

2022 MIT Science Bowl High School Invitational

Round 11

TOSS UP

1) PHYSICS *Short Answer* How many independent types of gluons exist?

ANSWER: 8

BONUS

1) PHYSICS *Short Answer* Deep water waves have a phase velocity proportional to the square root of their wavelength. What is the ratio of the group velocity to the phase velocity for such waves?

ANSWER: $1/2$ (ACCEPT: 0.5)

TOSS UP

2) MATH *Multiple Choice* A binary string is a string of 0's and 1's. What is the closest power of 10 to the number of binary strings of length 100 that contain five 1's?

- W) 10^6
- X) 10^7
- Y) 10^8
- Z) 10^9

ANSWER: Y) 10^8

BONUS

2) MATH *Short Answer* By name or number, order the following three unit Platonic solids by increasing volume:

- 1) Unit tetrahedron
- 2) Unit cube
- 3) Unit octahedron

ANSWER: 1, 3, 2

TOSS UP

3) CHEMISTRY *Multiple Choice* Which of the following compounds has the lowest oxidation state of carbon?

- W) Benzene
- X) Methanol
- Y) Graphite
- Z) Formaldehyde (*for-MAL-duh-hide*)

ANSWER: X) Methanol

BONUS

3) CHEMISTRY *Short Answer* By name or number, identify all of the following four compounds which form an alcohol upon vigorous treatment with aqueous hydroiodic acid:

- 1) Dimethyl ether
- 2) Ethoxybenzene
- 3) *n*-propyl formate
- 4) Acetonitrile

ANSWER: 2 and 3

TOSS UP

4) BIOLOGY *Multiple Choice* Which of the following types of microscopy uses lasers to reduce out-of-focus light?

- W) Confocal
- X) Fluorescence
- Y) Phase contrast
- Z) Nomarski

ANSWER: W) Confocal

BONUS

4) BIOLOGY *Short Answer* By name or number, identify all of the following three forms of electron microscopy that can be used to create a 3D image:

- 1) Scanning
- 2) Transmission
- 3) Cryo

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

TOSS UP

5) ENERGY *Short Answer* The Hrvatin Lab at MIT studies neuronal regulation in torpor (*TOR-per*) and hibernation. What is the general term for the group of birds classified under the family Trochilidae (*trow-KIL-ih-day*) that undergo daily torpor and who also have the highest mass-specific metabolic rate of the homeotherms?

ANSWER: Hummingbirds

BONUS

5) ENERGY *Multiple Choice* Researchers in the Fraenkel Lab at MIT use data from all kinds of sequencing techniques. Which of the following techniques associated with transcription factor binding is unique for its use of antibodies?

- W) ATAC-seq (read: *uh-TACK seek*)
- X) MNase-seq (read: *M-N-ase seek*)
- Y) FAIRE-seq (read: *FAY-er seek*)
- Z) ChIP-seq (read: *chip seek*)

ANSWER: Z) ChIP-seq

TOSS UP

6) EARTH AND SPACE *Multiple Choice* Which of the following parts of a well developed cumulonimbus cloud commonly intrudes into the stratosphere?

- W) Anvil
- X) Mammatus region
- Y) Tuba
- Z) Overshooting top

ANSWER: Z) Overshooting top

BONUS

6) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three statements that are true regarding secondary rainbows:

- 1) They are generally dimmer than primary rainbows.
- 2) They have inverted colors compared to a primary rainbow
- 3) They are formed by double internal reflections within a water droplet

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

TOSS UP

7) EARTH AND SPACE *Multiple Choice* Amphidromic points are locations which have zero tide amplitude for a harmonic constituent of a tide. Which of the following factors contributes most to the circular rotation of tides in a basin around an amphidromic point?

- W) Water temperature
- X) Basin depth
- Y) Height of tidal crests
- Z) Coriolis effect

ANSWER: Z) Coriolis effect

BONUS

7) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three minerals that are cyclosilicates:

- 1) Beryl
- 2) Tourmaline (*TORE-muh-leen*)
- 3) Topaz

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

TOSS UP

8) MATH *Multiple Choice* What is the x -value of the vertex of the parabola $x = 4y^2 + 16y - 26$?

W) -42

X) -38

Y) -34

Z) -30

ANSWER: W) -42

BONUS

8) MATH *Short Answer* Solve the following equation over the real numbers: $4^{x+1} = 9 \cdot 2^x - 2$ (read: *four to the power of quantity x plus one equals 9 times two to the power of x minus two*).

