

# 2022 MIT Science Bowl High School Invitational

## Round 2

### TOSS UP

1) EARTH AND SPACE *Multiple Choice* At which of the following latitudes would you expect the greatest length of time between sunrise and sunset on December 21st?

- W) 75 degrees north
- X) 30 degrees north
- Y) 30 degrees south
- Z) 75 degrees south

ANSWER: Z) 75 degrees south

### BONUS

1) EARTH AND SPACE *Multiple Choice* Which of the following statements best explains why the S wave shadow zone is much larger than the P wave shadow zone?

- W) S waves move slower than P waves
- X) S waves are refracted more by the outer core than P waves
- Y) S waves cannot travel through the liquid outer core
- Z) S waves have more energy than P waves

ANSWER: Y) S waves cannot travel through the liquid outer core

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## **TOSS UP**

2) MATH *Short Answer* By name or number, identify all of the following three values that are possible values for the number of solutions for three linear equations in three variables:

- 1) Zero solutions
- 2) One solution
- 3) Two solutions

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

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## **BONUS**

2) MATH *Short Answer* What is the area bounded by the parabolas  $y = 4 - x^2$  and  $y = x^2 - 4$ ?

ANSWER:  $64/3$

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## **TOSS UP**

3) CHEMISTRY *Short Answer* What naturally occurring allotrope of carbon is the most thermodynamically stable at STP?

ANSWER: Graphite

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## **BONUS**

3) CHEMISTRY *Short Answer* What is the orbital hybridization of the carbon atoms in graphite and diamond, respectively?

ANSWER:  $sp^2$  and  $sp^3$

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## **TOSS UP**

4) PHYSICS *Short Answer* The muon decays via which fundamental force?

ANSWER: Weak (ACCEPT: Weak interactions, weak nuclear force)

## **BONUS**

4) PHYSICS *Multiple Choice* The final decay products of a muon are which of the following?

- W) A W-minus boson
- X) An antimuon and a photon
- Y) An electron, an electron antineutrino, and a muon neutrino
- Z) A proton, a neutron, and a muon neutrino

ANSWER: Y) An electron, an electron antineutrino, and a muon neutrino

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## **TOSS UP**

5) ENERGY *Short Answer* Researchers in the Yilmaz Lab at MIT have discovered that Paneth cells in the small intestine augment stem-cell function based on caloric intake. An increase in caloric intake will induce the small intestine to release what hunger suppressing hormone?

ANSWER: Peptide YY (ACCEPT: PYY)

## **BONUS**

5) ENERGY *Short Answer* Researchers in the Yilmaz Lab at MIT have discovered that blocking enzymes in a tryptophan (*TRIP-tuh-fan*) biosynthetic pathway caused preferential death of certain colon cancer cells. What vitamin can be produced from a tryptophan biosynthetic pathway, whereby the indole moiety (*MOY-uh-tee*) is converted to a pyridine moiety?

ANSWER: Niacin (ACCEPT: Vitamin B3)

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## **TOSS UP**

6) BIOLOGY *Multiple Choice* In a situation where a mother has a trait and all of her children are male, which of the following inheritance patterns always resembles a mitochondrial inheritance pattern?

- W) Autosomal recessive
- X) Autosomal dominant
- Y) X-linked recessive
- Z) X-linked dominant

ANSWER: Y) X-linked recessive

## **BONUS**

6) BIOLOGY *Short Answer* One difference between long interspersed nuclear elements and short interspersed nuclear elements is the presence of the coding sequence of what enzyme that facilitates the amplification of retrotransposons (*tran-SPOW-saanZ*)?

ANSWER: Reverse transcriptase

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## **TOSS UP**

7) MATH *Short Answer* Each of the 50 states in the US has a different 2-letter abbreviation. How many sequences of 2 letters are NOT state abbreviations?

ANSWER: 626

## **BONUS**

7) MATH *Short Answer* By name or number, identify all of the following three sets that are countably infinite:

- 1) The set of all rationals
- 2) The set of all points on a 2D plane
- 3) The set of all even integers

ANSWER: 1 and 3

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## **TOSS UP**

8) EARTH AND SPACE *Multiple Choice* Which of the following is NOT a method through which rock can melt to form magma?

- W) Decrease in pressure
- X) Increase in temperature
- Y) Addition of volatiles
- Z) Removal of mafic (*MA-fik*) minerals

ANSWER: Z) Removal of mafic minerals

## **BONUS**

8) EARTH AND SPACE *Multiple Choice* Which of the following terms best describes a fold whose axial plane is horizontal to the ground?

- W) Isoclinal
- X) Plunging
- Y) Recumbent
- Z) Ptygmatic (*TIG-matic*)

ANSWER: Y) Recumbent

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## **TOSS UP**

9) BIOLOGY *Multiple Choice* Which of the following functions is NOT one belonging to the central vacuole?

