

2023 MIT Science Bowl High School Invitational

Round 3

TOSS UP

1) MATH *Short Answer* The roots of the function $f(x)$ are -2 , 3 , and 4 . What are the real roots of the function $f(x^2)$ (read: *f of the quantity x squared*)?

ANSWER: $-2, -\sqrt{3}, \sqrt{3}, 2$

BONUS

1) MATH *Short Answer* An arithmetic sequence contains 100 integers, and its first and third terms are even. Identify all of the following three statements that must be true about the arithmetic sequence:

- 1) All terms are even
- 2) The sum of its terms is even
- 3) The average of its terms is even

ANSWER: 2 only

TOSS UP

2) CHEMISTRY *Short Answer* Huckel's (*Hue-kuhl's*) rule is used to predict whether a molecule observes what property, which is the stabilization observed from a fully conjugated, closed-shell pi system?

ANSWER: Aromaticity

BONUS

2) CHEMISTRY *Multiple Choice* Which of the following molecules has the lowest average bond dissociation?

- W) Water
- X) Hydrogen sulfide
- Y) Ammonia
- Z) Phosphine

ANSWER: Z) Phosphine

TOSS UP

3) BIOLOGY *Short Answer* Typically, nitrogen is a limiting nutrient in many aquatic biomes. Thus, when nitrogen-rich runoff enters these environments, algal blooms can occur, causing oxygen levels to drop. What term refers to this process?

ANSWER: Eutrophication

BONUS

3) BIOLOGY *Multiple Choice* Which of the following statements regarding carrying capacities in real populations is NOT true?

- W) A population can never exceed its carrying capacity
- X) A population's per capita growth rate decreases as it nears its carrying capacity
- Y) The formation of movement corridors can increase the carrying capacity
- Z) Abiotic factors can cause the carrying capacity to decrease

ANSWER: W) A population can never exceed its carrying capacity

TOSS UP

4) EARTH AND SPACE *Multiple Choice* A ternary compositional diagram describing mantle rocks would most likely describe compositions made of what minerals?

- W) Olivine and pyroxenes
- X) Olivine and amphiboles
- Y) Pyroxene and amphiboles
- Z) Amphibole and plagioclase

ANSWER: W) Olivine and pyroxenes

BONUS

4) EARTH AND SPACE *Multiple Choice* The Twomey and Albrecht effects both describe how cloud condensation nuclei, or CCN, affect cloud properties. Which of the following best describes both effects?

- W) Higher CCN density increases cloud albedo and cloud lifetime
- X) Higher CCN density increases cloud albedo and decreases cloud lifetime
- Y) Higher CCN density decreases cloud albedo and cloud lifetime
- Z) Higher CCN density decreases cloud albedo and increases cloud lifetime

ANSWER: W) Higher CCN density increases cloud albedo and cloud lifetime

TOSS UP

5) ENERGY *Short Answer* Researchers in the Chen Lab at MIT are trying to develop chimeric antigen receptors for natural killer cells in order to better combat disease. The release of granzymes and perforins by natural killer cells triggers what process in infected cells?

ANSWER: Apoptosis

BONUS

5) ENERGY *Multiple Choice* The Weissman lab at MIT is studying how misfolded proteins can lead to disease through the use of targeted gene expression and ribosome profiling. Proteins destined for secretion are commonly misfolded in which part of the cell?

- W) Free ribosomes
- X) Chaperonins
- Y) Golgi apparatus
- Z) Rough endoplasmic reticulum

ANSWER: Z) Rough endoplasmic reticulum

TOSS UP

6) PHYSICS *Multiple Choice* A parallel capacitor has circular plates of radius r , which are separated by a distance d . If r and d are both doubled, by what factor will the capacitance increase?

- W) 1
- X) 2
- Y) 8
- Z) 1/2

ANSWER: X) 2

BONUS

6) PHYSICS *Short Answer* A loop of wire is placed around the origin of the xy -plane, and a uniform constant magnetic field points in the positive z direction. From the perspective of an observer above the loop, identify all of the following three actions that would induce a counterclockwise current:

- 1) Rotating the loop around the z axis
- 2) Rotating the loop around the x axis
- 3) Shrinking the size of the loop

ANSWER: 2 and 3

TOSS UP

7) BIOLOGY *Short Answer* What structure located in the right atrium sets the rate and timing at which the heart contracts?

