AVES

DE 5

TOSS-UP

1) MATH *Short Answer* Identify all of the following three properties that a matrix with an eigenvalue of 0 must have:

1) Singular;

2) Upper triangular;

3) Lower triangular.

ANSWER: 1 only [RG]

BONUS

1) MATH *Short Answer* Rohan has the integers 1 through 6 listed on a board. Every second for 5 seconds, he chooses two of the remaining integers, calls them a and b, erases them, and writes down ab + a + b on the board. What is the maximum possible value for the final integer on the board?

ANSWER: 5039 [RG]

TOSS-UP

2) BIOLOGY *Multiple Choice* The enzyme nitrogenase would facilitate which of the following chemical conversions?

W) Ammonia to nitrate

X) Ammonia to ammonium

Y) Nitrate to nitrogen gas

Z) Nitrogen gas to ammonia

ANSWER: Z) Nitrogen gas to ammonia [RA]

BONUS

2) BIOLOGY *Short Answer* Identify all of the following three germ layers that tissue lining the body cavity of rotifers would be derived from:

1) Ectoderm;

2) Mesoderm;

3) Endoderm.

ANSWER: 2 and 3 [EH]

TOSS-UP

3) PHYSICS *Short Answer* A fluid with density double that of water is traveling at a constant height and its speed triples from 10 meters per second to 30 meters. In kilopascals, what is the change in pressure?

ANSWER: 800 [RG]

BONUS

3) PHYSICS *Short Answer* A spaceship is moving away from a quasar which produces emission lines of wavelength 300 nanometers. However, the spaceship observes the emission lines to have a wavelength of 500 nanometers. What is the Lorentz factor for the spaceship?

ANSWER: 17/15 [RG]

TOSS-UP

4) EARTH AND SPACE *Short Answer* Identify all of the following four Köppen classifications where oxisols would be found in:

1) A;

2) B;

3) D;

4) E.

ANSWER: 1 only [EH]

BONUS

4) EARTH AND SPACE *Multiple Choice* Which of the following dimensions of a channel would have the highest flow speed, assuming all other conditions are the same?

W) 3 units deep, 24 units wide

X) 4 units deep, 18 units wide

Y) 6 units deep, 12 units wide

Z) 8 units deep, 9 units wide

ANSWER: Y) 6 units deep, 12 units wide [RG]

TOSS-UP

5) CHEMISTRY *Short Answer* Tartaric acid has two chiral centers, but in certain instances when dissolved in a non racemic mixture, it can exhibit no optical activity**.** This is because in certain conformations, tartaric acid can be what type of compound which is achiral due to reflectional symmetry?

ANSWER: Meso compound [EH]

BONUS

5) CHEMISTRY *Short Answer* Identify all of the following three bases that would not be present at equilibrium in significant concentrations when dissolved in THF:

1) NH_2^-;

2) S_2^-;

3) F^-**.**

ANSWER: 2 only [EH]

TOSS-UP

6) MATH *Short Answer* How many ways can the integers 1 through 5 inclusive be arranged in a line such that every pair of adjacent integers are relatively prime?

ANSWER: 72 [RG]

BONUS

6) MATH *Short Answer* What is the expected number of times you must flip a coin in order to get 4 heads in a row?

ANSWER: 30 [RG]

TOSS-UP

7) BIOLOGY *Multiple Choice* If there was an absence of lactose in an E. coli cell, the expression of which of the following genes would be unaffected?

W) lacA

X) lacI

Y) lacY

Z) lacZ

ANSWER: X) lacI [EH]

BONUS

7) BIOLOGY *Short Answer* Identify all of the following three hormones that would stimulate the release of bile into the duodenum:

1) Secretin;

2) Cholecystokinin;

3) Gastrin.

ANSWER: 1 and 2 [EH]

TOSS-UP

8) PHYSICS *Short Answer* The cyclotron frequency of a given charged particle is omega**.** If a second particle has double the mass and double the charge of the first particle, what is the cyclotron frequency of the second particle, in terms of omega?

