TOSS-UP

1) Physics – *Short Answer* What dimensionless constant, equivalent to the product of the speed of light in a vacuum and the vacuum permeability divided by twice the von Klitzing constant, quantifies the electromagnetic force between elementary particles?

ANSWER: FINE-STRUCTURE CONSTANT (ACCEPT: FINE-STRUCTURE, ACCEPT: ALPHA)

BONUS

1) Physics – *Multiple Choice* Which of the following are valid units of the Boltzmann constant?

W) Mole per Kelvin
X) Electronvolt per Kelvin
Y) Kelvin per Coulomb
Z) Joules per Mole

ANSWER: X) ELECTRONVOLT PER KELVIN

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TOSS-UP

2) Energy – *Short Answer* Scientists at Oak Ridge National Laboratory are developing synthetic trees, which could be used as passive water pumps. These trees utilize what process that occurs in the leaves of plants, causing water to travel upwards?

ANSWER: TRANSPIRATION

BONUS

2) Energy – *Short Answer* Scientists at SLAC National Accelerator Laboratory are studying how uranium reacts after being leaked into the environment. What oxidation state is uranium in when it is originally leaked into the environment, which is also the oxidation state of uranyl, a stable uranium compound?

ANSWER: +6 (ACCEPT: URANIUM +6)
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TOSS-UP

3) Chemistry – *Multiple Choice* Which of the following acids is strongest?

W) HBr
X) HBrO
Y) $HBrO_2$
Z) $HBrO_3$

ANSWER: W) HBr

BONUS

3) Chemistry – *Short Answer* What is the electron pair geometry of the central atom in XeF_2?

ANSWER: TRIGONAL BIPYRAMIDAL

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TOSS-UP

4) Biology - *Short Answer* Which bacteria was used in the experiment involving transformation that led to the discovery that DNA is the macromolecule that makes up genetic material?

ANSWER: STREPTOCOCCUS PNEUMONIAE (ACCEPT: STREPTOCOCCUS)

BONUS

4) Biology - *Short Answer* Name all of the following 3 plants that are dicots: 1) Oak trees; 2) Soybean; 3) Wheat.

ANSWER: 1 AND 2
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TOSS-UP

5) Math – *Short Answer* What is the least possible positive solution, in radians, to the equation: $sin(2x) = 2\ sin(x)$?

ANSWER: π

BONUS

5) Math – *Short Answer* What term describes a point on the surface of the graph of a function where the slopes in orthogonal directions are all zero, but which is not a local extremum of the function?

ANSWER: SADDLE POINT

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TOSS-UP

6) Earth and Space - *Multiple Choice* Which of the following statements about ocean waves is correct?

W) Ocean waves display longitudinal motion
X) Ocean waves consist of the movement of water brought about by thermohaline circulation
Y) Unusually small ocean waves formed through various weather phenomena are known as swells
Z) Ocean waves are orbital and involve the transfer of energy, not water

ANSWER: Z) OCEAN WAVES ARE ORBITAL AND INVOLVE TRANSFER OF ENERGY, NOT WATER

BONUS

6) Earth and Space - *Short Answer* As waves reach the shore, they will change height due to decreasing water depth. What is the name for this process, that causes waves to "break" as surf?

ANSWER: SHOALING
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TOSS-UP

7) Energy – *Multiple Choice* Scientists at Pacific Northwest National Laboratory have utilized the cyanobacterium *Cyanothece* for energy production. What has this cyanobacterium been shown to be the first to do, that makes it so useful for energy production?

W) It can grow at rates unparalleled to any other cyanobacterium
X) It can release methane while performing photosynthesis
Y) It can release natural gas while performing photosynthesis
Z) It can produce oxygen and hydrogen simultaneously

ANSWER: Z) IT CAN PRODUCE OXYGEN AND HYDROGEN SIMULTANEOUSLY

BONUS

7) Energy – *Multiple Choice* Recent research at Lawrence Berkeley National Laboratory has been focused on measuring the weight of superheavy elements, known as transactinides. The process for discovering new transactinides over the past couple decades has been to fuse together actinide isotopes. Which of the following is a common isotope of an actinide?

W) Neodymium-265
X) Mendelevium-280
Y) Ytterbium-235
Z) Thorium-232

ANSWER: Z) THORIUM-232

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TOSS-UP

8) Biology - *Short Answer* What is the only bone that does not articulate with any other bone?

ANSWER: HYOID BONE

BONUS

8) Biology - *Multiple Choice* Which fontanelle closes around 2 months after birth?

