2025 MIT Science Bowl High School Invitational

Wildcard Round 1

TOSS-UP

1) EARTH AND SPACE – *Multiple Choice* Which of the following basaltic formations is indicative of non-subaerial volcanic activity?

W) Pillows
X) Colonnades
Y) Pahoehoe (read: *pa-hoy-hoy*) flows
Z) A'a (read: *a-a*) flows

ANSWER: W) PILLOWS

BONUS

1) EARTH AND SPACE – *Multiple Choice* Which of the following environments would most likely produce the most well-developed soil over time?

W) Steep slope, arid climate
X) Steep slope, humid climate
Y) Gentle slope, arid climate
Z) Gentle slope, humid climate

ANSWER: X) STEEP SLOPE, HUMID CLIMATE

TOSS-UP

2) CHEMISTRY – *Short Answer* In boron trichloride (read: *trai-cloride*), what is the formal charge on the central boron atom?

ANSWER: 0

BONUS

2) CHEMISTRY – *Short Answer* Water is completely electrolyzed to produce hydrogen and oxygen, and the resulting mixture of ideal gases is collected. If the volume of the mixture produced is 30 milliliters, how many milliliters of hydrogen were produced?

ANSWER: 20

TOSS-UP

3) BIOLOGY – *Short Answer* Order the following three portions of the cytoskeleton (read: *caito-skeleton*) in increasing radius of the fiber: 1) Intermediate filaments; 2) Microtubules (read: *Micro-tu-biuls*); 3) Microfilaments.

ANSWER: 312

BONUS

3) BIOLOGY – *Short Answer* ABC transporters are ATP dependant pumps that export compounds from the cell against their concentration gradients. Identify all of the following three ions in a human cell that ABC transporters would possibly export: 1) Na+ (read: *sodium plus*); 2) K+ (read: *potassium plus*); 3) Cl- (read: *chlorine*).

ANSWER: 1 AND 3

TOSS-UP

4) MATH – *Short Answer* Alice and Bob are standing ten steps apart on a number line. Each second, Bob has a 50% chance to take one step towards Alice and a 50% chance to stay still. What is the expected number of seconds until they meet?

ANSWER: 20

BONUS

4) MATH – *Multiple Choice* For the definite integral from 0 to 5 of e^{-x}, which of the following Riemann sums with a step-size of 0.2 gives the smallest approximation?

W) Left Riemann sum
X) Right Riemann sum
Y) Midpoint Riemann sum
Z) Trapezoidal sum

ANSWER: X) RIGHT RIEMANN SUM

TOSS-UP

5) ENERGY – *Multiple Choice* Marine biologists at the Darwin Project discovered the marine bacteria SAR11 (read: *S-A-R 11*) exclusively uses purines (read: *piu-rines*) as its source of carbon and nitrogen. Which of the following canonical nucleotide bases would promote DNA synthesis when added to a SAR11 cell culture?

W) Adenine (read: *ede-nin*)
X) Cytosine (read: *cai-to-sin*)
Y) Thymine (read: *thai-min*)
Z) Uracil

ANSWER: W) ADENINE (READ: *EDE-NIN*)

BONUS

5) ENERGY – *Short Answer* The Voigt (read: *voit*) Lab used gene-swapping to create microbes that can fix nitrogen into ammonia. These microbes are performing the biotic analogue of what industrial process used to produce most ammonia fertilizer consumed worldwide?

ANSWER: HABER-BOSCH PROCESS (ACCEPT: HABER)

TOSS-UP

6) PHYSICS – *Multiple Choice* Which of the following circuits has an equivalent resistance to a circuit with three 2-ohm resistors in parallel?

