TOSS-UP

1) Chemistry – *Short Answer* [4] When performing hydroboration oxidation on a terminal alkyne, a vinyl alcohol is formed, which forms what other functional group after isomerization?

ANSWER: ALDEHYDE (ACCEPT: CARBONYL, DO NOT ACCEPT: KETONE) [CT]

BONUS

1) Chemistry – *Short Answer* [7] Arrange the following three mechanistic steps of the Hoffman degradation from earliest to latest: 1) Isocyanate formation; 2) Amide bromination; 3) Decarboxylation.

ANSWER: 2, 1, 3 [RB]

TOSS-UP

2) Earth and Space – *Multiple Choice* [2] Which of the following regions of the Sun's atmosphere has the highest average temperature?

W) Inner corona
X) Outer corona
Y) Photosphere
Z) Chromosphere

ANSWER: X) OUTER CORONA [SF]

BONUS

2) Earth and Space – *Short Answer* [2] Identify all of the following three statements regarding the El Niño Southern Oscillation that are true: 1) In an El Niño year, there is a positive SST anomaly in the eastern Pacific; 2) In an El Niño year, there is suppressed upwelling in the eastern Pacific; 3) In a La Niña year, the thermocline in the eastern Pacific is anomalously deep.

ANSWER: 1 AND 2 [YL]

TOSS-UP

3) Math – *Short Answer* [4] 7 identical seats are evenly spaced around a circular table. If rotations are indistinct, how many ways are there to arrange 7 people in these seats?

ANSWER: 720 [CT]

BONUS

3) Math – *Short Answer* [6] Let point O be the center of a unit circle. Points A, B, C, and D are in clockwise order on the circle such that angles AOB, BOC, and COD are all 30 degrees. What is the area of polygon ABCDO?

ANSWER: 3/4 [CT]

TOSS-UP

4) Biology – *Multiple Choice* [2] Which of the following amino acids can form disulfide bonds with itself?

W) Tyrosine
X) Phenylalanine
Y) Methionine
Z) Cysteine

ANSWER: Z) CYSTEINE [SF]

BONUS

4) Biology – *Short Answer* [5] Identify all of the following three clades of plants that are considered non-vascular: 1) Lycopodiophyta; 2) Marchantiophyta; 3) Pinophyta.

ANSWER: 2 ONLY [SF]

TOSS-UP

5) Physics – *Short Answer* [6] On a stress-strain graph, a Hookean solid follows a straight line in the elastic region. However, when a non-Hookean solid is stretched and then released, the curve that it takes when released is different from the curve it takes when initially stretched. What is the term for this effect?

ANSWER: HYSTERESIS [CT]

BONUS

5) Physics – *Short Answer* [5] A ball is dropped from a height of 30 meters and repeatedly bounces on the ground with a coefficient of restitution of 2/3. What is the limit of the total distance that the ball travels?

ANSWER: 78 [CT]

TOSS-UP

6) Energy – *Short Answer* [2] Researchers at Oak Ridge National Lab are investigating the kinetics of various methods of uranium isotope separation. What corrosive acid is produced when uranium hexafluoride is hydrolyzed?

ANSWER: HYDROFLUORIC ACID (ACCEPT: HF) [YL]

BONUS

6) Energy – *Short Answer* [6] Scientists at Fermilab are constructing liquid argon chambers in order to better detect hypothetical sterile neutrinos. While sterile neutrinos only interact with the gravitational force, active neutrinos are able to interact with the weak nuclear force because they have a value of +1/2 for what quantity?

ANSWER: WEAK ISOSPIN (DO NOT ACCEPT: ISOSPIN) [CT]

TOSS-UP

7) Biology – *Short Answer* [4] The inheritance of the *Igf-2* gene in mice is known for only expressing paternal phenotype. This is an example of what phenomena which is mediated by DNA methylation?

ANSWER: GENOMIC IMPRINTING (ACCEPT: IMPRINTING; DO NOT ACCEPT: EPIGENETICS) [SF]

BONUS

7) Biology – *Short Answer* [6] Identify all of the following three statements that are true concerning viruses: 1) The lytic cycle is found in temperate phages; 2) The lysogenic cycle is always deadly; 3) Prophages never leave the host's genome while proviruses do.

ANSWER: 1 ONLY [SF]

TOSS-UP

8) Physics – *Short Answer* [4] What is the coefficient of performance of a Carnot refrigerator with a hot reservoir of 600 Kelvin and a cold reservoir of 500 Kelvin?

ANSWER: 5 [CT]

BONUS

8) Physics – *Short Answer* [6] A uniform wood block with side lengths of 10, 6, and 4 meters is falling through a fluid with constant density and with its biggest side face down, reaching a terminal velocity of v. It spontaneously rotates so that its smallest side is face down, reaching a new terminal velocity. In terms of v, what is the new terminal velocity?

