2025 MIT Science Bowl High School Invitational

Round 12

TOSS-UP

1) MATH – *Short Answer* Identify all of the following three values for positive integer n such that the equation $x^n = 2025$ has exactly 10 distinct non-real roots: 1) 10; 2) 11; 3) 12.

ANSWER: 2 AND 3

BONUS

1) MATH – *Multiple Choice* Which of the following is closest to the cosine of 0.02 radians?

W) 0.98
X) 0.998
Y) 0.9998
Z) 0.99998

ANSWER: Y) 0.9998

TOSS-UP

2) BIOLOGY – *Short Answer* Order the following three blood vessels from first to last in terms of time needed to reach them from the right ventricle: 1) Pulmonary vein; 2) Pulmonary artery; 3) Hepatic portal vein.

ANSWER: 2, 1, 3

BONUS

2) BIOLOGY – *Multiple Choice* Which of the following glial cells is derived from hematopoietic stem cells?

W) Microglia
X) Oligodendrocytes
Y) Ependymal cells
Z) Astrocytes

ANSWER: W) MICROGLIA

TOSS-UP

3) ENERGY – *Short Answer* Physicists at the Laboratory for Nuclear Science studied the nuclear decay of radium-226 compounds. Free radium-226 ejects five alpha particles and four beta particles to decay into what stable lead isotope?

ANSWER: LEAD-206

BONUS

3) ENERGY – *Short Answer* The Collins Lab has artificially engineered gut bacteria that are resistant to the beta-lactam family of antibiotics. To do this, they genetically edited what enzyme that is responsible for cross linking peptidoglycan?

ANSWER: TRANSPEPTIDASE

TOSS-UP

4) CHEMISTRY – *Multiple Choice* In a sodium-sulfur battery, molten sodium and molten sulfur react to form sodium polysulfide. Which of the following acts as the cathode in this reaction?

W) Molten sodium
X) Molten sulfur
Y) Graphite
Z) Sodium polysulfide

ANSWER: Y) GRAPHITE

BONUS

4) CHEMISTRY – *Multiple Choice* Which of the following real gases has a compressibility factor greater than 1 at sufficiently low pressures?

W) Hydrogen
X) Ammonia
Y) Methane
Z) Sulfur hexafluoride

ANSWER: W) HYDROGEN

TOSS-UP

5) EARTH AND SPACE – *Short Answer* What phenomenon occurs when adjacent crystals of a mineral share lattice points, causing them to grow in a symmetric manner?

ANSWER: CRYSTAL TWINNING

BONUS

5) EARTH AND SPACE – *Multiple Choice* Although fluvial sediment transport ends at the mouth of a river, submarine fans may continue to transport terrigenous sediment hundreds of kilometers away from their associated river deltas. Which of the following best explains how submarine fans transport sediment?

W) Remanent river currents on the ocean floor continue to propagate sediment outwards
X) Oceanic currents pick up river sediment and preserve their buoyancy until they eventually settle out
Y) Water-saturated sediment is denser than oceanic water and causes underwater landslides that carry sediment away from the river delta
Z) Earthquakes cause instability in the submarine fan, causing sediment to lurch downslope

ANSWER: Y) WATER-SATURATED SEDIMENT IS DENSER THAN OCEANIC WATER AND CAUSES UNDERWATER LANDSLIDES THAT CARRY SEDIMENT AWAY FROM THE RIVER DELTA

TOSS-UP

6) PHYSICS – *Short Answer* The amplitude of a damped harmonic oscillator decays with a half-life of 6 seconds. In seconds, what is the half-life of the oscillator's total energy?

ANSWER: 3

BONUS

6) PHYSICS – *Short Answer* An infinitely long straight wire carries a current of 5 amperes. In teslas and rounded to one significant figure, what is the magnetic field 1 centimeter from the wire?

ANSWER: 0.0001 (ACCEPT: 1×10^{-4} (READ: *ONE TIMES TEN TO THE NEGATIVE FOURTH POWER*))

TOSS-UP

7) BIOLOGY – *Multiple Choice* Brian is studying addiction to Genshin Impact, where gamers' reward system overreleases dopamine. Which of the following regions of gamers' brains should Brian inhibit to treat this addiction?

