

DOUBLE ELIMINATION 6

TOSS-UP

- 1) X-Risk - *Short Answer* Methicillin-resistant Staphylococcus [STAF-uh-low-kaw-kis] aureus can grow in the presence of methicillin due to the *mecA* gene present in the Staphylococcal cassette chromosome. This gene encodes what group of enzymes that target a namesake motif found in methicillin and penicillin?

ANSWER: Beta-lactamases

BONUS

- 1) X-Risk - *Short Answer* In regression problems, multicollinearity can be prevented by using which regression method, which adds an extra penalty term to the squared magnitude of the regression coefficients?

ANSWER: Ridge regression

TOSS-UP

2) Math - *Short Answer* Postman Pete has to deliver 300 letters to 300 mailboxes, 1 per mailbox. However, he isn't very good at his job, so he puts each letter in a distinct, random mailbox. What is the average number of letters that Pete delivers to the correct mailbox?

ANSWER: 1

BONUS

2) Math - *Short Answer* Postman Pete is up to his antics again - he again randomly delivers 300 letters to 300 mailboxes, 1 per each mailbox. Given that 300 factorial is approximately 3.06×10^{614} , in scientific notation to one significant figure, how many ways are there for Pete to deliver his letters such that at least 1 letter is delivered to the correct mailbox?

ANSWER: 2×10^{614}

TOSS-UP

3) Chemistry - *Short Answer* Iodobenzene is reacted with magnesium in dimethyl-formamide [di-meth-ul-form-am-id] at negative 78 Celsius for some time. The reaction is then allowed to warm up to room temperature, and the product is isolated via an acidic workup. What is the preferred IUPAC name of the final major product?

ANSWER: Benzaldehyde

BONUS

3) Chemistry - *Short Answer* The chemical reaction $2 A(g) + B(s) \leftrightarrow C(g) + 2 D(aq)$ [2 moles of gas A plus 1 mole of solid B yields 1 mole of gas C plus 2 moles of aqueous D] has an equilibrium that favors the products under standard conditions and shifts toward the products as temperature is increased. Identify each of the following thermodynamic state functions that increase for the chemical reaction under standard conditions: 1) Gibbs free energy; 2) Internal energy; 3) Entropy.

ANSWER: 2 and 3

TOSS-UP

4) Earth and Space - *Multiple Choice* Which of the following structures would indicate the flow direction of a paleoriver bed?

- W) Imbrication of sediments
- X) Symmetric ripples
- Y) Scour marks
- Z) Graded bedding in levees

ANSWER: W) Imbrication of sediments

BONUS

4) Earth and Space - *Short Answer* By name or number, identify all of the following three rocks that generally would not be classified using a QAPF diagram:
1) Obsidian; 2) Dunite; 3) Pyroxenite.

ANSWER: All

TOSS-UP

5) Biology - *Short Answer* What is the name of the process by which neutrophils pass through the walls of a blood vessel into interstitial fluid?

ANSWER: Diapedesis

BONUS

5) Biology - *Short Answer* Identify all of the following three statements that are true about C-reactive protein: 1) It is a G protein-coupled receptor; 2) It is produced by the liver; 3) It facilitates opsonization [op-suh-ny-ZAY-shin].

ANSWER: 2 and 3

TOSS-UP

6) Physics - *Multiple Choice* According to Noether's theorem, U(1) gauge invariance leads to the conservation of which of the following quantities?

- W) Mass
- X) Angular momentum
- Y) Electric charge
- Z) Color charge

ANSWER: Y) Electric charge

BONUS

6) Physics - *Short Answer* Identify all of the following three particles whose wavefunctions are symmetric under exchange: 1) Kaon; 2) Tau neutrino; 3) Photon.

ANSWER: 1 and 3

TOSS-UP

7) X-Risk - *Multiple Choice* Eliciting latent knowledge is a problem in alignment theory about evaluating the truthfulness of what type of model which represents the conditional dependencies between variables in a directed acyclic graph?

- W) Bayesian network
- X) Markov decision process
- Y) Conditional random field
- Z) Likelihood function

ANSWER: W) Bayesian network

BONUS

7) X-Risk - *Multiple Choice* Which type of decision theory is based on performing the action which, conditional on it happening, maximizes expected value?

- W) Timeless decision theory
- X) Causal decision theory
- Y) Functional decision theory
- Z) Evidential decision theory

ANSWER: Z) Evidential decision theory

TOSS-UP

8) Math - *Multiple Choice* What is the term for the matrix of all first-order partial derivatives of a vector-valued function of several variables?

- W) Center manifold
- X) Hessian matrix
- Y) Jacobian matrix
- Z) Pushforward

ANSWER: Y) Jacobian matrix

BONUS

8) Math - *Short Answer* Solve the following equation for all x between 0 and $\pi/2$ inclusive: $\cos(2x) - 5\cos(x) + 3 = 0$.

