

TJSBT 2025

Double Elimination 6

Tossup

1. Biology – *Short Answer* What is the effective population size of a population of giraffes where the number of breeding males and females are 30 and 60, respectively?

Answer: 80

Bonus

1. Biology – *Short Answer* By name or number, identify all of the following 4 visual fields that would be damaged if the optic chiasm were severed:

1) Left visual field of left eye
2) Left visual field of right eye
3) Right visual field of left eye
4) Right visual field of right eye

Answer: 1, 4

Tossup

2. Chemistry – *Short Answer* What quantity is used to describe the effective pressure of a gas in a non-ideal system?

Answer: Fugacity

Bonus

2. Chemistry – *Multiple Choice* What term refers to the delocalization of electrons in a molecule where sigma bonds interact with adjacent p orbitals, which causes the molecule to become more stable?

W) Antibonding overlap
X) Hyperconjugation
Y) Diastereomeric coupling
Z) Pericyclic resonance

Answer: X) Hyperconjugation

Tossup

3. Earth and Space – *Short Answer* When hydrochloric acid is dropped in calcite, a white, chalky substance begins to fizz and bubble vigorously. This is an example of what property?

Answer: Effervescence

Bonus

3. Earth and Space – *Multiple Choice* Sophia is in the southern hemisphere and is traveling east across the South Atlantic gyre. If she takes a profile of the sea surface height with longitude, which of the following best describes the shape of her plot?

W) Hill with a steeper western side
X) Hill with a steeper eastern side
Y) Valley with a steeper western side
Z) Valley with a steeper eastern side

Answer: W) Hill with a steeper western side

Tossup

4. Math – *Short Answer* What is the eccentricity of a hyperbola that opens up horizontally with asymptotes at $y = \frac{-5}{12}x$ and $y = \frac{5}{12}x$?

Answer: $\frac{13}{12}$

Bonus

4. Math – *Multiple Choice* How many real values of x satisfy the equation $sin\ (x) = log\ (x)$?

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

Answer: Y) 3

Tossup

5. Physics – *Short Answer* What term describes the increase in strength of the strong force between quarks and gluons as they are pulled farther apart?

Answer: Asymptotic freedom

Bonus

5. Physics – *Short Answer* Alan is standing on the edge of a ship that is moving towards a mountain at 20 m/s. He plays a violin at a frequency of 440 Hz. If the speed of sound is 340 m/s, what is the frequency of sound that is reflected back to him?

Answer: 495

Tossup

6. Energy – *Multiple Choice* Students at Thomas Jefferson's Computer Systems Lab are studying game theory. A certain game is played with several piles of stones. Two players, Alice and Bob, take turns choosing a nonempty pile and removing a positive number of stones from it. Alice goes first, and the person who can't make a move loses. If there are initially 2 piles with 7 and 5 stones, respectively, what is Alice's first move to guarantee that she wins?

W) Remove 4 stones from the first pile
X) Remove 2 stones from the first pile
Y) Remove 5 stones from the second pile
Z) Remove 1 stone from the second pile

Answer: X) Remove 2 stones from the first pile

Bonus

6. Energy – *Short Answer* By name or number, identify all of the following 3 pieces of evidence proving the hypothesis that charophyte algae are the closest relatives of land plants:

1) Charophytes exhibit double fertilization
2) Charophytes have flagellated sperm with an asymmetric flagellum
3) Charophytes have linear protein rings that synthesize cellulose

Answer: 2 only

Tossup

7. Biology – *Multiple Choice* Sophia is in a greenhouse collecting samples of rice seeds and notices that the seeds are growing out of a scutellum. Which of the following botanical features is the scutellum a modified version of?

W) Radicle
X) Seed coat
Y) Endosperm
Z) Cotyledon

Answer: Z) Cotyledon

Bonus

7. Biology – *Short Answer* As Sophia is collecting rice seeds, she cuts herself on a piece of equipment, triggering inflammation and swelling at the site of injury. What term refers to the immunological process by which leukocytes exit blood vessels and move into the affected tissue?

Answer: Diapedesis (accept: Extravasation, Adhesion cascade)

Tossup

8. Chemistry – *Short Answer* By name or number, order the following 3 free radicals in terms of increasing stability:

1) Methyl radical
2) Isopropyl radical
3) Allyl radical

Answer: 1, 2, 3

Bonus

8. Chemistry – *Multiple Choice* Which of the following diagrams represents the thermodynamic stability of chemical species in aqueous solution as a function of pH and reduction potential?

W) Frost diagram
X) Latimer diagram
Y) Pourbaix diagram (read as: *POOR-bay*)
Z) Ellingham diagram

Answer: Y) Pourbaix diagram

Tossup

9. Earth and Space – *Short Answer* Eshaan is looking at an image of the Sun when he notices that the edges of the Sun seem to be getting slightly darker compared to the center. What effect is this known as?

