

2025 MIT Science Bowl High School Invitational

Round 2

TOSS-UP

1) PHYSICS – *Short Answer* A circuit consists of an ideal 12-volt battery connected to an ideal 72-ohm resistor. In watts, what is the power dissipated by the circuit?

ANSWER: 2

BONUS

1) PHYSICS – *Multiple Choice* Anurag starts driving along a straight road at a constant speed. Which of the following describes how his car's angular momentum changes with respect to a fire hydrant on the side of the road?

- W) Constant
- X) Increases monotonically
- Y) Decreases monotonically
- Z) Decreases, then increases

ANSWER: W) CONSTANT

TOSS-UP

2) EARTH AND SPACE – *Short Answer* Temperature increases with height in the stratosphere due to the presence of what UV-absorbing molecule?

ANSWER: OZONE

BONUS

2) EARTH AND SPACE – *Short Answer* Identify all of the following three processes that would decrease the strength of a tropical halocline: 1) River run-off; 2) Converging storms; 3) Coastal upwelling.

ANSWER: ALL

TOSS-UP

3) BIOLOGY – *Short Answer* Often considered the most abundant protein in the world, which protein is responsible for fixing carbon into RuBP (read: *roo-bee-pee*) in the Calvin cycle?

ANSWER: RUBISCO (ACCEPT: RIBULOSE-1,5-BISPHOSPHATE CARBOXYLASE/OXYGENASE)

BONUS

3) BIOLOGY – *Short Answer* Identify all of the following three statements that are true of mitochondria: 1) They contain circular chromosomes; 2) They have a higher pH in the matrix than the intermembrane space; 3) The folds that increase surface area in them are called cisternae.

ANSWER: 1 AND 2

TOSS-UP

4) CHEMISTRY – *Multiple Choice* Graphite is composed of layers of graphene held together by which of the following interactions?

- W) Covalent
- X) Ionic
- Y) Van der Waals
- Z) Dipole-dipole

ANSWER: Y) VAN DER WAALS

BONUS

4) CHEMISTRY – *Short Answer* Identify all of the following three diatomic molecules that are predicted to be paramagnetic by molecular orbital theory: 1) N₂; 2) NO; 3) O₂.

ANSWER: 2 AND 3

TOSS-UP

5) MATH – *Short Answer* Doug has a 10% off coupon and a 20% off coupon for hot dogs. If he buys one hot dog and uses both coupons simultaneously, what is his total percent discount?

ANSWER: 28 (ACCEPT: 28%)

BONUS

5) MATH – *Short Answer* The number 2025 is a perfect square. How many perfect squares less than or equal to 2025 end in the digit 5?

ANSWER: 5

TOSS-UP

6) ENERGY – *Short Answer* Chemists at MIT supported by the DOE studied pheophytin (read: *fee-o-fye-tin*), a carrier in the light reactions. Pheophytin is a modified form of what molecule without the central magnesium ion?

ANSWER: CHLOROPHYLL

BONUS

6) ENERGY – *Short Answer* Researchers at the Spranger Lab at MIT have been studying the immunosuppressive effects of tumors on T cells meant to kill them. These T cells kill tumor cells by recognizing an abnormal version of what structure on the cell surface?

ANSWER: MAJOR HISTOCOMPATIBILITY COMPLEX (ACCEPT: MHC I, DO NOT ACCEPT: MHC II)

TOSS-UP

7) BIOLOGY – *Multiple Choice* Which of the following substances would diffuse the fastest through a mammalian cell lipid bilayer?

- W) Water
- X) Sodium
- Y) Carbon dioxide
- Z) Glucose

ANSWER: Y) CARBON DIOXIDE

BONUS

7) BIOLOGY – *Multiple Choice* Alice and Bob have a daughter named Christine. If Alice has a disease while Bob does not, which of the following inheritance patterns would lead to Christine having the lowest probability of having the disease?

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

ANSWER: Z) X-LINKED RECESSIVE

TOSS-UP

8) MATH – *Short Answer* How many positive integers less than 1,000,000 are perfect squares but not perfect cubes?

ANSWER: 990

BONUS

8) MATH – *Short Answer* What is the largest prime factor of $2^8 + 8^2$ (read: *quantity two to the power of eight plus quantity eight squared*)?

ANSWER: 5

TOSS-UP

9) EARTH AND SPACE – *Multiple Choice* Which of the following minerals is a silicate?

- W) Pyrite
- X) Calcite
- Y) Muscovite
- Z) Sphalerite

ANSWER: Y) MUSCOVITE

BONUS

9) EARTH AND SPACE – *Short Answer* What term describes the upward movement of the lithosphere in recently deglaciated regions?

