FE!M 2025

Round 11

TOSS UP

1) CHEMISTRY *Short Answer* [18]-annulene is a very weird compound when viewed under a 1H NMR spectrum. The inside hydrogens have a chemical shift of 9.28 ppm, while those on the outside have a shift of -2.9 ppm. This is due to what effect?

ANSWER: Ring currents (ACCEPT: Anisotropy effects) [AA]

BONUS

1) CHEMISTRY *Short Answer* Advaith reacts acetaldehyde with a methyl vinyl ketone in the presence of the non-nucleophilic base DABCO. Identify all of the following functional groups present in the resulting compound.

1) Alcohol
2) Ether
3) Olefin

ANSWER: 13 [AA]

TOSS UP

2) PHYSICS *Short Answer* Identify all of the following three quantities that are Lorentz invariant:

1) Rest mass
2) Charge
3) Spacetime interval

ANSWER: ALL [RoA]

BONUS

2) PHYSICS *Short Answer* A Wheatstone bridge is composed of two resistors on each side of an ammeter. The two resistors on one side have resistances of 4 ohms and 6 ohms. One resistor on the other side has a resistance of 24 ohms. What is the positive difference between the possible values of the resistance of the last resistor such that no current flows through the ammeter?

ANSWER: 20 [RuA]

TOSS UP

3) ESS *Multiple Choice* Lithification of which of the following dune types would result in cross-bedding that is the poorest paleowind indicator?

W) Barchan
X) Transverse
Y) Longitudinal
Z) Parabolic

ANSWER: Y) Longitudinal [RoA]

BONUS

3) ESS *Short Answer* Identify all of the following four minerals that commonly exhibit hackly fracture:

1) Copper
2) Hematite
3) Pyrite
4) Sphalerite

ANSWER: 1 only [RoA]

TOSS UP

4) MATH *Short Answer* Select ALL of the following four changes that would increase the power of a statistical test:

1) Increasing the significance level
2) Increasing the sample size
3) Decreasing the effect size
4) Reducing the population variance

ANSWER: 124 [AdM]

BONUS

4) MATH *Short Answer* Compute the value of $1^1 + 2^2 + ... + 8^8 + 9^9 + 10^{10}$ modulo 8.

ANSWER: 5 [AdM]

TOSS UP

5) BIOLOGY *Short Answer* Order the following three hemoglobin subunits by chronological order of expression in human development:

1) Gamma
2) Zeta
3) Beta

ANSWER: 213 [TS]

BONUS

5) BIOLOGY *Short Answer* Advaith is conducting a genome-wide analysis of a population of yaks with 320 breeding males and 80 breeding females with a generation time of 1 year. If a neutral mutation occurs in an individual, how many years will pass, on average, before the mutation is fixed in the population?

ANSWER: 1024 [TS]

TOSS UP

6) CHEMISTRY *Short Answer* Order the following 3 ligands by increasing hapticity:

1) Oxalate
2) Cyclopentadienyl
3) Allyl

ANSWER: 132 [TS]

BONUS

6) CHEMISTRY *Multiple Choice* Which of the following is the major product of the reaction between sodium hydroxide and 4-methoxy butan-2-one?

W) 4-methoxy 2,2 dihydroxybutane

X) 3-buten-2-one

Y) 2,2 dihydroxy but-3-ene

Z) 2-Butene

ANSWER: X) 3-buten-2-one [TS]

TOSS UP

7) PHYSICS *Multiple Choice* Which of the following particles in the Standard Model is not correctly matched to its corresponding superpartner?

W) Neutrino, Neutralino

X) Electron, selectron

Y) Gluon, gluino

Z) Bottom quark, sbottom squark

ANSWER: W) Neutrino, neutralino [RoA]

BONUS

7) PHYSICS *Short Answer* The Navier-Stokes equations describe the behavior of any fluid. What simpler equations are similar to the Navier-Stokes equations but only apply to nonviscous and nonconductive fluids?

ANSWER: Euler equations [RuA]

TOSS UP

8) ESS *Short Answer* Wollastonite is classified as a pyroxenoid rather than a pyroxene because of an abundance of what large ion that distorts the pyroxene crystal structure?

