

High School
Set 9

TOSS-UP

1) Math – *Short Answer* The sums of three whole numbers taken in pairs are 10, 15, and 17. What is the largest of these three numbers?

ANSWER: 11

BONUS

1) Math – *Short Answer* What is the area of a circle that circumscribes a rectangle with sides of lengths 16 and 22?

ANSWER: 185π



TOSS-UP

2) Physics – *Short Answer* An organ pipe open at one end has a fundamental frequency of 50 hertz. Identify all of the following three frequencies that would remain as harmonics if both ends of the organ pipe were opened to the air: 1) 150 hertz; 2) 250 hertz; 3) 350 hertz.

ANSWER: NONE

BONUS

2) Physics – *Multiple Choice* Andrew connects a vacuum pump to a long tube and dips the other end of the tube into a swimming pool directly below him. In meters, which of the following distances is closest to the maximum height he could pump water up the tube?

- W) 1
- X) 5
- Y) 10
- Z) 25

ANSWER: Y) 10

TOSS-UP

3) Biology – *Short Answer* While the lens of the eye provides dynamic tuning of its focus, the majority of the optical power of the eye derives from what structure?

ANSWER: CORNEA

BONUS

3) Biology – *Short Answer* Identify all of the following three types of carbon fixation that utilize oxaloacetate [*ox-ahoe-ASS-eh-tate*] as an intermediate to concentrate carbon dioxide around rubisco [*roo-BIS-koh*]: 1) C3; 2) C4; 3) CAM.

ANSWER: 2, 3

TOSS-UP

4) Chemistry – *Short Answer* While amino acids can be either D or L, life on Earth only uses L amino acids. These are an example of what type of isomers?

ANSWER: STEREOISOMERS (ACCEPT: OPTICAL, OPTICAL ISOMERS, STEREO, ENANTIOMERS)

BONUS

4) Chemistry – *Short Answer* Consider a reaction that obeys the Arrhenius [*ah-REE-nee-us*] equation. If the natural log of reaction rate is graphed on the y -axis and one over absolute temperature is graphed on the x -axis, then, in terms of the activation energy E , the ideal gas constant R , and the pre-exponential factor A , what will the slope of this graph be?

ANSWER: NEGATIVE E/R

TOSS-UP

5) Earth and Space – *Short Answer* The subtropical jet stream usually lies between what two circulation cells?

ANSWER: HADLEY AND FERRELL (either order)

BONUS

5) Earth and Space – *Short Answer* Identify all of the following three statements that are true of lahars: 1) Lahars are typically generated by composite cone volcanoes; 2) The eruption of Mount Vesuvius in CE 79 created lahars; 3) Lahars [*lah-HARS*] can occur without a volcanic eruption.

ANSWER: 1, 3

TOSS-UP

6) Energy – *Short Answer* Researchers at Thomas Jefferson National Accelerator Facility use hadron calorimeters to detect particles created in their accelerator. Identify all of the following four particles that are hadrons: 1) Muon; 2) Kaon; 3) Proton; 4) Neutrino.

ANSWER: 2 AND 3

BONUS

6) Energy – *Multiple Choice* Scientists at the Joint Genome Institute are using 16S rRNA sequencing to profile bacterial populations. What is the typical purpose of this sequence in the bacterium?

- W) Transferring amino acids from the tRNA to the nascent peptide
- X) Binding the codon at the A site
- Y) Binding the start codon
- Z) Binding the Shine-Dalgarno sequence

ANSWER: Z) BINDING THE SHINE-DALGARNO SEQUENCE

TOSS-UP

7) Math – *Short Answer* The zeroes of a function f of x on the real numbers are at -3 , 4 , and 5 . What are the zeroes of the function f of the absolute value of x ?

ANSWER: -5 , -4 , 4 , AND 5 (ACCEPT: ± 4 AND ± 5) (must give all answers, in any order)

BONUS

7) Math – *Short Answer* What is the volume of the solid obtained by rotating about the y -axis the first-quadrant region bounded by the graphs of $y = x - x^5$ and $y = 0$?

ANSWER: $8\pi/21$ (ACCEPT: $(8/21)\pi$)

TOSS-UP

8) Physics – *Short Answer* In Compton scattering, a charged particle receives energy and momentum from a collision with what other particle?

ANSWER: PHOTON

BONUS

8) Physics – *Short Answer* A spacecraft is orbiting a star, and powering itself using a photovoltaic cell. If the star's absolute temperature is doubled, and the spacecraft moves to a distance three times as great from the star, by what factor will the power output of its photovoltaic cell be multiplied?

ANSWER: 16/9 (ACCEPT: 1 7/9)

TOSS-UP

9) Biology – *Short Answer* What complex removes introns from pre-mRNA?

ANSWER: SPLICEOSOME (ACCEPT: snRNP)

BONUS

9) Biology – *Multiple Choice* Pseudogenes are commonly found in the genome of an organism. Which of the following describes the most likely mechanism of how these features arose?

- W) Inversion
- X) Polyploidy [*poly-ploy-dee*]
- Y) Deletion
- Z) Duplication

ANSWER: Z) DUPLICATION

TOSS-UP

10) Chemistry – *Short Answer* What is the denticity of EDTA?