ANSWER: $\pi/3$

TOSS-UP

9) Chemistry - *Multiple Choice* Which of the following best describes octaaza-cubane [oc-tuh-az-uh-CUBE-ane], a hypothetical metastable compound with chemical formula N₈?

- W) Thermodynamically stable and kinetically stable
- X) Thermodynamically stable and kinetically unstable
- Y) Thermodynamically unstable and kinetically stable
- Z) Thermodynamically unstable and kinetically unstable

ANSWER: Y) Thermodynamically unstable and kinetically stable

BONUS

9) Chemistry - *Short Answer* Order the following three substituents on a carbonyl [CAR-buh-nul] group by increasing activation of the carbonyl group toward attack by a nucleophile: 1) Hydrogen; 2) Fluorine; 3) Methoxy.

ANSWER: 3, 1, 2

TOSS-UP

10) Earth and Space - *Multiple Choice* What materials found in many chondrites are used to date the formation of the solar system as they were the first to form from the planetary disk?

- W) Chondrules
- X) Pre-solar grains
- Y) Calcium-aluminum inclusions
- Z) Trapped gas from protosolar wind

ANSWER: Y) Calcium-aluminum inclusions

BONUS

10) Earth and Space - *Short Answer* What specific phenomenon describes the increase in brightness of astrophysical jets when they are pointed towards an observer?

ANSWER: Relativistic beaming (ACCEPT: Doppler beaming, Doppler boosting, DO NOT ACCEPT: Doppler effect)

TOSS-UP

11) Biology - *Short Answer* Identify all of the following three cranial nerves that transmit information from taste buds: 1) Hypoglossal [hy-poh-GLOSS-ul]; 2) Glossopharyngeal [gloss-oh-fuh-RIN-jee-ul]; 3) Facial.

ANSWER: 2 and 3

BONUS

11) Biology - *Multiple Choice* Which of the following is not an assumption made by the Lotka-Volterra model?

- W) The rate of change of a population is proportional to its size
- X) The prey population always has sufficient food
- Y) The predator's appetite decreases linearly with each prey consumed
- Z) The predator's food supply only depends on the prey population size

ANSWER: Y) The predator's appetite decreases linearly with each prey consumed

TOSS-UP

12) Physics - *Multiple Choice* An electron is observed to circularly rotate in space with a linear velocity v . The greatest amount of energy per unit time emitted by the particle is proportional to v to what power?

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

ANSWER: Z) 4

BONUS

12) Physics - *Short Answer* Order the following four types of motion in the order that molecules of hydrogen gas would most likely exhibit as temperature increases:
1) Rotation; 2) Translation; 3) Dissociation; 4) Oscillation.

ANSWER: 2, 1, 4, 3

TOSS-UP

13) X-Risk - *Short Answer* Often, someone delegated to make a decision on someone else's behalf will act in their own self-interest rather than that of their beneficiary. What is the name for this problem in economics?

ANSWER: Principal-agent problem

BONUS

13) X-Risk - *Multiple Choice* The AI company Anthropic is currently working on a proposal known as Constitutional AI, which relies on AI ensuring its responses follow a set of principles by using what?

- W) AI feedback
- X) Human feedback
- Y) Automated theorem proof
- Z) Automated interpretability

ANSWER: W) AI feedback

TOSS-UP

14) Math - *Short Answer* What is the value of the positive integer n such that $\frac{3+4i}{3+4i+n} = \frac{1}{2} + \frac{1}{4}i$ [the quantity $3 + 4i$ over the quantity $3 + 4i + n$ equals one half plus one fourth i]?

ANSWER: 5

BONUS

14) Math - *Short Answer* How many 2 digit base 6 numbers that are divisible by 5, have digits from left to right that are non-increasing?

ANSWER: 4

TOSS-UP

15) Chemistry - *Multiple Choice* Which of the following liquids has the greatest entropy of vaporization?

- W) Water
- X) Mercury
- Y) Helium
- Z) Benzene

ANSWER: W) Water

BONUS

15) Chemistry - *Multiple Choice* In the anharmonic model of the carbon-hydrogen single bond, light with a wavelength of 3,000 nanometers is required to excite the vibrational mode from its ground state to its first excited state. What wavelength of light is required to excite the carbon-hydrogen single bond from its first excited state to its second excited state?

- W) Slightly less than 1,000 nanometers
- X) Slightly more than 1,000 nanometers
- Y) Slightly less than 3,000 nanometers
- Z) Slightly more than 3,000 nanometers

ANSWER: Z) Slightly more than 3,000 nanometers

TOSS-UP

16) Earth and Space - *Multiple Choice* According to recent models, which of the following factors most significantly contributes to the movement of the North American plate?

