2024 SMH Invitational Cup - DOUBLE ELIMINATION 6

TOSSUP

1) Biology – *Multiple Choice* Which of the following values for an enzyme's Hill coefficient indicates that the enzyme displays no cooperativity?
W) 0
X) 0.5
Y) 1
Z) 1.5

ANSWER: Y) 1 [SO]

BONUS

1) Biology – *Short Answer* What cell type, found only in the stomach, secretes mucus to prevent the digestion of the stomach wall?

ANSWER: FOVEOLAR CELL (ACCEPT: SURFACE MUCOUS CELL, DO NOT ACCEPT: GOBLET CELL) [SO]

TOSSUP

2) Chemistry – *Multiple Choice* Why does sodium hydroxide act as a catalyst for hemiacetal formation?
W) It forms an adduct with the carbonyl group
X) It strengthens the electrophilicity of the carbonyl group
Y) It strengthens the nucleophilicity of the alcohol
Z) It stabilizes the resulting hemiacetal

ANSWER: Y) It strengthens the nucleophilicity of the alcohol [CZ]

BONUS

2) Chemistry – *Multiple Choice* Which of the following products can be produced by both the oxidative and reductive workup of an ozonide after the ozonolysis of an alkene?
W) Formaldehyde
X) Carbon dioxide
Y) Acetone
Z) Acetic acid

ANSWER: Y) Acetone [CZ]

TOSSUP

3) Physics – *Short Answer* The continuity equation can be written in a differential form, which utilizes the time derivative of density alongside what vector operator?

ANSWER: DIVERGENCE [SO]

BONUS

3) Physics – *Short Answer* Suzuko has an ideal gas with molar heat capacity 24.9 J/mol K under isobaric processes. Assuming the ideal gas constant is equal to 8.3 J/mol K, when 83 Joules of heat are applied to one mole of the gas in an isochoric process, by how many Kelvin does the gas heat up?

ANSWER: 5 K [DL]

TOSSUP

4) Earth and Space – *Multiple Choice* Which of the following igneous rocks likely has the highest concentration of plagioclase feldspars?
W) Diorite
X) Gabbro
Y) Granite
Z) Peridotite

ANSWER: W) Diorite [PB]

BONUS

4) Earth and Space – *Short Answer* Identify all of the following three mantle structures that are associated with negative seismic wave velocity anomalies: 1) Mantle plumes; 2) Subducting slabs; 3) Crustal roots.

ANSWER: 1 only [PB]

TOSSUP

5) Math – *Short Answer* Identify all of the following 3 2 by 2 matrices that are considered to be in row-echelon form.
1) First row 0,0, second row 0,0
2) First row 0,0, second row 1,0
3) First row 1,0, second row 0,0

ANSWER: 1, 3 [RG]

BONUS

5) Math – *Short Answer* Consider the cubic P(x) = x^3 - 3x^2 + 7x - 10, which has distinct roots a, b, and c. Let Q(x) be a monic cubic with roots a^2, b^2, and c^2. What is the sum of the coefficients of Q?

ANSWER: -105 [RG]

TOSSUP

6) Biology – *Multiple Choice* Altair is using A. tumefaciens to study gene transfer. Which of the following organisms could he be working with?
W) D. melanogaster
X) E. coli
Y) lambda phage
Z) A. thaliana

ANSWER: Z) A. thaliana [SO]

BONUS

6) Biology – *Short Answer* Suzuko is studying the role of estradiol in the human body. Identify all of the following three signallers whose release is upregulated by estradiol: 1) prostaglandins, 2) growth hormone, 3) follicle-stimulating hormone.

ANSWER: 12 [SO]

TOSSUP

7) Chemistry – *Short Answer* What is the point group of the molecule methane?

ANSWER: Td [CZ]

BONUS

7) Chemistry – *Short Answer* How many filled antibonding orbitals are there in the peroxide anion, which has formula O2 2-?

