AVES

DE 8

TOSS-UP

1) MATH *Short Answer* Identify all of the following 3 things that are true about a metric space.

1) The distance function satisfies the triangle inequality

2) If a pair of points are zero distance apart, the points must be identical

3) The distance between any two points can be any real number

ANSWER: 1 and 2 [RG]

BONUS

1) MATH *Short Answer* Gaurav has cyclic quadrilateral ABCD with center O. He lets X be the intersection of line AB and line CD, Y be the intersection of line AC and line BD, and Z be the intersection of line AD and line BC. Answer the following two questions about this setup.

1) In triangle XYZ, what special center is O?

2) What theorem gives this result?

ANSWER: 1) Orthocenter 2) Brokard's theorem [RG]

TOSS-UP

2) BIOLOGY *Short Answer* Gaurav is examining the tertiary structure of a protein. He notices that the side chains of certain amino acids form hydrogen bonds with the surrounding water. Identify all of the following four amino acids that could fit this description:

1) Cysteine;

2) Aspartate;

3) Methionine;

4) Tyrosine.

ANSWER: 1, 2, and 4 [EH]

BONUS

2) BIOLOGY *Short Answer* Since DNA polymerase delta can only synthesize DNA from the 5' to 3' direction, the final RNA primer synthesized in the lagging strand cannot be replaced by DNA polymerase delta. Instead, telomerase extends the parental DNA strand, allowing what other DNA polymerase with a primase subunit to finish synthesizing the lagging strand?

ANSWER: DNA polymerase alpha [EH]

TOSS-UP

3) PHYSICS *Short Answer* In the solution to the schrodinger equation for quantum harmonic oscillators, a numerical expression in terms of the system's constants is multiplied by what specific type of polynomial, which depends on the principal quantum number n?

ANSWER: Hermite polynomials [RG]

BONUS

3) PHYSICS *Short Answer* Identify all of the following 3 properties that a Bloch sphere must possess:

1) The north and south pole of the sphere are the standard basis vectors;

2) A pair of diametrically opposite points are orthogonal vectors;

3) The sphere can be generalized to higher level quantum systems.

ANSWER: 2 and 3 [RG]

TOSS-UP

4) EARTH AND SPACE *Short Answer* Supernova explosions produce shockwaves of expanding magnetized clouds that can repeatedly reflect charged particles to form cosmic rays**.** What phenomenon is occurring in these supernova remnants where particles gain non-thermal energies from the reflection of magnetic mirrors?

ANSWER: Fermi acceleration (Accept: diffusive shock acceleration) [RA/EH]

BONUS

4) EARTH AND SPACE *Short Answer* Identify all of the following 4 stages of star which you would expect a 100 solar mass type O star to pass through:

1) Wolf-Rayet star;

2) Yellow hypergiant;

3) Luminous blue variable;

4) Red supergiant**.**

ANSWER: 1 and 3 [RA]

TOSS-UP

5) CHEMISTRY *Short Answer* The maximum absorption wavelength during a UV-Vis spectroscopy can be estimated using what set of rules, which add in contributions from the different substituents to a base wavelength?

ANSWER: Woodward-Fieser rules (ACCEPT: Woodward's rules) [RG]

BONUS

5) CHEMISTRY *Short Answer* Identify all of the following three mechanisms which include a SN2 step:

1) Ring opening of an epoxide with a strong nucleophile;

2) Ring opening of an epoxide with an acid;

3) Oxidation of a thiol.

ANSWER: All of them [RG]

TOSS-UP

6) MATH *Short Answer* The solutions to x to the power of 2024 equals 2 are plotted on the complex plane. What is the area of the circle that goes through all these solutions, to the nearest hundredth?

ANSWER: 3.14 [RG]

BONUS

6) MATH *Multiple Choice* An isosceles trapezoid has bases of length 4 and 8. If a circle can be inscribed inside it, what is the radius of the circle?

W) $\sqrt{5}$

X) $2\sqrt{2}$

X) 3

Y) $2\sqrt{3}$

ANSWER: W) $\sqrt{5}$

TOSS-UP

7) BIOLOGY *Short Answer* Andrey is trying to treat his rheumatoid arthritis, which is associated with excessive cell death. He attempts to prevent this cell death by injecting himself with caspase inhibitors, but his symptoms persist as cells continue to die via what method?

