

2022 MIT Science Bowl High School Invitational

Round 1

TOSS UP

1) CHEMISTRY *Multiple Choice* Which of the following statements is true when the pH of a solution increases by 1?

- W) The concentration of H^+ doubles
- X) The concentration of H^+ increases tenfold
- Y) The concentration of OH^- doubles
- Z) The concentration of OH^- increases tenfold

ANSWER: Z) The concentration of OH^- increases tenfold

BONUS

1) CHEMISTRY *Multiple Choice* Which of the following acidic solutions has the greatest percentage dissociation of the acid?

- W) 0.1 molar acetic acid solution
- X) 1 molar acetic acid solution
- Y) 0.1 molar trifluoroacetic acid solution
- Z) 1 molar trifluoroacetic acid solution

ANSWER: Y) 0.1 molar trifluoroacetic acid solution

TOSS UP

2) MATH *Short Answer* What quadrant would contain the angle measuring 1300 degrees in standard position?

ANSWER: Quadrant III (ACCEPT: 3)

BONUS

2) MATH *Short Answer* If $\log_2 \log_3 \log_4 x = 0$ (read: *log base two of log base three of log base four of x equals zero*), then what is the value of x ?

ANSWER: 64

TOSS UP

3) ENERGY *Multiple Choice* The Gehring Lab at MIT is studying gene imprinting in the endosperm, a plant structure that typically has which of the following polyploidys?

- W) n
- X) $2n$
- Y) $3n$
- Z) $4n$

ANSWER: Y) $3n$

BONUS

3) ENERGY *Short Answer* The Jaenisch Lab at MIT was one of the pioneers of reprogramming iPSCs, and even used iPSCs to treat a disease in mice. What is the term for this disease characterized by abnormal hemoglobin, and whose effect is protective against malaria?

ANSWER: Sickle-cell anemia

TOSS UP

4) BIOLOGY *Multiple Choice* Which of the following interactions found in the tertiary structure of proteins is the strongest?

- W) Van der Waals interactions
- X) Hydrogen bonding
- Y) Disulfide bridges
- Z) Ionic interactions

ANSWER: Y) Disulfide bridges

BONUS

4) BIOLOGY *Multiple Choice* Which of the following can be classified as a fibrous protein?

- W) Collagen
- X) Hemoglobin
- Y) Albumin
- Z) Oxytocin

ANSWER: W) Collagen

TOSS UP

5) EARTH AND SPACE *Multiple Choice* Which of the following types of dunes is formed when wind direction is variable?

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

ANSWER: Z) Star

BONUS

5) EARTH AND SPACE *Short Answer* By name or number, order the following three igneous rocks from fastest to slowest cooling time during formation:

- 1) Obsidian
- 2) Granite
- 3) Rhyolite

ANSWER: 1, 3, 2

TOSS UP

6) PHYSICS *Short Answer* Galileo drops a ball from the top of a tower, and it takes 2 seconds for the ball to reach the ground. If the Earth's gravity were suddenly doubled, how many seconds would it take the ball to reach the ground if Galileo repeated his experiment?

ANSWER: $\sqrt{2}$

BONUS

6) PHYSICS *Short Answer* Two cylinders are similar with a 1 to 2 ratio; the dimensions of one cylinder are exactly twice the dimensions of the other. Anka pours the same amount of water into each cylinder, and neither overflows. What is the ratio of the water pressure at the bottom of the larger cylinder to the water pressure at the bottom of the smaller cylinder?

ANSWER: 1/4 (ACCEPT: 0.25)

TOSS UP

7) BIOLOGY *Multiple Choice* Which of the following factors most commonly leads to speciation?

- W) Geographic barriers
- X) Polyploidy
- Y) Sexual selection
- Z) Infertility

ANSWER: W) Geographic barriers

BONUS

7) BIOLOGY *Multiple Choice* Which of the following conditions is present in Hardy-Weinberg equilibrium?

- W) Migration
- X) Nonrandom mating
- Y) Large population
- Z) Random mutations

ANSWER: Y) Large populations

TOSS UP

8) MATH *Multiple Choice* Which of the following functions does NOT have an inverse?

