

TJSBT 2025

Double Elimination 8

Tossup

1. Biology – *Multiple Choice* Which of the following embryonic defects would be observed if one were to remove the apical ectodermal ridge?

W) Loss of limb growth along the proximal-distal axis
X) Loss of digit formation along the anterior-posterior axis
Y) Mirror-image duplication of limbs along the proximal-distal axis
Z) Mirror-image duplication of digits along the anterior-posterior axis

Answer: W) Loss of limb growth along the proximal-distal axis

Bonus

1. Biology – *Short Answer* Eshaan is studying a population of phoenixes, whose feather color is determined by polygenic inheritance. Each gene has 2 possible alleles, making feathers range from white to red, where red is phenotypically dominant to white. If a cross between two heterozygous phoenixes yields white phoenixes at a frequency of $\frac{1}{4096}$, how many genes control feather color?

Answer: 6

Tossup

2. Chemistry – *Multiple Choice* A transition metal ion with a d^7 electron configuration forms an octahedral complex with a strong field ligand. How will the d-electrons be distributed among the t_{2g} and e_g orbitals?

W) Seven electrons fill the t_{2g} (read as: t two g) orbital
X) Six electrons fill the t_{2g} orbital, and one electron fills the e_g orbital
Y) Four electrons fill the t_{2g} orbital, and three electrons fill the e_g orbital
Z) One electron fills the t_{2g} orbital, and six electrons fill the e_g orbital

Answer: X) Six electrons fill the t_{2g} orbital, and one electron fills the e_g orbital

Bonus

2. Chemistry – *Short Answer* By name or number, identify all of the following values that are directly involved in calculating the lattice energy of an ionic crystal using the Born–Landé equation:

1) Madelung constant
2) Electron affinity
3) Ionic radii

Answer: 1, 3

Tossup

3. Earth and Space – *Multiple Choice* Aarushi is shivering while standing next to TJ's 3rd floor pool before relaxing as a warm wind travels by. Which of the following winds has Aarushi found herself in?

W) Veering wind going counterclockwise, indicating cold advection
X) Veering wind going clockwise, indicating cold advection
Y) Veering wind going counterclockwise, indicating warm advection
Z) Veering wind going clockwise, indicating warm advection

Answer: Z) Veering winds going clockwise, indicating warm advection

Bonus

3. Earth and Space – *Short Answer* By name or number, identify all of the following 3 regions that would increase in depth if sea-surface temperatures were increased:

1) Pycnocline
2) Carbonate compensation depth
3) Oxygen-minimum zone

Answer: 2, 3

Tossup

4. Math – *Multiple Choice* How many 3D faces does a tesseract have?

W) 8
X) 12
Y) 16
Z) 24

Answer: W) 8

Bonus

4. Math – *Short Answer* What is the units digit of $(3+\sqrt{5})^4 + (3-\sqrt{5})^4$?

Answer: 2

Tossup

5. Physics – *Short Answer* In order for a laser to emit continuous light, the active medium must be in a state where more atoms occupy an excited energy level than a lower one. What is the name given to this state of non-equilibrium?

Answer: Population inversion

Bonus

5. Physics – *Short Answer* By name or number, identify all of the following assumptions that are typically made in deriving the Navier–Stokes equation for incompressible flow:

1) Irrotational flow
2) Constant density
3) Newtonian fluid behavior

Answer: 2, 3

Tossup

6. Energy – *Short Answer* A Monte Carlo algorithm is a randomized algorithm which can vary in its accuracy but guarantees efficient runtime. What is the name for the dual of Monte Carlo algorithms, which are randomized algorithms that always return the correct answer but can vary in their runtime?

Answer: Las Vegas algorithms

Bonus

6. Energy – *Multiple Choice* Students at Thomas Jefferson's Biotechnology Lab are using bioinformatics analyses to analyze the human genome. One method they are using involves Tajima's D statistic. Tajima's D statistic would be most helpful for which of the following tasks?

W) Finding the degree of similarity between two DNA sequences
X) Identifying metabolic pathways associated with a gene
Y) Quantifying how randomly a gene evolves
Z) Locating single nucleotide polymorphisms

Answer: Y) Quantifying how randomly a gene evolves

Tossup

7. Biology – *Multiple Choice* Sophia is studying the applications of porin channel proteins from Gram-negative bacteria, which transport small hydrophilic molecules past the outer membrane of the bacterial cell wall. Which of the following best describes the secondary structure formed by a porin protein?

W) Alpha helix
X) Beta barrel
Y) TIM barrel
Z) EF-hand motif

Answer: X) Beta barrel

Bonus

7. Biology – *Short Answer* By name or number, arrange the following 3 clotting factors in the order they are activated during the intrinsic pathway of the coagulation cascade:

1) Factor XI
2) Factor X
3) Factor IX

Answer: 1, 3, 2

Tossup

8. Chemistry – *Short Answer* What is the name of the law that states that the rate of diffusion of a solute across a membrane is proportional to the concentration gradient across the membrane?

