2023 MIT Science Bowl High School Invitational Round 8

TOSS UP

1) PHYSICS *Multiple Choice* Which of the following particles does NOT obey the Pauli exclusion principle?

W) Pion
X) Proton
Y) Neutrino
Z) Electron

ANSWER: W) Pion

BONUS

1) PHYSICS *Short Answer* Heat is transferred to two moles of a monatomic ideal gas at constant volume such that the temperature rises by 1 degree celsius. In joules to the nearest integer, how much heat was transferred?

ANSWER: 25

TOSS UP

2) ENERGY *Multiple Choice* Scientists at the Suess group at MIT are studying iron-sulfur proteins in organisms. In which of the following locations would they find these iron-sulfur proteins?

W) Oxygen evolving complex
X) Mitochondrial electron transport chain
Y) Inside of peroxisomes
Z) Nucleolus

ANSWER: X) Mitochondrial electron transport chain

BONUS

2) ENERGY *Multiple Choice* Researchers in the Fink Lab at MIT have studied how m6A modifications in the 3' (read: *three prime*) UTR of certain yeast mRNA molecules can promote meiosis. Which of the following is NOT true concerning the 3' UTRs of eukaryotic mRNA?

W) A frameshift mutation may cause the 3' UTR to be translated
X) The polyadenylation signal is contained within the 3' UTR
Y) The 3' UTR is spliced by snRNAs
Z) The 3' UTR promotes mRNA stability

ANSWER: Y) The 3' UTR is spliced by snRNAs

TOSS UP

3) EARTH AND SPACE *Multiple Choice* Karst topography is more readily found in tropical and temperate regions even though calcite dissolves more readily in polar regions. What observation best accounts for this apparent incongruency?

W) Polar regions tend to be drier
X) Polar regions receive less sunlight
Y) Polar flora secrete fewer acids into the ground
Z) Snow cover in polar regions prevents rainfall intrusion

ANSWER: W) Polar regions tend to be drier

BONUS

3) EARTH AND SPACE *Multiple Choice* A seismic gap found below an active volcano could reasonably be interpreted as what feature?

W) A related lopolith
X) An anomalously shallow moho
Y) The volcano's magma chamber
Z) A sill-like intrusion

ANSWER: Y) The volcano's magma chamber

TOSS UP

4) CHEMISTRY *Multiple Choice* The isotherms of an ideal gas on a $P-V$ diagram are most closely related to which of the following types of conic sections?

W) Circle
X) Ellipse
Y) Parabola
Z) Hyperbola

ANSWER: Z) Hyperbola

BONUS

4) CHEMISTRY *Short Answer* What is the average oxidation state of iron in iron(II) hexacyanoferrate(III) (*iron two hexa sai-an-oh fair-rate three*)?

ANSWER: 2.4 (ACCEPT: 12/5)

TOSS UP

5) BIOLOGY *Short Answer* Gregory is studying pea plants. He notes that the purple flower trait is dominant to the white flower trait, the yellow pea trait is dominant to the green pea trait, and the round pea trait is dominant to the wrinkled pea trait. He performs a trihybrid cross. Assuming independent assortment, what fraction of the offspring of this cross will have purple flowers and yellow, round peas?

ANSWER: 27/64

BONUS

5) BIOLOGY *Short Answer* A macrophage (*MACK-row-fayzh*) engulfs a protist with a mitochondria. How many lipid bilayers are between the interior of the protist mitochondria and the exterior of the macrophage?

ANSWER: 5

TOSS UP

6) MATH *Multiple Choice* On the number line, the distance between the number x and the number 0 is twice the distance between the number x and the number 3. What is the sum of all possible values of x?

W) 2
X) 4
Y) 6
Z) 8

ANSWER: Z) 8

BONUS

6) MATH *Multiple Choice* Arnold has ten red ducks and two blue ducks in a row. If the red ducks must form two contiguous segments, how many ways can Arnold arrange his ducks?

W) 18
X) 19
Y) 27
Z) 28

ANSWER: Y) 27

TOSS UP

7) ENERGY *Short Answer* Researchers in the Willard group are working on fine-tuning the properties of organic electronic devices, where these properties are often highly-dependent on what quasiparticle, which is the bound state of an electron and electron hole?

ANSWER: Excitons

BONUS

7) ENERGY *Short Answer* Researchers in the Jamison group at MIT are investigating methods of carbon-carbon bond formation via nickel catalysis. When refining metallic nickel, an impure ore is heated up with carbon monoxide until nickel tetracarbonyl is formed, which observes what geometry?

ANSWER: Tetrahedral

TOSS UP

8) MATH *Multiple Choice* What is the smallest positive integer that can be written in the form $2023x + 13y$ (read: *two thousand twenty three x plus thirteen y*) where x and y are integers?

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

ANSWER: W) 1

BONUS

8) MATH *Short Answer* The base-6 representation of a number ends in 120 (read: *one two zero*). In base-10, what is the largest number which it must be a multiple of?

ANSWER: 24

TOSS UP

9) BIOLOGY *Multiple Choice* Which of the following is NOT true concerning hyperthyroidism?

