Double Elimination 7

TOSS-UP

1) Energy (ML Triv) – *Short Answer* As opposed to the linear weight matrices used by Multilayer Perceptrons, Kolmogorov-Arnold Networks use learnable 1D functions parameterized as what mathematical object in the edges between their nodes?

ANSWER: Splines

BONUS

1) Energy (Sci Phys) – *Short Answer* Identify all of the following three statements that are true of the quantum fourier transform:

1. The quantum fourier transform can be represented as a unitary matrix
2. The quantum fourier transform can be constructed purely from Hadamard gates
3. The quantum fourier transform can be applied to the factoring of numbers in Shor's algorithm

ANSWER: 1 and 3

TOSS-UP

2) Physics (Mech) – *Multiple Choice* In an appropriate reference frame, nutation can be defined as oscillation of which of the following?

W. First euler angle
X. Second euler angle
Y. Precession frequency
Z. Principal Axis

ANSWER: X

BONUS

2) Physics (EM) – *Short Answer* You set up an infinite cubic grid of resistors of resistance 1 ohm. Consider two adjacent points A and B in this grid. If the resistor between them were to be removed, then, in terms of R, what is the equivalent resistance between A and B?

ANSWER: 0.5 ohms

TOSS-UP

3) Math – *Multiple Choice* Which of the following surreal ordinals is the smallest?
W. $log\omega$ [logarithm of omega]
X. $\omega^{1/\omega}$ [omega raised to the quantity one over omega]
Y. $2^{1/\log\log\omega}$ [two raised to the quantity one over log log omega]
Z. $(\log\log\omega)^{\omega}$ [open parenthesis log log omega closed parentheses raised to omega]
ANSWER: Y

BONUS

3) Math – *Short Answer* Evaluate the definite integral from zero to pi of the sum from n equals zero to infinity of the quantity $\frac{\sin(x2^n)}{2^n}$ [sine open-parenthesis x times two to the power of n closed parenthesis divided by the quantity two to the power of n].
ANSWER: 2

TOSS-UP

4) Biology – *Multiple Choice* Edwin is studying defects in cell signaling in the immune system. He notices a decreased secretion of histamine in response to an invasion by parasitic worms. Low levels of which of the following cytokines is most directly responsible?
W) Interleukin-1
X) Interleukin-2
Y) Interleukin-4
Z) Interleukin-5
ANSWER: Y) Interleukin-4

BONUS

4) Biology – *Short Answer* Identify all of the following four types of extinction vortices that would be caused by environmental factors:

1. R Vortex
2. D Vortex
3. F Vortex
4. A Vortex

ANSWER: 1 and 2

TOSS-UP

5) Chemistry – *Short Answer* What synthetic process can be used to form a three-ringed product from phenylhydrazine and 1,3-cyclohexanedione?

ANSWER: Fischer Indole Synthesis

BONUS

5) Chemistry – *Short Answer* One example of click chemistry, for which Sharpless won the Nobel Prize in Chemistry in 2022, can be carried out between an alkyne and an azide. What is the name for the general class of molecules that reacts as azide does in this reaction?

ANSWER: 1,3-dipole

TOSS-UP

6) Earth and Space – *Short Answer* The minerals pyrite and pyrrhotite exist in a type of solid solution series in which some of the iron (II) in pyrite is partially replaced by iron (III) and other iron atoms are missing from the crystal lattice to balance charge. What name is given to this type of solid solution series?

ANSWER: Omission Solid Solution Series

BONUS

6) Earth and Space – *Multiple Choice* The tholeiitic magma series is characterized by the initial crystallization of minerals richest in which of the following components?

W) Alkali metals
X) Iron
Y) Magnesium
Z) Heavy metals

ANSWER: Y) Magnesium

TOSS-UP

7) Math – *Short Answer* Alice, Albert, Alex, Allan, and Alfons are sitting around a circular table. If rotations are distinguishable, in how many ways can they sit such that nobody is next to another person whose name either directly precedes or succeeds theirs alphabetically?

ANSWER: 10

BONUS

7) Math – *Multiple Choice* Every toad has a unique pattern of warts. Let C be the morphism from the category of frogs to the category consisting of positions of warts. Which of the following correctly describes C?

W. Monomorphism
X. Automorphism
Y. Endomorphism
Z. Epimorphism

ANSWER: W

TOSS-UP

8) Biology – *Multiple Choice* Which of the following amino acids is cleaved to form ornithine in the urea cycle?
W) Asparagine
X) Glutamine
Y) Arginine
Z) Lysine
ANSWER: Y) Arginine

BONUS

8) Biology – *Short Answer* A patient is diagnosed with increased H+ concentration and decreased partial pressure of CO2 in their bloodstream. Identify all of the following four scenarios that can cause this situation:

1. Lipoxygenase hyperactivity in the lungs;
2. Increased glutamine metabolism in tubular cells of the kidney;
3. Inhibition of the pre-Botzinger complex;
4. Decreased plasma insulin levels.

