

# 2025 Texas Science Bowl Invitational

## Finals 2



## Authors

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### TOSS UP

1) BIOLOGY *Short Answer* The companion cells that support sieve tube elements in angiosperms are actually derived evolutionarily from what cells that perform similar functions in the phloem of seedless vascular plants?

ANSWER: Albuminous Cells [ACCEPT: Strasbourger Cells]

### BONUS

1) BIOLOGY *Short Answer* Param is studying the behavior of graded potentials. In particular, he is studying the length constant, a value used to quantify the distance traveled by a graded potential along an axon. The length constant is equal to  $\sqrt{\frac{r_m}{r_i}}$  [READ: *the square root of the quantity axonal membrane resistance divided by axonal internal resistance*]. Identify all of the following changes that would increase the length constant:

- 1) Increasing the permeability of the axonal membrane
- 2) Increased myelination of the axon
- 3) Increasing the axon diameter

ANSWER: 2 and 3 only

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### TOSS UP

2) MATH *Multiple Choice* How many solutions are there to the equation  $\sin(\sin(x)) = x$  [READ: *sine-of-sine-of-x-equals-x*]?

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

ANSWER: 1

### BONUS

2) MATH *Short Answer* Let  $L_1$ ,  $L_2$ , and  $L_3$  be three pairwise skew lines with points  $A_1$ ,  $A_2$ , and  $A_3$  on  $L_1$ ,  $L_2$ , and  $L_3$  respectively. Which of the following statements are true:

- 1)  $A_1$ ,  $A_2$ , and  $A_3$  cannot be collinear
- 2)  $A_1$  and  $A_2$  must be distinct
- 3) Points  $A_1$ ,  $A_2$ , and  $A_3$  cannot all lie on a plane containing  $L_1$

ANSWER: 2

### TOSS UP

3) PHYSICS *Short Answer* Aryan stacks two neutral plates of glass with differing dielectric constants on top of each other in the  $z$  direction. He then sets up an external electric field. Which of the following must be continuous at the boundary between the two plates?

- 1) The  $x$  component of the electric field
- 2) The  $z$  component of the electric field
- 3) The direction of the electric field

ANSWER: 1

### BONUS

3) PHYSICS *Short Answer* Ben attaches a spring with a spring constant of 3 Newtons per meter and rest length zero to the origin of a Cartesian plane. He attaches a mass of 6 kilograms to the other end of the spring and stretches the spring 2 meters in the  $y$  direction. He then gives the mass a velocity of 1 meter per second in the negative  $x$  direction. The mass traces out an orbit in the plane. What is the area of this orbit, in square meters?

ANSWER:  $2\pi\sqrt{2}$

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### TOSS UP

4) EARTH AND SPACE *Short Answer* What term refers to the solutions of the Lane-Emden equation, used as models to approximate the internal structure of stars?

ANSWER: Polytropes

### BONUS

4) EARTH AND SPACE *Short Answer* Consider a star-planet-moon system. The planet rotates once every 3 days and orbits the star every 360 days, while its moon orbits the planet in 36 days. Assuming all motions are prograde, what is the length of the lunar cycle as observed from the planet?

ANSWER: 40 days

### TOSS UP

5) CHEMISTRY *Short Answer* What term describes the volume of the sphere of solvent encompassing a polymer?

ANSWER: Hydrodynamic volume [ACCEPT: Hydrodynamic radius]

### BONUS

5) CHEMISTRY *Short Answer* Under which of the following conditions does the Fermi-Dirac distribution for particles with half-integer spin approach the Maxwell-Boltzmann distribution?

- 1) Low temperature
- 2) Low particle density
- 3) High temperature

ANSWER: 2 and 3 only

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### TOSS UP

6) BIOLOGY *Short Answer* Homologous recombination usually occurs between very similar sequences. This is because similar sequences increase the stability of what key 4-armed heteroduplex DNA structure intermediate?

ANSWER: Holliday Junction

### BONUS

6) BIOLOGY *Multiple Choice* High altitude pulmonary edema occurs when there is a build-up of fluid in the alveoli, a potentially lethal condition that threatens visitors to montane regions. Which of the following describes the pathogenesis of high-altitude pulmonary edema?

