

# 2022 MIT Science Bowl High School Invitational

## Round 4

### TOSS UP

1) MATH *Short Answer* Emily has a bag of marbles, with 4 each of 3 different colors. She draws two marbles randomly out of the bag without replacement. What is the probability that they are different colors?

ANSWER:  $8/11$

### BONUS

1) MATH *Short Answer* What is the maximum possible area of a triangle with perimeter 18?

ANSWER:  $9\sqrt{3}$

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### TOSS UP

2) ENERGY *Short Answer* The Fraenkel Lab at MIT works with large biological datasets, one of which is phosphoproteomics (*FAWS-foe-pro-tee-aw-miks*), the characterization of proteins with phosphate groups attached. Enzymes that attach phosphate groups to proteins belong to what class of enzymes?

ANSWER: Kinases

### BONUS

2) ENERGY *Multiple Choice* Researchers in the Hrvatin Lab at MIT have discovered that initiation of mouse torpor (*TOR-per*) relies on regulation by neurons in a certain area of the brain called the preoptic area, which is housed in which of the following structures of the brain?

- W) Hypothalamus
- X) Thalamus
- Y) Pons
- Z) Medulla oblongata

ANSWER: W) Hypothalamus

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### TOSS UP

3) PHYSICS *Short Answer* A simple screw has a radius of 1 centimeter and a distance of 1 millimeter between its threads. To the nearest integer, what is the mechanical advantage of this screw?

ANSWER: 63

### BONUS

3) PHYSICS *Short Answer* A car is turning in a circle of radius 5 meters, while moving at a speed of 7 meters per second. A beaker full of water sits inside the car. In degrees, what angle does the surface of the water make with the horizontal?

ANSWER: 45

### TOSS UP

4) BIOLOGY *Multiple Choice* Which of the following cellular structures does NOT possess a double membrane?

- W) Chloroplasts
- X) Golgi bodies
- Y) Nuclei
- Z) Mitochondria

ANSWER: X) Golgi bodies

### BONUS

4) BIOLOGY *Short Answer* Lynette the zoologist (*zoo-AW-luh-jist*) likes animals. She finds a sample containing malpighian (*mal-PIH-gee-uhn*) tubules (*TOO-byoolz*). By name or number, identify all of the following three animals that this sample CANNOT be from:

- 1) Dragonfly
- 2) Leech
- 3) Sea urchin

ANSWER: 2 and 3 (ACCEPT: All but 1)

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### TOSS UP

5) EARTH AND SPACE *Multiple Choice* Titus finds a glacier and decides to drill a hole straight down to the bottom of the glacier. After a year, which of the following best describes the shape and location of this hole?

- W) The hole's shape and location have not changed
- X) The hole's shape is the same, but its location has moved several meters
- Y) The base of the hole has not moved, but the top has moved several meters
- Z) The base of the hole has moved a few meters, and the top of the hole has moved several meters

ANSWER: Z) The base of the hole has moved a few meters, and the top of the hole has moved several meters

### BONUS

5) EARTH AND SPACE *Multiple Choice* Which of the following is characteristic of regions of the ocean under the calcite compensation depth, or CCD?

- W) An abundance of foraminiferal ooze
- X) Decreased pressure with increased depth
- Y) Low carbon dioxide levels
- Z) Low pH levels

ANSWER: Z) Low pH levels

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### TOSS UP

6) CHEMISTRY *Multiple Choice* Gideon is investigating the decomposition of hydrogen peroxide and finds that the reaction has a constant half-life. Which of the following is the order of the reaction?

- W)  $-1$
- X)  $0$
- Y)  $1$
- Z)  $2$

ANSWER: Y)  $1$

### BONUS

6) CHEMISTRY *Short Answer* Hydrogen gas and bromine gas are allowed to react in a rigid vessel according to the reaction  $\text{H}_2 + \text{Br}_2 \rightleftharpoons 2 \text{HBr}$  (read: *H-2 plus B-R-2 in equilibrium with 2-H-B-R*). If the initial concentrations of  $\text{H}_2$  and  $\text{Br}_2$  are both  $0.5$  molar and  $K_c$  for this reaction is equal to  $4$ , calculate, to one significant figure, the final molar concentration of  $\text{HBr}$  once equilibrium has been reached.

ANSWER:  $0.5$  (ACCEPT:  $5 \times 10^{-1}$ )

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### TOSS UP

7) ENERGY *Short Answer* Researchers at MIT have used observations of gravitational waves to confirm a theorem of Stephen Hawking, which states that the surface areas of what astronomical objects should never decrease?

ANSWER: Black hole (ACCEPT: Event horizon)

### BONUS

7) ENERGY *Multiple Choice* Astronomers at MIT were recently part of a team which detected a fast radio burst in which a series of periodic radio signals persisted for a few seconds. Of the following options, which is the most likely source for such an event?

