2025 MIT Science Bowl High School Invitational

Wildcard Round 2

TOSS-UP

1) PHYSICS – *Short Answer* Daniel is driving his 2 metric ton car along Memorial Drive at 20 meters per second when he collides with Fiona's stationary car. If Daniel's car slows to a stop within 0.5 seconds, what was the time-averaged impact force experienced by Fiona's car in Newtons?

ANSWER: 80,000

BONUS

1) PHYSICS – *Short Answer* An asteroid of radius 100 meters and surface gravitational acceleration 0.1 meters per second squared spins with angular velocity 0.02 radians per second. Garfield, of mass 100 kilograms, sits on the equator of this asteroid. To the nearest Newton, what is the normal force of the asteroid on Garfield?

ANSWER: 6

TOSS-UP

2) EARTH AND SPACE – *Multiple Choice* Titus is camping in Plumas National Forest when he observes the following series of clouds approaching him from a distance: Cirrus, Altostratus, Nimbostratus. Which of the following weather fronts is likely approaching him?

W) Warm Front
X) Cold Front
Y) Occluded Front
Z) Dryline

ANSWER: W) WARM FRONT

BONUS

2) EARTH AND SPACE – *Multiple Choice* What type of fog most commonly develops alongside a thermal inversion?

W) Radiation fog
X) Upslope fog
Y) Steam fog
Z) Advection fog

ANSWER: W) RADIATION FOG

TOSS-UP

3) BIOLOGY – *Multiple Choice* Which of the following is most likely true about the first enzymes on earth?

W) They were composed of amino acid subunits
X) They contained phosphodiester bonds
Y) They were similar in structure to most current enzymes
Z) They required other macromolecules for replication

ANSWER: X) THEY CONTAINED PHOSPHODIESTER BONDS

BONUS

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

ANSWER: 2, 1, 2003

TOSS-UP

4) CHEMISTRY – *Short Answer* What is the molecular geometry of sulfur atom in the sulfate ion?

ANSWER: TETRAHEDRAL

BONUS

4) CHEMISTRY – *Short Answer* The atomic weights of lithium, oxygen, and sulfur are 7, 16, and 32 atomic mass units, respectively. To the nearest hundredth, how many moles of lithium sulfate are in a 13.2 gram sample?

ANSWER: 0.12

TOSS-UP

5) MATH – *Short Answer* Two numbers have a sum of 6 and a difference of 8. What is the sum of the squares of the numbers?

ANSWER: 50

BONUS

5) MATH – *Short Answer* How many four digit positive integers satisfy the property that the product of their digits is 2025?

ANSWER: 6

TOSS-UP

6) ENERGY – *Short Answer* The Walker Lab developed a peptide therapy to sequester free hemes in the bloodstream. What metal at the center of hemes binds to their peptide?

ANSWER: IRON

BONUS

6) ENERGY – *Multiple Choice* MIT engineers used aluminum from soda cans and seawater to sustainably produce hydrogen. What type of electrochemical cell could be more sustainable as a result of their work?

W) Leclanché cell
X) Downs cell
Y) Bunsen cell
Z) Fuel cell

ANSWER: Z) FUEL CELL

TOSS-UP

7) BIOLOGY – *Short Answer* Dideoxynucleotide (read: *di-dee-oxy-NEW-clee-oh-tide*) triphosphates, used for Sanger Sequencing, lack what functional group at the 3' carbon necessary for DNA elongation?

ANSWER: HYDROXYL (ACCEPT: OH)

BONUS

7) BIOLOGY – *Multiple Choice* Which of the following fungal divisions have the highest proportion of organisms that form arbuscular mycorrhizae (read: *ar-BUS-kew-lar mai-koh-RIH-zae*)?

W) Chytridiomycota (read: *ky-try-dee-oh-my-koh-tuh*)
X) Glomeromycota (read: *glom-er-o-my-CO-ta*)
Y) Ascomycota (read: *as-koh-my-ko-tuh*)
Z) Basidiomycota (read: *buh-sid-ee-oh-mahy-koh-tuh*)

ANSWER: X) GLOMEROMYCOTA (READ: *GLOM-ER-O-MY-CO-TA*)

TOSS-UP

8) MATH – *Short Answer* What is the smallest three digit integer with no odd prime factors?

ANSWER: 128

BONUS

8) MATH – *Short Answer* Two of the digits of a three digit number are 2 and 9. Given that the number is divisible by 11, what are all possible values for the remaining digit?

ANSWER: 0, 4, 7

TOSS-UP

9) EARTH AND SPACE – *Short Answer* Identify all of the following three features that definitively indicate a retreating glacier: 1) Terminal Moraine; 2) Kettle Lakes; 3) Esker

ANSWER: 2 ONLY

BONUS

9) EARTH AND SPACE – *Short Answer* What type of storm system is characterized by a mesocyclone within a thunderstorm and spatially separated updraft and downdraft regions?

ANSWER: SUPERCELL

TOSS-UP

10) ENERGY – *Multiple Choice* Researchers in the Radosevich group at MIT are studying homogenous catalysis based on p-block elements. Which of the following is not a p-block element?

