2022 MIT Science Bowl High School Invitational Round 5

TOSS UP

1) EARTH AND SPACE *Short Answer* What type of streams consist of multiple converging and diverging channels that thread their way among gravel bars?

ANSWER: Braided streams

BONUS

1) EARTH AND SPACE *Multiple Choice* Cassiterite is an ore of which of the following elements?

W) Molybdenum
X) Vanadium
Y) Zirconium
Z) Tin

ANSWER: Z) Tin

TOSS UP

2) BIOLOGY *Short Answer* What is the name of the species or group of species in an evolutionary lineage that is closely related to but not included in the group of species one is studying?

ANSWER: Outgroup

BONUS

2) BIOLOGY *Multiple Choice* Which of the following is NOT considered a bryophyte (*BRAI-uh-fite*)?

W) Club moss
X) Liverwort
Y) Hornwort
Z) Pincushion moss

ANSWER: W) Club moss

TOSS UP

3) CHEMISTRY *Short Answer* Consider the balanced reaction for the formation of bromine pentafluoride: $Br_2 + 5\,F_2 \longrightarrow 2\,BrF_5$ (read: *B-R-2 plus 5-F-2 yields 2-B-R-F-5*). If the rate of disappearance of F_2 is 0.7 molar per second, what is the rate of appearance of BrF_5 in molar per second?

ANSWER: 0.28

BONUS

3) CHEMISTRY *Short Answer* Samples of benzene and toluene are mixed together to create a liquid mixture with a vapor pressure of 86 millimeters of mercury. Given that the vapor pressures of benzene and toluene are 105 millimeters of mercury and 29 millimeters of mercury, respectively, and assuming ideal behavior, calculate the mole fraction of benzene in this mixture to two significant figures.

ANSWER: 0.75 (ACCEPT: 3/4, 75%)

TOSS UP

4) PHYSICS *Short Answer* A block is attached to a wall by means of an ideal spring, such that the system undergoes simple harmonic motion with period 1 second. The spring is then cut in half, and both halves are used in parallel to attach the block to the wall. In seconds, what is the period of oscillations of the resulting system?

ANSWER: 0.5 (ACCEPT: 1/2)

BONUS

4) PHYSICS *Short Answer* Masses of extremely small subatomic particles are often measured in terms of electronvolts per c squared. To one significant digit and in scientific notation, how many kilograms are equivalent to one electronvolt per c squared?

ANSWER: 2×10^{-36}

TOSS UP

5) MATH *Multiple Choice* The polynomial $P(x)$ over the real numbers has a multiple root at 2. Which of the following statements is NOT necessarily true?

W) The derivative of $P(x)$ evaluated at $x = 2$ equals zero
X) $P(x)$ does not have degree 1
Y) $(x-2)^2$ is a factor of $P(x)$
Z) $P(x)$ has a local minimum or maximum at 2

ANSWER: Z) $P(x)$ has a local minimum or maximum at 2

BONUS

5) MATH *Short Answer* Five friends are sitting in five differently colored chairs around a table. How many ways are there for them to rearrange themselves in these chairs so that nobody is sitting next to anybody that they sat next to before?

ANSWER: 10

TOSS UP

6) ENERGY *Multiple Choice* The Hemann Lab at MIT studies drug resistance in the tumor microenvironment, where tumor cytokine release plays an important role. This type of cytokine release also occurs due to physiological stresses such as low levels of oxygen, which is given which of the following terms when it occurs in the body tissues?

W) Hypoxemia (*hai-paak-SEE-mee-uh*)
X) Hypoxia (*hai-PAAK-see-uh*)
Y) Hypoventilation
Z) Hypercapnia

ANSWER: X) Hypoxia

BONUS

6) ENERGY *Short Answer* Researchers in the Hemann Lab at MIT have also developed an approach to assess drug mechanisms, which is reliant on a form of gene silencing involving the Dicer and Argonaute proteins. What is the term for this general mechanism that involves non-coding RNA molecules?

ANSWER: RNAi (ACCEPT: RNA interference)

TOSS UP

7) CHEMISTRY *Multiple Choice* The pressure of which of the following gases at a known temperature and volume would have the largest deviation from the pressure predicted by the ideal gas law?

W) Ammonia
X) Nitrogen
Y) Nitrous oxide
Z) Hydrogen cyanide

ANSWER: W) Ammonia

BONUS

7) CHEMISTRY *Short Answer* A 100 milliliter sample of a monoprotic organic acid is titrated against a standard solution of 0.2 molar sodium hydroxide. It takes 50 milliliters of the titrant solution to reach the half-equivalence point, where the pH is 5.0. To the nearest tenth, what is the pH at the equivalence point?

ANSWER: 9.0

TOSS UP

8) ENERGY *Multiple Choice* Physicists at MIT are working with the KATRIN experiment to determine a new upper bound on the mass of the neutrino. Which of the following is known about neutrinos?

