TOSS-UP

1) Physics – *Multiple Choice* A test charge is placed perpendicular to a dipole at a distance d from the dipole's midpoint. Assuming that the distance between the dipoles is negligible compared to d, the electric field produced by the dipole on the test charge is proportional to what power of d? [SA]

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

ANSWER: Y) -3

BONUS

1) Physics – *Short Answer* A uniformly charged rod of length 2 meters and linear charge density of 3 nanocoulombs per meter is bent to form a semicircle. What is the magnitude of the electric field at the center of the semicircle in Newtons per Coulomb? [SA]

ANSWER: 27π

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TOSS-UP

2) Biology – *Short Answer* What tough polymer is a major component of the walls of plant spores and pollen and is one of the most chemical-resistant biopolymers known?

ANSWER: SPOROPOLLENIN

BONUS

2) Biology – *Short Answer* What gelatinous region separates the two layers of cells of a sponge?

ANSWER: MESOHYL (ACCEPT: MESENCHYME, MESOGLEA; DO NOT ACCEPT: MESOPHYLL)

TOSS-UP

3) Earth and Space – *Multiple Choice*   Which of the following statements is NOT true regarding the Saros cycle, which may be used to predict eclipses? [JI]

W) The Sun will return to the same position relative to the nodes of the Moon's orbit after a Saros cycle
X) After one Saros cycle the pattern of eclipses repeats
Y) One Saros cycle after an eclipse, an eclipse with similar geometry will occur in the same place on Earth
Z) The Moon will be in the same phase it originally was after one Saros cycle

ANSWER: Y) ONE SAROS CYCLE AFTER AN ECLIPSE, AN ECLIPSE WITH SIMILAR GEOMETRY WILL OCCUR IN THE SAME PLACE ON EARTH

BONUS

3) Earth and Space – *Short Answer* The initiating step of the proton-proton chain that occurs within the sun is the fusion of two protons. Name all THREE of the products of this initial step. [CJ]

ANSWER: NEUTRINO, POSITRON, AND DEUTERIUM (ACCEPT: HYDROGEN-2 FOR DEUTERIUM)

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TOSS-UP

4) Math – *Multiple Choice*   Given that there are 8 elements in a set, how many subsets contain at least two elements? [SA]

W) 247
X) 248
Y) 249
Z) 250

ANSWER: W) 247

BONUS

4) Math – *Short Answer*   The number m is a natural number between 6 and 100, inclusive. Find the number of possible values of m such that $x^2 - x - m = 0$ has integral roots. [SA]

ANSWER: 8

TOSS-UP

5) Chemistry – *Multiple Choice*   The heat of vaporization of an unknown compound is 60 kilojoules per mole. Given that one mole of the sample is vaporized reversibly at its normal boiling point of 30 degrees Celsius, which of the following is closest to the entropy change of the process in joules per degree Celsius? [CK]

W) 200
X) 400
Y) 2,000
Z) 4,000

ANSWER: W) 200

BONUS

5) Chemistry – *Multiple Choice*   Which of the following is nearest to the enthalpy of vaporization, in joules per mole, of a liquid with a vapor pressure of 0.272 atmospheres at 200 kelvin and a vapor pressure of 0.1 atmospheres at 100 kelvin? [JI]

W) 850
X) 1650
Y) 2500
Z) 4000

ANSWER: X) 1650

TOSS-UP

6) Energy – *Multiple Choice* Scientists at Ames National Lab developed a new method to examine superconducting materials called a nitrogen vacancy magnetoscope. This technique allows for the more accurate measure of what property, which is the distance that a magnetic field can enter into the superconductor? [JI]

W) Meissner distance
X) London penetration depth
Y) Critical depth
Z) Magnetic flux capacity

ANSWER: X) LONDON PENETRATION DEPTH

BONUS

6) Energy – *Short Answer* Researchers at Ames National Lab are studying ways to increase the durability of samarium cobalt magnets, which are very powerful and heat resistant, but weak to physical strain. Cobalt is one of only a few ferromagnetic elements. Order the following three ferromagnetic materials by INCREASING Curie temperature: 1) Iron 2) Cobalt 3) Nickel [JI]

