

# 2025 MIT Science Bowl High School Invitational

## Round 1

### **TOSS-UP**

1) EARTH AND SPACE – *Multiple Choice* The Alps in northern Italy are an example of which of the following types of tectonic boundaries?

- W) Continental-continental convergence
- X) Continental-oceanic convergence
- Y) Oceanic-oceanic convergence
- Z) Continental-continental divergence

ANSWER: W) CONTINENTAL-CONTINENTAL CONVERGENCE

### **BONUS**

1) EARTH AND SPACE – *Short Answer* Identify all of the following three landmarks that are usually glacial in origin: 1) Kettle lake; 2) Intermittent stream; 3) Submarine valley.

ANSWER: 1 ONLY

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## **TOSS-UP**

2) CHEMISTRY – *Multiple Choice* Which of the following compounds violates the octet rule?

- W) Sulfur tetrafluoride
- X) Ozone
- Y) Dinitrogen tetroxide
- Z) Phosphorus trichloride

ANSWER: W) SULFUR TETRAFLUORIDE

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## **BONUS**

2) CHEMISTRY – *Multiple Choice* Which of the following inorganic acids has the highest pKa?

- W) Sulfuric acid
- X) Hydrofluoric acid
- Y) Perchloric acid
- Z) Nitric acid

ANSWER: X) HYDROFLUORIC ACID

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## **TOSS-UP**

3) BIOLOGY – *Short Answer* Tay-Sachs disease is caused by a 4 base pair insertion into the hexosaminidase (read: *hex-oh-sah-MIN-ee-days*) A gene. This 4 base pair insertion is an example of what type of mutation?

ANSWER: FRAMESHIFT MUTATION

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## **BONUS**

3) BIOLOGY – *Multiple Choice* In 2007, scientists successfully induced the differentiation of a fibroblast into a stem cell. These induced stem cells have which of the following potencies?

- W) Totipotent
- X) Unipotent
- Y) Multipotent
- Z) Pluripotent

ANSWER: Z) PLURIPOTENT

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## **TOSS-UP**

4) MATH – *Short Answer* Half of  $16^{16}$  (read: *the quantity 16 to the power of 16*) can be expressed as 2 raised to what power?

ANSWER: 63

## **BONUS**

4) MATH – *Short Answer* Juliet is on a ship at 0 degrees East, 60 degrees North. She sails along the 60 degree latitude line to reach Romeo at 45 degrees West, 60 degrees North. If the Earth's circumference is 40,000 kilometers, how many kilometers does Juliet travel?

ANSWER: 2500

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## **TOSS-UP**

5) ENERGY – *Short Answer* MIT Researchers at the Whitehead institute are studying daily torpor, which is a state of dormancy marked by a significant drop in body temperature, low metabolic activity, and reduced food intake. In addition to daily torpor, animals living in harsh winter conditions often undergo what type of prolonged torpor?

ANSWER: HIBERNATION

## **BONUS**

5) ENERGY – *Short Answer* Researchers in the Ovchinnikov (read: *ov-CHIN-ee-kov*) Group developed a heuristic to efficiently search for high-scoring phylogenetic trees. What principle is used to score phylogenetic trees by the total number of character-state changes?

ANSWER: PRINCIPLE OF MAXIMUM PARSIMONY (ACCEPT: MAXIMUM PARSIMONY, PARSIMONY, OCCAM'S RAZOR)

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## **TOSS-UP**

6) PHYSICS – *Multiple Choice* Which of the following gives the magnitude and direction, respectively, of the net acceleration experienced by an object falling to the ground at its terminal velocity?

- W)  $g$  downward
- X)  $g/2$  (read:  $g$  over two) downward
- Y) 0
- Z)  $g$  upward

ANSWER: Y) 0

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## **BONUS**

6) PHYSICS – *Short Answer* Josh places a 10-gram wooden block at rest on his desk, then applies a constant force of 10 millinewtons to the block along the desk's surface. If the coefficients of static and kinetic friction between the block and desk are 0.6 and 0.05, respectively, what is the acceleration of the block in meters per second squared?

ANSWER: 0

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## **TOSS-UP**

7) EARTH AND SPACE – *Short Answer* Identify all of the following three characteristics of meandering streams that typically increase as one moves downstream: 1) Capacity; 2) Competence; 3) Gradient.