ANSWER: ISOSTATIC REBOUND (ACCEPT: POST-GLACIAL REBOUND, CRUSTAL REBOUND, DO NOT ACCEPT: GRAVITY)

TOSS-UP

10) ENERGY – *Short Answer* Researchers in the Weiss Group are studying Mars' paleomagnetic history through samples from the Perseverance rover. What effect is believed to be responsible for Mars' past magnetic field as well as Earth's current magnetic field?

ANSWER: DYNAMO

BONUS

10) ENERGY – *Short Answer* The Kulik Group studied DMFases that catalyze the hydrolysis of amides into an amine and what other functional group?

ANSWER: CARBOXYLIC ACID (ACCEPT: CARBOXYLATE, CARBOXYL)

TOSS-UP

11) PHYSICS – *Short Answer* What is the name of the probability distribution followed by the speeds of non-relativistic ideal gas particles at thermal equilibrium?

ANSWER: MAXWELL-BOLTZMANN

BONUS

11) PHYSICS – *Short Answer* Identify all of the following three physical quantities that are considered state functions: 1) Volume; 2) Pressure; 3) Temperature.

ANSWER: ALL

TOSS-UP

12) CHEMISTRY – *Short Answer* An atom emits two alpha particles and two beta-minus particles, resulting in the stable isotope lead-207. What was the mass number of the original atom?

ANSWER: 215

BONUS

12) CHEMISTRY – *Multiple Choice* At a fixed pressure, volume, and temperature, which of the following properties of an ideal gas is independent of the gas's identity?

- W) Density
- X) Average kinetic energy
- Y) Mean-squared velocity
- Z) Adiabatic index

ANSWER: X) AVERAGE KINETIC ENERGY

TOSS-UP

13) MATH – *Short Answer* Students in Baker House are baking cookies. They have 30 ounces of cookie dough, and are making small and large cookies that use 3 and 5 ounces of dough, respectively. What is the difference between the minimum and maximum number of cookies they can make using all of their dough?

ANSWER: 4

BONUS

13) MATH – *Short Answer* Eric has one red, one orange, one yellow, and one green ball in a bag. He repeatedly draws balls from the bag randomly and without replacement until he draws the red ball, at which point he stops. What is the probability that all four balls are drawn?

ANSWER: 1/4

TOSS-UP

14) BIOLOGY – *Multiple Choice* Todd is studying a certain plant ground tissue under the microscope that stains red with phloroglucinol-HCl (read: *florr-oh-GLOO-suh-nol*). He notices that the tissue is extremely lignified, has secondary cell walls, and is also dead at maturity. Which of the following classes of tissue is he likely studying?

- W) Aerenchyma (read: *air-ENG-kuh-muh*)
- X) Parenchyma (read: *pair-ENG-kuh-muh*)
- Y) Collenchyma (read: *coll-ENG-kuh-muh*)
- Z) Sclerenchyma (read: *sclair-ENG-kuh-muh*)

ANSWER: Z) SCLERENCHYMA (READ: *SCLAIR-ENG-KUH-MUH*)

BONUS

14) BIOLOGY – *Short Answer* Starting from the thylakoid space of a chloroplast, the Magic School Bus would like to travel to the inside of the nucleus of the same cell. How many membranes does the Magic School Bus need to travel through?

ANSWER: 5

TOSS-UP

15) CHEMISTRY – *Multiple Choice* Which of the following compounds has a square planar molecular geometry?

- W) Carbon tetrafluoride
- X) Silicon tetrafluoride
- Y) Sulfur tetrafluoride
- Z) Xenon tetrafluoride

ANSWER: Z) XENON TETRAFLUORIDE

BONUS

15) CHEMISTRY – *Short Answer* If the energy difference between the $n = 3$ and $n = 2$ levels in a hydrogen atom is 1.9 electron-volts, then to two significant figures and in electron-volts, what is the energy difference between the $n = 3$ and $n = 2$ levels in a He^+ (read: *Helium 1+*) cation?

ANSWER: 7.6

TOSS-UP

16) ENERGY – *Short Answer* Researchers from the MIT LIGO Group are studying gravitational waves. In terms of the speed of light in a vacuum c , what is the speed of a gravitational wave?

ANSWER: c (DO NOT ACCEPT: $1, 3 \times 10^8$)

BONUS

16) ENERGY – *Multiple Choice* Researchers in the Summons Lab used instruments they developed to extract DNA from nanopores in olivine's structure. Which of the following best describes olivine's structure?

- W) Thin layered silicate sheets
- X) Chains of linked silica tetrahedra
- Y) Silica tetrahedra linked in three-dimensional network
- Z) Isolated silica tetrahedra

ANSWER: Z) ISOLATED SILICA TETRAHEDRA

TOSS-UP

17) PHYSICS – *Short Answer* Select all of the following three particles that are baryons: 1) Photons; 2) Protons; 3) Neutrinos

ANSWER: 2 ONLY (ACCEPT: PROTONS ONLY)

BONUS

17) PHYSICS – *Short Answer* A ball is launched horizontally off a vertical cliff of height 20 meters, and lands 20 meters away from the base of the cliff. To the nearest whole number and in meters per second, what horizontal velocity was the ball launched at?