ANSWER: $x = -2, 1$

TOSS UP

9) CHEMISTRY *Short Answer* By name or number, identify all of the following four reactions that are *syn* additions:

- 1) Oxymercuration
- 2) Hydroboration-oxidation
- 3) Halohydrin formation
- 4) Palladium-catalyzed hydrogenation (read: *hi-DRAW-guh-nay-shun*)

ANSWER: 2 and 4

BONUS

9) CHEMISTRY *Short Answer* A chemist dissolves a ketone in diethyl ether and adds K-selectride, followed by the addition of dimethyl sulfate. The chemist notices that a significant amount of the enol ether is formed. By name or number, identify all of the following three changes that will disfavor the O-alkylation that forms the enol ether:

- 1) Switching the base to LDA
- 2) Changing the solvent to DMSO
- 3) Changing the electrophile to methyl iodide

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

TOSS UP

10) ENERGY *Short Answer* Scientists in the MIT Department of Physics are studying unconventional superconductivity which depends on the angle between two stacked layers of graphene. Unconventional superconductivity is distinguished from conventional superconductivity by NOT conforming to which theory, which was proposed in 1957 and was the first microscopic explanation for superconductivity?

ANSWER: BCS theory (ACCEPT: Bardeen-Cooper-Schrieffer)

BONUS

10) ENERGY *Short Answer* Scientists in the MIT Department of Physics are studying unconventional superconductivity which depends on the angle between two stacked layers of graphene. What is the magnetic susceptibility of an ideal superconductor which expels all external magnetic fields?

ANSWER: -1

TOSS UP

11) BIOLOGY *Short Answer* What is the general term for the secretory group of white blood cells consisting only of neutrophils, eosinophils, and basophils?

ANSWER: Granulocytes (ACCEPT: Polymorphonuclear leukocytes, polymorphonuclear granulocytes, PMN, PML, PMNL)

BONUS

11) BIOLOGY *Short Answer* By name or number, identify all of the following three characteristics that are derived traits of vascular plants:

- 1) Heterospory
- 2) Possessing megaphylls
- 3) Possessing tracheids (*TRAY-keedz*)

ANSWER: 3 only

TOSS UP

12) PHYSICS *Multiple Choice* Which of the following statements best describes the relationship between commutators and slip rings in an electric generator?

- W) Commutators convert mechanical power to DC current, while slip rings convert mechanical power to AC current
- X) Commutators convert mechanical power to AC current, while slip rings convert mechanical power to DC current
- Y) Both commutators and slip rings convert mechanical power to AC current
- Z) Both components are interchangeable and serve identical functions in an electric generator

ANSWER: W) Commutators convert mechanical power to DC current, while slip rings convert mechanical power to AC current

BONUS

12) PHYSICS *Short Answer* A grounded spherical conducting shell has a radius of 1 meter. A positive 3 coulomb charge is placed 2 meters from the center of the sphere. In coulombs, how much total charge is induced on the sphere?

ANSWER: -1.5 (ACCEPT: $-3/2$)

TOSS UP

13) CHEMISTRY *Short Answer* By name or number, identify all of the following three transformations which are oxidations:

- 1) Alcohol to aldehyde
- 2) Alcohol to ketone
- 3) Carboxylic acid to aldehyde

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

BONUS

13) CHEMISTRY *Short Answer* By name or number, identify all of the following three reagents that would convert an alcohol to a better leaving group:

- 1) TMSCl (read: *T-M-S-C-L*)
- 2) TsCl (read: *T-S-C-L*)
- 3) MsCl (read: *M-S-C-L*)

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

TOSS UP

14) EARTH AND SPACE *Multiple Choice* Which of the following events is NOT theorized to happen during magnetic breaking in a stellar system?

- W) Material escapes from the star due to its solar wind
- X) The star's spin slows
- Y) Escaping material rotates close to the star's surface
- Z) Escaping material will rotate with the same angular frequency as the star temporarily

ANSWER: Y) Escaping material rotates close to the star's surface

BONUS

14) EARTH AND SPACE *Multiple Choice* Which of the following types of particles are emitted in the Urca process, which is thought to play a role in supernovae through the heating of the gain region?

- W) Neutrinos and antineutrinos
- X) Neutrinos only
- Y) Antineutrinos only
- Z) Photons

ANSWER: W) Neutrinos and antineutrinos

TOSS UP

15) MATH *Short Answer* Suppose $f(x) = \sin(x) + \sin(x + 90^\circ)$ (read: *f of x equals sine of x plus sine of x plus ninety degrees*). What is the maximum value of $f(x)$?

ANSWER: $\sqrt{2}$

BONUS

15) MATH *Short Answer* What is the sum of the squares of the eigenvalues of the 2×2 (read: *two by two*) matrix with first row 11, 12 and second row 20, 22?

ANSWER: 1085

TOSS UP

16) BIOLOGY *Multiple Choice* Which of the following is NOT an antigen-presenting cell?

- W) B cell
- X) Neutrophil
- Y) Macrophage
- Z) Dendritic cell

ANSWER: X) Neutrophil

BONUS

16) BIOLOGY *Short Answer* What channels in pacemaker cells are unusual for opening at negative membrane potentials, and what type of ion do they regulate?