W) Two 3-ohm resistors in parallel
X) Four 1.5-ohm resistors in parallel
Y) One 1-ohm and one 2-ohm resistor in parallel
Z) One 2-ohm and one 3-ohm resistor in parallel

ANSWER: Y) ONE 1-OHM AND ONE 2-OHM RESISTOR IN PARALLEL

BONUS

6) PHYSICS – *Short Answer* A cube of side length 5 centimeters is floating in a tank containing water covered by a 1 centimeter thick layer of oil of density 0.6 grams per cubic centimeter. The cube displaces 100 cubic centimeters of fluid. To the nearest gram, what is the cube's mass?

ANSWER: 90

TOSS-UP

7) EARTH AND SPACE – *Short Answer* What layer in a body of water is characterized by a density gradient that rapidly changes with depth?

ANSWER: PYCNOCLINE (READ: *PIK-NOK-LINE*)

BONUS

7) EARTH AND SPACE – *Multiple Choice* Which of the following best describes the Wilson Cycle?

W) The formation of transform faults along mid-ocean ridges
X) The cyclical formation and breakup of supercontinents
Y) The alternation of magnetic field polarity over geologic time
Z) The sequence of volcanic island formation at hot spots

ANSWER: X) THE CYCLICAL FORMATION AND BREAKUP OF SUPERCONTINENTS

TOSS-UP

8) MATH – *Multiple Choice* A test in MIT's 6.191 class had a mean score of 58 and a standard deviation of 15. Assuming scores are normally distributed, which of the following is closest to the percentage of scores below 73?

W) 50
X) 68
Y) 84
Z) 95

ANSWER: Y) 84

BONUS

8) MATH – *Short Answer* Aryan has invented a new version of solitaire chess. He places a pawn in the bottom left corner of the board, and every turn, he can choose to move the pawn one space up, one space right, or do nothing and leave the pawn where it is. After four moves, how many possible squares could the pawn be?

ANSWER: 15

TOSS-UP

9) BIOLOGY – *Multiple Choice* Aryan is studying a certain plant. He is trying to figure out what must be true about the plant if it stores malic acid at night in it's central vacuole. Which of the following statements MUST also be true of this plant?

W) It utilizes PEP carboxylase (read: *carbO-xi-laze*)
X) It is a halophyte (read: *Halo-fight*)
Y) It undergoes significant photorespiration
Z) It opens it's stomata (read: *stO-mata*) during the day

ANSWER: W) IT UTILIZES PEP CARBOXYLASE (READ: *CARBO-XI-LAZE*)

BONUS

9) BIOLOGY – *Multiple Choice* Which of the following environmental pressures most strongly favors the evolution of intercalary (read: *inter-Kalary*) meristems in a plant?

W) Shading by taller plants
X) Grazing by herbivores
Y) Extreme temperature variations
Z) Strong winds

ANSWER: X) GRAZING BY HERBIVORES

TOSS-UP

10) ENERGY – *Short Answer* The Fu Lab is studying the properties of layered graphene materials. What is the hybridization of each carbon atom in graphene?

ANSWER: SP2

BONUS

10) ENERGY – *Multiple Choice* The Freedman Lab recently studied the high-pressure material $MnBi_2$ (read: *M n B i two*) for its quantum mechanical properties. What is the oxidation state of manganese (read: *mEn-ganese*) in $MnBi_2$?

W) -6 (read: *minus six*)
X) -2 (read: *minus two*)
Y) $+2$ (read: *plus two*)
Z) $+6$ (read: *plus six*)

ANSWER: Z) +6 (READ: *PLUS SIX*)

TOSS-UP

11) CHEMISTRY – *Short Answer* What term describes the minimum amount of energy an incoming photon must have to cause the ejection of an electron from a metal surface?

ANSWER: WORK FUNCTION

BONUS

11) CHEMISTRY – *Multiple Choice* Wrapping aluminum foil around silver oxide in a salt solution results in visible brightening of the silver. Which of the following metals can also be used instead of aluminum foil?

W) Gold
X) Sodium
Y) Tin
Z) Platinum

ANSWER: Y) TIN

TOSS-UP

12) PHYSICS – *Multiple Choice* How does the work done by the drag force on an object moving downwards change as the object approaches terminal velocity?

