TOSS-UP

1) Physics [] – *Short Answer* A 3 ohm external resistor is connected to a 14 volt battery with an internal resistance of 4 ohms. In watts, what is the power dissipated by the resistor?

ANSWER: 12 [BZ, Circuits]

BONUS

1) Physics [] – *Short Answer* Identify all of the following three interactions which must conserve strangeness: 1) Strong; 2) Weak; 3) Electromagnetic

ANSWER: 1 AND 3 [BZ, Particles]

TOSS-UP

2) Biology [] – *Short Answer* The majority of glucose-6-phosphate in the body is produced by what enzyme?

ANSWER: HEXOKINASE [SS, Biochem]

BONUS

2) Biology [] – *Multiple Choice* Which of the following organisms has the most stable internal osmolarity?

W) Striped bass
X) Camel
Y) Atlantic lobster
Z) Salmon

ANSWER: Y) ATLANTIC LOBSTER [DJ, OSMOREGULATION]

TOSS-UP

3) Math [3] – *Short Answer* The three real numbers a, b, c form both an arithmetic and a geometric sequence. If a = 28, then what is the value of c?

ANSWER: 28 [GW, Sequences]

BONUS

3) Math [] – *Short Answer* A line with a slope of 2 is graphed on the cartesian plane. If the line is rotated by 45 degrees counter-clockwise about the origin, what is the new slope of the line?

ANSWER: -3 [SS, Coordinates]

TOSS-UP

4) Earth and Space [] – *Multiple Choice* Which of the following is closest to the speed of a gravitational wave in terms of c?

W) 0.4c
X) 0.6c
Y) 0.8c
Z) c

ANSWER: Z) C [SS, Cosmology]

BONUS

4) Earth and Space [] – *Short Answer* Identify all of the following three rocks that have a phaneritic texture. 1) Granite; 2) Basalt; 3) Gabbro

ANSWER: 1 AND 3 [SS, Rocks]

TOSS-UP

5) Chemistry [] – *Short Answer* Elemental boron at standard temperature and pressure forms an icosahedral structure. If each boron-boron bond has an enthalpy of formation of 300 kJ/mol, what is the standard molar enthalpy of formation of icosahedral boron?

ANSWER: 0 [SS, Thermo]

BONUS

5) Chemistry [] – *Multiple Choice* Which of the following best describes the characters of the sigma and sigma-star orbitals in HF?

W) Sigma has F-character, Sigma-star has H-character
X) Sigma has H-character, Sigma-star has F-character
Y) Both sigma and sigma-star have F-character
Z) Both sigma and sigma-star have H-character

ANSWER: W) SIGMA HAS F-CHARACTER, SIGMA-STAR HAS H-CHARACTER [SS, Bonding]

TOSS-UP

6) Energy [] – *Multiple Choice* Researchers at Pacific Northwest National Lab are studying nuclear waste drainage by modeling the behavior as a laminar flow. Which of the following best describes Laminar flow?

W) Low velocity, low Reynolds number
X) Low velocity, high Reynolds number
Y) High velocity, low Reynolds number
Z) High velocity, high Reynolds number

ANSWER: W) LOW VELOCITY AND LOW REYNOLDS NUMBER [DJ, PHYSICS]

BONUS

6) Energy [] – *Multiple Choice* Researchers at Ames National Lab have been employing platinum nanoparticle based catalysts in the recycling of polyolefin plastics. Which of the following combinations of carbon chain lengths and nanoparticle diameters would result in the fastest reaction?

W) Small chain and small nanoparticle
X) Small chain and large nanoparticle
Y) Large chain and small nanoparticle
Z) Large chain and large nanoparticle

ANSWER: Z) LARGE CHAIN LARGE NANOPARTICLE [DJ, Chem]

TOSS-UP

7) Physics [] – *Multiple Choice* Suppose that a region has a coefficient of static friction equal to its coefficient of kinetic friction. Which of the following best describes the shape of a graph of the applied force vs. the frictional force acting on the block?

W) Straight line with nonzero slope
X) Horizontal straight line
Y) Diagonal straight line, followed by horizontal line
Z) Diagonal straight line, followed by vertical line

ANSWER: Y) DIAGONAL STRAIGHT LINE, FOLLOWED BY HORIZONTAL LINE [GW, Forces]

BONUS

7) Physics [] – *Short Answer* On a 2-dimensional space-time diagram, identify all of the following three points that lie inside the light-cone of an observer located at the origin. 1) (1, 0.5); 2) (-1,-2); 3) (2, -1).

