2025 MIT Science Bowl High School Invitational

Round 4

TOSS-UP

1) PHYSICS – *Multiple Choice* Students in East Campus are spray-painting the walls of their dorm. After the paint hits and sticks to a wall, which of the following best describes where the majority of the momentum and kinetic energy of the paint are transferred to, respectively?

W) In the paint and released as heat
X) In the paint and in the Earth
Y) In the Earth and released as heat
Z) In the Earth and in the Earth

ANSWER: Y) IN THE EARTH AND RELEASED AS HEAT

BONUS

1) PHYSICS – *Short Answer* A charged particle undergoes circular motion in a uniform magnetic field. If the magnetic field's strength is quadrupled, by what factor does the particle's period of revolution change?

ANSWER: 1/4 (ACCEPT: 0.25)

TOSS-UP

2) BIOLOGY – *Multiple Choice* Caleb is studying certain amino acid residues in the insulin receptor that are phosphorylated upon dimerization (read: *dye-murr-ih-ZAY-shun*) of the receptor. Which amino acid, which is chemically similar to phenylalanine, is he studying?

W) Threonine
X) Tyrosine
Y) Alanine
Z) Histidine

ANSWER: X) TYROSINE

BONUS

2) BIOLOGY – *Multiple Choice* Jonah is trying to measure the transcriptome of T-cells that he treated with a promising phase 1 trial antitumor drug. Which of the following techniques could he NOT use to measure the transcriptome?

W) Northern blotting
X) RNA-seq (read: *R-N-A seek*)
Y) Fluorescence resonance energy transfer
Z) RT-PCR, followed by sequencing

ANSWER: Y) FLUORESCENCE RESONANCE ENERGY TRANSFER

TOSS-UP

3) ENERGY – *Multiple Choice* MIT neuroscientists at the Tonegawa group recently showed that fear can be learned in mouse brains. To study the development of fear, what region of the brain were the scientists likely studying?

W) Amygdala (read: *uh-MIG-duh-luh*)
X) Hypothalamus
Y) Cerebellum
Z) Wernicke's (read: *VERR-nick-uhs*) area

ANSWER: W) AMYGDALA (READ: *UH-MIG-DUH-LUH*)

BONUS

3) ENERGY – *Short Answer* Researchers in the Willard Group at MIT are studying the electrodynamics of conjugated molecular systems. Identify all of the following three numbers of delocalized pi electrons that result in an aromatic conjugated hydrocarbon: 1) 6; 2) 7; 3) 8.

ANSWER: 1 ONLY

TOSS-UP

4) MATH – *Short Answer* When the number 2025 is written in tally marks, how many vertical lines are drawn?

ANSWER: 1620

BONUS

4) MATH – *Short Answer* Ricky rearranges the integers from one to six with the restriction that the integer six cannot be first or last in the sequence. How many ways are there for him to order the numbers?

ANSWER: 480

TOSS-UP

5) CHEMISTRY – *Multiple Choice* When dissolved in water, ten grams of which of the following types of compounds will form a solution with the highest freezing point?

W) Molecular compound with low molar mass
X) Ionic compound with low molar mass
Y) Molecular compound with high molar mass
Z) Ionic compound with high molar mass

ANSWER: Y) MOLECULAR COMPOUND WITH HIGH MOLAR MASS

BONUS

5) CHEMISTRY – *Short Answer* Rank the following three elements by increasing first ionization energy: 1) Silicon; 2) Phosphorus; 3) Sulfur.

ANSWER: 1, 3, 2

TOSS-UP

6) EARTH AND SPACE – *Multiple Choice* Which of the following best describes what happens to P waves and S waves, respectively, when they encounter the outer core?

