

TOSS-UP

1. Chemistry *Short Answer* Identify all of the following three compounds that are commonly used as radical initiators:

- 1) AIBN [read out the letters]
- 2) TMSCI [read out the letters]
- 3) Benzoyl peroxide.

ANSWER: 1 AND 3 [YL]

BONUS

1. Chemistry *Short Answer* The Lennard-Jones potential can be written as $k_1r^A - k_2r^B$ for constants k_1 and k_2 and integers A and B. What is the value of A + B?

ANSWER: -18 [YL]

TOSS-UP

2. Math *Short Answer* Stephen is interested in determining whether different age groups have different favorite organic reactions. Stephen splits the population of Washington DC into 4 age groups and takes a random sample from each group, then asks every participant to report their favorite organic reaction out of 10 given choices. If Stephen wishes to perform a Chi-square test for homogeneity, how many degrees of freedom should he use?

ANSWER: 27 [YL]

BONUS

2. Math *Multiple Choice* Which of the following best compares a t distribution to a normal distribution?

- W) Greater spread, greater peak
- X) Greater spread, lower peak
- Y) Lower spread, greater peak
- Z) Lower spread, lower peak

ANSWER: X) GREATER SPREAD, LOWER PEAK [YL]

TOSS-UP

3. Earth and Space *Short Answer* Angela the bumblebee flies into a coastal cliff because she mistakes its honeycomb pattern for her hive. This pattern, characterized by many shallow pockets in the rock, results from what weathering process?

ANSWER: SALT WEDGING [KW]

BONUS

3. Earth and Space *Short Answer* Identify all of the following phenomena that form due to reflection from flat ice crystals?

- 1) 46 degree halo
- 2) Parhelic circle
- 3) Light pillars

ANSWER: 23 [SC]

TOSS-UP

4. Biology *Multiple Choice* Aven John has recently been prescribed atenolol, an antagonist for beta-1 adrenergic receptors, to treat his hypertension. However he misreads the recommended dose as 500 mg instead of 50 mg. Which of the following would Aven most likely experience after taking such a high dose?

- W) Pulmonary Edema
- X) Cloudy Vision
- Y) Bradycardia
- Z) Diarrhea

ANSWER: Y) BRADYCARDIA [KD]

BONUS

4. Biology *Short Answer* In a certain population in Hardy-Weinberg Equilibrium, there is a gene locus with 3 distinct alleles: J, O, and E. If the frequency of the JJ genotype is 36% and the frequency of the EE genotype is 4%, what is the frequency of heterozygotes in this population?

ANSWER: 56% [KD]

TOSS-UP

5. Physics *Multiple Choice* Which of the following statements correctly describes the differential form of Faraday's Law?

- W) The divergence of \mathbf{E} equals negative partial \mathbf{B} over partial t
- X) The divergence of \mathbf{B} equals negative partial \mathbf{E} over partial t
- Y) The curl of \mathbf{E} equals negative partial \mathbf{B} over partial t

Z) The curl of **B** equals negative partial **E** over partial t

ANSWER: Y) THE CURL OF E EQUALS NEGATIVE PARTIAL B OVER PARTIAL T [YL]

BONUS

5. Physics *Multiple Choice* An infinitely long cylinder with uniform surface charge rolls without slipping down a ramp. Which of the following is true about its velocity?

W) Always increases

X) Increases, asymptotically approaching a constant value

Y) Increases initially, then decreases asymptotically to a constant value

Z) Increases initially, then oscillates between increasing and decreasing

ANSWER: X) INCREASES, ASYMPTOTICALLY APPROACHING A CONSTANT VALUE [SC]

TOSS-UP

6. Chemistry *Short Answer* The ground-state energy of a 1D particle-in-a-box is 4.5 eV. In electron volts, what is the energy of the second excited state of this particle-in-a-box system?

ANSWER: 40.5 eV [YL]

BONUS

6. Chemistry *Short Answer* Identify all of the following three prototype cell structures that contain cations [**CAT-ions**] in tetrahedral holes of a face-centered lattice of anions:

1) Zincblende

2) Fluorite

3) Antifluorite

ANSWER: 1 AND 3 [YL]

TOSS-UP

7. Math *Short Answer* What is the maximum number of intersection points between two ellipses and two lines?

ANSWER: 13 [EZ]

BONUS

7. Math *Short Answer* Stephen rolls a fair six sided die. He paints a number of faces of a cube corresponding to the number on the die. Stephen then cuts the cube into 64 smaller cubes and picks one at random to roll. What is the probability that the top face of the small cube is painted?

