ROUND 8

TOSS-UP

1) Math – *Short Answer* Using the Maclaurin series to 2 terms, compute sine of 1.

ANSWER: 5/6

BONUS

1) Math – *Short Answer* What is the area enclosed by the polar curve $r = 1 - \cos\theta$?

ANSWER: $3\pi/2$

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TOSS-UP

2) Earth and Space – *Short Answer* Rounding your answer to the nearest integer, calculate the phase velocity, in meters per second, of a wave travelling in a lagoon with water depth of 40 centimeters.

ANSWER: 2 METERS PER SECOND

BONUS

2) Earth and Space – *Short Answer* Meridiana is the alpha star of the Corona Australis constellation. If it is observed to have a parallax angle of 0.025 arcseconds, calculate the distance to Meridiana in light years. Round your answer to two significant figures.

ANSWER: 130 LIGHT YEARS
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TOSS-UP

3) Physics – *Multiple Choice* Which of the following types of particle detectors uses a superheated liquid?

W) Bubble chamber
X) Cloud chamber
Y) Geiger counter
Z) Scintillation counter

ANSWER: W) BUBBLE CHAMBER

BONUS

3) Physics – *Short Answer* Identify all of the following three statements that are true about the characteristic K-alpha X-ray line: 1) It is produced when a hole moves from the $n = 1$ to the $n = 2$ energy level; 2) It is shorter in wavelength than the K-beta line; 3) Its wavelength increases as atomic number increases.

ANSWER: 1 ONLY

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TOSS-UP

4) Biology – *Multiple Choice* - Decreased fibrin production can be traced back to a malfunction in what organ?

W) Spleen
X) Adrenal Glands
Y) Liver
Z) Lymph Nodes

ANSWER: Y) LIVER

BONUS

4) Biology – *Short Answer* - The reaction converting prothrombin to thrombin in the liver is dependent on which vitamin?

ANSWER: VITAMIN K (ACCEPT: PHYLLOQUINONE or PHYTOMENADIONE)
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TOSS-UP

5) Chemistry – *Short Answer* Rank the following three elements in terms of increasing standard reduction potential: 1) Fluorine; 2) Oxygen; 3) Silver.

ANSWER: 3, 2, 1

BONUS

5) Chemistry – *Short Answer* When bonded to a central metal atom, cyanide ligands can either donate their lone pair on carbon or nitrogen. What type of isomerism is exhibited due to this effect?

ANSWER: LINKAGE ISOMERISM

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TOSS-UP

6) Energy – *Short Answer* Scientists at Lawrence Livermore National Laboratory operate the National Ignition Facility, which is currently being used to study high-energy density science. There, they are trying to get a chamber to temperatures of up to 300 million Kelvin in order to give deuterium and tritium nuclei enough kinetic energy to start fusion. What energy barrier must be overcome to get the nuclei close enough to fuse?

ANSWER: COULOMB BARRIER

BONUS

6) Energy – *Short Answer* Scientists at Brookhaven National Lab are studying superconductive grains in iron-nickel meteorites. Identify all of the following three statements that are true regarding iron-nickel meteorites: 1) They are thought to originate from cores of differentiated planetesimals; 2) They are the most common type of meteorite; 3) The iron-nickel alloy is almost completely present in the taenite and kamacite phases.

ANSWER: 1, 3
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TOSS-UP

7) Math – *Short Answer* At what x value is the Mean Value Theorem satisfied when applied to $f(x) = 10x^2 - 2x + 1$ across the interval $x = 0$ to $x = 8$?

ANSWER: 4

BONUS

7) Math – *Short Answer* The double factorial is similar to the factorial, but is defined as the product of every other integer. For example, 7 double factorial equals 7 times 5 times 3 times 1. How many trailing zeros does 2020 double factorial have?

ANSWER: 251

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TOSS-UP

8) Earth and Space – *Multiple Choice* Which of the following statements about guyot ***[ge-YO]*** formation is not true?

W) Guyots are generally volcanic in origin
X) Guyots subside as they move away from the mid-ocean ridge
Y) Guyots become flat topped as they are eroded at the sea surface
Z) Guyots rarely contain coral due to their depth

ANSWER: Z) GUYOTS RARELY CONTAIN CORAL DUE TO THEIR DEPTH

BONUS

8) Earth and Space – *Short Answer* Order the following four stages of the Wilson cycle following a continent-continent collision: 1) Subduction of oceanic lithosphere; 2) Pre-drift extension; 3) Seafloor spreading; 4) Opening of shallow ocean basin.