ANSWER: v ROOT 10 OVER 2

TOSS-UP

9) Earth and Space – *Multiple Choice* [6] Which of the following statements regarding carbonates in the ocean is false?

W) Aragonite is more soluble than calcite
X) Bicarbonate is the dominant carbonate-containing anion in the ocean
Y) The formation of calcium carbonate acts as a net carbon dioxide sink
Z) The calcite compensation depth is at a depth of 4000 to 4100 meters in all of the major oceans

ANSWER: Z) THE CALCITE COMPENSATION DEPTH IS AT A DEPTH OF 4000 TO 4100 METERS IN ALL OF THE MAJOR OCEANS [YL]

BONUS

9) Earth and Space – *Short Answer* [5] What is the altitude angle, in degrees, of the sun at noon on the summer solstice for an observer at 30 degrees north?

ANSWER: 83.5 [YL]

TOSS-UP

10) Chemistry – *Short Answer* [4] Identify all of the following 3 statements regarding the one-dimensional particle in a box model that are true: 1) The particle can have exactly 0 potential energy; 2) The particle can never escape the box; 3) The particle's potential energy is directly proportional to its mass.

ANSWER: 1 AND 2 [AS]

BONUS

10) Chemistry – *Multiple Choice* [6] Electrospray ionization mass spectrometry is used to determine the molar mass of an unknown organic compound. The highest mass peak observed at significant intensity has a mass to charge ratio of 55 and represents the trace formation of a sodium adduct inside of the detector. Which of the following could be the molecular formula of the unknown molecule?

W) CH_4O
X) C_2H_6O
Y) C_2H_2
Z) CH_4

ANSWER: W) CH_4O [RB]

TOSS-UP

11) Math – *Short Answer* [3] Phillip makes a set of the 9 smallest positive multiples of 1000. Jay takes Phillip's set and increases the smallest number by 11 and decreases the largest number by 4. Identify all of the following 3 quantities that are bigger for Jay's set than Phillip's set: 1) Mean; 2) Median; 3) Range.

ANSWER: 1 ONLY [CT]

BONUS

11) Math – *Short Answer* [4] Let x = root 2 over 2 + i times root 2 over 2. What is the magnitude of the imaginary component of the sum from k = 1 to 26 of x to the k power?

ANSWER: 1 + ROOT 2 OVER 2 [CT]

TOSS-UP

12) Energy – *Short Answer* [7] Scientists at Pacific Northwest National Lab have been using electrospray ionization mass spectrometry to study the lipid surface proteins of lung tissues in order to understand various diseases, such as the lack of surfactant production in infants that are born early. What is the term for this disease where the lack of surfactant production causes emphysema in infants born prematurely?

ANSWER: RESPIRATORY DISTRESS SYNDROME [SF]

BONUS

12) Energy – *Short Answer* [6] Researchers at Fermilab are investigating the induced wave broadening by the generalized uncertainty principle. They are using what type of mathematical series in order to approximate and model these waves by combining sine waves of varying amplitudes and frequencies?

ANSWER: FOURIER SERIES (ACCEPT: FOURIER TRANSFORM) [CT]

TOSS-UP

13) Biology – *Multiple Choice* [3] If Jack has hemophilia, an X linked disease, and he marries a woman that is not a carrier and does not have hemophilia, which of the following must be true?

W) All of his daughters are neither affected nor carriers
X) Exactly half of his children are affected
Y) All of his sons are unaffected
Z) Exactly half of his daughters are affected

ANSWER: Y) ALL OF HIS SONS ARE UNAFFECTED [SF]

BONUS

13) Biology – *Short Answer* [4] Identify all of the following three hormones that are steroids: 1) Aldosterone; 2) Cortisol; 3) Thyroxine.

ANSWER: 1 AND 2 [SF]

TOSS-UP

14) Physics – *Short Answer* [3] If the radius of curvature for a concave spherical mirror is 3 meters, what is the focal length of the mirror?

ANSWER: 1.5 [CT]

BONUS

14) Physics – *Short Answer* [5] In units of kilogram meters squared, what is the moment of inertia of a uniform cylinder of radius 30 centimeters and mass 4 kilograms about an axis parallel to its central axis running along its surface?

ANSWER: 0.54 [DK]

TOSS-UP

15) Math – *Short Answer* [6] A complex number z with magnitude 8 is plotted on the complex plane, and the triangle with vertices at 0, z, and z^2 is drawn. What is the maximum area of this triangle?

ANSWER: 256 [CT]

BONUS

15) Math – *Short Answer* [7] A computer starts printing the positive integers in base 16 in ascending order. What is the 2020th digit that the computer prints?

