MEHS ROUND 15

TOSS-UP

1) Physics – *Short Answer* The pressure on an object at 4 meters below surface level in a pool on a strange planet is 130 x 10^4 pascals. Assuming that the pressure at the surface of the pool is 10 x 10^4 pascals, and that the density of water is 100 kilograms per meter cubed, and giving your answer in newtons, what is the magnitude of the force of gravity on this planet?

ANSWER: 300

BONUS

1) Physics – *Short Answer* As a cat falls out of a plane, the drag force on it increases by 1 centinewton per second. Assuming that the force of gravity on the cat is 9.8 meters per second, how many seconds will it take for the cat to be falling at terminal velocity?

ANSWER: 980 SECONDS

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TOSS-UP

2) Chemistry – *Multiple Choice* Which of the following features in the Proton NMR spectrum provides information about the number of types of different protons in a compound?

W) Integral
X) Number of signals
Y) Splitting
Z) Chemical shift

ANSWER: X) NUMBER OF SIGNALS

BONUS

2) Chemistry – *Short Answer* How many equivalent sets of protons are there in 1-methylhexane?

ANSWER: 7
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TOSS-UP

3) Energy – *Multiple Choice* Scientists at Pacific Northwest National Lab are conducting large eddy simulations of offshore boundary layers to study the properties of eddies. Which of the following factors do NOT affect their frictional influence?

W) Surface heating
X) Strong wind speeds
Y) Contact area between the bodies
Z) Roughness of the landscape

ANSWER: Y) CONTACT AREA BETWEEN THE BODIES

BONUS

3) Energy – *Short Answer* Scientists at Argonne National Lab are studying the role of clays in mercury emission from soils. Mercury accumulation in plants causes phytotoxicity and impairs metabolic processes. Identify all of the following 3 statements that are true about mercury in plants: 1) Signal transduction pathways are mobilized to neutralize the source of toxicity; 2) Hg^{2+} is the most common form of mercury in agricultural soils; 3) Plants lack the ability to escape from contaminated sites.

ANSWER: ALL OF THEM

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TOSS-UP

4) Earth and Space – *Short Answer* In the crystalloblastic series, porphyroblasts filled with inclusions of other minerals that were formed during metamorphosis are said to have what kind of texture?

ANSWER: POIKILOBLASTIC TEXTURE

BONUS

4) Earth and Space – *Short Answer* Identify all of the following 3 statements regarding the TOV limit in stars that are true: 1) The limit describes the maximum mass of a cold, nonrotating white dwarf; 2) In stars less massive than the limit, the weight of the star is balanced by neutron-neutron interactions; 3) In rigidly spinning stars, the mass limit can sometimes increase by up to 50%.

ANSWER: 2 ONLY
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TOSS-UP

5) Math – *Multiple Choice* For which of the following functions would the Intermediate Value function not be applicable over the interval [0.5, 5]?

W) The quantity (x minus 2) to the 2 thirds power
X) The quantity (x plus 2) to the 2 thirds power
Y) The quantity (x minus 2) to the negative 2 thirds power
Z) The quantity (x plus 2) to the negative 2 thirds power

ANSWER: Y) THE QUANTITY (X MINUS 2) TO THE NEGATIVE 2 THIRDS POWER

BONUS

5) Math – *Short Answer* Given that f of negative 7 is negative 3, and f prime of x is less than or equal to 2, what is the largest possible value for f of x when x equals 0?

ANSWER: 11

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TOSS-UP

6) Chemistry – *Multiple Choice* What is the name given to the pH at which a molecule carries no net electrical charge?

W) Equivalence point
X) Isoelectric point
Y) Half-equivalence point
Z) Critical point

ANSWER: X) ISOELECTRIC POINT

BONUS

6) Chemistry – *Short Answer* If a 1.288 kilogram mass of technetium decays into an 80.5 gram mass of technetium after 140 seconds, and the natural log of 2 can be approximated as 0.7, what is the decay constant of technetium?

ANSWER: 0.02
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TOSS-UP

7) Physics – *Short Answer* What is the frequency, in hertz, of the 3rd harmonic in a half-open tube with a fundamental frequency of 110 Hz?

ANSWER: 550

BONUS

7) Physics – *Short Answer* What is the name of the term that describes a unit of vibrational energy that arises from oscillating atoms within a crystal, causing it to be treated as a singular particle in Quantum mechanics?

ANSWER: PHONON

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TOSS-UP

8) Biology – *Short Answer* The middle lamella is a layer of sticky substances that is primarily made up of what kind of polysaccharide which is commonly used as a thickening agent?