ANSWER: 4 [CZ]

TOSSUP

8) Physics – *Multiple Choice* Connor is experimenting with a water-filled cylinder on the ground. He drills holes at evenly spaced intervals from the top to the bottom of the cylinder. He opens one hole at a time, measures the distance from the cylinder to where the water hits the ground, then closes it and proceeds to the next hole. Which of the following describes how the distance measured changes as distance from the top of the cylinder increases?
W) always increases
X) always decreases
Y) increases, then decreases
Z) decreases, then increases

ANSWER: Y) increases, then decreases [SO]

BONUS

8) Physics – *Short Answer* What theorem of DC circuit simplification replaces an arbitrary group of circuit elements with a current source and a resistance source in parallel?

ANSWER: Norton's Theorem [DL]

TOSSUP

9) Earth and Space – *Multiple Choice* Which of the following stellar classes has the most positive B-V color index?

W) O
X) A
Y) G
Z) M

ANSWER: Z) M [PB]

BONUS

9) Earth and Space – *Short Answer* Stars that do not undergo a helium flash can enter the instability strip during what stage of their evolution, characterized by a significant increase in temperature before they return to the asymptotic giant branch?

ANSWER: Blue loop [PB]

TOSSUP

10) Math – *Multiple Choice* Rohan, on a given day, sleeps at a random time between 12 am and 2 am chosen uniformly and at random. If he sleeps for a random time between 6 and 8 hours inclusive, what is the probability that he wakes up by 8 am?
W) 1/6
X) 1/4
Y) 1/3
Z) 1/2

ANSWER: Z) 1/2 [RG]

BONUS

10) Math – *Multiple Choice* How many nonempty subsets of the first 2024 positive integers exist such that the minimum and maximum sum up to 2025?
W) (2^2022-1)/3

X) (2^2024-1)/3
Y) 2^2022-1
Z) 2^2024-1

ANSWER: X) (2^2024-1)/3 [RG]

TOSSUP

11) Biology – *Short Answer* Identify all of the following three proteins which can be found in the I band of sarcomeres: 1) myosin, 2) actin, 3) titin.

ANSWER: 2 AND 3 [SO]

BONUS

11) Biology – *Multiple Choice* Which of the following statements is NOT true about AT-rich sequences?
W) they can be found at prokaryotic origins of replication
X) they can be found in eukaryotic promoters
Y) they have a lower melting temperature than GC-rich sequences
Z) they are relatively more common in euchromatin than heterochromatin

ANSWER: Z) they are relatively more common in euchromatin than heterochromatin [SO]

TOSSUP

12) Chemistry – *Short Answer* Rank the following 3 compounds from least to most likely to form a geminal diol in acidic conditions:
1) Acetone
2) Formaldehyde

3) 2-pentanone

ANSWER: 312 [CZ]

BONUS

12) Chemistry – *Short Answer* Rank the following 3 reducing agents by order of increasing strength:
1) Lithium aluminum hydride
2) Sodium borohydride
3) Sodium cyanoborohydride

ANSWER: 321 [CZ]

TOSSUP

13) Physics – *Short Answer* What coupling constant, obtained from applying perturbation theory to quantum electrodynamics, was originally interpreted as the ratio between an electron's speed in the first energy level of the Bohr model and the speed of light?

ANSWER: fine structure constant [DL]

BONUS

13) Physics – *Multiple Choice* A uniform and infinitely large plane of positive charge lies in the xy-plane and is moving with constant speed in the positive-x direction. Which of the following best describes the direction of the magnetic field experienced by a stationary observer at the point (0, 0, 1)?
W) positive y
X) negative y
Y) positive z
Z) negative z

ANSWER: X) negative y [BC]

TOSSUP

14) Earth and Space – *Short Answer* Recent studies of the spectral lines of kilonovae have found that the amount of elements heavier than iron is much lower than expected. This contradicts the dominance of what fusion process in the creation of neutron-rich isotopes of these heavy elements?

