2020 MIT Science Bowl High School Invitational Round 10

TOSS UP

1) ENERGY *Multiple Choice* Researchers in the Kaiser group at MIT are studying quality control in the ER, which can lead to degradation of misfolded proteins. What protein is commonly attached to proteins to mark them for destruction?

W) Viperin
X) Ubiquitin
Y) Trypsin
Z) P53

ANSWER: X) Ubiquitin

BONUS

1) ENERGY *Multiple Choice* Researchers in the Baker group at MIT are studying the mechanisms of proteins that catalyze protein unfolding, which often involves large conformational changes. Which technique can be used to actively monitor protein conformational changes?

W) Förster Resonance Energy Transfer
X) Fluorescence In Situ Hybridization
Y) Fluorescence Recovery After Photobleaching
Z) Mass Spectrometry

ANSWER: W) Förster Resonance Energy Transfer

TOSS UP

2) EARTH AND SPACE *Short Answer* What is the common name for the brightest star in the constellation of Leo?

ANSWER: Regulus

BONUS

2) EARTH AND SPACE *Short Answer* Star X has apparent magnitude 5 and is located 1000 parsecs from the earth. What is the absolute magnitude of star X?

ANSWER: -5

TOSS UP

3) MATH *Multiple Choice* Which of the following is a real number?

W) i^i (read: *i to the i*)
X) i^3
Y) $5 + 2i$
Z) $e^{i\pi/2}$ (read: *e to the iπ over 2*)

ANSWER: W) i^i

BONUS

3) MATH *Short Answer* What is the largest integer less than cosine of i, where i is the square root of -1?

ANSWER: 1

TOSS UP

4) BIOLOGY *Short Answer* A long-day plant is subjected to 200 flashes of red light after nightfall. How many flashes of far-red light after treatment with all of the red flashes are required to make the plant flower?

ANSWER: 0

BONUS

4) BIOLOGY *Short Answer* By name or number, identify all of the following 3 hormones which stimulate secretion by the pancreas.

1) Secretin
2) Cholecystokinin (*kol-eh-cisto-KY-nin*)
3) Gastric Inhibitory Peptide

ANSWER: 1, 2, 3

TOSS UP

5) PHYSICS *Multiple Choice* Which of the following circuit elements, when placed in an AC circuit, has a low impedance at low frequencies and a high impedence at high frequencies?

W) Resistor
X) Inductor
Y) Capacitor
Z) Diode

ANSWER: X) Inductor

BONUS

5) PHYSICS *Multiple Choice* A simple harmonic pendulum has a period of T when oscillating in the air. Ignoring drag, if the density of the pendulum is twice that of water, then when the pendulum is fully submerged in water, what is the period of oscillation?

W) $T/2$
X) $T/\sqrt{2}$
Y) $T\sqrt{2}$
Z) $2T$

ANSWER: Y) $T\sqrt{2}$

TOSS UP

6) CHEMISTRY *Multiple Choice* Which of the following is true about the position of the resulting double bond from reaction of LDA with 2-phenylcyclohexanone at low temperatures?

W) The double bond forms between the carbonyl carbon and then alpha carbon further away from the phenyl group
X) The double bond forms between the carbonyl carbon and the alpha carbon closer to the phenyl group
Y) The double bond forms between the alpha and beta carbons further away from the phenyl group
Z) The double bond forms between the alpha and beta carbons closer to the phenyl group

ANSWER: W) The double bond forms between the carbonyl carbon and then alpha carbon further away from the phenyl group

BONUS

6) CHEMISTRY *Multiple Choice* A 25 meter long tube is evacuated, and two cotton balls are placed on either end. One cotton ball was soaked in ammonia and the other in HCl. After some time, a white precipitate forms. Which of the following is closest to how far from the ammonia cotton ball the precipitate forms?

W) 5 meters
X) 10 meters
Y) 15 meters
Z) 20 meters

ANSWER: Y) 15 meters

TOSS UP

7) ENERGY *Short Answer* Researchers at MIT and many other universities collaborated to construct LIGO, which detected the first gravitational waves and provided strong evidence for the theory of General Relativity. One of the fundamental ideas in general relativity is that gravity is nothing more than the curvature of spacetime described by the metric tensor. What is the name of the set of equations in general relativity that relate the metric tensor to the stress-energy tensor?

ANSWER: Einstein Field Equations

BONUS

7) ENERGY *Multiple Choice* Researchers at MIT's Plasma Science and Fusion Center are using numerical simulations to study the phsyics of plasma to better understand the process of fusion in stars. Which of the following is not a property of plasma that needs to be considered?

W) Plasma behaves like a fluid and is governed by hydrodynamic equations such as Navier-Stokes
X) Plasma particles are charged and generate strong magnetic fields when they move
Y) Thermodynamic interactions between plasma particles cause most plasma flow to eventually become laminar
Z) The physical dynamics of plasmas are highly nonlinear making them computationally difficult

ANSWER: Y) Thermodyamic interactions between plasma particles cause most plasma flow to eventually become laminar

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TOSS UP

8) PHYSICS *Short Answer* What is the name of the vector which represents the directional energy flux due to electromagnetic radiation?

