2025 Bay Area Science-Estimathon Duel

Double Elimination
Question Set 7

Questions will begin on the next page.

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

TOSS-UP

1) **Math – *Multiple Choice*** A lot of multivariable calculus revolves around doing goofy stuff with the gradient, curl, divergence, and Laplacian operators, each accepting an input and output of either a vector or scalar. Keeping this in mind, in 3 dimensional space, which of the following sequence of operations wouldn't yield a valid output?

W) Divergence of the gradient of a scalar field
X) Gradient of the Laplacian of a scalar field
Y) Curl of the curl of a vector field
Z) Laplacian of the curl of a vector field

ANSWER: Z) LAPLACIAN OF THE CURL OF A VECTOR FIELD [MR]

BONUS

1) **Math – *Multiple Choice*** What is the expected number of throws of a fair coin needed to land a sequence of 3 heads in a row?

W) 12
X) 13
Y) 14
Z) 15

ANSWER: Y) 14 [QG]

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TOSS-UP

2) **Y-Risk – *Multiple Choice*** Which of the following crown ethers would best chelate a sodium ion?

W) 12 crown 4
X) 15 crown 5
Y) 18 crown 6
Z) 21 crown 7

ANSWER: X) 15 CROWN 5 [AG]

BONUS

2) **Y-Risk – *Short Answer*** For a phase diagram of a single-component system at equilibrium, how many degrees of freedom are there for the triple point?

ANSWER: 0 [AG]

TOSS-UP

3) **Earth and Space – *Multiple Choice*** Which of the following represents the most common rocks in oceanic and continental crust, respectively?

W) Basalt, Granodiorite
X) Basalt, Granite
Y) Peridotite, Granodiorite
Z) Peridotite, Granite

ANSWER: W) BASALT, GRANODIORITE [AG]

BONUS

3) **Earth and Space – *Short Answer*** What process, which generates new mid-ocean ridges, denotes the generation by mantle plumes via melting of intermediate to mafic rock following a water-vapor-based pressure drop in the mantle?

ANSWER: DECOMPRESSION MELTING [AG]

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TOSS-UP

4) **Physics – *Short Answer*** What mathematical objects are used to generate new solutions for the quantum harmonic oscillator by raising or lowering the energy of the solution?

ANSWER: LADDER OPERATORS (accept RAISING AND LOWERING OPERATORS) [MR]

BONUS

4) **Physics – *Short Answer*** Inductors of 0.5, 2, 6, 24, and 120 henry are placed in parallel with an initially fully charged 5.4 farad capacitor. To two significant figures and in seconds, what is the angular frequency of the resulting LC circuit?

ANSWER: 0.71 [MR]

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TOSS-UP

5) **Biology – *Short Answer*** While swimming, Max bumps into a stingray. He observes that it's rather bendable. What biological class encompasses cartilaginous fishes such as rays?

ANSWER: CHONDRICHTHYES[1] (accept CONDRICHTHYANS or obvious efforts) [EP]

BONUS

5) **Biology – *Short Answer*** By name or number, identify all of the following fish that are chondrichthyans[1]:

1. Tiger shark
2. Ratfish
3. Sawfish
4. Lamprey

ANSWER: 1, 2, AND 3 (TIGER SHARK, RATFISH, SAWFISH) [EP]

[1] The correct pronunciation is *con-DRICK-thees* or *con-DRICK-thee-yans*.

TOSS-UP

6) **Chemistry – *Multiple Choice*** Which of the following cyclic molecules is anti-aromatic?

W) Benzene
X) Cyclooctatetraene (pronounce cyclo-octa-tetra-een)
Y) Pyridine
Z) Cyclotetradiene (pronounce cyclo-tetra-di-een)

ANSWER: Z) CYCLOTETRADIENE [AG]

BONUS

6) **Chemistry – *Short Answer*** Four groups, labeled A, B, C, and D, are bonded to the same carbon atom. When this molecule is oriented with d behind the plane, clockwise from the top are a, b, and c, respectively. Given that A is a chlorine atom, B is a tert-butyl group, C is a hydroxyl group, select all of the three following potential choices for group D that would make the carbon atom an R stereocenter.

