2025 Bay Area Science-Estimathon Duel

Double Elimination

Question Set 8

-Finals Round 1-

Questions will begin on the next page.

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*E&S = Earth and Space, Est = Estimation.

TOSS-UP

1) **Chemistry – *Short Answer*** By name or number, select all of the following three modifications to benzoic acid at the para position in order of increasing pKa.

1. Hydroxy group
2. Methoxy group
3. Fluorine atom

ANSWER: 3, 1, 2 [AG]

BONUS

1) **Chemistry – *Multiple Choice*** When 2-aminopentane is treated with excess iodomethane, then silver oxide in water, what product is preferentially produced?

W) 1-pentene
X) 2-pentene
Y) 1-pentyne
Z) 2-pentyne

ANSWER: W) 1-PENTENE [AG]

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TOSS-UP

2) **Biology – *Short Answer*** In intracellular trafficking, which coat protein complex is primarily responsible for the anterograde transport of vesicles from the endoplasmic reticulum to the Golgi apparatus?

ANSWER: COPII [AK]

BONUS

2) **Biology – *Multiple Choice*** Which small GTP-binding protein regulates the COPI [cop-one] coat assembly for retrograde transport from the Golgi to the ER?

W) Sar1
X) Rho
Y) ADP-Ribosylation Factor 1
Z) Ran

ANSWER: Y) ADP-RIBOSYLATION FACTOR 1 [AK]

TOSS-UP

3) **Physics – *Multiple Choice*** Students at Saratoga High School have discovered a new supermassive black hole, UR-M0M* [read as: you-are-dash-em-zero-em-star], with mass M and entropy S. If the mass of the black hole was instead 3M, in terms of S, what would be the new entropy of this black hole?

W) S/3
X) S
Y) 3S
Z) 9S

ANSWER: Z) 9S [MR]

BONUS

3) **Physics – *Multiple Choice*** Students at Saratoga High School continue studying black holes. They learn that photons can orbit a black hole inside the photon sphere, a region just outside the Schwarzschild radius, where any small push to a photon inward or outward would send a photon either spiraling into the black hole or allowing it to escape the black hole entirely, respectively. What type of equilibrium describes these photon orbits?

W) Asymptotically stable
X) Metastable
Y) Dynamically unstable
Z) Lyapunov [*li-a-pu-nov*] unstable

ANSWER: Y) DYNAMICALLY UNSTABLE [MR]

TOSS-UP

4) **Math – *Multiple Choice*** Lawson the ant is placed on the bottom left square in a 3x3 square grid. Every second, he randomly chooses to move to a vertically or horizontally adjacent square, with an equal probability to move to each adjacent square. What is the probability that Lawson is in the center square after 2026 seconds have passed?

W) 1/9
X) 1/6
Y) 1/3
Z) 1/2

ANSWER: Y) 1/3 [QG]

BONUS

4) **Math – *Short Answer*** Lawson the ant decides that a 3x3 grid is too small, so he renovates the environment to be a 5x5 grid instead. He starts in the center square and follows the same procedure as before. Each second, he moves to an adjacent square, with an equal probability to move to each adjacent square. What is the probability that Lawson is back in the center after 4 seconds?

ANSWER: 7/48 [QG]

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TOSS-UP

5) **Earth and Space – *Multiple Choice*** Historically, Vega has been used as the zero-point reference star for the magnitude scale, meaning it was assigned apparent magnitude 0 at all wavelengths and every star's magnitude was measured relative to Vega's. However, more modern research indicates that Vega might not be the ideal calibration star it was once thought of. Which of the following is NOT a reason for why Vega is an unreliable calibration star?

W) Its high recessional velocity causes significant Doppler shifts, altering its magnitude inconsistently across wavelengths
X) It has been discovered to be a variable star, making its brightness inconsistent
Y) Its rapid rotation causes temperature differences, causing it to have variable emission spectra across its surface
Z) It has unique infrared excesses due to a debris disk, altering its spectrum

ANSWER: W) ITS HIGH RECESSIONAL VELOCITY CAUSES SIGNIFICANT DOPPLER SHIFTS, ALTERING ITS MAGNITUDE INCONSISTENTLY ACROSS WAVELENGTHS [MR]

BONUS

5) **Earth and Space – *Multiple Choice*** Which of the following does the Torino scale measure?