- W) Increased capillary permeability caused by inflammation leads to fluid leakage in the alveoli
- X) Decreased atmospheric pressure causes fluid to be drawn into the alveoli
- Y) Decreased atmospheric oxygen causes vasodilation, causing fluid leakage into alveoli
- Z) Decreased atmospheric oxygen causes vasoconstriction, causing fluid leakage into alveoli

ANSWER: Z) Decreased atmospheric oxygen causes vasoconstriction, causing fluid leakage into alveoli

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### TOSS UP

7) MATH *Short Answer* Which of the following are Jordan Curves?

- 1) Circle
- 2) Hyperbola
- 3) Cardioid
- 4) Lemniscate

ANSWER: 1 and 3 only

### BONUS

7) MATH *Multiple Choice* Aryan stands on the circumference of a completely reflective circle and shoots out a laser. It bounces off the circumference exactly 20 times before coming back to him. In how many different directions could Aryan have pointed the laser?

- W) 10
- X) 11
- Y) 12
- Z) 13

ANSWER: Y) 12

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### TOSS UP

8) PHYSICS *Multiple Choice* Krutharth observes the elliptical orbit of Mercury and plots its velocity throughout one complete orbit on the Cartesian plane. What shape does he draw?

- W) A circle
- X) An ellipse with eccentricity less than that of Mercury's orbit
- Y) An ellipse with eccentricity equal to that of Mercury's orbit
- Z) An ellipse with eccentricity greater than that of Mercury's orbit

ANSWER: W) A circle

### BONUS

8) PHYSICS *Multiple Choice* In Quantum Mechanics, a self-adjoint operator is termed Hermitian [READ: *her-mission*]. Which of the following is true about Hermitian operators?

- W) They commute with other Hermitian operators
- X) They operate on the momentum space of a particle
- Y) Their eigenvalues are observable quantities
- Z) They satisfy the Schrodinger equation

ANSWER: Y) Their eigenvalues are observable quantities

### TOSS UP

9) EARTH AND SPACE *Short Answer* Identify all of the following three statements that are true regarding geostrophic flow:

- 1) Most major ocean currents are in geostrophic balance
- 2) The pressure gradient force points outward from the center of a gyre
- 3) Winds cannot be in geostrophic balance within the planetary boundary layer

ANSWER: All

### BONUS

9) EARTH AND SPACE *Short Answer* A parcel at ground level has a dry bulb temperature of 20 degrees Celsius, a wet bulb temperature of 15 degrees Celsius, and a dew point of 10 degrees Celsius. If the dew point lapse rate is 2 Celsius per kilometer, the environmental lapse rate 8 Celsius per kilometer, and the dry adiabatic lapse rate 10 Celsius per kilometer, at what altitude, in meters, will the cloud base be?

ANSWER: 1250

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### TOSS UP

10) CHEMISTRY *Short Answer* What ring-expansion reaction, which proceeds by an alkyl migration of a cyclic oxime [READ: *OX-eem*] under acidic conditions, is used in the industrial process for the production of caprolactam, a precursor to nylon?

ANSWER: Beckmann rearrangement

### BONUS

10) CHEMISTRY *Multiple Choice* Proton NMR signals of an alcohol proton will disappear when acquired in which solvent?

- W) Deuterated benzene
- X) Deuterated water
- Y) Deuterated chloroform
- Z) Deuterated tetrahydrofuran

ANSWER: X) Deuterated water

### TOSS UP

11) BIOLOGY *Short Answer* Order the following three groups by increasing genetic similarity to the causative agent of malaria:

- 1) Dinoflagellates
- 2) Radiolarians
- 3) Parabasalids

ANSWER: 3, 2, 1

### BONUS

11) BIOLOGY *Short Answer* What is the name of the molecular biology technique that uses a mutant transposase to assess chromatin accessibility in genomes?

ANSWER: ATAC-seq (Assay for Transposase-Accessible Chromatin using sequencing)

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### TOSS UP

12) MATH *Short Answer* When plotted on the complex plane, the roots of the polynomial  $x^8 - 1$  form an octagon. Find the area of this octagon.

ANSWER:  $2\sqrt{2}$

### BONUS

12) MATH *Short Answer*  $ABC$  is a triangle with  $AB = 13$ ,  $BC = 14$ , and  $CA = 15$ . Let  $G$  be the centroid of triangle  $ABC$ , and let  $XYZ$  be a triangle with side lengths  $AG$ ,  $BG$ , and  $CG$ . Find the area of triangle  $XYZ$ .

