TOSS-UP

1) Biology – *Short Answer* In swampy, anoxic environments like the Everglades, mangroves have evolved to facilitate air exchange through small lenticels on specialized roots. What is the name for these specialized roots?

ANSWER: PNEUMATOPHORES [VS]

BONUS

1) Biology – Peter and Vedang are walking along a roadcut in Oklahoma looking for crinoid fossils. Crinoids are passive suspension feeders who attach themselves to the sea bottom. What phylum do crinoids belong to?

ANSWER: ECHINODERMATA [VS]

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TOSS-UP

2) Chemistry – *Short Answer* Diphenic acid exhibits a type of isomerism where its bulky carboxyl groups stop rotation about a single bond. What is the name for this kind of isomerism?

ANSWER: ATROPISOMERISM [CT]

BONUS

2) Chemistry – *Multiple Choice* The cell membrane is best described by which of the following classifications of a liquid crystal?

W) Cholesteric
X) Discotic
Y) Nematic
Z) Smectic

ANSWER: Z) SMECTIC [JH]

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TOSS-UP

3) Computer Science [3] – *Short Answer* What system allows web browsers to find a server IP address given a website's URL, and is hosted on thousands of nameservers across the globe?

ANSWER: DOMAIN NAME SYSTEM (ACCEPT: DNS) [CH]

BONUS

3) Computer Science [3] – *Multiple Choice* Which of the following top-level Linux directories is NOT correctly matched with its function?

W) /bin, stores system and user binaries
X) /dev, stores files used for Linux development
Y) /root, serves as the home directory of the root user
Z) /tmp, stores temporary files that can be deleted at any time if necessary

ANSWER: X) /dev, STORES FILES USED FOR LINUX DEVELOPMENT [CH]

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TOSS-UP

4) Earth and Space – *Short Answer* Order the following three sediment types from lowest to highest porosity: 1) Clay; 2) Sand; 3) Silt.

ANSWER: 2, 3, 1 [PB]

BONUS

4) Earth and Space – *Multiple Choice* Which of the following best explains why 500 millibar isobars typically increase in height closer to the equator?

W) Equatorial air is warmer
X) Equatorial air is pulled outward by centrifugal force
Y) Equatorial convergence causes upwelling
Z) Strong equatorial winds thicken the planetary boundary layer

ANSWER: W) EQUATORIAL AIR IS WARMER [PB]

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TOSS-UP

5) Math – *Short Answer* A point is chosen uniformly and at random on the surface of a solid hemisphere. What is the probability that the point lies on the base?

ANSWER: 1/3 [CT]

BONUS

5) Math – *Short Answer* An arithmetic sequence starts at -40 and has a common difference of 5. What is the sum of the first 24 terms of the sequence?

ANSWER: 420 [CT]

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TOSS-UP

6) Physics [7] – *Short Answer* The sum over all macrostates of the probability of the macrostate times the natural log of the probability of the macrostate is directly proportional to what thermodynamic state variable?

ANSWER: ENTROPY [CH]

BONUS

6) Physics – *Short Answer* Assuming ideal conditions, identify all of the following 3 wave properties that always stay the same after reflection. 1) Speed; 2) Frequency; 3) Phase.

ANSWER: 1 AND 2 [RE]

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TOSS-UP

7) Biology – *Multiple Choice* In which of the following biomes is an inverted biomass pyramid common?

W) Northern coniferous forest
X) Oceanic pelagic zone
Y) Savanna
Z) Tundra

ANSWER: X) OCEANIC PELAGIC ZONE [JH, uh might have appeared in MIT 2021?]

BONUS

7) Biology – *Short Answer* Sharks are able to sense weak electrical fields in order to detect prey. What jelly-filled pores found in the shark's head are responsible for this sense?

ANSWER: AMPULLAE OF LORENZINI [VS]

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TOSS-UP
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8) Chemistry – *Short Answer* What is the formal charge on each phosphorus atom in one molecule of white phosphorus, which takes the form of four phosphorus atoms bonded in a tetrahedral arrangement?

ANSWER: 0 [CH]

BONUS

8) Chemistry – *Short Answer* Order the following 3 molecules in terms of increasing average oxidation state on the carbon atoms: 1) Ethanol; 2) Pentyne; 3) Acetic acid.

ANSWER: 1, 2, 3 [CH]

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TOSS-UP

9) Computer Science [3] – *Multiple Choice* Which of the following problems in computer science is NOT considered an NP-hard problem?

W) Traveling Salesman Problem
X) Subset Sum Problem
Y) Shortest Path Problem
Z) Finding a Hamiltonian cycle

ANSWER: Y) SHORTEST PATH PROBLEM [CH]

BONUS

9) Computer Science [3] – *Short Answer* What character in a regular expression signifies that a given character must occur at least once, but may repeat in a matched string?

ANSWER: + [CH]

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TOSS-UP

10) Earth and Space – *Multiple Choice* Which of the following tectonic environments would form a Wadati-Benioff zone?

