2024 SMH Invitational Cup - FINALS 3

TOSSUP

1) Biology – *Multiple Choice* Kris is studying transcriptional circuits in bacteria, where all genes have a basal level of transcription and inhibition completely prevents transcription. Which of the following genetic circuits does not have any stable, self-sustaining configurations?

W) A inhibits B inhibits C activates A

X) A activates B activates C activates A

Y) A inhibits B inhibits C inhibits A

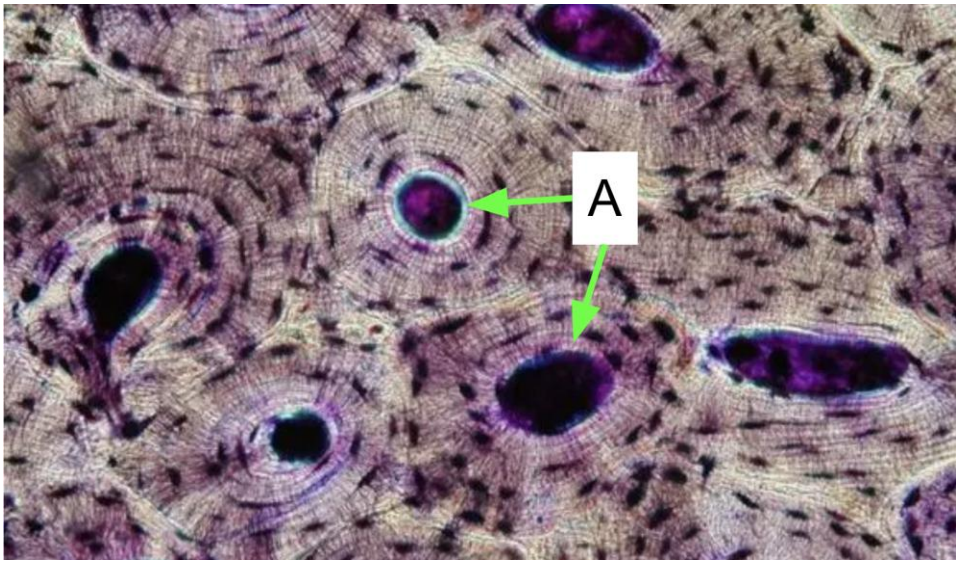
Z) A activates B inhibits C inhibits A

ANSWER: Y) A inhibits B inhibits C inhibits A [SO]

BONUS

1) Biology – *Short Answer* Edwin is studying connective tissues. He takes a sample of tissue and places it under the microscope. Answer the following two questions about his image:

1. From what type of connective tissue did Edwin get his sample?
2. What is the name of the structures labeled A?



ANSWER: 1. bone, 2. Haversian canal [SO]

TOSSUP

2) Chemistry – *Short Answer* Name all of the following crystal structures where the anions occupy a close-packed lattice:

1) rock salt

2) zincblende

3) cesium chloride

ANSWER: 12 [CZ]

BONUS

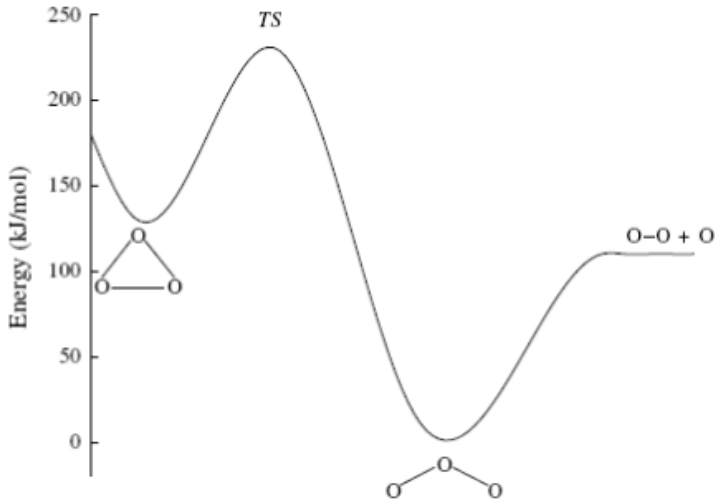
2) Chemistry – *Multiple Choice* The displayed image shows an energy diagram of ozone and its isomer trioxirane. Isomerization is predicted to be accelerated by quantum tunneling. The probability of quantum tunneling is proportional to e to what power of barrier thickness?

