MEHS ROUND 1

TOSS-UP

1) Physics – *Short Answer* An electron is traveling with its velocity directed in the positive *x* direction through a uniform magnetic field directed in the positive *y* direction. In what direction does the magnetic field act on the electron?

ANSWER: NEGATIVE Z

BONUS

1) Physics – *Multiple Choice* According to the Born interpretation of quantum mechanics, the square of an orbital wave function describes which of the following?

W) The probability that a electron can be found in a certain area
X) The frequency of the electron
Y) The speed of the electron
Z) The exact position of the electron

ANSWER: W) THE PROBABILITY THAT A PARTICLE CAN BE FOUND IN A CERTAIN AREA

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TOSS-UP

2) Chemistry – *Multiple Choice* What is the term used to describe molecules with a nonzero dipole moment?

W) Ionic
X) Nonpolar
Y) Polar
Z) Secondary

ANSWER: Y) POLAR

BONUS

2) Chemistry – *Short Answer* What is the name of the process in which a substance in the gaseous state transitions directly into a solid?

ANSWER: DEPOSITION
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TOSS-UP

3) Energy – *Short Answer* Scientists at Pacific Northwest National Lab have studied how secondary organic aerosols have affected the Amazon rainforest's atmosphere. In what atmospheric layer does the majority of the atmosphere's mass reside in?

ANSWER: TROPOSPHERE

BONUS

3) Energy – *Short Answer* Scientists at Princeton Plasma Physics Lab are using the MRI experiment to elucidate the creation of celestial bodies around black holes. Identify all of the following three statements regarding black holes that are true: 1) The event horizon of a black hole is the point where the escape velocity surpasses the speed of light, 2) Black holes gain mass through accretion; 3) Black holes are inside their own Schwarzschild radii.

ANSWER: ALL (ACCEPT: 1, 2, AND 3)

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TOSS-UP

4) Earth and Space – *Short Answer* What is the astronomical term that describes the gas, dust, and radiation found between stars in a galaxy?

ANSWER: INTERSTELLAR MEDIUM (DO NOT ACCEPT: NEBULA)

(SOLUTION: The interstellar medium refers to all of the gas, dust and radiation between the star systems in a galaxy while nebulae are only clouds of gas and dust within galaxies. Nebulae is too specific in this context.)

BONUS

4) Earth and Space – *Short Answer* What astronomical term describes the process of separating out different constituents of a planetary body as a result of its physical or chemical behavior?

ANSWER: PLANETARY DIFFERENTIATION (ACCEPT: DIFFERENTIATION)

5) Math – *Multiple Choice* Which of the following is the expected value for the sum of three consecutive dice rolls?

W) 9
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TOSS-UP

X) 10.5
Y) 12.25
Z) 15

ANSWER: X) 10.5

BONUS

5) Math – *Short Answer* What is the probability of getting at least 3 heads when flipping a total of 5 coins?

ANSWER: 1/2 (ACCEPT: 0.5 or 50%)

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TOSS-UP

6) Chemistry – *Multiple Choice* Which of the following is an example of a physical change?

W) Burning of a candle
X) Heating sugar to form caramel
Y) Mixing hydrochloric acid with a weak base
Z) Vaporization of gasoline

ANSWER: Z) VAPORIZATION OF GASOLINE

BONUS

6) Chemistry – *Short Answer* Identify all of the following 4 molecules that are polar:
1) Sulfur trioxide; 2) Benzene; 3) Ammonia; 4) Carbon monoxide.

ANSWER: 3 AND 4
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TOSS-UP

7) Physics – *Short Answer* Jebediah Kerman throws a baseball with an initial speed of 8 meters per second at a 45 degree angle from the ground. To two significant figures and in meters, how far away does the baseball land from Jebediah?

ANSWER: 6.5

BONUS

7) Physics – *Short Answer* How many degrees of freedom does an ideal monatomic gas have?