ANSWER: 3, 1, 2 (NICKEL, IRON, COBALT)

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TOSS-UP

7) Physics – *Short Answer* According to the Born interpretation, the probability of finding a particle at a given location and time is proportional to the square of the value of what quantity? [SA]

ANSWER: WAVEFUNCTION

BONUS

7) Physics – *Multiple Choice*   Which of the following is incorrect about relativity? [SA]

W) The length of an object in a moving frame is contracted in the direction of motion.
X) The effective mass of an object can be found by dividing its rest mass by the Lorentz factor.
Y) In Minkowski space, the spacetime interval between two events is independent of the inertial frame of reference.
Z) Time dilation increases with the strength of the gravitational field.

ANSWER: X) THE EFFECTIVE MASS OF AN OBJECT CAN BE FOUND BY DIVIDING ITS REST MASS BY THE LORENTZ FACTOR.

8) Biology – *Multiple Choice* Which of the following classes of animal viruses is responsible for the mosquito-transmitted Zika Fever, Dengue Fever, and West Nile Fever? [CJ]

W) Adenovirus
X) Rhabdovirus
Y) Reovirus
Z) Flavivirus

ANSWER: Z) FLAVIVIRUS

BONUS

8) Biology – *Short Answer* What term collectively describes the morphological changes that a plant undergoes when it grows in darkness, such as the growth of tall, pale stems and non expanded leaves in a potato that has not been exposed to light?

ANSWER: ETIOLATION

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TOSS-UP

9) Earth and Space – *Multiple Choice* Which of the following metamorphic processes causes the grains to become longer in one direction and shorter in another due to the uneven application of pressure on a wet rock? [JI]

W) Plastic deformation
X) Neocrystallization
Y) Phase change
Z) Pressure Solution

ANSWER: Z) PRESSURE SOLUTION

BONUS

9) Earth and Space – *Short Answer* Kerogen, a form of solid, insoluble organic material, makes up between 15 to 30 percent of what specific fine-grained sedimentary rock? [JI]
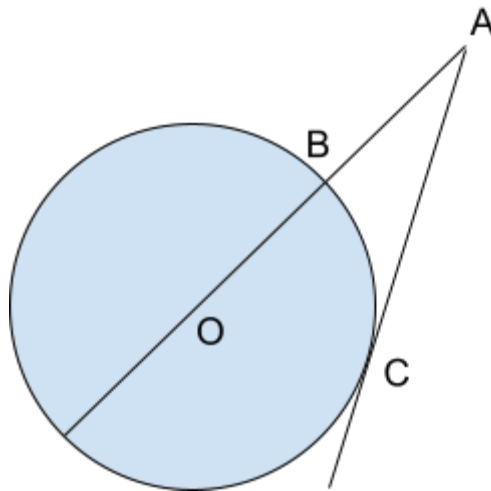
ANSWER: OIL SHALE (DO NOT ACCEPT: SHALE)

10) Math – *Multiple Choice*   An equilateral triangle is inscribed inside a circle. If the side length of the triangle is 3, which of the following is the radius of the circle? [SA]

W) $\sqrt{3}$
X) $2\sqrt{3}$
Y) $3\sqrt{3}$
Z) $4\sqrt{3}$

ANSWER: W) $\sqrt{3}$

BONUS

10) Math – *Short Answer* Answer the following question using the diagram shown. Circle O has a radius of 15 units and line segment AC measures 20 units. What is the length of line segment AB? [SA]

ANSWER: 10 (UNITS)

TOSS-UP

11) Chemistry – *Multiple Choice* Which of the following will occur if a small amount of sodium chloride is added to a saturated solution of silver chloride? [JI]

W) A white precipitate will form
X) A colored precipitate will form
Y) A gas will be evolved
Z) No precipitate or gas is formed

ANSWER: W) A WHITE PRECIPITATE WILL FORM

BONUS

11) Chemistry – *Multiple Choice* Which of the following gases would experience the largest amount of cooling from the Joule-Thomson effect when allowed to expand? [JI]