Answer: Limb darkening

Bonus

9. Earth and Space – *Short Answer* Sophia is studying the trajectories of a comet as it orbits a star. The comet has an elliptical orbit with eccentricity e = 9/11. From the perspective of the comet, what is the positive difference between the apparent magnitude of the star at perihelion compared to at aphelion?

Answer: 5

Tossup

10. Math – *Short Answer* By name or number, identify all of the following 3 sets that have the same cardinality as the set of natural numbers:

1) The set of prime numbers
2) The set of subsets of natural numbers
3) The set points in 3D space with integer coordinates

Answer: 1, 3

Bonus

10. Math – *Short Answer* Given that $\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}$ (read as: *the sum from 1 to infinity of 1 over n squared equals pi squared over 6)*, compute the sum $\sum_{n=0}^{\infty} \frac{1}{(2n+1)^2}$ (read as: *the sum from 0 to infinity of 1 over the quantity of open parentheses two n plus one closed parentheses squared*).

Answer: $\frac{\pi^2}{8}$

Tossup

11. Physics – *Multiple Choice* A particle is acted upon by a central attractive force with magnitude $F(r) = -\frac{1}{r^3}$, where r is the particle's distance from the center. Which of the following answer choices best describes the particle's orbit around the center?

W) Hyperbolic escape
X) Elliptical
Y) Radial
Z) Spiral into the center

Answer: Z) Spiral into the center

Bonus

11. Physics – *Short Answer* Consider a rod of length L and mass density $\lambda = \sqrt{x}$ (read as: lambda equals the square root of x). In terms of L, what is the center of mass of the rod?

Answer: $\frac{3}{5}L$

Halftime

Tossup

12. Energy – *Short Answer* Students at Thomas Jefferson's Quantum lab are studying quantum computers. In quantum mechanics, what geometric representation is commonly used to visualize the state of a qubit, where energy eigenstates are typically represented as points on a sphere?

Answer: Bloch sphere

Bonus

12. Energy – *Short Answer* By name or number, identify all of the following 3 statements which must be true for a topological sort of a graph to exist:

1) It must be connected
2) It must be directed
3) It must have no cycles

Answer: 2, 3

Tossup

13. Biology – *Multiple Choice* Loss-of-function mutations in genes coding for the production of connexin proteins will most directly disrupt which of the following cellular processes?

W) Passive diffusion of ions across adjacent cytoplasms
X) Vesicle pinching from the Golgi apparatus via coat-protein complexes
Y) Recycling of membrane proteins via early endosomes
Z) Calcium-dependent transmembrane cell-to-cell adhesion

Answer: W) Passive diffusion of ions across adjacent cytoplasms

Bonus

13. Biology – *Short Answer* By name or number, identify all of the following 3 plants that contain microphylls:

1) Spikemoss
2) Horsetail fern
3) Liverwort

Answer: 1 only

Tossup

14. Chemistry – *Short Answer* Sophia is investigating diboron, or B_2 [read as: B-2]. What is the bond order of diboron?

Answer: 1

Bonus

14. Chemistry – *Multiple Choice* Rishabh is working on improving the efficiency of solar cells. He decides to incorporate quantum dots into the device to take advantage of their size-dependent optical properties. Which of the following properties of quantum dots will most directly contribute to the enhanced performance in a solar cell?

W) Their ability to exhibit discrete energy levels and absorb light at multiple wavelengths
X) Their high thermal conductivity
Y) Their ability to emit light at a fixed wavelength regardless of their size
Z) Their capability to conduct electricity in a wide range of temperatures

Answer: W) Their ability to exhibit discrete energy levels and absorb light at multiple wavelengths

Tossup

15. Earth and Space – *Multiple Choice* Which of the following best explains the process behind cloud street formation?

W) Rising thermals create convective clouds that are aligned by strong downdrafts in the upper atmosphere
X) Alternating bands of warm and cold air lead to the condensation of moisture into parallel rows of clouds
Y) Rising thermals generate cumulus clouds, which are then organized into parallel rows by horizontal wind shear and convection
Z) Jet stream turbulence causes air to spiral downward, leading to linear cloud formations along pressure gradients

Answer: Y) Rising thermals generate cumulus clouds, which are then organized into parallel rows by horizontal wind shear and convection

Bonus

15. Earth and Space – *Short Answer* Aaryan is redownloading Minecraft after the first semester and decides to do some mining. By name or number, arrange the following 3 mineral facies in chronological order as Aaryan mines downward near a subduction zone:

1) Blueschist
2) Eclogite
3) Zeolite

Answer: 3, 1, 2

Tossup

16. Math – *Multiple Choice* For a tree graph with 10 nodes, what is the minimum possible diameter, where the diameter is defined as the maximum path length between any two nodes in a graph?

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

Answer: X) 2

Bonus

16. Math – *Short Answer* In how many ways can Lucas paint a unit cube with white and black, given that each face is painted one color and rotations are considered identical?

Answer: 10

Tossup

17. Physics – *Short Answer* What quantity is calculated as the ratio of the molar volume of a real gas to that of an ideal gas under the same conditions of temperature and pressure?