W) Near-Earth object impacts
X) Subsurface volcanic eruptions
Y) Impacts of CFCs in the atmosphere
Z) Size of sunspots

ANSWER: W) NEAR-EARTH OBJECT IMPACTS [AG]

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TOSS-UP

6) **Y-Risk – *Multiple Choice*** Students at Saratoga High School are researching a very important question: What does the fox say? Max thinks he can solve for what the fox says, if only he had a theory of everything. Which of the following is not a candidate for a theory of everything?

W) Pilot Wave Theory
X) Quantum Loop Gravity
Y) String Theory
Z) Casual Dynamical Triangulations

ANSWER: W) PILOT WAVE THEORY [MR]

BONUS

6) **Y-Risk – *Short Answer*** Which of the following mechanisms allows models such as ResNet to take advantage of much deeper neural network architectures?

W) Feature extraction pyramids
X) Attention modules
Y) Feature map caching
Z) Skip connections

ANSWER: Z) SKIP CONNECTIONS [WC]

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TOSS-UP

7) **Chemistry – *Multiple Choice*** Which of the following ligands is incapable of pi-backbonding?

W) NO_2^-
X) Phosphine
Y) Cyclobutadiene
Z) Ammonia

ANSWER: Z) AMMONIA [AG]

BONUS

7) **Chemistry – *Multiple Choice*** Which of the following molecules would yield a positive result with Fehling's reagent?

W) Cyclopentanone
X) Pentanal
Y) Pentanol
Z) ethylpropyl-ether

ANSWER: X) PENTANAL [AG]

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TOSS-UP

8) **Math – *Short Answer*** What is the name of the point within a triangle where the nine point circle and incircle intersect?

ANSWER: FEUERBACH POINT [QG]

BONUS

8) **Math – *Short Answer*** Let us define the piecewise function f(x) as follows:

$f(x) = \sqrt{4 - 4x^2}$ for -1 < x< 0
$f(x) = -x^2 + 2$ for x ≥ 0

What is the value of the definite integral from -1 to 1 of f(x)dx

ANSWER: pi/2 + 5/3 [QG]

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TOSS-UP

9) **Earth and Space – *Multiple Choice*** Which of the following features of Mars is shared between the Noachian and Amazonian periods of its development?

W) Carbon dioxide-dominated atmosphere
X) Global magnetic field
Y) Large-scale presence of liquid water
Z) High geologic activity

ANSWER: W) CARBON DIOXIDE-DOMINATED ATMOSPHERE [MR]

BONUS

9) **Earth and Space – *Multiple Choice*** Which of the following combination of plate boundaries at a triple junction is always unstable?

W) FFF
X) FTF
Y) TRT
Z) RRR

ANSWER: W) FFF [AG]

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TOSS-UP

10) **Biology – *Short Answer*** In the secondary xylem of angiosperms, the hydraulic conductivity of a vessel increases sharply with its radius, creating a trade-off between water transport efficiency. What phenomenon occurs when air bubbles interrupt the continuous water column under tension?

ANSWER: CAVITATION [AK]

BONUS

10) **Biology – *Multiple Choice*** In angiosperms, which type of secondary xylem is characterized by uniform vessel diameters across the growth ring, providing consistent water transport throughout the growing season but offering less mechanical support?

W) Early wood (spring wood)
X) Late wood (summer wood)
Y) Diffuse-porous wood
Z) Ring-porous wood

ANSWER: Y) DIFFUSE-POROUS WOOD [AK]

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TOSS-UP

11) **Physics – *Short Answer*** The Dirac equation is the relativistic wave equation for half-integer spin particles, like electrons. The equation predicts that in a hydrogen atom, the energies of the 2S 1/2 and 2P 1/2 electron orbitals should be identical. Experimentally, however, the energies of these orbitals are separated by what discrepancy, which was finally resolved with the introduction of QED?

ANSWER: LAMB SHIFT [MR]

BONUS

11) **Physics – *Multiple Choice*** An industrial Carnot engine operates between two heat reservoirs with temperatures of 242 and 355 Kelvin. Which of the following fractions is closest to the ideal efficiency of this engine?

