2025 Bay Area Science-Estimathon Duel

Double Elimination

Question Set 6

Questions will begin on the next page.

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Quick Navigation:

1. Physics	2. Chemistry	3. Biology	4. Y-Risk	5. E&S	6. Math
7. Biology	8. Physics	9. Chemistry	10. Y-Risk	11. Math	12. E&S
13. Y-Risk	14. Biology	15. Math	16. E&S	17. Chemistry	18. Physics
19. E&S	20. Biology	21. Chemistry	22. Math	23. Physics	24. Est

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

TOSS-UP

1) **Physics – *Short Answer*** What is the name for the abstract space whose axes are position and momentum?

ANSWER: PHASE SPACE [MR]

BONUS

1) **Physics – *Multiple Choice*** Which theorem states that, for a particle performing one-dimensional motion with a very slowly changing potential, the area of the orbit calculated with an integral remains constant?

W) Adiabatic Invariant Theorem
X) Hamilton's Conservation Theorem
Y) Virial Theorem
Z) D'Alembert's Phase Theorem

ANSWER: W) ADIABATIC INVARIANT THEOREM [MR]

TOSS-UP

2) **Chemistry – *Multiple Choice*** Which of the following conformers of butane would exhibit the greatest torsional strain?

W) Anti-periplanar
X) Syn-periplanar
Y) Anti-clinal
Z) Syn-clinal

ANSWER: X) SYN-PERIPLANAR [AG]

BONUS

2) **Chemistry – *Short Answer*** By name or number, list the following three molecules by increasing N-O bond length:

1. NO_2^+
2. NO_2^-
3. NO

ANSWER: 3, 1, 2 [AG]

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TOSS-UP

3) **Biology – *Multiple Choice*** Arjun orders a package from Amazon. Unfortunately, he selects the wrong delivery address and sends his Amazon package to the Amazon River. Arjun decides to follow the river to retrieve his package, while observing its inhabitant fish species to keep his mind busy. He notices significant numbers of neon tetra along the river, but as he got close to the mouth of the river, which opened to the sea, their population dropped significantly. Based on these observations, what type of organism would Neon Tetra be classified as?

W) Eurythermal
X) Euryhaline
Y) Stenothermal
Z) Stenohaline

ANSWER: Z) STENOHALINE [AK]

BONUS

3) **Biology – *Multiple Choice*** Given that the Neon tetra are small, schooling fish found in large populations throughout most of the Amazon, what type of survivorship curve would they follow and what type of selection would they exhibit?

W) Type I, R-Selection
X) Type I, K-Selection
Y) Type III, K-Selection
Z) Type III, R-Selection

ANSWER: Z) TYPE 3, R-SELECTION [AK]

TOSS-UP

4) **Y-Risk – *Short Answer*** What type of electromagnetic radiation is released when an electron is deflected by the magnetic field of an atom, releasing significant energy in the conversion?

ANSWER: BREMSSTRAHLUNG RADIATION (accept BREMSSTRAHLUNG) [AG]

BONUS

4) **Y-Risk – *Multiple Choice*** Which of the following best explains why heavy water is used in favor of light water in nuclear reactors?

W) Heavy water has a larger neutron cross section than light water
X) Heavy water evaporates at a lower rate than light water, allowing more reactor resilience
Y) Heavy water slows neutrons down without absorbing them, leading to greater efficiency
Z) Heavy water can react with neutrons, forming tritium which will decay for extra energy

ANSWER: Y) HEAVY WATER SLOWS DOWN NEUTRONS WITHOUT ABSORBING THEM LEADING TO GREATER EFFICIENCY [AG]

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TOSS-UP

5) **Earth and Space – *Short Answer*** Having rented the James Webb space telescope for a week, Max aims to maximize his productivity by doing some serious stargazing. He identifies a large blue star of about six solar masses situated in a globular cluster. What spectral class would this star be classified as?

ANSWER: B [EP]

BONUS

5) **Earth and Space – *Short Answer*** Upon further observations, Max finds several more similar-sized blue stars in the center of his globular cluster. He also notes that these stars are much more luminous than expected and show a very blue hue. What term best describes the stars Max has found?

ANSWER: BLUE STRAGGLERS [EP]

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TOSS-UP

6) **Math – *Multiple Choice*** Which of the following points are NOT on the nine point circle of a triangle?

