

# 2025 Texas Science Bowl Invitational

## Finals 1



## Authors

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## TOSS UP

- 1) CHEMISTRY *Short Answer* Cyclobutadiene is a reactive, cyclic compound with chemical formula C<sub>4</sub>H<sub>4</sub>. What effect causes cyclobutadiene's geometry to be rectangular, rather than a square?

ANSWER: Jahn-Teller effect [READ: *YON TELLER*] [ACCEPT: Jahn-Teller distortions, pseudo-Jahn-Teller effect, second order Jahn-Teller effect; DO NOT ACCEPT: Antiaromaticity]

## BONUS

- 1) CHEMISTRY *Short Answer* According to Baldwin's rules, which of the following ring closures are favored:

- 1) 3-exo-dig
- 2) 5-endo-trig
- 3) 6-endo-tet

ANSWER: None

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## TOSS UP

- 2) MATH *Multiple Choice* How many pairs of perfect squares differ by 60?

- W) 0
- X) 1
- Y) 2
- Z) 3

ANSWER: Y) 2

## BONUS

- 2) MATH *Short Answer* Points A and B lie on the lines  $\frac{x}{2} = \frac{y}{3} = \frac{z}{4}$  and  $x = y - 2 = \frac{z-1}{2}$  [READ: *x equals y minus 2 equals the quantity z-1 divided by 2*], respectively. Find the smallest possible value of AB.

ANSWER:  $\frac{2\sqrt{30}}{5}$

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## TOSS UP

3) EARTH AND SPACE *Short Answer* Identify all of the following three objects whose structure is influenced by Lindblad resonances:

- 1) Spiral arms of galaxies
- 2) Saturn's rings
- 3) Roche lobes of binary star systems

ANSWER: 1 and 2

## BONUS

3) EARTH AND SPACE *Short Answer* If the Titius-Bode law worked for all planets in our solar system, and the semimajor axis of Mercury is 0.4 AU, and the semi-major axis of Venus is 0.7 AU, what is the predicted semi-major axis of Neptune, in AU to two significant figures?

ANSWER: 19 AU

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## TOSS UP

4) PHYSICS *Short Answer* Yale is trying to send a small payload with a dry mass of 1 kilogram to space with 50 kilograms of propellant. His propulsion mechanism expels propellant at a constant rate and constant exit velocity of 2000 meters per second. Assuming no air resistance and to the nearest hundred kilograms, what mass of propellant should Yale use if he wants to double the maximum final velocity of his payload?

ANSWER: 2500

## BONUS

4) PHYSICS *Short Answer* Krutharth is studying the motion of a physical system by calculating its Lagrangian and solving the corresponding Euler-Lagrange equations. Which of the following could be true about his solution:

- 1) The solution is a minimum of the action
- 2) The solution is a saddle point of the action
- 3) The solution is a maximum of the action

ANSWER: 1 and 2 only

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## TOSS UP

5) BIOLOGY *Multiple Choice* While physiological levels of epinephrine in circulation generally lead to vasodilation, very high levels of epinephrine such as those found in EpiPens can serve as potent vasoconstrictors. This constriction is due to the presence of what particular type of smooth muscle adrenergic receptor?

- W) Alpha-1
- X) Alpha-2
- Y) Beta-1
- Z) Beta-2

ANSWER: W) Alpha-1

## BONUS

5) BIOLOGY *Short Answer* The distinct smell of the Eucalyptus tree arises due to the leaves' production of what class of highly volatile organic polymers, commonly associated with protection from herbivory across the plant kingdom?

ANSWER: Terpenoids [ACCEPT: Terpenes]

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## TOSS UP

6) CHEMISTRY *Multiple Choice* Which of the following elementary steps in the catalytic cycle of a typical cross-coupling reaction is the rate-determining step?

- W) Oxidative addition
- X) Transmetalation
- Y) Reductive elimination
- Z) Beta-hydride elimination

ANSWER: X) Transmetalation

## BONUS

6) CHEMISTRY *Short Answer* Order the following three aromatic compounds in terms of increasing reactivity towards electrophilic aromatic substitution:

- 1) Benzene
- 2) Pyrrole
- 3) Pyridine

ANSWER: 3, 1, 2

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## TOSS UP

7) MATH *Multiple Choice* Let X be a random variable picked from the normal distribution with mean 0 and standard deviation 0.6, and let Y be a random variable picked from the normal distribution with mean 1 and standard deviation 0.8. Which of the following is closest to the probability that  $X < Y$ ?