W) Pons
X) Ventral tegmental area
Y) Substantia nigra (read: *sub-STAN-shee-uh NIGH-gruh*)
Z) Hypothalamus

ANSWER: X) VENTRAL TEGMENTAL AREA

BONUS

7) BIOLOGY – *Multiple Choice* Which of the following statements is NOT true about fluorescence resonance electron energy transfer?

W) It is extremely sensitive to small changes in distance
X) The energy is transferred through a nonradiative process
Y) The radius of interaction is larger than the wavelength of light emitted
Z) Measurements can be used to determine if two fluorophores are within a certain distance of each other

ANSWER: Y) THE RADIUS OF INTERACTION IS LARGER THAN THE WAVELENGTH OF LIGHT EMITTED

TOSS-UP

8) CHEMISTRY – *Multiple Choice* The solvolysis of a fully deuterated alkyl iodide shows a large primary kinetic isotope effect. Which reaction mechanism is most likely?

W) SN1
X) SN2
Y) E1
Z) E2

ANSWER: Z) E2

BONUS

8) CHEMISTRY – *Short Answer* An aqueous solution is prepared containing silver (I) acetate, barium acetate, and lithium acetate. Order the following three solutions in the order they should be added to selectively precipitate each metal: 1) Potassium fluoride; 2) Sodium chloride; 3) Sodium sulfate.

ANSWER: 2, 3, 1

TOSS-UP

9) PHYSICS – *Multiple Choice* A large sphere is travelling at constant velocity in space in zero gravity. Then it slowly enters a region with a constant gravitational field perpendicular to the sphere's direction of motion, until the entire sphere is eventually contained in the region. Which of the following best describes the motion of the sphere from the instant it first enters the region to the instant it is fully inside the region?

W) Constant linear acceleration, zero angular acceleration
X) Constant linear acceleration, nonzero angular acceleration
Y) Increasing linear acceleration, zero angular acceleration
Z) Increasing linear acceleration, nonzero angular acceleration

ANSWER: Z) INCREASING LINEAR ACCELERATION, NONZERO ANGULAR ACCELERATION

BONUS

9) PHYSICS – *Short Answer* Identify all of the following three systems that have identical momentum and energy eigenstates: 1) Free particle; 2) Harmonic oscillator; 3) Two-dimensional finite potential well.

ANSWER: 1 ONLY

TOSS-UP

10) EARTH AND SPACE – *Multiple Choice* Which of the following best describes the most significant contribution of the 1883 eruption of Krakatoa to the global climate over the following year?

W) Dark carbon aerosols absorbed sunlight, raising temperatures
X) Greenhouse gases trapped infrared radiation, raising temperatures
Y) Ash blotted out the Sun, lowering temperatures
Z) Sulfuric acid promoted cloud formation, lowering temperatures

ANSWER: Z) SULFURIC ACID PROMOTED CLOUD FORMATION, LOWERING TEMPERATURES

BONUS

10) EARTH AND SPACE – *Short Answer* What type of volcanic eruption does not occur due to movement of magma, but rather groundwater coming in contact with magma and flashing to steam?

ANSWER: PHREATIC ERUPTION (ACCEPT: STEAM BLAST ERUPTION, ULTRAVULCANIAN ERUPTION)

TOSS-UP

11) ENERGY – *Short Answer* Experimental physicists at MIT study phase transitions in magnetic materials by measuring the ratio of magnetization to magnetic field intensity. What quantity are they measuring?

ANSWER: MAGNETIC SUSCEPTIBILITY (DO NOT ACCEPT: SUSCEPTIBILITY)

BONUS

11) ENERGY – *Short Answer* Scientists at the Drennan Lab are using X-ray imaging to elucidate complex 3D protein structures. What general class of techniques are the scientists using to reconstruct the 3D protein structure from a collection of 2D images?

ANSWER: TOMOGRAPHY (ACCEPT: COMPUTED TOMOGRAPHY, CT, CT SCAN)

TOSS-UP

12) MATH – *Short Answer* Identify all of the following three conic sections that can contain 3 or more collinear points: 1) Circle; 2) Parabola; 3) Hyperbola.