ANSWER: Ca^{2+} [RoA]

BONUS

8) ESS *Short Answer* Identify all of the following four atmospheric lapse rates that can be negative:

1) Dry adiabatic lapse rate
2) Moist adiabatic lapse rate
3) Environmental lapse rate
4) Dew point lapse rate

ANSWER: 34 [RoA]

TOSS UP

9) MATH *Short Answer* What is the derivative with respect to x of the integral from x to x^2 of $\ln t \, dt$ at $x = e$?

ANSWER: $4e - 1$ [AdM]

BONUS

9) MATH *Short Answer* The Mandelbrot set consists of all complex numbers c such that the sequence obtained by repeatedly applying the transformation $f(z) = z^2 + c$ to the number 0 remains bounded. Select ALL of the following numbers that are contained in the Mandelbrot set:

1) 1

2) i

3) -2

4) $-\frac{3}{4}$

ANSWER: 234 [AdM]

TOSS UP

10) BIOLOGY *Short Answer* Australian lungfishes primarily rely on their gills for gas exchange. Consequently, when their pond habitats dry up during the summer, they enter what specific state of low metabolic rate?

ANSWER: Estivation (DO NOT ACCEPT: Torpor, Hibernation) [TS]

BONUS

10) BIOLOGY *Multiple Choice* While performing an ELISA, Selena accidentally adds beta-mercaptoethanol to an antibody solution. If she runs a Western blot on this sample, which of the following will be observed?

1) 2 bands of equal intensity
2) 3 bands of equal intensity
3) 2 bands of different intensity
4) 3 bands of different intensity

ANSWER: W) 2 bands of equal intensity [TS]

TOSS UP

11) CHEMISTRY *Short Answer* In the presence of acetic anhydride, pyrrole reacts with nitric acid to form what compound in high yield?

ANSWER: Ortho-nitropyrrole (ACCEPT: 2-nitropyrrole) [AA]

BONUS

11) CHEMISTRY *Multiple Choice* When benzyl alcohol is reacted with hydrochloric acid, triphenylphosphine, and diethyl azodicarboxylate, what is the resulting product?

W) Phenyl Chloride

X) 2-chloroethyl benzene

Y) Benzyl chloride

Z) 2-chloromethyl benzene

ANSWER: Y) Benzyl chloride [TS]

TOSS UP

12) PHYSICS *Short Answer* Rank the following three materials in order of increasing absorption of light, based on their indices of refraction:

1) 0.6 + 0.8i

2) 0.5 + 0.5i

3) 0.8 + 0.6i

ANSWER: 231 [RoA]

BONUS

12) PHYSICS *Multiple Choice* An arc welder functions by first ionizing the air around it to establish an electrical current with metal, then melting the metal with this current. Which of the following best describes the voltage profile of an arc welder?

W) Always high

X) High, then low

Y) Low, then high

Z) Always low

ANSWER: X) High, then low [RoA]

TOSS UP

13) ESS *Multiple Choice* Gas surrounding stars belonging to which of the following spectral classes would be most likely to result in the formation of a reflection nebula?

W) O

X) B

Y) G

Z) M

ANSWER: X) B [RoA]

BONUS

13) ESS *Multiple Choice* In contrast to wind-driven surface ocean currents, coastal geostrophic currents occur due to a pressure gradient caused by water piling up along shores. Which of the following best describes the flow direction of coastal geostrophic currents on the western and eastern coast of North America respectively?

W) Northward and northward

X) Northward and southward

Y) Southward and northward

Z) Southward and southward

ANSWER: X) Northward and southward [RoA]

TOSS UP

14) MATH *Multiple Choice* Which of the following numbers is irrational but not algebraic?

W) $\sin(\frac{\pi}{6})$

X) $\sqrt{2}$

Y) $\frac{\sqrt[3]{5}-1}{4}$

Z) $\ln(2)$

ANSWER: Z) $\ln(2)$ [AdM]

BONUS

14) MATH *Short Answer* A circle of radius 6 is cut into a sector with central angle 240 degrees and a sector with central angle 120 degrees. Each sector is then rolled into a cone. What is the ratio of the volume of the larger cone to the volume of the smaller cone?