W) Anterior
X) Mastoid
Y) Posterior
Z) Sphenoidal

ANSWER: Y) POSTERIOR

TOSS-UP
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9) Physics – *Multiple Choice* Which of the following best explains why neutron poisons are held in position above the nuclear reaction by electromagnets?

W) In case of traditional safety mechanisms failing due to complete loss of electricity, the neutron poisons would automatically drop into the reaction and avert a meltdown
X) The magnetic field generated by the electromagnet leads to convection of the fast neutrons produced by nuclear chain reactions
Y) In case of tectonic activity leading to a subcritical state, current could be increasing to move the neutron poisons away from the reaction
Z) Moving the neutron poisons downward is easier using an electromagnet than by using a mechanical apparatus

ANSWER: W) IN CASE OF TRADITIONAL SAFETY MECHANISMS FAILING DUE TO COMPLETE LOSS OF ELECTRICITY, THE NEUTRON POISONS WOULD AUTOMATICALLY DROP INTO THE REACTION AND AVERT A MELTDOWN

BONUS

9) Physics – *Short Answer* If an observer is traveling directly toward the Sun with speed $c/2$, by what factor will the frequency of light observed be greater than the frequency of light emitted?

ANSWER: $\sqrt{3}$

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TOSS-UP

10) Chemistry – *Short Answer* What is the chemical formula of potassium arsenate?

ANSWER: K_3AsO_4

BONUS

10) Chemistry – *Multiple Choice* Which of the following compounds is the least stable?

W) Vanadium(I) nitrite
X) Vanadium(II) sulfate
Y) Vanadium(III) phosphate
Z) Vanadium(IV) oxide

ANSWER: W) VANADIUM(I) NITRITE
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TOSS-UP

11) Math – *Short Answer* What is the sum of the number of vertices, edges, and faces of a regular icosahedron?

ANSWER: 62

BONUS

11) Math – *Short Answer* A regular tetrahedron has a side length of 8. What is the radius of the inscribed sphere of the tetrahedron?

ANSWER: $2\sqrt{6}/3$

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TOSS-UP

12) Earth and Space - *Multiple Choice* Which of the following is not a type of galaxy that exhibits a high rate of star formation?

W) Wolf-Rayet Galaxy
X) Blue Compact Galaxy
Y) Luminous Infrared Galaxy
Z) Divergent Geocentric Galaxy

ANSWER: Z) DIVERGENT GEOCENTRIC GALAXY

BONUS

12) Earth and Space - *Short Answer* What is the term for the property where different angles of polarized light cause a mineral to appear different colors?

ANSWER: PLEOCHROISM (ACCEPT: ANISOTROPISM)
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TOSS-UP

13) Biology - *Short Answer* It is believed that secondary endosymbiosis occurred when red or green algae was engulfed by heterotrophic eukaryotes. What is the name given to the small vestigial nucleus found in some plastids that provides evidence for this theory?

ANSWER: NUCLEOMORPH

BONUS

13) Biology - *Multiple Choice* The CRISPR Cas9 system utilizes the natural immune system of bacteria against bacteriophages. Which of the following parts of the bacterial genome is made up of parts of the DNA of bacteriophages that tried to infect the cell in the past?

W) Leader
X) Spacer
Y) Repeat
Z) Cas9 gene

ANSWER: X) SPACER

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TOSS-UP

14) Energy – *Short Answer* Recent experiments and theoretical calculations at SLAC National Accelerator Laboratory mimic supernovas. What is the term for the stream of high-energy particles that move at close to the speed of light, caused by the shock of a supernova?

ANSWER: COSMIC RAY

BONUS

14) Energy – *Multiple Choice* Scientists postulate that particles are accelerated to relativistic speeds by supernovas because of which of the following?

W) Strong Electric Fields
X) Strong Magnetic Fields
Y) Strong Gravitational Fields
Z) Electric, Magnetic, and Gravitational Fields all have roughly equal contributions

ANSWER: X) STRONG MAGNETIC FIELDS
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TOSS-UP

15) Physics – *Multiple Choice* Which of the following provides an accurate reason and explanation for why the top quark was the last quark observed experimentally?

W) The top quark has a relatively high mass, so it can be easily confused with larger particles
X) The top quark has a relatively high degree of instability, so it is more difficult to observe with accuracy
Y) The top quark has a relatively high mass, so it requires more energy to produce
Z) The top quark has a relatively high degree of instability, so it can cause explosive reactions at accelerators

ANSWER: Y) THE TOP QUARK HAS A RELATIVELY HIGH MASS, SO IT REQUIRED MORE ENERGY TO PRODUCE

BONUS

15) Physics – *Short Answer* What principle best explains the Venturi effect, in which the pressure is lower in water flowing through a constricted portion of a pipe?