1. Hydrogen atom
2. Sec-butyl group
3. Amine group

ANSWER: 3 ONLY [AG]

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TOSS-UP

7) **Y-Risk – *Short Answer*** Max and Warren are experimenting with quantum communication protocols. They begin an experiment each possessing one of two entangled qubits, which are in a Bell state. Then, using quantum gates, Max is able to transmit two classical bits of information to Warren by sending one qubit. What is the name of this protocol?

ANSWER: SUPERDENSE CODING (accept: DENSE CODING, do not accept: QUANTUM TELEPORATION) [QG]

BONUS

7) **Y-Risk – *Multiple Choice*** Students at SHS have managed to get their hands on a quantum computer. They decide to use it to crack a 6-digit iPhone passcode by using Grover's algorithm, where each possible code is considered as one option in the solution space. If they run the algorithm for 666 iterations, which of the following is closest to the probability that the quantum computer returns the correct code?

W) 1/2
X) 3/4
Y) 7/8
Z) 15/16

ANSWER: X) 3/4 [QG]

TOSS-UP

8) **Earth and Space – *Short Answer*** Which of the following types of silicates does epidote belong to?

W) Tectosilicate
X) Nesosilicate
Y) Inosilicate
Z) Sorosilicate

ANSWER: Z) SOROSILICATE [AG]

VISUAL BONUS

8) **Earth and Space – *Short Answer*** The image below shows an analemma, the superimposed position of the Sun at a set location and time on different days of the year. Answer the following two questions about analemmas:

1. What orbital property of the Earth is chiefly responsible for the north-south, or vertical, size of the analemma?
2. What orbital property of the Earth is chiefly responsible for the east-west, or horizontal, size of the analemma?



ANSWERS:
1. OBLIQUITY (accept AXIAL TILT)
2. ECCENTRICITY [MR]

TOSS-UP

9) **Math – *Multiple Choice*** Which of the following represents a solution to the differential equation xy' = 2/y?

W) y = +/- sqrt(2x)
X) y = 2ln(x)
Y) y = +/- 2/sqrt(x)
Z) y = +/- 2sqrt(ln|x|)

ANSWER: Z) Y = +/- 2SQRT(LN|X|) [DO NOT ACCEPT 2SQRT(LN(X))] [QG]

BONUS

9) **Math – *Short Answer*** What is the indefinite integral of e^x sin(x) dx?

ANSWER: 1/2 e^x (sin(x)-cos(x)) + C[2] [QG]

[2] Equivalents, like 1/2e^xsin(x) - 1/2e^x cos(x) + C, may be accepted.

TOSS-UP

10) **Biology – *Short Answer*** Alex has several isopods. What leglike appendages, located on the underside of isopods and other crustaceans, are commonly used by isopods for respiration and motility and function similarly to gills?

ANSWER: PLEOPODS [EP]

BONUS

10) **Biology – *Short Answer*** Alex is observing his isopods. One of his isopods is "twerking," or rapidly relaxing and contracting its abdominal muscles to clear fluid from its pleopodal lungs. These lungs, which evolved from gills, are analogous to what similar feature of tube-shaped pores found in many insects and arachnids?

ANSWER: SPIRACLES [AG]

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TOSS-UP

11) **Physics – *Multiple Choice*** Richard Feynman [*fine-man*] is playing his bongo drums and starts thinking about vibrations. What functions describe the radial part of the vibrations on the circular membrane of his drum?

W) Bessel functions
X) Green's functions
Y) Spherical harmonics
Z) Euler functions

ANSWER: W) BESSEL FUNCTIONS [MR]

BONUS

11) **Physics – *Multiple Choice*** Feynman continues thinking about non-elementary functions. He looks at the pendulum swinging in his grandfather clock and writes down the exact solution for its period, without using the small angle approximation. What special function did he use?