W) Whether or not the tau neutrino exists
X) Whether or not the neutrino interacts via the strong force
Y) Whether or not the neutrino is its own antiparticle
Z) What ordering the neutrino masses follow

ANSWER: W) Whether or not the tau neutrino exists

BONUS

8) ENERGY *Multiple Choice* MIT scientists are developing a next-generation PET scanner that can be used simultaneously with magnetic resonance imaging. PET works by using radioisotopes, which decay to emit positrons. When these positrons annihilate with electrons, they produce two gamma rays in opposite directions, which are then detected by the PET scanner. Which of the following is closest to the energy of one of these gamma rays?

W) 50 electronvolts
X) 5 kilo-electronvolts
Y) 500 kilo-electronvolts
Z) 50 mega-electronvolts

ANSWER: Y) 500 kilo-electronvolts

TOSS UP

9) BIOLOGY *Short Answer* Transition areas between biomes are given by what term?

ANSWER: Ecotone

BONUS

9) BIOLOGY *Multiple Choice* Which of the following statements best describes why bats have a higher metabolic rate compared to animals with similar body masses?

W) Bats have less efficient muscles that require more energy
X) The large brains required for echolocation consume much more energy than those of land animals
Y) Flight is very energy-intensive, and requires a high metabolism
Z) Bat immune systems consume much more energy, due to having to fight off more pathogens

ANSWER: Y) Flight is very energy-intensive, and requires a high metabolism

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TOSS UP

10) EARTH AND SPACE *Multiple Choice* Which of the following Köppen (*KAWH-puhn*) classification climates would be the most likely to have significant permafrost?

W) Af (read: *A-F*)
X) BSk (read: *B-S-K*)
Y) Csa (read: *C-S-A*)
Z) Dfc (read: *D-F-C*)

ANSWER: Z) Dfc

BONUS

10) EARTH AND SPACE *Short Answer* By name or number, identify all of the following four glacial features which are partially or fully depositional in nature:

1) Drumlin
2) Glacial striations (*STRY-eyy-shuns*)
3) Roche moutonnée (*rawsh MOO-tuh-nay*)
4) Crag and tail

ANSWER: 1 and 4

TOSS UP

11) PHYSICS *Multiple Choice* Andrew is fishing for penguins and notices a penguin swimming at an apparent depth of 19 meters underwater directly below him. Assuming the index of refraction of water is 1.3, which of the following is closest to the actual separation between Andrew and the penguin in meters?

W) 15
X) 20
Y) 25
Z) 30

ANSWER: Y) 25

BONUS

11) PHYSICS *Multiple Choice* A black body has a temperature of 4000 kelvin. Which of the following best describes the form of light that corresponds to the peak of the blackbody spectrum?

W) Radio
X) Microwave
Y) Red visible
Z) Blue visible

ANSWER: Y) Red visible

TOSS UP

12) MATH *Short Answer* How many 8-digit numbers have all their digits in increasing order from left to right?

ANSWER: 9

BONUS

12) MATH *Short Answer* x and y are chosen uniformly at random from the closed interval from 0 to 1. What is the probability that $3x > y$ and $3y > x$?

ANSWER: 2/3

TOSS UP

13) MATH *Short Answer* What is the probability that three vertices of a regular hexagon chosen uniformly at random form an equilateral triangle?

ANSWER: 1/10 (ACCEPT: 0.1, 10%)

BONUS

13) MATH *Short Answer* What is the area of the region bounded by the x-axis and the conic with equation $y = x^2 - 25$?

ANSWER: 500/3

TOSS UP

14) CHEMISTRY *Multiple Choice* Which of the following intermolecular interactions extends over the greatest distance of separation?

W) Ion-ion
X) Ion-dipole
Y) Dipole-dipole
Z) Rotating dipole-rotating dipole

ANSWER: W) Ion-ion

BONUS

14) CHEMISTRY *Short Answer* By name or number, rank the following three ionic salts by increasing pH of their saturated aqueous solution:

1) Aluminum hydroxide
2) Barium hydroxide
3) Calcium hydroxide

ANSWER: 1, 3, 2

TOSS UP

15) ENERGY *Short Answer* Researchers in the Radosevich group at MIT have been developing homogenous catalysts based on inexpensive and earth-abundant elements of the *p*-block such as phosphorus. By name or number, order the following three phosphorus containing species by increasing phosphorus oxidation state:

1) Phosphate
2) Phosphine (*FAWS-feen*)
3) Trimethoxyphosphine (*tri-muh-THOCK-see FAWS-feen*)

ANSWER: 2, 3, 1

BONUS

15) ENERGY *Short Answer* Researchers in the Radosevich group at MIT have been developing homogeneous catalysts based on inexpensive and earth-abundant elements of the *p*-block such as phosphorus. One such catalyst has a phosphine (*FAWS-feen*) oxide in the +5 (read: *plus five*) oxidation state as one of the species in the catalytic cycle. What is the most likely oxidation state of phosphorus for the reduced version of the phosphine oxide?

