

TJSBT 2025

Double Elimination 3

Tossup

1. Biology – *Short Answer* What behavioral model suggests that organisms searching for food maximize their energy intake while minimizing their energy expenditure?

ANSWER: Optimal foraging model (accept: Optimal foraging theory)

Bonus

1. Biology – *Short Answer* Avnith has started running every morning, except he gets tired by the time he is done with his route. By name or number, rank the following 3 fibers in Avnith's muscles in order of increasing time passed to experience fatigue:

1) Slow-oxidative
2) Fast-oxidative glycolytic
3) Fast glycolytic

ANSWER: 3, 2, 1

Tossup

2. Chemistry – *Short Answer* What quantity is defined as the partial derivative of Gibbs free energy with respect to particle number at constant temperature and pressure?

ANSWER: Chemical potential

Bonus

2. Chemistry – *Short Answer* By name or number, arrange the following 3 functional groups in order of increasing wavenumber in an IR spectrum:

1) Ketone
2) Imine
3) Nitrate

ANSWER: 3, 2, 1

Tossup

3. Earth and Space – *Multiple Choice* In a closed system, what happens to the dew point when the temperature of the system is increased?

W) It increases
X) It decreases
Y) It stays the same
Z) It is impossible to tell

ANSWER: Y) It stays the same

Bonus

3. Earth and Space – *Short Answer* By name or number, identify all of the following three plate boundaries where shallow-focus earthquakes may occur:

1) Divergent
2) Convergent
3) Transform

ANSWER: All

Tossup

4. Math – *Multiple Choice* Which of the following values is equivalent to $\sqrt[3]{8i}$ (read as: the cube root of the quantity 8i)?

W) -2i
X) 2i
Y) √(3)−i (read as: square root of the quantity 3 minus i)
Z) √(3)+i (read as: square root of the quantity 3 plus i)

ANSWER: Z) √(3)+i

Bonus

4. Math – *Short Answer* An infinite geometric series with first term 1 and common ratio r^2 has a sum of 2. What is the sum of the infinite geometric series with first term 1 and common ratio r?

ANSWER: 2+√2

Tossup

5. Physics – *Multiple Choice* 10 balls of identical mass are lined up in a straight line on a frictionless surface. The first ball is moving toward the second with a speed of v. If all collisions are inelastic, what is the ratio of the system's initial kinetic energy to its kinetic energy after the tenth ball has been struck?

W) $\sqrt{10}$
X) 10
Y) 100
Z) 1000

ANSWER: X) 10

Bonus

5. Physics – *Multiple Choice* Lucas builds two circular loops A and B such that A is in front of B. If the current in loop A is decreasing in magnitude and circulating in a clockwise direction, which of the following describes the direction of the induced current in B and what will happen to the loops, respectively?

W) Clockwise, attract
X) Counterclockwise, attract
Y) Clockwise, repel
Z) Counterclockwise, repel

ANSWER: W) Clockwise, attract

Tossup

6. Energy – *Multiple Choice* Students from Thomas Jefferson's Oceanography Lab are studying sea surface data obtained from the TOPEX/Poseidon satellite. The TOPEX/Poseidon satellite primarily operates in what part of the electromagnetic spectrum?

W) Infrared
X) Visible
Y) Microwave
Z) Radiowave

ANSWER: Y) Microwave

Bonus

6. Energy – *Short Answer* While in the Oceanography lab, the TJ students decide to call some TJ students in the Quantum QLab studying particle accelerators which can accelerate particles close to the speed of light. The speed of light can be written as one over the square root of vacuum permittivity and what other constant?

ANSWER: Vacuum permeability (accept: Permittivity of free space)

Tossup

7. Biology – *Short Answer* Recombination frequency can be used to determine the distance between two genes on a chromosome. What is the unit most commonly used to measure this distance?

ANSWER: Centimorgan (accept: map units)

Bonus

7. Biology – *Multiple Choice* Which of the following best explains the cellular mechanism by which apicomplexans establish host infection?

W) Consumption of contaminated fungal matter followed by larval activation in the host intestine
X) Consumption of contaminated plant matter followed by larval activation in the host intestine
Y) Release of tachyzoites from vectors penetrating host skin and migrating to liver cells
Z) Release of sporozoites from vectors penetrating host skin and migrating to liver cells

ANSWER: Z) Release of sporozoites from vectors penetrating host skin and migrating to liver cells

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Tossup

8. Chemistry – *Multiple Choice* Rishabh enjoys studying the oxidation states of manganese. Which of the following oxidation states does manganese NOT typically occur in?

W) +2
X) +3
Y) +4
Z) +5

ANSWER: Z) +5

Bonus

8. Chemistry – *Short Answer* The nuclear binding energy for an unknown atom is 9×10^{-15} J. Given this information, in kilograms and to one significant figure, what is the mass defect for this atom?