W) Bessel functions of the first kind
X) Bessel functions of the second kind
Y) Elliptical integral of the first kind
Z) Elliptical integral of the second kind

ANSWER: Y) ELLIPTICAL INTEGRAL OF THE FIRST KIND [MR]

TOSS-UP

12) **Chemistry – *Short Answer*** Some trigonal bipyramidal molecules, such as PF_3Cl_2, rapidly flip pairs of axial and equatorial groups for stability. What is the name of this mechanism?

ANSWER: BERRY PSEUDOROTATION (ACCEPT: BERRY MECHANISM) [AG]

BONUS

12) **Chemistry – *Short Answer*** In some octahedral complexes, the axial bonds will geometrically distort to become longer or shorter than the equatorial bonds, reducing its symmetry and thus energy. What is the name of this effect?

ANSWER: JAHN-TELLER DISTORTION [AG]

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TOSS-UP

13) **Math – *Short Answer*** Name all of the following four operations which represent an inner product.

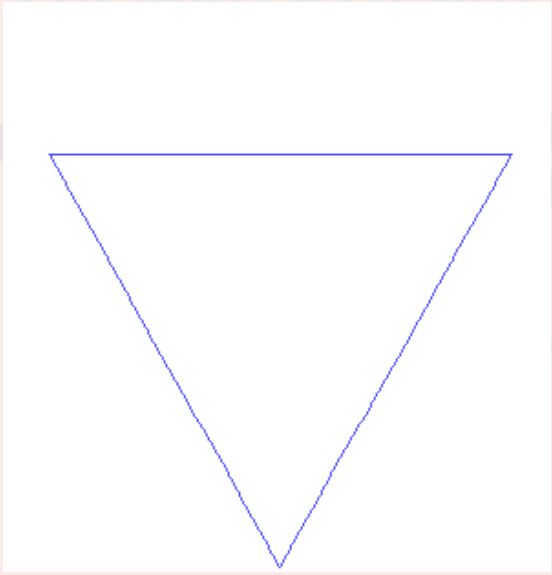
1. x.y (read x dot y) = xy for real numbers x and y
2. x.y = xy for complex numbers x and y
3. x.y = x^Ty (read x transpose times y) for vectors x and y in Rn
4. f(x).g(x) = the integral from 0 to 1 of f(x)g(x)dx for continuous, real valued functions f and g of x on the interval [0,1]

ANSWER: 1, 3, AND 4 [QG]

VISUAL BONUS

13) **Math – *Multiple Choice*** Shown in the GIF is the formation of a Koch snowflake, the fractal formed iteratively by starting with an equilateral triangle and subdividing each segment into thirds and constructing a smaller equilateral triangle from the center third segment. Given an initial equilateral triangle with area A, in terms of A, what is the area of the resulting Koch snowflake formed around the equilateral triangle?

W) 10A/7
X) 3A/2
Y) 8A/5
Z) 5A/3



ANSWER: Y) 8A/5 [QG]

TOSS-UP

14) **Physics – *Multiple Choice*** In an elastic, head-on collision involving two balls, one with mass m and the other with mass 3m, both bounce away from each other with half the initial velocity of the less massive ball. Consider four similar balls of masses m, 3m, 9m, and 27m on one line left to right in that order. If the ball of mass m is given a velocity v to the right, what is the speed and direction of the 9m and 27m balls center of mass after all possible elastic collisions have occurred?

W) 3v/32 to the left
X) v/16 to the left
Y) v/16 to the right
Z) 3v/32 to the right

ANSWER: Y) V/16 TO THE RIGHT [MR]

BONUS

14) **Physics – *Short Answer*** Max is building an electric motor. He places a circular conducting coil with radius 10cm and 3 turns in a uniform magnetic field of magnitude 2 Teslas. He then has the coil rotate a speed of 50 radians per second about a diameter perpendicular to the field. In volts and to one significant figure, what is the difference between the peak voltage and RMS voltage generated in the coil?