W) Ocean-ocean divergent boundary
X) Continent-continent divergent boundary
Y) Ocean-ocean convergent boundary

Z) Continent-continent convergent boundary

ANSWER: Y) OCEAN-OCEAN CONVERGENT BOUNDARY [PB]

BONUS

10) Earth and Space – *Short Answer* What group of objects in the Kuiper belt are unusual in that they orbit in a 2:3 mean-motion resonance with Neptune?

ANSWER: PLUTINOS [PB]

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TOSS-UP

11) Math – *Multiple Choice* John has two cubes, one of which has double the volume of the other. Which of the following is closest to the ratio of their surface areas?

W) 1.3
X) 1.4
Y) 1.5
Z) 1.6

ANSWER: Z) 1.6 [CT]

BONUS

11) Math – *Short Answer* Let N equal 30 to the power of 2023. What is the ratio of N to the Euler totient function of N?

ANSWER: 15/4 (ACCEPT: 3.75) [CT]

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TOSS-UP

12) Physics – *Short Answer* When a photon with energy at least twice the rest mass energy of the electron passes near a nucleus, what process is commonly observed, resulting in the creation of an electron and a positron?

ANSWER: PAIR PRODUCTION [RE]

BONUS

12) Physics – *Multiple Choice* In electromagnetism, which of the following best describes the difference between the B and H vector fields?

W) The B field is always real, but the H field may be complex.
X) The B field is constant given constant boundary conditions, but the H field may change.
Y) The tangential B field can be affected by a change in magnetic permeability, but the tangential H field cannot.
Z) The B field is generated from all electric currents, while the H field is only present for changing electric currents.

ANSWER: Y) THE TANGENTIAL B FIELD CAN BE AFFECTED BY A CHANGE IN MAGNETIC PERMEABILITY, BUT THE TANGENTIAL H FIELD CANNOT. [CH]

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TOSS-UP

13) Biology – *Short Answer* In animal somatic cells, the Hayflick limit sets a bound on the number of cell cycles until senescence. One cause of senescence is the absence of what reverse transcriptase enzyme that acts to elongate the ends of chromosomes?

ANSWER: TELOMERASE [JH]

BONUS

13) Biology – *Short Answer* Order the following four brain structures from superior to inferior in a normal human brain: 1) Cerebrum; 2) Medulla oblongata; 3) Pons; 4) Thalamus.

ANSWER: 1, 4, 3, 2 [JH]

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TOSS-UP

14) Chemistry – *Multiple Choice* Consider a collection of molecules whose velocities follow a Maxwell-Boltzmann distribution. As temperature increases, which of the following describes how the most probable velocity and the maximum value of the probability density function change?

W) The most probable velocity increases and the maximum value increases.
X) The most probable velocity increases and the maximum value decreases.
Y) The most probable velocity decreases and the maximum value increases.
Z) The most probable velocity decreases and the maximum value decreases.

ANSWER: X) THE MOST PROBABLE VELOCITY INCREASES AND THE MAXIMUM VALUE DECREASES [JH]

BONUS

14) Chemistry – *Short Answer* How many stereoisomers are there for pentane-2,3,4-triol?

ANSWER: 4 [JH]

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TOSS-UP

15) Computer Science – *Multiple Choice* Consider a processor where the clock cycle is five nanoseconds, where a new operation is input every cycle, and an operation takes six cycles to process. What is the latency and throughput of this processor, respectively?

W) 5 ns and 1/5 ns^{-1} **[*one-fifth inverse nanoseconds*]**
X) 5 ns and 1/30 ns^{-1} **[*one-thirtieth inverse nanoseconds*]**
Y) 30 ns and 1/5 ns^{-1} **[*one-fifth inverse nanoseconds*]**
Z) 30 ns and 1/30 ns^{-1} **[*one-thirtieth inverse nanoseconds*]**

ANSWER: Y) 30 ns and 1/5 ns^{-1} [JH]

BONUS

15) Computer Science – *Short Answer* Expressing your answer in hexadecimal, how is the decimal number -5 written in two's complement notation in a one-byte system?

ANSWER: FB [JH]

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TOSS-UP

16) Earth and Space – *Multiple Choice* In which of the following environments would precipitation formation be most dominated by the Bergeron process rather than the collision-coalescence process?

W) High latitudes and high altitudes
X) High latitudes and low altitudes
Y) Low latitudes and high altitudes
Z) Low latitudes and low altitudes

ANSWER: W) HIGH LATITUDES AND HIGH ALTITUDES [JH]

BONUS

16) Earth and Space – *Short Answer* Identify all of the following three minerals that can dissolve to create karst topography: 1) Calcite; 2) Dolomite; 3) Gypsum.

ANSWER: ALL [PB]

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TOSS-UP

17) Math – *Short Answer* Alice is on the 2D coordinate plane. If Alice can only move either one unit right or one unit up every step, how many paths can she take from the origin to (3, 4) [***three comma four***]?