W) The midpoints of the triangle's sides
X) The feet of the triangle's altitudes
Y) The midpoints between the triangle's vertices and its orthocenter
Z) The midpoints between the triangle's vertices and its circumcenter

ANSWER: Z) THE MIDPOINTS BETWEEN THE TRIANGLE'S VERTICES AND ITS CIRCUMCENTER [QG]

BONUS

6) **Math – *Short Answer*** A parametric curve is defined by the equations y = 2cos(t) and x = sin(t). What is the slope of the tangent line to this curve at x = 1/2?

ANSWER: -2sqrt(3) [QG]

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TOSS-UP

7) **Biology – *Short Answer*** In vertebrate embryonic development, what signaling pathway is directly mediated by the release of β-catenin from cadherin junctions and its subsequent translocation to the nucleus?

ANSWER: WNT/BETA-CATENIN SIGNALING PATHWAY (accept WNT *[WINT]* SIGNALING PATHWAY, do not accept BETA-CATENIN SIGNALING only) [AK]

BONUS

7) **Biology – *Short Answer*** During limb bud development, the apical ectodermal ridge maintains the progress zone in the underlying mesenchyme. What specific types of signaling molecules secreted by the AER are essential for this activity?

ANSWER: FIBROBLAST GROWTH FACTORS (accept FGFs) [AK]

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TOSS-UP

8) **Physics – *Multiple Choice*** Quinn owns a simple pendulum, which has length 4.9 meters and a bob with mass 4 kilograms. He holds it at an angle of 5 degrees from the vertical and releases it at time t = 0. At which of the following times, in seconds, is the height of the bob the highest?

W) t = 1
X) t = 2
Y) t = 3
Z) t = 4

ANSWER: X) t = 2 [QG]

BONUS

8) **Physics – *Short Answer*** After an hour watching his pendulum swing back and forth, Quinn leaves his room to play Celeste. During this time, Max decides to prank Quinn by tying another pendulum to the end of Quinn's pendulum. What is the term for the resulting motion of this new double pendulum?

ANSWER: CHAOTIC (accept DETERMINISTIC CHAOTIC) [EP]

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TOSS-UP

9) **Chemistry – *Short Answer*** What is the VSEPR molecular shape of the octafluoroxenate ion, XeF_8^{2-}?

ANSWER: SQUARE ANTIPRISMIC (do not accept SQUARE PRISMIC) [AG]

BONUS

9) **Chemistry – *Short Answer*** Warren desperately yearns for a large amount of titanium to produce rockets. He decides to utilize what commercial process, which reacts Mg metal to reduce $TiCl_4$?

ANSWER: KROLL [AG]

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TOSS-UP

10) **Y-Risk – *question format*** What deep model architecture, created in 2017, is used by LLMs like ChatGPT?

W) Recurrent neural networks
X) Transformers
Y) Memory operation networks
Z) Highway networks

ANSWER: X) TRANSFORMERS [WC]

BONUS

10) **Y-Risk – *Short Answer*** Quinn is swimming in the ocean when he feels a sudden urge to perform a grass touching speedrun. To reach the grass, he will need to swim out of the ocean and run along the beach. He can swim at a maximum speed of 1 unit per second and run at a maximum speed of 2 units per second. Modeling Quinn's starting coordinates as (0, 4), the line between the ocean and the beach as y=0, and the grass at coordinates (6,0), how many seconds will it take him to reach the grass, to one significant figure, assuming optimal routing?

ANSWER: 6 [QG]

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TOSS-UP

11) **Math – *Multiple Choice*** What is the largest area of a triangle that can be inscribed in a semicircle of radius r?

W) 1/4 r^2
X) 1/2 r^2
Y) r^2
Z) 2r^2

ANSWER: Y) r^2 [MR]

BONUS

11) **Math – *Short Answer*** Which theorem, proven by Percy John Heawood in 1890, concerns the possibility of a map being colored with its namesake number of colors in such a way that no two adjacent regions have the same color?

ANSWER: FIVE COLOR THEOREM [MR]

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TOSS-UP

12) **Earth and Space – *Short Answer*** Earth's magnetic field is responsible for the Van Allen belts, rings of trapped charged particles from the solar wind. How many of the Solar System's non-Earth planets have a magnetic field strong and stable enough to support such rings?

