2024 SMH Invitational Cup - FINALS 2

TOSSUP

1) Biology – *Multiple Choice* Connor is designing an artificial cell to mimic the conditions within a living eukaryotic cell and its organelles. Which of the following artificial organelles would it be accurate for Connor to place beta-mercaptoethanol in?
W) cytoplasm
X) endoplasmic reticulum
Y) peroxisome
Z) Golgi apparatus

ANSWER: W) cytoplasm [SO]

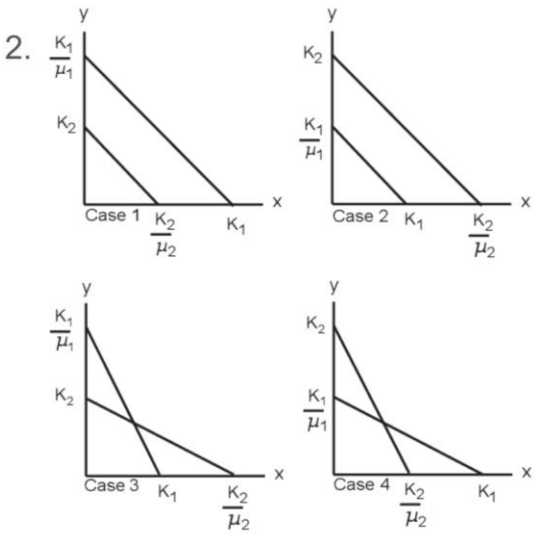
VISUAL BONUS

1) Biology – *Short Answer* Shown on the screen are two diagrams labeled 1 and 2. Answer the following two questions about these diagrams.
1. The diagram labeled 1 is a payoff matrix for a hypothetical interaction. The number in each cell represents the payoff for the organism using the strategy labeled on the left against an organism using the strategy labeled on the top of the matrix. Which of the three strategies X, Y, or Z, is the evolutionarily stable strategy in this interaction?
2. The diagram labeled 2 represents the interaction between 2 species on their population sizes. What is the name of the model that this diagram represents?

1.

	X	Y	Z
X	8	5	3
Y	9	7	4
Z	7	6	3

2.



ANSWER: 1. Y; 2. Lotka-Volterra [SO]

TOSSUP

2) Chemistry – *Multiple Choice* Note to players from Anurag and Dan Ni: lock in bro. Which of the following series of reagents does not produce the same product as the other three?

W) addition of sodium cyanide to 1-bromobutane followed by sulfuric acid

X) ozonolysis and oxidative cleavage of 1-pentyne

Y) treatment of carbon dioxide with propylmagnesium bromide followed by acidic workup

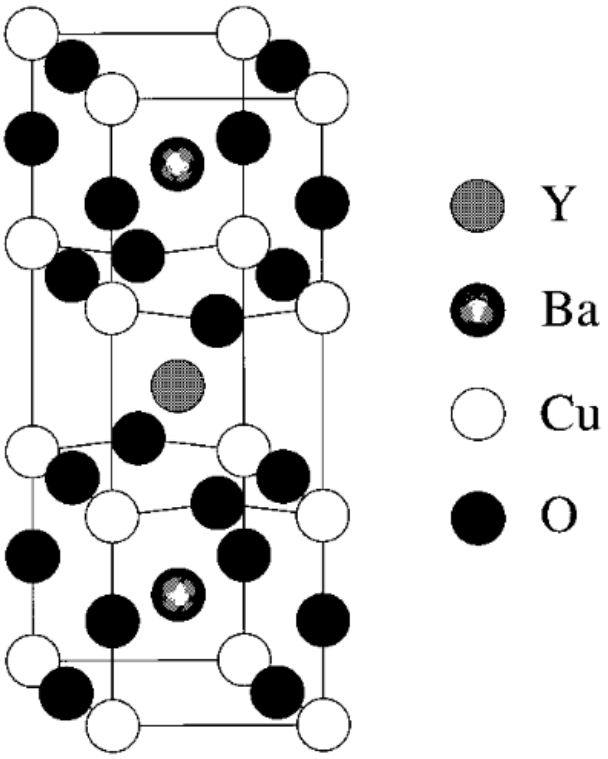
Z) addition of strong acid to propyl butanoate

ANSWER: W) addition of sodium cyanide to 1-bromobutane followed by sulfuric acid [CZ]

BONUS

2) Chemistry – *Short Answer* The attached image shows a diagram of YBCO, a high temperature superconductor. Answer the following two questions about YBCO:

1) Is YBCO a Type I or Type II superconductor?
2) Based on the diagram, what is the formula of the unit cell?



