FE!M 2025

Round 8

TOSS UP

1) CHEMISTRY *Multiple Choice* Which of the following best explains why the enol forms of 1, 3-dicarbonyl compounds are highly stable?

W) Steric effects

X) Electron donation

Y) Electron delocalization

Z) Hyperconjugation

ANSWER: Y) Electron delocalization

BONUS

1) CHEMISTRY *Short Answer* Dr. Sawicka is studying sodium benzoate, a food preservative present in many canned and packaged goods. Given that the pKa of benzoic acid is 4.2, what is the pH of a 1M solution of sodium benzoate to one decimal place?

ANSWER: 9.1 [TS]

TOSS UP

2) PHYSICS *Multiple Choice* Advaith is standing on a hill with an incline of 40° to the horizontal and throws a ball. At what angle, measured with respect to the incline of the hill and in degrees, should he throw a ball to maximize the distance from him that it lands?

W) 40

X) 45

Y) 50

Z) 65

ANSWER: Z) 65

BONUS

2) PHYSICS *Multiple Choice* A spring is connected to the ceiling of a large box of mass 6kg and a 3kg mass hangs from it. The period of oscillation is T. In terms of T, which of the following is the period of oscillation if this system were put in free fall?

W) T

X) $2T/3$

Y) $T\sqrt{6}/3$

Z) $T\sqrt{2}/2$

ANSWER: Y) $T\sqrt{6}/3$ [RuA]

TOSS UP

3) ESS *Multiple Choice* Which of the following statements is most accurate about the relationship between solar activity and locations of sunspots on the Sun?

W) Solar activity is a maximum when sunspots are concentrated at low latitudes

X) Solar activity is a maximum when sunspots are concentrated at high latitudes

Y) Solar activity is a minimum when sunspots are concentrated at low latitudes

Z) Solar activity is a minimum when sunspots are concentrated at high latitudes

ANSWER: Y) Solar activity is a minimum when sunspots are concentrated at low latitudes [RoA]

BONUS

3) ESS *Short Answer* Identify all of the following three properties of glacial ice that increase with increasing age:

1) Hardness

2) Grain size

3) Albedo

ANSWER: 12 [RoA]

TOSS UP

4) MATH *Short Answer* A parallelogram has sides given by the vectors $\hat{\mathbf{i}} + 2\hat{\mathbf{j}}$ and $3\hat{\mathbf{i}} + \hat{\mathbf{j}}$. What is its area?

ANSWER: 5

BONUS

4) MATH *Short Answer* How many distinct nets exist for a tetrahedron?

ANSWER: 2

TOSS UP

5) BIOLOGY *Short Answer* Order the following three photosynthetic electron carriers by increasing reduction potential:

1) Plastoquinone
2) Ferredoxin
3) Plastocyanin

ANSWER: 213 [TS]

BONUS

5) BIOLOGY *Multiple Choice* Gokul grows a pea plant in a greenhouse to study abscisic acid signaling. An increase in which of the following ambient conditions would decrease transpiration rate the most?

W) Atmospheric humidity
X) Soil moisture
Y) Atmospheric temperature
Z) Soil temperature

ANSWER: Z) Soil temperature [TS]

TOSS UP

6) CHEMISTRY *Multiple Choice* Which of the following gas-phase reactions has a larger K_p than K_c?

W) $3H_2 + N_2 \rightarrow 2NH_3$

X) $O_3 + H_2O \rightarrow 2O_2 + H_2$

Y) $H_2 + CO_2 \rightarrow H_2O + CO$

Z) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

ANSWER: X) $O_3 + H_2O \rightarrow 2O_2 + H_2$ [TS]

BONUS

6) CHEMISTRY *Multiple Choice* Julius performs a permanganometric titration of a solution of iron (II) chloride to find the mass percent of iron in an alloy. Which of the following errors would result in a negative deviation from the true concentration?