ANSWER: 5 [MR]

BONUS

12) **Earth and Space – *Multiple Choice*** Warren is eating Starbursts and starts thinking about the tidal tails in starburst galaxies. Which of the following stellar objects would be expected in significant quantities in a tidal tail?

W) Exoplanets
X) Population I stars
Y) OB associations
Z) Globular clusters

ANSWER: Z) GLOBULAR CLUSTERS [MR]

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TOSS-UP

13) **Y-Risk – *Short Answer*** In lasers, a variable attenuator inside the resonance chamber can prevent feedback and suppress lasing even if population inversion is present. This allows energy to build up in the gain medium. When the attenuator is switched, feedback is restored and the stored energy is released in a short, high-intensity laser pulse. What is the name of this technique?

ANSWER: Q-SWITCHING (accept GIANT PULSE FORMATION, Q-SPOILING) [AG]

BONUS

13) **Y-Risk – *Short Answer*** By name or number, identify all of the following three applications where Q-switching would be applied.

1. LIDAR
2. Nonlinear optics
3. time-resolved spectroscopy

ANSWER: All [AG]

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TOSS-UP

14) **Biology – *Multiple Choice*** Alex has discovered a new species of plant. He notices that it has funnel-shaped flowers with five petals and fused stamens, as well as alternate and palmately lobed leaves. After running genetic tests, he determines it to be a relative of hibiscus, cotton, and okra. Which of the following families of plants does Alex's discovery most likely belong to?

W) Fabaceae
X) Malvaceae
Y) Asteraceae
Z) Orchidaceae

ANSWER: X) MALVACEAE [EP]

BONUS

14) **Biology – *Multiple Choice*** Alex decides to name his plant the marsh mallow, after its family and the habitat it was found in. Using quadrat sampling, Alex determines that the population of marsh mallow in a certain area, labeled A, is 400 individuals, and the population of a nearby group, labeled B, is 100. In population A, 64% of the plants display a recessive white-flowered phenotype, while in population B, 25% display the recessive phenotype. If Alex causes 20 individuals to "migrate" from population B to population A by replanting them, what is the expected frequency of the recessive allele in population A after migration?

W) 0.74
X) 0.76
Y) 0.78
Z) 0.80

ANSWER: Y) 0.78 [AK]

TOSS-UP

15) **Math – *Multiple Choice*** Which of the following properties changes linearly with curve length for an Euler spiral?

W) Curvature
X) Slope
Y) Square root of the slope
Z) Area enclosed between curve and origin

ANSWER: W) CURVATURE [MR]

BONUS

15) **Math – *Short Answer*** By name or number, indicate all of the following five sets that constitute a vector space, assuming complex coefficients for the following:

1. All polynomials in x with degree less than N
2. All even polynomials in x with degree less than N
3. All polynomials in x with degree less than N with leading coefficient 1
4. All polynomials in x with degree less than N that equal 0 at x=1
5. All polynomials in x with degree less than N that equal 1 at x=0

ANSWER: 1, 2, AND 4 [MR]

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TOSS-UP

16) **Earth and Space – *Short Answer*** Powerful cold fronts often feature a leading row of severe thunderstorms, which develop at the head or slightly before the front itself. What is the term for these lines of strong storms?

ANSWER: SQUALL LINE [AG]

BONUS

16) **Earth and Space – *Short Answer*** By name or number, identify all of the following three statements that accurately describe a Nor'easter (read: nor-eas-ter) storm:

1. They are most common between September and April.
2. They involve a low pressure region travelling from the Northeast towards Florida.
3. The direction of wind in a Nor'easter is from the Northwest towards the Southeast.

ANSWER: 1 ONLY [AG]

TOSS-UP

17) **Chemistry – *Short Answer*** How many vibrational modes exist for a molecule of CO_2?

ANSWER: 4 [AG]

BONUS

17) **Chemistry – *Short Answer*** Alex is looking to model pitting corrosion at different conditions to investigate the effects of acid rain on steel beams, where metallic iron forms a voltaic cell with atmospheric gases that leads to the corrosion of metal and thus structural failure. He would likely use what type of diagram, which describes the most favorable phases of a compound at different electric potentials and pHs?

ANSWER: POURBAIX DIAGRAM (grudgingly accept POTENTIAL/pH DIAGRAM) [AG]

TOSS-UP

18) **Physics – *Short Answer*** Let Warren be a solid atomic system which must be treated as quantum mechanical below 10 kelvin. If Warren's interatomic spacing is halved, below what temperature, in kelvin, would Warren need to be treated quantum mechanically?

