# 2024 MIT Science Bowl High School Invitational

# Round 3

## TOSS UP

1) MATH *Short Answer* If Ricky is 20% shorter compared to Eric, by what percent is Eric taller compared to Ricky?

ANSWER: 25

## BONUS

1) MATH *Short Answer* Given that the four numbers 20, 24, $a$, and $b$ (read: *20 comma 24 comma a comma b*) have a median of 15 and range of 15, what is the average of all possible values of $a$?

ANSWER: 19/2 (ACCEPT: 9.5)

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## TOSS UP

2) BIOLOGY *Multiple Choice* There are 61 unique versions of which of the following in humans?

W) tRNAs
X) Amino-acyl (*a-meen-o-as-ill*) tRNAs
Y) Codons coding for amino acids
Z) Anticodons

ANSWER: Y) Codons coding for amino acids

## BONUS

2) BIOLOGY *Short Answer* Identify all of the following three quantities that are likely to be higher in a mouse than in an elephant:

1) Basal metabolic rate per kilogram of body mass
2) Breathing rate
3) Pulse pressure.

ANSWER: 1 and 2

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## TOSS UP

3) EARTH AND SPACE *Short Answer* What line, visible on the moon, separates the illuminated and obscured regions of its phases?

ANSWER: Terminator

## BONUS

3) EARTH AND SPACE *Short Answer* Radioisotopic dating of lunar rocks indicates that much of the Moon's surface was molten in a narrow time interval. What period in the Moon's history does this observation provide evidence for?

ANSWER: Late heavy bombardment (ACCEPT: Lunar cataclysm)

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## TOSS UP

4) ENERGY *Short Answer* Researchers at MIT's Lincoln Laboratory are studying high electron mobility materials made from crystal films. What law describes the linear relationship between the speed of charge carriers through these materials and the strength of the external electric field?

ANSWER: Ohm's Law

## BONUS

4) ENERGY *Short Answer* MIT researchers at the Picower institute are using retroviruses to introduce extra, cloned copies of genes that produce Yamanaka factors to differentiated cells, transforming them into a specific type of embryonic stem cell. What are these "deprogrammed" cells known as?

ANSWER: Induced pluripotent stem cells (ACCEPT: iPS cells)

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## TOSS UP

5) PHYSICS *Multiple Choice* Which of the following particles can cause Rayleigh scattering of light with a wavelength of 500 nanometers?

W) 10 nanometer photon
X) 10 micrometer photon
Y) 10 nanometer dust particle
Z) 10 micrometer dust particle

ANSWER: Y) 10 nanometer dust particle

## BONUS

5) PHYSICS *Short Answer* Train A and train B begin at rest in the same position. Train A begins accelerating at 2 meters per second squared. After 10 seconds have passed, train B begins accelerating at 8 meters per second squared in the same direction as train A. In seconds, how long after train A initially left does train B catch up to train A?

ANSWER: 20

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## TOSS UP

6) CHEMISTRY *Short Answer* According to molecular orbital theory, the superoxide anion's oxygen-oxygen bond has what bond order?

ANSWER: 1.5

## BONUS

6) CHEMISTRY *Short Answer* The combustion of a sample of methane requires 192 grams of oxygen gas and releases 1600 kilojoules of heat. What is the enthalpy of combustion of methane to the nearest hundred kilojoules per mole, given that methane has a molecular weight of 16 grams per mole and oxygen gas has a molecular weight of 32 grams per mole?

ANSWER: -500 (ACCEPT: -500 kilojoules per mole, DO NOT ACCEPT: 500)

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## TOSS UP

7) ENERGY *Short Answer* Researchers in the Robert's group at MIT discovered a mechanism with an unusual electrically neutral unsubstituted benzyne (read: *benz-ign*) intermediate. What is the chemical formula of this benzyne (read: *benz-ign*) intermediate, which is formed by converting a double bond into a triple bond in a benzene ring?

ANSWER: $C_6H_4$

## BONUS

7) ENERGY *Multiple Choice* Researchers at MIT's Johnson Laboratory recently developed an amber-like polymer for long-term storage of DNA by cross-linking aromatic styrene monomers with sulfur-containing rings. Which of the following best describes the mechanism of this cross-linking reaction?

W) The sulfur atom is radically substituted directly onto styrene's aromatic ring
X) The sulfur atom is added across styrene's aromatic ring
Y) The sulfur atom is radically substituted onto styrene's alkene substituent
Z) The sulfur atom is added across styrene's alkene substituent

ANSWER: Z) The sulfur atom is added across styrene's alkene substituent

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## TOSS UP

8) MATH *Short Answer* One-fifth of the rooms at a particular dorm hall in MIT contain one person each, and the remaining four-fifths contain two people each. Expressed as a fraction in simplest form, what proportion of the students in this dorm have a roommate?

