

2024 MIT Science Bowl High School Invitational

Round 5

TOSS UP

1) MATH *Multiple Choice* Connor writes the number 3 on a blackboard. Every day, he squares the number currently on the blackboard. Vigyan computes the natural logarithm of the number on the board every day. Which of the following choices best describes how Vigyan's number changes every day?

- W) Increases by a factor of two
- X) Increases by a factor of three
- Y) Increases by two
- Z) Increases by three

ANSWER: W) Increases by a factor of two

BONUS

1) MATH *Short Answer* Find the sum of all positive integers m less than 13 such that $12 \times m$ is a perfect square.

ANSWER: 15

TOSS UP

2) PHYSICS *Short Answer* Albert walks up a 10 meter flight of stairs on Mars. Given that Albert has a mass of 70 kilograms, the coefficient of static friction between his shoes and the stairs is 1.0, and the gravitational acceleration on Mars is 3.7 meters per second squared, how much work is done on Albert by the stairs, in joules?

ANSWER: 0

BONUS

2) PHYSICS *Short Answer* A 4 Ohm resistor and a 2 Ohm resistor are placed in parallel, and then together linked in series with a 10 volt battery and another resistor of resistance R . If the current through the 2 ohm resistor is 4 amps, what is R , in Ohms?

ANSWER: $\frac{1}{3}$

TOSS UP

3) CHEMISTRY *Short Answer* Rank the bond angle of the following three molecules from least to greatest:

- 1) Water
- 2) Ammonia
- 3) Methane

ANSWER: 1, 2, 3

BONUS

3) CHEMISTRY *Short Answer* Rank the following three ions by increasing size:

- 1) Hydrogen cation
- 2) Hydride anion
- 3) Sodium cation

ANSWER: 1, 3, 2

TOSS UP

4) ENERGY *Short Answer* Researchers at the Bawendi Lab at MIT are studying quantum dots. Solutions of quantum dots, which consist of solid semiconductor nanocrystals dispersed within a liquid medium, are best described as what type of mixture?

ANSWER: Colloid (ACCEPT: Colloidal suspension, DO NOT ACCEPT: Suspension)

BONUS

4) ENERGY *Short Answer* Scientists at the Birnbaum Lab are studying the immune response to viral pathogens. What viral pathogen uses hemagglutinin and neuraminidase to invade cells?

ANSWER: Influenza

TOSS UP

5) BIOLOGY *Multiple Choice* The causative agent of malaria belongs to which of the following phyla?

- W) Euglenozoa (read: *Eug-len-oh-zoh-ah*)
- X) Apicomplexa (read: *Ap-ee-complex-ah*)
- Y) Parabasilia (read: *Para-bahs-ill-ee-ah*)
- Z) Diplomonada (read: *Di-ploh-moh-nada*)

ANSWER: X) Apicomplexa (read: *Ap-ee-complex-ah*)

BONUS

5) BIOLOGY *Short Answer* In a dihybrid cross, what proportion of offspring with both dominant phenotypes are only homozygous at one of the loci?

ANSWER: $\frac{4}{9}$

TOSS UP

6) EARTH AND SPACE *Short Answer* Which major crater on Mercury lies antipodal to the planet's jumbled terrain?

ANSWER: Caloris Basin (ACCEPT: Caloris Planitia)

BONUS

6) EARTH AND SPACE *Short Answer* Identify all of the following three statements that are true regarding igneous rocks:

- 1) Larger crystals in porphyritic texture are known as porphyroBLASTS
- 2) Pumice is generally felsic in composition
- 3) Basaltic lava has a lower viscosity than rhyolitic lava

ANSWER: 2 and 3

TOSS UP

7) MATH *Short Answer* Maseeh Hall at MIT has 6 floors, each with 60 rooms numbered from 1 to 60. If Pavan is assigned a random room in Maseeh Hall, what is the probability the sum of his floor number and room number is a multiple of 3?

ANSWER: $\frac{1}{3}$

BONUS

7) MATH *Short Answer* In an arithmetic sequence with three terms and common difference 3, the sum of the squares of the three terms is 381. What is the first term of the sequence?

ANSWER: 8

TOSS UP

8) ENERGY *Multiple Choice* Chemists at the Freedman Lab trained an artificial intelligence model on diffraction patterns and their associated structures from the Materials Project dataset, before using their model to generate structures from a testing dataset of unused diffraction patterns. Which of the following types of learning paradigms did the chemist's AI model likely follow?

