TOSS-UP

1) Chemistry – *Multiple Choice*   Steven plots temperature versus time as he heats water while adding energy at a constant rate. Which of the following statements best explains why the heating curve reaches a plateau at 100 degrees Celsius?

W) Energy is required to decrease the entropy *[EN-troh-pee]* of the water
X) Energy is required to decrease the enthalpy *[EN-thul-pee]* of the water
Y) Energy is required to break the hydrogen-oxygen bonds in water
Z) Energy is required to break the hydrogen bonds between water molecules

ANSWER: Z) ENERGY IS REQUIRED TO BREAK THE HYDROGEN BONDS BETWEEN WATER MOLECULES

BONUS

1) Chemistry – *Short Answer*   How many distinct carbon signals are in the 13C NMR spectrum for ethyl isobutyl ether, also known as 1-ethoxy-2-methylpropane?

ANSWER: 5

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TOSS-UP

2) Biology – *Short Answer*   How many chambers are in a fish heart?

ANSWER: 2

BONUS

2) Biology – *Short Answer*   Identify all of the following three types of plants for which the gametophyte *[gah-MEET-oh-fite]* is the dominant stage of the plant life cycle: 1) Mosses; 2) Ferns; 3) Gymnosperms *[JIM-no-sperms]*.

ANSWER: 1

TOSS-UP

3) Physics – *Short Answer*   Electric eels can generate a 500-volt potential difference that they use to stun their prey. If the potential difference is generated by a network of cells all connected in series, each of which can generate a 100-millivolt potential difference, how many cells are required to generate the total voltage?

ANSWER: 5000

BONUS

3) Physics – *Short Answer*   An ideal gas expands from 5 liters to 10 liters against a constant pressure of 2.5 bars. In joules, how much work is done by the gas during the expansion?

ANSWER: 1,250

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TOSS-UP

4) Energy – *Short Answer*   Scientists at Fermilab participate in the NOvA *[nova]* collaboration to understand the physics of neutrinos *[new-TREE-noze]*. One of their many projects is to understand the differences between the three flavor states of neutrinos. What are these three types?

ANSWER: ELECTRON, MUON, AND TAU (ACCEPT: ELECTON, MUON, AND TAUON)

BONUS

4) Energy – *Short Answer*   Argonne National Lab researchers are researching materials capable of processing information using multivalued logic. One class of materials of interest are perovskite *[purr-OFF-skite]* films that change their electrical polarization in the presence of an external electric field. What is the term for this phenomenon?

ANSWER: FERROELECTRICITY

TOSS-UP

5) Math – *Multiple Choice*   In the conversion of the rectangular coordinates (–5, 12) to polar coordinates, to the nearest whole number, what is the degree measure of the angle?

W) 113
X) 157
Y) 293
Z) 337

ANSWER: W) 113

BONUS

5) Math – *Short Answer*   Express the fraction with numerator 1 – 4*i* and denominator 3 + *i* in standard *a* + *bi* form.

ANSWER: –1/10 – (13/10)*i* (ACCEPT: –0.1 – 1.3*i*)

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TOSS-UP

6) Earth and Space – *Short Answer*   Relative to continental land masses, tropical cyclones typically occur to which cardinal direction?

ANSWER: EAST

BONUS

6) Earth and Space – *Short Answer*   The Cretaceous *[creh-TAY-shus]* quiet zone was a period of time during the Cretaceous Period marked by a long period of lack of change in what?

ANSWER: GEOMAGNETIC FIELD (ACCEPT: EARTH'S MAGNETIC FIELD)

7) Physics – *Short Answer*   Abigail steps on a bathroom scale and notes that the internal spring has compressed 1 centimeter from her 220-newton weight. How much work, in joules, has she done in compressing the spring on the scale?

ANSWER: 1.1

BONUS

7) Physics – *Short Answer*   By what factor is the resonant frequency of an LC circuit muliplied if the inductor is replaced by one with 4 times as many turns?

ANSWER: 1/4   (ACCEPT: 0.25)

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TOSS-UP

8) Math – *Multiple Choice*   With respect to *x*, which of the following has $-8x^3$ as an antiderivative?

W) $-24x^2$
X) $24x^2$
Y) $-2x^4$
Z) $2x^4$

ANSWER: W) $-24x^2$

BONUS

8) Math – *Short Answer*   The terminal side of an angle in standard position passes through the point (–8, –15). Find the sine and tangent, respectively, of the angle.