ANSWER: NONE

BONUS

12) MATH – *Short Answer* The numbers 1, 2, 3, and 4 are written on a blackboard. Tim picks two numbers on the board, erases them, and writes their arithmetic mean. He repeats this until one number is left. What is the greatest possible value for the remaining number?

ANSWER: 25/8

TOSS-UP

13) PHYSICS – *Multiple Choice* A uniform and infinitely large plane of positive charge lies in the xy-plane and is moving with constant speed in the positive-x direction. Which of the following best describes the direction of the magnetic field experienced by a stationary observer at the point (0, 0, 1)?

W) Positive y-direction
X) Negative y-direction
Y) Positive z-direction
Z) Negative z-direction

ANSWER: X) NEGATIVE y-DIRECTION

BONUS

13) PHYSICS – *Short Answer* In the rest frame of a laboratory, a muon has half-life 2 microseconds. To the nearest microsecond, what is the half-life of a muon traveling at 99 percent of the speed of light?

ANSWER: 14

TOSS-UP

14) ENERGY – *Short Answer* Researchers in the Hen group at MIT are extending parton model analysis to extract quark-gluon distributions inside correlated nucleon pairs. The researchers are primarily working with what theory that is the leading framework in describing the strong force?

ANSWER: QUANTUM CHROMODYNAMICS (ACCEPT: QCD)

BONUS

14) ENERGY – *Short Answer* Researchers at CSAIL's Complexity Theory Group are studying computational problems that are both in NP and NP-hard. What complexity class do these problems belong to?

ANSWER: NP-COMPLETE

TOSS-UP

15) EARTH AND SPACE – *Multiple Choice* Which of the following, in Kelvin, is closest to the average temperature of a Herbig-Haro Object?

W) 10,000
X) 100,000
Y) 1,000,000
Z) 10,000,000

ANSWER: W) 10,000

BONUS

15) EARTH AND SPACE – *Short Answer* The Hilda asteroids share an orbital resonance with Jupiter and visit the L3, L4, and L5 lagrange points between Jupiter and the Sun at their aphelion. What is the ratio of the orbital period of Hilda asteroids with respect to Jupiter's orbital period?

ANSWER: 3:2

TOSS-UP

16) CHEMISTRY – *Multiple Choice* Which of the following homonuclear single bonds has the highest bond dissociation energy?

W) H-H
X) C-C
Y) O-O
Z) F-F

ANSWER: W) H-H

BONUS

16) CHEMISTRY – *Short Answer* When one mole of dry ice reversibly sublimes at -78.5 degrees celsius, 25 kilojoules of heat are released. To two significant figures and in joules per kelvin, what is the entropy of sublimation of one mole of dry ice?

ANSWER: +130 (ACCEPT: 130)

TOSS-UP

17) MATH – *Multiple Choice* Last year, competitors complained that math multiple choice answers favored certain letters over others, rather than being uniformly random. Which of the following statistical tests should the writers use to test this hypothesis?

W) One-tailed z test
X) Two-tailed z test
Y) Chi-squared test ***[kai squared]***
Z) Paired t test

ANSWER: Y) CHI-SQUARED TEST ***[KAI SQUARED]***

BONUS

17) MATH – *Short Answer* Order the following three functions from smallest to largest based on the value attained at their global maximum: 1) e^{-x^2} (read: *e to the power of quantity negative* x^2); 2) $\sin(x)/(x+1)^4$ (read: *sine of x divided by the quantity x+1 to the fourth power*); 3) xe^{-x} (read: *x times e to the negative x*).

ANSWER: 2, 3, 1

TOSS-UP

18) BIOLOGY – *Short Answer* In humans, negative feedback systems exist for many kinds of signals. In males, Sertoli cells prevent the overproduction of sperm by releasing what hormone which inhibits FSH release?

ANSWER: INHIBIN

BONUS

18) BIOLOGY – *Short Answer* Order the following three immune cells by increasing side scatter when conducting flow cytometry: 1) T cell; 2) Monocyte; 3) Basophil

ANSWER: 1, 2, 3

TOSS-UP

19) MATH – *Short Answer* How many terminal zeroes does the binary representation of 17 factorial have?

ANSWER: 15

BONUS

19) MATH – *Short Answer* If the five by five matrix M has a determinant of 3, what is the determinant of the matrix $2M$ (read: *2 times M*)?

