FE!M 2025

Round 7

TOSS UP

1) CHEMISTRY *Short Answer* The IR spectrum of $SnCl_2$ exhibits absorptions at 352, 334, and 120 cm^{-1}. What shape does this data suggest for the molecule?

ANSWER: Bent [AA]

BONUS

1) CHEMISTRY *Multiple Choice* Which of the following reaction mechanisms is observed in the reaction between benzene and chlorine gas in the presence of a ferric chloride catalyst?

W) Nucleophilic Aromatic Substitution

X) Elimination-addition

Y) Electrophilic Aromatic Substitution

Z) Cycloaddition

ANSWER: Y) Electrophilic Aromatic Substitution

TOSS UP

2) PHYSICS *Short Answer* An infinite sheet of uniform charge density is located at $z = 0$. If the electric potential is set to be zero at $z = 0$, and the potential at the point $(6, 8, 10)$ is 20 volts, then what is the electric potential at the point $(6, 6, 7)$?

ANSWER: 14 [RuA]

BONUS

2) PHYSICS *Short Answer* The air pressure inside a water bubble is 12 Pa more than the air pressure outside the bubble. Given that water has a surface tension of 72 mN/m, what is the radius of the bubble to the nearest millimeter?

ANSWER: 24

TOSS UP

3) ESS *Multiple Choice* Advaith is stranded on an isolated island surrounded by water. Which of the following best describes the movement of air at the surface of the island at 3PM and 3AM, respectively?

W) Convergence, convergence

X) Convergence, divergence

Y) Divergence, convergence

Z) Divergence, divergence

ANSWER: X) Convergence, divergence

BONUS

3) ESS *Short Answer* Identify all of the following three types of folds for which the hinge line of the fold always intersects the horizontal plane:

1) Symmetrical
2) Overturned
3) Recumbent

ANSWER: None

TOSS UP

4) MATH *Short Answer* A $2 \times 2 \times 2$ cube is cut from the corner of a $3 \times 3 \times 3$ cube. What is the surface area of the resulting solid?

ANSWER: 54

BONUS

4) MATH *Short Answer* Alice and Bob can eat a pizza together in 2 hours. Bob and Chloe can eat a pizza together in 1 hour. What is the difference between the minimum and maximum amount of time, in hours, it could take for Alice and Chloe to eat a pizza together?

ANSWER: 4/3

TOSS UP

5) BIOLOGY *Short Answer* A maize zygote is genetically modified such that the alpha-amylase promoter is coupled to an enhanced GFP coding sequence. As the resulting seed is germinating, what layer of cells required for breakdown of the endosperm would likely appear green?

ANSWER: Aleurone layer

BONUS

5) BIOLOGY *Short Answer* Arrange the following three phases of meiotic prophase I in chronological order:

1) Pachytene
2) Leptotene
3) Diplotene

ANSWER: 213

TOSS UP

6) CHEMISTRY *Multiple Choice* Roshan finds that a mystery compound produces a positive Tollen's test. Which of the following could be his mystery compound?

W) Methane
X) Propanone
Y) Ethanal
Z) Benzene

ANSWER: Y) Ethanal

BONUS

6) CHEMISTRY *Multiple Choice* Which of the following statements is true about the reversibility of amide hydrolysis in acid?

W) It is reversible since all of the steps are reversible

X) It is reversible since the intermediates are all stable

Y) It is irreversible since the resulting carboxylic acid is deprotonated

Z) It is irreversible since the resulting amine is protonated

ANSWER: Z) It is irreversible since the resulting amine is protonated

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TOSS UP

7) PHYSICS *Short Answer* What is the the ratio of the energies of the first excited state to the third excited state of a quantum harmonic oscillator?

ANSWER: 3/7

BONUS

7) PHYSICS *Short Answer* Rotite is a brand new resistor building material. Roshan creates a resistor of resistance R using Rotite by shaping it into a cylindrical shell with inner radius 1 meter and outer radius 2 meters. If he then fills in the hole in the shell with more Rotite, what is the new resistance of his resistor in terms of R?