W) Necrosis

X) Necroptosis

Y) Pyroptosis

Z) Apoptosis

ANSWER: Y) Necroptosis [AN]

BONUS

7) BIOLOGY *Short Answer* Identify all of the following three pathways that have some of its constituents decussating:

1) Anterolateral pathway;

2) Dorsal column pathway;

3) Corticobulbar pathway.

ANSWER: All of them [RA]

TOSS-UP

8) PHYSICS *Multiple Choice* Connor is studying the Seebeck effect and wants to build a circuit in which he can generate electricity with a temperature difference**.** Which of the following types of diodes should he use?

W) Peltier diode

X) Gunn diode

Y) Tunnel diode

Z) Zener diode

ANSWER: W) Peltier diode [AK]

BONUS

8) PHYSICS *Short Answer* When a two-dimensional electron gas is subjected to a strong perpendicular magnetic field, the electrons undergo cyclotron motion, which causes their energy levels to become quantized**.** The formation of what phenomenon gives rise to this quantization?

ANSWER: Landau levels [RG]

TOSS-UP

9) EARTH AND SPACE *Short Answer* What regions, the chromospheric counterpart to facula, describes relatively bright regions of the Sun's surface around active regions?

ANSWER: Plages [RA]

BONUS

9) EARTH AND SPACE *Short Answer* Because cratons extend deeper than most crust, the mantle beneath them often lacks what zone in the asthenosphere, which is characterized by significant partial melting around Earth?

ANSWER: Low-velocity zone (ACCEPT: LVZ) [PB]

TOSS-UP

10) CHEMISTRY *Short Answer* The potential energy of an ionic solid is approximated to vary with the inverse of distance. However, an ionic solid does not collapse into a single point due to repulsions. What equation can be used to calculate the minimum possible potential energy of an ionic solid?

ANSWER: Born-Mayer equation [RG]

BONUS

10) CHEMISTRY *Short Answer* In the mass spectrum of 2,2,3,3-tetramethylpentane, order the following 3 peaks by increasing intensity:

1) M-113;

2) M-71;

3) M-29.

ANSWER: 1, 3, 2 [RG]

TOSS-UP

11) MATH *Short Answer* Ritwik is given a complex number c and starts with x=0. Every second, he squares x and adds c to x. What named set of values are the values of c such that x always stays bounded?

ANSWER: Mandelbrot Set [RG]

BONUS

11) MATH *Short Answer* Consider complex numbers a, b, and c such that a is equal to e^(i * pi), b is equal to e^(i * pi/2), and c is equal to e^(i * pi/4). Rohan plots a, b, and c on the complex plane and creates a triangle with the vertices being these points. What is the real part of the complex number that represents the orthocenter of the triangle?

ANSWER: -1 + √2/2 [RG]

TOSS-UP

12) BIOLOGY *Short Answer* Photoreceptor cells in the eyes face away from the incoming light, so light must pass through all the retinal layers to stimulate photoreceptors**.** To help light rays pass through the retina, what elongated funnel-shaped glia act like fiber-optic cables to deliver light rays directly to the photoreceptor cells?

ANSWER: Muller cells [EH]

BONUS

12) BIOLOGY *Short Answer* Ritwik is studying transposase**.** He notices that transposase recognizes special DNA sequences on both ends of a DNA-only transposon**.** The sequence that transposase recognizes at the 5' end of the transposon reads, 5' ATCTGC 3' **[read slowly: 5 prime A-T-C-T-G-C 3 prime]. ** If looking at the same DNA strand, what does the special sequence on the other end of the transposon read from 5' to 3'?

ANSWER: GCAGAT [EH]

TOSS-UP

13) PHYSICS *Short Answer* Rohan has created a market breaking shoe that is able to become longer and wider when stretched**.** This is likely because the material he used has a negative value of what quantity?

ANSWER: Poisson's ratio [RG]

BONUS

13) PHYSICS *Short Answer* Able to account for supersymmetry, the Haag–Łopuszański–Sohnius theorem is an extension of what theorem, which states that the charges associated with the internal symmetries always transform as Lorentz scalars?

ANSWER: Coleman-Mandula theorem [RG]

TOSS-UP

14) EARTH AND SPACE *Short Answer* An eddy in the Northern Atlantic ocean rotates counterclockwise. Which of the following best describes the relative water temperature and vertical motion inside this eddy, respectively?