ANSWER: 4 only

TOSS-UP

9) Physics (Modern) – *Short Answer* Consider a 9-dimensional lorentzian manifold. What is the metric signature of this manifold?

ANSWER: Electromagnetic tensor, field strength tensor, faraday tensor, or Maxwell bivector

BONUS

9) Physics (Mech) – *Short Answer* A zero rest length circular spring with spring constant 6 N/m and mass 2 kg is stretched into a circle with radius 3 meters. The spring is then set spinning about its center with constant angular velocity. At what angular velocity, in radians per second, will the spring stay at an equilibrium radius of 3 meters?

ANSWER: $2\pi\sqrt{3}$

TOSS-UP

10) Earth and Space – *Short Answer* Order the following three igneous rocks in terms of increasing speed of crystallization: 1) Dacite; 2) Diabase; 3) Tachylite.

ANSWER: 2, 1, 3

BONUS

10) Earth and Space – *Multiple Choice* Which of the following statements correctly describes the impact of the curvature effect in the formation of precipitation?

W) Small droplets may evaporate in saturated air
X) Small droplets may condense in unsaturated air
Y) Large droplets may evaporate in saturated air
Z) Large droplets may condense in unsaturated air

ANSWER: W) Small droplets may evaporate in saturated air

TOSS-UP

11) Chemistry – *Short Answer* What effect, in which spatially close hydrogens affect each others' integrated peak intensities, is used in proton NMR to determine stereochemical and conformational relationships between hydrogen atoms?

ANSWER: Nuclear Overhauser Effect

BONUS

11) Chemistry – *Short Answer* Answer the following two questions about metal complexes.

1. What phenomena is largely responsible for carbon monoxide being such a strong-field ligand?

2. The LUMOs of benzene have Cn symmetry. What is the value of n?

ANSWER: 1) pi-back bonding, 2) n = 2

TOSS-UP

12) Energy (ML Triv) – *Multiple Choice* Which of the following best describes the operation of graph convolutional neural networks?
W. Applying a convolution to the graph adjacency matrix
X. Pooling node features
Y. Creating and pruning edges
Z. Clustering and combining nodes
ANSWER: X

BONUS

12) Energy (ML Triv) – *Short Answer* Answer the following questions about this image:

1. The operation of what recently popularized generative model is being shown in this image?

2. This type of model generally uses what loss function for the distance between probability distributions?

3. What variant of this model approximates the gradient of the log probability distribution?

ANSWER: 1. Diffusion Model 2. Kullback-Leibler Divergence (Accept: KL Divergence) 3. Score-based generative model

TOSS-UP

13) Physics (Thermo) – *Multiple Choice* A discontinuity in which of the following would indicate a second-order phase transition?
W. Entropy
X. Heat Capacity
Y. Gibbs Free Energy
Z. Volume
ANSWER: X

BONUS

13) Physics (Rel) – *Short Answer* A particle of rest mass m is at rest. A photon with energy 5 times the rest energy of the particle strikes it moving downward at an angle 30 degrees from the horizontal, and is deflected such that it then moves straight downward, and the particle moves rightwards. What is the ratio of the final mass of the particle to its initial mass?
ANSWER: sqrt(3/2)

TOSS-UP

14) Chemistry – *Multiple Choice* An ylide (ILL-IDE) bearing an ester group reacts with a carbonyl compound. What stereochemistry will be observed in the products?
W. Mostly Z
X. Mostly E
Y. A roughly racemic mixture of E and Z
Z. It depends on the pH of the reaction
ANSWER: X. Mostly E

BONUS

14) Chemistry – *Short Answer* Albert wishes to synthesize 5-hydroxypentanaldehyde from 3-bromopropanol. Order the following five steps in order to achieve this synthesis.

1. Addition of dilute acid and water
2. Addition of Ethylene glycol in acid with dehydration
3. Addition of Ethylene oxide

4. Addition of Magnesium
5. Addition of PCC

ANSWER: 5,2,4,3,1

TOSS-UP

15) Math – *Multiple Choice* How many intersections are there between the two graphs $x^2 - 2x + y^2 = 0$ and $x^2 + 2x - 2y^2 = 0$?
W) 1
X) 2
Y) 3
Z) 4
ANSWER: Y) 3

BONUS

15) Math – *Multiple Choice* Let $f(x) = \frac{1}{5}(x^3 - 4x^2 + 6x + 6)$. Let $a_0 = 0$ and $a_{n+1} = f(a_n)$. Which of the following is closest to a_{100}?
W) -1
X) 1
Y) 2
Z) 3
ANSWER: Y) 2

TOSS-UP

16) Biology – *Short Answer* Plants use the glutamine synthetase–glutamate synthase pathway to assimilate nitrogen into usable organic compounds. What electron carrier reduces glutamine in the pathway to convert it to glutamate for later transamination?
ANSWER: Ferredoxin

BONUS

16) Biology – *Short Answer* A person with a normal phenotype has a Robertsonian translocation in which long arms of chromosomes 14 and 21 are fused together. If they have offspring with someone with normal gametes, what is the probability that their offspring will die in birth?
ANSWER: 50%

TOSS-UP

17) Earth and Space – *Short Answer* The cooling of white dwarfs and neutron stars is partially thought to take place due to the release of neutrinos via what type of process?