W) 1

X) -½

Y) -1

Z) -2



ANSWER: Y) -1 [CZ]

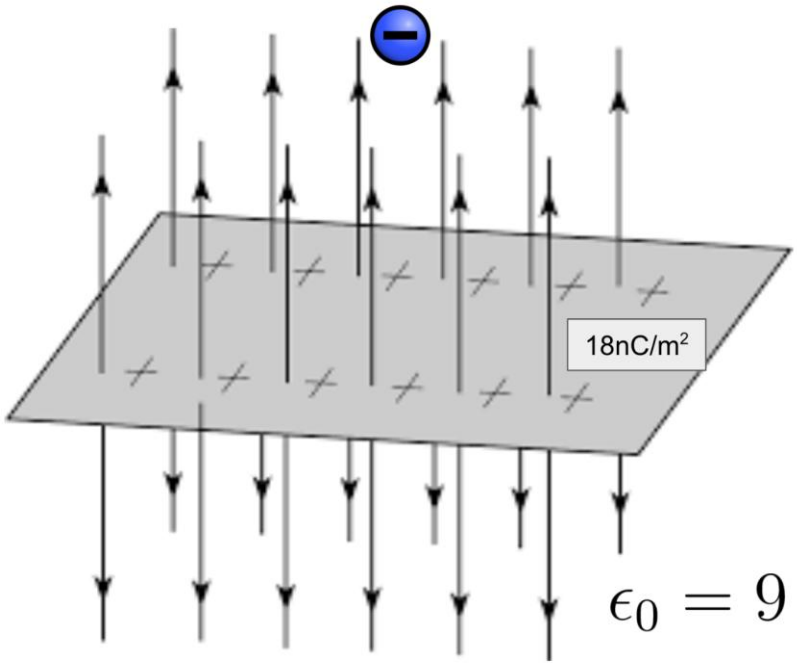
TOSSUP

3) Physics – *Short Answer* An interaction must follow the Sakharov Conditions to be responsible for what CP-symmetry violating process, currently unexplained by the Standard Model and general relativity?

ANSWER: baryogenesis [CZ]

VISUAL BONUS

3) Physics – *Short Answer* An infinitely large sheet far from any gravitational influence has a uniform charge density of 18 nanocoulombs per square meter. In seconds to one significant figure, how long does it take for a charge of negative 1 coulomb and mass 1 kilogram initially 5 meters above the sheet to hit the sheet?



$$\epsilon_0 = 9 \times 10^{-12}\mathrm{F/m}$$

ANSWER: 0.1 [BC]

TOSSUP

4) Earth and Space – *Multiple Choice* Which of the following best describes the sources of the majority of anions and cations in the ocean?

W) both originate from chemical weathering of rocks

X) both originate from volcanic gases

Y) cations originate from chemical weathering of rocks, while anions originate from volcanic gases

Z) anions originate from chemical weathering of rocks, while cations originate from volcanic gases

ANSWER: Y) cations originate from chemical weathering of rocks, while anions originate from volcanic gases [SO]

BONUS

4) Earth and Space – *Short Answer* By name or number, identify all of the following 4 moons of the solar system that contain more water in their subsurface oceans than is in Earth's oceans:
1. Titan
2. Ganymede
3. Europa
4. Triton

ANSWER: All [DL]

TOSSUP

5) Math – *Short Answer* Daniel is computing the integral from -infinity to infinity of f(x) dx. He evaluates it and notices that when he evaluates the integral with the same bounds but the integrand replaced with f(x-1/x) [read: f of open parenthesis x - 1 over x close parenthesis], he gets the same result. What theorem in integration can be used to prove this and gives a general class of substitutions helpful in solving complex integrals?