W) There was excess water left in his buret

X) His permanganate solution had partially oxidized

Y) He calibrated the permanganate against a diluted standard

Z) He used a known mass of potassium manganate instead of potassium permanganate

ANSWER: Y) He calibrated the permanganate against a diluted standard [TS]

TOSS UP

7) PHYSICS *Multiple Choice* A hoop is rolling without slipping. Which of the following general curves does a single point on the hoop follow as the hoop rolls?

W) Circular Arc

X) Cycloid

Y) Sinusoid

Z) Parabola

ANSWER: X) Cycloid [RuA]

BONUS

7) PHYSICS *Short Answer* A woodchuck chucks wood of mass 6 kilograms and velocity 7 meters per second per piece at a rate of 6 wood pieces per second. This wood hits a 7 kg movable wall that is initially at rest. Assuming each piece of wood comes to a complete stop upon hitting the wall, how many seconds does it take for the wall to move 72 meters?

ANSWER: 2 [RuA]

TOSS UP

8) ESS *Multiple Choice* Theenash finds a sediment composed of well-sorted, sand-sized grains with low angularity. Mineralogical analysis shows a high proportion of feldspars and lithic fragments. Which of the following best describes the textural and compositional maturity of this sediment, respectively?

W) Texturally mature, compositionally mature

X) Texturally mature, compositionally immature

Y) Texturally immature, compositionally mature

Z) Texturally immature, compositionally immature

ANSWER: X) Texturally mature, compositionally immature [RoA]

BONUS

8) ESS *Multiple Choice* Which of the following factors does not directly affect the width of a spectral absorption line?

W) Identity of the absorbing atom

X) Pressure in the star's atmosphere

Y) Rotation rate of the star

Z) Distance between the star and the observer

ANSWER: Z) Distance between the star and the observer [RoA]

TOSS UP

9) MATH *Multiple Choice* If $a = b \ln c$, then in terms of a, what is $c^{2 \ln b}$?

W) $a + 2$

X) $2a$

Y) $4a$

Z) a^2

ANSWER: Z) a^2 [JW]

BONUS

9) MATH *Short Answer* If $\cos x = \tan x$, what is the sum of all possible values of $\sin x$?

ANSWER: $\frac{-1+\sqrt{5}}{2}$

TOSS UP

10) BIOLOGY *Multiple Choice* In a bacterial CRISPR screen, Arjun notices that a certain sgRNA results in toxicity due to abnormally long mRNAs. Which of the following proteins is likely targeted by this sgRNA?

W) Sigma

X) RecA

Y) Rho

Z) Cas9

ANSWER: Y) Rho [TS]

BONUS

10) BIOLOGY *Multiple Choice* After a stroke, a phenomenon known as excitotoxicity promotes a chain reaction of neuronal apoptosis. Targeting which of the following glutamate receptor types would best combat excitotoxicity?

W) Metabotropic receptors

X) NMDA receptors

Y) Kainate receptors

Z) AMPA receptors

ANSWER: X) NMDA receptors [TS]

TOSS UP

11) CHEMISTRY *Multiple Choice* The Frost-Ebsworth diagram is a graphical representation of relative energies of different oxidation states for an element. If the oxidation state forms a peak above the line on the diagram connecting its neighbors, what type of reaction will it most likely undergo?

W) Oxidation

X) Reduction

Y) Disproportionation

Z) Comproportionation

ANSWER: Y) Disproportionation

BONUS

11) CHEMISTRY *Short Answer* Inside of a container, Rutvik adds acetone to iodine (I_2) and sodium hydroxide ($NaOH$). Identify all of the following three statements that are true regarding the reaction:

1) It leads to the formation of a yellow precipitate
2) It creates a carboxylic acid
3) In the end, it creates a triiodomethyl ketone

ANSWER: 12

TOSS UP

12) PHYSICS *Short Answer* Two identical point charges with equal and opposite charges are fixed a certain distance apart. The positive charge is at the origin and the negative charge is at $x = 2$. Identify all of the following three regions that contain a point that experiences zero electric field:

1) $x < 0$
2) $0 < x \leq 2$
3) $x > 2$

ANSWER: None [RuA]

BONUS

12) PHYSICS *Short Answer* A spaceship moves at a speed of $0.8c$ relative to the Earth. In the Earth's reference frame, what is the ratio of its apparent kinetic energy to its total energy?