ANSWER: +3

TOSS UP

16) PHYSICS *Short Answer* An isolated capacitor with capacitance 2 farads has been charged to a voltage of 5 volts. The capacitor is then connected in series with a 2 kilo-ohm resistor. After discharging for a long time, how much heat in joules has been dissipated through the resistor?

ANSWER: 25

BONUS

16) PHYSICS *Short Answer* The temperature of an ideal gas is increased from 127 degrees celsius to 167 degrees celsius. To the nearest hundredth, what is the ratio of the speed of sound in this gas at the higher temperature to that at the lower temperature?

ANSWER: 1.05

TOSS UP

17) EARTH AND SPACE *Short Answer* What sub-stellar body may be differentiated from red dwarfs by the presence of lithium in their spectra?

ANSWER: Brown dwarf

BONUS

17) EARTH AND SPACE *Short Answer* By name or number, order the following three groups of resonant trans-Neptunian objects from least to greatest semimajor axis:

1) Plutinos
2) Twotinos
3) Neptune trojans

ANSWER: 3, 1, 2

TOSS UP

18) BIOLOGY *Short Answer* Which immune cell, named for its absorption of pink dye in certain staining schemes, functions as a defense against parasitic worms?

ANSWER: Eosinophil

BONUS

18) BIOLOGY *Short Answer* Phil, a blood scientist, is looking at a blood smear from a patient suffering from a strange fever. While there are normal levels of white blood cells, there are fewer red blood cells than normal, and there are also many smaller, orb shaped cells, some of which appear to be inside the red blood cells. What disease does he have?

ANSWER: Malaria

TOSS UP

19) BIOLOGY *Short Answer* By name or number, identify all of the following three diseases which are inherited through a dominant mechanism:

1) Albinism
2) Phenylketonuria (*feh-nuhl-kee-tuh-NUR-ee-uh*)
3) Cystic fibrosis

ANSWER: None

BONUS

19) BIOLOGY *Multiple Choice* Which of the following is NOT a reason that inbreeding is evolutionarily unfavorable?

W) It makes populations less adaptable
X) It leads to more frequent expression of genetic diseases
Y) It decreases the effects of heterozygote advantage
Z) It increases the viability of hybrid offspring

ANSWER: Z) It increases the viability of hybrid offspring

TOSS UP

20) EARTH AND SPACE *Multiple Choice* Which of the following objects would have the largest radius?

W) 0.075 solar mass brown dwarf
X) 0.1 solar mass red dwarf
Y) 1.0 solar mass white dwarf
Z) 2.0 solar mass neutron star

ANSWER: X) 0.1 solar mass red dwarf

BONUS

20) EARTH AND SPACE *Multiple Choice* A star is observed to have a luminosity of 32 solar luminosities and a temperature of approximately 11,400 kelvin. Which of the following is closest to the radius of this star in solar radii?

W) 0.7
X) 1.4
Y) 2
Z) 4

ANSWER: X) 1.4

TOSS UP

21) MATH *Multiple Choice* If $a \star b = a^2b + ab^2$ (read: *a star b equals a squared b plus a b squared*), what is the value of $10 \star 11$ (read: *ten star eleven*)?

W) 2300
X) 2310
Y) 2320
Z) 2330

ANSWER: X) 2310

BONUS

21) MATH *Multiple Choice* What is the units digit of $3^{3^{3^3}}$ (read: *three to the power of three to the power of three to the power of three to the power of three*)?

W) 1
X) 3
Y) 5
Z) 7

ANSWER: Z) 7

TOSS UP

22) PHYSICS *Multiple Choice* A particle lies on the positive x-axis, and experiences a force of $7\boldsymbol{i}+6\boldsymbol{k}$ newtons. Which of the following could be the torque about the origin experienced by the particle?

W) $5\boldsymbol{j}$
X) $-5\boldsymbol{j}$
Y) $10\boldsymbol{i}+6\boldsymbol{k}$
Z) $-10\boldsymbol{i}-6\boldsymbol{k}$

ANSWER: X) $-5\boldsymbol{j}$

BONUS

22) PHYSICS *Short Answer* A monkey sits in a tree and throws a banana upwards at 2 meters per second. Unfortunately, this causes the monkey to lose its balance, and it falls off the tree. If the monkey hits the ground after 1.5 seconds, how far above the ground in meters is the banana when the monkey hits the ground?

ANSWER: 3

TOSS UP

23) CHEMISTRY *Short Answer* High-spin metal complexes are weakly attracted to external magnetic fields because they display what type of magnetism?

ANSWER: Paramagnetism

BONUS

23) CHEMISTRY *Short Answer* At atmospheric pressure, methane hydrates decompose above 4 degrees celsius. Identify the sign of each of the following three quantities for the formation of methane hydrates at STP as positive, negative, or zero:

1) ΔH
2) ΔS
3) ΔG

ANSWER: Negative, negative, and negative