- W) $y = x^3$
- X) $y = \arctan x$
- Y) $y = \arcsin x$
- Z) $y = \lfloor x \rfloor$ (read: y equals the floor of x)

ANSWER: Z) $y = \lfloor x \rfloor$

BONUS

8) MATH *Short Answer* How many sets of single-digit positive integers contain at least one odd and at least one even number?

ANSWER: 465

TOSS UP

9) ENERGY *Short Answer* MIT physicists at the LIGO Lab have used black holes to search for ultralight bosons such as the hypothetical axion. If these particles existed, they would make up what hypothetical substance, whose existence is inferred from its gravitational effects?

ANSWER: Dark matter

BONUS

9) ENERGY *Short Answer* Scientists at MIT's Plasma Science and Fusion Center are studying the usage of tokamak (*TOW-kuh-mack*) devices to magnetically confine plasma composed of deuterium and tritium for fusion. In addition to energy, the fusion of deuterium and tritium produces helium-4 and what other nuclear product?

ANSWER: Neutron

TOSS UP

10) CHEMISTRY *Multiple Choice* Which of the following molecules is nonpolar?

- W) NH_3
- X) PBr_5
- Y) SO_2
- Z) ClF_5

ANSWER: X) PBr_5

BONUS

10) CHEMISTRY *Short Answer* By name or number, identify all of the following three statements which are true about fluorine:

- 1) Fluorine's elemental form is the strongest oxidizing agent compared to other elements
- 2) Fluorine is the element with the greatest electronegativity
- 3) Fluorine is the element with the most negative electron affinity

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

TOSS UP

11) PHYSICS *Short Answer* A solenoid inductor has 100 coils over a length of 1 centimeter. The solenoid is then stretched to a length of 2 centimeters, without changing its cross-sectional area. By what factor does the inductance of the solenoid change?

ANSWER: 1/2 (ACCEPT: 0.5)

BONUS

11) PHYSICS *Short Answer* Suppose the xy -plane has a uniform, nonzero charge density. What is the ratio of the magnitude of the electric field at $z = 3$ meters to that at $z = 1$ meter?

ANSWER: 1

TOSS UP

12) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three types of moraines that run parallel to the direction of movement of glaciers:

- 1) Lateral moraine
- 2) Medial moraine
- 3) Terminal moraine

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

BONUS

12) EARTH AND SPACE *Multiple Choice* Which of the following processes is NOT a way which air can be forced to rise?

- W) Orographic lifting
- X) Frontal wedging
- Y) Evaporative cooling
- Z) Convergence of air

ANSWER: Y) Evaporative cooling

TOSS UP

13) BIOLOGY *Short Answer* By name or number, identify all the following three groups of animals that have limbs with digits:

- 1) Frogs
- 2) Turtles
- 3) Mammals

ANSWER: 1, 2, 3 (ACCEPT: All)

BONUS

13) BIOLOGY *Short Answer* What taxonomic class does the sand cat, *Felis marginata*, appear in?

ANSWER: Mammalia (ACCEPT: Mammals)

TOSS UP

14) EARTH AND SPACE *Multiple Choice* Valley networks on the surface of Mars are thought to have been formed by which of the following?

- W) Wind
- X) Tectonic activity
- Y) Flowing water
- Z) Volcanism

ANSWER: Y) Flowing water

BONUS

14) EARTH AND SPACE *Short Answer* What is the name of the region on the HR diagram where a combination of size and temperature causes stars to become unstable and pulsate?

ANSWER: Instability strip

TOSS UP

15) PHYSICS *Multiple Choice* Which of the following is the SI unit of capacitance?

- W) Ohm
- X) Farad
- Y) Henry
- Z) Maxwell

ANSWER: X) Farad

BONUS

15) PHYSICS *Multiple Choice* In a driven series RLC circuit, the voltage across the inductor is proportional to which of the following?

- W) Current squared
- X) Inverse of inductance
- Y) Second derivative of charge on the capacitor
- Z) Voltage across the battery

ANSWER: Y) Second derivative of charge on the capacitor

TOSS UP

16) ENERGY *Short Answer* Researchers in the Lippard group at MIT have developed a fluorescent sensor to detect minute concentrations of NO, nitric oxide, and HNO, nitroxyl, in living cells. What is the molecular geometry of the nitroxyl molecule?