ANSWER: $\frac{\sqrt{10}}{2}$ [AdM]

TOSS UP

15) BIOLOGY *Short Answer* Select ALL of the following 3 visual disorders that can be corrected with a convex lens:

1) Hyperopia
2) Astigmatism
3) Presbyopia

ANSWER: 1 and 3 [TS]

BONUS

15) BIOLOGY *Short Answer* A large population of heterozygous, sporophytically self-incompatible mustard contains 12 distinct incompatibility alleles at a single locus. What is the probability that two randomly selected plants from this population will be able to successfully cross-pollinate?

ANSWER: $\frac{15}{22}$ [TS]

TOSS UP

16) CHEMISTRY *Short Answer* Although it is sterically disfavored, the hydroxyl group adjacent to the oxygen in furan rings generally occupies an axial position. What effect explained by hyperconjugation into sigma antibonding orbitals best explains this phenomenon?

ANSWER: Anomeric effect [TS]

BONUS

16) CHEMISTRY *Short Answer* Roshan pumps 2.5 moles of an ideal gas into a rigid container at 500 K and 10 bar. He then heats the gas until it reaches 1000 K and 2 bars. Given that the molar heat capacity at constant pressure is $C_{p,m} = 10$ J/(mol·K), calculate, to one significant figure, the entropy change (ΔS) for this process in J/K.

ANSWER: 50 [AA]

TOSS UP

17) PHYSICS *Multiple Choice* Which of the following quantum states is *not* entangled?

W) $|110\rangle + |011\rangle$ (read: *ket 110 plus ket 011*)

X) $|111\rangle + |000\rangle$ (read: *ket 111 plus ket 000*)

Y) $|100\rangle + |001\rangle$ (read: *ket 100 plus ket 001*)

Z) $|000\rangle + |010\rangle$ (read: *ket 000 plus ket 010*)

ANSWER: Z) $|000\rangle + |010\rangle$ [AdM]

BONUS

17) PHYSICS *Short Answer* Select ALL of the following statements that are true about the vector potential:

1) It is invariant under gauge transformations
2) The vector potential cannot affect particles in regions where the magnetic field is 0
3) The line integral of vector potential around a closed loop equals the magnetic flux through the loop

ANSWER: 3 only [AdM]

TOSS UP

18) ESS *Short Answer* Order the following three varieties of shale by increasing average oxidation state of iron:

1) Black shale
2) Red shale
3) Yellow shale

ANSWER: 132 [RoA]

BONUS

18) ESS *Multiple Choice* Advai is measuring the B−V and U−B color indices of a star. The star is moving rapidly away from Earth. If he does not correct for the star's motion, how will the observed color indices compare to the star's intrinsic color indices?

W) Both B−V and U−B will be higher than intrinsic

X) B−V will be higher, but U−B will be lower than intrinsic

Y) B−V will be lower, but U−B will be higher than intrinsic

Z) Both B−V and U−B will be lower than intrinsic

ANSWER: W) Both B−V and U−B will be higher than intrinsic [RoA]

TOSS UP

19) MATH *Short Answer* Select ALL of the following statements that are true of matrices A and B:

1) $\det(AB) = \det(A)\det(B)$ (read: *the determinant of AB is equal to the determinant of A times the determinant of B*)

2) $\det(A + B) = \det(A) + \det(B)$ (read: *the determinant of A+B is equal to the determinant of A plus the determinant of B*)

3) $(AB)^{\intercal} = A^{\intercal}B^{\intercal}$ (read: *read as: the transpose of A+B is equal to the transpose of A plus the transpose of B*)

ANSWER: 13 [AdM]

BONUS

19) MATH *Short Answer* What is the volume of the solid formed by rotating an equilateral triangle with side length 2 centered at (2, 2) about the y-axis?

ANSWER: $4\pi\sqrt{3}$ [TS]

TOSS UP

20) BIOLOGY *Short Answer* A female mates with a male homozygous recessive for a maternal-effect trait and has four offspring, only two of which have offspring with the trait. What is the probability that this female is heterozygous for the trait?