Answer: Compression factor

Bonus

17. Physics – *Short Answer* Water has an isothermal bulk modulus of about 2 gigapascals. Assuming that the bulk modulus of water does not change with depth, and indicating sign, what is the percent fractional change in volume for water at the bottom of the Pacific Ocean, which is approximately 4000 meters below sea level?

Answer: -2%

Tossup

18. Energy – *Short Answer* Students at Thomas Jefferson's Neuroscience Lab are using fMRI technology to study how brain regions respond to different reward tasks. In fMRI scans, what is the name for the smallest distinguishable unit of tissue, which is the 3D equivalent of a pixel in a 2D image?

Answer: Voxel

Bonus

18. Energy – *Multiple Choice* Balanced ternary is an alternative number system that uses the digits -1, 0, and 1 in base 3. Which of the following statements best describes an advantage of using balanced ternary on a computer with a binary number system?

W) Balanced ternary requires fewer digits than binary for storing large numbers
X) Balanced ternary allows for more efficient arithmetic operations for large numbers
Y) Balanced ternary representations are easier for computer hardware to handle for large numbers
Z) Balanced ternary is useful for specialized applications in Machine Learning requiring a base 3 number system

Answer: X) Balanced ternary allows for more efficient arithmetic operations for large numbers

Tossup

19. Biology – *Short Answer* Sophia is observing the concentration of leukocyte precursors in the human body by conducting a peripheral blood smear. By name or number, identify all of the following cells that Sophia would NOT be observing:

1) Progranulocyte
2) Reticulocyte
3) Megakaryocyte

Answer: 2, 3

Bonus

19. Biology – *Short Answer* Scientists studying evolutionary relationships often compare DNA sequences across species to estimate how long ago they diverged from a common ancestor. What constant mutation rate-based tool is used to make these time estimates?

Answer: Molecular clock

Tossup

20. Chemistry – *Multiple Choice* What is the degree of unsaturation for the molecule with chemical formula $C_6H_9NO_2S$?

W) 1.5
X) 2
Y) 2.5
Z) 3

Answer: Z) 3

Bonus

20. Chemistry – *Short Answer* Rohan is performing an electrolysis experiment using an aqueous solution of copper (II) sulfate with copper electrodes. A current of 5 amperes is passed through the solution for 193 seconds. Given that the molar mass of copper is 64 grams per mol and the Faraday constant as 96,500 coulombs per mol, then to two significant figures and in grams, what is the mass of copper deposited at the cathode?

Answer: 3.2 g

Tossup

21. Earth and Space – *Short Answer* By name or number, identify all of the following 3 effects that are associated with an El Niño:

1) Drier winters in the southwestern United States
2) Strengthening of the Walker circulation
3) Decline in phytoplankton productivity in the Western Pacific

Answer: 3 only

Bonus

21. Earth and Space – *Multiple Choice* Which of the following locations would be the best place to drill an artesian well?

W) A gravel bed in between two layers of fractured basalt with a river channel downhill
X) A sandstone layer in between one layer of shale and one layer of fractured basalt with a manmade irrigation canal downhill
Y) A coarse sand deposit in between two unbroken clay layers with a manmade irrigation canal uphill
Z) A shale layer in between one layer of sandstone and one layer of fractured basalt with a river channel uphill

Answer: Y) A coarse sand deposit in between two unbroken clay layers with a manmade irrigation canal uphill

Tossup

22. Math – *Multiple Choice* A is a set with 6 elements. How many possible sets B and C are there, such that they are subsets of A, $B \cup C = A$ (read as: the union of B and C is equal to A) and $|B \cap C| = 2$ (read as: the cardinality of the intersection of B and C is equal to 2)?

W) 120
X) 160
Y) 200
Z) 240

Answer: Z) 240

Bonus

22. Math – *Short Answer* By name or number, select all of the following 3 series that will converge:

1) $\sum_{n=2}^{\infty} \frac{1}{\sqrt{n}}$ (read as: *the sum of 1 over the square root of n from n = 2 to infinity*)
2) $\sum_{n=2}^{\infty} \frac{1}{n\ln(n)}$ (read as: *the sum of 1 over n times the natural log of n from n = 2 to infinity*)
3) $\sum_{n=2}^{\infty} \sin(\pi/n)$ (read as: *the sum of sine of pi over n from n = 2 to infinity*)

Answer: None

Tossup

23. Physics – *Multiple Choice* Which of the following answer choices is NOT considered a potential candidate for dark matter?

W) WIMPs
X) Axions
Y) Photinos
Z) Magnons

Answer: Z) Magnons

Bonus

23. Physics – *Short Answer* Rishabh wants to shoot a projectile out of a cannon. He wants to ensure the projectile has a horizontal range that is more than twice its maximum height. By name or number, identify all of the following 3 angles at which he should shoot the cannon to achieve this:

1) 15°
2) 45°
3) 75°

Answer: 1, 2

End of packet