2022 MIT Science Bowl High School Invitational Round 10

TOSS UP

1) EARTH AND SPACE *Multiple Choice* The topset beds of Gilbert deltas, which tend to be the closest to the stream entering the body of standing water, are largely composed of which of the following types of sediment?

W) Gravels
X) Fine sands
Y) Silts
Z) Clays

ANSWER: W) Gravels

BONUS

1) EARTH AND SPACE *Multiple Choice* Downdrafts at the rear of squall lines are associated with air that has been cooled primarily by which of the following phenomena?

W) Adiabatic cooling of air parcel
X) Black body radiation from dust in the air
Y) Evaporation of precipitating rain
Z) Condensation of water vapor

ANSWER: Y) Evaporation of precipitating rain

TOSS UP

2) BIOLOGY *Short Answer* Summation of action potentials in a muscle fiber leads to what type of prolonged smooth contraction that shares its name with a bacterial disease that causes unwanted versions of the same type of contraction?

ANSWER: Tetanus

BONUS

2) BIOLOGY *Multiple Choice* By name or number, identify all of the following three changes that would shift the hemoglobin curve strictly to the left:

1) Increase in carbon monoxide concentration in blood
2) Increase in dissolved oxygen concentration in blood
3) Increase in blood pH

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

TOSS UP

3) CHEMISTRY *Short Answer* Gold cannot dissolve in nitric acid or hydrochloric acid alone. However, in a mixture of nitric acid and hydrochloric acid, gold dissolves and forms a salt where gold is in what oxidation state?

ANSWER: +3

BONUS

3) CHEMISTRY *Multiple Choice* Electrophilic aromatic substitution on a 3-substituted indole forms a bridged tricyclic compound, where the new ring is created on the "pyrrole side". Although direct cyclization to the 2 position of the indole is a plausible mechanism, which of the following experimental techniques was used to prove that cyclization happens first to the 3 position, followed by an alkyl shift?

W) Isotopic labeling
X) Crossover experiment
Y) Kinetic isotope experiments
Z) EPR spectroscopy

ANSWER: W) Isotopic labeling

TOSS UP

4) PHYSICS *Multiple Choice* A cylinder with a small hole in the bottom is filled with water to a height h and allowed to drain. Ignoring the effects of surface tension, which of the following best describes the time interval it will take for the water to drain completely?

W) Proportional to h
X) Proportional to $h^{-1/2}$
Y) Proportional to $h^{1/2}$
Z) Infinite, as the water level will asymptotically approach zero

ANSWER: Y) Proportional to $h^{1/2}$

BONUS

4) PHYSICS *Short Answer* A waterfall with height 500 meters has a flow rate of 1.5 meters cubed per second. To two significant figures and in newtons, what is the force with which water impacts the ground level of the waterfall?

ANSWER: 150,000 (ACCEPT: 1.5×10^5)

TOSS UP

5) ENERGY *Multiple Choice* The Gehring Lab at MIT is studying gene imprinting in nutritive plant tissues. During germination, what modified organelles are responsible for breaking down fatty tissue for the plant?

ANSWER: Glyoxysomes

BONUS

5) ENERGY *Short Answer* Researchers in the Gehring Lab at MIT are investigating the role of RNA polymerase IV (read: *four*) in endosperm epigenetics and have discovered that the enzyme can be influenced such that it is only inherited paternally or maternally. What is the term for such an effect, where the expression of a gene depends on the side of inheritance?

ANSWER: Genomic imprinting

TOSS UP

6) MATH *Short Answer* How many subsets of the set of the first six positive integers have an odd total sum?

ANSWER: 32

BONUS

6) MATH *Short Answer* A circle is growing at a steady rate with its area increasing by 3 square meters per second. If its current area is 16 square meters, then at what rate, in meters per second, is its diameter increasing?

ANSWER: $3\sqrt{\pi}/4\pi$

TOSS UP

7) BIOLOGY *Multiple Choice* Jonathan is researching operons and wants to identify which bases are involved in repressor binding to the operator. Which of the following methods would best allow him to do so?

W) DNase (*D-N-ase*) footprinting
X) Gel mobility shift assay
Y) Sanger sequencing
Z) S1 mapping

ANSWER: W) DNase footprinting

BONUS

7) BIOLOGY *Multiple Choice* Lynette is studying a mysterious substance she found in Arthur's room. First, she mixes the sample with Benedict's solution, resulting in a blue solution. She then mixes it with Lugol's iodine, resulting in a yellow solution. Lastly, she mixes it with Bradford reagent, resulting in another blue solution. Which of the following would be the best method to further identify the substance?

W) Northern blot
X) Eastern blot
Y) Southern blot
Z) Western blot

ANSWER: Z) Western blot

TOSS UP

8) CHEMISTRY *Multiple Choice* Commercial superglues are pure ethyl 2-cyanoacrylate, a monomer consisting of an ethylene group attached to a cyano group and an ester group. Which of the following polymerization methods does superglue undergo?