ANSWER: 7/48 [EZ]

TOSS-UP

8. Earth and Space *Multiple Choice* Which of the following qualities cannot be used to differentiate between Type I and Type II Seyfert galaxies?

- W) Emission lines
- X) Jet velocity
- Y) Total luminosity
- Z) Mass

ANSWER: Z) MASS [SC]

BONUS

8. Earth and Space *Multiple Choice* Which of the following metamorphic rocks would you LEAST expect to find anywhere along a subducting plate?

- W) Coesite
- X) Eclogite
- Y) Hornfels
- Z) Blueschist

ANSWER: Y) HORNFELS [KW]

TOSS-UP

9. Biology *Short Answer* According to the ABCDE hypothesis for floral organ identity, identify all of the following 4 structures that would be able to form if the E gene was suppressed:

- 1) Sepals
- 2) Petals
- 3) Stamens
- 4) Carpels

ANSWER: NONE [KD]

BONUS

9. Biology *Short Answer* A patient is measured to have a systolic blood pressure of 135 mmHg and a pulse pressure of 75 mmHg. What is this patient's mean arterial pressure in mmHg?

ANSWER: 85 [KD]

TOSS-UP

10. Physics *Short Answer* In the early universe, the universe was dominated by quark-gluon plasma. This is because nearly all matter was hotter than what threshold, at which hadronic matter evaporates?

ANSWER: HAGEDORN TEMPERATURE [SC]

BONUS

10. Physics *Multiple Choice* Consider a neutral *nongrounded* conducting spherical shell with radius R centered at the origin with a point charge q placed at $x > R$ away from the origin. There are two image charges in this problem, q_1 located at the origin and q_2 located inside the sphere but not at the origin. Which of the following gives the correct values for q_1 and q_2 , respectively?

- W) $qx/R, -qx/R$
- X) $-qx/R, qx/R$
- Y) $qR/x, -qR/x$
- Z) $-qR/x, qR/x$

ANSWER: Y) $qR/x, -qR/x$ [YL]

TOSS-UP

11. Chemistry *Multiple Choice* When eluting benzoic acid through a thin-layer chromatography [**chrome-a-TOG-ra-fee**] experiment, which of the following solvents would be expected to give the SMALLEST R_f value?

- W) n-hexane
- X) Ethyl acetate
- Y) Acetate
- Z) Isopropyl alcohol

ANSWER: W) N-HEXANE [YL]

BONUS

11. Chemistry *Short Answer* Just as reductive elimination is the microscopic reverse reaction of oxidative addition, what is the name for the microscopic reverse reaction of migratory insertion?

ANSWER: BETA ELIMINATION (ACCEPT: BETA HYDRIDE ELIMINATION) [YL]

TOSS-UP

12. Math *Multiple Choice* Which basic binary operation forms a group with the set of integers?

- W) Addition
- X) Subtraction
- Y) Multiplication
- Z) Division

ANSWER: W) ADDITION [EZ]

BONUS

12. Math *Multiple Choice* Consider the multivariable function $f(x, y) = x^2y + xy^2$. At the point (2, 2), along which of the following vectors would the directional derivative of $f(x, y)$ be the greatest?

- W) (1, 0)
- X) (1, 1)
- Y) (-1, -1)
- Z) (0, 1)

ANSWER: X) (1, 1) [YL]

TOSS-UP

13. Earth and Space *Multiple Choice* Which of the following correctly describes a horst?

- W) Shared foot wall of two normal faults
- X) Shared foot wall of two reverse faults
- Y) Shared hanging wall of two normal faults
- Z) Shared hanging wall of two reverse faults

ANSWER: W) SHARED FOOT WALL OF TWO NORMAL FAULTS [SC]

BONUS

13. Earth and Space *Short Answer* Due to the rotation of the Sun, the Heliospheric Current Sheet is not confined to a single plane, but is instead warped into an undulating shape. What is the term for this topology?