W) 1/3
X) 7/22
Y) 23/73
Z) 32/103

ANSWER: X) 7/22 [MR]

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TOSS-UP

12) **Y-Risk – *Short Answer*** What is the orbital maneuver that uses two engine burns to efficiently transfer a spacecraft between two circular orbits using an elliptical trajectory tangent to both orbits?

ANSWER: HOHMANN (pronounced: HO-MAN) TRANSFER (ACCEPT: HOHMANN TRANSFER ORBIT) [MR]

BONUS

12) **Y-Risk – *Multiple Choice*** After a long day playing League of Legends, Arjun decides to go outside to touch grass. He stumbles upon a strange flowering plant with highly modified bracts, which rose from the stem and appeared to be an appendage of the flower calyx. He concludes that the unusual morphology is likely due to the fusion of the leaf and either the stem holding the bud or the bud itself. What term best describes this type of inflorescence?

W) CONCAULESCENT
X) SCAPOSE
Y) CYMOSE
Z) RECAULESCENT

ANSWER: Z) RECAULESCENT [AK]

TOSS-UP

13) **Earth and Space – *Short Answer*** Usually, white dwarfs evolve by releasing their energy through regular blackbody radiation. However, in their infancy, the dominant contribution to their cooling comes from radiating neutrinos, as opposed to photons, which occurs through what astrophysical process, typically consisting of a beta decay followed by an electron capture?

ANSWER: URCA PROCESS [MR]

BONUS

13) **Earth and Space – *Short Answer*** What cycle, which repeats every thirty to sixty days, describes the travelling and oscillatory nature of moisture plumes and regions of dry air as a means to predict weather in tropical latitudes?

ANSWER: MADDEN-JULIAN OSCILLATION [AG]

TOSS-UP

14) **Biology – *Short Answer*** By name or number, identify all of the following that are true about enzyme kinetics:

1. In competitive inhibition, Vmax *[vee-max]* remains unchanged while Km *[kay-emm]* is increased
2. In uncompetitive inhibition, both Vmax and Km decrease
3. in noncompetitive inhibition, Vmax remains unchanged while Km is decreased

ANSWER: 1 AND 2 [AK]

BONUS

14) **Biology – *Short Answer*** Arjun is studying keepwatchingase, an enzyme responsible for making him keep watching his beloved team Liverpool continually lose in the Premier League. To inhibit this enzyme, he designs a trick substrate called YEP!. When bound to keepwatchingase, YEP! is converted into YEPPERS!, a highly reactive intermediate that covalently bonds to the enzyme's active site, permanently inactivating it. What is the name for this type of inhibition?

ANSWER: SUICIDE INHIBITION [AK]

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TOSS-UP

15) **Chemistry – *Short Answer*** In general, the elements in period 3 have higher electron affinities than elements in the same group in period 2. However, this is not always the case. By name or number, list all of the following pairs of elements that violate this trend.

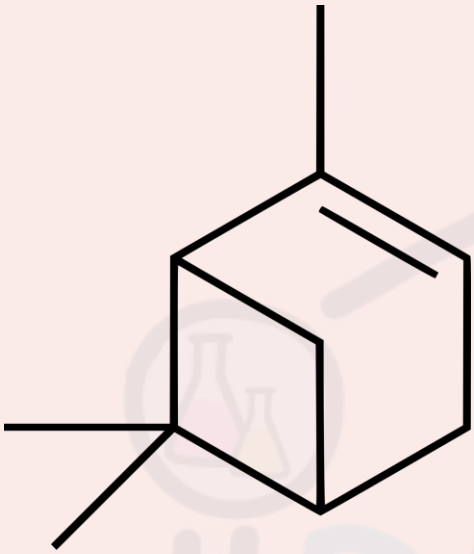
1. Lithium and Sodium
2. Boron and Aluminum
3. Carbon and Silicon
4. Oxygen and Sulfur

ANSWER: 1 ONLY [QG]

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VISUAL BONUS

15) **Chemistry – *Short Answer*** Pinene is a monoterpene found in pine trees and other conifers. The structure of pinene is provided below. Answer the following two questions about pinene.



