FE!M 2025

Round 4

TOSS UP

1) BIOLOGY *Short Answer* Lateral branches in eudicots grow from discrete axillary buds nestled between the petiole and main branch. In contrast, lateral roots arise from what continuous ring of tissue surrounding the stele?

ANSWER: Pericycle [TS]

BONUS

1) BIOLOGY *Short Answer* In molecules of nucleic acid, hydrogen bonds exist between complementary bases. However, molecules of nucleic acids are also further stabilized by what attractive forces between aromatic nucleobase systems?

ANSWER: Pi-stacking (ACCEPT: Van Der Waals) [ArK]

TOSS UP

2) PHYSICS *Short Answer* According to the BGV theorem, a universe that undergoes expansion on average over its lifetime must have originated from what infinitely dense point in space time?

ANSWER: Singularity [JW]

BONUS

2) PHYSICS *Short Answer* The angular frequency of an electron moving in a circle due to a uniform magnetic field is proportional to the radius of the circle raised to what power?

ANSWER: 0 [RoA]

TOSS UP

3) CHEMISTRY *Multiple Choice* Which of these compounds is nonaromatic?

W) Cyclobutadiene

X) Pyridine

Y) Cyclopentadiene

Z) Benzene

ANSWER: Y) Cyclopentadiene [AA]

BONUS

3) CHEMISTRY *Short Answer* A 2 by 2 by 2 lattice of carbon monoxide molecules has two equally possible configurations for each molecule. In terms of the Boltzmann constant k, what is the residual entropy of this lattice?

ANSWER: $8k \ln 2$ [TS]

TOSS UP

4) MATH *Short Answer* Which of the following four transformations are affine?

1) Translations
2) Shears
3) Rotations
4) Dilations

ANSWER: 1234 [AdM]

BONUS

4) MATH *Short Answer* Gabriel's horn is formed by revolving the graph of $y = 1/x$ for $x \geq 1$ around the x-axis. What is the volume of Gabriel's horn?

ANSWER: π [AdM]

TOSS UP

5) ESS *Multiple Choice* Advai is studying a specimen of andesite porphyry from the Andes mountains. He plots its grain-size distribution on a graph of frequency versus grain size. Which of the following best describes the expected grain-size distribution of this rock?

W) Uniform
X) Unimodal
Y) Bimodal
Z) Multimodal

ANSWER: Y) Bimodal [RoA]

BONUS

5) ESS *Multiple Choice* A melt that exhibits crystal settling would be most depleted in which of the following elements?

W) Sodium

X) Silicon

Y) Magnesium

Z) Potassium

ANSWER: Y) Magnesium [RoA]

TOSS UP

6) BIOLOGY *Short Answer* Prader-Willi syndrome only manifests if the mutant allele is inherited from the paternal genome. This is an example of what genetic phenomenon where genes are silenced in a parent-specific manner?

ANSWER: Genomic Imprinting [TS]

BONUS

6) BIOLOGY *Short Answer* Select ALL of the following three proteins that are produced by the liver:

1) Angiotensinogen

2) Albumin

3) Insulin-like growth factor 2

ANSWER: ALL [TS]

TOSS UP

7) PHYSICS *Short Answer* Advaith is zooming about on his new car. He wants to go navigate a vertical circular loop of radius 4 m. Assuming that the car and Advaith are point masses, at what minimum speed, in m/s, must he enter the loop in order to complete it without falling off?

ANSWER: 14 [RoA]

BONUS

7) PHYSICS *Short Answer* A car moves along a circular track of radius 25 meters. Its speed increases uniformly from 10 m/s to 40 m/s over a time period of 10 seconds. What is the magnitude of its total initial acceleration?

ANSWER: 5 [RuA]

TOSS UP

8) CHEMISTRY *Multiple Choice* Which of the following 0.1 molar solution has lowest pH?

W) $NaCl$

X) $NaOH$

Y) HCl

Z) H_2CO_3

ANSWER: Y) HCl [AA]

BONUS

8) CHEMISTRY *Multiple Choice* According to the Hammond Postulate, in an exothermic reaction, the transition state resembles which of the following?

W) Products

X) Intermediate

Y) Reactants

Z) Catalyst

ANSWER: Y) Reactants [AA]

TOSS UP

9) MATH *Short Answer* What is the 5^{th} derivative of $\ln x$?

ANSWER: $24/x^5$ [AdM]

BONUS

9) MATH *Short Answer* Compute the median of the angles in a triangle with sides of length 5, 7, and 8.

ANSWER: 60° [AdM]

TOSS UP

10) ESS *Multiple Choice* Which of the following best explains how infrared satellites can determine cloud height?

W) Higher clouds contain more ice crystals that reflect infrared light

X) Lower clouds emit more infrared radiation because they are warmer

Y) Taller clouds block more ultraviolet radiation from the Sun

Z) Lower clouds scatter microwave signals more efficiently

ANSWER: X) Lower clouds emit more infrared radiation because they are warmer [AS]

BONUS

10) ESS *Short Answer* Ring rain is a process in which material from Saturn's rings drifts inward and falls into the planet's atmosphere. Order the following three molecules in terms of increasing abundance in Saturn's ring rain.

1) Water

2) Carbon dioxide

3) Methane

ANSWER: 231 [IK]

TOSS UP

11) BIOLOGY *Multiple Choice* An elemental analysis of an unknown pathogen reveals that it does not contain any phosphorus. Which of the following diseases is likely caused by this pathogen?

