2025 MIT Science Bowl High School Invitational

Wildcard Round 3

TOSS-UP

1) EARTH AND SPACE – *Multiple Choice* Which of the following sediment characteristics would typically have the highest porosity?

W) Sorted and Angular
X) Sorted and Rounded
Y) Unsorted and Angulalr
Z) Unsorted and Rounded

ANSWER: X) SORTED AND ROUNDED

BONUS

1) EARTH AND SPACE – *Multiple Choice* Highly unstable atmospheric conditions are most associated with which of the following types of precipitation?

W) Sleet
X) Freezing Rain
Y) Hail
Z) Snow

ANSWER: Y) HAIL

TOSS-UP

2) BIOLOGY – *Short Answer* Rank the following three cells by increasing size of their rough ER: 1) B cell; 2) Erythrocyte; 3) T cell.

ANSWER: 2, 3, 1

BONUS

2) BIOLOGY – *Short Answer* Identify all of the following three groups of algae that have sporopollenin: 1) Green algae; 2) Brown algae; 3) Red algae;

ANSWER: 1 ONLY

TOSS-UP

3) MATH – *Multiple Choice* Which of the following best describes the function $f(x) = 2^{1/x}$ (read: *f of x equals two to the power of the quantity one over x*), defined for all nonzero x?

W) increasing for all nonzero x
X) decreasing for all nonzero x
Y) increasing for all negative x, decreasing for all positive x
Z) decreasing for all negative x, increasing for all positive x

ANSWER: X) DECREASING FOR ALL NONZERO x

BONUS

3) MATH – *Short Answer* Identify all of the following three numbers that could be even: 1) The sum of two odd numbers; 2) The ratio between an even number and an odd number; 3) An odd number raised to the power of an even number.

ANSWER: 1 AND 2

TOSS-UP

4) CHEMISTRY – *Multiple Choice* Which of the following ions has the smallest ionic radius?

W) Aluminum 3 plus
X) Calcium 2 plus
Y) Fluoride 1 minus
Z) Sodium 1 plus

ANSWER: W) ALUMINUM 3 PLUS

BONUS

4) CHEMISTRY – *Short Answer* Given that the bond dissociation energy for an oxygen-oxygen double bond is 495 kilojoules per mole, then in kilojoules per mole, what is the standard enthalpy of formation for O_2?

ANSWER: 0

TOSS-UP

5) PHYSICS – *Multiple Choice* A rocket is travelling in an elliptical orbit around the Sun. In order to maximize the resulting increase in its semimajor axis, where should it apply an impulse tangential to its orbit?

W) Perihelion
X) Aphelion
Y) An endpoint of the latus rectum
Z) A covertex

ANSWER: W) PERIHELION

BONUS

5) PHYSICS – *Short Answer* When water is moving at 2 meters per second through a pipe of radius 6 meters, it has a pressure of 80 kilopascals. If it now moves to a part of the pipe at the same height with radius of 3 meters, and assuming the water is incomprehensible with a uniform density of 1000 kilograms per cubic meter, what is the new pressure, rounded to three significant figures and expressed in kilopascals?

ANSWER: 50

TOSS-UP

6) ENERGY – *Multiple Choice* Joint MIT-Harvard Medical school scientists have been studying the sinoatrial node in the heart in hopes of developing noninvasive pacemakers. In which chamber of the heart is the SA node located?

W) Left atrium
X) Left ventricle
Y) Right atrium
Z) Right ventricle

ANSWER: Y) RIGHT ATRIUM

BONUS

6) ENERGY – *Short Answer* The Surendranath Group is studying the conversion of gaseous oxygen to water vapor by a catalytic solid surface. What type of catalysis is this an example of?

ANSWER: HETEROGENEOUS

TOSS-UP

7) EARTH AND SPACE – *Multiple Choice* Which of the following sedimentary rocks is non-clastic?

W) Siltstone
X) Travertine
Y) Conglomerate
Z) Breccia

ANSWER: X) TRAVERTINE

BONUS

7) EARTH AND SPACE – *Multiple Choice* Which of the following best describes the creation of andesitic magmas?

W) Decompression melting of dry peridotite at a mid-ocean ridge, followed by fractional crystallization of olivine and pyroxene
X) Partial melting of lower continental crust during continental collision, with assimilation of mantle-derived basaltic melts
Y) Direct melting of subducted oceanic basaltic crust at high pressures in the mantle transition zone, with little interaction with the mantle wedge
Z) Partial melting of hydrated peridotite in the mantle wedge above a subducting slab, followed by assimilation of continental crustal material

ANSWER: Z) PARTIAL MELTING OF HYDRATED PERIDOTITE IN THE MANTLE WEDGE ABOVE A SUBDUCTING SLAB, FOLLOWED BY ASSIMILATION OF CONTINENTAL CRUSTAL MATERIAL

TOSS-UP

8) BIOLOGY – *Short Answer* Choanoflagellates (read: *koh-ANN-oh-fla-gel-ates*) are considered the sister group to animals because they resemble the feeding cells of what animal phylum?

