

2022 MIT Science Bowl High School Invitational

Round 6

TOSS UP

1) BIOLOGY *Short Answer* The bacteria causing botulism (*BAA-chuh-li-zm*) and tetanus belong to what genus?

ANSWER: Clostridium

BONUS

1) BIOLOGY *Short Answer* By name or number, identify all of the following four plant phyla (*FAI-luh*) that are NOT vascular plants:

- 1) Cycadophyta (*SAI-kah-doh-fai-tuh*)
- 2) Angiosperms
- 3) Bryophyta
- 4) Hepatophyta

ANSWER: 3 and 4

TOSS UP

2) PHYSICS *Short Answer* By name or number, identify all of the following three statements which are true of constant-volume thermodynamic processes in closed systems of ideal gases:

- 1) No expansion work is done to the system
- 2) On a T - S diagram, these processes are depicted as horizontal lines
- 3) On a P - V diagram, these processes are depicted as vertical lines

ANSWER: 1 and 3 (ACCEPT: All but 2)

BONUS

2) PHYSICS *Short Answer* What phenomenon, in which two plane mirrors in empty space are observed to attract one another, gives evidence to support the existence of electromagnetic waves within a vacuum?

ANSWER: Casimir effect

TOSS UP

3) MATH *Short Answer* A function f satisfies the property that f' (read: f prime) is a strictly increasing function, $f(0) = 0$, and $f(1) = 1$. What is the smallest possible integer value of $f(10)$?

ANSWER: 11

BONUS

3) MATH *Short Answer* What is the value of $\cot 75^\circ \sin 75^\circ$ (read: *cotangent of 75 degrees times sine of 75 degrees*)?

ANSWER: $(\sqrt{6} - \sqrt{2})/4$

TOSS UP

4) ENERGY *Short Answer* The Calo Lab at MIT is studying high-order assemblies in the nucleolus and how its organization contributes to function. What organelle made from protein and RNA is assembled in the nucleolus?

ANSWER: Ribosome

BONUS

4) ENERGY *Short Answer* Researchers in the Wilson Lab at MIT utilize local field potential, or LFP recordings, which are generated not by action potentials, but rather the same currents that generate the postsynaptic potential. What term describes a neuron receiving multiple excitatory postsynaptic potentials in a short period of time, causing membrane depolarization of the postsynaptic cell?

ANSWER: Temporal summation

TOSS UP

5) CHEMISTRY *Multiple Choice* Dihydrogen bonding is a special type of hydrogen bonding that involves attraction between a partially positive hydrogen and a partially negative hydrogen. Which of the following molecules would have the strongest degree of dihydrogen bonding?

- W) NH_3BH_3
- X) CH_3NH_2
- Y) N_2H_4
- Z) C_2H_6

ANSWER: W) NH_3BH_3

BONUS

5) CHEMISTRY *Short Answer* Given that iron is a group 8 transition metal, in terms of Δ , the crystal field splitting energy, what is the crystal field stabilization energy for the $\text{Fe}(\text{CN})_6^{3-}$ (read: *F-E-C-N six three minus*) ion?

ANSWER: -2Δ (ACCEPT: 2Δ)

TOSS UP

6) EARTH AND SPACE *Multiple Choice* Which of the following types of volcanic hazards forms when an eruption column collapses and rushes down the flanks of a volcano?

- W) Volcanic outflow
- X) Lahar
- Y) Volcanic ash fall
- Z) Pyroclastic flow

ANSWER: Z) Pyroclastic flow

BONUS

6) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three values that increase as you move from the headwaters to the mouth of a stream:

- 1) Gradient
- 2) Discharge
- 3) Flow velocity

ANSWER: 2 and 3 (ACCEPT: All but 1)

TOSS UP

7) PHYSICS *Multiple Choice* A spinning ping-pong ball travels forwards through air, with an angular velocity which points directly upwards. The spin generates differences in air pressure, deflecting the ball's path in which of the following directions?

- W) Left
- X) Right
- Y) Up
- Z) Down

ANSWER: W) Left

BONUS

7) PHYSICS *Short Answer* A particle with mass 10 kilo-electronvolts per c squared is moving with a velocity of 98% the speed of light. To the nearest kilo-electronvolt, what is the kinetic energy of this particle?

ANSWER: 50

TOSS UP

8) ENERGY *Short Answer* Scientists at MIT's Kavli Institute for Astrophysics have been examining the behavior and composition of late-stage stars such as neutron stars and white dwarves. By name or number, rank the following three types of degeneracy pressure experienced by these stars by increasing magnitude:

- 1) Neutron degeneracy pressure
- 2) Electron degeneracy pressure
- 3) Proton degeneracy pressure

ANSWER: 3, 2, 1

BONUS

8) ENERGY *Multiple Choice* Astronomers at MIT were part of the TESS team which recently discovered a planet with a radius of 1.5 times that of the Earth orbiting a star with a radius of 0.44 times that of the Sun at a distance of 0.05 astronomical units. Which of the following is closest to the fraction of light which is blocked when the planet transits the star?

