

2023 MIT Science Bowl High School Invitational

Round 2

TOSS UP

1) ENERGY *Short Answer* The Davis Lab at MIT is studying the mechanisms governing the formation of biological complexes found in cells, one of which is the autophagosome. Which organelle is responsible for fusing with the autophagosome during autophagy to promote the breakdown and recycling of intracellular molecules?

ANSWER: Lysosome

BONUS

1) ENERGY *Short Answer* Researchers at the Lourido Lab at MIT are studying the parasite-host interactions of protist pathogens like Plasmodium falciparum (*plas-mo-di-um fal-sih-pa-rum*), the infectious agent of malaria. After being bitten by a mosquito infected with P. falciparum, the cells of what human organ are first infected by the sporozoites (*spo-ro-zo-ights*)?

ANSWER: Liver

TOSS UP

2) BIOLOGY *Multiple Choice* Which of the following structures is NOT a modified stem?

- W) Pneumatophores
- X) Rhizomes
- Y) Stolons
- Z) Tubers

ANSWER: W) Pneumatophores

BONUS

2) BIOLOGY *Short Answer* Identify all of the following four choices that describe a process in the innate immune system.

- 1) B cells release antibodies that neutralize a foreign bacterial toxin
- 2) Natural killer cells destroy viral-infected cells by detecting abnormal surface proteins
- 3) Helper T cells release cytokines to activate immune cells
- 4) Mast cells release histamine to cause local inflammation

ANSWER: 2 and 4

TOSS UP

3) MATH *Multiple Choice* Kaden sold his car to a collector for 150% more than its original price of \$1,000,000. What percent of the selling price is the original price?

W) 40

X) 50

Y) 60

Z) 70

ANSWER: W) 40

BONUS

3) MATH *Short Answer* The parabola $y = x^2 + 9x$ (read: *y equals x squared plus nine x*) intersects the line $y = 36$ at two points. What is the sum of the x -coordinates of those two points?

ANSWER: -9

TOSS UP

4) EARTH AND SPACE *Multiple Choice* The velocity of a shallow wave is proportional to which of the following functions of depth, d ?

- W) $1/d$
- X) d
- Y) $1/\sqrt{d}$
- Z) \sqrt{d}

ANSWER: Z) \sqrt{d}

BONUS

4) EARTH AND SPACE *Multiple Choice* What hypothesis proposed the correct mechanism for the magnetization of earth's crust around mid ocean ridges?

- W) Vine Matthew Morley hypothesis
- X) Hess hypothesis
- Y) Continental drift
- Z) Dana's hypothesis

ANSWER: W) Vine Matthew Morley hypothesis

TOSS UP

5) CHEMISTRY *Multiple Choice* Which of the following is the VSEPR (read: *ves-per*) predicted molecular geometry of xenon tetrafluoride?

- W) Tetrahedral
- X) Octahedral
- Y) Square pyramidal
- Z) Square planar

ANSWER: Z) Square planar

BONUS

5) CHEMISTRY *Short Answer* During the reaction between excess oxygen and 5.8 grams of butane, how many grams of water vapor are produced to the nearest whole number?

ANSWER: 9

TOSS UP

6) PHYSICS *Multiple Choice* An electron is traveling in a circle inside a uniform magnetic field. If the speed of the electron doubles, by what factor does the radius of its path increase?

- W) $1/4$
- X) $1/2$
- Y) 2
- Z) 4

ANSWER: Y) 2

BONUS

6) PHYSICS *Short Answer* Three identical particles are placed in the coordinate plane, at the points $(-1, 0)$ (read: *negative one comma zero*), $(1, 0)$, and $(0, 1)$. They start from rest, and gradually fall together under the influence of gravity. Eventually, the particles all collide perfectly inelastically and come to rest. What is the distance from the origin to their final resting point?

ANSWER: $1/3$

TOSS UP

7) MATH *Multiple Choice* The base-3 representation of a number is 100210 (read: *one-zero-zero-two-one-zero*). When written in base-9, what is its final digit?

- W) 0
- X) 1
- Y) 2
- Z) 3

ANSWER: Z) 3

BONUS

7) MATH *Short Answer* How many positive five-digit integers contain the three digit block '513'?

ANSWER: 280

TOSS UP

8) ENERGY *Short Answer* Researchers in the Gilliard Lab at MIT are researching analogues of Pepto-Bismol. What group 15 element is present as the metal center in Pepto-Bismol?