ANSWER: PORIFERA (DO NOT ACCEPT: SPONGES)

BONUS

8) BIOLOGY – *Short Answer* Derek is isolating in vivo dog chromosomes, but he finds that there is a double strand break. Identify all of the following three biological repair mechanisms that are able to repair double strand breaks: 1) Nucleotide excision repair; 2) Base excision repair; 3) Mismatch repair.

ANSWER: NONE

TOSS-UP

9) ENERGY – *Short Answer* Scientists at the Weiss Group discovered rare iron (III) phosphite (read: *faa-sfite*) deposits on the Martian surface. What is the chemical formula of iron (III) phosphite?

ANSWER: $FEPO_3$

BONUS

9) ENERGY – *Short Answer* Climate scientists at MIT are studying tipping point events that could accelerate climate change. What weakening system of ocean currents in the North Atlantic Ocean is the focal point of their research because its collapse could disrupt global climate patterns?

ANSWER: ATLANTIC MERIDIONAL OCEAN CURRENTS (ACCEPT: AMOC)

TOSS-UP

10) CHEMISTRY – *Short Answer* A thermodynamic process does 560 joules of work on the enviornment, while 360 joules of heat are transferred to the system. What is the change in internal energy of the environment during the thermodynamic process?

ANSWER: -180 (DO NOT ACCEPT: 180)

BONUS

10) CHEMISTRY – *Multiple Choice* Which of the following bonds has the most covalent character, assuming atoms are in their most common oxidation states?

W) Sodium and chlorine
X) Sodium and iodine
Y) Aluminum and chlorine
Z) Aluminum and iodine

ANSWER: Z) ALUMINUM AND IODINE

TOSS-UP

11) MATH – *Short Answer* Let p be a prime number. Identify all of the following 3 options that are necessarily coprime to p: 1) $p + 1$; 2) $p + 2$; 3) $p + 3$

ANSWER: 1 ONLY

BONUS

11) MATH – *Short Answer* Daina is manually computing the sum of the first n positive odd numbers. He forgets to add one of the numbers and gets a sum of 29. Which number did he forget to include?

ANSWER: 7

TOSS-UP

12) PHYSICS – *Short Answer* Ginger observes a neutrino and determines that it is an electron neutrino, but later, she finds that the same neutrino has become a tau neutrino. What behavior is the neutrino exhibiting?

ANSWER: FLAVOR OSCILLATION (ACCEPT: NEUTRINO OSCILLATION)

BONUS

12) PHYSICS – *Multiple Choice* Jenny connects an AC voltage source to a series RC circuit and measures the voltage across the capacitor. Which of the following best describes the amplitude of this voltage at low and high AC frequencies, respectively?

W) Low, low
X) Low, high
Y) High, low
Z) High, high

ANSWER: Y) HIGH, LOW

TOSS-UP

13) MATH – *Short Answer* Tim writes the positive integers from 1 through 100, and calculates their mean by adding them all together and dividing by 100. However, unbeknownst to him, he forgot to include one of the integers. If his final result is an integer, then what number did Tim forget?

ANSWER: 50

BONUS

13) MATH – *Short Answer* If $x^2 - y^2 = 24$ and $x - y = 8$, then what is the value of xy?

ANSWER: -55/4

TOSS-UP

14) PHYSICS – *Multiple Choice* Phoebe has a cylinder of uniform density rolling without slipping down an incline. Which of the following options is false regarding this situation?

W) The ramp must have nonzero coefficient of kinetic friction
X) The cylinder would travel faster if it were sliding down a frictionless incline without rolling
Y) The fastest point on the cylinder is the point furthest from the incline
Z) The speed of the cylinder is independent of the coefficients of friction

ANSWER: W) THE RAMP MUST HAVE NONZERO COEFFICIENT OF KINETIC FRICTION

BONUS

14) PHYSICS – *Short Answer* Cyan is in a rocket that leaves the surface of the Earth at one-third its escape velocity. What is the ratio between the kinetic energy of the rocket and the total mechanical energy of the rocket when it first departs from Earth?

ANSWER: -1/8

TOSS-UP

15) BIOLOGY – *Short Answer* During fertilization, the cortical reaction is triggered by the entry of what ion into the egg?

ANSWER: CA2+ (ACCEPT: CALCIUM)

BONUS

15) BIOLOGY – *Short Answer* Yunyi has overwatered his bean plant. To form an airway for the submerged roots, the bean plant sends a death signal to cells in the root cortex. It does this using what hormone?

ANSWER: ETHYLENE

TOSS-UP

16) CHEMISTRY – *Short Answer* What atomic orbital in a hydrogen-like atom is degenerate with the $2p_x$, $2p_y$, and $2p_z$ orbitals?

ANSWER: $2s$

BONUS

16) CHEMISTRY – *Short Answer* To one significant figure, what percent, in mass, of water is oxygen?

ANSWER: 90

TOSS-UP

17) ENERGY – *Multiple Choice* Researchers in MIT's Earth and Planetary Sciences department are studying turbulence in the ocean using machine learning. Which of the following best describes a dataset of ocean turbulence that contains 100 years of data only for the month of July?