ANSWER: E [CT]

TOSS-UP

16) Earth and Space – *Multiple Choice* [3] Which of the following elements comprises the majority of the core of a 1 solar mass subgiant star?

W) Hydrogen
X) Helium
Y) Carbon
Z) Iron

ANSWER: X) HELIUM [YL]

BONUS

16) Earth and Space – *Short Answer* [3] Identify all of the following three variables that affect open ocean wave height: 1) Ocean depth; 2) Wind fetch; 3) Wind velocity.

ANSWER: 2 AND 3 [YL]

TOSS-UP

17) Chemistry – *Multiple Choice* [2] Which of the following elements has a first ionization energy closest to that of boron?

W) Beryllium
X) Carbon
Y) Magnesium
Z) Silicon

ANSWER: Z) SILICON [CK]

BONUS

17) Chemistry – *Multiple Choice* [4] Hydrobromic acid is added to 1,3-butadiene. Which of the following statements is true regarding the 1,2 adduct formed in this reaction?

W) It is the kinetic product and dominates at low temperatures
X) It is the kinetic product and dominates at high temperatures
Y) It is the thermodynamic product and dominates at low temperatures
Z) It is the thermodynamic product and dominates at high temperatures

ANSWER: W) IT IS THE KINETIC PRODUCT AND DOMINATES AT LOW TEMPERATURES [CT]

TOSS-UP

18) Math – *Short Answer* [5] The line segment connecting the origin and the point (35, 40) is drawn. Including its endpoints, how many lattice points does the segment contain?

ANSWER: 6 [CT]

BONUS

18) Math – *Short Answer* [6] Identify all of the following 3 statements that are true about a positive integer n with k positive factors: 1) if k is divisible by 4, n is a perfect cube, 2) if k is even, n is never a square, 3) if k is an odd prime, n is a perfect power.

ANSWER: 2 AND 3 [CT]

TOSS-UP

19) Physics – *Multiple Choice* [4] A silicon wafer doped with which of the following elements will have holes as the majority carrier?

W) Boron
X) Phosphorus
Y) Germanium
Z) Arsenic

ANSWER: W) BORON [DK]

BONUS

19) Physics – *Short Answer* [7] A hollow sphere with radius 2 meters and mass 3 kg uniformly distributed around its surface starts rolling down a 75 meter long slope from rest with an angle of declination of 30 degrees. At the bottom of the slope and in radians per second, what is the angular speed of the sphere?

ANSWER: 10.5 [CT]

TOSS-UP

20) Earth and Space – *Short Answer* [4] What type of highly variable protostar possesses a stellar cocoon and has not yet reached the Hayashi track?

ANSWER: T-TAURI STAR [SF]

BONUS

20) Earth and Space – *Short Answer* [6] Identify all of the following three statements regarding glacier flow that are true: 1) Polar glaciers flow primarily through basal slip; 2) The bottom of a polar glacier flows faster than the top; 3) The sides of a warm glacier flow faster than the center.

ANSWER: NONE [YL]

TOSS-UP

21) Biology – *Short Answer* [5] What is the term for the major relay center within the brain that lies in the diencephalon?

ANSWER: THALAMUS [SF]

BONUS

21) Biology – *Short Answer* [6] Kaposi's sarcoma is a rare cancer usually only found in people with what immune disorder?

ANSWER: AIDS (DO NOT ACCEPT: HIV) [SF]

TOSS-UP

22) Energy – *Short Answer* [2] Researchers at Lawrence Livermore National Lab have investigated alpha radiation damage in metals used for radiation storage. They observed surficial nanometer-scale bubbles generated from the release of what gas?

ANSWER: HELIUM (ACCEPT: HELIUM-4) [YL]

BONUS

22) Energy – *Short Answer* [3] Scientists at Lawrence Livermore National Lab have been studying photosynthesis and the effects of wildfires on the atmosphere. Identify all of the following three statements that are true about a wildfire in a previously inhabited ecosystem: 1) It demonstrates primary succession; 2) It results in a short term increase in biodiversity; 3) Following the wildfire, the surviving inhabitants are classified as the climax community.

ANSWER: NONE [SF]

TOSS-UP

23) Chemistry – *Short Answer* [5] At a pH of 8, some L-proline molecules have a negative charge on the carboxylic group and a positive charge on the amine group. What is the term for these molecules which have separate oppositely charged groups?

ANSWER: ZWITTERIONS [AS]

BONUS

23) Chemistry – *Short Answer* Consider the following reaction: Borane reacts with ammonia. Answer the following two questions regarding this reaction: 1) What type of covalent bond is formed; 2) What is the molecular geometry around the boron atom before the reaction and after the reaction?

ANSWER: 1) COORDINATE COVALENT BOND (ACCEPT: DATIVE); 2) TRIGONAL PLANAR THEN TETRAHEDRAL [AS]