W) Helium
X) Oxygen
Y) Phosphorus
Z) Bromine

ANSWER: W) HELIUM

BONUS

10) ENERGY – *Short Answer* Economists at MIT applied regression to school assignment models. To handle multicollinearity in their dataset, the researchers added a penalty term to the objective that is only dependent on the regression model's derived weights. This approach is an example of what general technique in machine learning to prevent overfitting?

ANSWER: REGULARIZATION (DO NOT ACCEPT: VARIANTS OF REGULARIZATION)

TOSS-UP

11) PHYSICS – *Short Answer* When a sound wave is emanated isotropically from a point source, the intensity of the wave is linearly proportional to what power of the distance from the point source?

ANSWER: -2

BONUS

11) PHYSICS – *Short Answer* Billy is measuring an AC signal in a circuit when he notices that placing his hand near the circuit causes the signal amplitude to jump from 2 volts to 4 volts. To the nearest whole number, this is a change by how many decibels in signal strength?

ANSWER: 6

TOSS-UP

12) CHEMISTRY – *Multiple Choice* Which of the following elements burns red in a flame test?

W) Lithium
X) Beryllium
Y) Sodium
Z) Magnesium

ANSWER: W) LITHIUM

BONUS

12) CHEMISTRY – *Multiple Choice* Which of the following solutions has the highest osmotic pressure at STP?

W) 1 molar glucose
X) 1 molar acetic acid
Y) 0.5 molar sodium chloride
Z) 0.5 molar sulfuric acid

ANSWER: Z) 0.5 MOLAR SULFURIC ACID

TOSS-UP

13) MATH – *Short Answer* In Tim's ball collection, every ball is red, green, or blue. If 3/5 of Tim's balls are red, 1/3 of Tim's balls are green, and the remaining 3 balls are blue, how many balls are in Tim's ball collection?

ANSWER: 45

BONUS

13) MATH – *Short Answer* Brian writes down an infinite sequence, beginning $6, 2, 1, 1/3, 1/6$ and continuing infinitely, alternating dividing by three and dividing by two. What is the sum of all terms in this sequence?

ANSWER: $48/5$ (ACCEPT: 9.6)

TOSS-UP

14) BIOLOGY – *Short Answer* Mollusks are able to mechanically breakdown food before it enters their digestive tract through what teeth like feeding structure?

ANSWER: RADULA

BONUS

14) BIOLOGY – *Short Answer* Select all of the following four hormones in the female reproductive system whose level rises during the luteal phase after ovulation in a nonpregant person. 1) LH; 2) FSH; 3) Estrogen; 4) Progesterone

ANSWER: 3 AND 4

TOSS-UP

15) CHEMISTRY – *Short Answer* What is the formal charge on the carbon atom in the cyanide anion?

ANSWER: -1

BONUS

15) CHEMISTRY – *Short Answer* Identify all of the following three inorganic acids that are considered strong acids: 1) HF; 2) HOCl; 3) $IO(OH)_5$.

ANSWER: NONE

TOSS-UP

16) ENERGY – *Short Answer* MIT physicists supported by the LHC are searching for the Higgs boson in the remnants of proton-proton collisions. Through its namesake mechanism, the Higgs boson generates what intrinsic property of all particles in the standard model?

ANSWER: MASS (ACCEPT: REST MASS)

BONUS

16) ENERGY – *Short Answer* Researchers at the Broad Institute are modelling the spatial arrangement of cells in various tissues using adjacency matrices. As each cell has a relatively small number of neighbors, most entries in this matrix are equal to 0. What general term is given to matrices with few nonzero entries?

ANSWER: SPARSE

TOSS-UP

17) PHYSICS – *Short Answer* A beaver is driving a Tim-mobile, whose displacement as a function of the number of seconds t after starting its engine is $13t^4 - 6t^2 - 1$ (read: *thirteen t to the fourth minus six t squared minus one*). What is the acceleration of the Tim-mobile 2 seconds after the beaver starts its engine?

ANSWER: 612 (ACCEPT: 612 UNITS)

BONUS

17) PHYSICS – *Short Answer* Jessie measures the side length of a cube as 10 ± 0.2 (read: *ten plus-or-minus zero point two*) meters. What is the uncertainty in the cube's volume, in cubic meters?

ANSWER: 60

TOSS-UP

18) EARTH AND SPACE – *Multiple Choice* Which of the following types of stars has the strongest stellar winds?

W) Blue Horizontal Branch
X) Luminous Blue Variable
Y) Red Supergiant
Z) T Tauri

ANSWER: X) LUMINOUS BLUE VARIABLE

BONUS

18) EARTH AND SPACE – *Short Answer* Order the following four celestial bodies by increasing density: 1) Europa; 2) Saturn; 3) Neptune; 4) Mars

ANSWER: 2,3,1,4

TOSS-UP

19) CHEMISTRY – *Multiple Choice* The rate constant for the reaction between aqueous A and B has units of liters squared per mole squared seconds. Which of the following could correctly describe the orders of this reaction with respect to A and B?