ANSWER: SINE = –15/17, TANGENT = 15/8 (ACCEPT: 1 7/8)

TOSS-UP

9) Biology – *Multiple Choice* In a tree, older, nonfunctioning xylem *[ZYE-lum]* is called what?

W) Springwood
X) Sapwood
Y) Summer wood
Z) Heartwood

ANSWER: Z) HEARTWOOD

BONUS

9) Biology – *Multiple Choice* Which of the following statements about stomata *[stow-MAH-tah]* in plants is NOT correct?

W) Stomata are primarily located in leaf and stem tissue
X) Stomata allow carbon dioxide, but not oxygen, to pass through the leaf
Y) In CAM plants, stomata are closed during the day
Z) Stoma *[STOW-ma]* are regulated by guard cells on either side of the pore

ANSWER: X) STOMATA ALLOW CARBON DIOXIDE, BUT NOT OXYGEN, TO PASS THROUGH THE LEAF

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TOSS-UP

10) Energy – *Short Answer* Scientists at the Oak Ridge Titan supercomputer are simulating the interaction of electrons and lattice vibrations in copper-oxide materials. What property of these materials are they studying?

ANSWER: SUPERCONDUCTIVITY (ACCEPT: HIGH-TEMPERATURE SUPERCONDUCTIVITY)

BONUS

10) Energy – *Multiple Choice* The NOvA *[nova]* collaboration is performing an experiment in which neutrinos *[new-TREE-noze]* generated at Fermilab are sent to a detector 500 miles away in Minnesota. Which of the following best describes how the neutrinos travel between these facilities?

W) Neutrinos travel on a curved path over the surface of the Earth
X) Neutrinos oscillate, preventing them from traveling in straight lines
Y) Neutrinos interact very little with matter, enabling them to travel through the ground
Z) Neutrinos are reflected off the stratosphere

ANSWER: Y) NEUTRINOS INTERACT VERY LITTLE WITH MATTER, ENABLING THEM TO TRAVEL THROUGH THE GROUND

TOSS-UP

11) Earth and Space – *Multiple Choice*   Which of these is not an example of a Milankovich *[mil-AYN-koh-vitch]* cycle?

W) Shifting tilt of the Earth's axis
X) Axial "wobble"
Y) Sunspot cycle
Z) Change in shape of orbit

ANSWER: Y) SUNSPOT CYCLE

BONUS

11) Earth and Space – *Short Answer*   Identify all of the following three statements that are true of binary star systems: 1) It is impossible to tell if a given star is actually an astrometric binary; 2) For a visual binary, the masses of both stars can be determined; 3) For a spectroscopic *[spek-troh-SCAW-pik]* binary, the semimajor axis can be determined.

ANSWER: 2 AND 3

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TOSS-UP

12) Chemistry – *Short Answer*   What is the systematic name of tert-butyl *[turt-BYOO-til]* chloride?

ANSWER: 2-CHLORO-2-METHYLPROPANE

BONUS

12) Chemistry – *Short Answer*   Identify all of the following three compounds that can be considered soluble in water: 1) Ammonium chloride; 2) Silver bromide; 3) Lead (II) sulfate.

ANSWER: 1

TOSS-UP

13) Math – *Short Answer* A special coin has a 1/3 probability of landing on heads, and a 2/3 probability of landing on tails. In a series of three coin flips, what is the probability of the outcome sequence <u>heads, tails, tails</u>?

ANSWER: 4/27

BONUS

13) Math – *Short Answer* The perimeters of two squares differ by 16 inches and their areas differ by 92 square inches. What is the perimeter, in inches, of the larger square?

ANSWER: 54

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TOSS-UP

14) Earth and Space – *Short Answer* What sea in the North Atlantic Ocean, named for a genus of brown seaweed, is characterized by notably warm, clear, and nutrient-poor surface waters?

ANSWER: SARGASSO SEA

BONUS

14) Earth and Space – *Multiple Choice* Which of the following characteristics would make a species a poor index fossil?

W) Globally-distributed
X) Highly-conserved physical characteristics
Y) Short-lived in terms of geologic time
Z) Ability to form mineral hard parts

ANSWER: X) HIGHLY-CONSERVED PHYSICAL CHARACTERISTICS

TOSS-UP

15) Physics – *Multiple Choice*   A mixture of steam and liquid water is being heated at an increasing rate. Which of the following best describes the temperature of the mixture?