W) Remains constant
X) Approaches zero
Y) Decreases
Z) Increases

ANSWER: Z) INCREASES

BONUS

12) PHYSICS – *Short Answer* Identify all of the following three statements about electric field lines that are true: 1) Electric field lines always intersect the surface of conductors at right angles; 2) Electric field lines can have sharp corners; 3) Electric field lines can intersect each other.

ANSWER: 1 AND 2 (ACCEPT: ALL EXCEPT 3)

TOSS-UP

13) ENERGY – *Short Answer* Researchers from the MIT LIGO Group are studying gravitational waves emitted by a neutron star collapsing into what compact stellar object?

ANSWER: BLACK HOLE

BONUS

13) ENERGY – *Short Answer* Researchers in the Berger lab are studying Kolmogorov-Arnold Networks, or KANs (read: *K A Ns*). As opposed to traditional neural networks that learn weights and biases, KANs learn what functions that are used to introduce nonlinearities in standard neural networks?

ANSWER: ACTIVATION FUNCTIONS

TOSS-UP

14) PHYSICS – *Short Answer* What physical constant in thermodynamics and statistical physics is equal to the ratio between the ideal gas constant and Avogadro's number?

ANSWER: BOLTZMANN'S CONSTANT

BONUS

14) PHYSICS – *Short Answer* In fluid mechanics, the compressibility is the negative partial derivative of volume with respect to pressure, divided by volume. In terms of SI base units, what are the units of compressibility?

ANSWER: METER SECOND SQUARED PER KILOGRAM (ACCEPT: SECOND SQUARED METER PER KILOGRAM, METERS SECOND SQUARED INVERSE KILOGRAM, DO NOT ACCEPT: INVERSE PASCAL)

TOSS-UP

15) MATH – *Short Answer* By name or number, order the following 3 numbers from smallest to largest: 1. 100^{100}, 2. 100!, 3. $10!^{10}$

ANSWER: 3,2,1

BONUS

15) MATH – *Short Answer* What is the largest power of 3 that divides the number 2 cubed plus 7 cubed?

ANSWER: 27

TOSS-UP

16) CHEMISTRY – *Multiple Choice* In which of the following 1 molar aqueous (read: *ei-quias*) solutions would silver chloride be most soluble?

W) Hydrochloric acid
X) Sodium hydroxide (read: *HydrO-xide*)
Y) Ammonia
Z) Sodium fluoride

ANSWER: Y) AMMONIA

BONUS

16) CHEMISTRY – *Short Answer* Identify all of the following three orbitals that have two radial nodes: 1) 3s; 2) 4f; 3) 5d

ANSWER: 1 AND 3

TOSS-UP

17) BIOLOGY – *Short Answer* Jason is trying to manually insert aquaporins into the wall of the collecting duct of a mammalian kidney. The same effect is triggered by what posterior pituitary (read: *pitu-a-tery*) hormone?

ANSWER: ADH (ACCEPT: VASOPRESSIN)

BONUS

17) BIOLOGY – *Multiple Choice* Caleb is studying cells with MHC class one. Which of the following cells could he NOT be studying?

W) Platelets (read: *plate-lets*)
X) Dendritic Cells
Y) Red blood cells
Z) Astrocytes (read: *astro-sites*)

ANSWER: Y) RED BLOOD CELLS

TOSS-UP

18) EARTH AND SPACE – *Multiple Choice* The Hoyle state is an excited spinless state of Carbon-12 that is an intermediate in which of the following stellar fusion reactions?

W) Rp process
X) Proton proton chain
Y) CNO cycle
Z) Triple alpha process

ANSWER: Z) TRIPLE ALPHA PROCESS

BONUS

18) EARTH AND SPACE – *Short Answer* Mercury completes one rotation about its axis in 58.7 Earth days. To the nearest whole number, how many Earth days does Mercury take to complete one revolution about the Sun, given its 3:2 spin orbit resonance?