ANSWER: PARKER SPIRAL [SC]

TOSS-UP

14. Biology *Multiple Choice* The Hill coefficient for glutathione transferase, an enzyme involved in the detoxification of harmful electrophiles, is roughly 0.5. Which of the following best describes the cooperativity of this enzyme?

- W) Negative cooperativity
- X) Weak positive cooperativity
- Y) Strong positive cooperativity
- Z) No cooperativity

ANSWER: W) NEGATIVE COOPERATIVITY [KD]

BONUS

14. Biology *Short Answer* Order the following 4 classes of lipoproteins in terms of increasing lipid content by percentage of total mass:

- 1) LDL
- 2) VLDL
- 3) HDL
- 4) Chylomicrons

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

TOSS-UP

15. Physics *Short Answer* Yunyi has traveled to a universe where gravity obeys an inverse cube relationship. He observes a star and its planet — what is the shape of the region of space where the gravitational field due to the planet is stronger in magnitude than that due to the star?

ANSWER: SPHERE [SC]

BONUS

15. Physics *Short Answer* Fred weighs 30 kg, and is riding a 10-kg ring-shaped unicycle down a ramp that makes an angle of 60 degrees to the horizontal, without slipping. In terms of g, is his rate of acceleration?

ANSWER: 3/10 g [SC]

TOSS-UP

16. Chemistry *Multiple Choice* Radical polymerization of alkenes can sometimes be a challenge due to regioselective and stereoselective issues. What class of catalysts are often used to accomplish highly regio and stereoselective alkene polymerization?

- W) Grubbs Catalyst
- X) Ziegler-Natta Catalyst
- Y) Lindlar Catalyst
- Z) BINOL [BYE-nol]

ANSWER: X) ZIEGLER-NATTA CATALYST [YL]

BONUS

16. Chemistry *Short Answer* Calculate the enthalpy change in kilojoules to 2 significant figures when 2 moles of an ideal monatomic gas are expanded at a constant pressure of 3 bar from 30 liters to 90 liters.

ANSWER: 45 kJ [YL]

TOSS-UP

17. Math *Multiple Choice* Kian and Yunyi are playing a game with a pile of coins. Each turn, a player must take anywhere from 1 to 10 coins from the pile. If Kian goes first, which of the following coin amounts will cause him to lose regardless of what move he makes, given that Yunyi plays optimally?

- W) 2023
- X) 2024
- Y) 2025
- Z) 2026

ANSWER: X) 2024 [EZ]

BONUS

17. Math *Short Answer* Kian has 6 distinct textbooks and is arranging them on a bookshelf at random. The shelf has 2 shelves fitting 3 books each, one directly above the other. What is the probability that his biology textbook is to the left of his chemistry textbook?

ANSWER: $\frac{1}{2}$ [EZ]

TOSS-UP

18. Earth and Space *Multiple Choice* Which of the following types of eruptions would a submarine volcano most likely produce?

- W) Surtseyan
- X) Phreatic
- Y) Strombolian
- Z) Plinean

ANSWER: W) SURTSEYAN [KW]

BONUS

19. Earth and Space *Short Answer* Identify all of the following four galaxy types that usually indicate a close gravitational interaction in the object's past:

- 1) Dwarf elliptical
- 2) Anemic spiral
- 3) Starburst
- 4) Jellyfish

ANSWER: 3 ONLY [SC]

TOSS-UP

19. Biology *Multiple Choice* Andy is lifting weights when suddenly, his Golgi tendon organs disappear. Which of the following would Andy likely experience?

- W) Flaccid Paralysis
- X) Spastic Paralysis
- Y) Resting Tremor
- Z) Intention Tremor

ANSWER: X) SPASTIC PARALYSIS [KD]

BONUS

19. Biology *Multiple Choice* Which of the following statements is an accurate comparison between uncouplers and inhibitors of oxidative phosphorylation?

- W) Inhibitors decrease ATP production, uncouplers increase ATP production
- X) Inhibitors increase ATP production, uncouplers decrease ATP production
- Y) Inhibitors decrease oxygen consumption, uncouplers increase oxygen consumption
- Z) Inhibitors increase oxygen consumption, uncouplers decrease oxygen consumption

ANSWER: Y) INHIBITORS DECREASE OXYGEN CONSUMPTION, UNCOUPLERS INCREASE OXYGEN CONSUMPTION [KD]

TOSS-UP

20. Physics *Short Answer* What is the term for an event in which an extremely energetic lepton collides with a hadron and interacts with quarks directly?

