

TOSS-UP

1. **BIOLOGY** *Multiple Choice* Which of the following is not true of the origin of birds from reptiles?

(W) Because of their common ancestry, both birds and dinosaurs have hollow, pneumatized bones

(X) The sex determination system of birds is a shared ancestral character because it is also present in most reptiles

(Y) Because of their common ancestry, dinosaurs share similar nest-building and brooding behaviors as birds

(Z) Birds originated during the Mesozoic Era, before the diversification of mammals in the Cenozoic Era

ANSWER: X

TOSS-UP

2. **PHYSICS** *Short Answer* Which particle accelerator is currently among the largest in the world, and has discovered W and Z bosons and CP violation, and on December 13th 2011 announced that it may have been the first to observe the Higgs boson?

ANSWER: CERN

TOSS-UP

3. **CHEMISTRY** *Multiple Choice* Which of the following groups would not be found in butylated hydroxytoluene, or BHT?

(W) Benzene ring

(X) Tert-butyl group

(Y) Hydroxyl group

(Z) Isobutyl group

ANSWER: Z

TOSS-UP

4. MATH *Short Answer* If the sine of an angle θ is 0.8, what is the sine of the angle 2θ ?

ANSWER: 0.96

TOSS-UP

5. EARTH AND SPACE *Short Answer* By name or number, identify all of the following places in which you would find a divergent boundary: Mid-Atlantic ridge, Andes, Himalayas

ANSWER: MID-ATLANTIC RIDGE

TOSS-UP

6. ENERGY *Short Answer* This indole alkaloid terpene was formerly used as a pesticide before being banned in the United States. A potent neurotoxin, its symptoms of poisoning are due to its effects as an antagonist to glycine in the central nervous system, causing severe muscular convulsions and eventually death. Research institutes are currently developing antidotes to it because it may also be a possible chemical terrorism agent in the future. Name this pesticide.

ANSWER: STRYCHININE

TOSS-UP

7. BIOLOGY *Short Answer* Using words or numbers, name all of the following four choices that is or are true of G protein-coupled-receptor signalling:

- I. G proteins are specific to G protein coupled receptor pathways
- II. Caffeine and theophylline are effective because they are phosphodiesterase inhibitors
- III. G protein coupled receptors are normally found in cell cycle stimulation or inhibition pathways
- IV. One G protein coupled receptor may activate several heterotrimeric G proteins to amplify the signal

ANSWER: II, IV

TOSS-UP

8. PHYSICS *Multiple Choice* Which of the following is true of superconductivity?

(W) A superconductor has a direct proportionality between absolute temperature and electrical resistance at all temperatures

(X) Compounds such as bismuth strontium calcium copper oxide and yttrium barium copper oxide are termed high temperature superconductors because their critical temperatures are above 30 Kelvin, previously thought to be the highest critical temperature possible

(Y) Currently, it is not possible for superconductors to maintain an electric current with no voltage applied

(Z) Because the electrons in superconductors form Cooper pairs, there is no energy gap, and so the sea of electrons will readily absorb heat from the surroundings to compensate for heat loss

ANSWER: X

TOSS-UP

9. CHEMISTRY *Short Answer* Which heterocyclic organic compound with the chemical formula C_5H_5N is structurally related to benzene, with one C-H group replaced by a nitrogen atom?

ANSWER: PYRIDINE

TOSS-UP

10. MATH *Multiple Choice* Let P be the set of prime numbers below 100, and M be the set of Mersenne numbers below 100. How many elements are there in the set $P \cap M$?

(W) 1

(X) 2

(Y) 3

(Z) 4

ANSWER: X

TOSS-UP

11. EARTH AND SPACE *Short Answer* Which layer of the Earth is the highly viscous, mechanically weak and ductilely-deforming region of the upper mantle of the Earth that lies below the lithosphere at depths between 100 and 200 km?