ANSWER: 3 [QG]

TOSS-UP

15) **Biology – *Multiple Choice*** In yeast, tetrad analysis allows geneticists to dissect all four products of a single meiotic event. This technique is especially useful for determining the genetic distance between two loci because it distinguishes parental ditypes, non-parental ditypes, and tetratypes. Which of the following principles of inheritance does tetrad analysis directly test?

W) Law of independent assortment
X) Principle of Dominance
Y) Law of segregation
Z) Principle of Paired Factors

ANSWER: W) LAW OF INDEPENDENT ASSORTMENT [AK]

BONUS

15) **Biology – *Short Answer*** By name or number, identify all of the following statements which are true about tetrad analysis in yeast:

1. A 2:2 segregation of alleles in an ascus demonstrates Mendel's law of segregation.
2. The frequency of tetratypes can be used to calculate recombination frequency between two genes.
3. Ordered tetrads allow the detection of centromere linkage and second-division segregation.

ANSWER: ALL [AK]

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TOSS-UP

16) **Chemistry – *Multiple Choice*** Which of the following best describes the rate of pyramidal inversion in ammonia relative to that of phosphine gas as pressure increases?

W) Lesser, then greater
X) Greater, then lesser
Y) Always greater
Z) Always lesser

ANSWER: Y) ALWAYS GREATER [AG]

BONUS

16) **Chemistry – *Short Answer*** Using Slater's Rules and to two decimal places, approximate the effective nuclear force on a 4s electron in a ground state atom of zinc.

ANSWER: 4.35 [AG]

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TOSS-UP

17) **Y-Risk – *Multiple Choice*** Warren is making some popcorn, but most of his corn doesn't pop and he complains about constant kernels ruining his UX. Where is a kernel most likely to be used in the context of neural networks?

W) In a connected layer of a perceptron
X) In a convolutional layer of a CNN [read as C-N-N]
Y) As one of the intermediate neurons in a recurrent network
Z) As an intermediate layer in a GAN [read as a single word]

ANSWER: X) IN A CONNECTED LAYER OF A CNN [WC]

BONUS

17) **Y-Risk – *Short Answer*** Mathematicians love coming up with ridiculously big numbers. Order the following four numbers from smallest to largest:

1. Graham's number
2. Rayo's number
3. TREE(3)
4. Googolplex

ANSWER: 4, 1, 3, 2 [QG]

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TOSS-UP

18) **Earth and Space – *Multiple Choice*** Which of the following best determines the ultimate fate of the Universe's expansion?

W) The total mass of the Universe
X) The average density of dark matter
Y) The average density of all matter and energy
Z) The ratio of dark matter to baryonic matter

ANSWER: Y) THE AVERAGE DENSITY OF ALL MATTER AND ENERGY [MR]

BONUS

18) **Earth and Space – *Short Answer*** By name or number, select all of the following three geological features that are a product of differential erosion.

1. Flared slopes
2. Tombolos
3. Bornhardts

ANSWER: 1, 3 [AG]

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TOSS-UP

19) **Math – *Short Answer*** A set of 10 real numbers has a mean of 14 and a median of 11. Name all of the following four changes that might occur when replacing a data value of 16 with one of 15 in this set:

1. The median decreases
2. The median is unchanged
3. The standard deviation decreases
4. The standard deviation is unchanged

ANSWER: 2, 3, AND 4 [QG]

BONUS

19) **Math – *Multiple Choice*** The science bowl team is dividing their 8 new members into two teams of 4 for a practice game. Among these members, there are 3 math mains, 3 biology mains, and 1 main each for chemistry and physics. Each team must have mains for at least 3 different categories. If members, but not teams, are distinct, how many different playable pairs of teams are there?