W) Increases at a constant rate
X) Increases at an increasing rate
Y) Increases at a decreasing rate
Z) Remains constant

ANSWER: Z) REMAINS CONSTANT

BONUS

15) Physics – *Short Answer*   How many times as fast would a rocket need to travel to escape Earth's gravitational field if Earth's average density were multiplied by a factor of 100?

ANSWER: 10 TIMES

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TOSS-UP

16) Energy – *Short Answer*   In general, nickel-cadmium batteries have fallen out of use and been replaced with another type of nickel-containing battery. What general type of nickel-containing battery replaced nickel-cadmium batteries?

ANSWER: NICKEL-METAL HYDRIDE

BONUS

16) Energy – *Short Answer*   Scientists working at Fermilab on the ArgoNeuT neutrino detector observe neutrinos up to the energy scale of 10 GeV. In joules, what is the energy, to two significant figures and in scientific notation, of a 10 GeV neutrino?

ANSWER: 1.6×10^{-9}

17) Chemistry – *Short Answer*   One mole of water is electrolyzed. To the nearest whole gram, how much oxygen is produced by this reaction?

ANSWER: 16

BONUS

17) Chemistry – *Short Answer*   Identify all of the following three statements that are true regarding the kinetic molecular *[moh-LEK-yoo-lur]* theory of gases: 1) Particle volume is negligible compared to the volume occupied by the gas; 2) Gas particles interact only weakly; 3) Gas particles collide elastically.

ANSWER: 1 AND 3

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TOSS-UP

18) Biology – *Multiple Choice*   Which of the following brain regions is primarily responsible for coordinating basic reflexes like swallowing and vomiting?

W) Cerebellum *[sarah-BELL-um]*
X) Amygdala *[ah-MIG-dah-la]*
Y) Medulla *[meh-DULL-ah]* oblongata *[awb-lawn-GAH-tah]*
Z) Thalamus

ANSWER: Y) MEDULLA OBLONGATA

BONUS

18) Biology – *Short Answer*   Bacterial cells are able to transfer DNA between themselves by temporarily joining together. What is the term for this process?

ANSWER: CONJUGATION

TOSS-UP

19) Chemistry – *Short Answer*   The carbon dioxide dissolved in a sealed can of soda is at equilibrium with its partial pressure in the air above the liquid. By what factor would the solubility of carbon dioxide in the soda be multiplied if the pressure of the air above the liquid were doubled by pumping in nitrogen gas?

ANSWER: ONE

BONUS

19) Chemistry – *Short Answer*   Assuming that bond lengths are the sum of the bonding atomic radii of their component atoms, rank the following three bonds by increasing bond length: 1) Carbon-sulfur; 2) Carbon-hydrogen; 3) Sulfur-hydrogen.

ANSWER: 2, 3, 1

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TOSS-UP

20) Math – *Short Answer*   Evaluate the following expression: log base 4 of 64 + log base 5 of 125.

ANSWER: 6

BONUS

20) Math – *Short Answer*   The three-dimensional graph $z = 2 - x$ contains points in how many different octants?

ANSWER: 6

TOSS-UP

21) Earth and Space – *Short Answer*   If a newly-discovered elliptical galaxy appears to be spherical, what Hubble classification will be given to it?

ANSWER: E-ZERO

BONUS

21) Earth and Space – *Short Answer*   The Titius-Bode *[TIH-tee-us-bowd]* Law, originally proposed to predict the geometric spacing of planets orbiting the Sun, fails to closely predict the orbit of what planet in our solar system?

ANSWER: NEPTUNE

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TOSS-UP

22) Biology – *Short Answer*   Flatworms, such as tapeworms, belong to what phylum *[FYE-lum]*?

ANSWER: PLATYHELMINTHES *[plat-ih-hell-MIN-thees]*

BONUS

22) Biology – *Short Answer*   Identify all of the following three diseases that are genetically recessive:
1) Cystic fibrosis; 2) Huntington's chorea *[kah-REE-ah]*; 3) Albinism *[AL-beh-nih-zim]*.

ANSWER: 1 AND 3

TOSS-UP

23) Physics – *Short Answer*   According to the Standard Model, what elementary boson *[BOH-sawn]* acts as the exchange particle for the strong nuclear force?

ANSWER: GLUONS

BONUS

23) Physics – *Short Answer*   Identify all of the following three particles that are considered fermions *[FUR-mee-awnz]*: 1) Photon; 2) Electron; 3) Up quark.

ANSWER: 2 AND 3