- W) Ridge push
- X) Slab pull
- Y) Slab suction
- Z) Mantle convection

ANSWER: W) Ridge push

BONUS

16) Earth and Space - *Short Answer* Identify all of the following four minerals that can be expected to form porphyroblasts: 1) Calcite; 2) Staurolite; 3) Muscovite; 4) Garnet.

ANSWER: 2 and 4

TOSS-UP

17) Biology - *Short Answer* What polysaccharide is considered the gold standard for measuring glomerular filtration rate because it is filtered but not reabsorbed, secreted, or metabolized?

ANSWER: Inulin

BONUS

17) Biology - *Short Answer* Identify all of the following three statements that are true about pre-RNA modifications: 1) Splicing is a transamination reaction; 2) Some ribozymes can undergo self-splicing; 3) The 5' cap contains an acetylated guanine.

ANSWER: 2 only

TOSS-UP

18) Physics - *Short Answer* A roller coaster has a loop of radius 10 meters. In meters, what is the shortest possible height of the rollercoaster in order for the car to complete the loop?

ANSWER: 12.5

BONUS

18) Physics - *Multiple Choice* Which of the following is closest to the de Broglie wavelength in meters of an electron moving at 1 meter per second?

- W) 6×10^{-4}
- X) 6×10^{-3}
- Y) 6×10^{-2}
- Z) 6×10^{-1}

ANSWER: Y) 6×10^{-2}

TOSS-UP

19) X-Risk - *Short Answer* The first artificial neural networks used which function, also commonly used in modeling population dynamics, as an activation function?

ANSWER: Sigmoid function (ACCEPT: Logistic function)

BONUS

19) X-Risk - *Short Answer* Identify all of the following three statements that are true regarding the Atlantic Meridional Overturning Circulation: 1) Global warming will likely strengthen the AMOC; 2) Weakening of the AMOC will lead to cooler temperatures in Europe; 3) The AMOC shuts down during the winter.

ANSWER: 2 only

TOSS-UP

20) Math - *Multiple Choice* In right triangle ABC with angle C equal to 90 degrees, 2 times the cosine of A is equal to 3 times the cosine of B . What is the cosine of A ?

W) $\frac{2\sqrt{13}}{13}$

X) $\frac{\sqrt{10}}{5}$

Y) $\frac{\sqrt{15}}{5}$

Z) $\frac{3\sqrt{13}}{13}$

ANSWER: Z) $\frac{3\sqrt{13}}{13}$

BONUS

20) Math - *Short Answer* What are the last 2 digits of the number 3^{2023} ?

ANSWER: 27

TOSS-UP

21) Chemistry - *Short Answer* Order the following three gas-phase anions by increasing first ionization energy: 1) F^- ; 2) Na^- ; 3) Mg^- .

ANSWER: 3, 2, 1

BONUS

21) Chemistry - *Short Answer* Order the following three 0.1 molal aqueous solutions from most negative to most positive free energy of vaporization: 1) Ethanol; 2) NaCl; 3) Formic acid.

ANSWER: 1, 3, 2

TOSS-UP

22) Earth and Space - *Short Answer* About 5 percent of the observable universe is occupied by what massive structures composed of galactic superclusters?

ANSWER: Filaments (ACCEPT: Walls, Sheets, Galactic Filaments, Cosmological Filaments)

BONUS

22) Earth and Space - *Short Answer* A black hole of size M and entropy S , and Schwarzschild [SHVARS-shild] radius r merges with a black hole of size $4M$. Assuming no mass is lost in the merger, in terms of S , what is the entropy of the new black hole?

ANSWER: $25S$

TOSS-UP

23) Biology - *Short Answer* 2,3 BPG decreases the affinity of hemoglobin for oxygen by stabilizing which state of hemoglobin?

ANSWER: T state

BONUS

23) Biology - *Short Answer* In tropical regions, soil pH can dip below five leading to soil toxicity. Identify all of the following three statements that are true about soil: 1) Aluminum ions become soluble under pH 5; 2) Aluminum prevents the absorption of calcium by the plant; 3) Acidic soil increases cation exchange capacity.

ANSWER: All

TOSS-UP

24) Physics - *Short Answer* What effect describes the increase in fuel efficiency when fuel is burned to propel a spacecraft within a strong gravitational field?

ANSWER: Oberth effect

BONUS

24) Physics - *Multiple Choice* A tube of radius 0.1 meters with liquid has a concave meniscus angled at 60 degrees to the vertical. If the surface tension of a liquid is given as 10^{-3} newtons per meter and the density of the liquid is 10^3 kilograms per meter cubed, which of the following is closest to the height the liquid will rise due to capillary action in meters?

- W) 10^{-6}
- X) 10^{-7}
- Y) 10^{-8}
- Z) 10^{-9}

ANSWER: W) 10^{-6}