W) 9
X) 15
Y) 18
Z) 24

ANSWER: Y) 18 [QG]

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TOSS-UP

20) **Physics – *Multiple Choice*** A pendulum is made of a point mass attached to one end of a uniform rod, each initially having the same mass. The other end of the rod is hung from a frictionless hinge and the pendulum undergoes small oscillations. If all other variables are held constant, what will happen to the period of these small oscillations as the mass at the end of the rod is slowly increased to infinity?

W) The period will slowly decrease, approaching a non-zero constant
X) The period will stay the same
Y) The period will slowly increase, approaching a non-zero constant
Z) The period will increase indefinitely

ANSWER: Y) THE PERIOD WILL SLOWLY INCREASE, APPROACHING A NON-ZERO CONSTANT [MR]

BONUS

20) **Physics – *Multiple Choice*** Quinn learns about a new prospective field of physics: lubrication theory. Lubrication theory assumes that film thickness is much smaller than the length of the overall domain of the system, which allows the Navier-Stokes equations to be substantially simplified. Why does this thin-film assumption result in this simplification?

W) It allows for pressure gradients normal to the film to be neglected
X) It provides extremely simple boundary conditions
Y) It causes all viscous forces to become negligible relative to inertial forces
Z) It allows for pressure to be assumed constant throughout the fluid

ANSWER: W) IT ALLOWS FOR PRESSURE GRADIENTS NORMAL TO THE FILM TO BE NEGLECTED [MR]

TOSS-UP

21) **Biology – *Short Answer*** Arjun is titrating some amino acids with a strong base. By name or number, identify all of the following amino acids that will produce three buffer regions during titration:

1. Glycine
2. Selenocysteine
3. Aspartic acid
4. Hydroxyproline

ANSWER: 2 AND 3 [AK]

BONUS

21) **Biology – *Short Answer*** What enzyme catalyzes the addition of a methyl group to cytosine residues in DNA, and is essential for gene silencing and genomic imprinting in mammals?

ANSWER: DNA METHYLTRANSFERASE (accept METHYLTRANSFERASE) [AK]

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TOSS-UP

22) **Chemistry – *Short Answer*** 3-oxobutanoic acid is known to spontaneously decompose at room temperature. What are the likely two products of this reaction?

ANSWER: ACETONE AND CARBON DIOXIDE [AG]

BONUS

22) **Chemistry – *Multiple Choice*** Which of the following polymers would best retain FD&C Yellow 6, a polar and ionic dye?

W) Polyethylene
X) Polystyrene
Y) Polyurethane
Z) Polyethylene terephthalate

ANSWER: Y) POLYURETHANE [AG]

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TOSS-UP

23) **Earth and Space – *Multiple Choice*** Which moon of Jupiter exhibits a characteristic red hue and orbits extremely close to the planet?

W) Epimetheus
X) Amalthea
Y) Nereid
Z) Umbriel

ANSWER: X) AMALTHEA [EP]

BONUS

23) **Earth and Space – *Multiple Choice*** Amalthea is unusual in that it is the reddest object in the Solar System. Which of the following is the most commonly accepted explanation for Amalthea's red hue?

W) Residual volcanic sulfur deposited by eruptions on nearby Io
X) High concentration of iron oxides on its surface
Y) Reflected light from Jupiter's red atmospheric clouds
Z) Extreme tidal heating due to its proximity to Jupiter melting its surface

ANSWER: W) RESIDUAL VOLCANIC SULFUR DEPOSITED BY ERUPTIONS ON NEARBY IO [EP]

TOSS-UP (30 seconds)

24) **Estimation – *Short Answer*** After doing some interpolation, Max discovers that the relationship between the radius of a circular particle accelerator and its construction cost is approximately linear. Given this, to the nearest order of magnitude, estimate the ratio of the projected construction cost of a particle accelerator going all the way around the Earth's equator to the United States' national debt.

ANSWER: 0 [MR]

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End of Questions.