ANSWER: Bismuth

BONUS

8) ENERGY *Short Answer* Researchers at the Cummins group at MIT have synthesized a stabilized form of P_2 . This however, is not the most stable allotrope of phosphorus. The standard enthalpy of formation of phosphorus is defined with respect to what other allotrope of phosphorus?

ANSWER: White phosphorus (ACCEPT: P_4)

TOSS UP

9) CHEMISTRY *Short Answer* Rank the following three elements in terms of increasing first ionization energy:

- 1) Carbon
- 2) Nitrogen
- 3) Oxygen

ANSWER: 1, 3, 2

BONUS

9) CHEMISTRY *Short Answer* Rank the following three triatomic molecules by increasing bond angle:

- 1) Sulfur dioxide
- 2) Xenon difluoride
- 3) Oxygen difluoride

ANSWER: 3, 1, 2

TOSS UP

10) EARTH AND SPACE *Short Answer* Hematite and magnetite are both oxides of what metal?

ANSWER: Iron

BONUS

10) EARTH AND SPACE *Multiple Choice* What type of water body is characterized by steep inclines and high loads of coarse grained sediment that lead to rapidly shifting, interconnected channels?

- W) Anastamosing (*a-nas-sta-mo-zing*) river
- X) Yazoo tributary
- Y) Braided stream
- Z) Meandering river

ANSWER: Y) Braided Stream

TOSS UP

11) BIOLOGY *Multiple Choice* Based on the island equilibrium model, which of the following would have the greatest species biodiversity?

- W) A large island far from the mainland
- X) A large island close to the mainland
- Y) A small island far from the mainland
- Z) A small island close to the mainland

ANSWER: X) A large island close to the mainland

BONUS

11) BIOLOGY *Multiple Choice* Which of the following immunoglobulin types can cross the placenta and is thus implicated in hemolytic disease of the newborn?

- W) IgA
- X) IgD
- Y) IgG
- Z) IgM

ANSWER: Y) IgG

TOSS UP

12) PHYSICS *Multiple Choice* Andy pushes a ball of radius 0.25 meters, across the floor to the right. The ball's center of mass gains a velocity of 3 meters per second rightwards, while the ball simultaneously rotates with a clockwise angular velocity of 10 radians per second. Which of the following best describes the friction experienced by the ball?

- W) Leftwards and static
- X) Leftwards and kinetic
- Y) Rightwards and static
- Z) Rightwards and kinetic

ANSWER: X) Leftwards and kinetic

BONUS

12) PHYSICS *Short Answer* A cup is shaped like a cylinder with base area 20 square centimeters, and is partly filled with water. An ice cube with side length 2 centimeters is dropped into the cup, and eventually reaches equilibrium. Assuming the density of ice is 0.9 grams per cubic centimeter, what is the distance, in centimeters to two significant figures, that the water level has risen in the cup?

ANSWER: 0.36

TOSS UP

13) ENERGY *Short Answer* Scientists in the Gedik group at MIT have discovered a strange composite quasiparticle inside nickel phosphorous trisulfide. This quasiparticle consists of an electron paired with what other quasiparticle, which describes a collective excitation of the solid lattice?

ANSWER: Phonon

BONUS

13) ENERGY *Short Answer* Scientists at the MIT Lincoln Laboratory are investigating superconducting materials for their use in quantum computers. One characteristic feature of superconducting materials is the complete expulsion of external magnetic fields from the interior of the material. What is the name of this effect?

ANSWER: Meissner effect

TOSS UP

14) PHYSICS *Short Answer* An object's position as a function of time is given by $x(t) = -t^2 + 6t + 3$ (read: x of t equals negative t squared plus six t plus three). At what time is the object stationary?

ANSWER: 3 (ACCEPT: $t = 3$)

BONUS

14) PHYSICS *Short Answer* Alice launches a projectile from ground level. She wishes for the projectile to land at least 5 meters away. In meters per second, what is the minimum speed required for the projectile to do this?

ANSWER: 7

TOSS UP

15) EARTH AND SPACE *Multiple Choice* Which of the following is the current most commonly accepted hypothesis for the origin of the Moon?

- W) The Moon was captured by Earth's gravitational field
- X) The Moon condensed from the same cloud of matter as the Earth
- Y) The Moon broke off from a rapidly spinning Earth
- Z) The Moon formed from ejected debris after a collision with the Earth

ANSWER: Z) The Moon formed from ejected debris after a collision with the Earth

BONUS

15) EARTH AND SPACE *Multiple Choice* Stellar atmospheres rich in free carbon would also most likely be rich in what spectroscopic signature?