1. Calculate the degree of unsaturation of pinene.
2. Calculate the molecular formula of pinene.

ANSWERS:

1. 3
2. C10H16 [AG]

TOSS-UP

16) **Math – *Short Answer*** A and B are similar n by n matrices. If the eigenvalues of A are 2, 6, and 9, then what are the eigenvalues of $((2B)^T)^{-1}$ [read: the inverse of the transpose of 2 times B]?

ANSWER: 1, 1/3, AND 2/9 [QG]

BONUS

16) **Math – *Short Answer*** Mr. Yim is ascending to a higher dimension. He owns a 4D unit hypercube, which he plans to transform by performing the linear transformation T on every point in the cube. The standard matrix of T is (read slowly):

First Row: 2, 0,-3, 5
Second Row: 3, 1, 4, 1
Third Row: 0, 0, 4, 0
Forth Row: -1, 0, 3, 2

What is the 4D hypervolume of the resulting figure?

ANSWER: 36 [QG]

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TOSS-UP

17) **Y-Risk – *Short Answer*** In an effort to be more environmentally sustainable, green chemists have developed a new metric to rate chemical reactions, where 100% is perfectly efficient conversion and 0% is zero desired product generation. The percentage is calculated by considering the molecular weight of the products relative to that of the reactants: thus wasted catalysts negatively impact this metric. What is the name of this concept?

ANSWER: ATOM ECONOMY [AG]

BONUS

17) **Y-Risk – *Short Answer*** By name or number, rank the following three reactions in increasing atom economy.

1. Isomerizations
2. Wittig reaction
3. Diels-Alder reactions

ANSWER: 2, 3, 1 [AG]

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TOSS-UP

18) **Physics – *Short Answer*** By name or number, name all of the following five quantities that are represented by polar (not psuedo) vectors:

1. Linear momentum
2. Angular momentum
3. Torque
4. Electric field
5. Magnetic field

ANSWER: 1 AND 4 [MR]

VISUAL BONUS

18) **Physics – *Short Answer*** Depicted in the GIF is the Death Star firing. Some theories behind the physics of the Death Star treat the beams as streams of plasma, which allows the individual beams to be more easily redirected into one central beam, as occurs in the GIF. What technique is often used to redirect beams of plasma, typically employed in fusion reactors such as tokamaks and stellarators, and, so, is possibly used to focus the Death Star beam?



ANSWER: MAGNETIC CONFINEMENT [MR]

TOSS-UP

19) **Chemistry – *Short Answer*** What effect, which is generally negligible in O2 and F2, is responsible for the 2p sigma g bonding MOs in molecules of N2 or lower atomic number being higher in energy than the corresponding 2p pi u bonding MOs?

ANSWER: S-P MIXING [AG]

BONUS

19) **Chemistry – *Short Answer*** What is the point group of a molecule of SF6?

ANSWER: D4h (Accept: Oh) [AG]

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TOSS-UP

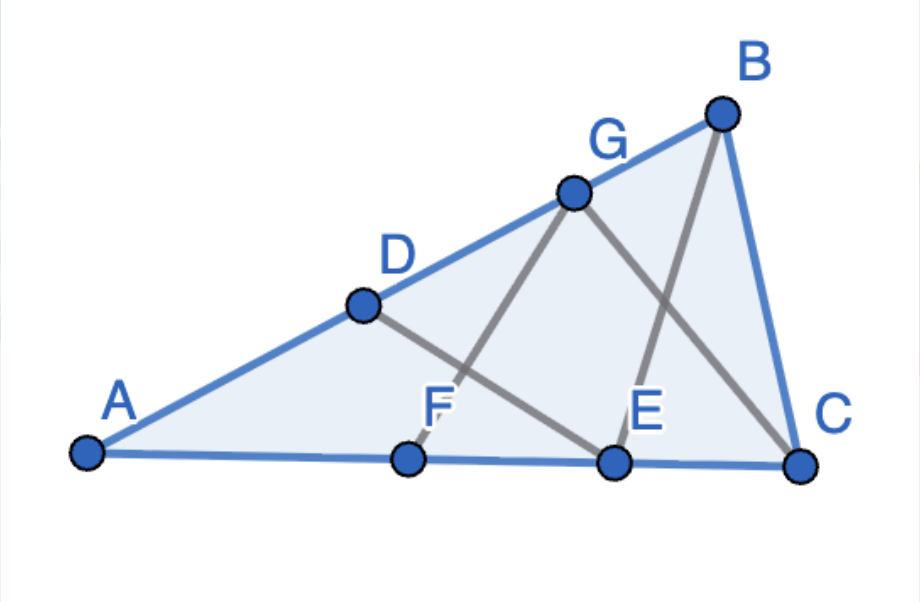
20) **Math – *Short Answer*** Carmichael numbers are composite numbers n which satisfy the relation b^n is congruent to b mod n for all integers b. Name all of the following four statements that are true about the Carmichael numbers.