ANSWER: 28

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### TOSS UP

13) PHYSICS *Multiple Choice* Eric shoots a ball from a cannon stationed on a flat surface at an angle that measures  $5 \pm 0.1$  [READ: *5 plus or minus 0.1*] degrees from the horizontal. Air resistance is negligible. Which of the following is closest to Eric's relative uncertainty in his measurement of the ratio between the vertical range and horizontal range of the cannonball?

- W) 0.005
- X) 0.02
- Y) 0.08
- Z) 0.2

ANSWER: 0.02

### BONUS

13) PHYSICS *Short Answer* Identify all of the following statements that are true about the Faraday Tensor in electromagnetism:

- 1) The Faraday tensor is symmetric
- 2) The determinant of the Faraday tensor is zero
- 3) The trace of the Faraday tensor is zero

ANSWER: 3 only

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### TOSS UP

14) EARTH AND SPACE *Short Answer* Identify all of the following three conditions that would favor the formation of epeiric seas:

- 1) Rapid seafloor spreading
- 2) Increased global temperatures
- 3) Marine regression

ANSWER: 1 and 2 only

### BONUS

14) EARTH AND SPACE *Short Answer* For high-redshift quasars, what feature in their emission spectrum replaces the Lyman-Alpha forest due to the abundance of neutral hydrogen in the intergalactic medium?

ANSWER: Gunn-Peterson Trough

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### TOSS UP

15) CHEMISTRY *Multiple Choice* Which best describes the role of carbon dioxide in the Kolbe-Schmitt reaction?

- W) Lewis acid
- X) Lewis base
- Y) Catalyst
- Z) Inhibitor

ANSWER: W) Lewis acid

### BONUS

15) CHEMISTRY *Short Answer* The reaction conversion of reactant A to product P proceeds through the Lindemann mechanism. Identify all of the following three statements that are true about this reaction:

- 1) The reaction is first-order at low concentrations of A and second-order at high concentrations of A
- 2) The rate constant for the forward reaction of the first elementary step,  $k_1$ , is larger than the rate constant for the reverse reaction of the first elementary step,  $k_{-1}$
- 3) The rate constant for the reverse reaction of the first elementary step,  $k_{-1}$ , is larger than the rate constant for the second step,  $k_2$

ANSWER: 3 ONLY

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### TOSS UP

16) BIOLOGY *Short Answer* Doctor Reveck injects 100.0 millimoles of deuterium oxide into your blood. After you take some time to rest, you excrete 20 millimoles of the deuterium oxide, and he measures your blood concentration of deuterium oxide to be 2.0 millimolar. In liters and to two significant figures, what is the total volume of water in your body?

ANSWER: 40 L

### BONUS

16) BIOLOGY *Short Answer* Identify all of the following which are true about the nucleotide sequence of a tRNA:

- 1) Dihydrouridine is commonly found in the D loop
- 2) Inosine is commonly found in the acceptor loop
- 3) Pseudouridine is commonly found in the T loop

ANSWER: 1 and 3 only

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### TOSS UP

17) MATH *Short Answer* What is the minimum possible value of the expression  $\frac{x^2}{4} + \frac{4x}{y^3} + \frac{8y^3}{x^3}$  [READ: *x squared divided by four plus four x divided by y cubed plus eight y cubed divided by x cubed*], where  $x$  and  $y$  are positive real numbers?

ANSWER: 6

### BONUS

17) MATH *Short Answer* Let  $P(x)$  be the monic polynomial of minimum degree with integer coefficients that has  $\sqrt[3]{3} + \sqrt[3]{4}$  [READ: *cube root of 3 plus cube root of 4*] as a root. Find  $P(0)$ .

ANSWER: -343

### TOSS UP

18) PHYSICS *Short Answer* In particle physics, the laws of physics are invariant under certain symmetries. Which of the following symmetries holds for all known physical interactions?

- 1) Charge conjugation
- 2) Parity reversal
- 3) Time reversal

ANSWER: None

### BONUS

18) PHYSICS *Short Answer* Alex has a coordinate plane with index of refraction at point  $(x, y)$  given by  $n = y^k$ . For what two values of  $k$  will any light ray originating at the origin either trace out a straight line or a (possibly inverted) catenary curve?

ANSWER: 0 and  $-2$

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### TOSS UP

19) EARTH AND SPACE *Multiple Choice* Which of the following statements regarding Venus's atmosphere is false?