W) Infectious Mononucleosis

X) Malaria

Y) Creutzfeldt-Jakob disease (read: *Croyts-felt Yah-kob*)

Z) Trichinosis

ANSWER: Y) Creutzfeldt-Jakob disease [TS]

BONUS

11) BIOLOGY *Multiple Choice* After conducting a bulk RNA-seq (read: *RNA-seek*) experiment, Arjun is analyzing the sequence composition of his reads. Which of the following noncoding RNA types is not encoded by the genome?

W) siRNA

X) miRNA

Y) piRNA

Z) snRNA

ANSWER: W) siRNA [TS]

TOSS UP

12) PHYSICS *Multiple Choice* Which of the following best describes the surface charge density on a charged conductor of irregular shape?

W) Uniform throughout the volume

X) Uniform throughout the surface

Y) Higher in smoother regions, lower in sharp regions

Z) Higher in sharp regions, lower in smoother regions

ANSWER: Z) Higher in sharp regions, lower in smoother regions [RuA]

BONUS

12) PHYSICS *Short Answer* A pipe closed on one end and open on the other end has a length of 50 cm. Assuming the speed of sound is 340 m/s, what is the fundamental frequency of the pipe in Hertz?

ANSWER: 170 [RuA]

TOSS UP

13) CHEMISTRY *Multiple Choice* In which of the following compounds does chlorine have the lowest oxidation state?

W) $NaClO$

X) $HClO_3$

Y) Cl_2O

Z) Cl_2

ANSWER: Y) Cl_2 [AA]

BONUS

13) CHEMISTRY *Short Answer* At 298 K, substance A has a vapor pressure of 20 torr and substance B has a vapor pressure of 30 torr. What is the mole fraction of substance A in an ideal solution of these two substances with vapor pressure 24 torr?

ANSWER: 0.6 [TS]

TOSS UP

14) MATH *Short Answer* Theenash can buy nuggets in 3 different sized packs; one with 3 nuggets, one with 5 nuggets, and one with 7 nuggets. Given that Theenash can buy an infinite number of any of these packs, what is the largest number of nuggets that Theenash cannot buy?

ANSWER: 4 [AdM]

BONUS

14) MATH *Short Answer* How many ways are there to insert the operations + and − in between the numbers 1, 2, 3, ... 2027 (read: *one, two, three, and so on until two thousand twenty-seven*), in that order, so that the resulting sum is even?

ANSWER: 2^{2026} [AdM]

TOSS UP

15) ESS *Multiple Choice* Which of the following best explains how the very first free oxygen molecules formed in the Earth's early atmosphere over four billion years ago?

W) Oxygen was released in large amounts by cyanobacteria during photosynthesis

X) Oxygen atoms were split from water and carbon dioxide molecules by ultraviolet sunlight

Y) Oxygen was created when the Earth's atmosphere cooled and condensed

Z) Oxygen formed spontaneously from nitrogen gas in the early atmosphere

ANSWER: X) Oxygen atoms were split from water and carbon dioxide molecules by ultraviolet sunlight [RoA]

BONUS

15) ESS *Short Answer* Expressing your answer to the nearest degree, what is the inclination of Earth's orbital plane to the ecliptic?

ANSWER: 0 [RoA]

TOSS UP

16) BIOLOGY *Multiple Choice* In the sodium potassium antiporter, also known as the Na-K pump, how many Na+ and K+ ions, respectively, are transported per ATP?

W) 3, 2

X) 3, 1

Y) 2, 3

Z) 1, 1

ANSWER: W) 3, 2 [ArK]

BONUS

16) BIOLOGY *Short Answer* Parthenogenesis is used for asexual propagation from unfertilized embryos in animals. Similar to parthenogenesis, what process in plants involves the asexual production of seeds?

ANSWER: Apomixis [TS]

TOSS UP

17) PHYSICS *Multiple Choice* A mass-spring system has a mass of 3kg and a spring constant of 300 N/m. If it is pulled back at an amplitude of 2 meters, what is its velocity when it reaches its equilibrium position?

ANSWER: 20 [RoA]

BONUS

17) PHYSICS *Short Answer* A certain capacitor is made up of parallel square plates with side length 10 cm, separated by a distance 0.1 cm. In terms of the permittivity of free space, what is the magnitude of the electric field between the plates of the capacitor given that the charge on one of the plates is 5 C?

ANSWER: $500/\epsilon_0$ [AdM]

TOSS UP

18) CHEMISTRY *Short Answer* How many vibrational modes are present in the linear molecule carbon suboxide, with formula C_3O_2?

ANSWER: 10 [AA]

BONUS

18) CHEMISTRY *Short Answer* A buffer solution at pH 7 has equal concentration of weak acid and conjugate base. If the solution is diluted to four times its original volume, by what factor does the pH change?

ANSWER: 1 [AA]

TOSS UP

19) MATH *Short Answer* What is the sum of the first 10 rows of Pascal's triangle?

ANSWER: 1023 [AdM]

BONUS

19) MATH *Short Answer* The integral of $f(x)$ from $x = 1$ to $x = 7$ is 4, and the integral of $f(x)$ from $x = -5$ to $x = 7$ is 3. What is the integral from 1 to -5 of the quantity $2f(x) + 6$?

ANSWER: -34 [AdM]

TOSS UP

20) ESS *Multiple Choice* Which of the following best explains why scientists have difficulty pinpointing the sources of cosmic rays?

W) Their sources emit them only during brief, unpredictable bursts

X) They possess electric charge and are deflected by magnetic fields

Y) Their paths are blurred by interactions with interstellar gas

Z) They are blocked by Earth's atmosphere

ANSWER: X) They possess electric charge and are deflected by magnetic fields [AS]

BONUS

20) ESS *Multiple Choice* Which of the following would likely be found in high abundance above the K-T boundary?

W) Zircons

X) Tektites

Y) Chalk

Z) Iron nodules

ANS: X) Tektites [AS]