1. There are infinitely many
2. They must have at least 4 prime factors
3. They must be odd
4. They are strong pseudoprimes to all relatively prime bases

ANSWER: 1 AND 3 [QG]

LONG VISUAL BONUS

20) **Math – *Short Answer*** Given that AD = DE = EB = BC = CG = GF = FA, what is the measure of angle A, in degrees?



ANSWER: 180/7 [QG]

TOSS-UP

21) **Biology – *Multiple Choice*** Arjun performs a chemotaxis assay, an experimental tool that evaluates the chemotactic ability of prokaryotic or eukaryotic cells. Which of the following best describes his observations made through a chemotaxis assay in a plate of prokaryotes with a strong chemical attractant present?

W) Completely random movement
X) Longer tumbles and shorter runs with no net movement
Y) Longer tumbles and shorter runs with net movement towards the attractant
Z) Shorter tumbles and Longer runs with net movement towards the attractant

ANSWER: Z) SHORTER TUMBLES AND LONGER RUNS WITH NET MOVEMENT TOWARDS THE ATTRACTANT [AK]

BONUS

21) **Biology – *Short Answer*** Arjun observes that bacteria such as E. coli are able to decide whether to run or tumble based on their cell density in different areas. What type of cell-to-cell communication is used by bacteria to detect and respond to cell density?

ANSWER: QUORUM SENSING [AK]

TOSS-UP

22) **Physics – *Short Answer*** Max is deconstructing his computer when he observes a minor but consistent electronic noise in his circuit. He identifies the agitation of electrons as the source and attempts to avoid it by changing the voltage, to no avail. What type of noise is he dealing with?

ANSWER: THERMAL (ACCEPT: JOHNSON OR NYQUIST) [AG]

BONUS

22) **Physics – *Short Answer*** For a bound system in which an object's potential is proportional to inverse distance cubed, answer the following two questions:

1. In an electric analog of this system, how many point charges of alternating charge sign would be needed to construct such a system?
2. What is the ratio of the time-averaged kinetic energy to time-averaged potential energy of the system?

ANSWERS: 1. 4 2. -3/2 [MR]

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TOSS-UP

23) **Earth and Space – *Short Answer*** By name or number, order the following three events by increasing time passed since their occurrence:

1. Younger Dryas
2. Maunder Minimum
3. Last Glacial Maximum

ANSWER: 2, 1, 3 [AG]

BONUS

23) **Earth and Space – *Short Answer*** Ethan observes a nearby galaxy 30 megaparsecs away with a redshift of 0.00667. Assuming the Hubble constant to be 70 kilometers per second per megaparsec, the observed redshift differs from that which would be seen if the galaxy had the velocity predicted by Hubble's law. This difference is known as the galaxy's peculiar velocity. To one significant figure and in kilometers per second, what is the magnitude of this galaxy's peculiar velocity?

ANSWER: 100 [MR]

TOSS-UP (30 seconds)

24) **Estimation – *Short Answer*** If Max gently throws a tennis ball directly upwards at an initial velocity of 3 m/s, there are 3 models he could use to calculate the time it takes for the tennis ball to return to its starting height: 1) no drag; 2) linear drag; 3) quadratic drag. Let the times for these three models be t_1, t_2, and t_3 respectively. Estimate the order of magnitude of $(t_1 - t_2)(t_2 - t_3)$ in seconds squared, in other words, the product of the time difference between no drag and linear drag and the difference between linear drag and quadratic drag.

ANSWER: -8 [MR]

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End of Questions.