ANSWER: Bent

BONUS

16) ENERGY *Short Answer* Researchers in the Schrock group at MIT have discovered a method of catalytically reducing dinitrogen to ammonia at room temperature and pressure using molybdenum complexes. In the half-reaction for the reduction of dinitrogen to ammonia, how many electrons are transferred per molecule of dinitrogen?

ANSWER: 6

TOSS UP

17) MATH *Short Answer* If four friends of different heights are arranged randomly in a line, what is the probability that they are in order of either increasing or decreasing height?

ANSWER: 1/12

BONUS

17) MATH *Multiple Choice* A real-valued polynomial with degree 5 has no repeated real roots. What is the sum of the possible numbers of real roots that it can have?

- W) 6
- X) 9
- Y) 12
- Z) 15

ANSWER: X) 9

TOSS UP

18) CHEMISTRY *Multiple Choice* Which of the following nuclear decay modes is plutonium-242 most likely to undergo?

- W) Alpha decay
- X) Beta minus decay
- Y) Beta plus decay
- Z) Electron capture

ANSWER: W) Alpha decay

BONUS

18) CHEMISTRY *Short Answer* The nuclear decay pathway of plutonium-242 to lead-206 involves a mix of alpha and beta decays. How many alpha decays occur during this decay process?

ANSWER: 9

TOSS UP

19) EARTH AND SPACE *Short Answer* What type of galaxy does the Faber-Jackson (*FAY-bur JACK-suhn*) relation apply to, setting the luminosity of the galaxy proportional to the fourth power of the central stellar velocity dispersion?

ANSWER: Elliptical galaxy

BONUS

19) EARTH AND SPACE *Short Answer* What is the apparent magnitude of a star that has 100 times the flux of Vega?

ANSWER: -5

TOSS UP

20) MATH *Multiple Choice* Consider the sequence of 10 numbers where the n -th number represents the number of positive integer factors of n . What is the mode of this sequence?

- W) 1
- X) 2
- Y) 3
- Z) 4

ANSWER: X) 2

BONUS

20) MATH *Short Answer* The math, science, and history classes at a school each have 35 students. Every pair of classes has exactly 9 students in common, and there are 3 students in all three classes. How many students are in at least one of the three classes?

ANSWER: 81

TOSS UP

21) PHYSICS *Multiple Choice* A cannonball is launched from ground level at a 60 degree angle to the ground, with velocity of 6 meters per second. In meters per second, what is the maximum speed that the cannonball will take during its journey?

- W) 4
- X) 5
- Y) 6
- Z) 7

ANSWER: Y) 6

BONUS

21) PHYSICS *Short Answer* An ideal, frictionless pulley consists of a massless string connecting two masses of 3 and 4 kilograms. What is the magnitude of the acceleration of the 4-kilogram mass in meters per second squared?

ANSWER: $7/5$ (ACCEPT: 1.4)

TOSS UP

22) CHEMISTRY *Short Answer* By name or number, rank the following three emissions from a hydrogen atom by increasing wavelength:

- 1) $n = 4$ to $n = 2$
- 2) $n = 4$ to $n = 1$
- 3) $n = 6$ to $n = 5$

ANSWER: 2, 1, 3

BONUS

22) CHEMISTRY *Multiple Choice* Which of the following sets of quantum numbers is NOT possible?

- W) $n = 2, l = 0, m_l = 0$
- X) $n = 2, l = 1, m_l = -1$
- Y) $n = 3, l = 2, m_l = 3$
- Z) $n = 5, l = 3, m_l = 3$

ANSWER: Y) $n = 3, l = 2, m_l = 3$

TOSS UP

23) BIOLOGY *Multiple Choice* Which of the following traits is NOT a derived trait of chordates (*CORE-dates*)?

- W) Notochord
- X) Pharyngeal (*fur-IN-jee-uhl*) slits
- Y) Post-anal tail
- Z) Limb buds

ANSWER: Z) Limb buds

BONUS

23) BIOLOGY *Short Answer* By name or number, identify all of the following five organisms that are deuterostomes (*DOO-tuhr-uh-stowmz*):

- 1) Humans
- 2) Snails
- 3) Nematodes
- 4) Earthworms
- 5) Jellyfish

ANSWER: 1 only