W) Hydrogen
X) Hydrogen sulfide
Y) Methane
Z) Sulfur dioxide

ANSWER: Z) SULFUR DIOXIDE

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TOSS-UP

12) Energy – *Short Answer* Researchers at the National Institute of Standards and Technology have proposed an experiment that will use a billion tiny pendulums to detect what type of substance, which does not interact with the electromagnetic force? [JI]

ANSWER: DARK MATTER (DO NOT ACCEPT: DARK ENERGY)

BONUS

12) Energy – *Short Answer* Scientists at SLAC National Accelerator Lab are studying the surprising efficiencies of certain types of solar cells. They found that polarons, brief distortions of the substance's crystal lattice, may be responsible for these high efficiencies. The polarons are likely able to form because the cells are made from materials with what type of structure, which allows for high mobility of electrons and holes? [JI]

ANSWER: PEROVSKITE

13) Physics – *Multiple Choice* Gluons are the carrier particles of the strong force. How many types of gluons exist? [SA]

W) 1
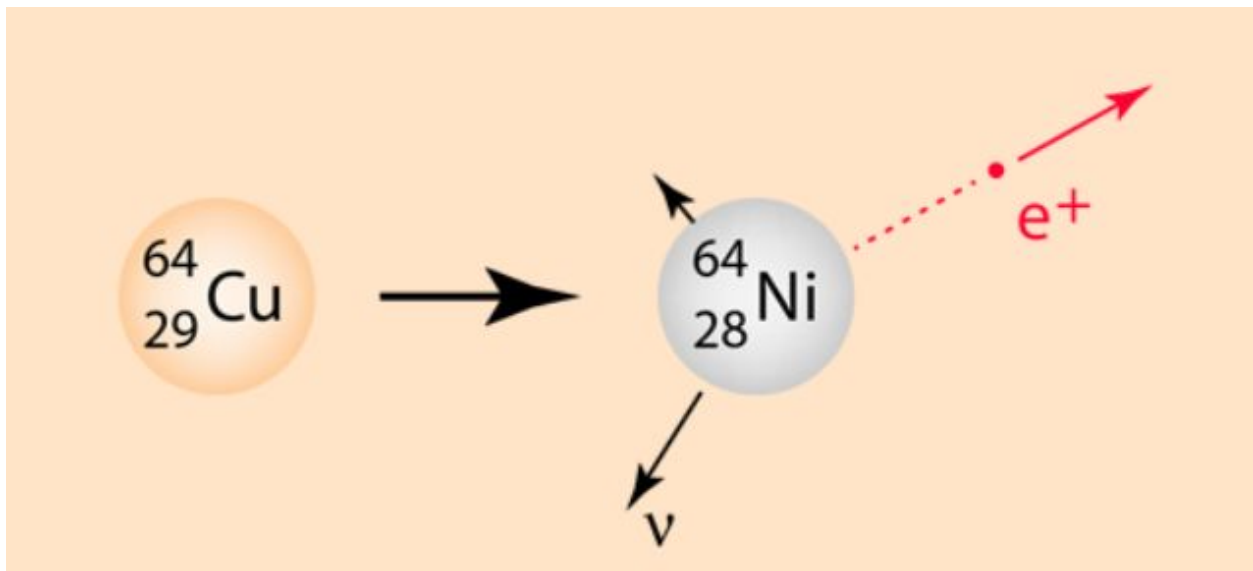X) 3
Y) 6
Z) 8

ANSWER: Z) 8

BONUS

13) Physics – *Short Answer* Answer the following two questions about the process shown in the diagram. [SA]
   1) What are the names of the particles labeled Nu and E+, respectively?
   2) Shown in the diagram is beta-plus decay. In this type of decay, an up quark decays into a down quark and what other particle, which mediates the weak force and subsequently decays into E+ and Nu?