W) First order in A, first order in B
X) First order in A, zeroth order in B
Y) Second order in A, first order in B
Z) Second order in A, second order in B

ANSWER: Y) SECOND ORDER IN A, FIRST ORDER IN B

BONUS

19) CHEMISTRY – *Multiple Choice* Robert is using dilute hydrochloric acid to titrate a solution of sodium bicarbonate. Which of the following apparatuses would be best suited for Robert's experiment?

W) Pasteur pipette ***[pipe-ET]***
X) Volumetric pipette
Y) Micropipette
Z) Buret ***[bier-ET]***

ANSWER: Z) BURET ***[BIER-ET]***

TOSS-UP

20) BIOLOGY – *Short Answer* Aryan is studying germ layers and tries to identify them in Cnidarians (read: *nai-DAR-ee-uhnz*). Identify all of the following three germ layers that can be found in all cnidarians: 1) Ectoderm; 2) Endoderm; 3) Mesoderm.

ANSWER: 1 AND 2

BONUS

20) BIOLOGY – *Multiple Choice* If Aryan has constituitively active G protein coupled receptors, the signaling pathway of which of the following tastes is least likely to be affected?

W) Sour
X) Bitter
Y) Umami
Z) Sweet

ANSWER: W) SOUR

TOSS-UP

21) PHYSICS – *Multiple Choice* A physics textbook is at rest on a flat table. Ethan attempts to push the textbook but fails to overcome friction. Which of the following statements cannot be true regarding this situation?

W) The magnitude of friction force is greater than the magnitude of normal force
X) The coefficient of kinetic friction is zero
Y) Ethan does positive work on the textbook
Z) The friction force is less than the coefficient of static friction times the normal force

ANSWER: Y) ETHAN DOES POSITIVE WORK ON THE TEXTBOOK

BONUS

21) PHYSICS – *Short Answer* A copper sphere of radius 3 centered at the origin has a spherical cavity of radius 0.25 centered at x equals 0.5. After thermal expansion, the volume of the copper sphere increases by a factor of three. What is the new x position of the center of the cavity, assuming that the center of the entire sphere doesn't move?

ANSWER: $\sqrt[3]{3}/2$ (READ: *ONE-HALF TIMES THE CUBE ROOT OF THREE*)

TOSS-UP

22) ENERGY – *Multiple Choice* Scientists from the Solomon Group predicted with 95% confidence that the Antarctic ozone hole is recovering from damage by CFCs. Which of the following was their null hypothesis?

W) CFCs are damaging the ozone layer above Antarctica
X) CFCs are not damaging the ozone layer above Antarctica
Y) The ozone layer above Antarctica is recovering
Z) The ozone layer above Antarctica is not recovering

ANSWER: Z) THE OZONE LAYER ABOVE ANTARCTICA IS NOT RECOVERING

BONUS

22) ENERGY – *Short Answer* The Wisdom Group is advancing numerical integration techniques to solve the N-body problem in astronomy. What is the smallest number of bodies in an N-body problem that cannot be solved analytically in general and instead requires numerical integration?

ANSWER: 3

TOSS-UP

23) EARTH AND SPACE – *Multiple Choice* An isolated binary system consists of two neutron stars orbiting each other. Over a very long time, how does their period change?

W) Lengthens at an accelerating pace
X) Lengthens at a decelerating pace
Y) Shortens at an accelerating pace
Z) Shortens at a decelerating pace

ANSWER: Y) SHORTENS AT AN ACCELERATING PACE

BONUS

23) EARTH AND SPACE – *Short Answer* Order the following three nuclear fusion reactions by increasing temperature of ignition: 1) two hydrogen-1 nuclei produce a hydrogen-2 nucleus; 2) three helium-4 nuclei produce a carbon-12 nucleus; 3) a lithium-7 nucleus and a hydrogen-1 nucleus fuse to form two helium-4 nuclei

ANSWER: 3,1,2

TOSS-UP

24) MATH – *Multiple Choice* Given that x has more than one distinct prime factor, which of these could NOT be the number of factors of x?

W) 97
X) 98
Y) 99
Z) 100

ANSWER: W) 97

BONUS

24) MATH – *Short Answer* What is the greatest positive integer that must divide the sum of the first 2025 terms of an arithmetic sequence of integers?

ANSWER: 2025

TOSS-UP

25) PHYSICS – *Multiple Choice* Which of the following configurations of quarks has the same net charge as a proton?

W) 3 up quarks
X) 2 up quarks and 1 down quark
Y) 1 up quark and 2 down quarks
Z) 3 down quarks

ANSWER: X) 2 UP QUARKS AND 1 DOWN QUARK

BONUS

25) PHYSICS – *Short Answer* A planet's mass doubles without changing its density or angular rate of rotation. By what factor does the radius of its geostationary orbit change?

ANSWER: $\sqrt[3]{2}$ (READ: *THE CUBE ROOT OF TWO*) (ACCEPT: $2^{1/3}$ (READ: *TWO RAISED TO THE ONE-THIRD POWER*))