ANSWER: BERNOULLI'S PRINCIPLE

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TOSS-UP

16) Earth and Space - *Multiple Choice* Cinder cones, a type of structure typically formed through a single large eruption, are made primarily of what rock?

W) Pumice
X) Scoria
Y) Obsidian
Z) Basalt

ANSWER: X) SCORIA

BONUS

16) Earth and Space - *Short Answer* List all of the following four statements that are true regarding stratovolcanoes: 1) The formation of stratovolcanoes is associated with more viscous lavas; 2) Generally steep structures, stratovolcanoes exhibit more gently sloping sides as you move farther from the peak; 3) Lahars cannot occur on stratovolcanoes. 4) Stratovolcanoes are made of cinders and ash cemented with lava flows.

ANSWER: 1, 2, AND 4
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TOSS-UP

17) Chemistry – *Multiple Choice* Which of the following compounds is the least soluble in water at 25 degrees celsius?

W) Aluminum Sulfate
X) Silver Iodide
Y) Lead Nitrate
Z) Calcium Acetate

ANSWER: X) SILVER IODIDE

BONUS

17) Chemistry – *Short Answer* What two functional groups are the products of alkyl radical disproportionation?

ANSWER: ALKANE AND ALKENE

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TOSS-UP

18) Math – *Short Answer* How many ways can Alice, Bob, Carol, Dante, and Evan sit around a circular table if Alice and Evan demand to sit next to each other?

ANSWER: 12

BONUS

18) Math – *Multiple Choice* A right circular cone is inscribed in another right circular cone such that the vertex of one cone lies on the base of the other. If the volume of the inscribed cone is maximized, which of the following would be the ratio of the volume of the inscribed cone to that of the circumscribed cone?

W) 1 : 8
X) 4 : 27
Y) 1 : 4
Z) 4 : 9

ANSWER: X) 4 : 27
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TOSS-UP

19) Chemistry – *Multiple Choice* Which of the following is not a free radical?

W) Hydroxyl
X) Triplet carbene
Y) Superoxide
Z) Hydrazine

ANSWER: Z) HYDRAZINE

BONUS

19) Chemistry – *Multiple Choice* Which of the following is not a type of step in a radical chain reaction?

W) Termination
X) Initiation
Y) Generation
Z) Propagation

ANSWER: Y) GENERATION

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TOSS-UP

20) Physics – *Short Answer* All physical systems have a nonzero minimum energy, even vacuums. What is the term for this energy?

ANSWER: ZERO-POINT ENERGY

BONUS

20) Physics – *Multiple Choice* Which of the following can be used to directly derive the ideal gas law?

W) Equipartition Theorem
X) Virial Theorem
Y) Boltzmann Theorem
Z) Graham's Law of Effusion

ANSWER: W) EQUIPARTITION THEOREM
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TOSS-UP

21) Earth and Space - *Short Answer* Order the following three galaxy types by increasing typical age: 1) Round elliptical galaxy; 2) Flat spiral galaxy; 3) Flat elliptical galaxy.

ANSWER: 2, 3, 1

BONUS

21) Earth and Space - *Short Answer* When the Sun and Moon are on the same side of Earth, they are said to be in conjunction. When they are on opposite sides, they are said to be in opposition. Give the term for the general straight line configuration of three or more celestial bodies.

ANSWER: SYZYGY

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TOSS-UP

22) Biology - *Short Answer* Mathew Meselson and Franklin Stahl demonstrated that DNA was copied semi-conservatively in their namesake experiment. Isotopes of what element were used in this experiment to differentiate between parent and copied DNA?

ANSWER: NITROGEN

BONUS

22) Biology - *Multiple Choice* What type of cartilage is found in the fetal skeleton?

W) Mesenchyme
X) Elastic
Y) Reticular
Z) Hyaline

ANSWER: Z) HYALINE
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TOSS-UP

23) Math – *Short Answer* What is the area of the region bounded by the x axis and the curve $y = \sqrt{9 - x^2}$[the square root of the quantity 9 minus x squared]?

ANSWER: $\frac{9\pi}{2}$ (ACCEPT: 4.5π)

BONUS

23) Math – *Short Answer* A particle moves along the curve defined by $s(t) = sin(t)$ for time $t > 0$. What is the jerk of the particle at time t = π/6?

ANSWER: $-\frac{\sqrt{3}}{2}$