ANSWER: ASTHENOSPHERE

TOSS-UP

12. ENERGY *Multiple Choice* Which of the following cellular activities would be the energetically most expensive?

(W) Conversion of 1 molecule of glucose to 2 molecules of glyceraldehyde-3-phosphate in glycolysis

(X) Conversion of 1 molecule of pyruvate to 1 molecule of lactate in fermentation

(Y) Elongation of the peptide chain by 1 amino acid in translation by a ribosome

(Z) Conversion of 1 molecule of citrate to 1 molecule of oxaloacetate in the tricarboxylic acid cycle

ANSWER: X

TOSS-UP

13. BIOLOGY *Short Answer* Using words or numbers, name all two of the following three choices that is or are true of gel electrophoresis of DNA:

I. The most common gel used is agarose because of its porosity

II. Sodium lauryl sulfate is used to overwhelm the negative charges on DNA

III. Ethidium bromide is required for imaging of the completed product

ANSWER: I AND III

TOSS-UP

14. PHYSICS *Short Answer* A planet has a radius of $1 \cdot 10^9$ meters and a mass of $2 \cdot 10^3$ kilograms. In terms of the gravitational constant G, what is the escape velocity of the planet at its surface?

ANSWER: $2\sqrt{G} \cdot 10^2$ M/S

TOSS-UP

15. CHEMISTRY *Short Answer* Using words or numbers, identify all 2 of the following 4 sets of quantum numbers which is possible for an electron to have:

- I. $n=1, l=1, m_l=-1$
- II. $n=2, l=1, m_l=-2$
- III. $n=2, l=1, m_l=-1$
- IV. $n=1, l=0, m_l=1$

ANSWER: III, IV

TOSS-UP

16. MATH *Short Answer* Collectively, how many times does the following function intersect the x, y, and z axes: $x^2 + y^2 + z^2 = 5$

ANSWER: 6

TOSS-UP

17. EARTH AND SPACE *Short Answer* Of the 88 modern constellations, which is the largest in the night sky, spanning 1303 square degrees, and is commonly represented by a water snake?

ANSWER: HYDRA

TOSS-UP

18. ENERGY *Short Answer* Which quantum number parametrizes the intrinsic angular momentum of a given particle, and, for electrons in an orbital, can take the values of +1 or -1 regardless of the other quantum numbers?

ANSWER: SPIN

TOSS-UP

19. BIOLOGY *Short Answer* Using words or numbers, name all of the following 4 phyla that that is or are heterosporous:

- I. Bryophyta
- II. Lycophyta
- III. Anthophyta
- IV. Ginkgophyta

ANSWER: III, IV

TOSS-UP

20. PHYSICS *Short Answer* Which diagram used in special relativity is used to measure distances in spacetime and consists of at least 1 space axes and 1 time axis?

ANSWER: MINKOWSKI DIAGRAM (ACCEPT: SPACETIME DIAGRAM)

TOSS-UP

21. CHEMISTRY *Short Answer* Using words or numbers, name all of the following 3 statements that is or are true of the relationship between HOMO/LUMO and inorganic semiconductor theory
- I. Highest occupied molecular orbital is analogous to the valence band
 - II. Lowest unoccupied molecular orbital is analogous to the conduction band
 - III. The HOMO-LUMO gap is analogous to the energy gap

ANSWER: I, II, III

TOSS-UP

22. MATH *Multiple Choice* The dot product of which of the following vectors with the vector $3\hat{i} + 4\hat{j}$ would yield 2?
- (W) $3\hat{i} + 4\hat{j}$
 - (X) $0.4\hat{i} + 0\hat{j}$
 - (Y) $\sqrt{2}\hat{i} + \sqrt{14}\hat{j}$
 - (Z) $\sqrt{2}\hat{i} + \sqrt{5}\hat{j}$

ANSWER: X

TOSS-UP

23. EARTH AND SPACE *Short Answer* Which large and prominent constellation in the winter sky of the northern hemisphere, bounded by Orion, Perseus, and Auriga, contains the star Aldebaran and the supernova remnant Crab Nebula?

ANSWER: TAURUS

TOSS-UP

24. ENERGY *Short Answer* Which principle, often applied in the theory of quantum dots, describes the phenomenon resulting from electrons and electron holes being squeezed into a dimension that approaches a critical quantum measurement, called the exciton Bohr radius?

ANSWER: QUANTUM CONFINEMENT

TOSS-UP

25. BIOLOGY *Short Answer* Mutations in which specific tumor suppressor gene can cause colorectal cancer in humans?

ANSWER: ADENOMATOUS POLYPOSIS COLI
