, the produced diploid yeast cell can grow in a leucine-deficient medium. What phenomenon that can be used to test if two different mutations are in separate genes is being demonstrated in this example?

ANSWER: Complementation

BONUS

20) Biology - *Multiple Choice* Which of the following is true about arbuscular mycorrhizae?

W) Arbuscular mycorrhizae are much more commonly found than ectomycorrhizae
X) The fungus exchanges nutrients with plants primarily within the vascular cylinder
Y) Hyphae penetrate the cell membrane of plant cells
Z) A mantle of mycelia forms over the surface of the plant's roots

ANSWER: W) Arbuscular mycorrhizae are much more commonly found than ectomycorrhizae

TOSS-UP

21) Earth and Space - *Multiple Choice* In which of the following types of meteorites would kamacite and taenite most likely be found?

W) Chondrite
X) Iron
Y) Mesosiderite
Z) Pallasite

ANSWER: X) Iron

BONUS

21) Earth and Space - *Multiple Choice* Which of the following statements is NOT true regarding solar faculae?

W) They are brighter than the surrounding photosphere
X) They are located between granules
Y) They are most often seen towards the solar limb
Z) They are associated with weak magnetic fields

ANSWER: Z) They are associated with weak magnetic fields

TOSS-UP

22) Energy - *Short Answer* Scientists in the Blau Lab at Stanford are tracking the contractile function in cardiomyocytes derived from induced pluripotent stem cells. Oct3/4, Sox2, Klf4, and c-Myc are part of what set of transcription factors used to produce these induced pluripotent stem cells by reprogramming differentiated somatic cells?

ANSWER: Yamanaka factors

BONUS

22) Energy - *Multiple Choice* Researchers in the Vanorio group at Stanford are determining when carbon dioxide can be sequestered through natural methane-producing reactions, which require a metal catalyst such as nickel. Which of the following rock types would be most useful for these researchers' purposes?

W) Komatiite
X) Rhyolite
Y) Sanidinite
Z) Serpentinite

ANSWER: Z) Serpentinite

TOSS-UP

23) Physics - *Multiple Choice* Which of the following correctly gives the Lagrangian for an ideal pendulum with length ℓ, mass m, and oscillating in a gravitational field with strength g, where θ is the angle away from the vertical?

W) $\frac{1}{2}m\ell^2\dot{\theta}^2 + mg\ell\cos\theta$ **[one half m ℓ squared d theta squared plus m g ℓ cosine theta]**
X) $\frac{1}{2}m\ell^2\dot{\theta}^2 - mg\ell\cos\theta$
Y) $-\frac{1}{2}m\ell^2\dot{\theta}^2 + mg\ell\cos\theta$
Z) $-\frac{1}{2}m\ell^2\dot{\theta}^2 - mg\ell\cos\theta$

ANSWER: W) $\frac{1}{2}m\ell^2\dot{\theta}^2 + mg\ell\cos\theta$

BONUS

23) Physics - *Multiple Choice* A qubit has an initial state of (1,0) before the Hadamard gate is applied to it. What is the final state of the qubit?

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

ANSWER: Z) $(\frac{\sqrt{2}}{2},\frac{\sqrt{2}}{2})$