ANSWER: 1) (ELECTRON) NEUTRINO AND POSITRON 2) W+ BOSON

14) Biology – *Multiple Choice* Secondary oocytes are formed from the developmental arrest of primary oocytes at what stage of meiosis? [CJ]

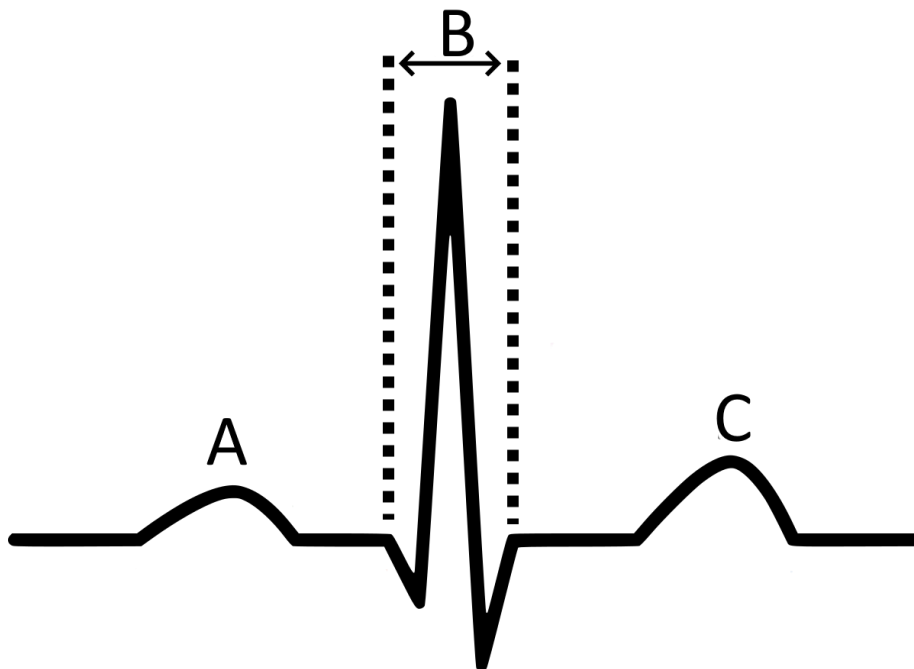W) Prophase 1
X) Telophase 1
Y) Metaphase 2
Z) Anaphase 2

ANSWER: Y) METAPHASE 2

BONUS

14) Biology – *Short Answer*   Shown in the diagram is a standard electrocardiogram of a heart in normal sinus rhythm. Answer the following three questions regarding the diagram.
   1) What is the name of the interval represented by B?
   2) The horizontal line between region A and B represents the delaying of a cardiac action potential at what node of the heart?
   3) The wave labeled C represents the repolarization of which chambers of the heart?

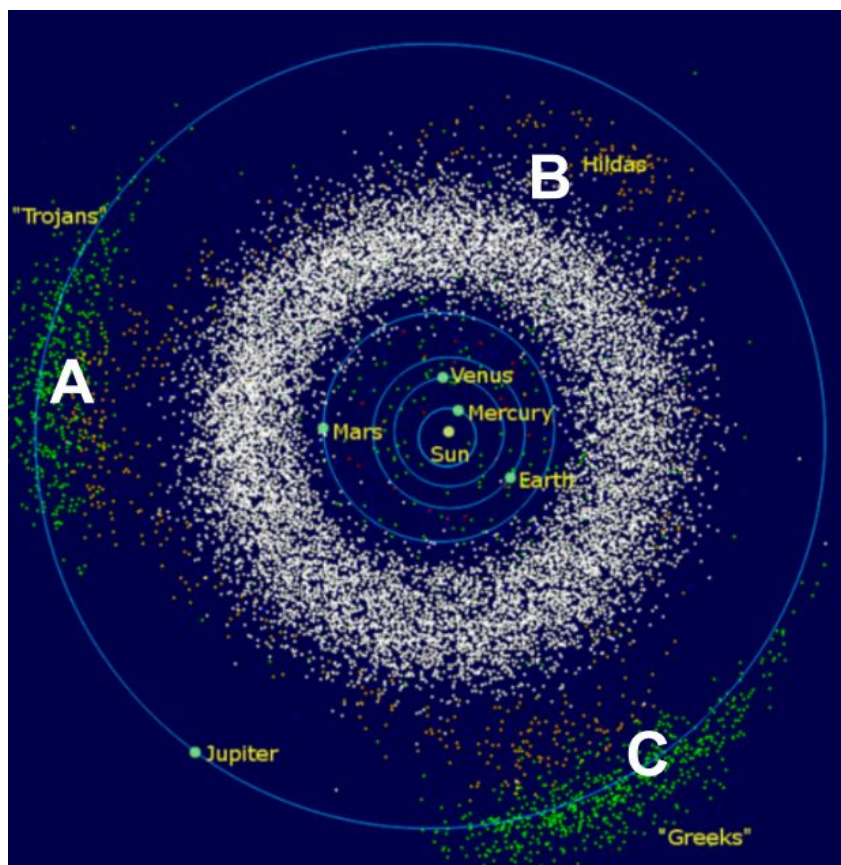ANSWER: QRS INTERVAL, ATRIOVENTRICULAR NODE, VENTRICLES (ACCEPT LEFT AND RIGHT VENTRICLE)