ANSWER: 1 ONLY

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## **BONUS**

7) EARTH AND SPACE – *Multiple Choice* Which of the following quadrants of a Northern Hemisphere hurricane, relative to its direction of motion, experiences the strongest storm surge?

- W) Left front
- X) Right front
- Y) Left rear
- Z) Right rear

ANSWER: X) RIGHT FRONT

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## **TOSS-UP**

8) MATH – *Short Answer* Ricky rolls a fair six-sided die and sees an even number. What is the expected value of the number Ricky saw?

ANSWER: 4

## **BONUS**

8) MATH – *Short Answer* A cheeseburger has 2 slices of bread and 1 patty, and is 300 calories. A Big Mac has 3 slices of bread and 2 patties, and is 560 calories. How many calories does one slice of bread have?

ANSWER: 40

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## **TOSS-UP**

9) BIOLOGY – *Short Answer* Foolish rice seedling disease is characterized by rice plants growing so tall that they topple over before they can mature. This disease is associated with the hypersecretion of which plant hormone?

ANSWER: GIBBERELLINS

## **BONUS**

9) BIOLOGY – *Multiple Choice* The Allee (read: *ah-LEE*) effect states that at smaller population sizes, per capita population growth slows. Which of the following is NOT a valid explanation for the Allee effect?

- W) At smaller population sizes, organisms are more vulnerable to predator attack
- X) At smaller population sizes, populations are more likely to experience strong genetic drift
- Y) At smaller population sizes, organisms have a harder time finding mates
- Z) At smaller population sizes, disease spreads more rapidly

ANSWER: Z) AT SMALLER POPULATION SIZES, DISEASE SPREADS MORE RAPIDLY

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## **TOSS-UP**

10) ENERGY – *Short Answer* Researchers in the Kulik Group computationally studied the enzyme methane monooxygenase, which catalyzes the transformation of methane to what simple alcohol?

ANSWER: METHANOL

## **BONUS**

10) ENERGY – *Multiple Choice* Researchers in the Van der Hilst Group are using seismic imaging to study the Mohorovičić (read: *MOH-he-ROH-vih-chitch*) discontinuity. Where is the Mohorovičić discontinuity located?

- W) Between the upper and lower crust
- X) Between the lower crust and upper mantle
- Y) Between the upper and lower mantle
- Z) Between the lower mantle and outer core

ANSWER: X) BETWEEN THE LOWER CRUST AND UPPER MANTLE

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## **TOSS-UP**

11) CHEMISTRY – *Short Answer* A 0.40 molar solution of hydrochloric acid is used to titrate 25 milliliters of 0.16 molar sodium hydroxide. In milliliters, how much hydrochloric acid is required to reach the equivalence point?

ANSWER: 10

## **BONUS**

11) CHEMISTRY – *Short Answer* How many sigma and pi bonds, respectively, are found in the highest contributing resonance form of  $\text{SOF}_4^-$ ?

ANSWER: 5 SIGMA, 1 PI (ACCEPT: 5 AND 1, DO NOT ACCEPT: 1 AND 5)

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## **TOSS-UP**

12) PHYSICS – *Multiple Choice* In optics, the angle of incidence is always equal to which of the following angles?

- W) Angle of refraction
- X) Angle of reflection
- Y) Critical angle
- Z) Brewster's angle

ANSWER: X) ANGLE OF REFLECTION

## **BONUS**

12) PHYSICS – *Short Answer* A satellite is orbiting the Earth at 12,800 kilometers above the Earth's surface. If the radius of the Earth is 6,400 kilometers, then to two significant figures and in meters per second squared, what is the gravitational acceleration experienced by the satellite due to the Earth?

ANSWER: 1.1

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## **TOSS-UP**

13) ENERGY – *Short Answer* Physicists from the Kavli Institute studied the Hubble tension, which is the disparity between measurements of the universe's current rate of expansion. What is the proposed source for the accelerating expansion of the universe?

ANSWER: DARK ENERGY (DO NOT ACCEPT: DARK MATTER)

## **BONUS**

13) ENERGY – *Short Answer* Physicists at the Plasma Science and Fusion Center are studying tritium breeding, which produces tritium by bombarding lithium-7 with a neutron. This reaction splits the resulting lithium-8 nucleus into tritium, a neutron, and what other nuclide?