ANSWER: Omega [RG]

BONUS

8) PHYSICS *Multiple Choice* A gas is expanded at constant pressure from an initial temperature of A to a final temperature of 2A**.** Which of the following describes how the change in entropy during the expansion changes if the gas instead expanded from a temperature of A to a temperature of 3A?

W) The entropy change increases and is multiplied by some constant

X) The entropy change decreases and is multiplied by some constant

Y) The entropy change increases by a constant

Z) The entropy change decreases by a constant

ANSWER: Y) The entropy change increases by a constant [RG]

TOSS-UP

9) EARTH AND SPACE *Short Answer* Molecular hydrogen in molecular clouds is difficult to locate due to its lack of radio lines and transitions in the visible part of the electromagnetic spectrum. Instead, the spectra of what molecule, whose luminosity is constant to H2 mass in molecular clouds, is searched for to find presence of molecular hydrogen?

ANSWER: Carbon monoxide (Accept: CO) [RA]

BONUS

9) EARTH AND SPACE *Short Answer* Identify all of the following four types of clouds that can produce precipitation:

1) Stratocumulus;

2) Cirrostratus;

3) Altostratus;

4) Cumulus

ANSWER: 1 and 3 only [EH]

TOSS-UP

10) CHEMISTRY *Short Answer* Rohan has a reaction and he calculates the enthalpy change of the reaction at a certain temperature. If he wants to calculate the standard enthalpy change of the same reaction at a new temperature, with all other parameters unchanged, what law can he use that applies the difference in heat capacities between products and reactants?

ANSWER: Kirchhoff's law of Thermochemistry (ACCEPT: Kirchhoff's law) [RG]

BONUS

10) CHEMISTRY *Multiple Choice* Pyridine is a compound similar to benzene except one of the carbon atoms is replaced by a nitrogen atom. Which of the following best describes the nitrogen atom's hybridization and its lone pair respectively?

W) sp2; localized

X) sp2; delocalized

Y) sp3; localized

Z) sp3; delocalized

ANSWER: W) sp2; localized [EH]

TOSS-UP

11) MATH *Short Answer* What is the name of the function, that when evaluated at k, is equal to the sum from n = 1 to infinity of 1 over n to the power of k?

ANSWER: Zeta function (ACCEPT: Riemann zeta function) [RG]

BONUS

11) MATH *Multiple Choice* Which of the following is the sum of the digits of 2 to the power of 100?

W) 113

X) 114

Y) 115

Z) 116

ANSWER: Y) 115 [RG]

TOSS-UP

12) BIOLOGY *Short Answer* Identify all of the following three cells that would undergo meiosis:

1) Angiosperm megaspore;

2) Human zygote;

3) Heterocyst.

ANSWER: None of them [EH]

BONUS

12) BIOLOGY *Multiple Choice* Which of the following hormones would not be secreted from the cell through exocytosis?

W) Thyroxine

X) Oxytocin

Y) Epinephrine

Z) Insulin

ANSWER: W) Thyroxine [EH]

TOSS-UP

13) PHYSICS *Multiple Choice* The most probable speed for a particle in a gas obeying the Maxwell Boltzmann distribution is proportional to what power of the mass of the gas?

W) -1

X) -1/2

Y) 0

Z) 1/2

ANSWER: X) - 1/2 [RG]

BONUS

13) PHYSICS *Short Answer* A photon with wavelength 1 times 10^{-12} meters strikes an electron and is scattered at an angle of 120 degrees. Given that the Compton wavelength of an electron is 2.43 times 10^{-12} meters, find the wavelength of the photon after the collision to one significant figure and in SI units.

ANSWER: 5 x 10^{-12} meters [RG]

TOSS-UP

14) EARTH AND SPACE *Short Answer* Rohan is an omniscient being observing the universe. He finds that the average density of a theoretical universe is greater than the critical density. From this observation, identify all of the following four statements he could conclude about this universe:

1) It will expand then contract;

2) It has no center;

3) It is flat;

4) It has finite volume.