ANSWER: Poynting vector

BONUS

8) PHYSICS *Short Answer* Planet X has density equal to that of Earth, but radius twice that of Earth. What is the ratio of the gravitational binding energy of planet X to that of Earth?

ANSWER: 32

TOSS UP

9) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three statements that follow from the cosmological principle:

1) The universe is flat
2) The universe is isotropic
3) The universe is homogeneous

ANSWER: 2 and 3

BONUS

9) EARTH AND SPACE *Short Answer* By name or number, arrange the following three cosmological events from earliest to latest:

1) Big Bang nucleosynthesis
2) Re-ionization
3) Recombination

ANSWER: 1, 3, 2

TOSS UP

10) BIOLOGY *Multiple Choice* Which of the following are essential amino acids for humans?

W) Alanine
X) Cysteine (*SIS-teen*)
Y) Serine
Z) Tryptophan

ANSWER: Z) Tryptophan

BONUS

10) BIOLOGY *Multiple Choice* Approximately what percentage of the human genome is comprised of LINE-1?

W) 10%
X) 20%
Y) 40%
Z) 80%

ANSWER: X) 20%

TOSS UP

11) CHEMISTRY *Short Answer* Many metal-carbonyl complexes are known to be stable. Give the name or formula of the most stable neutral iron-carbonyl complex.

ANSWER: $Fe(CO)_5$ (accept: iron pentacarbonyl)

BONUS

11) CHEMISTRY *Short Answer* By name or number, identify all of the following 3 polymers that you would expect to find amide bonds in:

1) Nylon
2) Latex
3) Polystyrene

ANSWER: 1 only

TOSS UP

12) MATH *Short Answer* What is the obtuse angle between the hour hand and minute hand of a clock at 3:40 PM?

ANSWER: 130

BONUS

12) MATH *Short Answer* Find the period of the function $f(x) = \sin^4(x) + \cos^4(x)$.

ANSWER: $\pi/2$

TOSS UP

13) EARTH AND SPACE *Multiple Choice* Which of the following is true of interstellar reddening?

W) It causes spectral lines to shift towards longer wavelengths
X) It is caused by preferential scattering of shorter wavelengths of light
Y) It occurs only in dark nebulae
Z) It is responsible for the decrease in observed magnitude of faraway stars

ANSWER: X) It is caused by preferential scattering of shorter wavelenghts of light

BONUS

13) EARTH AND SPACE *Short Answer* What is the primary constituent of the atmosphere of Titan?

ANSWER: Nitrogen

TOSS UP

14) MATH *Multiple Choice* In 3-dimensional space, a reflection about the x-axis followed by a reflection about the y-axis is equivalent to which of the following single operations?

W) A reflection about the z-axis
X) A reflection about the xy-plane
Y) A 90-degree clockwise rotation about the z-axis
Z) Doing nothing

ANSWER: W) A reflection about the z-axis

BONUS

14) MATH *Short Answer* Suppose you take a line in three-dimensional space and rotate it around another line. By name or number, identify all of the following four surfaces that can be swept out by the line that is being rotated:

1) plane
2) cylinder
3) double cone
4) hyperboloid (*hy-PER-bull-oid*)

ANSWER: 1, 2, 3, 4 (accept: all)

TOSS UP

15) ENERGY *Multiple Choice* Researchers in the Johnson group at MIT are creating biodegradable polymers to be used in drug delivery. One method that they have discovered involves the introduction of a silyl ether group, which is also often used to protect alcohol groups. Which of the following reagents would not be suitable for removing a silyl ether group?

W) OH^-
X) H_3O^+
Y) TBAF
Z) HF

ANSWER: W) OH^-

BONUS

15) ENERGY *Multiple Choice* Researchers in the Buchwald group at MIT are designing new methods for the formation of carbon-nitrogen bonds, such as those in amines. Typically, the Boc (*BOCK*) and Fmoc (*EFF-mock*) groups are used to protect amine groups by decreasing their reactivity. Under what conditions can the Boc and Fmoc groups be removed? Assume that everything is conducted under aqueous conditions.

W) Both protecting groups are removed under acidic conditions
X) Boc is removed under acidic conditions, while Fmoc is removed under basic conditions
Y) Boc is removed under basic conditions, while Fmoc is removed under acidic conditions
Z) Both protecting groups are removed under basic conditions

ANSWER: X) Boc is removed under acidic conditions, while Fmoc is removed under basic conditions

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TOSS UP

16) CHEMISTRY *Multiple Choice* Anton decides to make a solution of ammonium nitrate by dissolving some of the white solid in some water at room temperature. As the solid ammonium nitrate dissolves, Anton notices that the solution begins to grow very cold. Which of the following statements is true about the spontaneity of this reaction?