ANSWER: 2, 4, 3, 1
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TOSS-UP

9) Physics – *Multiple Choice* What shape are the nodal surfaces that correspond to fully destructive interference between two coherent wave sources in 3D space?

W) Spheres
X) Hyperbolic paraboloids
Y) Hyperboloids of one sheet
Z) Hyperboloids of two sheets

ANSWER: Z) HYPERBOLOIDS OF TWO SHEETS

BONUS

9) Physics – *Short Answer* A train is headed directly towards an observer with an initial velocity of 360 m/s. As the bell on the train rings for the first time, it begins decelerating at 18 m/s^2. The bell rings a total of four times with a uniform spacing of 1 second. Assuming the speed of sound to be 343 m/s, order the four bell rings from FIRST to reach the observer to the last, using 1 for the first ring, 2 for the second ring, and so on.

ANSWER: 2, 1, 3, 4

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TOSS-UP

10) Biology – *Multiple Choice* What process in animal cells is likely to be most negatively impacted by the presence of ionophores?

W) Transcription
X) Translation
Y) Glycolysis
Z) Oxidative phosphorylation

ANSWER: Z) OXIDATIVE PHOSPHORYLATION

BONUS

10) Biology – *Short Answer* Order the following four steps of ion exchange chromatography sequentially: 1) Loading the protein solution, 2) Salting out, 3) Dialysis, 4) Pouring a buffer over the column.

ANSWER: 4, 1, 2, 3
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TOSS-UP

11) Chemistry – *Multiple Choice* Which of the following ligands would be most likely to form a low-spin octahedral complex when bonded to a transition metal ion?

W) Fluoro
X) Aquo
Y) Carbonyl
Z) Oxalato

ANSWER: Y) CARBONYL

BONUS

11) Chemistry – *Short Answer* In substituted alkenes, alkyl groups can stabilize molecules via hyperconjugation. In this phenomenon, electron density from an alkyl sigma orbital is donated into which of the following molecular orbitals?

W) Sigma
X) Sigma star
Y) Pi
Z) Pi star

ANSWER: Z) PI STAR

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TOSS-UP

12) Energy – *Short Answer* Scientists at Argonne National Lab are studying the distribution of the 2+ and 4+ oxidation states of tin in magma bodies. Though tin is not a transition metal, it may exist in both 2+ and 4+ oxidation states due to what effect?

ANSWER: INERT-PAIR EFFECT

BONUS

12) Energy – *Short Answer* Scientists at Brookhaven National Laboratory studying protein solutions at ultra-low temperatures found that some of these solutions re-emitted absorbed light after a delay of a few milliseconds. This is indicative of what type of photoluminescence, associated with forbidden energy transitions?

ANSWER: PHOSPHORESCENCE
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TOSS-UP

13) Math – *Short Answer* A fair coin is flipped six times. Given that the first two flips were both heads, what is the probability that there were three consecutive heads in those six flips?

ANSWER: 9/16

BONUS

13) Math – *Short Answer* What are the last two digits of the following expression: $7^{77} + 7^7 + 7$?

ANSWER: 57

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TOSS-UP

14) Earth and Space – *Short Answer* Identify all of the following three statements that are true about sunspots: 1) The sunspot cycle lasts roughly 11 years; 2) At the start of a sunspot cycle, sunspots typically appear at mid-latitudes and move closer to the equator; 3) There are very few sunspots at latitudes higher than 45 degrees north or south.

ANSWER: ALL

BONUS

14) Earth and Space – *Short Answer* What is the zone underneath a river in which the groundwater moves in the same general direction as the river?

ANSWER: HYPORHEIC ZONE
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TOSS-UP

15) Physics – *Short Answer* Two moles of an ideal diatomic gas expand from 4 liters to 12 liters at a constant temperature of 500 K. In terms of the ideal gas constant *R*, by how much does the entropy of the gas change?

ANSWER: 2*R* ln(3)

BONUS

15) Physics – *Multiple Choice* If the maximum transverse velocity of a wave is equal to its phase velocity, what is the amplitude of the wave in terms of its wavelength λ ***[lambda]***?

W) $\lambda/\sqrt{2}$
X) $\lambda/2\pi$
Y) $\lambda\sqrt{2}$
Z) $2\pi\lambda$

ANSWER: X) $\lambda/2\pi$

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TOSS-UP

16) Biology – *Short Answer* A 9:7 phenotypic ratio in the offspring of a dihybrid cross is indicative of the involvement of what genetic phenomenon?