ANSWER: HELIUM-4 (ACCEPT: ALPHA PARTICLE)

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## **TOSS-UP**

14) PHYSICS – *Short Answer* A 10-gram billiard ball traveling at 10 meters per second collides perfectly inelastically with a 500 gram wooden block at rest on a flat pool table. In kilogram-meters per second, what is the momentum of the ball-block system after the collision?

ANSWER: 0.1

## **BONUS**

14) PHYSICS – *Short Answer* Identify all of the following three systems that generate a magnetic field: 1) Point charge at rest in zero external electric field; 2) Point charge at rest in a nonzero external electric field; 3) Point charge moving in a line with constant speed in zero external electric field.

ANSWER: 3 ONLY

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## **TOSS-UP**

15) MATH – *Short Answer* Identify all of the following three theorems that always apply to the absolute value function on any closed interval: 1) Intermediate value theorem; 2) Mean value theorem; 3) Extreme value theorem.

ANSWER: 1 AND 3

## **BONUS**

15) MATH – *Short Answer* Eric has an 8 ounce cup of bubble tea that is currently 50% ice by volume. If Eric drinks the bubble tea until it is 80% ice by volume, and no ice melts, how many ounces of bubble tea did he drink?

ANSWER: 3

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## **TOSS-UP**

16) CHEMISTRY – *Multiple Choice* Which of the following properties of a liquid increases when a non-volatile solute is added to form a dilute solution?

- W) Vapor pressure
- X) Surface tension
- Y) Freezing point
- Z) Boiling point

ANSWER: Z) BOILING POINT

## **BONUS**

16) CHEMISTRY – *Multiple Choice* The first, second, and third ionization energies of an element are 500, 950, and 3500 kilojoules per mole, respectively. Which of the following is the most likely identity of the element?

- W) Tellurium
- X) Antimony
- Y) Barium
- Z) Cesium

ANSWER: Y) BARIUM

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## **TOSS-UP**

17) BIOLOGY – *Multiple Choice* Moths circle around lights due to an innate response that causes them to orient themselves such that light sources are behind them. This kind of movement is a general example of which of the following phenomena?

- W) Kinesis (read: *Kine-EE-sis*)
- X) Taxis (read: *Tax-iss*)
- Y) Tropism (read: *Trope-ism*)
- Z) Mimicry

ANSWER: X) TAXIS (READ: *TAX-ISS*)

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## **BONUS**

17) BIOLOGY – *Short Answer* Order the following three steps of cellular respiration in chronological order starting from glucose: 1) Glucose phosphorylation (read: *FOS-four-ill-AY-shun*); 2) Cytochrome c reduction; 3) Citrate formation.

ANSWER: 1, 3, 2

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## **TOSS-UP**

18) EARTH AND SPACE – *Multiple Choice* A star with which of the following solar masses would have the longest lifespan?

- W) 100
- X) 10
- Y) 1
- Z) 0.1

ANSWER: Z) 0.1

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## **BONUS**

18) EARTH AND SPACE – *Multiple Choice* Which of the following terms describes a galaxy with a densely populated halo and prominent dust rings forming a disk?

- W) Lenticular
- X) Spiral
- Y) Irregular
- Z) Elliptical

ANSWER: W) LENTICULAR

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## **TOSS-UP**

19) ENERGY – *Multiple Choice* Researchers at CSAIL’s Julia Lab improved an upper-bound on the Gaussian elimination algorithm. Which of the following tasks could Gaussian elimination directly perform?

- W) Removing blurring from image
- X) Solving system of linear equations
- Y) Optimizing real-valued function
- Z) Finding roots to higher-order polynomials

ANSWER: X) SOLVING SYSTEM OF LINEAR EQUATIONS

## **BONUS**

19) ENERGY – *Multiple Choice* Researchers in the Aouad Group studied stochastic processes where independent events occur at a constant mean rate. For these processes, the number of occurrences in a fixed time interval follows what family of probability distributions?