ANSWER: $\frac{8}{9}$

## BONUS

8) MATH *Short Answer* What is the perimeter of an isosceles trapezoid with bases of length 5 and 10 and height 6?

ANSWER: 28

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## TOSS UP

9) CHEMISTRY *Multiple Choice* Hydrogen bonding is an example of which of the following types of intermolecular interactions?

W) Induced dipole-induced dipole
X) Dipole-dipole
Y) Ion-dipole
Z) Ion-ion

ANSWER: X) Dipole-dipole

## BONUS

9) CHEMISTRY *Multiple Choice* A sample of ammonium nitrite (*ammo-nee-um night-right*) is exposed to an oxygenated atmosphere. Given that the chemical formula of ammonium nitrite is $NH_4NO_2$, which of the following best describes what occurs next?

W) Ammonium nitrite combusts into nitrogen gas and water vapor
X) Ammonium nitrite decomposes into nitrogen gas and water vapor
Y) Ammonium nitrite decomposes into ammonia, nitrogen dioxide, and water vapor
Z) Ammonium nitrite oxidizes into ammonium nitrate

ANSWER: X) Ammonium nitrite decomposes into nitrogen gas and water vapor

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## TOSS UP

10) EARTH AND SPACE *Multiple Choice* Around which of the following times of day is the atmosphere typically most stable?

W) Sunrise
X) Noon
Y) Sunset
Z) Midnight

ANSWER: W) Sunrise

## BONUS

10) EARTH AND SPACE *Short Answer* To two significant figures and in solar masses, what is the mass of the smaller star in a binary immediately before the system produces a type Ia (*one A*) supernova?

ANSWER: 1.4

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## TOSS UP

11) PHYSICS *Multiple Choice* Gideon is in a cylindrical rocket accelerating upwards. He pushes on a side of the rocket horizontally with force A, and the rocket's hull exerts a normal force B back on him. Which of the following best describes the relationship between the magnitudes of forces A and B?

W) A is greater than B
X) A is less than B
Y) A is equal to B
Z) The relationship between A and B depends on the acceleration

ANSWER: Y) A is equal to B

## BONUS

11) PHYSICS *Short Answer* Consider 2 point charges of charge 1 coulomb each that are 1 meter apart. What is the ratio of the potential energy of this configuration to the potential energy of four identical 1 coulomb point charges placed on the vertices of a regular tetrahedron with a side length of 1 meter?

ANSWER: $\frac{1}{6}$

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## TOSS UP

12) BIOLOGY *Short Answer* Identify all of the following three functional groups that are present in all amino acids:

1) Carboxyl
2) Thiol
3) Phosphate

ANSWER: 1 only

## BONUS

12) BIOLOGY *Short Answer* Identify all of the following three interspecific interactions in which at least one of the involved organisms benefits:

1) Commensalism
2) Parasitism
3) Mutualism.

ANSWER: All

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## TOSS UP

13) ENERGY *Short Answer* The Coley group at MIT is studying encodings for chemical molecules, such as SMILES codes, which represent chemical formulae by their atomic symbols excluding all hydrogen atoms. What is water's SMILES code?

ANSWER: O

## BONUS

13) ENERGY *Multiple Choice* Physicists from MIT and Caltech discovered a black hole triple, where two stars are orbiting a central black hole with periods of 7 days and 70,000 years, respectively. According to Kepler's third law, about how many times greater is the semimajor axis of the further-out star's orbit compared to the closer star's orbit?

W) 200
X) 2,000
Y) 20,000
Z) 200,000

ANSWER: Y) 20,000

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## TOSS UP

14) PHYSICS *Short Answer* In a container of an ideal gas, what term describes the average distance traveled by an individual particle without colliding with another particle?

ANSWER: Mean Free Path

## BONUS

14) PHYSICS *Short Answer* A 2 kilogram block going at 2 meters per second to the right is acted on by a force $F(t) = 2t + 5$ Newtons from time $t = 0$ to $t = 2$. At time $t = 2$, what is the speed of the block, in meters per second?

ANSWER: 9

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## TOSS UP

15) BIOLOGY *Multiple Choice* To kill pathogens, macrophages and neutrophils sometimes undergo an oxidative burst, releasing reactive oxygen species such as superoxide. Which of the following organelles would be most involved in respiratory bursts?

W) Lysosome
X) Mitochondrion
Y) Peroxisome
Z) Golgi apparatus

ANSWER: Y) Peroxisome

## BONUS

15) BIOLOGY *Short Answer* Identify all of the following three choices that are correct regarding eukaryotic (*you-KAIR-ee-aw-tic*) translation:

1) Can involve polyribosomes acting on the same mRNA
2) Can be regulated by miRNA
3) Can occur at the same time as the transcription of the same mRNA

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

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## TOSS UP

16) MATH *Short Answer* Sarah walks 15 units east. What is the minimum positive integer distance she should walk north such that her total displacement is also an integer?