- W) Supermassive black hole
- X) Magnetar
- Y) Solar flare
- Z) Supernova

ANSWER: X) Magnetar

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### TOSS UP

8) MATH *Short Answer* By name or number, identify all of the following four properties that the set of integers possess:

- 1) Additive inverses
- 2) Multiplicative inverses
- 3) Additive identity
- 4) Multiplicative identity

ANSWER: 1, 3, 4 (ACCEPT: All but 2)

### BONUS

8) MATH *Short Answer* A piece of paper in the shape of an equilateral triangle is folded once. What is the maximum number of sides in the outline of the folded figure?

ANSWER: 7

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### TOSS UP

9) EARTH AND SPACE *Short Answer* What term describes the standing waves or oscillations that form in normally still bodies of water when seismic activity occurs?

ANSWER: Seiche

### BONUS

9) EARTH AND SPACE *Multiple Choice* Which of the following layers of the atmosphere contains the region of the atmosphere with the lowest temperature?

- W) Thermosphere
- X) Mesosphere
- Y) Stratosphere
- Z) Troposphere

ANSWER: X) Mesosphere

### TOSS UP

10) BIOLOGY *Short Answer* In recent years, the need for more specific biochemical tools has been met by a new technique, where new variants of enzymes are developed through multiple rounds of artificial selection rather than being designed from scratch. What is the name of this method?

ANSWER: Directed evolution

### BONUS

10) BIOLOGY *Multiple Choice* Which of the following is NOT a limitation of directed evolution?

- W) A related protein with similar function must first exist to be used as a base
- X) The number of generations needed may result in overly long waiting times
- Y) The mechanism of action must be already known
- Z) Badly designed test criteria may cause other aspects of the protein to suffer

ANSWER: Y) The mechanism of action must be already known

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### TOSS UP

11) CHEMISTRY *Multiple Choice* Which of the following substances has the lowest vapor pressure?

- W) Methane
- X) Ammonia
- Y) Water
- Z) Hydrogen chloride

ANSWER: Y) Water

### BONUS

11) CHEMISTRY *Short Answer* By name or number, rank the following three diatomic molecules by increasing bond strength:

- 1) Carbon monoxide
- 2) Nitrogen gas
- 3) Nitric oxide

ANSWER: 3, 2, 1

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### TOSS UP

12) PHYSICS *Short Answer* To one significant digit and in atmospheres, what is the total pressure at the bottom of a 30 meter deep lake?

ANSWER: 4

### BONUS

12) PHYSICS *Short Answer* Water flows through a horizontal pipe of radius 2 centimeters at a velocity of 2 meters per second. The pipe narrows to a radius of 1 centimeter. Given that the density of water is 1000 kilograms per meter cubed, what is the difference in water pressure between the two sections of the pipe in pascals and to one significant figure?

ANSWER: 30,000 (ACCEPT:  $3 \times 10^4$ )

### TOSS UP

13) CHEMISTRY *Short Answer* A biochemical reaction, when carried out in the presence of varying amounts of carbon monoxide and an excess of other reactants over multiple trials, is found to have a rate constant with units moles squared per liter squared per second. What is the order of the reaction with respect to carbon monoxide?

ANSWER:  $-1$  (ACCEPT: Inverse first order)

### BONUS

13) CHEMISTRY *Short Answer* By name or number, identify all of the following three elements that are paramagnetic in their most abundant allotrope:

- 1) Carbon
- 2) Oxygen
- 3) Fluorine

ANSWER: 2 only

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### TOSS UP

14) MATH *Short Answer* A regular polygon has perimeter 120. What is the smallest possible area of the polygon?

ANSWER:  $400\sqrt{3}$

### BONUS

14) MATH *Short Answer* A group of hungry hippos plans to share 500 gumballs. If all hippos share equally, to the nearest tenth, each hippo eats 29.4 gumballs. How many hippos are in the group?

ANSWER: 17

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### TOSS UP

15) ENERGY *Short Answer* Researchers in the Swager group at MIT have synthesized a macrocyclic polyamide cage that has high affinity for the dihydrogen arsenate ion,  $\text{H}_2\text{AsO}_4^-$ . What is the oxidation state of the arsenic atom in the dihydrogen arsenate ion?

ANSWER: +5

### BONUS

15) ENERGY *Short Answer* Researchers in the Ceyer group at MIT are developing catalysts to convert natural gas directly into methanol. Methanol is currently produced by reacting syngas, a mixture of carbon monoxide and hydrogen gas. Assuming that all methanol produced is in the gas phase, if 4 liters of carbon monoxide gas and 4 liters of hydrogen gas are reacted completely to produce methanol, what is the final volume of the reaction mixture in liters?