- W) Supervised
- X) Semi supervised
- Y) Unsupervised
- Z) Reinforcement

ANSWER: W) Supervised

BONUS

8) ENERGY *Short Answer* Astronomers at MIT's Kavli Institute are analyzing emissions from the Cosmic Microwave Background Radiation, or CMBR. While the CMBR can not be accurately modeled using a Maxwell-Boltzmann distribution, what related statistical distribution is instead used to model photons in the CMBR?

ANSWER: Bose-Einstein (ACCEPT: Planck, Black-body)

TOSS UP

9) BIOLOGY *Short Answer* What part of the human brain secretes Thyrotropin-releasing hormone, Corticotropin-releasing hormone, and Growth-hormone releasing hormone and is attached to the posterior pituitary via the infundibulum (read: *in-fuhn-di-byoo-luhm*)?

ANSWER: Hypothalamus (ACCEPT: Diencephalon)

BONUS

9) BIOLOGY *Short Answer* Identify all of the following three cells that are multi-potent:

- 1) Epidermal cells
- 2) Embryonic stem cells
- 3) Hemocytoblasts

ANSWER: 3 only

TOSS UP

10) PHYSICS *Short Answer* Bob's baby elephant, with a mass of 200 kg, is sitting on a see-saw 50 centimeters from the fulcrum. If Bob balances the see-saw by sitting 2.5 meters from the fulcrum, how much is Bob's mass in kilograms?

ANSWER: 40

BONUS

10) PHYSICS *Short Answer* Newton's law of gravitation tells us that gravity weakens with the square of distance, which implies that the gravity experienced by the side of Earth near the sun is greater than that experienced by the side away from the sun. What is the term for this difference in force, which causes phenomena like spaghettification in neutron stars?

ANSWER: Tidal force

TOSS UP

11) CHEMISTRY *Short Answer* A galvanic cell is constructed using copper and zinc, which have standard reduction potentials of 0.34 and -0.76 volts respectively. In volts, what is the cell voltage under standard conditions?

ANSWER: 1.10 volts

BONUS

11) CHEMISTRY *Short Answer* The pKa of acetic acid is approximately 4.8. To one decimal place, what is the pH of a 0.01 M solution of acetic acid?

ANSWER: 3.4

TOSS UP

12) EARTH AND SPACE *Multiple Choice* Which of the following scattering phenomena cause reflection nebulae to appear blue?

- W) Compton scattering
- X) Mie scattering
- Y) Thomson scattering
- Z) Rayleigh scattering

ANSWER: Z) Rayleigh scattering

BONUS

12) EARTH AND SPACE *Multiple Choice* Which of the following dune types would form in regions with excess sand, no vegetation, and steady wind direction?

- W) Transverse
- X) Longitudinal
- Y) Parabolic
- Z) Barchan

ANSWER: W) Transverse

TOSS UP

13) PHYSICS *Short Answer* Alice launches a projectile from the surface of a planet at the escape velocity. During its trajectory, the speed of the projectile when it is a distance d away from the center of the planet is proportional to what power of d ?

ANSWER: $-\frac{1}{2}$

BONUS

13) PHYSICS *Multiple Choice* Joseph conducts a nuclear decay experiment and detects a gamma ray with a wavelength of 250 picometers. In electron-volts and to one significant figure, how much energy does this gamma ray carry?

- W) 5
- X) 50
- Y) 500
- Z) 5000

ANSWER: Z) 5000

TOSS UP

14) EARTH AND SPACE *Short Answer* To one significant figure and in parsecs, what is the distance to a star with parallax angle of 0.005 arcseconds?

ANSWER: 200

BONUS

14) EARTH AND SPACE *Short Answer* On which layer of the sun would you expect to find sunspots?

ANSWER: Photosphere

TOSS UP

15) BIOLOGY *Short Answer* In a growing eudicot root, order the following 3 zones by increasing distance from the root cap:

- 1) Zone of elongation
- 2) Zone of differentiation
- 3) Zone of cell division.

ANSWER: 3, 1, 2

BONUS

15) BIOLOGY *Short Answer* Learning and memory in the brain is thought to originate from reinforcement of highly active synaptic connections, a process known as long-term potentiation. What excitatory neurotransmitter mediates long-term potentiation?

ANSWER: Glutamate

TOSS UP

16) ENERGY *Short Answer* Researchers from MIT's Quantum Measurement Group discovered that the topology of semi-metals can stabilize magnetic ordering above what characteristic temperature of the material?