ANSWER: 2.5 [RuA]

TOSS UP

13) ESS *Short Answer* Identify all of the following three environmental conditions that are conducive to the formation of dust devils:

1) Rough terrain
2) Strong winds
3) Clear skies

ANSWER: 3 [RoA]

BONUS

13) ESS *Multiple Choice* While lag deposits are a leading theory to explain the formation of desert pavement in aeolian environments, they can also occur in other environments. Which of the following sedimentary rocks would most likely form from a lag deposit in a fluvial environment?

W) Shale
X) Arkose
Y) Conglomerate
Z) Breccia

ANSWER: Y) Conglomerate [RoA]

TOSS UP

14) MATH *Short Answer* Identify all of the following three functions that satisfy the differential equation $y = y''$ (read: *y double prime*):

1) e^x

2) $\cos x$

3) $\cosh x$

ANSWER: 13

BONUS

14) MATH *Short Answer* Rutvik draws a dodecagon. What is the maximum number of interior angles in the dodecagon that could be right angles?

ANSWER: 9

TOSS UP

15) BIOLOGY *Multiple Choice* An increased number of reticulocytes in the bloodstream would best indicate a higher secretion of which of the following hormones?

W) Prostacyclin

X) Thromboxane A2

Y) Thrombopoietin

Z) Erythropoietin

ANSWER: Z) Erythropoietin [EH]

BONUS

15) BIOLOGY *Short Answer* A plant root is grown in a medium supplemented with radioactively labeled nucleotides. Upon autoradiography, a patch of cells in between the promeristem and rootcap displays faint radiolabeling. This unlabeled region is most likely what slowly dividing reservoir of initials that regulates the root apical meristem?

ANSWER: Quiescent center [TS]

TOSS UP

16) CHEMISTRY *Multiple Choice* Which of the following compounds can exist as a pair of enantiomers?

W) 1-butanol

X) Pentane

Y) 2-propanol

Z) 2-butanol

ANSWER: Z) 2-butanol

BONUS

16) CHEMISTRY *Short Answer* The K_{sp} of lead sulfate is $1.5 \cdot 10^{-6}$ and the K_{sp} of lead carbonate is $3.0 \cdot 10^{-5}$. In a given solution with a specified concentration of lead, the concentration of sulfate in solution is $1.0 \cdot 10^{-10}$M, what is the concentration of carbonate in solution?

ANSWER: $2.0 \cdot 10^{-9}$M

TOSS UP

17) PHYSICS *Multiple Choice* The force binding protons and neutrons together in atomic nuclei is mediated by the exchange of which of the following virtual particles?

W) Gluons

X) Kaons

Y) Pions

Z) Partons

ANSWER: Y) Pions

BONUS

17) PHYSICS *Short Answer* Rutvik is accelerating particles in his homemade cyclotron. Using the cyclotron, he can accelerate protons from the ion source to energies of up to 12 KeV. If he instead used alpha particles, then to the nearest KeV, what is the maximum energy he could accelerate them to?

ANSWER: 24

TOSS UP

18) ESS *Short Answer* Order the following ocean currents by increasing average Chlorophyll-a concentration, from lowest to highest:

1) Gulf stream

2) California current

3) Kuroshio current

ANSWER: 132 [AS]

BONUS

18) ESS *Multiple Choice* Only considering radiative forcing from Milankovitch cycles, which of the following best describes the predicted temperatures of seasons in the Northern Hemisphere in 13,000 years?