ANSWER: EPISTASIS (ACCEPT: DUPLICATE RECESSIVE EPISTASIS, COMPLEMENTARY)

BONUS

16) Biology – *Multiple Choice* Uniparental disomy ***[DIE-somy]*** will have the most phenotypic effect if it occurs in which of the following?

W) Purine rich sequences
X) Pyrimidine rich sequences
Y) CpG islands
Z) TATA box

ANSWER: Y) CpG islands
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TOSS-UP

17) Chemistry – *Multiple Choice* Which of the following classes of carbocations ***[carbo-CAT-ion]*** is the least stable?

W) Allylic
X) Benzylic
Y) Vinylic
Z) Tertiary

ANSWER: Y) VINYLIC

BONUS

17) Chemistry – *Short Answer* What is the major product formed by the reaction of sodium azide with chlorohexane in acetonitrile?

ANSWER: 1-AZIDOHEXANE (ACCEPT: AZIDOHEXANE; HEXYL AZIDE)

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TOSS-UP

18) Energy – *Short Answer* Scientists at Lawrence Livermore National Lab have synthesized a nickel-argon compound that is stable as a solid solution under conditions present in the Earth's inner core. Significant amounts of argon may be present in the Earth's core due to the decay of what radioactive isotope?

ANSWER: POTASSIUM-40 (ACCEPT: K-40)

BONUS

18) Energy – *Short Answer* Scientists at Argonne National Lab are developing techniques to experimentally determine the structure of transition states. Identify all of the following three features that they would observe for the transition state of an S_N2 reaction: 1) Partial carbocationic character; 2) Three-center four-electron bonding; 3) Tetrahedral geometry.

ANSWER: 1, 2
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TOSS-UP

19) Math – *Short Answer* What is the limit as x approaches 0 of the fraction with numerator e to the x minus 1 and denominator natural log of quantity $x + 1$?

ANSWER: 1

BONUS

19) Math – *Short Answer* Find the radius of the circumscribed sphere of the tetrahedron with vertices at (0, 0, 0), (0, 0, 1), (0, 1, 0), and (1, 0, 0).

ANSWER: SQUARE ROOT 3 OVER 2

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TOSS-UP

20) Earth and Space – *Multiple Choice* For stars at the Eddington Limit, what is the most significant outwards-going force that counteracts gravity to keep hydrostatic equilibrium?

W) Thermal pressure
X) Radiation pressure
Y) Electron degeneracy pressure
Z) Neutron degeneracy pressure

ANSWER: X) RADIATION PRESSURE

BONUS

20) Earth and Space – *Short Answer* Identify all of the following three statements that are true regarding RR Lyrae variables: 1) They are generally old, population II stars; 2) Their periods are generally shorter than the periods of Cepheid variables; 3) They are very common in globular clusters.

ANSWER: ALL
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TOSS-UP

21) Physics – *Short Answer* An infinitely long straight wire has a current of 6 Amperes. Given that the permeability of free space is $4\pi * 10^{-7}$ Tesla meters per Ampere, then, in scientific notation, give the magnitude of the magnetic field at a distance of 3 meters generated in Tesla.

ANSWER: $4 * 10^{-7}$ TESLA

BONUS

21) Physics – *Short Answer* To an observer at rest, a particle is moving at 0.28 times the speed of light c. What is the ratio of the particle's energy to its rest mass, in terms of c?

ANSWER: $25/24\ c^2$

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TOSS-UP

22) Biology – *Short Answer* In modern PCR, Pfu ***[P-F-U]*** DNA polymerase is typically used instead of Taq ***[Tack]*** polymerase because Taq polymerase has a high error rate. This is because Taq polymerase is missing which of the following functionalities?

W) 3'-5' exonuclease activity
X) 5'-3' exonuclease activity
Y) 3'-5' polymerase activity
Z) 5'-3' polymerase activity

ANSWER: W) 3'-5' EXONUCLEASE ACTIVITY

BONUS

22) Biology – *Short Answer* Urate oxidase is known to form large electron-dense paracrystalline cores. In what eukaryotic organelle is this enzyme most commonly found?

ANSWER: PEROXISOME
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TOSS-UP

23) Chemistry – *Multiple Choice* When *t*-butyl iodide undergoes a solvolysis reaction with ethanol, which of the following functional groups will most likely be formed by this reaction?

W) Ester
X) Tertiary alcohol
Y) Carboxylic acid
Z) Ether

ANSWER: Z) ETHER

BONUS

23) Chemistry – *Short Answer* What rule states that bridged bicyclic compounds consisting of rings with less than 8 carbons cannot possess *trans* double bonds at the bridgehead?

ANSWER: BREDT'S RULE