W) P waves are stopped, S waves are stopped
X) P waves are stopped, S waves are refracted
Y) P waves are refracted, S waves are stopped
Z) P waves are refracted, S waves are refracted

ANSWER: Y) P WAVES ARE REFRACTED, S WAVES ARE STOPPED

BONUS

6) EARTH AND SPACE – *Short Answer* Identify all of the following three settings where magma is mainly formed by decompression melting: 1) Subduction zone; 2) Continental rift; 3) Rising mantle plume.

ANSWER: 2 AND 3

TOSS-UP

7) PHYSICS – *Multiple Choice* Which of the following quantities has the same units as energy?

W) Entropy
X) Power
Y) Impulse
Z) Torque

ANSWER: Z) TORQUE

BONUS

7) PHYSICS – *Short Answer* Identify all of the following three statements about magnetic fields that are true in classical electromagnetism: 1) Magnetic fields only exert a force on particles carrying non-zero charge; 2) Magnetic fields only exert a force on moving objects; 3) Magnetic fields only do work on objects moving perpendicular to the field.

ANSWER: 1 AND 2

TOSS-UP

8) MATH – *Short Answer* If the incircle of a triangle has a radius of 3, what is the ratio of the triangle's area to its perimeter?

ANSWER: 1.5

BONUS

8) MATH – *Short Answer* There are 3 different earthlings and 3 different martians in a room. They must send a delegation of at least 2 beings to a meeting. How many ways are there to choose such a delegation, if there must be an equal number of earthlings and martians on it?

ANSWER: 19

TOSS-UP

9) ENERGY – *Short Answer* Researchers from CSAIL computationally engineered mutations to increase the brightness of what common fluorescent protein that fluoresces under blue light?

ANSWER: GREEN FLUORESCENT PROTEIN (ACCEPT: GFP)

BONUS

9) ENERGY – *Multiple Choice* The Teague Group studied the dynamics of fifteen protoplanetary disks using observations from the exoALMA program. Which of the following best describes where most mass in a protoplanetary disk is concentrated?

W) At the center
X) Near the center
Y) Near the edge
Z) At the edge

ANSWER: X) NEAR THE CENTER

TOSS-UP

10) CHEMISTRY – *Short Answer* Jonathan fills a balloon with two moles of an ideal gas at standard temperature and pressure. To the nearest whole number, how many liters of volume will the gas occupy inside the balloon?

ANSWER: 45

BONUS

10) CHEMISTRY – *Short Answer* Rank the following three substances by increasing standard melting point: 1) Gallium; 2) Iodine; 3) Lead.

ANSWER: 1, 2, 3

TOSS-UP

11) BIOLOGY – *Short Answer* Order the following three sites by when a charged tRNA would encounter them on the ribosome from earliest to latest: 1) A site; 2) E site; 3) P site.

ANSWER: 1, 3, 2

BONUS

11) BIOLOGY – *Short Answer* Caleb is studying the epigenome of his retina cells and notices that the region around the myoglobin protein is heavily compacted. Identify all of the following three treatments that could decrease the compaction in this region: 1) Removing methylated cytosines; 2) Adding acetyl groups to the histone tails; 3) Removing phosphate groups from the histone tails.

ANSWER: 1 AND 2

TOSS-UP

12) EARTH AND SPACE – *Multiple Choice* Which of the following best describes the formation of an occluded front?

W) A cold front overtakes a warm front
X) A warm front overtakes a cold front
Y) A cold front overtakes a cold front
Z) A warm front overtakes a warm front

ANSWER: W) A COLD FRONT OVERTAKES A WARM FRONT

BONUS

12) EARTH AND SPACE – *Short Answer* Identify all of the following three coastal landforms that require wave refraction to form: 1) Marine terrace; 2) Barrier island; 3) Sea arch.

ANSWER: 3 ONLY

TOSS-UP

13) BIOLOGY – *Short Answer* The first time Caleb pets a turtle, it retracts back into its shell. However, after petting the turtle many more times, it no longer retracts into its shell. What type of learning is this an example of?