15) Earth and Space – *Short Answer* The Sunyaev-Zeldovich effect is caused by inverse Compton scattering and distorts what radiation left over from the Big Bang? [JI]

ANSWER: COSMIC MICROWAVE BACKGROUND RADIATION (ACCEPT: CMB, CMBR)

BONUS

15) Earth and Space – *Short Answer* Answer the following TWO questions about the depicted diagram. Assume that Jupiter orbits counterclockwise. [JI]
   1) Each of the regions labelled A, B, and C are in one of the Lagrange points of Jupiter, match each region to the appropriate Lagrange point
   2) The objects in regions A and C are analogous to what faintly luminous clouds of dust that are at the corresponding Lagrange points of the Earth Moon system?

ANSWER: 1) A - L5, B - L3, C - L4, 2) KORDYLEWSKI CLOUDS

TOSS-UP

16) Math – *Multiple Choice*   Given that the sum of the first three terms of a geometric sequence is 10 and the common ratio is 5, what is the sum of the 4th, 5th, and 6th terms? [SA]

W) 250
X) 750
Y) 1250
Z) 1750

ANSWER: Y) 1250

BONUS

16) Math – *Short Answer*   Cubes of side lengths 5,4,3,2,1 are placed on top of each other in that order from bottom to top. What is the total surface area of this solid? [SA]

ANSWER: 270

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TOSS-UP

17) Chemistry – *Short Answer*   How many vibrational degrees of freedom does carbon dioxide have? [SA]

ANSWER: 4

BONUS

17) Chemistry – *Short Answer* Denticity is the number of donor groups from a ligand that bind to the central atom. Order the following three ligands in order of INCREASING denticity 1) EDTA 2) Ammonia 3) Ethylenediamine [JI]

ANSWER: 2, 3, 1 (ACCEPT: AMMONIA, ETHYLENEDIAMINE, EDTA)

TOSS-UP

18) Energy – *Short Answer* Researches at LIGO and Virgo gravitational wave observatories observed a merger between two black holes with masses of about 66 and 85 solar masses. It was previously thought that black holes could not be formed in the range of about 50 to 120 solar masses because of what phenomenon in the core of large stars, in which an electron and a positron are produced from a high energy photon? [JI]

ANSWER: PAIR PRODUCTION

BONUS

18) Energy – *Short Answer* A farmer near UW Madison cut their corn maze into the shape of a tardigrade, a peculiar animal that is able to survive even in very extreme conditions. Select each of the following three types of cryptobiosis which a tardigrade is able to undergo: 1) Anhydrobiosis; 2) Anoxybiosis; 3) Cryobiosis. [JI]

ANSWER: ALL (ACCEPT: 1, 2, 3; ANHYDROBIOSIS, ANOXYBIOSIS, CRYOBIOSIS)

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TOSS-UP

19) Physics – *Multiple Choice* Which of the following is incorrect about torque? [SA]

W) Torque and energy have the same dimensions.
X) Torque experienced by a dipole in an electric field is maximized at a 90 degree orientation with respect to the electric field.
Y) The power of an engine can be calculated by multiplying its torque and angular acceleration
Z) Torque can be found by differentiating angular momentum with respect to time.

ANSWER: Y) THE POWER OF AN ENGINE CAN BE CALCULATED BY MULTIPLYING ITS TORQUE AND ANGULAR ACCELERATION.

