

2024 MIT Science Bowl High School Invitational

Round 2

TOSS UP

1) PHYSICS *Multiple Choice* In Newtonian mechanics, the time derivative of which of the following quantities is equivalent to the net force acting on an object?

- W) Energy
- X) Torque
- Y) Linear momentum
- Z) Angular momentum

ANSWER: Y) Linear momentum

BONUS

1) PHYSICS *Short Answer* A projectile launched at an angle of 15 degrees has a range of 40 meters. The launch angle is then changed to maximize the range. In meters, what is this maximum range?

ANSWER: 80

TOSS UP

2) BIOLOGY *Short Answer* S-adenosyl methionine is a powerful biological methylating agent. This is largely due to the methyl group in methionine being bonded to an atom of what electronegative, polarizable element that is also present in cysteine?

ANSWER: Sulfur

BONUS

2) BIOLOGY *Short Answer* Order the following three structures in the heart in the order the electrical impulse travels through them in the heart rhythm pathway:

- 1) Purkinje (*purr-KIN-jee*) fibers
- 2) AV node
- 3) SA node.

ANSWER: 3, 2, 1

TOSS UP

3) ENERGY *Short Answer* Computer scientists at MIT CSAIL are studying digital representations of information, such as 8-bit strings for unsigned integers. What is the maximum possible decimal value of an unsigned 8-bit integer?

ANSWER: 255

BONUS

3) ENERGY *Multiple Choice* Researchers at the Rett Lab have been studying Rett syndrome. Rett syndrome is a genetic disorder that typically occurs in girls from a de novo mutation and is usually lethal for boys. Given this information, which of the following is the most likely mode of inheritance for Rett syndrome and other genetic disorders that match the description?

- W) X-linked dominant
- X) X-linked recessive
- Y) Mitochondrial
- Z) Y-linked

ANSWER: X) X-linked recessive

TOSS UP

4) EARTH AND SPACE *Multiple Choice* Which of the following minerals would melt first according to Bowen's reaction series?

- W) Muscovite
- X) Orthoclase
- Y) Olivine
- Z) Biotite

ANSWER: W) Muscovite

BONUS

4) EARTH AND SPACE *Short Answer* Jonathan is at a location in the ocean with no difference in sea height between the low and high tide. What type of location is at Jonathan at?

ANSWER: Amphidromic Point

TOSS UP

5) MATH *Short Answer* Josh claims that when he gambles, he either loses 10 dollars or wins 1000 dollars, so the chance of winning is 50%. If this was true, what is his expected profit of gambling?

ANSWER: 495

BONUS

5) MATH *Short Answer* Rank the following three fractions from least to greatest:

- 1) $110/111$,
- 2) $222/223$,
- 3) $331/334$

ANSWER: 1, 3, 2

TOSS UP

6) CHEMISTRY *Multiple Choice* Which of the following statements is true about enzymes?

- W) All enzymes are folded proteins containing at least one active site
- X) Enzymes shift the equilibrium position of biological reactions
- Y) Enzymes provide an alternative mechanism with a decreased activation energy
- Z) Enzymes provide an alternative mechanism with a decreased free energy

ANSWER: Y) Enzymes provide an alternative mechanism with a decreased activation energy

BONUS

6) CHEMISTRY *Multiple Choice* Which of the following elements has the highest first ionization energy?

- W) Boron
- X) Carbon
- Y) Nitrogen
- Z) Oxygen

ANSWER: Y) Nitrogen

TOSS UP

7) ENERGY *Short Answer* MIT researchers in the Jarillo-Herrero group are studying a robust superconducting structure. This structure consists of stacked twisted sheets of what 2D material composed of repeated carbon atoms?

ANSWER: Graphene

BONUS

7) ENERGY *Multiple Choice* Researchers at the Jacks Lab in the Koch institute are studying the two hit model for tumor suppressor genes. Which of the following is NOT a tumor suppressor gene?

- W) kRas (*kay-RAS*)
- X) Rb
- Y) APC
- Z) BRCA2

ANSWER: W) kRas (*kay-RAS*)

TOSS UP

8) CHEMISTRY *Short Answer* In nitric acid, what is the oxidation state of nitrogen?

ANSWER: +5 (ACCEPT: 5)

BONUS

8) CHEMISTRY *Multiple Choice* A sample of ideal gas at STP has a volume of 3.0 liters. What will the volume of the gas be when it is heated to 546 degrees celsius and the pressure is increased to 2 atmospheres?