ANSWER: HABITUATION (ACCEPT: DESENSITIZATION)

BONUS

13) BIOLOGY – *Short Answer* Identify all of the following three statements that are true about mycorrhizae (read: *my-koh-RYE-zee*): 1) Most mycorrhizal fungi are glomeromycetes (read: *glom-er-oh-MY-seets*); 2) Mycorrhizae primarily help absorb nitrogenous nutrients; 3) Nutrients taken up by ectomycorrhizae must enter the apoplast before they can enter the symplast.

ANSWER: 1 AND 3

TOSS-UP

14) MATH – *Short Answer* A cube is divided into two identical pieces by a cut parallel to one of its faces. What is the ratio of the combined surface area of the two resulting pieces to the surface area of the initial cube?

ANSWER: 4/3

BONUS

14) MATH – *Short Answer* What is the exponent of the largest power of 8 that evenly divides 20! (read: *20 factorial*)?

ANSWER: 6

TOSS-UP

15) ENERGY – *Short Answer* Polymer scientists at the Olsen Group developed a technique to recycle rubber. Recycling rubber requires breaking cross-linking bonds formed between atoms of what element?

ANSWER: SULFUR

BONUS

15) ENERGY – *Multiple Choice* Scientists from the Earthquake Science Group measure the seismic moment of earthquakes, which is the product of the area of the fault rupture, the fault displacement, and the shear modulus of the fault's material. Which of the following physical quantities has the same SI units as the seismic moment?

W) Linear momentum
X) Force
Y) Angular momentum
Z) Torque

ANSWER: Z) TORQUE

TOSS-UP

16) CHEMISTRY – *Multiple Choice* Which of the following compounds can act as a Lewis acid, but not as a Bronsted-Lowry acid?

W) Sulfuric acid
X) Ammonia
Y) Borane
Z) Potassium iodide

ANSWER: Y) BORANE

BONUS

16) CHEMISTRY – *Multiple Choice* The photoelectron spectrum of an unknown element contains five peaks. Which of the following could be the identity of the unknown element?

W) Magnesium
X) Aluminum
Y) Potassium
Z) Chromium

ANSWER: X) ALUMINUM

TOSS-UP

17) PHYSICS – *Multiple Choice* Two spherical cows have the same mass distribution and identical concentric spherical stomachs. The first cow is fed with no change in its stomach's radius, while the second cow's stomach remains empty. When both cows are rolled from the same height down an incline, which cow will reach the bottom first?

W) The first cow, because its mass is greater
X) The first cow, because its mass is more concentrated at its center
Y) The second cow, because its moment of inertia is smaller
Z) The second cow, because it experiences less friction

ANSWER: X) THE FIRST COW, BECAUSE ITS MASS IS MORE CONCENTRATED AT ITS CENTER

BONUS

17) PHYSICS – *Short Answer* Abigail is frolicking the Infinite Corridor according to the one-dimensional position function $x(t) = \sqrt{t}$ (read: *x of t equals the square root of t*). Identify all of the following three properties of Abigail's motion that remain constant over time: 1) Velocity; 2) Acceleration; 3) Kinetic energy.

ANSWER: NONE

TOSS-UP

18) EARTH AND SPACE – *Multiple Choice* Io's bright colouration is primarily caused by allotropes of which element?

W) Sulfur
X) Phosphorus
Y) Iron
Z) Carbon

ANSWER: W) SULFUR

BONUS

18) EARTH AND SPACE – *Multiple Choice* Which of the following is closest to the time in years a one solar-mass star spends on the red giant branch?

W) 1 million
X) 10 million
Y) 100 million
Z) 1 billion

ANSWER: Z) 1 BILLION

TOSS-UP

19) PHYSICS – *Multiple Choice* Which of the following describes the electric potential inside of a positively charged solid conducting sphere, relative to infinity?