BONUS

19) Physics – *Short Answer* A 2 meter long rod rotating about its center has an angular velocity of 20 radians per second and an angular momentum of 120 kilogram meters squared per second. Find its mass in kilograms. [SA]

ANSWER: 18 (KILOGRAMS)

TOSS-UP

20) Biology – *Multiple Choice* Which of the following kinds of muscle fibers has the lowest myoglobin content?

W) Slow oxidative
X) Slow glycolytic
Y) Fast oxidative
Z) Fast glycolytic

ANSWER: Z) FAST GLYCOLYTIC

BONUS

20) Biology – *Multiple Choice* Acetylation of histones is a common epigenetic mechanism in eukaryotes that results in an increase in transcription of the chromosomal region that has been acetylated by reducing the electrostatic interactions between histone tails and DNA. The acetylation of which of the following amino acid residues causes this response?

W) Proline
X) Isoleucine
Y) Lysine
Z) Aspartic Acid

ANSWER: Y) LYSINE

21) Earth and Space – *Multiple Choice*   Which of the following factors of Earth's movements is not taken into account when considering Milankovitch cycles to describe climate change? [JI]

W) Axial Tilt
X) Orbital eccentricity
Y) Precession
Z) Orbital period

ANSWER: Z) ORBITAL PERIOD

BONUS

21) Earth and Space – *Multiple Choice*   The Atlantic Meridional Overturning Circulation is a circulation involving both warm, shallow currents from the equatorial Atlantic and cold, deep currents from the northern Atlantic. Which of the following best describes how global warming has led to a weakening of the AMOC? [JI]

W) The melting of ice caps near the North pole cools the water temperature in the North Atlantic which strengthens the deep sea currents and destabilizes the circulation
X) The acidification of ocean water raises the density of the ocean water which interferes with density dependent currents.
Y) The melting of glacial ice in Greenland creates a low density cap which prevents down-welling of surface currents to join the deep sea currents
Z) The increase in global ocean temperatures weakens the deep sea currents and strengthens surface currents which destabilizes the circulation.

ANSWER: Y) THE MELTING OF GLACIAL ICE IN GREENLAND CREATES A LOW DENSITY CAP WHICH PREVENTS THE DOWN-WELLING OF SURFACE CURRENTS TO JOIN THE DEEP SEA CURRENTS

TOSS-UP

22) Math – *Multiple Choice*   What is the surface area of a cone with radius 3 and height 4? [SA]

W) 22π
X) 23π
Y) 24π
Z) 25π

ANSWER: Y) 24π

BONUS

22) Math – *Short Answer*   a, b, and c are 3 nonnegative integers such that a + b + c = 11. What is the total number of solutions for this equation?
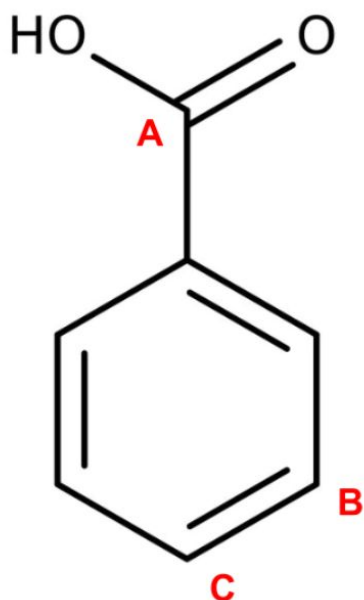
ANSWER: 78

23) Chemistry – *Short Answer* Rank the following three gases in terms of INCREASING solubility in water: 1) Oxygen; 2) Carbon dioxide; 3) Ammonia. [CK]

ANSWER: 1, 2, 3 (OXYGEN, CARBON DIOXIDE, AMMONIA)

BONUS

23) Chemistry – *Short Answer* Answer the following two questions about the benzoic acid molecule, which is depicted in the provided image. [JI]
1) What functional group is attached to the phenyl group in this compound?
2) Order the carbons labeled A, B, and C in order of decreasing electrophilicity.

ANSWER: 1) CARBOXYLIC ACID; 2) A, C, B (IN THAT ORDER)