ANSWER: PECTIN

BONUS

8) Biology – *Short Answer* Identify all of the following 4 cytoskeletal structures that have a 9+0 arrangement of microtubules: 1) Centrioles; 2) Basal bodies; 3) Cilia; 4) Flagella.

ANSWER: 1 AND 2
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TOSS-UP

9) Earth and Space – *Short Answer* During the early-AGB phase for red giant stars, the main source of energy is helium fusion in a shell surrounding the core. What two elements mainly make up the core?

ANSWER: CARBON AND OXYGEN

BONUS

9) Earth and Space – *Short Answer* In stellar physics, what condition occurs when internal gas pressure is not strong enough to prevent gravitational collapse, causing the collapse of interstellar gas clouds?

ANSWER: JEANS CRITERION (ACCEPT: JEANS INSTABILITY)

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TOSS-UP

10) Math – *Multiple Choice* Which of the following is a critical number of the function f of x equals 4 plus the absolute value of the quantity x plus 2?

W) -4
X) -2
Y) 2
Z) 4

ANSWER: X) -2

BONUS

10) Math – *Short Answer* What is the indefinite integral of x times the sine of x?

ANSWER: SINE X MINUS X COSINE X PLUS C

11) Physics – *Short Answer* Light emitted in a double-slit interference experiment has an initial intensity of 13 watts per square meter before any diffractions. Giving your answer in watts per square meter, what is the intensity of the light at an interference maxima?

ANSWER: 52
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TOSS-UP

BONUS

11) Physics – *Multiple Choice* A simple pendulum has an angular amplitude of 60 degrees. Assuming that a gravitational torque with a magnitude of 37 newton meters acts on it, and that it has a rotational inertia of 23 kilogram meters squared, which of the following is the closest to the period of the pendulum?

W) 0.5 seconds
X) 5.4 seconds
Y) 1.2 seconds
Z) 4.9 seconds

ANSWER: X) 5.4 SECONDS

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TOSS-UP

12) Energy – *Multiple Choice* Researchers at Argonne National Lab are looking into nuclear microreactors as a solution for powering electronic trucks. Which of the following is always a disadvantage of microreactors compared to full-scale nuclear reactors?

W) There will be more severe neutron leakage in microreactors
X) There will be more non-fission neutron capture in the reactor
Y) The moderators will need to be added to slow neutrons down in the reactor
Z) The microreactor will generate less energy per kilogram of uranium-235 than coal

ANSWER: W) THERE WILL BE MORE SEVERE NEUTRON LEAKAGE IN MICROREACTORS

BONUS

12) Energy – *Short Answer* Researchers at Thomas Jefferson National Lab are conducting research into the arrangement of quarks inside the proton. Quarks inside of protons are bonded together through gluons. What is the spin of a gluon?

ANSWER: 1
13) Biology – *Multiple Choice* Which of the following 3-carbon intermediates are required in the biosynthesis of fatty acids?

W) Glyceraldehyde 3-phosphate
X) Malonyl-CoA
Y) Acetyl-CoA
Z) Propionyl-CoA carboxylase
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TOSS-UP

ANSWER: X) MALONYL-COA

BONUS

13) Biology – *Short Answer* Identify all of the following 3 processes that cortisol stimulates: 1) Glycogenolysis; 2) Gluconeogenesis; 3) Lipolysis.

ANSWER: 2 AND 3

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TOSS-UP

14) Earth and Space – *Multiple Choice* Which of the following physiographic features would NOT be found between a barrier island and the beach?

W) Dunes
X) Salt marshes
Y) Smokers
Z) Lagoons

ANSWER: Y) SMOKERS

BONUS

14) Earth and Space – Short Answer Identify all of the 3 following minerals that often exhibit contact twinning: 1) Plagioclase; 2) Gypsum; 3) Pyrite.

ANSWER: 1 AND 2
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TOSS-UP

15) Math – *Short Answer* What is the tenth derivative of sin 2x?

ANSWER: NEGATIVE 1024 SINE 2X

BONUS

15) Math – *Short Answer* What is the coefficient of the x squared term in the MacLaurin series expansion of e to the power of negative 4x

ANSWER: NEGATIVE 64 OVER 3

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TOSS-UP

16) Chemistry – *Multiple Choice* A chemist needs to identify a functional group based on its characteristic absorption bands. Which of the following forms will most likely help the chemist determine the functional group?