ANSWER: 1, 2, and 4 [RA]

BONUS

14) EARTH AND SPACE *Short Answer* A dense star of mass M has a radius four times as large as its Schwarzschild radius. If the star maintains its density, in terms of M, what mass would the star have to have such that its radius was equal to its Schwardschild radius?

ANSWER: 8M [PB]

TOSS-UP

15) CHEMISTRY *Short Answer* Assuming the nuclei are perfect spheres and rounding your answer to the nearest integer, what is the ratio of the radius of the nucleus of a uranium-238 atom to the radius of the nucleus of a deuterium atom?

ANSWER: 5 [RG]

BONUS

15) CHEMISTRY *Short Answer* Order the following three ionic compounds in terms of increasing coordination number of the cations.

1) Caesium chloride;

2) Zinc sulfide;

3) Sodium chloride.

ANSWER: 2, 3, 1 [RG]

TOSS-UP

16) MATH *Multiple Choice* What is the limit as x approaches 0 of cotangent of x minus cosecant of x?

W) -1

X) 0

Y) 1

Z) Indeterminate

ANSWER: X) 0 [RG]

BONUS

16) MATH *Short Answer* In how many ways can Rohan choose 3 subsets of the first 4 positive integers such that the union of the 3 subsets contains all of the first 4 positive integers? The order of the subsets matters.

ANSWER: 2401 [RG]

TOSS-UP

17) BIOLOGY *Short Answer* During fertilization in sea urchins, cortical granules fuse with the egg plasma membrane and release their contents outside the cell. In response to the cortical reaction, what layer on the outside of the sea urchin egg cell hardens to form a protective fertilization envelope?

ANSWER: Vitelline layer (Do not accept: zona pellucida) [EH]

BONUS

17) BIOLOGY *Short Answer* Order the following three histone modifications from most negative to most positive charge of the modified histone:

1) Acetylation;

2) Phosphorylation;

3) Methylation.

ANSWER: 2, 1, 3 [EH]

TOSS-UP

18) PHYSICS *Short Answer* In condensed matter physics, what is the name of the theory that describes superconductivity in terms of Cooper pairs, forming a condensate that flows without resistance?

ANSWER: BCS theory [RG]

BONUS

18) PHYSICS *Multiple Choice* Rohan obtains an asymmetric top and is spinning it around its 3 different principal axes. He notices that around one of the axes, the top's rotation is unstable. Which of the following must be true about this axis?

W) It has the smallest moment of inertia among the three axes

X) It has the largest moment of inertia among the three axes

Y) It has a moment of inertia between the other two axes

Z) It can either have the smallest or largest moment of inertia among the three axes

ANSWER: Y) It has a moment of inertia between the other two axes [RG]

TOSS-UP

19) EARTH AND SPACE *Short Answer* Polynyas are spots absent of sea ice that act as regions of sea ice formation. At these spots, strong winds blow the ice away from the coast, exposing the water underneath. What is the name of these winds?

ANSWER: Katabatic winds [GG]

BONUS

19) EARTH AND SPACE *Short Answer* The parallax angle from Earth to a made-up star is 30 degrees. Gaurav stands at a point on Earth and measures the distance from his position to the star. What is the maximum distance he could measure in astronomical units?

ANSWER: 1 + root 3 [GG]

TOSS-UP

20) CHEMISTRY Short Answer In infrared spectroscopy, what term is used to describe the region from 4000 to 1500 wavenumbers, where most functional groups show characteristic absorption bands that can be helpful in the qualitative analysis of a compound?

ANSWER: Diagnostic region [RG]

BONUS

20) CHEMISTRY *Short Answer* Identify all of the following 3 names that accurately describe an organic compound according to IUPAC nomenclature.

1) **[read slowly]** 1,2,3-trimethylpropane;

2) **[read slowly]** 2-propylbutane;

3) **[read slowly]** 2,4-dimethylcyclohexane.

ANSWER: None of them [RG]