- W) Carbon monoxide
- X) Ammonia
- Y) Calcium I (read: *calcium one*)
- Z) He III (read: *helium three*)

ANSWER: W) Carbon monoxide

TOSS UP

16) CHEMISTRY *Short Answer* Rank the following three elements in terms of increasing ionic radius of their most common ion:

- 1) Fluorine
- 2) Sodium
- 3) Magnesium

ANSWER: 3, 2, 1

BONUS

16) CHEMISTRY *Short Answer* The enthalpy of vaporization of water is 40.7 kilojoules per mole. To two significant figures and in joules per mole per kelvin, what is the entropy of vaporization of water?

ANSWER: +110 (ACCEPT: 110)

TOSS UP

17) BIOLOGY *Multiple Choice* Which of the following statements is NOT true regarding differences between arteries and veins?

- W) Veins have thicker walls than arteries
- X) Blood pressure is higher in arteries than in veins
- Y) Arteries bring blood away from the heart whereas veins bring blood towards the heart
- Z) Veins have valves and arteries do not

ANSWER: W) Veins have thicker walls than arteries

BONUS

17) BIOLOGY *Short Answer* Identify all of the following three cells that are considered haploid:

- 1) Primary oocyte
- 2) Secondary oocyte
- 3) Egg cell prior to fertilization

ANSWER: 2 and 3

TOSS UP

18) MATH *Short Answer* What is the largest integer multiple of 22 less than 2023?

ANSWER: 2002

BONUS

18) MATH *Short Answer* One farmer plows 5 acres of land in 10 minutes. Assuming all farmers work at the same rate, how many minutes does it take for 5 farmers to plow 50 acres of land?

ANSWER: 20

TOSS UP

19) EARTH AND SPACE *Multiple Choice* Which of the following telescopes would be able to detect the Cosmic Microwave Background Radiation?

- W) ALMA (read: *all-ma*)
- X) Swift
- Y) Chandra
- Z) Hubble

ANSWER: W) ALMA

BONUS

19) EARTH AND SPACE *Short Answer* Identify all of the following three quantities that are greater for the moon Enceladus (*en-sell-a-dus*) compared to the moon Titan:

- 1) Albedo (*al-bee-doe*)
- 2) Atmospheric density
- 3) Radius

ANSWER: 1

TOSS UP

20) BIOLOGY *Short Answer* What is the recombination frequency between two genes that are located on different chromosomes?

ANSWER: 50% (ACCEPT: 0.5)

BONUS

20) BIOLOGY *Multiple Choice* Which of the following elements of an HIV virus is NOT encoded by its genome?

- W) Reverse transcriptase
- X) Viral capsid
- Y) Viral envelope
- Z) Viral glycoproteins

ANSWER: Y) Viral envelope

TOSS UP

21) PHYSICS *Short Answer* Two resistors with resistances 2 ohms and 4 ohms are connected in parallel to a 6 volt battery. In amperes, what is the current across the 2 ohm resistor?

ANSWER: 3

BONUS

21) PHYSICS *Short Answer* Water is being pumped from the basement to the second floor of a building. If the pressure at the outlet of the pump is 150 kilopascals, what is the pressure in kilopascals at the second floor which is 10 meters higher?

ANSWER: 52

TOSS UP

22) CHEMISTRY *Multiple Choice* Which of the following conditions on a real gas leads to behavior that is closest to that of ideal gases?

- W) Low temperature, low pressure
- X) Low temperature, high pressure
- Y) High temperature, low pressure
- Z) High temperature, high pressure

ANSWER: Y) High temperature, low pressure

BONUS

22) CHEMISTRY *Multiple Choice* Which of the following atoms' ground state electron configuration violates the Aufbau principle?

- W) Chlorine
- X) Iron
- Y) Copper
- Z) Zinc

ANSWER: Y) Copper

TOSS UP

23) MATH *Multiple Choice* A faucet supplies water at a rate of three cubic inches per second. In seconds, how long does it take to fill half of a fish tank with volume one cubic foot?

- W) 144
- X) 288
- Y) 432
- Z) 576

ANSWER: X) 288

BONUS

23) MATH *Short Answer* How many positive integers have a cube root that is strictly between 3 and 4?

ANSWER: 36