FE!M 2025

Round 6

TOSS UP

1) BIOLOGY *Multiple Choice* Which of the following enzymes is possessed by phage T4, but not phage lambda?

W) Reverse transcriptase

X) Endonuclease

Y) Exonuclease

Z) Integrase

ANSWER: X) Endonuclease [TS]

BONUS

1) BIOLOGY *Short Answer* A flowering plant has a sequential pigment synthesis pathway, where a colorless precursor is converted to blue pigment, and then converted into purple pigment. If two diploid plants heterozygous for loss-of-function mutations in both enzymes in this pathway are crossed, what is the probability that the flowers are not purple?

ANSWER: 7/16 [TS]

TOSS UP

2) PHYSICS *Short Answer* For a particle undergoing Brownian motion, the square of its expected displacement is directly proportional to the dynamic viscosity of the medium raised to what power?

ANSWER: −1 [RuA]

BONUS

2) PHYSICS *Multiple Choice* You drop a ball from a very tall tower on Earth's surface. Ignoring air resistance, which of the following best describes the impact point of the ball?

W) It will land north of its release point

X) It will land south of its release point

Y) It will land west of its release point

Z) It will land east of its release point

ANSWER: Z) It will land east of its release point [RoA]

TOSS UP

3) CHEMISTRY *Multiple Choice* In degrees, which of the following is closest to the value to the carbon-carbon-carbon bond angles in the chair conformation of cyclohexane?

W) 98.5°

X) 107.5°

Y) 109.5°

Z) 112.5°

ANSWER: Y) 109.5° [AA]

BONUS

3) CHEMISTRY *Multiple Choice* Find the number of stereoisomers of the compound $[CoCl_3(NH_3)_33]^{2+}$ (read: *tri-ammine-tri-chlorido-cobalt two*)

ANSWER: 2

TOSS UP

4) MATH *Short Answer* What is the 1003^{rd} derivative of $-\sin(x)$?

ANSWER: $\cos(x)$ [AA]

BONUS

4) MATH *Short Answer* A cube is circumscribed about a sphere of radius 1, and then a smaller sphere is placed between the cube and the larger sphere so that it is tangent to 3 faces of the cube and the sphere. What is the radius of the smaller sphere?

ANSWER: $2-\sqrt{3}$ [AA]

TOSS UP

5) ESS *Multiple Choice* Which of the following best describes how the strength of the titanium oxide spectral line changes as the surface temperature of a star increases from 5000 K to 50, 000 K?

W) Always increases

X) Always decreases

Y) Increases then decreases

Z) Decreases increases

ANSWER: X) Always decreases [RoA]

BONUS

5) ESS *Multiple Choice* Which of the following best describes a reaction involved in the chemical weathering of iron-bearing minerals?

W) Hematite is reduced into magnetite

X) Magnetite is reduced into hematite

Y) Hematite is oxidized into magnetite

Z) Magnetite is oxidized into hematite

ANSWER: Z) Magnetite is oxidized into hematite [RoA]

TOSS UP

6) BIOLOGY *Short Answer* To increase the potency of local anesthetics, researchers are looking into the design of strong vasoconstricting agents. What peptide is considered the strongest natural vasoconstrictor?

ANSWER: Endothelin (ACCEPT: Endothelin-1)

BONUS

6) BIOLOGY *Multiple Choice* Order the following three cell types by increasing proximity to the retinal pigmented epithelium:

1) Horizontal cell
2) Cone cell
3) Ganglion cell

ANSWER: 312

TOSS UP

7) PHYSICS *Short Answer* Theenash constructs a non-linear rigid body using seven particles. How many normal modes of vibration does this body have?

ANSWER: 0 [RoA]

BONUS

7) PHYSICS *Short Answer* In Keplerian orbits, the effective potential energy includes a correction term in addition to the gravitational potential energy. This correction term arises from what force that arises when we switch to the frame of the orbiting body?

ANSWER: Centrifugal force [RuA]

TOSS UP

8) CHEMISTRY *Multiple Choice* Advaith is conducting a study about molecular orbitals of the hydrogen molecule using computational chemistry. Which of the following is true about the molecular orbitals of the hydrogen molecule?

W) The molecular orbitals are formed from an overlapping of the 1s orbitals of three hydrogen atoms

X) The highest energy molecular orbital is sigma antibonding orbital

Y) The highest energy molecular orbital is sigma bonding orbital

Z) The electron density of each of the hydrogen atoms is different

ANSWER: X) The highest energy molecular orbital is sigma antibonding orbital [AA]

BONUS

8) CHEMISTRY *Short Answer* Arrange the following carboxylic acid derivatives in order of increasing reactivity toward nucleophilic acyl substitution:

1) Acyl chloride

2) Amide

3) Ester

Answer: 2, 3, 1 [AA]

TOSS UP

9) MATH *Short Answer* The point $(2, 3, 4)$ is rotated 90 degrees counterclockwise in the yz-plane, and then reflected across the y-axis. What are the coordinates of the resulting point?