ANSWER: Curie Point

BONUS

16) ENERGY *Short Answer* Scientists from MIT Nano are developing quantum dots for future technologies. Identify all of the following three technologies that are potential applications of these quantum dots: 1) Deep tissue bio-imaging; 2) Quantum computing qubits; 3) Free electron laser.

ANSWER: All

TOSS UP

17) CHEMISTRY *Short Answer* How many unpaired electrons are in an atom of gas phase chromium, a group 6 transition metal, in its ground state?

ANSWER: 6

BONUS

17) CHEMISTRY *Short Answer* At physiological pH, what is the net charge on a lysine molecule?

ANSWER: +1

TOSS UP

18) MATH *Short Answer* A rectangular prism has length 3, height 12, and space diagonal 13. What is its width?

ANSWER: 4

BONUS

18) MATH *Short Answer* Stanley chooses three positive integers that sum to 38. For each of the pairs of the three numbers, he computes their positive difference. If his differences are 5, 8, and 3, find the smallest of Stanley's numbers.

ANSWER: 9

TOSS UP

19) CHEMISTRY *Short Answer* Identify all of the following three measurements of concentration that are dependent on temperature:

- 1) Molarity
- 2) Molality
- 3) Mole fraction

ANSWER: 1 only

BONUS

19) CHEMISTRY *Multiple Choice* Which of the following steps in the Born-Haber cycle of magnesium oxide is exothermic?

- W) First ionization of magnesium
- X) Second ionization of magnesium
- Y) First electron affinity of oxygen
- Z) Second electron affinity of oxygen

ANSWER: Y) First electron affinity of oxygen

TOSS UP

20) PHYSICS *Multiple Choice* A large rod with constant density per unit length stands on its end on the Earth's surface. Which of the following best describes the positions of the rod's center of mass and center of gravity, respectively?

- W) Both the center of mass and center of gravity are located at the midpoint of the rod
- X) The center of mass is located at the midpoint of the rod, and the center of gravity is slightly higher
- Y) The center of mass is located at the midpoint of the rod, and the center of gravity is slightly lower
- Z) The center of gravity is located at the midpoint of the rod, and the center of mass is slightly higher

ANSWER: Y) The center of mass is located at the midpoint of the rod, and the center of gravity is slightly lower

BONUS

20) PHYSICS *Multiple Choice* Which of the following could be used to construct a voltmeter?

- W) A small resistance connected in series with a galvanometer
- X) A small resistance connected in parallel with a galvanometer
- Y) A large resistance connected in series with a galvanometer
- Z) A large resistance connected in parallel with a galvanometer

ANSWER: Y) A large resistance connected in series with a galvanometer

TOSS UP

21) MATH *Short Answer* The price of Diana's craft paper increases by 30% and then decreases by 30%. Rounded to the nearest integer, by what percent must the new price increase to return to its original value?

ANSWER: 10

BONUS

21) MATH *Short Answer* 5 friends decide to do an escape room and split the cost. After they paid, they invited 3 more people. To ensure the cost was split evenly, each of the 3 people paid 2 dollars to each of the 5 people. How much did the escape room cost in total?

ANSWER: 80

TOSS UP

22) EARTH AND SPACE *Short Answer* What pattern characterized by interleaved kamacite and taenite (read: *tay-in-ite*) characterized the internal structure of many nickel-iron meteorites?

ANSWER: Widmanstatten

BONUS

22) EARTH AND SPACE *Short Answer* Place the following three stages of high-mass stellar evolution in chronological order:

- 1) Horizontal branch
- 2) Asymptotic giant branch
- 3) Main sequence

ANSWER: 3, 1, 2

TOSS UP

23) BIOLOGY *Multiple Choice* Lysozyme and alpha-lactalbumin are remarkably similar proteins with extremely different functions. Scientists propose that these proteins may have originated from an original protein in the genome that duplicated and diverged. What is the relationship between these two proteins?

- W) Orthologous
- X) Analogous
- Y) Homologous
- Z) Paralogous

ANSWER: Z) Paralogous

BONUS

23) BIOLOGY *Multiple Choice* Which of the following best describes the chemical structure of vitamin A?

- W) Modified oligopeptide
- X) Modified oligonucleotide
- Y) Conjugated polyene (read: *poly - een*)
- Z) Porphyrin metal complex

ANSWER: Y) Conjugated polyene (read: *poly - een*)