ANSWER: 1) Type II, 2) $YBa_2Cu_3O_7$ [CZ]

TOSSUP

3) Physics – *Multiple Choice* Which of the following best describes the local symmetry group in quantum electrodynamics?

W. U(1)
X. SU(2)
Y. U(2)
Z. SU(3)

ANSWER: W. U(1) [DL]

BONUS

3) Physics – *Short Answer* What is the moment of inertia of a spherical shell with inner radius 1 meters, outer radius 2 meters, and uniform mass density 15 kilograms per meter cubed?

ANSWER: 248pi [SO]

TOSSUP

4) Earth and Space – *Multiple Choice* Which of the following most accurately describes how the concentration of helium changes with distance from the surface in a red dwarf?

W) Uniformly increases
X) Uniformly decreases
Y) Increases, then decreases
Z) Does not change

ANSWER: Z) Does not change [PB]

BONUS

4) Earth and Space – *Short Answer* Order the following 4 rocks in the layer they would appear from top to bottom in a standard ophiolite sequence:

1) Chert
2) Dunite
3) Diabase
4) Basalt

ANSWER: 1432 [AS]

TOSSUP

5) Math – *Short Answer* Identify all of the following 3 statements that must be true about the kernel of a homomorphism.
1) It is a subgroup of the codomain.
2) If the kernel is trivial, the homomorphism is surjective.
3) All kernels are considered normal subgroups.

ANSWER: 3 only [RG]

BONUS

5) Math – *Short Answer* Edwin and Edwin's alter ego are moving in the coordinate plane and start at (0,0). Each second, they independently choose to move right or up 1 unit with equal probability. After 5 seconds, what is the probability they end up at the same spot?

ANSWER: 63/256 [RG]

TOSSUP

6) Biology – *Multiple Choice* Which of the following statements is false regarding inflammatory bowel disease?
W) Crohn's disease can be located anywhere in the GI tract
X) strictures are the abnormal narrowing of the intestines
Y) ingestion of dietary fiber is helpful in treating Crohn's disease
Z) treatment with glucocorticoids can cause osteoporosis

ANSWER: Y) ingestion of dietary fiber is helpful in treating Crohn's disease [SO]

BONUS

6) Biology – *Short Answer* Identify all of the following three respiratory disorders which are associated with decreased lung compliance: 1) infant respiratory distress syndrome, 2) fibrosis, 3) emphysema.

ANSWER: 1 and 2 [SO]

TOSSUP

7) Chemistry – *Short Answer* Carboxylic acids can be converted into acid chlorides using thionyl chloride. This reaction is driven forward by the evolution of which two gasses?

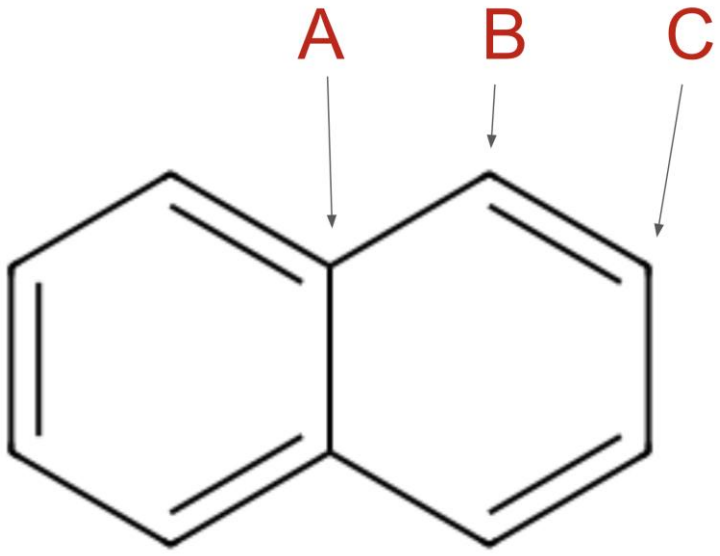
ANSWER: HCl and SO2 [CZ]

VISUAL BONUS

7) Chemistry – *Short Answer* Answer the following two questions about the aromatic molecule displayed:

a) What is the name of this molecule?

b) Is position A, B, or C most reactive to electrophilic aromatic substitution?