W) Zero
X) Nonzero constant
Y) Increasing with distance from center
Z) Decreasing with distance from center

ANSWER: X) NONZERO CONSTANT

BONUS

19) PHYSICS – *Short Answer* Sai holds a 1-kilogram ball with a volume of 2 liters underwater. To two significant figures and in newtons, what is the magnitude of the normal force of Sai's hand on the ball?

ANSWER: 9.8

TOSS-UP

20) ENERGY – *Multiple Choice* Particle physicists from MIT are analyzing normally distributed measurements made at Fermilab's DUNE particle detector. Which of the following percentiles is closest to one standard deviation above the mean in a symmetric normal distribution?

W) 68
X) 84
Y) 95
Z) 99

ANSWER: X) 84

BONUS

20) ENERGY – *Short Answer* Researchers at CSAIL improved models predicting chemical motifs using the special Euclidean group in three dimensions, whose elements are all motions of a rigid body. Identify all of the following three transformations that belong in this group: 1) Rotation; 2) Translation; 3) Reflection.

ANSWER: 1 AND 2

TOSS-UP

21) MATH – *Short Answer* Sir Anthony Eddington III is organizing his army of knights. When arranging them in rows of 4, he finds that 2 knights are left over. When arranging them in rows of 5, 3 knights are left over. When arranging them in rows of 7, 5 knights are left over. What is the minimum number of knights that could be in Sir Anthony's army?

ANSWER: 138

BONUS

21) MATH – *Short Answer* What is the sum of the coefficients of the polynomial $(x-2)^2(2x-3)(3x+5)$ (read: *quantity x minus two squared times quantity two x minus three times quantity three x plus five*)?

ANSWER: -8

TOSS-UP

22) EARTH AND SPACE – *Multiple Choice* The detection of electromagnetic radiation of which of the following wavelengths would be most impaired by high humidity conditions?

W) 1 millimeter
X) 1 centimeter
Y) 1 decimeter
Z) 1 meter

ANSWER: W) 1 MILLIMETER

BONUS

22) EARTH AND SPACE – *Multiple Choice* Which of the following best describes how an E7 galaxy differs from an E0 galaxy?

W) It is more elongated
X) It has a higher B-V index
Y) It is more massive
Z) It has higher metallicity

ANSWER: W) IT IS MORE ELONGATED

TOSS-UP

23) BIOLOGY – *Multiple Choice* Which of the following chambers of the heart has the thickest myocardium?

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

ANSWER: Z) LEFT VENTRICLE

BONUS

23) BIOLOGY – *Short Answer* James has just been prescribed Zestril to lower his blood pressure. Drugs like Zestril work because they inhibit the enzyme ACE (read: *ace*), which normally catalyzes the production of what vasoconstrictive hormone?

ANSWER: ANGIOTENSIN II

TOSS-UP

24) CHEMISTRY – *Multiple Choice* Which of the following gas-phase molecules is nonplanar in its ground state?

W) Xenon tetrafluoride
X) Boron tribromide
Y) Sulfur tetrachloride
Z) Water vapor

ANSWER: Y) SULFUR TETRACHLORIDE

BONUS

24) CHEMISTRY – *Multiple Choice* The average speed of an ideal gas is proportional to which of the following?

W) Temperature times molar mass
X) Square root of temperature times molar mass
Y) Temperature divided by molar mass
Z) Square root of temperature divided by molar mass

ANSWER: Z) SQUARE ROOT OF TEMPERATURE DIVIDED BY MOLAR MASS

TOSS-UP

25) PHYSICS – *Short Answer* A pile of sand cannot sustain its own weight if the angle of its slope exceeds 60 degrees. To the nearest tenth, what is the coefficient of static friction between individual grains of sand in the pile?

ANSWER: 1.7

BONUS

25) PHYSICS – *Short Answer* A Carnot (read: *kar-no*) engine is powered by two heat reservoirs of 270 and 540 degrees Celsius, respectively. To one significant figure, what is the efficiency of this engine?

ANSWER: 0.3