ANSWER: 2 ONLY [SS, Relativity]

TOSS-UP

8) Biology [] – *Multiple Choice* Humans and dogs each contain a gene coding for the cytochrome c protein in their genome. However, the sequence of nucleotides in each gene differs. Which of the following best describes the relationship between the cytochrome c genes in humans and dogs?

W) Orthologous
X) Paralagous
Y) Homoplasy
Z) Anaplasy

ANSWER: W) ORTHOLOGOUS [SS]

BONUS

8) Biology [] – *Short Answer* The Ti plasmid is the most commonly used vector for introducing new genes into plant cells. This plasmid originates from what genus of bacteria?

ANSWER: AGROBACTERIUM [SS]

TOSS-UP

9) Math [] – *Short Answer* In radians, what is the value of the inverse cotangent of the square root of 3?

ANSWER: $\pi/6$ [SS]

BONUS

9) Math [] – *Short Answer* A bug is situated at the origin of the Cartesian plane. Each minute, the bug randomly moves 1 unit left, right, up, or down with equal probability. What is the probability that the bug will be exactly one unit away from the origin after 3 minutes?

ANSWER: 9/16 [SS, Probability]

TOSS-UP

10) Earth and Space [] – *Short Answer* Order the following three features in increasing distance from the coastline. 1) Continental shelf; 2) Continental slope; 3) Continental rise.

ANSWER: 1, 2, 3 [SS, Oceanography]

BONUS

10) Earth and Space [] – *Short Answer* A rapidly rotating star of 20 solar masses collapses such that it emits intense radiation and gas along its axis of rotation. What type of stellar explosion, which is the result of an extreme core-collapse scenario, would most likely be the result of this process?

ANSWER: HYPERNOVA [SS]

TOSS-UP

11) Chemistry [] – *Short Answer* When a semiconductor is doped with p-type dopants, it results in the formation of what quasiparticles that represent the absence of electrons?

ANSWER: ELECTRON HOLES (ACCEPT: HOLES) [SS, Matter States]

BONUS

11) Chemistry [] – *Multiple Choice* Which of the following energies, in joules, is closest to the cutoff energy of a gamma ray?

W) 10^{-22}
X) 10^{-18}
Y) 10^{-14}
Z) 10^{-10}

ANSWER: Y) 10^{-14} [SS, Quantum]

TOSS-UP

12) Energy [] – *Short Answer* Researchers at Argonne National Lab are using the Advanced Photon Source to study mutation developments in SARS-CoV-2 to better learn how to target specific immune cells in vaccines that secrete antibodies. In mRNA based vaccines, what lymphocyte is induced, that matures in the bone marrow?

ANSWER: B CELLS [DJ, Bio]

BONUS

12) Energy [] – *Short Answer* Researchers at Argonne National Lab are studying the levels of conductivity during phase changes. The researchers found that under certain conditions, a magnetic state of matter is formed where the electron spin causes an insulating property. What is the term for this magnetic property stemming from an antiparallel electron spin alignment?

ANSWER: ANTIFERROMAGNETISM [DJ, Physics]

TOSS-UP

13) Physics [3] – *Short Answer* Suppose that a spring's displacement is increased by 50%. By what percent is the potential energy stored in the spring increased?

ANSWER: 125 [GW, SHO]

BONUS

13) Physics [] – *Short Answer* Four particles with charges of 2 Coulombs each are placed in a square with a side length of 3 centimeters. To one significant figure, and in scientific notation, what is the force on one of the charges due to the other three charges?

ANSWER: $8*10^{13}$ [SS, Electrostatics]

TOSS-UP

14) Biology [] – *Multiple Choice* Phytochromes are photoreceptors that absorb which of the following colors of light most intensely?

W) Green
X) Blue
Y) Yellow
Z) Red

ANSWER: Z) RED [SS, Plant]

BONUS

14) Biology [] – *Short Answer* Identify all of the following three statements that are true concerning action potentials. 1) They generally occur after a hyperpolarization; 2) Their magnitude is independent of the strength of the stimulus; 3) Immediately after an action potential, the membrane potential hyperpolarizes.

ANSWER: 2 AND 3 [SS, Neuro]

TOSS-UP

15) Math [] – *Multiple Choice* Which of the following primes can NOT be represented as the sum of 2 squares?

W) 197
X) 211
Y) 241
Z) 277

ANSWER: X) 211 [DJ, Primes]

BONUS

15) Math [3] – *Short Answer* Simplify the fraction with numerator 2 + *i* and denominator 3 + *i*.

