

High School
Set 5

TOSS-UP

1) Biology – *Multiple Choice* SNPs [*snips*] are used in DNA fingerprinting to distinguish individuals from each other. Which of the following events most likely precipitated the generation of a SNP [*snip*]?

- W) Inversion
- X) Reciprocal translocation
- Y) Point mutation
- Z) Frameshift mutation

ANSWER: Y) POINT MUTATION

BONUS

1) Biology – *Short Answer* Identify all of the following three statements about catabolic processes that are true in human cells:
1) Amino acids must be converted into glucose for entry into the Krebs cycle; 2) Fatty acids undergo beta oxidation to form acetyl-CoA [*ah-see-til-koh-AY*]; 3) Nitrogenous waste from protein metabolism is excreted as ammonia or urea.

ANSWER: 2, 3

TOSS-UP

2) Chemistry – *Short Answer* What is the molecular geometry of sulfur tetrafluoride?

ANSWER: SEE-SAW

BONUS

2) Chemistry – *Short Answer* What is the chemical formula of the ionic species formed when aluminum oxide reacts with hydroxide ions?

ANSWER: $\text{Al}(\text{OH})_4^-$

TOSS-UP

3) Earth and Space – *Short Answer* In the course of its evolution, what is the main element that has accumulated when helium becomes exhausted in the core of a red giant star?

ANSWER: CARBON

BONUS

3) Earth and Space – *Multiple Choice* What kind of telescope requires nested mirrors to form a focused image?

- W) Radio telescope
- X) Infrared telescope
- Y) Ultraviolet telescope
- Z) X-ray telescope

ANSWER: Z) X-RAY TELESCOPE

TOSS-UP

4) Energy – *Multiple Choice* Researchers at SLAC National Lab are studying scattering processes that violate the conservation of helicity [*heel-IH-sih-dee*] to the maximum possible extent. Which of the following best describes helicity?

- W) The projection of a particle's spin onto its momentum
- X) The angle between a particle's magnetic moment and its spin
- Y) The angular momentum of a particle with respect to the collision axis
- Z) The expectation value of a particle's magnetic quadrupole moment

ANSWER: W) THE PROJECTION OF A PARTICLE'S SPIN ONTO ITS MOMENTUM

BONUS

4) Energy – *Multiple Choice* Scientists supported by the Department of Energy are using machine learning to classify genetic data. Which of the following describes the difference between classification and clustering?

- W) Classification is performed with machine learning, while clustering is performed with mixed models
- X) Classification is performed with machine learning, while clustering is performed with generalized models
- Y) Classification is a type of unsupervised learning, while clustering is a type of supervised learning
- Z) Classification is a type of supervised learning, while clustering is a type of unsupervised learning

ANSWER: Z) CLASSIFICATION IS A TYPE OF SUPERVISED LEARNING, WHILE CLUSTERING IS A TYPE OF UNSUPERVISED LEARNING

TOSS-UP

5) Math – *Short Answer* A geometric sequence has second term -7 and third term 4. What is its first term?

ANSWER: $49/4$ (ACCEPT: $12\frac{1}{4}$, 12.25)

BONUS

5) Math – *Short Answer* A set of 15 points has 4 that are collinear, another 5 that are collinear, and the remaining 6 are also collinear. Otherwise, no three points in the set are collinear. How many lines contain at least two of the 15 points?

ANSWER: 77

TOSS-UP

6) Physics – *Multiple Choice* A firework is launched on a parabolic *[pair-uh-BAWL-ik]* arc and explodes into ten fragments at the apex of this arc. After these pieces fall to the ground, their positions and masses are measured. Which of the following will be closest to the center of mass of these pieces?

- W) The launch point of the firework
- X) The point directly below where the firework exploded
- Y) The point at which the firework would have landed had it not exploded
- Z) The focus of the parabola *[pah-RAB-ah-la]*

ANSWER: Y) THE POINT AT WHICH THE FIREWORK WOULD HAVE LANDED HAD IT NOT EXPLODED

BONUS

6) Physics – *Short Answer* In kilocalories and to two significant figures, how much energy does it take to heat 5 grams of water from 0 to 100 degrees Celsius and convert it all to steam, given that water has a heat of vaporization of 540 calories per gram?

ANSWER: 3.2

TOSS-UP

7) Biology – *Short Answer* What human organ is responsible for filtering and removing old red blood cells from the circulation, along with other various immunological roles?

ANSWER: SPLEEN

BONUS

7) Biology – *Short Answer* Identify all of the following three scenarios that are examples of facilitated diffusion: 1) A cortisol molecule passes through the plasma membrane; 2) A sodium ion is pumped out of a cell by an ATPase; 3) A water molecule passes through an aquaporin channel.

ANSWER: 3

TOSS-UP

8) Chemistry – *Short Answer* What sedimentary rock is the primary ore of aluminum?

ANSWER: BAUXITE

BONUS

8) Chemistry – *Multiple Choice* Rachel is trying to synthesize an alcohol from an alkane. Which of the following best describes the synthetic route she should take?

- W) An oxidation reaction followed by a substitution reaction
- X) A reduction reaction followed by a substitution reaction
- Y) A substitution reaction followed by an oxidation reaction
- Z) Two substitution reactions

ANSWER: Z) TWO SUBSTITUTION REACTIONS

TOSS-UP

9) Earth and Space – *Multiple Choice* Which of the following is an application of the principle of inclusions?