ANSWER: Sinoatrial node (ACCEPT: SA node, DO NOT ACCEPT: Pacemaker)

BONUS

7) BIOLOGY *Short Answer* What is the name of the process by which plant roots acidify the soil solution to release mineral ions from soil particles?

ANSWER: Cation exchange

TOSS UP

8) EARTH AND SPACE *Multiple Choice* Which of the following rocks is considered an extrusive igneous rock?

- W) Granite
- X) Gabbro
- Y) Diorite
- Z) Rhyolite

ANSWER: Z) Rhyolite

BONUS

8) EARTH AND SPACE *Short Answer* As global sea levels rise, certain regions with melting glaciers might experience local drops in sea level due to what phenomena?

ANSWER: Isostatic rebound (ACCEPT: Isostasy)

TOSS UP

9) PHYSICS *Short Answer* A wire carries a current of 0.3 amperes, perpendicular to a uniform magnetic field of strength 5 teslas. In newtons per meter, what is the force per unit length on the wire?

ANSWER: 1.5

BONUS

9) PHYSICS *Short Answer* A block on a frictionless table is attached to a wall via a spring, such that the block oscillates with frequency 2 radians per second. The spring is then cut into 9 identical segments, and the block is attached to the wall via these 9 springs in parallel. In radians per second, what is the new frequency at which the block oscillates?

ANSWER: 18

TOSS UP

10) CHEMISTRY *Multiple Choice* What is the average oxidation state of iron in magnetite, Fe_3O_4 (*read : F-E-3-O-4*)?

- W) 2
- X) $7/3$
- Y) $5/2$
- Z) $8/3$

ANSWER: Z) $8/3$

BONUS

10) CHEMISTRY *Short Answer* The redox reaction between permanganate ions and hydrogen peroxide to produce manganese ions and oxygen gas has a reaction quotient of Q . If the pH is increased by one unit, what is the new reaction quotient in terms of Q ?

ANSWER: 10^6Q

TOSS UP

11) MATH *Short Answer* Two fair six-sided dice are rolled. What is the probability that the smallest number rolled is a 5?

ANSWER: $1/12$

BONUS

11) MATH *Short Answer* How many three digit palindromes are divisible by 3?

ANSWER: 30

TOSS UP

12) ENERGY *Short Answer* Researchers in the Suess lab at MIT are studying iron-sulfur clusters. Sulfur tends to cluster, and hence its most stable allotrope at STP has how many sulfur atoms?

ANSWER: 8

BONUS

12) ENERGY *Short Answer* Researchers in the Radosevich lab at MIT are working on inexpensive p -block catalysis. Identify all of the following three elements that are in the p -block:

- 1) Phosphorus
- 2) Manganese
- 3) Germanium

ANSWER: 1 and 3

TOSS UP

13) EARTH AND SPACE *Short Answer* An astronomer measures stellar luminosity by approximating stars as perfect black bodies. If this astronomer observes a star with half the radius of the Sun but twice the temperature, how many times larger is the star's luminosity than the Sun's luminosity?

ANSWER: 4

BONUS

13) EARTH AND SPACE *Multiple Choice* Which of the following is the main feature that differentiates the gravitational waves detected by pulsar timing arrays compared to ones detected by ground-based Michaelson interferometers?

- W) Frequency
- X) Amplitude
- Y) Polarization
- Z) Speed of propagation

ANSWER: W) Frequency

TOSS UP

14) BIOLOGY *Multiple Choice* Which of the following steps of the nitrogen cycle is MOST affected by the presence of oxygen?

- W) Denitrification
- X) Nitrification
- Y) Ammonification
- Z) Nitrogen fixation

ANSWER: Z) Nitrogen fixation

BONUS

14) BIOLOGY *Short Answer* Identify all of the following four levels of protein structure that could be affected by an amino acid substitution from valine to aspartic acid in human myoglobin:

- 1) Primary
- 2) Secondary
- 3) Tertiary
- 4) Quaternary

ANSWER: 1, 2, and 3

TOSS UP

15) MATH *Multiple Choice* What is the value of $10^{\log_{100} 49}$ (read: *ten raised to the power of log base 100 of 49*)?

- W) $1/7$
- X) $1/2$
- Y) 2
- Z) 7

ANSWER: Z) 7

BONUS

15) MATH *Short Answer* N is a three-digit positive integer whose digits form an increasing geometric sequence from left to right. How many possible values are there for N ?