ANS: $(-2, -4, -3)$ [AdM]

BONUS

9) MATH *Short Answer* The maximum value of the function $f(x) = \sin(x) + \sin(2x)$ between $x = 0$ and $x = pi$ occurs at $x = a$. Compute $\cos(a)$.

ANSWER: $(-1 + \sqrt{33})/8$ [AA]

TOSS UP

10) ESS *Multiple Choice* Ultra-high pressure metamorphism of which of the following coarse-grained igneous rocks would most likely result in the formation of coesite?

W) Peridotite

X) Gabbro

Y) Diorite

Z) Granite

ANSWER: Z) Granite [RoA]

BONUS

10) ESS *Multiple Choice* The evolution of a G6-type, V-class main sequence star is observed over several billion years. Which of the following could describe the spectral type and luminosity class of the star during its helium flash?

W) G6 and V

X) K8 and III

Y) F4 and IV

Z) A2 and I

ANSWER: X) K8 and III

TOSS UP

11) BIOLOGY *Short Answer* Surrounded by unrelated ion transporters and structural proteins, the injectisome apparatus responsible for extending bacterial flagella shares significant homology with proteins used for Type III secretion systems. This can be attributed to the bacterial flagellum forming through what general process in which biological structures are evolutionarily repurposed?

ANSWER: Exaptation

BONUS

11) BIOLOGY *Multiple Choice* Which of the following correctly identifies the receptor types in the preganglionic and postganglionic neurons, respectively, in the parasympathetic nervous system?

W) Nicotinic, Nicotinic

X) Nicotinic, Muscarinic

Y) Muscarinic, Nicotinic

Z) Muscarinic, Muscarinic

ANSWER: X) Nicotinic, Muscarinic

TOSS UP

12) PHYSICS *Short Answer* An airplane flying at constant velocity v with power output P experiences quadratic drag. If an identical airplane is flying at velocity $3v$, what is its power output in terms of P?

ANSWER: $27P$ [RoA]

BONUS

12) PHYSICS *Short Answer* A projectile is thrown at an angle such that its maximum height and range are equal. What is the value of the tangent of this angle?

ANSWER: 4 [RuA]

TOSS UP

13) CHEMISTRY *Short Answer* Rank the following acids in the order of increasing acidity.

1) H_3BO_3
2) $HClO_3$
3) H_3PO_4

ANSWER: 132 [AA]

BONUS

13) CHEMISTRY *Short Answer* Rank the following three cycloalkanes in terms of increasing heat of combustion per CH_2 group.

1) Cyclobutane
2) Cyclohexane
3) Cyclopentane

ANSWER: 231 [AA]

TOSS UP

14) MATH *Short Answer* Arrange the following 4 intervals in order of increasing average value of $\sin(x)$ over the interval:

1) $0 \leq x \leq \pi$
2) $\pi/2 \leq x \leq 3\pi/2$
3) $\pi \leq x \leq 2\pi$
4) $3.14 \leq x \leq 3.15$

ANSWER: 3421 [RoA]

BONUS

14) MATH *Short Answer* How many space diagonals does an icosahedron have, given that it has 12 vertices, 30 edges, and 20 triangular faces?

ANSWER: 36 [IK]

TOSS UP

15) ESS *Multiple Choice* Which of the following types of seafloor sediment has the most uniform distribution across the global ocean?

W) Terrigenous
X) Biogenous
Y) Hydrogenous
Z) Cosmogenous

ANSWER: Z) Cosmogenous [RoA]

BONUS

15) ESS *Multiple Choice* Which of the following conditions would increase the strength of a sea breeze along a coastline?

W) Stronger solar heating of the land relative to the ocean

X) Cooler land temperatures relative to the ocean

Y) Strong synoptic-scale winds blowing onshore

Z) Overcast skies during the day

ANSWER: W) Stronger solar heating of the land relative to the ocean [AS]

TOSS UP

16) BIOLOGY *Short Answer* Select ALL of the following three brain regions that are derived from the metencephalon:

1) Pons

2) Medulla Oblongata

3) Cerebellum

ANSWER: 1 and 3

BONUS

16) BIOLOGY *Multiple Choice* Which of the following ETC complexes possesses catalytic activity in the citric acid cycle?

W) Complex I

X) Complex II

Y) Complex III

Z) Complex IV

ANSWER: X) Complex II

TOSS UP

17) PHYSICS *Short Answer* Theenash lives on planet Blar, which is spherical and has a uniform density. One day, he decides to dig to the center of Blar, but ends up stopping only a third of the way to the center. What is the ratio of the acceleration due to gravity that Theenash experiences now, compared to when he was on the surface of the planet?