ANSWER: $3R/4$

TOSS UP

8) ESS *Multiple Choice* In which of the following environments would gelifluction of sediment be most likely observed?

W) Glacial

X) Fluvial

Y) Aeolian

Z) Coastal

ANSWER: W) Glacial

BONUS

8) ESS *Short Answer* Order neutrinos from the following three sources by increasing average energy as observed on Earth:

1) Solar neutrinos

2) Extragalactic neutrinos

3) Cosmic neutrino background

ANSWER: 312

TOSS UP

9) MATH *Short Answer* A right triangle has legs of length 5 and 12. What is the ratio of the volumes of the cones produced when the triangle is rotated about its longer leg and its shorter leg, respectively?

ANSWER: 5/12

BONUS

9) MATH *Short Answer* Find the maximum value of the function $f(x) = 2cos(x) + 3cos(x + pi/3)$ (read: *two cosine of x plus 3 cosine of quantity x plus pi over 3*).

ANSWER: $\sqrt{19}$

TOSS UP

10) BIOLOGY *Multiple Choice* Which of the following types of epithelial histology would one expect to find in the urethra?

W) Simple cuboidal

X) Straitifed columnar

Y) Transitional

Z) Pseudostratified columnar

ANSWER: Y) Transitional

BONUS

10) BIOLOGY *Short Answer* Select ALL of the following 3 statements that are TRUE about oogenesis:

1) The secondary oocyte is arrested at prophase II prior to fertilization

2) The first and second polar bodies have distinct ploidies

3) Each primary oocyte produces only one ovum

ANSWER: 3 only

TOSS UP

11) CHEMISTRY *Multiple Choice* Dr. Mopuri is experimenting in his kitchen lab and is making a tropical potassium smoothie. He mixes potassium chromate in water which forms chromate and potassium ions. He accidentally spills extra potassium nitrate, adding even more potassium ions into the mixture. Which of the following statements is true with respect to the reaction quotient, Q compared to equilibrium constant, K for the dissolution of potassium chromate?

W) Q is greater than K

X) Q is less than K

Y) Q is exactly equal to K

Z) Q is approximately equal to K

ANSWER: W) Q is greater than K

BONUS

11) CHEMISTRY *Multiple Choice* Which of the following best explains why the electrophilic aromatic substitution of nitrobenzene with Br_2 is slower than benzene itself?

W) The nitro group is an ortho/para-directing group

X) The nitro group strongly deactivates the benzene ring via M and I effects

Y) Bromine is not electrophilic enough to react with nitrobenzene

Z) The nitro group stabilizes the carbocation intermediate

ANSWER: X) The nitro group strongly deactivates the ring via M and I effects

TOSS UP

12) PHYSICS *Short Answer* Answer Roshan throws an object of mass 2 kg in a constant gravitational field downwards of magnitude 10 N/kg. There is a constant wind force to the left of magnitude 20 N. At what acute angle, measured with respect to the horizontal and in degrees, must he throw the ball to maximize the distance between its landing point and its initial position?

ANSWER: 22.5°

BONUS

12) PHYSICS *Short Answer* A charged capacitor of capacitance 2F is connected in series with a 3Ω resistor. If the capacitor is then discharged, to the nearest tenth of a second how long does it take for the charge on the capacitor to drop to 50% of its initial value?

ANSWER: 4.2

TOSS UP

13) ESS *Multiple Choice* Which of the following best describes the composition and location of C-type asteroids?