ANSWER: 1×10^{-31} kg

Tossup

9. Earth and Space – *Multiple Choice* Sophia is exploring rocks in her backyard when she notices a mineral with single silicate tetrahedra. Which of the following minerals is she most likely examining?

W) Biotite
X) Amphibolite
Y) Pyroxene
Z) Olivine

ANSWER: Z) Olivine

Bonus

9. Earth and Space – *Short Answer* Aerosols such as sulfates can act as surfaces for water vapor to condense upon during cloud formation. What name is given to such particles?

ANSWER: Condensation nuclei (accept: CCN)

Tossup

10. Math – *Short Answer* Call a number *shady* if it's divisible by the sum of its digits. What is the largest 4-digit *shady* number?

ANSWER: 9990

Bonus

10. Math – *Short Answer* Sophia and Aarushi are playing a game that involves rolling a pair of dice. They take turns rolling the dice until one player rolls the dice such that the product of the two numbers on the top faces has an odd number of positive divisors. Given that Sophia has the first turn, what is the probability that she wins?

ANSWER: 9/16

Tossup

11. Physics – *Short Answer* In the Schrödinger equation, what operator is used that is equal to the sum of the kinetic and potential energies of a system?

ANSWER: Hamiltonian

Bonus

11. Physics – *Short Answer* By name or number, identify all of the following 3 quantities on which the entropy of a black hole is directly dependent:

1) Surface area of the black hole
2) Mass of the black hole
3) Velocity of the black hole

ANSWER: 1 only

Halftime

Tossup

12. Energy – *Multiple Choice* Students at Thomas Jefferson's Computer Systems Lab are using Large Language Models in their research. Which of the following answer choices is a key feature of LLMs?

W) They are only trained with large databases with labelled data
X) LLMs sequentially determine the next word in the output
Y) They use a recurrent structure to process words one at a time
Z) LLMs generally rely on graph neural networks internally

ANSWER: X) LLMs sequentially determine the next word in the output

Bonus

12. Energy – *Short Answer* Avnith has an infinite number of coins with values 1, 2, 6, 10 and wants to count the number of ways he can pay a cost of 15. By name or number, identify all of the following 3 algorithms which he could use to solve this task, in this specific case:

1) Brute force
2) Greedy
3) Dynamic programming

ANSWER: All

Tossup

13. Biology – *Multiple Choice* Which of the following genetic conditions is incorrectly matched to its chromosomal abnormality?

W) Cri du chat, deletion
X) Down's syndrome, duplication
Y) Philadelphia chromosome, translocation
Z) William's syndrome, inversion

ANSWER: Z) William's syndrome, inversion

Bonus

13. Biology – *Short Answer* By name or number, identify all of the following 3 gasses that were initially combined in the Miller-Urey experiment to replicate the atmospheric compositions of early Earth:

1) Methane
2) Ammonia
3) Carbon dioxide

ANSWER: 1, 2

Tossup

14. Chemistry – *Multiple Choice* What type of reagent is commonly used in the formation of carbon-carbon bonds and is formed from reacting magnesium with an organic halide?

W) Gilman reagent
X) Grignard reagent
Y) Wittig reagent
Z) Tollens' reagent

ANSWER: X) Grignard reagent

Bonus

14. Chemistry – *Short Answer* Rishabh is running a Tollen's test. He prepares Tollen's reagent and adds a few drops to each of his samples. By name or number, identify all of the following 3 molecules that would form a silver mirror in Tollen's test:

1) Acetaldehyde
2) Acetone
3) Benzaldehyde

ANSWER: 1, 3

Tossup

15. Earth and Space – *Multiple Choice* After missing a tossup on magnitude, Sophia is back to stargazing with Aarushi. For these two stationary observers, which of the following statements regarding the apparent magnitude and absolute magnitude is true?

W) Apparent magnitude is always greater than absolute magnitude
X) Absolute magnitude is always greater than apparent magnitude
Y) Apparent magnitude is only greater than absolute magnitude for distances less than 10 parsecs
Z) Absolute magnitude is only greater than apparent magnitude for distances less than 10 parsecs

ANSWER: Z) Absolute magnitude is only greater than apparent magnitude for distances less than 10 parsecs

Bonus

15. Earth and Space – *Short Answer* Star RK is a unique star because the temperature of the star is inversely proportional to its volume. If the radius of the star is multiplied by 1/2, by what factor would the luminosity of the star increase?

ANSWER: 1024

Tossup

16. Math – *Short Answer* What is the length of a diagonal of isosceles trapezoid ABCD, if AB = 4, BC = 8, CD = 9, and DA = 8?