ANSWER: 88

TOSS-UP

19) ENERGY – *Short Answer* Nuclear scientists at the MIT Reactor observe a blue glow emanated from water in the reactor. What phenomenon is responsible for the blue glow?

ANSWER: CHERENKOV RADIATION

BONUS

19) ENERGY – *Short Answer* Physicists at MIT discovered that graphite can act as both a superconductor and a magnet. What effect did the scientists use to measure the external magnetic field expelled by superconducting graphite samples?

ANSWER: MEISSNER EFFECT

TOSS-UP

20) MATH – *Multiple Choice* Which of the following conic sections is described by the equation $2x^2 = 6 - 3y^2$ (read: *2 x squared equals 6 minus 3 y squared*)?

W) Circle
X) Ellipse
Y) Parabola
Z) Hyperbola

ANSWER: X) ELLIPSE

BONUS

20) MATH – *Short Answer* How many ways are there to arrange six children of distinct heights around a circular table if the tallest child and shortest child must sit in adjacent chairs?

ANSWER: 48

TOSS-UP

21) PHYSICS – *Multiple Choice* Emily creates a circuit involving a battery, a resistor, and an LED. Sadly, her LED does not light up. Which of the following could not be the reason why the LED fails to light up?

W) The voltage across the LED is insufficient
X) The current across the LED is insufficient
Y) The LED is forward-biased
Z) The LED is reverse-biased

ANSWER: Y) THE LED IS FORWARD-BIASED

BONUS

21) PHYSICS – *Short Answer* A spacecraft initially floating at rest suddenly explodes into two pieces with masses 200 and 400 kilograms, such that each piece receives an impulse of 1500 newton-seconds. After the explosion, what is the relative speed of the two pieces, in meters per second?

ANSWER: 11.25 (ACCEPT: 45/4)

TOSS-UP

22) BIOLOGY – *Short Answer* Identify all of the following three blood types that are NOT possible for a child of two parents with blood types A and B: 1) O type; 2) A type; 3) B type

ANSWER: NONE

BONUS

22) BIOLOGY – *Multiple Choice* Which of the following amino acids could best replace tyrosine (read: *tairo-sin*) on receptor tyrosine kinases (read: *kina-ses*)?

W) Alanine
X) Serine
Y) Proline
Z) Phenylalanine

ANSWER: X) SERINE

TOSS-UP

23) CHEMISTRY – *Multiple Choice* Which of the following molecules obeys the octet rule?

W) Nitrogen dioxide
X) Boron trifluoride
Y) Sulfur tetrafluoride
Z) Carbon tetrachloride

ANSWER: Z) CARBON TETRACHLORIDE

BONUS

23) CHEMISTRY – *Short Answer* In semiconductors, what is the term for the energy difference between the valence and conduction bands?

ANSWER: BAND GAP

TOSS-UP

24) EARTH AND SPACE – *Short Answer* Identify all of the following four types of events from which gravitational waves have been detected: 1) Binary black hole merger; 2) Type 1a (read: *one a*) supernova; 3) Short gamma-ray burst; 4) Long gamma-ray burst

ANSWER: 1,3

BONUS

24) EARTH AND SPACE – *Multiple Choice* Joyce observes that 16 Cygni (read: *cig-na*) culminates at 3:00 AM local time on the summer solstice. To the nearest hour, what is the right ascension of 16 Cygni?

W) 3
X) 9
Y) 15
Z) 21

ANSWER: Z) 21

TOSS-UP

25) BIOLOGY – *Short Answer* What general phenomenon, which occurs when cells fail to undergo cytokinesis, is lethal in most animal cells but a common trait in plants?

ANSWER: POLYPLOIDY

BONUS

25) BIOLOGY – *Multiple Choice* After her bunny spins, Selena gives him a carrot. What type of operant conditioning is this?

W) Positive Punishment
X) Negative Punishment
Y) Poisitve Reinforcement
Z) Negative Reinforcement

ANSWER: Y) POISITVE REINFORCEMENT