W) Volatile-poor and in the inner edge of the asteroid belt

X) Volatile-poor and in the outer edge of the asteroid belt

Y) Volatile-rich and in the inner edge of the asteroid belt

Z) Volatile-rich and in the outer edge of the asteroid belt

ANSWER: Z) Volatile-rich and in the outer edge of the asteroid belt [RoA]

BONUS

13) ESS *Multiple Choice* In the intermediate stages of the formation of Antarctic Bottom Water, Dense Shelf Water forms and sits on the continental shelf directly after brine rejection. Which of the following best describes how this Dense Shelf Water becomes Antarctic Bottom Water?

W) Dense Shelf Water flows downwards as a gravity-driven plume, entraining ambient water during descent

X) Dense Shelf Water is transported offshore by Ekman Transport, sinking after it reaches netural buoyancy

Y) Dense Shelf Water gradually warms on the shelf, increasing in buoyancy until it mixes uniformly into the deep ocean

Z) A wedge of Dense Shelf Water is subducted below Circumpolar Deep Water, becoming modified from surface cooling

ANSWER: W) Dense Shelf Water flows downwards as a gravity-driven plume, entraining ambient water during descent

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TOSS UP

14) MATH *Short Answer* What is the unit normal vector to the plane with equation $2x + 3y + 6z + 4 = 0$?

ANSWEr: $(2/7, 3/7, 6/7)$

BONUS

14) MATH *Multiple Choice* What is the set of points in the Cartesian plane such that the Manhattan distance and Euclidean distance of each point to the origin are equal?

W) Line

X) Two lines

Y) Circle

Z) Parabola

ANSWER: X) Two lines

TOSS UP

15) BIOLOGY *Short Answer* Select ALL of the following three proteins whose knockout would result in constitutive skeletal muscle contraction:

1) Tropomyosin

2) Myosin light chain kinase

3) Sarcoplasmic reticulum Ca2+ ATPase

ANSWEr: 1 and 3

BONUS

15) BIOLOGY *Multiple Choice* Scientists at Stanford's Bendall Lab are studying Toll-like receptors. Which of the following viral genomes would likely be recognized by TLR3?

W) Retrovirus

X) Reovirus

Y) Parvovirus

Z) Orthomyxovirus

ANSWER: X) Reovirus

TOSS UP

16) CHEMISTRY *Short Answer* In the hydrolysis of methyl acetate under acidic conditions, what two products are formed?

ANSWER: Methanol and acetic acid

BONUS

16) CHEMISTRY *Short Answer* A non-electrolyte solute with molar mass of 180g/mol is dissolved to make 1.0L of aqueous solution with osmotic pressure equal to 2.46 atm at −27°C. Assuming that the ideal gas constant is 0.08 L·atm/(mol·K) (read: *liter atmospheres per mole kelvin*), and rounding your answer to the nearest whole gram, what is the approximate mass of the solute?

ANSWER: 23g

TOSS UP

17) PHYSICS *Short Answer* Theenash the baby-hater flips a baby 3 times, each time about a different one of its 3 principal axes. He notices that when flipping about the first and third principal axes, the baby experiences stable rotation, whereas it experiences unstable rotation when flipped about the second principal axis. What phenomenon describes this observation?

ANSWER: Intermediate axis theorem (ACCEPT: Tennis racket theorem, Dzhanibekov effect)

BONUS

17) PHYSICS *Short Answer* Identify all of the following three statements that are true about the mean free path of a particle in gas:

1) It is inversely proportional to the density of the gas
2) It is inversely proportional to the diameter of the particle
3) It is directly proportional to the temperature of the gas

ANSWER: 1 AND 3

TOSS UP

18) ESS *Short Answer* Order the following three compact objects by increasing slope of the thermocline in their crusts:

1) Black dwarf
2) Neutron star
3) White dwarf

ANSWER: 132 [AS]

BONUS

18) ESS *Multiple Choice* The fission model of the Moon's formation proposes that the Moon was spun off from a rapidly rotating Protoearth. Which of the following observations most strongly contradicts this model?