ANSWER: 3

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TOSS-UP

8) Biology – *Short Answer* What type of structures, which are examples of convergent evolution, are similar structures which have evolved independently in two organisms but serve the same purpose?

ANSWER: ANALOGOUS STRUCTURES

BONUS

8) Biology – *Short Answer* Identify all of the following three statements that are true regarding model organisms: 1) They are easy to grow in labs; 2) Lessons learned from a model organism are often applicable to a much wider group; 3) They are species that are extensively studied to understand biological phenomena.

ANSWER: ALL (ACCEPT: 1, 2, 3)
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TOSS-UP

9) Earth and Space – *Multiple Choice* Which of the following types of soils is dark and fertile and forms in forested regions in the eastern part of the United States?

W) Pedalfer
X) Pedocal
Y) Laterite
Z) Humus

ANSWER: W) PEDALFER

BONUS

9) Earth and Space – *Short Answer* In the interstellar medium, dust scatters photons with shorter wavelengths of light and causes stars to appear redder than they should be. What astronomical effect explains why this happens in stars?

ANSWER: INTERSTELLAR REDDENING

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TOSS-UP

10) Math – *Multiple Choice* Rounded to the nearest whole number, which of the following is the square root of 114?

W) 10
X) 11
Y) 12
Z) 13

ANSWER: X) 11

BONUS

10) Math – *Short Answer* What is the sum of the integers from 1 to 99?

ANSWER: 4950

11) Physics – *Short Answer* Given that the momentum of a photon is 0.2 kilogram meters per second, and assuming that planck's constant is 6.6×10^{-34} ,what is the photon's Broglie wavelength to two significant figures and in scientific notation?
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TOSS-UP

ANSWER: 3.3 x10^{-33}METERS

BONUS

11) Physics – *Short Answer* What is the potential difference, in volts, across a parallel plate capacitor containing a uniform electric field of 4 newtons per coulomb with a plate separation of 8 centimeters?

ANSWER: 0.32

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TOSS-UP

12) Energy – *Short Answer* Scientists at Brookhaven National Lab are conducting research on nearly massless, electrically neutral particles that normally pass through matter unhindered. What particles are they most likely studying?

ANSWER: NEUTRINOS

BONUS

12) Energy – *Short Answer* Scientists at Pacific Northwest National Lab are studying how tiny atmospheric particles called aerosols influence clouds. Identify all of the following three statements regarding aerosols that are true: 1) Aerosols are atmospheric particles that can be solid; 2) Aerosols are atmospheric particles that can be liquid; 3) Aerosols are atmospheric particles that can only be gaseous.

ANSWER: 1 AND 2
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TOSS-UP

13) Biology – *Multiple Choice* In which of the following cell organelles does the Krebs cycle occur?

W) Mitochondria
X) Chloroplasts
Y) Peroxisomes
Z) Nuclei

ANSWER: W) MITOCHONDRIA

BONUS

13) Biology – *Short Answer* Rank the following steps in cellular respiration in chronological order: 1) Krebs cycle; 2) Glycolysis; 3) Electron transport chain.

ANSWER: 2, 1, 3

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TOSS-UP

14) Earth and Space – *Multiple Choice* Greenhouse gases are gases in the atmosphere that trap the Sun's heat. Which of the following gases exhibits the greatest greenhouse effect in Earth's atmosphere?

W) Carbon dioxide
X) Water vapor
Y) Methane
Z) Ozone

ANSWER: X) WATER VAPOR

BONUS

14) Earth and Space – *Short Answer* What soil horizon is rich in minerals that have moved down from the A and E horizons?

ANSWER: B HORIZON

15) Math – *Short Answer* What parent trigonometric function has a period of 2π and passes through the origin?

ANSWER: SINE FUNCTION (ACCEPT: SINE)
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TOSS-UP

BONUS

15) Math – *Short Answer* What is the smallest value of x in radians within the interval from 0 to 2π where the sine of x is equal to 1/2?