- W) 10^{-7}
- X) 10^{-5}
- Y) 10^{-3}
- Z) 10^{-1}

ANSWER: Y) 10^{-3}

TOSS UP

9) MATH *Short Answer* Over all positive real values of x and y , what is the minimum possible value of $\log_x y + \log_y x$ (read: *log base x of y plus log base y of x*)?

ANSWER: 2

BONUS

9) MATH *Short Answer* What is the sum of the positive integer factors of 2022?

ANSWER: 4056

TOSS UP

10) CHEMISTRY *Short Answer* Sodium chloride is slowly dissolved in a beaker of distilled water. By name or number, identify all of the following three properties of the solution that are expected to increase:

- 1) Vapor pressure
- 2) Boiling point
- 3) Freezing point

ANSWER: 2 only

BONUS

10) CHEMISTRY *Multiple Choice* A solution of 0.1 molar sulfuric acid is added to a beaker, and two wires connected to a lightbulb are inserted in the beaker. A 0.1 molar solution of barium hydroxide is slowly dripped in using a buret. Which of the following statements is true regarding this experiment?

- W) The lightbulb is initially lit, but dims and eventually goes out
- X) The lightbulb is initially unlit, but starts glowing and gets brighter
- Y) The lightbulb is initially lit, dims and goes out, then starts glowing again
- Z) The lightbulb is initially unlit, reaches a maximum brightness, starts dimming, and eventually goes out

ANSWER: Y) The lightbulb is initially lit, dims and goes out, then starts glowing again

TOSS UP

11) EARTH AND SPACE *Multiple Choice* Absolute stability in clouds occurs under which of the following conditions?

- W) Environmental lapse rate is less than the dry adiabatic rate
- X) Environmental lapse rate is greater than the dry adiabatic rate
- Y) Environmental lapse rate is less than the wet adiabatic rate
- Z) Environmental lapse rate is greater than the wet adiabatic rate

ANSWER: Y) Environmental lapse rate is less than the wet adiabatic rate

BONUS

11) EARTH AND SPACE *Multiple Choice* The breakup of Pangaea occurred during the end of which of the following geologic periods?

- W) Cambrian
- X) Carboniferous
- Y) Triassic
- Z) Cretaceous

ANSWER: Y) Triassic

TOSS UP

12) BIOLOGY *Multiple Choice* Which of the following cell types is incorrectly paired with its function?

- W) Podocyte (*PAH-doh-site*) and selective filtration
- X) Osteoclast and bone decomposition
- Y) Fibroblast and keratin generation
- Z) Megakaryocyte and platelet formation

ANSWER: Y) Fibroblast and keratin generation

BONUS

12) BIOLOGY *Multiple Choice* Which of the following types of cell death is NOT correctly paired with its mechanism?

- W) Necrosis and unplanned cell death
- X) Autophagy (*aw-TAWH-fuh-jee*) and consumption by immune cells
- Y) Apoptosis and disintegration into blebs
- Z) Entosis and invasion by another cell

ANSWER: X) Autophagy and consumption by immune cells

TOSS UP

13) ENERGY *Short Answer* Researchers in the Raines group at MIT have synthesized a disulfide reducing agent from L-aspartic acid that is superior to standard reagents. Upon reduction of a disulfide bond, what functional group is formed?

ANSWER: Thiol (ACCEPT: Sulfhydryl, mercaptan)

BONUS

13) ENERGY *Short Answer* Researchers in the McGuire group at MIT have used high-resolution rotational spectroscopy to discover the first chiral molecule in space, propylene oxide. If a 1 molar solution of pure (*R*)-propylene oxide rotates plane-polarized light by 15 degrees, what percent (*R*)-propylene oxide is a 1 molar solution of propylene oxide that rotates plane-polarized light by 9 degrees?

ANSWER: 80% (ACCEPT: 0.8, 4/5)

TOSS UP

14) BIOLOGY *Multiple Choice* Which of the following disorders of the thyroid gland is representative of a hyperthyroid condition?

- W) Hashimoto disease
- X) Grave disease
- Y) Iodine deficiency
- Z) Myxedema (*mix-uh-DEE-muh*)

ANSWER: X) Grave disease

BONUS

14) BIOLOGY *Short Answer* Tyler's guppies, after many generations of tank life, have developed a genetic, instinctual love for Tyler. Since pineapples are one of his natural predators, they have started attacking anything that is colored yellow. What is the color yellow an example of for these guppies?