ANSWER: 40 [MR]

BONUS

18) **Physics – *Multiple Choice*** Alex is holding a speaker emitting sound at a frequency of 400 hertz in all directions between two perfectly reflecting walls. He starts walking with a speed of 1.7 meters per second towards one of the walls while still carrying the speaker. As a result, he hears two frequencies, one with a higher frequency from the wall he is walking towards and another with a lower frequency from the wall he is walking away from due to Doppler shift. Assuming the speed of sound to be 340 meters per second, to one significant figure and in hertz, what is the beat frequency of the sound produced?

W) 1
X) 2
Y) 4
Z) 8

ANSWER: Z) 8 [MR]

TOSS-UP

19) **Earth and Space – *Short Answer*** By name or number, rank the following three intrusive igneous features by increasing size:

1. Batholith
2. Phacolith
3. Pluton

ANSWER: 2, 3, 1 [AG]

BONUS

19) **Earth and Space – *Short Answer*** In what layer of Earth's atmosphere do red sprites occur?

ANSWER: MESOSPHERE [AG]

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TOSS-UP

20) **Biology – *Multiple Choice*** Which of the following best describes the Hill-Robertson effect in population genetics?

W) Advantage of heterozygotes in balancing selection
X) Reduction in effective population size due to inbreeding
Y) Interference between linked loci under selection reducing efficacy of natural selection
Z) Genetic drift resulting in fixation of neutral alleles

ANSWER: Y) INTERFERENCE BETWEEN LINKED LOCI UNDER SELECTION REDUCING EFFICACY OF NATURAL SELECTION [AK]

BONUS

20) **Biology – *Short Answer*** What is the term for the reduction in genetic variation at neutral loci due to the fixation of beneficial alleles at nearby sites under positive selection?

ANSWER: GENETIC HITCHIKING/SELECTIVE SWEEP (accept HITCHIKING) [AK]

TOSS-UP

21) **Chemistry – *Short Answer*** Which of the following halogens displays a mass spectrum M and M+2 ratio of approximately 1:1?

W) Fluorine
X) Chlorine
Y) Bromine
Z) Iodine

ANSWER: Y) BROMINE [AG]

BONUS

21) **Chemistry – *Short Answer*** By name or number, rank the following four single bonds by increasing bond energy.

1. F-F (read: fluorine-fluorine)
2. Cl-Cl (read: chlorine-chlorine)
3. Br-Br (read: bromine-bromine)
4. I-I (read: iodine-iodine)

ANSWER: 4, 1, 3, 2 (accept equivalent) [QG]

TOSS-UP

22) **Math – *Multiple Choice*** What is the remainder when $x^{13} + 1$ is divided by $x - 1$?

W) -1
X) 0
Y) 1
Z) 2

ANSWER: Z) 2 [MR]

BONUS

22) **Math – *Short Answer*** Warren is using Newton's method to evaluate the roots of $f(x) = x^2 - 3x + 1$. If he makes an initial guess at $x = 2$, what is his estimate for the x-intercept of $f(x)$ after two iterations?

ANSWER: 8/3 [QG]

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TOSS-UP

23) **Physics – *Short Answer*** In special relativity, what mathematical object is used to describe quantities such as energy-momentum, position in spacetime, and proper velocity in a way that remains invariant under Lorentz transformations?

ANSWER: FOUR-VECTOR [MR]

BONUS

23) **Physics – *Multiple Choice*** Max sees Warren in the hallway while walking to APUSH and waves to him. Which of the following accurately describes the derivatives of the amplitude function present in the wave equation?

W) First order with respect to time; first order with respect to position
X) First order with respect to time; second order with respect to position
Y) Second order with respect to time; first order with respect to position
Z) Second order with respect to time; second order with respect to position

ANSWER: Z) SECOND ORDER WITH RESPECT TO TIME; SECOND ORDER WITH RESPECT TO POSITION [MR]

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TOSS-UP (30 seconds)

24) **Estimation – *Short Answer*** Alex and Ethan typically talk about hurricane nonsense in the hidden #hurricaners channel in the BASED Discord server. Estimate, in Watts and to the nearest order of magnitude, the energy generated by the winds in a typical category 3 hurricane.

ANSWER: 12 [MR]

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End of Questions.