- W) Protection from mechanical damage
- X) Breakdown of waste products
- Y) Hydrolysis of macromolecules
- Z) Storage of pigments

ANSWER: W) Protection from mechanical damage

## **BONUS**

9) BIOLOGY *Multiple Choice* One of the functions of the smooth ER is detoxification of barbiturates. In liver cells, this process is mediated by adding what functional group to drug molecules to make them more soluble?

- W) Methyl
- X) Hydroxyl
- Y) Carboxyl
- Z) Sulfhydryl

ANSWER: X) Hydroxyl

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## **TOSS UP**

10) CHEMISTRY *Short Answer* By name or number, identify all of the following three elements that occur naturally in their diatomic form:

- 1) Hydrogen
- 2) Helium
- 3) Nitrogen

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

## **BONUS**

10) CHEMISTRY *Multiple Choice* Which of the following elements has the lowest boiling point?

- W) Hydrogen
- X) Helium
- Y) Nitrogen
- Z) Oxygen

ANSWER: X) Helium

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## **TOSS UP**

11) PHYSICS *Short Answer* A uniform rope with a linear density of 0.1 kilograms per meter and a length of 2 meters is hung vertically from a ceiling. In newtons, what is the tension at the top of the rope?

ANSWER: 49/25 (ACCEPT: 1.96)

## **BONUS**

11) PHYSICS *Multiple Choice* Joe throws a modern discus, which is a uniform disc with a radius of 10 centimeters and a weight of 2 kilograms. What is the moment of inertia in kilogram meters squared when the disc is rotated around any point on the circumference, perpendicular to the plane of the discus?

- W) 0.01
- X) 0.02
- Y) 0.03
- Z) 0.04

ANSWER: Y) 0.03

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## **TOSS UP**

12) ENERGY *Multiple Choice* Physicists at MIT have observed that ultracold superdense lithium atoms are less able to scatter light compared to lithium atoms at standard conditions. This likely occurs because the electrons are all at low energy states and cannot absorb the light to switch to other states because of which of the following phenomena?

- W) Pauli exclusion principle
- X) Bose-Einstein superfluidity
- Y) Zeeman effect
- Z) Planck's law

ANSWER: W) Pauli exclusion principle

## **BONUS**

12) ENERGY *Short Answer* Physicists at MIT's Laboratory for Nuclear Science are looking for evidence of mysterious particles, called X particles, which may have existed shortly after the Big Bang. The high energy particle collisions they are investigating generate what specific state of matter which made up the very early universe?

ANSWER: Quark-gluon plasma

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## **TOSS UP**

13) BIOLOGY *Multiple Choice* Which of the following statements about actin molecules is NOT true?

- W) Filaments are composed of three intertwined strands of actin
- X) In muscle contraction, they form a cross bridge within myosin
- Y) In cell division, they form the basis of the cleavage furrow
- Z) Together with intermediate filaments, they maintain cell shape as tension-bearing elements

ANSWER: W) Filaments are composed of three intertwined strands of actin

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## **BONUS**

13) BIOLOGY *Short Answer* What term is used to describe a plant cell in an isotonic environment?

ANSWER: Flaccid

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## **TOSS UP**

14) MATH *Short Answer* What is 80% of 120% of 25?

ANSWER: 24

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## **BONUS**

14) MATH *Multiple Choice* Which of the following best describes the shape of the polar plot of  $r = \csc \theta$  (read:  $r$  equals cosecant of theta)?

- W) Spiral
- X) Circle
- Y) Parabola
- Z) Line

ANSWER: Z) Line

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## **TOSS UP**

15) CHEMISTRY *Short Answer* By name or number, rank the following three elements by increasing atomic radius:

- 1) Argon
- 2) Xenon
- 3) Krypton

ANSWER: 1, 3, 2

## **BONUS**

15) CHEMISTRY *Short Answer* If the initial half-life of a second order reaction is 1 minute, how many minutes will it take for the starting material to reach one sixteenth of its starting concentration?

ANSWER: 15

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## **TOSS UP**

16) EARTH AND SPACE *Multiple Choice* Which of the following isotopes is NOT hypothesized to have been created by Big Bang nucleosynthesis?

- W) Hydrogen-2
- X) Helium-4
- Y) Lithium-7
- Z) Beryllium-8

ANSWER: Z) Beryllium-8

## **BONUS**

16) EARTH AND SPACE *Multiple Choice* Which of the following terms best describes a large group of non-gravitationally bound halo stars in the Milky Way, each with masses of approximately 10 solar masses, that are found by Gaia to be moving in roughly the same direction at the same speed?