- W) Normal
- X) Exponential
- Y) Poisson (read: *pwa-saun*)
- Z) Gamma

ANSWER: Y) POISSON (READ: *PWA-SAUN*)

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## **TOSS-UP**

20) MATH – *Multiple Choice* A class of 48 people takes a 50-point exam. When grading the exams, the professor accidentally adds an extra three 0s at the end of someone’s score. Which of the following measures for the class’s grades will have the smallest change in magnitude?

- W) Mean
- X) Median
- Y) Range
- Z) Variance

ANSWER: X) MEDIAN

## **BONUS**

20) MATH – *Short Answer* A regular hexagon has side lengths of 2 meters. What is the ratio between the length from the midpoint of a side to the center and a vertex to the center?

ANSWER:  $\sqrt{3}/2$

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## **TOSS-UP**

21) PHYSICS – *Short Answer* Claire observes the conversion of a high energy photon near an atomic nucleus to an electron and a positron. This is an example of what process?

ANSWER: PAIR PRODUCTION

## **BONUS**

21) PHYSICS – *Short Answer* A particle’s acceleration in meters per second squared is given by the equation  $a(t) = 12t^2$  (read: *a of t equals twelve times t squared*), where  $t$  is the time passed in seconds. If the particle’s velocity at  $t = 0$  is 1 meter per second, then in meters per second, what is the particle’s velocity at  $t = 2$ ?

ANSWER: 33

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## **TOSS-UP**

22) BIOLOGY – *Short Answer* The Wolff-Chaikoff (read: *Wolf-chai-cough*) effect is caused by high levels of what essential trace element, used in a thyroid hormone that increases basal metabolic rate secreted from the thyroid?

ANSWER: IODINE

## **BONUS**

22) BIOLOGY – *Short Answer* Identify all of the following three organs, that if removed, would cause a significant reduction in protein absorption in humans: 1) Pancreas; 2) Submandibular (read: *sub-MAN-dib-you-lar*) salivary gland; 3) Small intestine.

ANSWER: 1 AND 3

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## **TOSS-UP**

23) CHEMISTRY – *Multiple Choice* When added in trace amounts to pure silicon, which of the following elements would create a p-type semiconductor?

- W) Germanium
- X) Phosphorus
- Y) Antimony
- Z) Gallium

ANSWER: Z) GALLIUM

## **BONUS**

23) CHEMISTRY – *Multiple Choice* Yunyi is studying the solubility of calcium carbonate in aqueous solution, and observes his sample's solubility decreases as temperature increases. Which of the following best explains Yunyi's observation?

- W) Dissolving calcium carbonate is endothermic
- X) Dissolving calcium carbonate is exothermic
- Y) Dissolving calcium carbonate increase the solution's entropy
- Z) Dissolving calcium carbonate decreases the solution's entropy

ANSWER: X) DISSOLVING CALCIUM CARBONATE IS EXOTHERMIC

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## **TOSS-UP**

24) EARTH AND SPACE – *Multiple Choice* Although Mercury orbits the sun quickly, we only observe Mercury transiting the sun once about every seven years. Which of the following considerations explains this pattern?

- W) Mercury's orbit is highly eccentric
- X) Mercury's orbital precession is rapid
- Y) Mercury's transits can only be observed when Mercury is near its aphelion
- Z) Mercury's orbit is tilted relative to the ecliptic

ANSWER: Z) MERCURY'S ORBIT IS TILTED RELATIVE TO THE ECLIPTIC

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## **BONUS**

24) EARTH AND SPACE – *Short Answer* In a contact binary, the two stars' respective envelopes meet at which Lagrange point?

ANSWER: L1 (ACCEPT: LAGRANGE POINT 1)

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## **TOSS-UP**

25) CHEMISTRY – *Short Answer* How many electrons are transferred per manganese atom in the redox reaction between potassium permanganate and iron (II) chloride in acidic solution?

ANSWER: 5

## **BONUS**

25) CHEMISTRY – *Multiple Choice* Which of the following acids could not be safely stored using glass containers?

- W) Fluoroantimonic (read: *floor-oh-anti-monnic*) acid
- X) Sulfuric acid
- Y) Hydrochloric acid
- Z) Trichloroacetic (read: *Tri-chloro-as-ee-tic*) acid

ANSWER: W) FLUOROANTIMONIC (READ: *FLOOR-OH-ANTI-MONIC*) ACID