ANSWER: $\pi/6$ (DO NOT ACCEPT: 30^{o})

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TOSS-UP

16) Chemistry – *Multiple Choice* Which of the following substances is not a compound?

W) Diamond
X) Limestone
Y) Water
Z) Lye

ANSWER: W) DIAMOND

BONUS

16) Chemistry – *Short Answer* What is the magnetic quantum number of a chlorine atom's final electron in its ground state?

ANSWER: 0

17) Energy – *Multiple Choice* Scientists at Princeton Plasma Physics Lab are conducting research on magnetic reconnection events. Which of the following features is most likely to be produced on the sun during reconnection events?

W) Starquakes
X) Auroras
Y) Solar flares
Z) Supernovas
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TOSS-UP

ANSWER: Y) SOLAR FLARES

BONUS

17) Energy – *Short Answer* Scientists at Brookhaven National Lab have conducted research on neutrinos using deep underground detectors. Unfortunately, when scientists were trying to detect neutrinos being produced by the sun, they only observed 1/3 of the expected amount. Out of the three flavors of neutrinos, which kind was the sun emitting as a result of nuclear fusion?

ANSWER: ELECTRON NEUTRINOS

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TOSS-UP

18) Biology – *Multiple Choice* Which of the following organelles is present in animal cells but not in plant cells?

W) Chloroplast
X) Golgi apparatus
Y) Cell wall
Z) Lysosome

ANSWER: Z) LYSOSOME

BONUS

18) Biology – *Short Answer* To what site does mRNA first bind in a ribosome?

ANSWER: A-SITE
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TOSS-UP

19) Earth and Space – *Short Answer* Stars with masses less than or equal to that of the Sun convert hydrogen to helium using what type of nuclear fusion?

ANSWER: PROTON-PROTON CHAIN

BONUS

19) Earth and Space – *Short Answer* What type of equilibrium is reached when the rate of solar radiation absorption equals the rate of emission in Earth's atmosphere?

ANSWER: RADIATIVE EQUILIBRIUM

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TOSS-UP

20) Math – *Multiple Choice* Which of the following is a prime number?

W) 169
X) 171
Y) 173
Z) 175

ANSWER: Y) 173

BONUS

20) Math – *Short Answer* What is the largest prime factor of 114?

ANSWER: 19

21) Physics – *Multiple Choice* Which of the following thermodynamic processes, when performed, would always result in no work being done on a closed system?

W) Adiabatic
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TOSS-UP

X) Cyclic
Y) Isochoric
Z) Isobaric

ANSWER: Y) ISOCHORIC

BONUS

21) Physics – *Multiple Choice* Which of the following quantities is not conserved in a closed system?

W) Momentum
X) Angular momentum
Y) Velocity
Z) Charge

ANSWER: Y) VELOCITY

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TOSS-UP

22) Chemistry – *Multiple Choice* Which of the following nucleons is the most common isotope of chlorine?

W) Chlorine-33
X) Chlorine-35
Y) Chlorine-37
Z) Chlorine-39

ANSWER: X) CHLORINE-35

BONUS

22) Chemistry – *Short Answer* Identify all of the following four elements that are liquid at room temperature and atmospheric pressure: 1) Silicon; 2) Bromine; 3) Lithium; 4) Mercury.

ANSWER: 2 AND 4

23) Biology – *Short Answer* When polar substances such as water are placed in a graduated cylinder, a meniscus is formed. This is an example of what phenomenon?

ANSWER: ADHESION (DO NOT ACCEPT: HYDROGEN BONDING; COHESION)

BONUS
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TOSS-UP

23) Biology – *Short Answer* Identify all of the following three statements that are true regarding surface tension: 1) Surface tension is the primary reason that insects denser than water are capable of floating and sliding on a body of water; 2) Liquid water has the greatest surface tension of all liquids; 3) Surface tension is the measure of energy required to increase the surface area of a liquid due to intermolecular forces.

ANSWER: 1 AND 3