W) Radical addition
X) Cationic addition
Y) Anionic addition
Z) Condensation

ANSWER: Y) Anionic addition

BONUS

8) CHEMISTRY *Short Answer* How many stereoisomers are possible for a molecule of 2,3,4-pentanetriol (*two three four pen-tane-TRY-awl*)?

ANSWER: 4

TOSS UP

9) EARTH AND SPACE *Short Answer* What term describes the crescent-shaped gauges made when boulders are dragged along the base of a glacier?

ANSWER: Chatter marks

BONUS

9) EARTH AND SPACE *Short Answer* By name or number, rank the following three water masses by increasing density:

1) North Atlantic Deep Water
2) Antarctic Intermediate Water
3) Antarctic Bottom Water

ANSWER: 2, 1, 3

TOSS UP

10) ENERGY *Short Answer* Scientists at MIT's Plasma Science and Fusion Lab are studying the various challenges associated with achieving nuclear fusion. One potential method for lowering the temperature required for fusion involves catalyzing the reaction using what leptons?

ANSWER: Muons

BONUS

10) ENERGY *Short Answer* MIT physicists working on the Cryogenic Underground Observatory for Rare Events are searching for experimental evidence of neutrinoless double beta decay. If it exists, neutrinoless double beta decay would indicate that the neutrino is its own antiparticle. What is the general name for the class of particles which behave as their own antiparticles?

ANSWER: Majorana particles (ACCEPT: Majorana fermions)

TOSS UP

11) MATH *Short Answer* Solve the following equation over the complex numbers: $z^2 = -8i$.

ANSWER: $z = 2 - 2i, -2 + 2i$

BONUS

11) MATH *Short Answer* How many nonempty subsets of the set of the first six positive integers have total sum divisible by three?

ANSWER: 23

TOSS UP

12) PHYSICS *Short Answer* A massive particle is attached to a string and travels in a circle around the pole after being given an initial velocity. As the particle continues to travel, the string wraps around the pole until the particle eventually hits the pole. Assuming all surfaces are frictionless, by name or number, identify all of the following three physical quantities that are NOT conserved in this process:

1) Linear momentum
2) Angular momentum
3) Energy

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

BONUS

12) PHYSICS *Multiple Choice* Jeff is rolling an object that weighs 100 kilograms and has a radius of 0.1 meters down a frictionless 30 degrees ramp of a one meter height. Which of the following is closest to the moment of inertia of the object if it reaches a speed of 4 meters per second at the bottom of the ramp?

W) 0.15
X) 0.25
Y) 0.35
Z) 0.45

ANSWER: X) 0.25

TOSS UP

13) PHYSICS *Short Answer* A 2 farad capacitor, a 2 henry inductor, and a 2 ampere current source are all connected in parallel. After a while, this circuit reaches a steady state. The capacitor is then suddenly replaced with a 10 ohm resistor. What is the voltage across the resistor immediately after the switch?

ANSWER: 0

BONUS

13) PHYSICS *Short Answer* A Wye-Delta transformation turns a pattern of 3 loads placed in a Y-pattern around a common node into a triangle pattern, with each load placed on each side. If all loads have the same impedance Z in the Y-format, in terms of Z, what will be the value of each load placed in the delta format?

ANSWER: $3Z$ (ACCEPT: 3 times Z)

TOSS UP

14) BIOLOGY *Multiple Choice* Which of the following is true about the concept of a species?

W) Asexual species can be classified under the biological species definition
X) There are no recorded cases of 2 separate species producing fertile hybrids
Y) Speciation is always a very slow and steady process
Z) While usually thought of as a linear process, gene transfer is surprisingly frequent between unrelated species

ANSWER: Z) While usually thought of as a linear process, gene transfer is surprisingly frequent between unrelated species

BONUS

14) BIOLOGY *Short Answer* By name or number, identify all of the following five factors that affect the rate of arrival and extinction of species on islands, according to the theory of island biogeography:

1) Distance to mainland
2) Island size
3) Island shape
4) Island age
5) Depth of ocean

ANSWER: 1, 2, 3

TOSS UP

15) CHEMISTRY *Multiple Choice* Which of the following substances has the greatest band gap?

W) Silicon
X) Silicon dioxide
Y) Graphite
Z) Diamond

ANSWER: X) Silicon dioxide

BONUS

15) CHEMISTRY *Multiple Choice* Which of the following alkenes has the longest wavelength of maximum absorption?

W) Ethene
X) Nitroethene
Y) Propene
Z) 1-nitro-2-propene

ANSWER: Z) 1-nitro-2-propene

TOSS UP

16) EARTH AND SPACE *Multiple Choice* Which of the following statements best explains why neutrinos are not considered candidates for cold dark matter?

W) They are uncharged
X) They are only left handed
Y) They are their own antiparticle
Z) They have low masses and thus are ultrarelativistic

ANSWER: Z) They have low masses and thus are ultrarelativistic

BONUS

16) EARTH AND SPACE *Short Answer* The semi-major axis of a prograde asteroid with diameter of 150 meters will increase steadily, causing it to spiral away from the Sun due to what phenomenon?