W) In Graves' disease, anti-TSH receptor antibodies cause excessive release of T3 and T4
X) Hyperthyroidism often results in heat intolerance
Y) One would expect to see decreased levels of TRH in a person with hyperthyroidism
Z) Hyperthyroidism is associated with increased sensitivity of the hypothalamus to T3 and T4

ANSWER: Z) Hyperthyroidism is associated with increased sensitivity of the hypothalamus to T3 and T4

BONUS

9) BIOLOGY *Short Answer* Identify all of the following three factors that, when increased, would increase the Starling forces of filtration out of the capillary:

1) Capillary hydrostatic pressure
2) Interstitial colloid pressure
3) Total peripheral resistance

ANSWER: All

TOSS UP

10) PHYSICS *Short Answer* A charged particle is moving in the positive x direction at 3 meters per second. An observer at the origin sees that 1 meter away from the particle in the positive y direction, the magnetic field from the particle has a strength of 3 teslas. What is the magnetic field strength observed at the same point by an observer traveling at 3 meters per second in the positive x direction?

ANSWER: 0

BONUS

10) PHYSICS *Short Answer* A 30 kilogram astronaut in space is carrying a 20 kilogram object and traveling at 10 meters per second. She then throws the object in the direction of her motion. After the throw, the object moves at 5 meters per second relative to her body. What is the astronaut's new speed in meters per second?

ANSWER: 8

TOSS UP

11) EARTH AND SPACE *Short Answer* At what height in kilometers would a dry air parcel six Kelvin warmer than its environment stop ascending when the environmental lapse rate is 7 degrees Celsius per kilometer and the dry adiabatic lapse rate is 10 degrees Celsius per kilometer?

ANSWER: 2

BONUS

11) EARTH AND SPACE *Short Answer* Identify all of the following three geologic features which are correctly paired with their erosional agent:

1) Yardang (*yar-dang*), Aeolian
2) Roche mountonee (*rosh moo-ton-nee*), Glacial
3) Pothole, Fluvial

ANSWER: All

TOSS UP

12) CHEMISTRY *Short Answer* What is the VSEPR (read: *ves-per*) predicted molecular geometry of iodine pentafluoride?

ANSWER: Square pyramidal

BONUS

12) CHEMISTRY *Multiple Choice* Which of the following best explains why chlorine gas is formed instead of oxygen gas during the electrolysis of brine?

W) The oxidation potential of the chloride-chlorine electrode is greater than that of the water-oxygen electrode
X) The oxidation potential of the chloride-chlorine electrode is less than that of the water-oxygen electrode
Y) The overpotential of the chloride-chlorine electrode is greater than that of the water-oxygen electrode
Z) The overpotential of the chloride-chlorine electrode is less than that of the water-oxygen electrode

ANSWER: Z) The overpotential of the chloride-chlorine electrode is less than that of the water-oxygen electrode

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TOSS UP

13) MATH *Short Answer* What is the maximum value over real values of x for the expression $e^{\sin(x)+\cos(x)}$ (read: *e raised to the power of the quantity sine x plus cosine x*)?

ANSWER: $e^{\sqrt{2}}$

BONUS

13) MATH *Short Answer* A line segment is drawn in the plane. How many distinct regular pentagons contain the two endpoints of the line segment as vertices?

ANSWER: 4

TOSS UP

14) BIOLOGY *Multiple Choice* Hydroids (*HIGH-droids*) and leptoids are tissues found in which of the following types of plants?

W) Bryophyta (*BRY-yo-fighta*)
X) Lycophyta (*LIKE-oh-fighta*)
Y) Anthocerophyta (*ANTH-tho-sero-fighta*)
Z) Marchantiophyta (*mar-CHANT-tee-yo-fighta*)

ANSWER: W) Bryophyta

BONUS

14) BIOLOGY *Multiple Choice* The plant Mimosa pudica (*mim-MOH-sa POO-dica*) contains pulvini (*pull-VEE-nee*), specialized organs that can rapidly lose turgor (*TUR-gur*) pressure. Which of the following best describes the function of pulvini?

W) Regulates the movement of soil nutrients into the root
X) Moderates thigmonastic response in the leaves
Y) Controls the flow of xylem through the plant
Z) Coordinates the opening of stomata

ANSWER: X) Moderates thigmonastic response in the leaves

TOSS UP

15) ENERGY *Short Answer* Researchers in the Francis Bitter Magnet Laboratory at MIT are studying magnetism. Curie's law is an emperical law that relates the magnetic susceptibility of paramagnetic materials to their temperature. According to Curie's law, the magnetic susceptibility is proportional to temperature raised to what power?

ANSWER: -1

BONUS

15) ENERGY *Multiple Choice* Reasearchers in MIT's Center for Theoretical Physics are studying the structure of the proton, which can be modeled as a combination of 3 quarks. Which of the following is closest to the percent of the proton's mass constituted by these 3 quarks?