ANSWER: 4

TOSS UP

16) ENERGY *Short Answer* Researchers in the MIT Research Laboratory of Electronics are studying the anomalous Hall effect in materials. The classical Hall effect is often used to demonstrate that electric current is carried by negative charges. However, certain materials display a Hall voltage in the opposite direction than classically expected. In these materials, the majority of the current is carried by what positively charged quasiparticle?

ANSWER: Hole (ACCEPT: Electron hole)

BONUS

16) ENERGY *Short Answer* Scientists supported by MIT are studying spin glasses, which are a three-dimensional assortment of random spins. What type of magnetic state minimizes the energy of a spin glass?

ANSWER: Ferromagnetic

TOSS UP

17) PHYSICS *Short Answer* Charlie is standing still on a merry-go-round spinning at 2 radians per second, and he is standing 1.5 meters away from the center. If Charlie weighs 50 kg, in newtons, what is the centrifugal force that he experiences?

ANSWER: 300

BONUS

17) PHYSICS *Short Answer* A massless rod is rotating around one of its endpoints with constant angular velocity. Blocks A and B are attached to the rod 1 and 2 meters from the endpoint of rotation, respectively, such that the tension in the rod between the two blocks is 100 newtons. In newtons, what is the tension in the rod between the endpoint of rotation and block A?

ANSWER: 150

TOSS UP

18) CHEMISTRY *Short Answer* Rank the following three compounds by increasing strength of dispersion forces between their molecules:

- 1) Ammonia
- 2) Phosphine
- 3) Arsine

ANSWER: 1, 2, 3

BONUS

18) CHEMISTRY *Short Answer* Identify all of the following three compounds that can display geometric isomerism:

- 1) N_2Cl_2
- 2) C_2H_2
- 3) O_2F_2

ANSWER: 1 only

TOSS UP

19) PHYSICS *Multiple Choice* A student places a wooden block of mass 1 kilogram and volume 2 liters in water, and applies a constant downward force so that the block is submerged underwater and stationary. In newtons, how much force is the student applying?

- W) 4.9
- X) 9.8
- Y) 19.6
- Z) 38.2

ANSWER: X) 9.8

BONUS

19) PHYSICS *Short Answer* Andrew stands on a scale and measures himself to have a mass of 70 kilograms. Andrew jumps vertically with an initial velocity of 1.4 meters per second. Eventually, Andrew lands back on the scale, and completely decelerates in 0.2 seconds. While Andrew is decelerating, what is the average reading, to the nearest ten kilograms, of the scale?

ANSWER: 120

TOSS UP

20) MATH *Short Answer* When the number $30!$ (read: *thirty factorial*) is written in base-3, how many zeroes are at the end of its representation?

ANSWER: 14

BONUS

20) MATH *Short Answer* Two numbers x and y are chosen uniformly at random between 0 and 1. What is the probability that x is greater than y^2 (read: *y squared*)?

ANSWER: $\frac{2}{3}$

TOSS UP

21) EARTH AND SPACE *Multiple Choice* The plot of a galaxy's rotational velocity against distance from the galactic center is best described by which of the following?

- W) Horizontal line
- X) Upward slant then horizontal line
- Y) Downward slant then upward slant
- Z) Purely upward slant

ANSWER: X) Upward slant then horizontal line

BONUS

21) EARTH AND SPACE *Short Answer* Order the following three planets in order of increasing deuterium to protium ratio:

- 1) Earth
- 2) Jupiter
- 3) Venus

ANSWER: 2, 1, 3

TOSS UP

22) BIOLOGY *Multiple Choice* Which of the following groups of plants existed before the origin of vascular plants 470 million years ago?

- W) Liverworts
- X) Ferns
- Y) Club mosses
- Z) Angiosperms

ANSWER: W) Liverworts

BONUS

22) BIOLOGY *Short Answer* If a person has sex chromosomes XXXYY, how many Barr bodies would each cell of this person contain?

ANSWER: 2

TOSS UP

23) CHEMISTRY *Short Answer* The kinetic energy of a vibrating gas-phase molecule is dependent on what power of the temperature of the gas?

ANSWER: 1

BONUS

23) CHEMISTRY *Multiple Choice* Which of the following salts is insoluble under standard conditions?

- W) Mercury (II) iodide (read: *mercury two iodide*)
- X) Barium cyanide
- Y) Aluminum sulfate
- Z) Sodium fluoride

ANSWER: W) Mercury (II) iodide