ANSWER: Sign stimulus

TOSS UP

15) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three branches of the HR diagram that burn both helium and hydrogen:

- 1) Red giant branch
- 2) Horizontal branch
- 3) Asymptotic giant branch

ANSWER: 2 and 3 (ACCEPT: All but 1)

BONUS

15) EARTH AND SPACE *Multiple Choice* Which of the following supernova types most likely resulted from a Wolf-Rayet (*wolf-RYE-yey*) progenitor?

- W) Type Ia (read: *type one-A*)
- X) Type Ib (read: *type one-B*)
- Y) Type II-P (read: *type two-P*)
- Z) Type IIn (read: *type two-N*)

ANSWER: X) Type Ib

TOSS UP

16) CHEMISTRY *Multiple Choice* Which of the following compounds has the smallest bond angles?

- W) NH_3
- X) NF_3
- Y) NCl_3
- Z) NBr_3

ANSWER: X) NF_3

BONUS

16) CHEMISTRY *Short Answer* By name or number, rank the following three gases by increasing average speed:

- 1) Chlorine at 800 kelvin
- 2) Oxygen at 400 kelvin
- 3) Helium at 200 kelvin

ANSWER: 1, 2, 3

TOSS UP

17) MATH *Short Answer* By name or number, identify all of the following three types of quadrilaterals such that connecting the midpoints of the quadrilateral must form a rhombus:

- 1) Parallelogram
- 2) Rectangle
- 3) Trapezoid

ANSWER: 2 only

BONUS

17) MATH *Multiple Choice* To the nearest power of 10, how many primes are less than one million?

- W) 10^2
- X) 10^3
- Y) 10^4
- Z) 10^5

ANSWER: Z) 10^5

TOSS UP

18) PHYSICS *Short Answer* A mass connected to a spring undergoes simple harmonic motion with a period of 2 seconds and a maximum displacement of 2 meters. In meters per second, what is the maximum speed attained by the mass?

ANSWER: 2π

BONUS

18) PHYSICS *Short Answer* A 2 kilogram mass traveling at 7 meters per second elastically collides with a stationary 5 kilogram mass and rebounds in the opposite direction. In meters per second, what is the final speed of the 2 kilogram mass?

ANSWER: 3

TOSS UP

19) CHEMISTRY *Short Answer* By name or number, rank the following four ions by increasing size:

- 1) H^-
- 2) F^-
- 3) Cl^-
- 4) Br^-

ANSWER: 2, 1, 3, 4

BONUS

19) CHEMISTRY *Short Answer* Given that hydrogen cyanide can exist in four orientations, calculate the residual entropy of a crystal lattice of 1 mole of hydrogen cyanide, in joules per kelvin and to one significant figure.

ANSWER: 10

TOSS UP

20) BIOLOGY *Short Answer* By name or number, order the following bacterial structures from innermost to outermost:

- 1) Plasma membrane
- 2) Cell wall
- 3) Capsule

ANSWER: 1, 2, 3

BONUS

20) BIOLOGY *Multiple Choice* Which of the following cell structures can be found in both animal cells and mature plant cells?

- W) Glyoxysomes
- X) Centrioles
- Y) Flagella
- Z) Nucleoli

ANSWER: Z) Nucleoli

TOSS UP

21) MATH *Short Answer* The perimeters of the faces of a tetrahedron are 5, 6, 7, and 8. What is the sum of the lengths of all edges of the tetrahedron?

ANSWER: 13

BONUS

21) MATH *Short Answer* What is the smallest number k such that the product of the first k primes is at least 1 million?

ANSWER: 8

TOSS UP

22) EARTH AND SPACE *Short Answer* What radioactive isotope of beryllium is the intermediate nuclei in the triple alpha process?

ANSWER: Beryllium-8 (ACCEPT: Be-8)

BONUS

22) EARTH AND SPACE *Short Answer* Most outflow channels on Mars were formed during which of the three periods of Martian history?

ANSWER: Hesperian period (ACCEPT: Hesperian)

TOSS UP

23) PHYSICS *Short Answer* A ceiling fan motor exerts a torque of 4.0 newton meters, while a person keeps the blades from spinning by pressing upwards against the end of a 0.75 meter blade with a force of 4.0 newtons. To the nearest tenth, what is the minimum coefficient of static friction between the person's hand and the ceiling fan blade required to prevent the blades from spinning?

ANSWER: 1.3

BONUS

23) PHYSICS *Short Answer* An ideal electrical dipole is placed at the origin, such that the magnitude of the electric field on the x axis at $x = 2$ meters is 4 newtons per coulomb. In newtons per coulomb, what is the magnitude of the electric field on the x -axis at $x = 4$ meters?

ANSWER: 1/2 (ACCEPT: 0.5)