ANSWER: Naphthalene, B [CZ]

TOSSUP

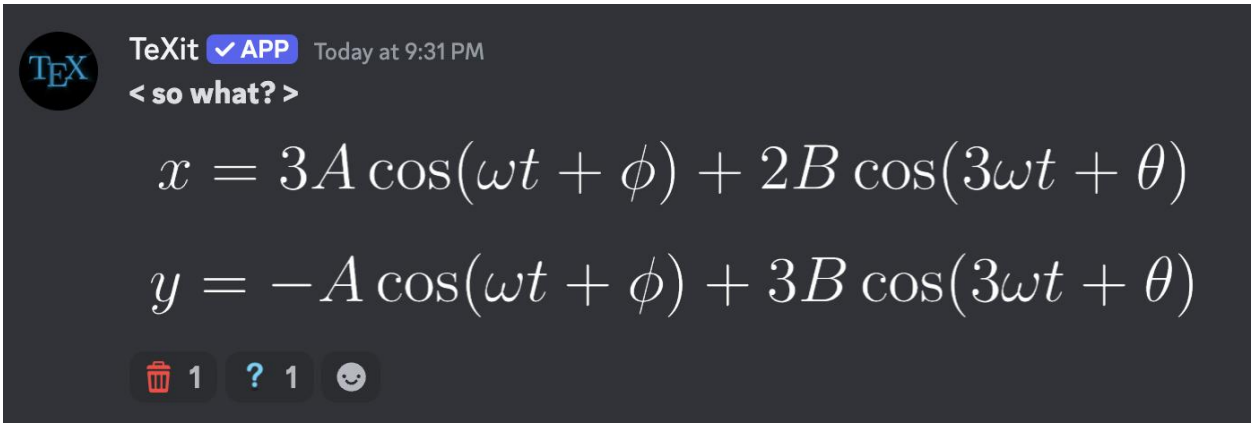
8) Physics – *Short Answer* Identify all of the following 3 quantities that are pseudovectors: 1) A-field, 2) H-field, 3) D-field.

ANSWER: 12 [SO]

VISUAL BONUS

8) Physics – *Short Answer* Answer the following two questions regarding the coupled harmonic oscillation that can be described by the pair of equations shown on the image.

1. What are the normal modes of this system?
2. For each normal mode, state the associated angular frequency.



ANSWER: (3, -1) - omega
(2, 3) - 3 omega [DL]

TOSSUP

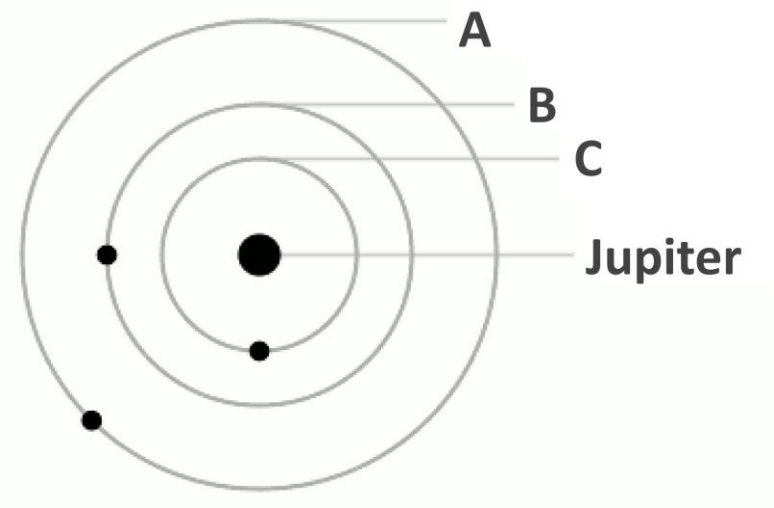
9) Earth and Space – *Multiple Choice* Red sprites typically occur in which of the following layers of the atmosphere?

W) Troposphere
X) Stratosphere
Y) Mesosphere
Z) Thermosphere

ANSWER: Y) Mesosphere [PB]

VISUAL BONUS

9) Earth and Space – *Short Answer* The following image depicts the orbits of Europa, Ganymede, and Io, which follow a 1:2:4 orbital resonance. Answer the following two questions about these moons:
1) Which moons correspond to A, B, and C, respectively?
2) Assuming each orbit is circular, what is the ratio of Jupiter's distance from Moon A to its distance from Moon C?



ANSWER: 1) Io, Europa, Ganymede; 2) 2^(4/3) or 2*cbrt2 [PB]

TOSSUP

10) Math – *Short Answer* Rohan is given two positive integers a,b and he writes down a^1 - b^1, a^2-b^2, and so on until, a^k - b^k, where k is also a positive integer. He notices that at least one prime factor of a^k-b^k does not divide any other element in the list. What theorem says that this statement is true for all triplets (a,b,k) other than a few notable exceptions?

ANSWER: Zsigmondy's theorem [RG]

BONUS

10) Math – *Multiple Choice* To the nearest tenth, which of the following is closest to the integral from 0 to 2 of e to the power of -1/2 x^2 dx?

W) 0.9

X) 1.0

Y) 1.1

Z) 1.2

ANSWER: Z) 1.2 [RG]