ANSWER: Glasser's master theorem [RG]

BONUS

5) Math – *Short Answer* Consider a group G with order 1440. Identify all of the following numbers that could be the order of a Sylow subgroup.
1) 5
2) 9
3) 16

ANSWER: 1,2 [RG]

TOSSUP

6) Biology – *Multiple Choice* Phoebe aims to design an effective protease and decides to utilize a variation of the catalytic triad. She has already decided on aspartate and histidine as members of her catalytic triad, but is undecided about the third. Which of the following amino acids is she LEAST likely considering?

W) serine

X) threonine

Y) alanine

Z) cysteine

ANSWER: Y) ALANINE [SO]

BONUS

6) Biology – *Short Answer* Assume that skin tone is coded only by four separately inherited genes with two alleles each, one that codes for dark skin and one that codes for light skin, and that alleles have a cumulative effect on skin tone. If two people who are both heterozygous for all four genes have a child, what is the expected probability, expressed as a fraction in simplest form, that their child will have exactly 5 alleles coding for dark skin?

ANSWER: 7/32 [SO]

TOSSUP

7) Chemistry – *Short Answer* Rank the following three aromatic molecules from least to most reactive to nucleophilic aromatic substitution:

1) Benzene

2) Pyrrole

3) Pyridine

ANSWER: 213 [CZ]

BONUS

7) Chemistry – *Short Answer* What is the ratio of the orbital angular momentum of the 3d to the 3p orbital?

ANSWER: sqrt(3) [CZ]

TOSSUP

8) Physics – *Multiple Choice* Which of the following statements is NOT true regarding ideal Fraunhofer single-slit diffraction?
W) more than two-thirds of the light is concentrated in the central peak
X) the width of the slit is inversely proportional to the width of the central peak
Y) intensity minima are evenly spaced out
Z) the wavelength of light is directly proportional to the spacing of the peaks

ANSWER: Y) intensity minima are evenly spaced out [BC]

BONUS

8) Physics – *Short Answer* Select all of the following three options that would increase the period of a pendulum consisting of a massless string tied to a small mass that experiences linear drag: 1) replacing the massless rope with a rope that has mass; 2) increasing the amplitude of the oscillations from ten to twenty degrees; 3) increasing the viscosity of the air

ANSWER: 23 [BC]

TOSSUP

9) Earth and Space – *Multiple Choice* Penelope recently bought a precious opal specimen on eBay, but is disappointed to find that the opal primarily displays green iridescence instead of the blue iridescence she wanted. Which of the following changes could be made to the opal to cause it to consistently display blue colors?

W. Increase silica particle size

X. Decrease silica particle size

Y. Increase silica hydration

Z. Decrease silica hydration

ANSWER: W. Increase silica particle size [AS]

BONUS

9) Earth and Space – *Short Answer* Order the following three events in the early universe from first to last to occur: 1) Cosmic microwave background formation; 2) Cosmic neutrino background formation; 3) Light element nucleosynthesis.

ANSWER: 231 [PB]

TOSSUP

10) Math – *Multiple Choice* How many primitive roots are there modulo 67?

W) 20

X) 33

Y) 34

Z) 66

ANSWER: W) 20 [RG]

BONUS

10) Math – *Short Answer* Peter the ant starts at the origin. Each second, Peter the ant moves up one unit, down one unit, right one unit, or left one unit at random with equal probability. After 3 seconds, he lands at (x,y). Being his main competitor, Rohan tries to get to (x,y) as well by only moving up, down, right, or left exactly one unit. What is the expected number of moves Rohan must take to get to (x,y) if he plays optimally?

ANSWER: 15/8 [RG]