ANSWER: Urca process

BONUS

17) Earth and Space – *Short Answer* Stars that do not undergo a helium flash can enter the instability strip during what stage of their evolution, characterized by a significant increase in temperature before they return to the asymptotic giant branch?

ANSWER: Blue loop

TOSS-UP

18) Biology – *Short Answer* Iodide ions are transported into follicular cells through symport with sodium. To attach iodide ions to thyroglobulin for thyroid hormone synthesis, iodide ions must then be transported into the colloid by what integral membrane protein?

ANSWER: Pendrin

BONUS

18) Biology – *Short Answer* Given that phospholipid synthesis takes place only in the cytosolic leaflet of the ER lipid bilayer, identify all of the following three scenarios that would happen if all the scramblase in the ER lipid bilayer was replaced by flippase:
1) The luminal leaflet will have an increased abundance of phosphatidylserines;
2) The luminal leaflet will have an increase abundance of phosphatidylcholines;
3) The cytosolic leaflet will have an increased abundance of phosphatidylcholines.

ANSWER: 1 and 3

TOSS-UP

19) Chemistry – *Multiple Choice* What principle states that when a molecule is undergoing an electronic transition, its nuclear configuration experiences no significant change?
W) Kasha's Rule
X) Franck-Condon Principle
Y) Lyderson Principle
Z) Principle of Detailed Balance
ANSWER: X) Franck-Condon Principle

BONUS

19) Chemistry – *Short Answer* What reaction concatenates an organohalide with boronic acid in the presence of a palladium catalyst?
ANSWER: Suzuki coupling

TOSS-UP

20) Energy (Classical) – *Short Answer* Identify all of the following three statements about complexity classes which are true.
1) Strongly NP-hard problems have a pseudopolynomial time algorithm but not a polynomial time algorithm
2) If P does not equal NP, then quasi-polynomial time algorithms are NP-Intermediate under the exponential time hypothesis
3) The halting problem is decidable
4) Boolean satisfiability is NP-Complete
ANSWER: 2, 4

BONUS

20) Energy (Sci Math) – *Multiple Choice* Which of the following types of cryptography is based on operations in a finite field?
W) RSA
X) Elliptic-Curve
Y) ElGamal
Z) Cramer-Shoup
ANSWER: X) Elliptic-Curve

TOSS-UP

21) Physics (Mech) – *Multiple Choice* Edwin has accidentally transported himself to a dimension where the gravitational force is a linear force law, as opposed to an inverse square one. Edwin spawns in a spherical dust cloud of uniform mass and radius R. Which of the following best describes the relationship between the force Edwin feels and his distance from the center of the cloud as he moves to a point R away from the boundary of the cloud?
W) Uniformly Linear
X) Piecewise Linear
Y) Quadratic, then Linear
Z) Quartic, then Linear
ANSWER: W) Uniformly Linear

BONUS

21) Physics (EM) – *Short Answer* A regular pentagon with side length 5 meters and surface charge density 3 C/m^2 is placed on the x-y plane centered at the origin. A point charge of charge 2 coulombs is placed at the point (0, 0, 5.5). Find the net electric flux through the pentagon to two significant figures in scientific notation in newton meters squared per coulomb.
ANSWER: 1.8×10^{10} N m^2/C

TOSS-UP

22) Math – *Short Answer* Dole and Chiquita are playing a game with Dole going first. Each turn, one of them rolls two six-sided dice. Whoever rolls two prime numbers first wins. What is the probability that the winner is Chiquita?
ANSWER: 3/7

BONUS

22) Math – *Short Answer* You are shown an image of a fractal that characterizes the complex values c for which the map from z to z^2+c is bounded when starting from zero. Answer the following three questions about this image.
1) What is the name of this fractal?
2) A number c is chosen from the entire black part of the fractal. What is its maximum possible absolute value?
3) What is the Hausdorff dimension of the boundary of the black parts of the fractal?
ANSWER: 1) Mandelbrot set, 2) 2, 3) 2

TOSS-UP

23) Earth and Space – *Multiple Choice* Which of the following best describes a Kerr-Newman black hole?
W) Charged and rotating
X) Charged and non-rotating
Y) Uncharged and rotating
Z) Uncharged and non-rotating
ANSWER: W) Charged and rotating

BONUS

23) Earth and Space – *Short Answer* When the first red dwarfs reach the end of their lives, identify all of the following three elements that will have higher concentrations on their surfaces than in the rest of the universe:
1) Hydrogen
2) Helium
3) Oxygen
ANSWER: 2 only