ANSWER: HEXADENTATE (ACCEPT: 6)

BONUS

10) Chemistry – *Short Answer* What is the IUPAC [***EYE-you-pack***] name of the major organic product formed when benzene is reacted with a concentrated mixture of nitric and sulfuric acid at high temperature?

ANSWER: NITRO-BENZENE

TOSS-UP

11) Earth and Space – *Multiple Choice* Which of the following is closest to the length of time, in years, it takes Earth to complete one cycle of its orbital eccentricity variation?

- W) 26,000
- X) 41,000
- Y) 87,000
- Z) 100,000

ANSWER: Z) 100,000

BONUS

11) Earth and Space – *Short Answer* Rank the following three spectral types of stars in order of increasing ability to ionize hydrogen with their emitted light: 1) B1; 2) O7; 3) O5.

ANSWER: 1, 2, 3

TOSS-UP

12) Energy – *Multiple Choice* Scientists at Oak Ridge National Lab’s Isotope Production Program are producing trans-uranium radioisotopes. Which of the following most accurately describes how they are produced?

- W) Multiple neutron captures by lighter nuclei
- X) Fusion of nuclei around half the mass of the target isotope
- Y) Fission of nuclei around twice the mass of the target isotope
- Z) Successive alpha decays of slightly heavier nuclei

ANSWER: W) MULTIPLE NEUTRON CAPTURES BY LIGHTER NUCLEI

BONUS

12) Energy – *Short Answer* Scientists at Pacific Northwest National Lab are using artificial neural networks with multiple hidden layers to design energy-efficient buildings. What is the term for this family of machine-learning algorithms that use artificial neural networks with multiple hidden layers?

ANSWER: DEEP LEARNING (ACCEPT: DEEP NEURAL NETWORKS)

TOSS-UP

13) Math – *Short Answer* What is the $4/3$ power of -27 ?

ANSWER: 81

BONUS

13) Math – *Short Answer* Alice and Bob each flip their own coin as many times as needed until their coin lands on heads. What is the probability that Alice and Bob each flipped their coin the same number of times?

ANSWER: $1/3$

TOSS-UP

14) Physics – *Multiple Choice* The intensity of light scattered by Rayleigh [*RAY-lee*] scattering is directly proportional to what power of wavelength?

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

ANSWER: W) -4

BONUS

14) Physics – *Short Answer* What nuclide has the lowest average nuclear binding energy per nucleon?

ANSWER: HYDROGEN-1 (ACCEPT: H-1, PROTIUM; do not accept: HYDROGEN)

TOSS-UP

15) Biology – *Multiple Choice* A certain flower has a large amount of nectar, is colored red, and has no fragrance. Which of the following pollination vectors did it evolve to exploit?

- W) Moths
- X) Birds
- Y) Bats
- Z) Butterflies

ANSWER: X) BIRDS

BONUS

15) Biology – *Multiple Choice* Which of the following basic tastes is NOT recognized by a G-protein-coupled receptor?

- W) Sweet
- X) Bitter
- Y) Sour
- Z) Umami

ANSWER: Y) SOUR

TOSS-UP

16) Chemistry – *Short Answer* According to VSEPR [*VESS-pur*] theory, what is the predicted molecular geometry of the nitrate ion?

ANSWER: TRIGONAL PLANAR

BONUS

16) Chemistry – *Short Answer* Rank the following three compounds in order of increasing distance traveled in a thin layer chromatography experiment using a mixture of hexane and ethyl acetate as the mobile phase on silica: 1) Nitrobenzene; 2) Hexane-1,6-dicarboxylic [*one-six-DYE-car-box-IHL-ik*] acid; 3) Toluene.

ANSWER: 2, 1, 3

TOSS-UP

17) Earth and Space – *Multiple Choice* Which of the following events is thought to be the main reason for the development of starburst galaxies?

- W) Hypernova
- X) Black hole collision
- Y) Galaxy merger
- Z) Activation of the galactic nucleus

ANSWER: Y) GALAXY MERGER

BONUS

17) Earth and Space – *Multiple Choice* You are observing an object traveling away from you approaching the event radius of a black hole. Which of the following would you expect to see?

- W) The object slows down and turns redder as it approaches
- X) The object slows down and turns bluer as it approaches
- Y) The object speeds up and turns redder as it approaches
- Z) The object speeds up and turns bluer as it approaches

ANSWER: W) THE OBJECT SLOWS DOWN AND TURNS REDDER AS IT APPROACHES

TOSS-UP

18) Energy – *Short Answer* Scientists at Oak Ridge National Lab are using defect engineering to control the electrical properties of graphene. Identify all of the following three statements that are accurate about graphene: 1) It is a monolayer; 2) The carbon atoms are sp^3 hybridized; 3) It can be doped.

ANSWER: 1, 3

BONUS

18) Energy – *Multiple Choice* Researchers at Lawrence Berkeley National Lab are studying acyl-CoA [*AY-sil koh-A*] dehydrogenase enzymes. In what process are these enzymes involved?

- W) Photosynthesis
- X) Beta oxidation
- Y) Steroid biosynthesis
- Z) Heme synthesis

ANSWER: X) BETA OXIDATION