Answer: Fick's Law

Bonus

8. Chemistry – *Multiple Choice* Which of the following is the best description of Koopmans' theorem?

W) The ionization energy of a molecule is approximately equal to the energy of the highest occupied molecular orbital
X) The electron affinity of a molecule is the negative of the energy of the highest occupied molecular orbital
Y) The ionization energy is determined by the energy of the lowest unoccupied molecular orbital
Z) The ionization energy is equal to the energy of the lowest unoccupied molecular orbital

Answer: W) The ionization energy of a molecule is approximately equal to the energy of the highest occupied molecular orbital

Tossup

9. Earth and Space – *Multiple Choice* Aaryan is on another walk after losing some Clash Royale, and notices that he is walking on an elevated landform sloping downwards before quickly leveling out. Assuming that Aaryan can walk vertically, which of the following landforms could Aaryan NOT have been walking on?

W) Plunging anticline in the Appalachians
X) Mesa in the Colorado Plateau
Y) Pediment at the foot of a mountain in Utah
Z) Yardang in the Gobi desert

Answer: Z) Yardang in the Gobi desert

Bonus

9. Earth and Space – *Short Answer* A fully saturated air parcel at sea level has a temperature of 12 °C, while the surrounding atmosphere has a temperature of 15 °C. Given a moist adiabatic lapse rate of 5 °C/km and an environmental lapse rate of 8 °C/km, how high will the air parcel rise, in kilometers?

Answer: 1

Tossup

10. Math – *Multiple Choice* Patrick is flipping a coin and he only stops when gets two heads in a row. What is the expected number of times he will flip the coin?

W) 4
X) 6
Y) 8
Z) 10

Answer: X) 6

Bonus

10. Math – *Short Answer* By name or number, identify all of the following 3 statements which must be true for a graph with 6 nodes and 10 edges:

1) It must be connected
2) It must have at least 5 cycles
3) Its complement graph must be disconnected

Answer: 2

Tossup

11. Physics – *Multiple Choice* Which of the following is closest to the Compton wavelength, in meters, of a particle with a mass 200 kg?
W) 10^{-24}
X) 10^{-34}
Y) 10^{-44}
Z) 10^{-54}

Answer: Y) 10^{-44}

Bonus

11. Physics – *Short Answer* Aaryan is eager to scroll Instagram reels, but his phone's battery is dead. He plugs it into a 7 centimeter USB cable that carries a current of 10 amperes. The cable consists of a wire with a radius of 1 millimeter and charge density of 1.4×10^{10} C/m^3. To one significant figure and in seconds, how long does it take for the phone to start charging once it is plugged in?

Answer: 300

Halftime

Tossup

12. Energy – *Short Answer* Quantum computing algorithms can find solutions for equations of the form $x^2 - dy^2 = 1$ with polynomial time complexity. What is the general name of equations written in this form?

Answer: Pell's equations

Bonus

12. Energy – *Short Answer* Students in the TJ Biotechnology lab are bored and decide to calculate the oscillation period in a Lotka-Volterra predator-prey system. By name or number, identify all of the following 3 changes that would lengthen the system's oscillation period:

1) Lower intrinsic growth rate of the prey
2) Higher attack efficiency of the predator
3) Decrease in the predator's natural death rate

Answer: 1, 3

Tossup

13. Biology – *Short Answer* What is the name of the phenomenon by which plants inhibit the germination or growth of neighboring plants through the release of biochemical substances?

Answer: Allelopathy

Bonus

13. Biology – *Short Answer* By name or number, identify all of the following 3 gymnosperm phyla that produce flagellated sperm:

1) Gnetophyta (read as: *NEE-tuh-fy-tuh*)
2) Cycadophyta
3) Ginkgophyta

Answer: 2, 3

Tossup

14. Chemistry – *Multiple Choice* Bredt's Rule describes a structural limitation in certain bicyclic molecules. Which of the following best explains why a double bond cannot easily form at a bridgehead carbon in small bicyclic systems?

W) The required p-orbital overlap cannot occur due to geometric strain
X) Bridgehead carbons are too reactive to hold a double bond
Y) The carbon-carbon bonds at the bridgehead are too weak
Z) Electrons are too delocalized to form a stable double bond

Answer: W) The required p-orbital overlap cannot occur due to geometric strain

Bonus

14. Chemistry – *Short Answer* The critical temperature for an ideal gas can be expressed using the van der Waals a and b parameters, along with the ideal gas constant. If the van der Waals a and b parameters for a certain ideal gas are both 1, then in terms of the ideal gas constant, what is the critical temperature of this gas?

Answer: $\frac{8}{27R}$

Tossup

15. Earth and Space – *Short Answer* What is the name given to sunbeams that seem to fan out from gaps in the clouds due to atmospheric scattering?