ANSWER: 4

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### TOSS UP

16) BIOLOGY *Short Answer* What form of transport involves the movement of substances without the use of plasmodesmata and thus is blocked by the Casparian strip?

ANSWER: Apoplastic transport (ACCEPT: Apoplast)

### BONUS

16) BIOLOGY *Short Answer* 2 newly discovered plants on neighboring islands are found to both have spiky leaves, despite being genetically isolated for 2 million years. While they both inherited this trait from a common ancestor, other plants in the same clade have evolved rounded leaves instead. What kind of trait are the spiky leaves?

ANSWER: Plesiomorphy (ACCEPT: Sympleisiomorphy)

### TOSS UP

17) PHYSICS *Multiple Choice* Which of the following pairs of quantities do NOT have the same units?

- W) Torque and work
- X) Angular momentum and Planck's constant
- Y) Conductivity and permittivity
- Z) Spring constant and surface tension

ANSWER: Y) Conductivity and permittivity

### BONUS

17) PHYSICS *Short Answer* By name or number, rank the following three circuit arrangements by increasing equivalent capacitance:

- 1) Two 10 microfarad capacitors in series
- 2) A 12 microfarad capacitor in series with two 3 microfarad capacitors
- 3) Three 2 microfarad capacitors in parallel

ANSWER: 2, 1, 3

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### TOSS UP

18) EARTH AND SPACE *Multiple Choice* Which of the following series of reactions occurs in asymptotic giant branch stars, and has a neutron-capture time scale which allows for radioactive decay to occur?

- W) P-process
- X) R-process
- Y) S-process
- Z) T-process

ANSWER: Y) S-process

### BONUS

18) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three particles that do NOT fit dark matter as described by the Lambda-CDM model:

- 1) Axion
- 2) Proton
- 3) Neutralino

ANSWER: 2 only

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### TOSS UP

19) CHEMISTRY *Multiple Choice* Which of the following elements has a red flame test?

- W) Lithium
- X) Sodium
- Y) Potassium
- Z) Cesium

ANSWER: W) Lithium

### BONUS

19) CHEMISTRY *Short Answer* By name or number, rank the following three compounds by increasing solubility in water:

- 1) Magnesium hydroxide
- 2) Calcium hydroxide
- 3) Strontium hydroxide

ANSWER: 1, 2, 3

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### TOSS UP

20) BIOLOGY *Short Answer* The superphylums Ecdysozoa (*eck-DIH-so-zo-uh*) and Lophotrochozoa (*luh-FAH-tro-ko-zo-uh*) both belong to what clade of animals, whose derived characteristics include being triploblastic (*trip-low-BLAS-tic*) and possessing a left and right side?

ANSWER: Bilateria (ACCEPT: Bilateral)

### BONUS

20) BIOLOGY *Multiple Choice* There is current controversy over whether sponges are the most basal (*BAY-suhl*) metazoans. Which of the following clades is believed by some to be a sister group to all other animals?

- W) Acoela (*uh-COH-li-uh*)
- X) Cnidaria (*ni-DAY-ri-uh*)
- Y) Ctenophora (*tuh-NAWH-fah-ruh*)
- Z) Placozoa (*pla-cuh-ZOH-uh*)

ANSWER: Y) Ctenophora

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### TOSS UP

21) EARTH AND SPACE *Short Answer* What is the name of the protoplanetary body that is theorized to have collided with a proto-Earth to form the Moon in the giant impact hypothesis?

ANSWER: Theia

### BONUS

21) EARTH AND SPACE *Multiple Choice* The Fermi Bubbles found above and below the plane of the Milky Way are thought to be the result of gas excited and pushed aside by which of the following features formed by Sagittarius A\* (read: *A-star*) during a previous active phase?

- W) Astrophysical jets
- X) Accretion disk
- Y) Obscuring torus
- Z) Narrow line regions

ANSWER: W) Astrophysical jets

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### TOSS UP

22) MATH *Short Answer* In base-11, what is the product of the base-11 values 11 and 11 (read: *one-one and one-one*)?

ANSWER: 121

### BONUS

22) MATH *Short Answer* What is the remainder when  $5x^5 + 4x^4 + 3x^3 + 2x^2 + x$  is divided by  $x - 2$ ?

ANSWER: 258



### TOSS UP

23) PHYSICS *Multiple Choice* Katherine throws a ball off of a 2000 meter tall cliff, with a velocity of 1 meter per second. Which of the following is closest to the maximum distance away from the cliff the ball can land, in meters?

- W) 14
- X) 20
- Y) 28
- Z) 40

ANSWER: X) 20

### BONUS

23) PHYSICS *Short Answer* An organ pipe of length 3 meters is closed at one end and open at the other. In meters, what is the wavelength of the first overtone of the pipe?

ANSWER: 4

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