2024 SMH Invitational Cup - DOUBLE ELIMINATION 4

TOSSUP

1) Biology – *Multiple Choice* After carbonic anhydrase converts carbon dioxide into carbonic acid, several ions are transported across an erythrocyte membrane to facilitate respiration. Which of the following correctly describes this ion transport?

W) hydrogen in, sodium out

X) sodium in, potassium out

Y) nitrate in, bicarbonate out

Z) bicarbonate in, chloride out

ANSWER: Z) bicarbonate in, chloride out [SO]

BONUS

1) Biology – *Short Answer* Connor is studying protein synthesis and export in a eukaryotic cell. After performing a genome-wide knockout of a certain sequence, he observes that there no longer seemed to be ribosomes attached to the rough endoplasmic reticulum. What is the name of the sequence that Connor targeted?

ANSWER: SIGNAL SEQUENCE [SO]

TOSSUP

2) Chemistry – *Multiple Choice* When adding electrons to a Sc^{3+} ion, which of the following correctly describes how the 4s and 3d subshells are filled, from first to last?

W) 4s, 4s, 3d

X) 3d, 4s, 4s

Y) 4s, 3d, 4s

Z) the subshells are degenerate

ANSWER: X) 3d, 4s, 4s [CZ]

BONUS

2) Chemistry – *Multiple Choice* The Lyman alpha and Balmer alpha lines are emitted when electrons transition exactly one energy level down in their respective spectral series. What is the ratio of the energy of the Lyman alpha line to the energy of the Balmer alpha line?
W) 16/9
X) 27/5
Y) 25/4
Z) 32/7

ANSWER: X) 27/5 [CZ]

TOSSUP

3) Physics – *Multiple Choice* Daniel is wrapping a roll of film. He wraps a constant amount of film per unit time. Assuming that the film has non-negligible thickness, which of the following best describes the graph of the moment of inertia of the rolled film about its central axis versus time?
W) increasing and concave up
X) increasing and concave down
Y) increasing linearly
Z) decreasing linearly

ANSWER: W) increasing and concave up [SO]

BONUS

3) Physics – *Short Answer* Kris observes the flow of a fluid in a pipe and notices a large number of eddies. Identify all of the following three statements which are likely true about the flow: 1) it is

associated with a high Reynolds number, 2) it has a small characteristic length, 3) the water is moving relatively quickly.

ANSWER: 1 and 3 [SO]

TOSSUP

4) Earth and Space – *Short Answer* Retrograde metamorphism often does not occur when metamorphic rocks are uplifted because it generally requires the input of what reactant, which is lost when rocks are subjected to heat and pressure?

ANSWER: Water [PB]

BONUS

4) Earth and Space – *Short Answer* Sahas is trying to determine the distance to Star A by calculating its absolute magnitude and observing its apparent magnitude. However, they forget to account for interstellar extinction, leading to their observed apparent magnitude being 5 units higher than the value with extinction factored in. How many times further away will Sahas think the star is, compared to its actual distance?

ANSWER: 10 [AS]

TOSSUP

5) Math – *Short Answer* The solutions to the equation x^4 - 1 = 0 are plotted on the complex plane. What is the area of the convex polygon that passes through these 4 points?

ANSWER: 2 [RG]

BONUS

5) Math – *Short Answer* Triangle ABC satisfies AB = 13, BC = 14, and AC = 15. Point I is the incenter of triangle ABC, and the incircle is tangent to AB and AC at points D and E, respectively. What is the area of quadrilateral ADIE?

ANSWER: 28 [RG]

TOSSUP

6) Biology – *Multiple Choice* Grace is researching the rate of mutations in cancer cells. When plotting the rate of mutation in a cell against time, which of the following relationships would Grace most likely expect?
W) constant
X) linear
Y) exponential
Z) sinusoidal

ANSWER: Y) exponential [SO]

BONUS

6) Biology – *Short Answer* Parallel to glycolysis, what anabolic pathway takes in glucose-6-phosphate and produces NADPH and ribose-5-phosphate?

ANSWER: pentose phosphate pathway [SO]

TOSSUP

7) Chemistry – *Multiple Choice* Connor measures diatomic oxygen gas at 300 K. Which of the following temperatures would his sample of sulfur dioxide gas have to be at so that the gas molecules have the same root mean square velocity?
W) 150 K
X) 300 K
Y) 600 K
Z) 1200 K

ANSWER: Y) 600 K [CZ]

BONUS

7) Chemistry – *Multiple Choice* Which of the following best describes the reaction that occurs when sodium cyanide is added to formaldehyde?
W) The sp hybridized nitrogen on cyanide attacks the sp2 hybridized carbon on formaldehyde
X) The sp hybridized nitrogen on cyanide attacks the sp3 hybridized carbon on formaldehyde
Y) The sp hybridized carbon on cyanide attacks the sp2 hybridized carbon on formaldehyde
Z) The sp hybridized carbon on cyanide attacks the sp3 hybridized carbon on formaldehyde

ANSWER: Y) The sp hybridized carbon on cyanide attacks the sp2 hybridized carbon on formaldehyde [CZ]

TOSSUP

8) Physics – *Short Answer* Identify all of the following three changes that would increase the de Broglie wavelength of a particle: 1) increasing its mass, 2) increasing its velocity, 3) increasing its spin.

ANSWER: none [SO]

BONUS

8) Physics – *Multiple Choice* Stephen constructs a buoy made of 2 identical spheres with mass separated by a massless rod. He places this buoy perfectly upright in still water and notices that the bottom sphere is completely submerged in the water. Which of the following best describes the equilibrium of this buoy?