Answer: Crepuscular rays

Bonus

15. Earth and Space – *Short Answer* By name or number, order the following 3 lakes in terms of increasing vertical stratification:

1) Monomictic
2) Dimictic
3) Holomictic

Answer: 3, 2, 1

Tossup

16. Math – *Short Answer* Find the unordered pair of positive integers (x, y) that satisfies $x^2 + xy + y^2 = 7^2$.

Answer: (5, 3) (accept: (3, 5))

Bonus

16. Math – *Short Answer* Consider the rectangle bounded by the lines $x = 0$, $x = 4$, $y = 0$, $y = 3$. Given that a sub-rectangle is a rectangle with sides aligned with the x and y axes and vertices at integer coordinates on or within the box, what is the sum of the areas of all the sub-rectangles of this rectangle?

Answer: 200

Tossup

17. Physics – *Multiple Choice* Rohan is moving a magnet towards a conducting loop with constant velocity v. If he graphs the magnetic flux through the loop as a function of time, which of the following will the shape of his graph most resemble?

W) Sine wave
X) Catenary curve
Y) Normal distribution
Z) Cauchy-Lorentz distribution

Answer: Z) Cauchy-Lorentz distribution

Bonus

17. Physics – *Short Answer* In a canonical ensemble, the average energy of the system can be obtained by differentiating which function with respect to temperature?

Answer: Helmholtz free energy

Tossup

18. Energy – *Short Answer* Students at Thomas Jefferson's Quantum Lab are investigating infinite potential wells where the energy level depends on the quantum number n. If the width of the well is multiplied by ½, by what factor does the ground state energy increase?

Answer: 4

Bonus

18. Energy – *Short Answer* By name or number, order the following 3 computational problems in terms of increasing difficulty:

1) Traveling salesman optimization
2) Halting problem
3) Linear programming

Answer: 3, 1, 2

Tossup

19. Biology – *Short Answer* By name or number, identify all of the following 3 EKG sections that are incorrectly matched with what they physiologically represent:

1) PR segment, atrial depolarization
2) QRS complex, ventricular depolarization
3) T wave, atrial repolarization

Answer: 1, 3

Bonus

19. Biology – *Multiple Choice* What specific region of prokaryotic ribosomal RNA is most commonly sequenced to build phylogenetic trees?

W) 5S rRNA
X) 16S rRNA
Y) 18S rRNA
Z) 28S rRNA

Answer: X) 16S rRNA

Tossup

20. Chemistry – *Short Answer* Sophia compares two similar reactions: one highly exothermic and the other endothermic. She observes that the transition state of the exothermic reaction resembles the reactants, while the transition state of the endothermic reaction resembles the products. Which principle explains these observations?

Answer: Hammond Postulate

Bonus

20. Chemistry – *Short Answer* Rishabh is designing a new oral medication. His drug has a molecular weight of 480 Daltons, a LogP value of 4.8, 4 hydrogen bond donors, and 8 hydrogen bond acceptors. What rule can Rishabh use to determine if the drug has good oral bioavailability?

Answer: Lipinski's Rule of Five

Tossup

21. Earth and Space – *Short Answer* By name or number, identify all of the following 3 features that astronomers look for when identifying a Milky Way tidal stream:

1) High metallicity gradient in a narrow band
2) Coherent stellar velocities along a narrow arc
3) Strong dust lanes concentrated in the stream's plane

Answer: 2 only

Bonus

21. Earth and Space – *Short Answer* Lucas is studying a star that has a central pressure P. Assuming the star has uniform density and in terms of P, what is the pressure in the center of the star if the radius is doubled?

Answer: 4P

Tossup

22. Math – *Short Answer* What is the special name for the number which satisfies the equation $cos\ (x) = x$, which approximately equals 0.73909?

Answer: Dottie number

Bonus

22. Math – *Multiple Choice* Sophia is studying Hausdorff dimensions, or how completely a fractal appears to fill space. What is the Hausdorff dimension of Serpinski's triangle?

W) 2
X) $\frac{\pi}{ln(2)}$
Y) $log_2(3)$
Z) $\frac{1+\sqrt{5}}{2}$

Answer: Y) $log_2(3)$

Tossup

23. Physics – *Short Answer* If quantum chromodynamics were changed to include four color charges instead of the usual three, how many distinct gluons would be possible?

Answer: 15

Bonus

23. Physics – *Multiple Choice* In a quantum eraser experiment, a photon passes through a double slit and then is split into two entangled photons. One of these photons is detected in such a way that the path information is erased. What is the outcome when the photon's interference pattern is observed?

W) The interference pattern will disappear because the photon has been detected
X) The interference pattern will appear only if the path information is unknown or erased, even after detection
Y) The interference pattern will appear regardless of whether the path information is known
Z) The interference pattern will appear only if the photon is detected as a particle

Answer: X) The interference pattern will appear only if the path information is unknown or erased, even after detection

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End of packet