ANSWER: 2/3 [AdM]

BONUS

17) PHYSICS *Short Answer* Physics - Short Answer: What statement defines 2 images as resolved if the center of one Airy disk is at or beyond the first minimum of the other Airy disk?

ANSWER: Rayleigh's criterion [RuA]

TOSS UP

18) CHEMISTRY *Short Answer* BINAP (read: *B I N A P*) exists as two different stereoisomers despite containing no stereogenic centers. This is due to what type of isomerism?

ANSWER: Atropisomerism [AA]

BONUS

18) CHEMISTRY *Multiple Choice* Cyclobutane occupies a puckered wing conformation as opposed to the predicted planar square geometry. This is best explained by which of the following?

W) The C-C bonds repel each other

X) The carbon nuclei repel each other

Y) The C-H bonds eclipse each other

Z) The hydrogen nuclei repel each other

ANSWER: Y) The C-H bonds eclipse each other [AA]

TOSS UP

19) MATH *Short Answer* Compute all *real* solutions of the equation $x^{10} = (x-1)^{10}$ (read: *x to the power of* 10 *equals quantity, x* − 1, *end quantity, to the power of* 10)

ANSWER: 1/2 [AdM]

BONUS

19) MATH *Short Answer* Four squares of a 3 × 3 grid are colored so that no two colored squares share an edge. In how many ways can this be done?

ANSWER: 6 [AdM]

TOSS UP

20) ESS *Short Answer* The Jeans mass is the minimum mass required for a molecular cloud to collapse under its own gravity into a protostar. Identify all of the following three changes to a molecular cloud that would increase its Jeans mass: 1) Increasing temperature; 2) Increasing density; 3) Increasing rate of rotation

ANSWER: 13 [IK, RoA]

BONUS

20) ESS *Multiple Choice* Which of the following ores is commonly mined for silver because it contains high concentrations of silver as an impurity?

W) Bauxite

X) Galena

Y) Hematite

Z) Chalcopyrite

ANSWER: X) Galena [AS]

TOSS UP

21) BIOLOGY *Multiple Choice* Brian Lu is in love with his plants and reluctantly digs up some soybean root nodules. Which of the following molecules helps maintain an anaerobic environment for nodule bacterioids?

W) Lignin

X) Leghemoglobin

Y) Flavonoids

Z) Suberin

ANSWER: X) Leghemoglobin

BONUS

21) BIOLOGY *Multiple Choice* Para-aminohippuric acid is a compound used in renal function tests for plasma flow. Which of the following best describes para-aminohippuric acid's relationship with the nephron?

W) Fully reabsorbed

X) Fully secreted

Y) Neither reabsorbed nor secreted

Z) Non-filterable

ANSWER: Fully secreted

TOSS UP

22) PHYSICS *Short Answer* Rutvik fires an alpha particle beam by accelerating particles through a potential difference. If each alpha particle has a final energy of 22 MeV, then in megavolts, through what potential difference were the alpha particles accelerated?

ANS: 11 [RoA]

BONUS

22) PHYSICS *Short Answer* Order the following three objects by increasing index of refraction:

1) An object with relative permittivity 3 and relative permeability 3
2) An object with relative permittivity 2 and relative permeability 4
3) An object with relative permittivity 4 and relative permeability 1

ANSWER:321 [RoA]

TOSS UP

23) CHEMISTRY *Multiple Choice* Dr. Sawicka is studying polymeric oxyanions such as triphosphate which are used in food preservatives. Which of the following is the charge of the dihydrogen triphosphate anion?

W) -3
X) -4
Y) -5
Z) -6

ANSWER: W) -3 [TS]

BONUS

23) CHEMISTRY *Multiple Choice* Which of the following amines has the lowest boiling point?

W) Methylamine

X) Ammonia

Y) Dimethylamine

Z) Trimethylamine

ANSWER: Z) Trimethylamine [AA]

TOSS UP

24) MATH *Short Answer* What is the equation of the line perpendicular to the curve $x^2 + y^2 = 25$ at the point $(3, 4)$?

ANSWER: $y = 4x/3$ [AdM]

BONUS

24) MATH *Short Answer* Compute the area of the triangle determined by the points $(6, 2, 1)$, $(0, 0, -2)$, and $(2, -2, -1)$

ANSWER: $4\sqrt{5}$ [AdM]

TOSS UP

25) ESS *Short Answer* On an isobaric map, contour lines connect points with an equal value of what quantity?

ANSWER: Elevation (ACCEPT: Height) [AS]

BONUS

25) ESS *Short Answer* Order the following variable stars by decreasing average pulsation period:

1) RR Lyrae
2) Cepheid
3) Mira

ANSWER: 321 [AS]