- W) 68%
- X) 84%
- Y) 95%
- Z) 97%

ANSWER: X) 84%

## BONUS

7) MATH *Multiple Choice* Which of the following facts is not true about Chebyshev polynomials of the first kind?

- W) All of their roots are real
- X) They have no double roots
- Y) They are monic
- Z) The product of their roots is rational

ANSWER: Y) They are monic

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## TOSS UP

8) EARTH AND SPACE *Multiple Choice* At depths below 300 km in a Wadati-Benioff zone, which of the following is the primary mechanism thought to be responsible for generating earthquakes?

- W) Dehydration reactions in the subducting slab
- X) Frictional thrusting at the plate interface
- Y) Formation of eclogite from gabbro
- Z) Phase transition from olivine to spinel

ANSWER: Z) Phase transition from olivine to spinel

## BONUS

8) EARTH AND SPACE *Short Answer* Identify all of the following three factors that would inhibit the formation of a nocturnal temperature inversion near the ground:

- 1) Increased thermal conductance of soil
- 2) Increased vegetation cover
- 3) Increased snow coverage

ANSWER: 1 and 2 only

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## TOSS UP

9) PHYSICS *Multiple Choice* A metal chain is hanging between two posts, forming a catenary. Aldric pulls downward at a point on the chain to the right of the midpoint, causing it to go taut. What direction does the center of mass of the chain move?

- W) Upwards and to the left
- X) Upwards and to the right
- Y) Downwards and to the left
- Z) Downwards and to the right

ANSWER: Y) Downwards and to the left

## BONUS

9) PHYSICS *Short Answer* Ben Lin bends a copper wire into a circular coil with radius 1 centimeter and measures the inductance of the resulting solenoid to be  $L$ . He then unwinds the coil and uses the same length of wire to make a square coil with side length 1 centimeter and an equal number of turns per meter as the circular coil. In terms of  $L$ , what is the inductance of the square coil?

ANSWER:  $\frac{2L}{\pi^2}$

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## TOSS UP

10) BIOLOGY *Multiple Choice* Krutharth has acquired a solution containing many proteins involved in the Cyclic AMP signalling pathway and wants to isolate adenylyl cyclase from the solution via affinity chromatography. Which of the following would be the best choice of stationary phase and eluant, respectively?

- W) Cyclic AMP, Cyclic AMP
- X) Cyclic AMP, ATP
- Y) ATP, Cyclic AMP
- Z) ATP, ATP

ANSWER: Z) ATP, ATP

## BONUS

10) BIOLOGY *Short Answer* Suzuko created a supercrop by identifying 5 high-fitness mutant corn strains and introducing one of these strains at a time to a population of corn under high selective pressure every four generations. The final population had multiple very-high-fitness individuals exhibiting all 5 mutant traits. However, when Aryan replicated the experiment, introducing the strains in a different order, his final population was genetically identical to wild-type. This implies the presence of what genetic phenomenon in this set of genes?

ANSWER: Epistasis

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## TOSS UP

11) CHEMISTRY *Short Answer* What equation describes how the rate of reaction depends on the thermodynamic favorability of the formation of the transition state?

ANSWER: Eyring equation [DO NOT ACCEPT: Arrhenius equation]

## BONUS

11) CHEMISTRY *Short Answer* Which of the following 3 reaction conditions will favor conjugate addition when adding a nucleophile to an alpha-beta unsaturated carbonyl:

- 1) Performing the reaction at low temperatures
- 2) Using stable carboxylic acid derivatives like amides
- 3) Adding a strong Lewis acid like cerium trichloride

ANSWER: 2 only

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## TOSS UP

12) MATH *Short Answer* What is the largest power of 5 that divides  $2^{25} + 3^{25}$ ?

ANSWER: 125

## BONUS

12) MATH *Multiple Choice* How many distinct roots does the polynomial  $(x - 1)(x^2 - 1) \dots (x^7 - 1)$  [READ: *the quantity x minus one times the quantity x squared minus one continued to x to the seventh minus one*] have?

- W) 15
- X) 16
- Y) 17
- Z) 18

ANSWER: Z) 18

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## TOSS UP

13) EARTH AND SPACE *Multiple Choice* If you plotted a histogram of the burst durations of a catalog of gamma ray bursts, which of the following distributions would you observe?