ANSWER: DEEP-INELASTIC SCATTERING [SC]

BONUS

20. Physics *Short Answer* A ball is initially attached to a rope and moving in a circle of radius R. There is a winch at the other end of the rope — when its power source supplies it with 5 J of energy, it can retract the ball to a distance of $R/2$. If the winch were instead given 20J, in terms of R, what radius could it retract the ball to?

ANSWER: $R/5$ [SC]

TOSS-UP

21. Chemistry *Multiple Choice* When balancing the reaction between acidified potassium permanganate and aqueous Fe^{2+} to lowest whole number coefficients, what is the coefficient of H^+

- W) 0
- X) 4
- Y) 8
- Z) 12

ANSWER: Y) 8 [YL]

BONUS

21. Chemistry *Short Answer* In three-membered ring openings, the nucleophile sometimes attacks the more substituted carbon and sometimes the less substituted carbon, depending on reaction conditions. Identify all of the following three three-membered ring-opening reactions where the nucleophile attacks the more substituted carbon:

- 1) Alkoxymercuration [**alk-ox-ee-mer-cu-RAY-tion**]
- 2) Epoxide [**ee-POX-ide**] opening under acidic conditions
- 3) Epoxide opening under basic conditions

ANSWER: 1 AND 2 [YL]

TOSS-UP

22. Math *Short Answer* A 3 by 5 matrix has 2 pivot points. Give the dimensions of the column space and row space in that order.

ANSWER: 2 and 2 [SC]

BONUS

22. Math *Short Answer* Yunyi has 4 alphabet cubes each labeled with the letters A through F. Yunyi wants to write down all of the possible “words” and order them alphabetically. What position will the word CAFE be in?

ANSWER: 467 [EZ]

TOSS-UP

23. Earth and Space *Multiple Choice* Which of the following forms of mass wasting is not accelerated by the presence of a surrounding fluid?

- W) Rockslide
- X) Debris flow
- Y) Earthflow
- Z) Avalanche

ANSWER: W) ROCKSLIDE [SC]

BONUS

23. Earth and Space *Multiple Choice* Agin' Tong is in his entrepreneur era and has decided to sell mushroom rocks on Ebay. To manufacture them, he plans on cementing 2 horizontal layers of rock together and leaving them to erode in the desert. He has decided to use plagioclase feldspar for the bottom layer. Which of the following could he use for the top?

- W) Olivine
- X) Amphibole
- Y) Biotite
- Z) Muscovite

ANSWER: Z) MUSCOVITE [KW]

TOSS-UP

24. Biology *Short Answer* Identify all of the following 3 types of cell junctions that are found within intercalated disks in the heart:

- 1) Gap Junctions
- 2) Desmosomes
- 3) Tight Junctions

ANSWER: 1 AND 2 [KD]

BONUS

24. Biology *Multiple Choice* Which of the following statements regarding the avian respiratory system is NOT true?

- W) Birds use specialized bronchi called parabronchi for gas exchange
- X) Air first reaches the anterior air sac when entering
- Y) Birds utilize negative pressure breathing
- Z) 2 cycles of inhalation and expiration are required to circulate air

ANSWER: X) AIR FIRST REACHES THE ANTERIOR AIR SAC WHEN ENTERING [KD]

TOSSUP

25. Physics *Multiple Choice* Which of the following combinations of quarks and antiquarks can be found in a kaon?

- W) Up and anti-down
- X) Down and anti-up
- Y) Strange and anti-up
- Z) Strange and anti-strange

ANSWER: Y) STRANGE AND ANTI-UP [YL]

BONUS

25. Physics *Multiple Choice* Ohm's law predicts that electric fields induce steady state currents in linear dielectrics. The Drude model explains this by suggesting the acceleration of charge carriers in these cases is impeded by what?

- W) Magnetic fields produced by induced current
- X) Electric fields due to induced bound charges
- Y) Collisions between electrons and ions

Z) Collisions between electrons and electrons

ANSWER: Y) COLLISIONS BETWEEN ELECTRONS AND IONS **[SC]**