ANSWER: 96

TOSS-UP

20) PHYSICS – *Short Answer* A laser beam is pointed at a pool with an index of refraction of 1.3. If the incident angle of the beam at the air-water interface is 8 degrees, then to one significant figure and in degrees, what is its refracted angle?

ANSWER: 6

BONUS

20) PHYSICS – *Short Answer* A small particle is sliding near the bottom of a frictionless hemispherical bowl with a diameter of 5 meters. To one significant figure and in seconds, what is the period of the particle's small oscillations?

ANSWER: 3

TOSS-UP

21) ENERGY – *Multiple Choice* The Pentelute Group developed PyBinder to calculate the p-values of proteomic studies. Which of the following rates, in expectation, is equal to the p-value of an experiment?

W) Rate of false positives
X) Rate of false negatives
Y) Rate of true positives
Z) Rate of true negatives

ANSWER: W) RATE OF FALSE POSITIVES

BONUS

21) ENERGY – *Short Answer* The Ono Lab studied minerals containing sulfur isotopes from the Great Oxidation Event. Identify all of the following three minerals that contain oxidized sulfur: 1) Galena; 2) Pyrite; 3) Anhydrite.

ANSWER: 2 AND 3

TOSS-UP

22) EARTH AND SPACE – *Multiple Choice* Which planet in our solar system has the largest Hill sphere?

W) Earth
X) Mars
Y) Uranus
Z) Neptune

ANSWER: Z) NEPTUNE

BONUS

22) EARTH AND SPACE – *Short Answer* Identify all of the following three luminosity relations that are correctly paired with their respective galaxy type: 1) Faber–Jackson relation, elliptical; 2) Tully–Fisher relation, spiral; 3) M–sigma relation, irregular.

ANSWER: 1 AND 2

TOSS-UP

23) BIOLOGY – *Short Answer* Order the following three types of muscle by increasing maximum V_{max} (read: *Vee-max*) of their myosin ATPases: 1) Cardiac; 2) Skeletal; 3) Smooth.

ANSWER: 3, 1, 2

BONUS

23) BIOLOGY – *Multiple Choice* Verno is studying a certain drug-protein complex localized to the membrane. He uses FRET (read: *fret*) to measure interaction between the drug and the protein. As his fluorescence signal increases in the FRET experiment, Verno photobleaches the membrane and finds that the fluorescence does not fully recover to its pre-bleach level. Which of the following is a logical conclusion he can make about the drug-protein complex?

W) They are interacting and increasing membrane fluidity
X) They are interacting and decreasing membrane fluidity
Y) They are not interacting and increasing membrane fluidity
Z) They are not interacting and decreasing membrane fluidity

ANSWER: X) THEY ARE INTERACTING AND DECREASING MEMBRANE FLUIDITY

TOSS-UP

24) CHEMISTRY – *Short Answer* How many nodal planes does the highest occupied molecular orbital of 1,3,5-hexatriene have?

ANSWER: 3

BONUS

24) CHEMISTRY – *Short Answer* Identify all of the following three reactions that could be propagation steps in the mechanism of an atmospheric reaction: 1) Water reacts with chlorine radical to yield hydrogen chloride and hydroxyl radical; 2) Hydrogen reacts with oxygen radical to yield water; 3) Water photolyzes to yield hydrogen and hydroxyl radical.

ANSWER: 1 ONLY

TOSS-UP

25) PHYSICS – *Multiple Choice* If the height from which water is poured into a lake is doubled while its flow rate remains constant, by what factor does the amplitude of the ripples produced change?

W) $1/2$ (read: *one over two*)
X) $\sqrt{2}/2$ (read: *the square root of two over two*)
Y) $\sqrt{2}$ (read: *the square root of two*)
Z) 2

ANSWER: Y) $\sqrt{2}$ (READ: *THE SQUARE ROOT OF TWO*)

BONUS

25) PHYSICS – *Short Answer* Evan adiabatically and reversibly expands an ideal gas from 1 liter to 10 liters. Rank the following three gases in order of increasing final temperature after this process: 1) Sulfur hexafluoride; 2) Carbon dioxide; 3) Hydrogen.

ANSWER: 3, 2, 1