ANSWER: Yarkovsky effect

TOSS UP

17) ENERGY *Multiple Choice* MIT chemists collaborated with Argonne National Lab researchers to design new polymer-based batteries to replace existing iron-air battery technology. Which of the following statements is true about iron-air batteries?

W) During discharge, the iron electrode acts as the anode
X) Iron-air batteries have higher energy densities than lithium-air batteries
Y) The oxygen electrode is operated under acidic conditions to maximize performance
Z) Iron-air batteries are examples of primary cells

ANSWER: W) During discharge, the iron electrode acts as the anode

BONUS

17) ENERGY *Short Answer* Researchers in the Hong group at MIT are actively pursuing novel solid-state NMR techniques for more rapid and higher quality biomolecule structure determination. By name or number, identify all of the following four isotopes whose nuclei are NMR active:

1) Hydrogen-2
2) Lithium-7
3) Nitrogen-14
4) Oxygen-16

ANSWER: 1, 2, and 3 (ACCEPT: All but 4)

TOSS UP

18) MATH *Short Answer* How many permutations of the string "1234" satisfy the property that no two adjacent digits differ by more than 2?

W) 6
X) 8
Y) 10
Z) 12

ANSWER: Z) 12

BONUS

18) MATH *Short Answer* What is the ratio of the length of the inradius to the circumradius of a 5-12-13 triangle?

ANSWER: 4/13

TOSS UP

19) BIOLOGY *Short Answer* By name or number, identify all of the following four extraembryonic membranes that are present in fish:

1) Allantois (*uh-LAN-tow-uhs*)
2) Amnion (*AM-nee-uhn*)
3) Chorion (*CORE-ee-uhn*)
4) Yolk sac

ANSWER: 4 only

BONUS

19) BIOLOGY *Multiple Choice* Which of the following is NOT true about lipoproteins and cholesterol?

W) High LDL to HDL ratio is a risk factor for cardiovascular disease
X) LDL particles deliver cholesterol from the liver to peripheral cells
Y) HDL particles binding to artery walls is the main cause of atherosclerosis
Z) Statins inhibit cholesterol production by inhibiting HMG-CoA reductase

ANSWER: Y) HDL particles binding to artery walls is the main cause of atherosclerosis

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TOSS UP

20) PHYSICS *Multiple Choice* A 1 kilogram block rests on a frictionless plane, with another 1 kilogram block resting on top of it. The coefficient of friction between the two blocks is 0.1. Which of the following is closest to the amount of force in newtons with which the bottom block must be pushed such that the top block slips relative to the bottom?

W) 1
X) 2
Y) 4
Z) 5

ANSWER: X) 2

BONUS

20) PHYSICS *Short Answer* A uniform square slab has a side length of 2 meters and a mass of 1 kilogram. What is the moment of inertia, in kilogram meters squared, of the slab about an axis which passes through two opposite vertices of the square?

ANSWER: 1/3

TOSS UP

21) EARTH AND SPACE *Multiple Choice* Which of the following types of resonance in the spiral disk is thought to give rise to spiral arms?

W) Tidal resonance
X) Kozai resonance
Y) Lindblad resonance
Z) Paired secular resonances

ANSWER: Y) Lindblad resonance

BONUS

21) EARTH AND SPACE *Multiple Choice* Which of the following elements is the final stable product of lithium burning early in a star's life?

W) Helium
X) Beryllium
Y) Carbon
Z) Fluorine

ANSWER: W) Helium

TOSS UP

22) MATH *Short Answer* In the Taylor series expansion of e^{3x} about $x = 0$, what is the coefficient of the x^3 term?

ANSWER: 9/2

BONUS

22) MATH *Short Answer* The non-integer solutions to $x^6 = 64$ are graphed on the complex plane. What is the area of the convex polygon formed by using the solutions as vertices?

ANSWER: $4\sqrt{3}$

TOSS UP

23) CHEMISTRY *Multiple Choice* Which of the following electrochemical diagrams plots the thermodynamically stable aqueous phases of a specific element, where pH is on the x-axis and E, the standard voltage potential, is on the y-axis?

W) Pourbaix (*POUR-bay*) diagram
X) Latimer diagram
Y) Ellingham diagram
Z) Frost diagram

ANSWER: W) Pourbaix diagram

BONUS

23) CHEMISTRY *Multiple Choice* In the Pourbaix (*POUR-bay*) diagram of selenium, which of the following expressions is equal to the slope of the line separating SeO_4^{2-} (read: *S-E-O four two minus*) and SeO_3^{2-} (read: *S-E-O three two minus*)?

W) $-RT/F \log(e)$
X) $RT/F \log(e)$
Y) $-RT/2F \log(e)$
Z) $RT/2F \log(e)$

ANSWER: W) $-RT/F \log(e)$