ANSWER: 10

Bonus

16. Math – *Multiple Choice* Given that n is a positive integer chosen uniformly and at random, what is the probability that n*(n+1)*(n+2) is divisible by 24?

W) $\frac{1}{4}$
X) $\frac{3}{8}$
Y) $\frac{1}{2}$
Z) $\frac{5}{8}$

ANSWER: Z) $\frac{5}{8}$

Tossup

17. Physics – *Short Answer* In the Navier-Stokes equation, which mathematical operator is used to represent the viscous terms?

W) Curl
X) Divergence
Y) Gradient
Z) Laplacian

ANSWER: Z) Laplacian

Bonus

17. Physics – *Short Answer* By name or number, rank the following 3 gasses in order of increasing adiabatic index:

1) He
2) H_2O
3) N_2

ANSWER: 2, 3, 1

Tossup

18. Energy – *Multiple Choice* Students at Thomas Jefferson's Biotech lab are studying cancer cell populations. If they are trying to differentiate cell populations that express CD4 vs CD8, which of the following techniques would be most appropriate?

W) Western blot
X) Gel electrophoresis
Y) Flow cytometry
Z) Sanger sequencing

ANSWER: Y) Flow cytometry

Bonus

18. Energy – *Short Answer* Students at Thomas Jefferson's Astronomy Lab are attempting to identify exoplanets using various techniques. By name or number, identify all of the following 4 techniques that are used for exoplanet detection:

1) Tully-Fisher method
2) Gravitational microlensing
3) Doppler spectroscopy
4) Transit method

ANSWER: 2, 3, 4

Tossup

19. Biology – *Multiple Choice* Sophia has an enzyme that participates in a biochemical reaction. When she adds a substance X, the maximum reaction rate of the enzyme decreases but it takes more substrate for the enzyme to reach saturation. Which of the following best describes substance X?

W) Competitive inhibitor
X) Non-competitive inhibitor
Y) Uncompetitive inhibitor
Z) Mixed inhibitor

Answer: Z) Mixed inhibitor

Bonus

19. Biology – *Short Answer* By name or number, identify all of the following 3 plants that produce simple fruits:

1) Pea
2) Pineapple
3) Peanut

Answer: 1, 3

Tossup

20. Chemistry – *Multiple Choice* In benzene, acetic acid molecules undergo dimerization through hydrogen bonding. Which of the following statements best explains why acetic acid dimerization in benzene leads to a higher boiling point compared to pure acetic acid in water?

W) The hydrogen bonds in the dimer are stronger than those in water
X) The dimerization reduces the number of acetic acid molecules that can evaporate, lowering vapor pressure
Y) The dimerization increases molecular size, increasing the effect of hydrogen bonding
Z) The presence of benzene stabilizes the acetic acid dimers through van der Waals interactions

Answer: X) The dimerization reduces the number of acetic acid molecules that can evaporate, lowering vapor pressure.

Bonus

20. Chemistry – *Short Answer* By name or number, order the following 3 elements in terms of increasing wavelength of light emitted by their flame test:

1) Sodium
2) Potassium
3) Boron

Answer: 2, 3, 1

Tossup

21. Earth and Space – *Multiple Choice* Lucas is reconnecting with nature after losing another game of Cup Pong when he realizes he's walking on the crest of an anticline. Which eras of Paleozoic rocks would he find farthest away from where he's walking?

W) Cambrian
X) Ordovician
Y) Silurian
Z) Permian

ANSWER: Z) Permian

Bonus

21. Earth and Space – *Short Answer* A shallow water wave has depth wave ot 20 meters and wavelength of 5 meters. To two significant figures, what is the velocity of the wave in meters per second?

ANSWER: 14

Tossup

22. Math – *Short Answer* What is the cosine of the smaller angle between the vectors 5i+2j (read as: *five i hat plus 2 j hat)* and 2i+5j (read as: *two i hat plus five j hat*)?

ANSWER: 20/29

Bonus

22. Math – *Short Answer* A frog is sitting at the origin of the coordinate plane. Every jump it randomly moves 1 unit up, down, left, or right with equal probability. After two jumps, what is the expected distance between the frog's current location and the origin?

ANSWER: $\frac{1}{2} + \frac{\sqrt{2}}{2}$

Tossup

23. Physics – *Multiple Choice* What shape will a rocket's orbit be if the rocket is traveling with a speed much less than the escape velocity of the planet it comes from?

W) Circle
X) Parabola
Y) Hyperbola
Z) Ellipse

ANSWER: Z) Ellipse

Bonus

23. Physics – *Short Answer* A planet has a density proportional to its distance from its center. To what power of the planet's radius is the planet's escape velocity proportional?

Answer: 3/2

End of packet