W) The Moon's orbital plane is tilted only 5.1° relative to the ecliptic rather than aligning with the Earth's equator

X) The Moon's average density is lower than Earth's

Y) The Moon has maria on its near side

Z) The Moon lacks a global magnetic field today

ANSWER: W) The Moon's orbital plane is tilted only 5.1° relative to the ecliptic rather than the Earth's equator [AS]

TOSS UP

19) MATH *Short Answer* In how many unique ways can a regular hexagon be triangulated? Assume that all vertices are identical.

ANSWER: 2

BONUS

19) MATH *Short Answer* Theenash is climbing up a ladder with 10 rungs, moving up either one or two rungs with each step. Given that Theenash cannot step on the 6^{th} rung because it is broken, how many ways are there for him to climb up the ladder?

ANSWER: 24

TOSS UP

20) BIOLOGY *Multiple Choice* Attenuation is a phenomenon in which ribosome stalling facilitates mRNA synthesis due to resource depletion. Which of the following bacterial operons contains an attenuator sequence?

W) lac

X) ara

Y) thi

Z) trp

ANSWER: Z) trp [TS]

BONUS

20) BIOLOGY *Multiple Choice* The basal metabolic rates of various species are plotted against body mass on a log-log plot. Which of the following is closest to the slope of this plot?

W) 0.25

X) 0.50

Y) 0.75

Z) 1.00

ANSWER: Y) 0.75 [TS]

TOSS UP

21) CHEMISTRY *Short Answer* Rank the following three solutions by increasing osmotic pressure.

1) 1 mol $CaCl_2$ dissolved in 1 kg water
2) 2 mol $AlCl_3$ dissolved in 5 kg water
3) 5 mol $C_{12}H_{22}O_{11}$ dissolved in 10 kg water

ANSWER: 321

BONUS

21) CHEMISTRY *Short Answer* In an IR spectrum, order the following three compounds by increasing wavenumber of the C double bonded O peak:

1) Benzaldehyde
2) Acetone
3) Methyl acrylate

ANSWER: 132

TOSS UP

22) PHYSICS *Short Answer* What law in optics states that the diffraction pattern created by an opaque obstacle is the same of that created by an aperture of the same size and shape?

ANSWER: Babinet's principle

BONUS

22) PHYSICS *Multiple Choice* A lens is made of a material with refractive index 2. By what factor does the focal length of this lens change by when it is submerged in water with a refractive index of 1.33?

W) 1.33

X) 0.75

Y) 2

Z) 0.5

ANSWER: Y) 2 [RuA]

TOSS UP

23) ESS *Short Answer* Order the following three island chains by increasing mafic character of their average composition:

1) Hawaiian-Emperor Seamount Chain

2) Aleutian Islands

3) Canary Islands

ANSWER: 321

BONUS

23) ESS *Short Answer* Which of the following three types of precipitation require a thermal inversion in order to occur:

W) Freezing rain

X) Glaze ice

Y) Snow

ANSWER: 12

TOSS UP

24) MATH *Short Answer* A spherical balloon is being pumped with helium so that its radius is increasing at a constant rate of 2 centimeters per second. Given that the balloon starts from a radius of 0 cm, at what time is its volume and surface area increasing at the same rate?

ANSWER: 1 s

BONUS

24) MATH *Short Answer* How many unique pairs of integers x and y are solutions to the equation $x^2 - 4y^2 = 36$?

ANSWER: 6

TOSS UP

25) BIOLOGY *Short Answer* Scientists at Cold Spring Harbor Labs are studying the biomechanics of the cupula. Select ALL of the following 3 structures that contain a cupula:

1) Lateral Line
2) Semicircular canals
3) Utricle

ANSWER: 12

BONUS

25) BIOLOGY *Short Answer* Researchers at Lawrence Berkeley National Labs are studying nucleic acid stricture. Select ALL of the following three amino acids that would disrupt the structure of alpha helices:

1) Tryptophan
2) Proline
3) Phenylalanine

ANSWER: 2 only