ANSWER: 35 [CT]

BONUS

17) Math – *Short Answer* Let f of x be a continuous and differentiable function such that f of 0 equals 0, f of 1 equals 6, f prime of 0 equals 2, and f prime of 1 equals 10. What is the integral from 0 to 1 of f of x times f prime of x dx?

ANSWER: 18 [CT]

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TOSS-UP

18) Physics – *Multiple Choice* An object is placed at a distance smaller than the focal length from a convex lens. Which of the following describes the image formed on the same side as the object?

W) Real and larger
X) Real and smaller
Y) Virtual and larger
Z) Virtual and smaller

ANSWER: Y) VIRTUAL AND LARGER [JH]

BONUS

18) Physics – *Short Answer* According to special relativity, the world line of a uniformly accelerating observer in Minkowski coordinates traces out what type of conic?

ANSWER: HYPERBOLA [JH]

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TOSS-UP

19) Biology – *Short Answer* Because of their immune system's special ability to tolerate viruses, what order of animals is believed to serve as a disease reservoir for diseases such as Ebola, Marburg, and likely COVID-19?

ANSWER: CHIROPTERA (ACCEPT: BATS) [JH]

BONUS

19) Biology – *Multiple Choice* Which of the following is TRUE about pollination?

W) Individuals of monoecious **[*mo-no-ee-shis*]** species cannot self-fertilize.
X) Sporophytic incompatibility implies only pollen grains with an *S*-gene allele present in the flower can pollinate the plant.
Y) The tube nucleus fuses with the polar nuclei to form the endosperm.
Z) In plants, a block to polyspermy is facilitated by calcium ion signaling.

ANSWER: Z) IN PLANTS, A BLOCK TO POLYSPERMY IS FACILITATED BY CALCIUM ION SIGNALING. [JH]

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TOSS-UP

20) Chemistry – *Short Answer* Following IUPAC carbon numbering, rank the following three carbon atoms in 1-pentene by increasing order of energy required for homolytic cleavage of one of their bonds to hydrogen: 1) C3; 2) C4; 3) C5

ANSWER: 1, 2, 3 [JH]

BONUS

20) Chemistry – *Short Answer* In order to increase the efficiency of reactions such as Fischer esterification or acetal formation from ketones, what molecule is removed via a Dean-Stark apparatus or a molecular sieve, driving the reaction forward per Le Chatelier's principle?

ANSWER: WATER (ACCEPT: H_2O) [JH]

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TOSS-UP

21) Computer Science – *Multiple Choice* Which of the following is the type of pseudorandom number generation used by Python's random module?

W) Shift-register generators
X) Middle-square method generators
Y) Mersenne Twister generators
Z) WELL **[*well*]** generators

ANSWER: Y) MERSENNE TWISTER GENERATORS [JH]

BONUS

21) Computer Science – *Short Answer* In several early chess engines, an improvement upon the naive minimax algorithm was to stop considering a possible move if any branch along the game tree resulted in a worse evaluation than the current best. What is the name for this pruning algorithm?

ANSWER: ALPHA-BETA PRUNING [JH]

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TOSS-UP

22) Earth and Space – *Multiple Choice* On August 30th, 2007, *Voyager 2* measured several sudden changes to the orientation of the Sun's magnetic field. This is because it is believed to have crossed what structure, which represents the boundary at which the solar wind slows to subsonic speed relative to the Sun?

W) Bow shock
X) Heliopause
Y) Hydrogen wall
Z) Termination shock

ANSWER: Z) TERMINATION SHOCK [JH]

BONUS

22) Earth and Space – *Short Answer* Identify all of the following three changes to a beach that are characteristic of a summertime beach as opposed to a wintertime beach: 1) High wave energy; 2) Prominent longshore bars; 3) Steep beach face.

ANSWER: 3 ONLY [JH]

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TOSS-UP

23) Math – *Short Answer* Using pennies and nickels, how many ways are there to make 69 cents?

ANSWER: 14 [CT]

BONUS

23) Math – *Short Answer* Consider a rectangular prism with the following two constraints: its height is twice its width, and the sum of its height, width, and length is 9. What is the largest possible volume of this rectangular prism?

ANSWER: 24 [JH]

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TOSS-UP

24) Physics – *Multiple Choice* Consider a circular loop of wire with a fixed current but variable radius r. The strength of the magnetic field in the center of the loop is linearly dependent on what power of r?

W) -2
X) -1
Y) 0
Z) 1

ANSWER: X) -1 [JH]

BONUS

24) Physics – *Short Answer* The potential energy of a one-dimensional particle is governed by the equation $U(x) = x^3 - 24x^2 + 48$ **[*x cubed minus twenty-four x squared plus forty-eight*]** Joules, where position is defined in units of meters. Identify all of the following three statements that are TRUE about the particle: 1) The particle is in a state of unstable equilibrium at $x = 0$; 2) The force on the particle at $x = 1$ is positive 45 Newtons; 3) This system could be created using a single Hookean spring with one end fixed.

ANSWER: 1 AND 2 [JH]

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