W) The dissolution is spontaneous only at high temperatures
X) The dissolution is spontaneous only at low temperatures
Y) The dissolution is always spontaneous
Z) The dissolution is never spontaneous

ANSWER: W) The dissolution is spontaneous only at high temperatures

BONUS

16) CHEMISTRY *Short Answer* By name or number, arrange the following four carboxylic acid derivatives in order of increasing reactivity:

1) Acyl (*EY-sil*) chloride
2) Amide
3) Ester
4) Acid anhydride

ANSWER: 2, 3, 4, 1

TOSS UP

17) PHYSICS *Short Answer* Indicate, by name or number, all of the following three statements that are true of the quantum harmonic oscillator:

1) The energy levels are evenly spaced
2) The energy eigenfunctions are symmetric about the origin
3) The energy eigenfunctions are orthogonal and complete

ANSWER: 1 and 3

BONUS

17) PHYSICS *Multiple Choice* For a column of air in a constant gravitational field, molecules of oxygen can be found at a height of zero with a probability density of 1/3 and at a height of h with a probability density of 1/6. What is the probability density of finding molecules of oxygen at a height of $2h$?

W) 1/12
X) 1/18
Y) 1/36
Z) 1/72

ANSWER: W) 1/12

TOSS UP

18) BIOLOGY *Short Answer* The strain of influenza virus that causes swine flu is also known by the moniker H1N1, where the H and N represent viral surface proteins. What are the names of these H and N proteins respectively?

ANSWER: Hemagglutinin, neuraminidase

BONUS

18) BIOLOGY *Multiple Choice* Which of the following is derived from the hindbrain in embryonic development?

W) Telencephalon (*tell-enn-SE-fa-lon*)
X) Myelencephalon (*my-uh-lenn-SE-fa-lon*)
Y) Diencephalon (*die-enn-SE-fa-lon*)
Z) Mesencephalon (*mess-enn-SE-fa-lon*)

ANSWER: X) Myelencephalon

TOSS UP

19) EARTH AND SPACE *Multiple Choice* Which of the following gases is NOT a significant component of Pluto's atmosphere?

W) H_2O
X) N_2
Y) CH_4
Z) CO

ANSWER: W) H_2O

BONUS

19) EARTH AND SPACE *Multiple Choice* Which of the following statements about the factors affecting stream flow velocity is NOT true?

W) Flow velocity tends to decrease from the head to the mouth of the stream
X) An increase in channel size increases the flow velocity
Y) An increase in channel slope increases the flow velocity
Z) An increase in discharge increases the flow velocity

ANSWER: W) Flow velocity tends to decrease from the head to the mouth of the stream

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TOSS UP

20) CHEMISTRY *Multiple Choice* Which of the following is used as a Breathalyzer oxidant, due to the green color that results in the presence of alcohols?

W) Permanganate
X) Dichromate
Y) Ozone
Z) Persulfate

ANSWER: X) Dichromate

BONUS

20) CHEMISTRY *Short Answer* Arrange the following four types of solid structures in increasing order of packing efficiency:

1) Diamond lattice
2) Face centered cubic
3) Body centered cubic
4) Simple cubic

ANSWER: 1, 4, 3, 2

TOSS UP

21) BIOLOGY *Multiple Choice* Which of the following is a type of water-conducting cell?

W) Sieve cells
X) Companion cells
Y) Tracheids (*TRAY-kee-ids*)
Z) Sclereids (*SKLAIR-eye-ds*)

ANSWER: Y) Tracheids

BONUS

21) BIOLOGY *Multiple Choice* Transcription factors can often be split into DNA-binding and activation domains. Scientists exploit this fact to study protein interactions in which of the following assays?

W) ChIP-seq (*CHIP-seek*)
X) Proximity ligation
Y) Yeast two-hybrid
Z) Phage display

ANSWER: Y) Yeast two-hybrid

TOSS UP

22) PHYSICS *Short Answer* In semiconductors, the application of an electric field penetrates deeply, resulting in an alteration in conductivity known as what effect?

ANSWER: Field effect

BONUS

22) PHYSICS *Short Answer* A particle moving in the xy-plane has Lagrangian $L = \dot{x}^2 + \dot{y}^2 - \alpha x$ (read: *L equals x-dot squared plus y-dot squared minus alpha x*). By name or number, identify all of the following three quantities that are conserved for this particle:

1) Energy
2) x component of momentum
3) y component of momentum

ANSWER: 1 and 3

TOSS UP

23) MATH *Short Answer* Giving your answer in simplest radical form, rationalize the denominator of the following expression: $1/(\sqrt[3]{7} - \sqrt[3]{2})$ (read: *1 over the quantity cube root of 7 minus cube root of 2*)

ANSWER: $(\sqrt[3]{49} + \sqrt[3]{14} + \sqrt[3]{4})/5$

BONUS

23) MATH *Multiple Choice* What is the expected number of times one must toss a weighted coin with a 2/3 probability of coming up heads to get two consecutive heads?

W) 3/2
X) 9/4
Y) 8/3
Z) 15/4

ANSWER: Z) 15/4