W) Infrared spectroscopy
X) UV spectroscopy
Y) X ray spectroscopy
Z) NMR spectroscopy

ANSWER: X) UV SPECTROSCOPY

BONUS

16) Chemistry – *Short Answer* Arrange the following four atoms from least to greatest first ionization energy: 1) Nitrogen; 2) Silicon; 3) Chlorine; 4) Arsenic.

ANSWER: 2. 4, 2, 1
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TOSS-UP

17) Energy – *Short Answer* Researchers at Oak Ridge National lab have been conducting research into building an unhackable quantum network. This entails that any information sent over the quantum network is unable to be intercepted and read by any parties outside of the ones for which the information was originally intended for. What is the specific name of the phenomena in quantum mechanics that lends to this quality of quantum networks?

ANSWER: WAVE FUNCTION COLLAPSE

BONUS

17) Energy – *Multiple Choice* Researchers at Fermi National lab have been researching the interactions of the Higgs Boson with massive particles. The Higgs boson is manifested through which of the following?

W) Decaying alpha particles
X) Exciting the Higgs field
Y) Gluon-gluon collisions
Z) Photon-photon collisions

ANSWER: X) EXCITING THE HIGGS FIELD

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TOSS-UP

18) Biology – *Short Answer* The porphyrin ring of chlorophylls a and b contain what metal atom that is present in the center of the molecule?

ANSWER: MAGNESIUM

BONUS

18) Biology – *Short Answer* Homologous desensitization occurs when a receptor decreases its response following the presence of a chemical at high concentrations. What is the specific name given to the chemical that binds to the receptor and activates it?

ANSWER: AGONIST

19) Earth and Space – *Short Answer* Which of the following periods on Mars was characterized by pummeling of the crust by debris due to heavy bombardment?

W) Noachian
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TOSS-UP

X) Hesperian
Y) Amazonian
Z) Orosirian

ANSWER: W) NOACHIAN

BONUS

19) Earth and Space – *Short Answer* In the phenomenon known as red tides, surface waves are colored red due to algal blooms. What specific type of unicellular algae are mainly responsible for the red pigment that dye the water red?

ANSWER: DINOFLAGELLATES

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TOSS-UP

20) Math – *Multiple Choice* Given that 7xy equals 21, and x equals negative 3, what is the value of dy over dx that satisfies the equation?

W) 63
X) 7
Y) Negative 1 over 3
Z) Negative 3

ANSWER: Y) NEGATIVE 1 OVER 3

BONUS

20) Math – *Short Answer* A large 98 percent confidence interval for the proportion of hotel reservations that are cancelled on the intended arrival day is (0.048. 0.112). What is the point estimate for the proportion of hotels reservations that are canceled on the intended arrival day based on this constructed interval?

ANSWER: 0.08
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TOSS-UP

21) Physics – *Multiple Choice* Which of the following factors does NOT directly affect the mean free path of a gas?

W) The density of molecules inside the gas
X) The average distance between each molecule in the gas
Y) The average number of collisions per second in the gas
Z) The pressure of the gas on its container

ANSWER: Z) THE PRESSURE OF THE GAS ON ITS CONTAINER

BONUS

21) Physics – *Short Answer* A half-charged capacitor can hold a maximum capacity of 58 coulombs. It also has a capacitance of 4 microcoulombs. Giving your answer in watts rounded to the nearest tenth in scientific notation, how much more work is needed to fully charge the capacitor?

ANSWER: 7.8×10^7

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TOSS-UP

22) Chemistry – *Multiple Choice* Which of the following statements is NOT true regarding Diels-Alder cycloadditions?

W) They are classified as [4+2] cycloadditions
X) They involve a five-membered ring transition state
Y) They proceed via a concerted reaction mechanism
Z) They are highly disfavored at high temperatures

ANSWER: X) THEY INVOLVE A FIVE-MEMBERED RING TRANSITION STATE

BONUS

22) Chemistry – *Short Answer* What is the name of the phenomenon that limits the strength of the strongest acid or base that can exist in a solvent?

ANSWER: LEVELLING EFFECT
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TOSS-UP

23) Biology – *Short Answer* D-glucose and D-mannose are examples of what kind of diastereomers that only differ in configuration at one carbon atom?

ANSWER: EPIMERS

BONUS

23) Biology – *Short Answer* Order the following 3 animal groups from earliest to latest appearance in the fossil record: 1) Sponges; 2) Annelids; 3) Echinoderms.

ANSWER: 1, 3, 2