- W) A unimodal distribution
- X) A bimodal distribution
- Y) A left-skewed distribution
- Z) A right-skewed distribution

ANSWER: X) A bimodal distribution

## BONUS

13) EARTH AND SPACE *Short Answer* Jophy, the smallest astronaut with only a tiny fuel reserve, is deciding between a Hohmann transfer and a bi-elliptic transfer for her interplanetary journey. Identify all of the following three planets that would be more fuel-efficient to reach from Earth through a bi-elliptic transfer compared to a Hohmann transfer:

- 1) Venus
- 2) Mars
- 3) Jupiter

ANSWER: None

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## **TOSS UP**

14) PHYSICS *Short Answer* Aryan places his twelve sided pencil on a surface with infinite friction. Given that the pencil has a regular dodecagonal cross section, how many degrees does he have to tilt the surface for the pencil to begin to roll?

ANSWER: 15

## **BONUS**

14) PHYSICS *Short Answer* Aprameya places a drop of unknown liquid on a table and measures its contact angle. Which of the following changes would increase this contact angle:

- 1) Increasing the surface tension between the liquid and air
- 2) Increasing the surface tension between the liquid and the table
- 3) Increasing the surface tension between the air and the table

ANSWER: 1, 2

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## **TOSS UP**

15) BIOLOGY *Multiple Choice* Selena discovers a rare *Arabidopsis ein/ctr* double mutant. The phenotype of this mutant would be most similar to which of the following *Arabidopsis* strains?

- W) Wild-Type
- X) Ein
- Y) Ctr
- Z) Eto

ANSWER: Y) Ctr

## **BONUS**

15) BIOLOGY *Short Answer* Members of the class Kinetoplastida contain multiple linked copies of circular mitochondrial DNA called minicircles. During mitosis, what specific enzyme is responsible for both the unlinking and relinking of these minicircles?

ANSWER: Topoisomerase II

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## TOSS UP

16) CHEMISTRY *Short Answer* The reaction of 2-hexene and hydrochloric acid proceeds by protonation of the alkene followed by trapping of the carbocation with the chloride ion. When deuterated hydrochloric acid is used, the reaction rate decreases. What is the phenomenon responsible for the decrease in reaction rate?

ANSWER: Kinetic isotope effect [DO NOT ACCEPT: Deuterium effect]

## BONUS

16) CHEMISTRY *Multiple Choice* Diethyl ether is placed in an evacuated container with a movable piston and is allowed to rest until the residual liquid has equilibrated with its vapor pressure. Which of the following best describes the monotonic behavior of the pressure P when the piston is pulled up to increase the volume of the container at constant temperature?

- W) P is strictly increasing.
- X) P is strictly decreasing.
- Y) P is non-increasing.
- Z) P is non-decreasing.

ANSWER: Y) P is non-increasing.

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## TOSS UP

17) MATH *Short Answer* An ant walks along the sides of a regular unit tetrahedron from a vertex to the center of the opposing face. What is the minimum distance it must walk?

ANSWER:  $\frac{2\sqrt{3}}{3}$

## BONUS

17) MATH *Short Answer* What is the minimum possible value of the expression  $\sqrt{x^2 + 9} + \sqrt{(3 - x)^2 + 1}$  [READ: the square root of  $x$  squared plus 9 plus the square root of the quantity 3 minus  $x$  squared plus 1]?

ANSWER: 5

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## TOSS UP

18) EARTH AND SPACE *Short Answer* Order the following three positions of Jupiter in increasing order of apparent magnitude as seen from Earth:

- 1) Quadrature
- 2) Opposition
- 3) Conjunction

ANSWER: 3, 1, 2

## BONUS

18) EARTH AND SPACE *Short Answer* Haerin from the K-pop group NewJeans observe that the surface rock on the east side of a reverse fault is from the Permian period, where the fault dips toward the west at 30 degrees. Identify all of the following three periods that the rock on the west side could belong to:

- 1) Mississippian
- 2) Jurassic
- 3) Devonian

ANSWER: 1 and 3 only

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## TOSS UP

19) PHYSICS *Short Answer* In electromagnetism, the magnetic vector potential is not unique and can be shifted by any irrotational vector field. Which gauge choice fixes the vector potential by restricting its divergence to be zero?