ANSWER: r-process [DL]

BONUS

14) Earth and Space – *Multiple Choice* Which of the following Cenozoic epochs had the strongest greenhouse effect and highest surface temperatures?

W) Eocene
X) Oligocene
Y) Pleistocene
Z) Holocene

ANSWER: W) Eocene [PB]

TOSSUP

15) Math – *Short Answer* Order the following 3 graphs in order of increasing chromatic number.
1) Star graph with 14 nodes
2) Complete graph with 4 nodes
3) Cycle graph with 27 nodes

ANSWER: 1, 3, 2 [RG]

BONUS

15) Math – *Short Answer* Consider the 2 by 2 matrix with first row 1, 4 and second row 3,4. If the eigenvalues of this matrix are x and y, find x^2 + y^2.

ANSWER: 41 [RG]

TOSSUP

16) Biology – *Multiple Choice* The leucine zipper motif is composed of two alpha helices wound around each other, both with leucine residues repeating at every 7th position. Which of the following interactions is most important in maintaining the quaternary structure of a leucine zipper?
W) disulfide bridges
X) hydrophobic interactions
Y) hydrogen bonds
Z) ionic bonds

ANSWER: X) hydrophobic interactions [SO]

BONUS

16) Biology – *Short Answer* In a certain population of humans, the three alleles in the ABO blood group all have equal frequency. Giving your answer to the nearest percent, what proportion of this population possesses a copy of the i allele AND are blood type A or B?

ANSWER: 44% [SO]

TOSSUP

17) Chemistry – *Multiple Choice* Connor would like to use fluoride as a nucleophile, but it does not react well in water. In an aprotic solvent, which of the following crown ethers would allow him to use the fluoride anion in potassium fluoride as a nucleophile?

W) 9-crown-3

X) 12-crown-4

Y) 15-crown-5

Z) 18-crown-6

ANSWER: Z) 18-crown-6 [CZ]

VISUAL BONUS

17) Chemistry – *Short Answer* The attached image shows the structure of allotropes of phosphorus. Answer the following two questions:

1) What allotropes of phosphorus are A, B, and C, respectively?
2) Order A, B, and C by increasing reactivity in standard conditions.



Answer: 1) A) White B) Black C) Red, 2) B, C, A

TOSSUP

18) Physics – *Short Answer* Contrary to Lagrangian mechanics, the fundamental quantity in Hamiltonian mechanics is a function of position and what other physical quantity it is conjugate with?

ANSWER: momentum (ACCEPT: generalized momentum) [DL]

BONUS

18) Physics – *Short Answer* A 2-coulomb charge is placed at the origin of a coordinate plane. What is the ratio of the energy density due to its electric field at a distance of 2 meters away and a distance of 4 meters away from the origin?

ANSWER: 16:1 [DL]

TOSSUP

19) Earth and Space – *Multiple Choice* Which of the following values for the density parameter would result in a universe whose local geometry must be modeled hyperbolically?

W. 0
X. 0.8
Y. 1
Z. 1.2

ANSWER: X. 0.8 [DL]

BONUS

19) Earth and Space – *Multiple Choice* Which of the following conditions in magma is NOT typically associated with the formation of pegmatites?

W) Very slow cooling
X) Low viscosity
Y) Low silica content
Z) High volatile content

ANSWER: Y) Low silica content [PB]

TOSSUP

20) Math – *Short Answer* Identify all of the following 3 positive integers n for which a regular n-gon is constructible with a straightedge and compass.

1) 10

2) 16

3) 17

ANSWER: All [RG]

BONUS

20) Math – *Short Answer* Starting at the origin, Boheng wants to go to the point (3,4), then touch the x-axis, and then go to the point (4,5). What is the minimum possible length of their path?

ANSWER: 5 + sqrt(82) [RG]