W) Warm, upwelling

X) Warm, downwelling

Y) Cold, upwelling

Z) Cold, downwelling

ANSWER: Y) Cold, upwelling [PB]

BONUS

14) EARTH AND SPACE *Short Answer* Identify all of the following three statements which would support the monolithic collapse theory model of galaxy formation:

1) Not all globular clusters are the same age;

2) Half of the halo stars are in retrograde orbit;

3) Stars are present outside of a galaxy's disk.

ANSWER: None of them [RA]

TOSS-UP

15) CHEMISTRY *Short Answer* Identify all of the following three crown ethers that are correctly paired with the ion they typically solvate.

1) 15-crown-5 and Li+

2) 18-crown-6 and Na+

3) 21-crown-7 and K+

ANSWER: None of them [RG]

BONUS

15) CHEMISTRY *Multiple Choice* Which of the following best describes the relationship between the C-H bond and the C-C bond in cyclopropane?

W) The C-H bond has a higher p character than the C-C bond

X) The C-H bond has a lower p character than the C-C bond

Y) Both bonds have the same p character

Z) The p character of the bonds varies dramatically based on the environment the compound is in

ANSWER: X) The C-H bond has a lower p character than the C-C bond [EH]

TOSS-UP

16) MATH *Short Answer* Gaurav has triangle ABC and he finds points X, Y, and Z outside the triangle such that BCX, ACY, and ABZ are equilateral**.** The intersection of AX, BY, and CZ is what point, which has the property that the sum of the distances from the vertices to the point is minimized?

ANSWER: Fermat point [RG]

BONUS

16) MATH *Short Answer* Identify all of the following 3 groups which have a subgroup isomorphic to the dihedral group of order 8**.**

1) Symmetric group on a set of size 8

2) Alternating group on a set of size 4

3) Direct product of the cyclic group of order 4 with the cyclic group of order 4

ANSWER: 1 only [RG]

TOSS-UP

17) BIOLOGY *Short Answer* If a certain species of grasshopper and bee have the same number of distinct autosomal chromosomes, order the following four organisms by increasing chromosome count:

1) Male bee
2) Male grasshopper
3) Female bee
4) Female grasshopper

ANSWER: 1, 3, 2, 4 [EH]

BONUS

17) BIOLOGY *Short Answer* The secretion of trypsinogen by pancreatic cells protects them from autodigestion. To turn trypsinogen into trypsin in the duodenum, what enzyme embedded in the plasma membranes of intestinal epithelial cells must activate trypsinogen?

ANSWER: Enterokinase (Accept: enteropeptidase) [EH]

TOSS-UP

18) PHYSICS *Short Answer* What experiment, in which electrons in a vacuum tube were shot through a thin vapor of mercury, showed that electrons lost a fixed amount of kinetic energy when collided with a mercury atom and was the first experiment to support the quantum nature of electrons in an electrical perspective?

ANSWER: Franck-Hertz Experiment [RG]

BONUS

18) PHYSICS *Multiple Choice* A particle slides from point A to point B along a frictionless curve under uniform gravity. Assuming the curve minimizes the time it takes to go from A to B, which of the following describes how the velocity changes as the particle falls?

W) Increases

X) Decreases

Y) Increases and then decreases

Z) Decreases and then increases

ANSWER: W) Increases [RG]

TOSS-UP

19) EARTH AND SPACE *Short Answer* What rock texture is formed by an intergrowth of lamellae of two different minerals, typically potassium- and sodium-rich feldspar, that once formed a solid solution before undergoing exsolution during cooling?

ANSWER: Perthitic [PB]

BONUS

19) EARTH AND SPACE *Multiple Choice* A coastal freshwater aquifer has a water table 5 feet above sea level**.** Which of the following is closest to the depth, in feet, at which the freshwater aquifer ends and saltwater begins?

W) 50

X) 100

Y) 150

Z) 200

ANSWER: Z) 200 [PB]

TOSS-UP

20) CHEMISTRY *Short Answer* Identify all of the following three modes of vibration for CO_2 that are considered Raman active:

1) Asymmetric stretching;

2) Symmetric stretching;

3) Symmetric bending.

ANSWER: 2 only [RG]

BONUS

20) CHEMISTRY *Short Answer* Identify all of the following three substances, when present, result in an anti-Markovnikov addition, when an alkene is hydrohalogenated with HBr:

1) Hydrogen peroxide;

2) Tetrahydrofuran;

3) Sodium amide.

ANSWER: 1 only [RG]