W) stable

X) metastable

Y) unstable

Z) not in equilibrium

ANSWER: Y) unstable [SO]

TOSSUP

9) Earth and Space – *Short Answer* Forsterite and fayalite are the endmembers for the solid solution of what group of minerals?

ANSWER: Olivine [PB]

BONUS

9) Earth and Space – *Short Answer* Titus is looking at an image of a dark nebula taken by the Hubble Space Telescope and wants to see the stars behind it. Identify all of the following 3 telescope wavelengths which Titus a telescope could utilize.

1. Near Infrared
2. Visible
3. Far Infrared

ANSWER: 1 [AS]

TOSSUP

10) Math – *Multiple Choice* Which of the following accurately describes Torricelli's trumpet?
W) Finite surface area, finite volume
X) Infinite surface area, finite volume
Y) Finite surface area, infinite volume
Z) Infinite surface area, infinite volume

ANSWER: X) Infinite surface area, finite volume [RG]

BONUS

10) Math – *Short Answer* A right triangle has area 13 and hypotenuse of length 7. What is the perimeter of the triangle, to the nearest integer?

ANSWER: 17 [RG]

TOSSUP

11) Biology – *Short Answer* What plant immune response involves localized cell death around infected leaf cells?

ANSWER: HYPERSENSITIVE RESPONSE [SO]

BONUS

11) Biology – *Short Answer* Identify all of the following three structures that are derived from the mesoderm: 1) teeth, 2) humerus, 3) neural tube.

ANSWER: 2 ONLY [SO]

TOSSUP

12) Chemistry – *Short Answer* Daniel is using infrared spectroscopy. Order the following three bonds from lowest to highest wavenumber on an IR absorbance spectrum:

1) Carbon-carbon double bond
2) Carbon-carbon single bond
3) Carbon-carbon triple bond

ANSWER: 213 [CZ]

BONUS

12) Chemistry – *Short Answer* Order the following 3 compounds by increasing acidity:

1) Water
2) Phenol
3) Tert-butanol

ANSWER: 312 [CZ]

TOSSUP

13) Physics – *Short Answer* What vessel, often filled with a superheated transparent liquid, was used to detect electrically charged particles and contributed to the discovery of the W and Z Bosons?

ANSWER: Bubble chamber [DL]

BONUS

13) Physics – *Short Answer* Holding radius constant, the gravitational binding energy of an astronomical body is proportional to what power of the body's mass?

ANSWER: 2 [DL]

TOSSUP

14) Earth and Space – *Multiple Choice* The polar front occurs on average near which of the following latitudes?

W) 45°
X) 60°
Y) 75°
Z) 90°

ANSWER: X) 60° [PB]

BONUS

14) Earth and Space – *Short Answer* Order the following three types of asteroids in terms of increasing metal content: 1) C; 2) M; 3) S.

ANSWER: 132 [PB]

TOSSUP

15) Math – *Short Answer* A function from the integers mod 26 to itself is defined by f(x) = 3x+2 mod 26. Since this function is bijective, it also has an inverse. What is the inverse of 6?

ANSWER: 10 [RG]

BONUS

15) Math – *Short Answer* Compute the definite integral from pi/6 to pi/2 of cos(x) sqrt(cot^2(x)+1) dx [read: cosine x times square root of open parenthesis cotangent squared of x + 1 close parenthesis].

ANSWER: ln 2 [RG]

TOSSUP

16) Biology – *Multiple Choice* A scientist observing a cell notices an unusually high concentration of succinyl-CoA and an unusually low concentration of succinate. Which of the following compounds would he expect to be depleted in this cell?
W) alpha-ketoglutarate
X) citrate
Y) fumarate
Z) isocitrate

ANSWER: Y) fumarate [SO]

BONUS

16) Biology – *Short Answer* Order the following three types of reproduction from least to most parental support.
I. oviparity
II. viviparity
III. ovoviviparity

ANSWER: I, III, II [SO]

TOSSUP

17) Chemistry – *Short Answer* In the Claus process, hydrogen sulfide and sulfur dioxide are reacted to form elemental sulfur. This is an example of what type of reaction, in which two reactants that have the same element in two different oxidation states form a single product with an intermediate oxidation state?

ANSWER: comproportionation (accept: symproportionation) [CZ]

BONUS

17) Chemistry – *Short Answer* Which halogen forms the least stable ionic compounds with silver?

ANSWER: Fluorine [CZ]

TOSSUP

18) Physics – *Multiple Choice* Which of the following correctly gives units for surface tension?
W) joules
X) newtons
Y) joules per meter
Z) newtons per meter

ANSWER: Z) newtons per meter [SO]

BONUS

18) Physics – *Short Answer* Edwin is studying SQUIDs. These devices use Josephson junctions to detect changes in what quantity?

ANSWER: magnetic field [CZ]

TOSSUP

19) Earth and Space – *Short Answer* Given that Mars is four times as far from the Sun as Mercury, what is the ratio of Mercury's orbital velocity to Mars' orbital velocity?

ANSWER: 2:1 (ACCEPT: 2) [PB]

BONUS

19) Earth and Space – *Multiple Choice* Which of the following best describes how western boundary currents typically compare to eastern boundary currents?
W) Slower and wider
X) Slower and thinner
Y) Faster and wider
Z) Faster and thinner

ANSWER: Z) Faster and thinner [PB]

TOSSUP

20) Math – *Short Answer* A polynomial has degree n. Identify all of the following 3 possible values of n for which the roots can always be solved for in terms of radicals.
1) 5
2) 6
3) 7

ANSWER: None [RG]

BONUS

20) Math – *Short Answer* Two real numbers are randomly chosen between 0 and 1. What is the probability the smaller number is less than the larger number squared?

ANSWER: 2/3 [RG]