W) Small size and low diversity
X) Small size and high diversity
Y) Large size and low diversity
Z) Large size and high diversity

ANSWER: Y) LARGE SIZE AND LOW DIVERSITY

BONUS

17) ENERGY – *Multiple Choice* Researchers at CSAIL's Cognitive AI Group are studying loss functions in machine learning. Which of the following measures of a dataset could be a loss function for ordinary least-squares linear regression?

W) Mean Absolute Error
X) Mean Squared Error
Y) Accuracy
Z) Precision

ANSWER: X) MEAN SQUARED ERROR

TOSS-UP

18) EARTH AND SPACE – *Multiple Choice* As plotted on an H-R diagram, which of the following best describes the shapes of the Hayashi and Henyey tracks respectively?

W) Horizontal, horizontal
X) Horizontal, vertical
Y) Vertical, horizontal
Z) Vertical, vertical

ANSWER: Y) VERTICAL, HORIZONTAL

BONUS

18) EARTH AND SPACE – *Short Answer* The inner boundary of Saturn's Cassini Division is primarily maintained by the gravitational influence of which moon, famously known for its resemblance to the Death Star?

ANSWER: MIMAS

TOSS-UP

19) MATH – *Short Answer* What is the width of a rectangular prism with a space diagonal of length 13, length 3, and height 12?

ANSWER: 4

BONUS

19) MATH – *Short Answer* Jayson begins with the number 2047, then performs the following operation until he reaches 0: if the current number is odd, he subtracts one, and if it is even, he divides it by two. How many times will Jayson perform this operation before stopping at 0?

ANSWER: 21

TOSS-UP

20) CHEMISTRY – *Short Answer* What is the ratio of the number of cations to anions in an ionic salt formed between an alkaline earth metal and a pnictide?

ANSWER: 3 : 2 (ACCEPT: 3/2, 1.5)

BONUS

20) CHEMISTRY – *Multiple Choice* The forward and reverse rate constants of a chemical reaction are k and r, respectively. In terms of k and r, what is the equilibrium constant of the reaction?

W) k/r
X) r/k
Y) $\sqrt{k/r}$
Z) $\sqrt{r/k}$

ANSWER: W) k/r

TOSS-UP

21) BIOLOGY – *Short Answer* Heartwood and sapwood in woody plants make up what tissue layer that forms interior to the vascular cambium?

ANSWER: SECONDARY XYLEM (DO NOT ACCEPT: PRIMARY XYLEM)

BONUS

21) BIOLOGY – *Short Answer* Rank the following three phyla of organisms by most related to least related to humans: 1) Nematoda; 2) Platyhelminthes (read: *pla-tee-hel-minth-ees*); 3) Echinodermata (read: *ee-k.ai-no-der-mah-ta*)

ANSWER: 3, 1, 2002

TOSS-UP

22) ENERGY – *Short Answer* MIT researchers frequently collaborate with Brookhaven National Lab to use the National Synchotron Light Source II. Light from the NSLS-II is produced by accelerating what subatomic particles through magnetic rings?

ANSWER: ELECTRONS

BONUS

22) ENERGY – *Multiple Choice* In a recent ecological study, scientists at the Fellows Group used a z-test on an algae population. Which of the following explains why they chose to use a z-test?

W) To test the mean of a population with unknown variance
X) To test the mean of a population with known variance
Y) To test the variance of a population with unknown mean
Z) To test the variance of a population with known mean

ANSWER: X) TO TEST THE MEAN OF A POPULATION WITH KNOWN VARIANCE

TOSS-UP

23) EARTH AND SPACE – *Short Answer* Order the following four celestial objects by increasing absolute magnitude: 1) Mercury 2) Venus 3) The Moon

ANSWER: 2,1,3

BONUS

23) EARTH AND SPACE – *Short Answer* You are using a telescope with a diameter of 100 cm and an objective lens diameter of 1 cm. Given that the dimmest object you can see with your naked eye has an absolute magnitude around 6, what is the magnitude of the dimmest object you could see with this telescope?

ANSWER: 16

TOSS-UP

24) PHYSICS – *Short Answer* What principle traces the path of fastest descent between two points in a uniform gravitational field as the brachistochrone (read: *brah-key-sto-cro-ne*) curve?

ANSWER: FERMAT'S PRINCIPLE

BONUS

24) PHYSICS – *Short Answer* Beth holds a rock of density 5000 kilograms per cubic meter at the surface of a pond of depth 1 meter. To one significant figure and neglecting drag, how many seconds does it take to reach the bottom when dropped, assuming that the density of water is 1000 kilograms per cubic meter?

ANSWER: 0.5 (ACCEPT: 1/2 (READ: *ONE-HALF*))

TOSS-UP

25) CHEMISTRY – *Short Answer* If the pKb of ammonia at 25 degrees celsius is 4.6, at what pH will a buffer formed between ammonia and ammonium chloride have a 1 to 1 ratio of ammonia to ammonium cations?

ANSWER: 9.4

BONUS

25) CHEMISTRY – *Short Answer* What is the VSEPR (read: *VESS-pur*) predicted molecular geometry of thionyl chloride?

ANSWER: TRIGONAL PYRAMIDAL