W) 1 percent
X) 30 percent
Y) 70 percent
Z) 99 percent

ANSWER: W) 1 percent

TOSS UP

16) CHEMISTRY *Short Answer* Rank the following three molecules in terms of increasing entropy of vaporization at 25 degrees Celsius:

1) Water
2) Methanol
3) Methane

ANSWER: 3, 2, 1

BONUS

16) CHEMISTRY *Short Answer* What type of magnetism is generally observed in metal-carbonyl complexes?

ANSWER: Diamagnetism

TOSS UP

17) EARTH AND SPACE *Multiple Choice* What type of objects are observed to contain Lyman alpha forests in their spectra due to their luminosity and large distance from Earth?

W) Pulsars
X) Quasars
Y) Type II Cepheids
Z) Type 1a supernovae

ANSWER: X) Quasars

BONUS

17) EARTH AND SPACE *Short Answer* It is currently 6 pm and the moon is highest in the sky. After three days, what phase will the moon be in?

ANSWER: Waxing gibbous

TOSS UP

18) PHYSICS *Short Answer* A wheel with radius 0.4 meters rolls without slipping at a speed of 3 meters per second. A point that is 0.2 meters away from the center of the wheel is chosen. In meters per second, as the wheel rolls, what is the maximum speed of the point?

ANSWER: 4.5

BONUS

18) PHYSICS *Short Answer* The resistivity of copper is approximately 1.5×10^{-8} ohm meters. Expressing your answer in scientific notation to one significant figure, what is the resistance in ohms of a cylindrical copper wire with length 20 centimeters and radius 4 millimeters?

ANSWER: 6×10^{-5}

TOSS UP

19) EARTH AND SPACE *Short Answer* Identify all of the following four statements are not true of the moons of Mars:

1) Phobos lies in a stable orbit
2) Deimos is the largest martian moon
3) Phobos and Deimos are in equatorial orbits
4) Deimos's composition resembles the asteroid Ceres

ANSWER: 1 and 2

BONUS

19) EARTH AND SPACE *Short Answer* Identify the following four structures that contain the Milky Way:

1) Local Group
2) Boötes (*boh-oh-tees*) Void
3) Virgo Cluster
4) Virgo Supercluster

ANSWER: 1 and 4

TOSS UP

20) PHYSICS *Multiple Choice* Which of the following is TRUE about the velocity of the wave crest for a light wavepacket?

W) Its velocity is the phase velocity and can exceed the speed of light
X) Its velocity is the phase velocity and cannot exceed the speed of light
Y) Its velocity is the group velocity and can exceed the speed of light
Z) Its velocity is the group velocity and cannot exceed the speed of light

ANSWER: Y) Its velocity is the group velocity and can exceed the speed of light

BONUS

20) PHYSICS *Short Answer* Two rods that are each 2 meters long are joined at right angles to make a plus shape with 4 arms. A 0.5 meter long segment of one of the arms is snapped off. What is the distance between the center of mass of the object and the intersection point in meters?

ANSWER: 3/28

TOSS UP

21) CHEMISTRY *Short Answer* When chlorine gas is bubbled into basic water, the chloride anion along with what other chlorine-containing ion is formed?

ANSWER: Hypochlorite anion (ACCEPT: Hypochlorite; OCl^-)

BONUS

21) CHEMISTRY *Multiple Choice* In terms of the ideal gas constant, R, which of the following is closest to the constant-volume heat capacity of dinitrogen at 400 Kelvin?

W) $2R$
X) $2.5R$
Y) $3R$
Z) $3.5R$

ANSWER: X) $2.5R$

TOSS UP

22) BIOLOGY *Multiple Choice* Which of the following statements is NOT true regarding the hormone cholecystokinin (*COLE-uh-SIS-toe-KAI-nin*), otherwise known as CCK?

W) CCK inhibits gastric emptying
X) CCK leads to secretion of pancreatic juice.
Y) CCK stimulates bile synthesis by the gallbladder
Z) CCK leads to the relaxation of the sphincter of Oddi

ANSWER: Y) CCK stimulates bile synthesis by the gallbladder

BONUS

22) BIOLOGY *Multiple Choice* Which of the following is LEAST likely to occur at the infection site if a plant is infected with bacterial effector proteins?

W) Increased expression of R genes
X) Decreased lignin synthesis to conserve metabolites
Y) Formation of localized lesions (*LEE-zhins*) to contain the pathogen
Z) Export of methylsalicylic (*METH-thul sally-sillic*) acid to promote systemic acquired resistance

ANSWER: X) Decreased lignin synthesis to conserve metabolites

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TOSS UP

23) MATH *Multiple Choice* Euler's (*oiler's*) totient function counts the number of positive integers up to a given integer N that are relatively prime to N. Which of the following is the largest value that the Euler's totient function attains over the first one hundred positive integers?

W) 95
X) 96
Y) 97
Z) 98

ANSWER: X) 96

BONUS

23) MATH *Short Answer* In slope-intercept form, what is the equation for the line perpendicular to the curve of $y = x^2$ (read: *y equals x squared*) at the point $(2, 4)$ (read: *two comma four*)?

ANSWER: $y = -\frac{1}{4}x + \frac{9}{2}$ (read: *y equals negative one fourth x plus nine halves*)