- W) 1.5 liters
- X) 3.0 liters
- Y) 4.5 liters
- Z) 6.0 liters

ANSWER: Y) 4.5 liters

TOSS UP

9) BIOLOGY *Multiple Choice* Zander is studying black smokers, which are hydrothermal vents associated with temperatures up to 480 degrees Celsius. He notices that there are living organisms that can survive at these extreme temperatures. Which of the following is the term for these organisms that can live at these high temperatures?

- W) Halophiles
- X) Xerophiles (*zero-files*)
- Y) Osmophiles
- Z) Thermophiles

ANSWER: Z) Thermophiles

BONUS

9) BIOLOGY *Multiple Choice* In a particular endothermic species, heat loss is roughly proportional to an individual's surface area and basal metabolic rate is roughly proportional to its volume. How would one expect a population of this species which lives at the poles to differ from a population that lives near the equator, on average?

- W) Smaller body size, shorter appendages
- X) Smaller body size, longer appendages
- Y) Larger body size, shorter appendages
- Z) Larger body size, longer appendages

ANSWER: Y) Larger body size, shorter appendages

TOSS UP

10) MATH *Short Answer* Given that the six numbers (read slowly) 2, 0, 2, 4, a , and b have an average of 15, what is the average of a and b ?

ANSWER: 41

BONUS

10) MATH *Short Answer* In a round robin tournament with four teams, each team plays each other exactly once, and is awarded 3 points for each win, 1 point for each draw, and 0 points for each loss. At the end of the tournament, the highest scoring team scored 9 points and the second-highest scoring team scored 4 points. If no two teams ended the tournament with the same number of points, how many points did the last-place team score?

ANSWER: 1

TOSS UP

11) EARTH AND SPACE *Multiple Choice* Which of the following types of fog is formed by warm moist air flowing over colder ground?

- W) Steam fog
- X) Precipitation fog
- Y) Advection fog
- Z) Radiation fog

ANSWER: Y) Advection fog

BONUS

11) EARTH AND SPACE *Short Answer* Rank the following three eras in the universe's history from earliest to latest:

- 1) Dark Energy Era
- 2) Radiation Era
- 3) Matter Era

ANSWER: 2, 3, 1

TOSS UP

12) PHYSICS *Multiple Choice* Which of the following length scales is most appropriate for the radius of the hydrogen atom?

- W) 10 centimeters
- X) 10 micrometers
- Y) 10 nanometers
- Z) 10 picometers

ANSWER: Z) 10 picometers

BONUS

12) PHYSICS *Short Answer* Alice sends out an electromagnetic wave at some fixed frequency. Nathan sends out an electromagnetic wave of the same frequency, but such that the amplitude of his electric field is twice that of Alice's. How many times more intense is Nathan's wave than Alice's?

ANSWER: 4

TOSS UP

13) MATH *Short Answer* Find the value of x such that $\log_x(8) = \log_{27}(3)$ (read: *log base x of eight is equal to log base twenty seven of three*).

ANSWER: 512

BONUS

13) MATH *Short Answer* Elle chooses real numbers x and y such that $y + \lfloor x \rfloor = 5.4$ (read: *y plus the floor of x equals five point four*) and $x + \lfloor y \rfloor = 5.7$ (read: *x plus the floor of y equals five point seven*). Find the sum of x and y .

ANSWER: 6.1

TOSS UP

14) PHYSICS *Multiple Choice* During the decay of carbon-14, what particle is emitted alongside the daughter nuclide and beta particle?

- W) Photon
- X) Neutrino
- Y) Anti neutrino
- Z) Exciton

ANSWER: Y) Anti neutrino

BONUS

14) PHYSICS *Short Answer* Identify all of the following three processes that MUST be reversible:

- 1) Ice melting
- 2) Isothermal expansion of a gas
- 3) Combustion of hydrogen

ANSWER: None

TOSS UP

15) ENERGY *Short Answer* Researchers at MIT's Center for Quantum Engineering are studying quantum computing. What term describes the linear combination of states that a qubit can exist in until measured?

ANSWER: Superposition

BONUS

15) ENERGY *Short Answer* Researchers at MIT CSAIL's natural language processing group have been using NLP to connect IUPAC names of chemicals to potential reactions. Identify all of the following three chemical names that are valid IUPAC names:

- 1) 1-methylhexane
- 2) 4-hexanol
- 3) 4-methyl-1-hexanol

ANSWER: 3 only

TOSS UP

16) BIOLOGY *Short Answer* While Darwin believed that evolution occurs gradually, Eldredge and Gould proposed a contrasting hypothesis which proposed that significant evolutionary change is restricted to rare and rapid events of speciation. What is the name for this hypothesis?