ANSWER: F-type channels, Na^+ (ACCEPT: HCN channels, sodium)

TOSS UP

17) ENERGY *Multiple Choice* Researchers in the Suess group at MIT are studying the properties of iron sulfur clusters in biology. In biology, 4 iron, 4 sulfur clusters are divided into two groups: ferredoxin-like clusters have an iron(II)/iron(I) (read: *iron two iron one*) redox couple, and HiPIP (*high P-I-P*) clusters have an iron(III)/iron(II) (read: *iron three iron two*) redox couple. Which of the following statements is true?

- W) Ferredoxin-like clusters are redox active at low potentials, but HiPIP clusters are redox active at high potentials
- X) Ferredoxin-like clusters are redox active at high potentials, but HiPIP clusters are redox active at low potentials
- Y) Both clusters are redox active at low potentials
- Z) Both clusters are redox active at high potentials

ANSWER: W) Ferredoxin-like clusters are redox active at low potentials, but HiPIP clusters are redox active at high potentials

BONUS

17) ENERGY *Short Answer* Researchers in the Suess group at MIT are studying the properties of iron sulfur clusters in biology. In biology, 4 iron, 4 sulfur clusters are arranged in a cube structure. By name or number, identify all of the following three statements which are true of 4 iron, 4 sulfur clusters:

- 1) The iron centers are low spin
- 2) Increased amount of hydrogen bonding to the sulfur atoms from amino acid residues increases the potential of the active redox couple
- 3) The oxidation state of sulfur in these clusters is 0

ANSWER: 2 only

TOSS UP

18) PHYSICS *Short Answer* The SI unit of temperature, the kelvin, is defined using a fixed numerical value of what fundamental constant?

ANSWER: Boltzmann constant

BONUS

18) PHYSICS *Short Answer* A 7 volt AC source with a frequency of 100 radians per second is connected in series with a 100 ohm resistor and a 100 microfarad capacitor. To one significant digit and in amperes, what is the maximum current in this circuit?

ANSWER: 0.05 (ACCEPT: 5×10^{-2})

TOSS UP

19) EARTH AND SPACE *Multiple Choice* Max is examining the spectral radiance of electromagnetic radiation from a stellar object emitting at low frequencies. Which of the following physical laws should Max use to most accurately approximate the experimental results from observations?

- W) Kirchhoff's (*KURCH-haafz*) law of thermal radiation
- X) Wien (*ween*) approximation
- Y) Rayleigh-Jeans (*RAY-lee jeenz*) law
- Z) Stefan-Boltzmann law

ANSWER: Y) Rayleigh-Jeans law

BONUS

19) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three objects that would be relatively absent from elliptical galaxies:

- 1) RR Lyrae variables
- 2) Giant molecular clouds
- 3) Herbig-Haro objects

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

TOSS UP

20) CHEMISTRY *Short Answer* Various plants contain reductases that are able to reduce carbonyl compounds. In particular, carrots often give good results; they contain NADH that can act as a chiral reductant and selectively reduce ketones to a specific enantiomer of the alcohol product. By name or number, identify all of the following four molecules that could be reduced by carrots to afford a chiral alcohol:

- 1) Acetone
- 2) Ethyl acetate
- 3) Acetophenone
- 4) Acetaldehyde

ANSWER: 3 only

BONUS

20) CHEMISTRY *Short Answer* Aromatic compounds can be treated with a mixture of nitric acid and sulfuric acid to install a nitro group. By name or number, identify all of the following three statements that are true regarding this reaction:

- 1) The sulfuric acid acts as a catalyst
- 2) Replacing the sulfuric acid with trifluoroacetic acid would speed up the reaction
- 3) The reaction is exothermic

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

TOSS UP

21) PHYSICS *Short Answer* By name or number, order the following three speeds in a Maxwell-Boltzmann distribution from slowest to fastest:

- 1) Average speed
- 2) RMS speed
- 3) Most probable speed

ANSWER: 3, 1, 2

BONUS

21) PHYSICS *Short Answer* Water flows through a pipe with radius 1 centimeter at a speed of 0.2 meters per second. Given that the dynamic viscosity of water is 10^{-3} kilograms per meter per second, the drag force will be proportional to what power of the speed?

ANSWER: 2 (ACCEPT: Squared)

TOSS UP

22) BIOLOGY *Short Answer* Oversecretion of growth hormone in childhood often leads to gigantism. What is the term for this condition in adults, which may also be associated with pituitary tumors?

ANSWER: Acromegaly

BONUS

22) BIOLOGY *Short Answer* By name or number, identify all of the following three types of enzyme inhibition which result in a decreased V_{max} :

- 1) Competitive
- 2) Noncompetitive
- 3) Uncompetitive

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

TOSS UP

23) MATH *Short Answer* The Tribonacci sequence begins with the numbers 1, 1, and 2, and every subsequent number is the sum of the three numbers before it. What is the eighth number in this sequence?

ANSWER: 44

BONUS

23) MATH *Short Answer* What is the only two-digit positive integer equal to twice the product of its digits?

ANSWER: 36