W) Warmer summers, warmer winters

X) Warmer summers, colder winters

Y) Colder summers, warmer winters

Z) Colder summers, colder winters

ANSWER: X) Warmer summers, colder winters [RoA]

TOSS UP

19) MATH *Short Answer* Find the positive difference between the maxima and minima of the function $f(x, y) = 2x^2 - y^2$ constrained to the unit circle in the xy-plane.

ANSWER: 3 [TS]

BONUS

19) MATH *Short Answer* What is the area of an equiangular hexagon with sides of length 4, 6, 2, 6, 4, and 4, in that order?

ANSWER: $27\sqrt{3}$

TOSS UP

20) BIOLOGY *Multiple Choice* Bill is attempting to reverse the anterior-posterior axis of his chick zygote. Which of the following treatments should he most likely use?

W) Inverting the cell

X) Transplanting the grey crescent

Y) Injecting acid opposite the side of sperm entry

Z) Reversing the side of sperm entry

ANSWER: W) Inverting the cell

BONUS

20) BIOLOGY *Short Answer* At the transition region of a cilium, the 9 + 0 arrangement of the basal body turns into a 9 + 2 arrangement. To two decimal places, what is the ratio between the number of microtubules in the former and latter arrangements?

ANSWER: 1.35

TOSS UP

21) CHEMISTRY *Short Answer* Order the following three compounds in terms of increasing molecular ion peak value in their mass spectra:

1) Methanol

2) Ethanol

3) Propane

ANSWER: 132

BONUS

21) CHEMISTRY *Short Answer* Advaith performs mass spectrometry on the disubstituted compound 1-bromo 3-chlorobenzene. What is the ratio between the intensities of the M+4 and M+2 peaks in the mass spectrum for this compound?

ANSWER: 3/4

TOSS UP

22) PHYSICS *Multiple Choice* Which of the following best describes the coherence of stimulated and spontaneous emission respectively?

W) Coherent, coherent

X) Coherent, incoherent

Y) Incoherent, coherent

Z) Incoherent, incoherent

ANSWER: X) Coherent, incoherent

BONUS

22) PHYSICS *Short Answer* Identify all of the following three statements that are true about Majorana particles:

1) They must have zero charge

2) They could violate CPT symmetry

3) They must obey the Pauli exclusion principle

ANSWER: 13

TOSS UP

23) ESS *Multiple Choice* Which of the following best explains why the cosmic microwave background (CMB) was not affected by interstellar extinction when it was first scattered?

W) The CMB photons are too energetic to be absorbed by dust

X) The CMB was emitted only in directions away from dust

Y) Magnetic fields prevented scattering

Z) There was no dust in the early universe at that time

ANSWER: X) There was no dust in the early universe at that time

BONUS

23) ESS *Short Answer* While gypsum can rarely occur as elongate crystals when it forms from precipitation out of water, it more commonly forms through the rehydration of anhydrite. As a result, it typically appears in a fine crystalline form consisting of small nodules and a massive habit. What specific variety of gypsum is characterized by this formation?

ANSWER: Alabaster [RoA]

TOSS UP

24) MATH *Short Answer* ABC is a right triangle with $AB = 5$ and $AC = 12$. What is the length of BD, where D is the foot of the altitude from A to BC?

ANSWER: 25/13

BONUS

24) MATH *Short Answer* How many lattice points are contained within or lie on the graph of $|x| + |y| = 10$?

ANSWER: 221

TOSS UP

25) BIOLOGY *Short Answer* Because of increased cross-bridging in cardiac sarcomeres, the contractile force of the heart increases with increased venous return. What is the name for this phenomenon?

ANSWER: Frank-Starling effect

BONUS

25) BIOLOGY *Multiple Choice* Individuals with Swyer syndrome have a complete knockout in the SRY gene. Which of the following would be likely be observed in these individuals?

W) Only Wolffian ducts

X) Only Mullerian ducts

Y) Both Wolffian and Mullerian ducts

Z) No reproductive duct formation

ANSWER: X) Only Mullerian ducts