ANSWER: Coulomb gauge

## BONUS

19) PHYSICS *Short Answer* Alex has three heat reservoirs with distinct temperatures  $T_1$ ,  $T_2$ , and  $T_3$ , all with the same constant heat capacity. He then runs a series of reversible processes between these three bodies, altering the temperatures of the reservoirs to  $T_1'$ ,  $T_2'$ , and  $T_3'$ . Identify all of the following three means which are necessarily the same for both the final and initial sets of temperatures:

- 1) Arithmetic Mean
- 2) Geometric Mean
- 3) Harmonic Mean

ANSWER: 1 and 2 only

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## **TOSS UP**

20) BIOLOGY *Short Answer* Identify all of the following three features of Zebrafish that make it an ideal model organism for studying development:

- 1) It has a 3-day generation time
- 2) Zebrafish embryos are transparent
- 3) Female Zebrafish have high fecundity

ANSWER: 2 and 3 only

## **BONUS**

20) BIOLOGY *Short Answer* Roundup-Ready soybeans are resistant to the glyphosate-derived herbicide Roundup because they have a mutant version of the EPSP Synthase gene. This gene is important to what metabolic pathway that can synthesize amino acids like tryptophan?

ANSWER: Shikimic Acid Pathway [ACCEPT: Shikimate Pathway]

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## **TOSS UP**

21) CHEMISTRY *Short Answer* During the 2023 USNCO National Exam, students panicked nationwide due to the slow kinetics of the dissolution of benzoic acid in water. What is the general name for the effect that causes the abnormally strong intermolecular forces of aromatic systems responsible for the national hysteria, caused by molecular orbital overlap?

ANSWER: pi-pi Stacking [ACCEPT: pi-stacking]

## **BONUS**

21) CHEMISTRY *Short Answer* Identify which of the following carbene-containing molecules will have a triplet ground state:

- 1) Carbene
- 2) Grubbs' catalyst
- 3) Dichlorocarbene

ANSWER: 1 only

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## TOSS UP

22) MATH *Short Answer* Jonathan flips a fair coin 10 times. What is the probability that he never flips a head followed by a tail?

ANSWER:  $\frac{11}{1024}$

## BONUS

22) MATH *Multiple Choice* Let X be a random variable picked from the normal distribution with mean 0 and standard deviation  $\sqrt{2}/2$ , and let Y be a random variable picked from the normal distribution with mean 1 and standard deviation  $\sqrt{2}/2$ . Which of the following is closest to the probability that  $X^2 < Y^2$ ?

- W) 67%
- X) 70%
- Y) 73%
- Z) 76%

ANSWER: Y) 73%

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## TOSS UP

23) EARTH AND SPACE *Short Answer* What hypothesis postulates that all singularities must lie behind an event horizon?

ANSWER: Cosmic Censorship Hypothesis

## BONUS

23) EARTH AND SPACE *Short Answer* Order the following three idealized, flat FRW universes from youngest to oldest based on their current age:

- 1) A universe dominated entirely by dark energy
- 2) A universe dominated entirely by radiation
- 3) A universe dominated entirely by matter

ANSWER: 2, 3, 1

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## TOSS UP

24) PHYSICS *Multiple Choice* Krutharth connects all pairs of lattice points that are unit distance apart with one ohm resistors, creating an infinite square grid. To one decimal place, find the resistance in Ohms between the points (0, 0) and (1, 0).

- W) 0.5
- X) 0.9
- Y) 1.3
- Z) 1.7

ANSWER: W) 0.5

## BONUS

24) PHYSICS *Short Answer* Which of the following pairs of quantum mechanical operators commute:

- 1) Position and momentum
- 2) Position in the x direction and momentum in the y direction
- 3) Position in the x direction and angular momentum in the y direction

ANSWER: 2 only

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## TOSS UP

25) BIOLOGY *Short Answer* Flow cytometry is a powerful technique capable of sorting cells by size and granularity. Identify all of the following which are true about the locations of immune cells on a granularity vs cell size plot:

- 1) Monocytes would be located to the right of Lymphocytes
- 2) Monocytes would be located above Neutrophils
- 3) Neutrophils would be located to the left of Lymphocytes

ANSWER: 1 only

## BONUS

25) BIOLOGY *Multiple Choice* For a particular Mendelian two-allele gene in an extremely large population, the recessive phenotype is lethal. If  $q(k)$  [READ:  $q$  of  $k$ ] represents the frequency of the recessive allele at generation  $k$ , which of the following functions of  $k$  will be closest to linear?

- W)  $q(k)$
- X)  $k \cdot q(k)$
- Y) The natural logarithm of  $q(k)$
- Z) The reciprocal of  $q(k)$

ANSWER: Z) The reciprocal of  $q(k)$

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