- W) Globular cluster
- X) Galactic nucleus
- Y) T association
- Z) OB association

ANSWER: Z) OB association

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## **TOSS UP**

17) ENERGY *Short Answer* Researchers in the Drennan group at MIT are combining X-ray crystallography with other biophysical methods to gain a better understanding of molecular processes. During X-ray crystallography, atoms scatter X-ray waves, producing a regular array of spherical waves. Most of these waves cancel out through destructive interference, but some add constructively in specific directions as determined by what physical law?

ANSWER: Bragg's law

## **BONUS**

17) ENERGY *Short Answer* Researchers in the Plasma Science and Fusion Center at MIT are investigating the tritium breeding capabilities of the molten salt FLiBe, a mixture of lithium fluoride and beryllium fluoride. When a high-energy neutron from fusion plasma interacts with the lithium-6 in FLiBe, tritium is formed alongside what other isotope?

ANSWER: Helium-4

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## TOSS UP

18) PHYSICS *Multiple Choice* A satellite is in a circular orbit around a planet. Over a long time, air friction dissipates some of its energy as heat. This happens slowly enough that the orbit remains approximately circular at all times. Which of the following best describes the change in the satellite's orbit?

- W) Its velocity decreases, and its orbital radius decreases
- X) Its velocity decreases, and its orbital radius increases
- Y) Its velocity increases, and its orbital radius decreases
- Z) Its velocity increases, and its orbital radius increases

ANSWER: Y) Its velocity increases, and its orbital radius decreases

## BONUS

18) PHYSICS *Short Answer* A star can be modeled as a uniform sphere of radius 200,000 kilometers, which is rotating with an angular velocity of  $10^{-6}$  radians per second. This star collapses to form a neutron star, which can be modeled as a rotating uniform sphere of radius 10 kilometers. Assuming none of the original star's mass was lost in the collapse, what is the angular velocity of the resulting neutron star in radians per second?

ANSWER: 400

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## TOSS UP

19) EARTH AND SPACE *Short Answer* The Jupiter trojans are a group of asteroids that share Jupiter's orbit around the Sun. Each trojan librates (*LIE-brates*) 60 degrees ahead or behind the planet. Which two Lagrangian (*luh-GRAWN-gee-uhn*) points of the Jupiter-Sun system do trojans congregate in?

ANSWER:  $L_4$  and  $L_5$

## BONUS

19) EARTH AND SPACE *Short Answer* What metric best describes an uncharged, rotating blackhole?

ANSWER: Kerr metric

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## **TOSS UP**

20) MATH *Multiple Choice* How many noncongruent triangles with integer side lengths have total perimeter 6?

- W) 0
- X) 1
- Y) 2
- Z) 3

ANSWER: X) 1

## **BONUS**

20) MATH *Short Answer* The corners of an equilateral triangle of side length 8 are cut off by straight lines to form a regular hexagon. What is the area of this hexagon?

ANSWER:  $32\sqrt{3}/3$

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## **TOSS UP**

21) CHEMISTRY *Short Answer* What amount of translational energy is required for the molecules in a reaction to pass through the transition state and form the end-products?

ANSWER: Activation energy

## **BONUS**

21) CHEMISTRY *Short Answer* Consider the reaction for the combustion of liquid propane with oxygen gas to yield gaseous carbon dioxide and gaseous water. By name or number, identify all of the following three statements that are true regarding this reaction:

- 1) If gaseous propane is reacted instead, less heat is produced
- 2) If liquid water is formed instead, more heat is produced
- 3) This reaction is spontaneous at all temperatures

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

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## TOSS UP

22) BIOLOGY *Short Answer* Alberto is the unfortunate victim of the genetic disease Albertism. While he has no children of his own, he knows that half of his brothers but none of their sons suffer from the disease, and that neither of his parents have the disease. What is the most likely form of inheritance for Albertism?

ANSWER: X-linked recessive

## BONUS

22) BIOLOGY *Short Answer* Alberto's only sister, Alberta, is deciding whether or not to start a family. Her fiancé, Daniel, is a fellow victim of Albertism. Given that Alberta is unaffected and that Albertism is not fatal for developing humans, what is the probability that if they have a child that it will be a daughter with Albertism?

ANSWER: 1/4 (ACCEPT: 0.25, 25%)

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## TOSS UP

23) PHYSICS *Short Answer* An object's position changes with time according to the equation  $x(t) = 2t^3 - 6t^2 + 4t + 6$ . At what times does the object experience no acceleration?

ANSWER:  $t = 1$

## BONUS

23) PHYSICS *Short Answer* A hypothetical planet has a mass of 3 times that of the Earth and a radius of 1.5 times that of the Earth. As a decimal to the nearest tenth, what is the ratio of the escape speed at the surface of this planet to that at Earth's surface?

ANSWER: 1.4

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