- W) Venus has two primary convective cells per hemisphere
- X) Zonal wind velocity on Venus is significantly greater than meridional velocity
- Y) Zonal wind velocity on Venus is greatest at the equator
- Z) Wind velocity increases with elevation in the troposphere

ANSWER: W) Venus has two primary convective cells per hemisphere

### BONUS

19) EARTH AND SPACE *Multiple Choice* Which of the following is characteristic of the third dredge-up in asymptotic giant branch stars?

- W) Increase in surface carbon-to-oxygen ratio
- X) Outer atmosphere displays a strong hydrogen fusion signature
- Y) Increase in surface abundance of helium-4 and nitrogen-14
- Z) Decrease in surface abundance of lithium and beryllium

ANSWER: W) Increase in surface carbon-to-oxygen ratio

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### TOSS UP

20) CHEMISTRY *Short Answer* What is the angle of rotation associated with  $C_6$  symmetry?

ANSWER: 60 degrees

### BONUS

20) CHEMISTRY *Short Answer* By name or number, identify all of the following 3 statements that correctly describe the difference between chain growth and step growth polymerization:

- 1) In chain growth reactions, the length of the polymer grows linearly with each reaction step while step growth reactions proceed exponentially
- 2) Chain growth reactions proceed with higher energy intermediates than step growth reactions
- 3) Condensation reactions proceed through chain growth in vivo, but step growth outside of biological processes

ANSWER: All

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### TOSS UP

21) BIOLOGY *Short Answer* What disease, characterized by a swollen-belly appearance resulting from edema in the abdominal cavity, commonly affects individuals suffering from protein malnutrition?

ANSWER: Kwashiorkor [ACCEPT: Edematous malnutrition]

### BONUS

21) BIOLOGY *Short Answer* Identify all of the following three signalling proteins that are correctly matched to extracellular signals that would most likely lead to their activation:

- 1) Janus Kinase and Cytokines
- 2) Beta-catenin and Wnt [READ: *wnt*]
- 3) MAP Kinase Kinase Kinase and Tumor Growth Factor Alpha

ANSWER: All

### TOSS UP

22) MATH *Short Answer* Kimmy rolls a die until she rolls a 5 or a 6. What is the expected sum of all of the numbers she rolls?

ANSWER: 10.5

### BONUS

22) MATH *Short Answer* How many digits are in the repeating block of the decimal expansion of  $\frac{1}{83}$ ?

ANSWER: 41

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### TOSS UP

23) PHYSICS *Multiple Choice* Krutharth is performing an experiment and observes that an electron experiences a phase shift in a region with no magnetic or electric fields. What effect is he observing?

- W) Aharonov-Bohm effect
- X) Casimir effect
- Y) Klein-Nishina effect
- Z) Quantum Hall effect

ANSWER: W) Aharonov-Bohm effect

### BONUS

23) PHYSICS *Short Answer* Aryan launches a satellite from Earth around the sun with an orbital period of one year. After some time, he measures the velocity of the satellite and notices that it is twice the original launch velocity. In astronomical units, how far is the satellite from the sun?

ANSWER: 0.4

### TOSS UP

24) EARTH AND SPACE *Multiple Choice* Which of the following statements regarding vorticity is false?

- W) Vorticity is maximized at the poles
- X) Increased curvature of air flow increases vorticity
- Y) An increase in absolute vorticity leads to upper-level divergence
- Z) Troughs are associated with high cyclonic vorticity

ANSWER: Y) An increase in absolute vorticity leads to upper-level divergence

### BONUS

24) EARTH AND SPACE *Short Answer* Identify all of the following statements about mica fish that are true:

- 1) Their longest dimension perfectly lies in the foliation direction
- 2) They are common in mylonites
- 3) They are a reliable shear stress indicator

ANSWER: 2 and 3 only

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### TOSS UP

25) CHEMISTRY *Short Answer* What subclass of Diels-Alder reactions involves dienes with low energy LUMOs [READ: *LOO-mows*] and dienophiles with high energy HOMOs [READ: *HOE-mows*]?

ANSWER: Reverse electron demand [ACCEPT: Inverse electron demand]

### BONUS

25) CHEMISTRY *Short Answer* Which of the following factors contribute to the stability of the radical formed by hydrogen atom abstraction from BHT.

- 1) Steric hindrance by the bulky tert-butyl groups
- 2) Delocalization of radical character in the aromatic ring
- 3) Electron-donation by the tert-butyl groups

ANSWER: All