ANSWER: Punctuated Equilibrium

BONUS

16) BIOLOGY *Short Answer* Whereas iron is the metal cofactor in hemoglobin and myoglobin, copper is the cofactor in which respiratory pigment found in the hemolymph of insects?

ANSWER: Hemocyanin

TOSS UP

17) EARTH AND SPACE *Short Answer* The Kirkwood gaps are formed by orbital resonances of asteroids in the asteroid belt with which solar system body?

ANSWER: Jupiter

BONUS

17) EARTH AND SPACE *Short Answer* Logan is examining a roadcut and observes a layer of unmetamorphosed mudstone atop a layer of granite. This formation is an example of what type of unconformity?

ANSWER: Nonconformity

TOSS UP

18) CHEMISTRY *Multiple Choice* Which of the following pairs of chemicals will produce a buffer when mixed in a one to one ratio in an aqueous solution?

- W) Sodium chloride and hydrochloric acid
- X) Sodium nitrate and nitric acid
- Y) Sodium bisulfate and sulfuric acid
- Z) Sodium acetate and acetic acid

ANSWER: Z) Sodium acetate and acetic acid

BONUS

18) CHEMISTRY *Short Answer* At large bond lengths, the potential energy of an ionic bond is proportional to bond length raised to what power?

ANSWER: -1

TOSS UP

19) BIOLOGY *Multiple Choice* Which of the following crops is most likely to be seedless or have weak seeds due to problems with chromosome pairing during meiosis?

- W) Diploid Tomato
- X) Triploid Banana
- Y) Tetraploid Cotton
- Z) Octoploid Strawberry

ANSWER: X) Triploid Banana

BONUS

19) BIOLOGY *Short Answer* Identify all of the following three statements concerning action potentials in mammalian cells that are true:

- 1) The refractory period occurs when the cell is depolarized following the action potential
- 2) Voltage gated sodium channels remain open for longer than voltage gated potassium channels
- 3) The action potential's amplitude varies based how fast the cell depolarizes.

ANSWER: None

TOSS UP

20) EARTH AND SPACE *Short Answer* What is the heaviest element that can be fused by a brown dwarf?

ANSWER: Lithium

BONUS

20) EARTH AND SPACE *Short Answer* Identify all of the following three statements that are TRUE regarding stellar evolution:

- 1) T Tauri Stars exist on the instability strip
- 2) During the main-sequence phase, most stars tend to cool
- 3) Brown Dwarfs are theorized to exist but have yet to been identified in the universe

ANSWER: 2 only

TOSS UP

21) MATH *Short Answer* Find the limit as x approaches zero of the quantity $\sin(7x)/\sin(4x)$ (read: *sine of seven x divided by sine of four x*).

ANSWER: $\frac{7}{4}$

BONUS

21) MATH *Short Answer* Brian and Luke randomly, independently, and uniformly select two points A and B on unit circle O. Expressed as a fraction in simplest form, what is the probability that the area of triangle ABO is greater than $\frac{\sqrt{3}}{4}$ (read: *the fraction with numerator square root of three and denominator four*)?

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

TOSS UP

22) CHEMISTRY *Multiple Choice* Which of the following aqueous solutions would have the lowest conductivity?

- W) 0.1 molar sodium acetate
- X) 0.1 molar acetic acid
- Y) 0.1 molar sodium chloride
- Z) 0.1 molar hydrochloric acid

ANSWER: X) 0.1 molar acetic acid

BONUS

22) CHEMISTRY *Multiple Choice* A solution of 10 milliliters of 1 molar acetic acid is titrated by a 1 molar solution of calcium hydroxide. Which of the following statements is not true?

- W) The equivalence point has been reached after 10 milliliters of calcium hydroxide have been added
- X) Phenolphthalein (read: *fee - nol - thay - lee - in*) would be a good indicator for this titration
- Y) The pH of the solution is moderately acidic after 2 milliliters of calcium hydroxide have been added
- Z) The solution behaves as a buffer when 2 milliliters of calcium hydroxide have been added

ANSWER: W) The equivalence point has been reached after 10 milliliters of calcium hydroxide have been added

TOSS UP

23) PHYSICS *Short Answer* An ant travels at 2 meters per second along the circumference of a circle with a radius of 20 meters. How many seconds will the ant travel for before the ant first maximizes its displacement from its starting point?

ANSWER: 10π

BONUS

23) PHYSICS *Short Answer* A block on a spring oscillates with amplitude 6 meters and period 3 seconds. In meters per second, what is the average speed of the block?

ANSWER: 8