ANSWER: 7/10 + 1/10*i* [GW, Complex Numbers]

TOSS-UP

16) Earth and Space [] – *Short Answer* Identify all of the following three locations at which the salinity of shallow water increases with increasing depth. 1) Tropics; 2) Poles; 3) Equator

ANSWER: 2 ONLY [SS, Oceanography]

BONUS

16) Earth and Space [] – *Short Answer* Identify all of the following three properties of a rock that metasomatism can change: 1) Foliation; 2) Chemical composition; 3) Water content.

ANSWER: ALL [SS, Rocks]

TOSS-UP

17) Chemistry [] – *Multiple Choice* Which of the following is FALSE regarding the azeotrope formed by a 20% concentration of HCl and an 80% concentration of water?

W) It is a negative azeotrope
X) It is a maximum boiling azeotrope
Y) It has a negative enthalpy of mixing
Z) It has a higher vapor pressure than predicted by Raoult's law

ANSWER: Z) IT HAS A HIGHER VAPOR PRESSURE THAN PREDICTED BY RAOULT'S LAW [SS, Equil]

BONUS

17) Chemistry [] – *Short Answer* A primary alcohol undergoes acid-catalyzed dehydration to form an ether. Identify all of the following three numbers that could be the number of carbon atoms in the major product of the reaction. 1) 5; 2) 6; 3) 7.

ANSWER: 2 ONLY [SS]

TOSS-UP

18) Energy [] – *Short Answer* Researchers at Argonne National Lab have been tracking the production and usage of several fuel additives, in order to find one more environmentally available. What biofuel additive is likely being studied, that is synthesized from corn and cane?

ANSWER: ETHANOL [DJ, Other]

BONUS

18) Energy [] – *Short Answer* Scientists at SLAC national labs have been studying the formation of a state of matter believed to exist at the cores of giant planets. What regime are they studying, which exists between condensed matter and hot plasma?

ANSWER: WARM-DENSE MATTER (ACCEPT: WDM) [SS, ESS]

TOSS-UP

19) Physics [] – *Short Answer* Identify all of the following 3 types of scattering that are elastic: 1) Rayleigh; 2) Raman; 3) Compton.

ANSWER: 1 ONLY [SS]

BONUS

19) Physics [] – *Short Answer* A rocket starts from rest and expels exhaust at a velocity of 2000 meters per second. The rocket loses 1% of its mass in the first second of launching. In meters per second squared, what is the rocket's acceleration at the instance it starts expelling exhaust?

ANSWER: 20 [SS]

TOSS-UP

20) Biology [] – *Short Answer* Identify all of the following 3 animals that have an alimentary canal: 1) Earthworm; 2) Cockroach; 3) Flatworm.

ANSWER: 1, 2 [DJ, DIGESTIVE]

BONUS

20) Biology [] – *Short Answer* In plant cells, actin-myosin interactions and sol-gel transformations induce a circular flow of cytosol within cells. What name is given to this movement?

ANSWER: CYTOPLASMIC STREAMING [SS]

TOSS-UP

21) Math [4] – *Multiple Choice* What is the maximum number of negative roots that the polynomial $x^{10} – 3x^9 + x^6 – x^3 + x$ can have, according to Descartes' rule of signs?

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

ANSWER: Z) 1 [GW, Polynomials]

BONUS

21) Math [] – *Multiple Choice* How many 3 digit positive integers have their middle digit as their uniquely largest digit?

W) 180
X) 200
Y) 220
Z) 240

ANSWER: Z) 240 [LY, DISCRETE]

TOSS-UP

22) Earth and Space [] – *Multiple Choice* The presence of molecular clouds in the Milky Way can be identified most easily by spectral line emission from which of the following compounds?

W) Carbon dioxide
X) Methane
Y) Carbon monoxide
Z) Hydrogen

ANSWER: Y) CARBON MONOXIDE [SS]

BONUS

22) Earth and Space [] – *Short Answer* What is the name of the location in the HR-diagram at which protostars lose their cocoons and become detectable at visible wavelengths?

ANSWER: BIRTH LINE [SS]

TOSS-UP

23) Chemistry [] – *Short Answer* Order the following three compounds by increasing boiling point: 1) Trimethylamine; 2) Diethylether; 3) Ethanol.

ANSWER: 1, 2, 3 [SS]

BONUS

23) Chemistry [] – *Short Answer* A gas at room temperature, with a molar mass of M, effuses from a small hole in a container into a balloon. Assuming the balloon is massless, after 1 second, the weight of the balloon is proportional to what power of M?

ANSWER: 0.5 (ACCEPT: 1/2) [SS, Matter States]