- W) Mineral size will decrease with increasing metamorphic grade
- X) Any feature cutting across a layered rock must be younger than the rock it transects
- Y) Porphyroblasts [*poor-feh-ROH-blasts*] are older than their host rock
- Z) Xenoliths [*ZEE-no-liths*] are older than their host rock

ANSWER: Z) XENOLITHS ARE OLDER THAN THEIR HOST ROCK

BONUS

9) Earth and Space – *Multiple Choice* Which of the following best explains why yardangs [*YAR-dangs*] are narrower at their base?

- W) They typically have sediment deposited at their tops
- X) Sand abrasion typically only occurs close to the ground
- Y) There is little desert wind above 10 meters above the ground
- Z) Their bases are eroded by water that cannot reach their tops

ANSWER: X) SAND ABRASION TYPICALLY ONLY OCCURS CLOSE TO THE GROUND

TOSS-UP

10) Energy – *Multiple Choice* Chemists at Ames Lab are using powder X-ray diffraction to study novel hetero-structures. Which of the following photon wavelengths is closest to the one they used for their diffraction experiment?

- W) 10 centimeters
- X) 100 microns
- Y) 100 nanometers
- Z) 1 angstrom

ANSWER: Z) 1 ANGSTROM

BONUS

10) Energy – *Short Answer* Scientists supported by the Department of Energy are studying twistronics, which is the study of how the angle between two layers of a two-dimensional material affects their electronic properties. What carbon-based material most commonly makes up the layers these scientists are studying?

ANSWER: GRAPHENE



TOSS-UP

11) Math – *Short Answer* What is the remainder when $2x^4 - 7x - 3$ is divided by $x - 2$?

ANSWER: 15

BONUS

11) Math – *Short Answer* What is the standard deviation of the following list of 4 numbers: 9, 11, 13, 19?

ANSWER: $\sqrt{14}$

TOSS-UP

12) Physics – *Short Answer* A battery that produces an electromotive force of 24 volts is connected to a 6-ohm resistor. Three amperes of current flows through the circuit. In ohms, what is the internal resistance of the battery?

ANSWER: 2

BONUS

12) Physics – *Short Answer* To the nearest decibel, if a sound wave doubles in intensity, by how much does its decibel value increase?

ANSWER: 3

TOSS-UP

13) Biology – *Short Answer* What is the term for rod-shaped prokaryotic [**PRO-care-ee-AW-tic**] cells?

ANSWER: BACILLI (ACCEPT: BACILLUS, BACILLIFORM)

BONUS

13) Biology – *Multiple Choice* Which of the following structures are possessed by lycophytes [**like-oh-fites**], cycads [**SIGH-cads**], and angiosperms?

W) Flowers

X) Pollen

Y) Megaphylls

Z) Xylem [**ZYE-lum**]

ANSWER: Z) XYLEM

TOSS-UP

14) Chemistry – *Short Answer* What rule in organic synthesis states that the more electropositive of a reacting species tends to bond to the least-highly-substituted carbon atom in an alkene [*al-KEEN*] during an addition reaction?

ANSWER: MARKOVNIKOV'S RULE

BONUS

14) Chemistry – *Multiple Choice* Infrared spectroscopy is most concerned with measuring what?

- W) Electronic transitions between valence energy levels
- X) Vibrational frequencies of chemical bonds
- Y) Electronic transitions between inner energy levels
- Z) Nuclear spin flips

ANSWER: X) VIBRATIONAL FREQUENCIES OF CHEMICAL BONDS

TOSS-UP

15) Earth and Space – *Short Answer* How far, in parsecs, is a star with a parallax of 0.4 arcseconds?

ANSWER: 2.5

BONUS

15) Earth and Space – *Multiple Choice* During the formation of a neutron star, protons and electrons will combine to form neutrons and neutrinos. This reaction is mechanistically similar to what mode of radioactive decay?

- W) Alpha
- X) Beta plus
- Y) Beta minus
- Z) Electron capture

ANSWER: Z) ELECTRON CAPTURE

TOSS-UP

16) Energy – *Short Answer* Pacific Northwest National Lab researchers are studying the genomes of a phylum [**FYE-lum**] of fungi that includes truffles, morels [**moor-ELLS**], and baker's yeast. What phylum are they researching?

ANSWER: ASCOMYCOTA (ACCEPT: ASCOMYCETES)

BONUS

16) Energy – *Short Answer* Scientists at Brookhaven National Lab are studying the muon. Identify all of the following three statements that are true of the muon: 1) It can have integer spin; 2) Its electric charge can be negative one-third; 3) It is a fermion.

ANSWER: 3

TOSS-UP

17) Math – *Short Answer* A bag contains 14 uniquely-colored marbles. Two marbles are drawn simultaneously. How many different combinations are possible?

ANSWER: 91

BONUS

17) Math – *Short Answer* A twice-differentiable function f of x on the real numbers has a negative second derivative for all x , and its graph contains the two points $(2, 4)$ and $(5, 9)$. What is the maximum possible integer value of f of 11?

ANSWER: 18



TOSS-UP

18) Physics – *Short Answer* A test charge is experiencing no net forces as it sits between two charges of +3 coulombs and +12 coulombs. If the distance between the test charge and the 3-coulomb charge is 5 meters, then, in meters, what is the distance between the 3-coulomb and the 12-coulomb charges?

ANSWER: 15

BONUS

18) Physics – *Multiple Choice* Astronomers can use which of the following to determine the surface temperature of a star after measuring the peak wavelength of the star's spectrum?

- W) Wien's Law
- X) Stefan-Boltzmann equation
- Y) Hertzsprung–Russell diagram
- Z) Rayleigh [*RAY-lee*]–Jeans law

ANSWER: W) WIEN'S LAW