ANSWER: 100% [TS]

BONUS

20) BIOLOGY *Multiple Choice* Scientists in Roshan's basement are studying porphyrin compounds due to their fluorescent properties. Alongside 5-amino levulinic acid, which of the following amino acids is a precursor in heme biosynthesis?

W) Serine

X) Histidine

Y) Glycine

Z) Alanine

ANSWER: Y) Glycine [TS]

TOSS UP

21) CHEMISTRY *Short Answer* Researchers at Bawendi Lab are studying the properties of quantum dots. By what factor would the peak absorption wavelength of a quantum dot increase if the mass is halved and the radius is tripled?

ANSWER: 4.5 [TS]

BONUS

21) CHEMISTRY *Short Answer* dentify all of the following statements that are true regarding Baldwin's rules for ring closure.

1) The classification 5-exo-trig describes a favored ring closure involving an sp2 attacked carbon
2) The dig classification is applied when the atom undergoing attack is sp-hybridized, as found in an alkyne
3) The 5-endo-trig closure is typically disfavored due to required strain in the transition state
4) Exo cyclizations are generally favored over endo closures due to a more accessible bond-forming trajectory

ANSWER: ALL [AA]

TOSS UP

22) PHYSICS *Short Answer* Gauss's Law only holds because the divergence of a radial, inverse-square vector field, such as the electric field produced by a point charge, is equal to what function, whose value is zero everywhere except at zero and has an integral over the real line equal to one?

ANSWER: Dirac delta function [RuA]

BONUS

22) PHYSICS *Short Answer* Two thin convex lenses, one with a focal length of 6 meters and another with a focal length of 3 meters are placed right next to each other. In meters, what is the focal length of the combined system?

ANSWER: 2 meters [AdM]

TOSS UP

23) ESS *Short Answer* As magma is injected into a sill, the sill can transition into a laccolith after reaching a critical radius. Identify all of the following three changes that would increase the critical radius for laccolith formation:

1) Increasing lithostatic pressure
2) Increasing viscosity of magma
3) Increasing strength of host rock

ANSWER: 13 [RoA]

BONUS

23) ESS *Multiple Choice* Which of the following best describes how the relative vorticity and of an air parcel in the Northern hemisphere changes as it moves south?

W) Relative vorticity remains constant, absolute vorticity increases

X) Relative vorticity remains constant, absolute vorticity decreases

Y) Relative vorticity increases, absolute vorticity remains constant

Z) Relative vorticity decreases, absolute vorticity remains constant

ANSWER: Y) Relative vorticity increases, absolute vorticity remains constant [RoA]

TOSS UP

24) MATH *Short Answer* Select ALL of the following three point that lie on the Euler line:

1) Incenter

2) Orthocenter

3) Nine-point center

ANSWER: 23 [AdM]

BONUS

24) MATH *Short Answer* Let alpha be the angle between a space diagonal and face diagonal of a cube that share a common vertex. Let beta be the angle between a space diagonal and edge of a cube that share a common vertex. Find the sum of alpha and beta.

ANSWER: 90 degrees [AdM]

TOSS UP

25) BIOLOGY *Multiple Choice* For flow cytometric identification of apoptotic cells, annexin V is used as a fluorescent marker for phospholipids on the outer membrane leaflet. Which of the following phospholipids does annexin V most likely bind?

W) Phosphatidylcholine

X) Phosphatidylethanolamine

Y) Cardiolipin

Z) Phosphatidylserine

ANSWER: Z) Phosphatidylserine [TS]

BONUS

25) BIOLOGY *Multiple Choice* Sydney is studying dosage compensation in D. melanogaster and crosses females homozygous for an X-linked GFP reporter with wild-type males. In the F1, nearly all males are fluorescent with brightness B. Which of the following is likely the relative brightness of the F1 females?

W) $\frac{B}{4}$

X) $\frac{B}{2}$

Y) B

Z) 2B

ANSWER: X) $\frac{B}{2}$ [TS]