ANSWER: 8

## BONUS

16) MATH *Short Answer* Given that $n$ is a positive integer such that the roots of the quadratic $x^2 + 2024x + n = 0$ are integers, find the number of possible values for $n$.

ANSWER: 1012

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## TOSS UP

17) CHEMISTRY *Short Answer* When glucose is completely oxidized, what carbon-containing molecule is produced?

ANSWER: Carbon Dioxide

## BONUS

17) CHEMISTRY *Multiple Choice* What is the concentration of chloride ions in a solution made by mixing 10 milliliters of 0.30 molar sodium chloride, 15 milliliters of 0.15 molar magnesium chloride, and 30 milliliters of 0.10 molar aluminum chloride, assuming complete dissociation?

W) 0.2 molar
X) 0.25 molar
Y) 0.3 molar
Z) 0.35 molar

ANSWER: Y) 0.3 molar

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## TOSS UP

18) EARTH AND SPACE *Multiple Choice* Which of the following properties is NOT needed to completely characterize a black hole according to the no hair theorem?

W) Mass
X) Angular momentum
Y) Charge
Z) Radius

ANSWER: Z) Radius

## BONUS

18) EARTH AND SPACE *Short Answer* Identify all of the following three properties that would be identical between all specimens of the same mineral:

1) Habit
2) Hardness
3) Crystal Structure

ANSWER: 3 only

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## TOSS UP

19) MATH *Short Answer* For what value of $x$ will the vectors $22i + xj$ (read: *22 i hat plus x j hat*) and $21i + 33j + 9k$ (read: *21 i hat plus 33 j hat plus 9 k hat*) be orthogonal?

ANSWER: -14

## BONUS

19) MATH *Short Answer* Alice rolls a fair 6-sided die numbered 1 to 6 and Bob rolls a fair 10-sided die numbered 1 to 10. What is the probability that Alice rolls a number strictly larger than Bob's number?

ANSWER: $\frac{1}{4}$ (DO NOT ACCEPT: 15/60)

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## TOSS UP

20) BIOLOGY *Multiple Choice* Which of the following types of cells are alive and most directly responsible for celery's crunch?

W) Parenchyma (*pear-EN-kai-ma*)
X) Collenchyma (*call-EN-kai-ma*)
Y) Sclerenchyma (*sklair-EN-kai-ma*)
Z) Aerenchyma (*air-EN-kai-ma*)

ANSWER: X) Collenchyma (*call-EN-kai-ma*)

## BONUS

20) BIOLOGY *Short Answer* Jane unexpectedly bleeds out after being injured by a rose thorn and is in dire need of a blood transfusion. Her blood type is B-positive. Identify all of the following three blood types that she can safely receive:

1) O-negative
2) O-positive
3) B-negative

ANSWER: All

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## TOSS UP

21) CHEMISTRY *Short Answer* When potassium permanganate (*per-mang-uh-nate*), $KMnO_4$ (read: *K M N O four*), is added to oxalic acid, $H_2C_2O_4$ (read: *H two C two O four*), in acidic aqueous solution, a redox reaction occurs. Given that the permanganate ion is reduced to manganese (II) ions, $Mn^{2+}$, and oxalic acid is oxidized to carbon dioxide, how many electrons are exchanged in the full balanced equation for this reaction?

ANSWER: 10

## BONUS

21) CHEMISTRY *Multiple Choice* When hydrogen and oxygen reacts to form water in an adiabatic rigid container, which of the following state functions remains constant?

W) Internal energy
X) Enthalpy
Y) Entropy
Z) Gibbs free energy

ANSWER: W) Internal energy

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**TOSS UP**

22) PHYSICS *Multiple Choice* A carousel is rotating at a constant angular velocity. Which of the following describes how the magnitude of the centripetal force changes with the distance to the center?

W) Linear
X) Quadratic
Y) Exponential
Z) Inverse

ANSWER: W) Linear

**BONUS**

22) PHYSICS *Multiple Choice* Joe has 1 kilogram of clay that he can shape into any object with any density. Which of the following shapes would cause the clay to roll down a ramp the fastest, given that they all have a diameter of 1 meter?

W) Solid sphere
X) Spherical shell
Y) Solid cylinder
Z) Cylindrical shell

ANSWER: W) Solid sphere

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**TOSS UP**

23) EARTH AND SPACE *Short Answer* The cores of horizontal branch stars are dominated by which fusion process?

ANSWER: Triple alpha process

**BONUS**

23) EARTH AND SPACE *Multiple Choice* At which of the following locations would regional metamorphism most likely be occuring?

W) Sedimentary basins
X) Metamorphic aureoles
Y) Mountain belts
Z) Meteorite craters

ANSWER: Y) Mountain belts