ANSWER: 10

TOSS-UP

18) EARTH AND SPACE – *Multiple Choice* Which of the following statements about Type Ia (read: *type one-A*) supernovae is not true?

- W) Type Ia supernovae spectra exhibit strong hydrogen lines
- X) Type Ia supernovae can be used as standard candles
- Y) Type Ia supernovae occur when the mass of white dwarves exceeds about 1.44 solar masses
- Z) Type Ia supernovae often occur in binary star systems

ANSWER: W) TYPE IA SUPERNOVAE SPECTRA EXHIBIT STRONG HYDROGEN LINES

BONUS

18) EARTH AND SPACE – *Short Answer* Order the following three regions of the Milky Way galaxy by increasing concentration of population II stars: 1) Bulge; 2) Disk; 3) Halo.

ANSWER: 2, 1, 3

TOSS-UP

19) CHEMISTRY – *Short Answer* Rank the following three elements by increasing electronegativity: 1) Oxygen; 2) Fluorine; 3) Chlorine.

ANSWER: 3, 1, 2

BONUS

19) CHEMISTRY – *Multiple Choice* Which of the following changes results in the greatest increase in entropy of the universe per mole at standard temperature and pressure?

- W) Dry ice sublimating
- X) Water ice melting
- Y) Sodium chloride dissolving
- Z) Hydrogen gas burning

ANSWER: Z) HYDROGEN GAS BURNING

TOSS-UP

20) BIOLOGY – *Short Answer* Even when a person is upside down, it is possible to completely swallow a bolus through the action of which muscular mechanism?

ANSWER: PERISTALSIS

BONUS

20) BIOLOGY – *Multiple Choice* Which of the following is NOT a shared feature among archaea and bacteria?

- W) Lack of nuclei
- X) Lack of histones
- Y) Circular chromosome
- Z) Lack of membrane enclosed organelles

ANSWER: X) LACK OF HISTONES

TOSS-UP

21) PHYSICS – *Short Answer* A frog on a one-dimensional axis has an instantaneous velocity of zero. Identify all of the following three vectors that could describe the frog’s instantaneous acceleration: 1) One meter per second squared to the left; 2) One meter per second squared to the right; 3) Zero.

ANSWER: ALL

BONUS

21) PHYSICS – *Short Answer* Rank the following three substances by increasing speed of sound in the substances: 1) Water vapor; 2) Liquid water; 3) Ice.

ANSWER: 1, 2, 3

TOSS-UP

22) ENERGY – *Multiple Choice* Researchers at CSAIL’s Julia Lab developed software for generating fast interpolations of datasets. Which of the following results from interpolating a dataset?

- W) Removing extraneous outliers
- X) Approximating shape of data
- Y) Separating data by similarity
- Z) Smoothing rough data

ANSWER: X) APPROXIMATING SHAPE OF DATA

BONUS

22) ENERGY – *Multiple Choice* Researchers at the Braatz Group are interpreting the coefficients of high-dimensional regression problems. Which of the following qualitatively describes how the interpretability of regression coefficients changes as the number of dimensions increases?

- W) The interpretability increases
- X) The interpretability decreases
- Y) The interpretability decreases, then increases
- Z) The interpretability is unaffected

ANSWER: X) THE INTERPRETABILITY DECREASES

TOSS-UP

23) EARTH AND SPACE – *Short Answer* Which two elements dominate the composition of M-type asteroids?

ANSWER: IRON, NICKEL (ACCEPT: FE, NI)

BONUS

23) EARTH AND SPACE – *Multiple Choice* In which of the following locations would one be most likely to find Bok globules?

- W) An open cluster
- X) A globular cluster
- Y) A star-forming nebula
- Z) A supernova remnant

ANSWER: Y) A STAR-FORMING NEBULA

TOSS-UP

24) MATH – *Short Answer* Two sides of a triangle have lengths 11 and 16. How many possible integer lengths are there for the third side?

ANSWER: 21

BONUS

24) MATH – *Short Answer* Alice and Bob are swimming back and forth across a pool. Alice swims the pool's length in 30 seconds, while Bob swims the pool's length in 40 seconds. If they leave at the same time and swim without stopping, how much later, in seconds, is the next time they meet at the starting point?

ANSWER: 240

TOSS-UP

25) BIOLOGY – *Short Answer* Found in cardiac muscle and made of desmosomes and gap junctions, what structures between cardiomyocytes occur at the Z line of the sarcomere?

ANSWER: INTERCALATED DISC

BONUS

25) BIOLOGY – *Short Answer* Order the following three populations of rabbits in increasing effective population size: 1) 3 males, 3 females; 2) 1 male, 5 females; 3) 12 males, 2 females.

ANSWER: 2, 1, 3