

TOSS-UP

1) Math – *Short Answer* What is the partial derivative with respect to y of x^3y^4 ?

ANSWER: $4x^3y^3$ (DO NOT ACCEPT: x^34y^3)

BONUS

1) Math – *Short Answer* A group of three friends each orders a sandwich from a menu of 12 different sandwiches. Assuming their choices are independent, what is the probability that exactly two of them order the same sandwich?

ANSWER: $11/48$

TOSS-UP

2) Physics – *Short Answer* Kepler's second law is a consequence of the conservation of what physical quantity?

ANSWER: ANGULAR MOMENTUM

BONUS

2) Physics – *Multiple Choice* Which of the following is closest to the ratio between the magnitude of the electric and gravitational forces between two electrons held at a fixed distance?

W) 10^{11}

X) 10^{20}

Y) 10^{34}

Z) 10^{42}

ANSWER: Z) 10^{42}

TOSS-UP

3) Biology – *Short Answer* What is the ecological term for a group of individuals of the same species that live together and interbreed?

ANSWER: POPULATION

BONUS

3) Biology – *Multiple Choice* As read from 5 prime to 3 prime, which of the following sequences would most likely function as the anticodon on an initiator tRNA molecule?

- W) CAU
- X) UAC
- Y) AUC
- Z) CUA

ANSWER: W) CAU

TOSS-UP

4) Chemistry – *Short Answer* What type of reaction converts a single stereoisomer into an equal mixture of both stereoisomers?

ANSWER: RACEMIZATION

BONUS

4) Chemistry – *Multiple Choice* Which of the following statements is true of first-order reactions?

W) The change in concentration of reactant is constant over time

X) The percentage change in concentration of reactant is constant over time

Y) The half-life changes depending on the concentration of reactant

Z) The half-life changes depending on the concentration of product

ANSWER: X) THE PERCENTAGE CHANGE IN
CONCENTRATION OF REACTANT IS CONSTANT OVER TIME

TOSS-UP

5) Earth and Space – *Short Answer* Which planet in our solar system has a semi-major axis closest to 2 AU?

ANSWER: MARS

BONUS

5) Earth and Space – *Short Answer* The Stefan-Boltzmann law states that the total energy emitted by a blackbody per unit time is linearly proportional to its temperature raised to what power?

ANSWER: 4

TOSS-UP

6) Energy – *Short Answer* Scientists at SLAC National Accelerator Laboratory are studying the gravitational lensing of active galactic nuclei. The non-stellar radiation from these nuclei originates from accretion onto a certain kind of astronomical object. What is the term for these objects?

ANSWER: BLACK HOLE (ACCEPT: SUPERMASSIVE BLACK HOLE)

BONUS

6) Energy – *Multiple Choice* Scientists at Thomas Jefferson National Accelerator Facility are studying decay processes that could provide insight into physics beyond the Standard Model. Which of the following phenomena is part of the Standard Model?

- W) Pion decay into a muon and an anti-muon neutrino
- X) Gravitational waves emitted by in-spiraling black holes
- Y) Conversion of axions to photons in electromagnetic fields
- Z) Production of stable free up quarks from proton-proton collisions

ANSWER: W) PION DECAY INTO A MUON AND AN ANTI-MUON NEUTRINO

TOSS-UP

7) Math – *Short Answer* What is the product of $4 - 9i$ and its conjugate?

ANSWER: 97

BONUS

7) Math – *Short Answer* Three cars average 20, 25, and 40 miles per gallon of fuel, respectively. If all three cars drive the same number of miles, then, to the nearest integer, what is the cars' combined miles per gallon?

ANSWER: 26

TOSS-UP

8) Physics – *Multiple Choice* Which of the following best describes the graph of position versus time for a damped harmonic oscillator?

W) Linear decay

X) Exponential decay

Y) Sinusoid with linearly-decaying envelope

Z) Sinusoid with exponentially-decaying envelope

ANSWER: Z) SINUSOID WITH EXPONENTIALLY-DECAYING ENVELOPE

BONUS

8) Physics – *Short Answer* In the photoelectric effect, what is the term for the minimum energy that an incident photon must have to cause emission of an electron?

ANSWER: WORK FUNCTION

TOSS-UP

9) Biology – *Multiple Choice* Which of the following reagents is NOT required to perform a polymerase chain reaction?

W) Polymerase

X) Restriction enzymes

Y) Nucleotides

Z) Primers

ANSWER: X) RESTRICTION ENZYMES

BONUS

9) Biology – *Multiple Choice* Which of the following can directly generate a heart murmur?

W) Irregular heart rhythm

X) Incomplete contraction of the atria

Y) Incomplete contraction of the ventricles

Z) Blood traveling the wrong direction through a valve

ANSWER: Z) BLOOD TRAVELING THE WRONG DIRECTION THROUGH A VALVE

TOSS-UP

10) Chemistry – *Short Answer* When sodium chloride is dissolved in water, each ion is surrounded by a cluster of water molecules called what?

ANSWER: SOLVATION SHELL (ACCEPT: HYDRATION SPHERE)

BONUS

10) Chemistry – *Multiple Choice* Which of the following best describes the difference between the Leclanche cell and the commercial alkaline battery?

W) They perform different chemical reactions

X) They have different electrolytes

Y) The alkaline battery has a carbon anode, while the Leclanche cell does not

Z) The alkaline battery has a carbon cathode, while the Leclanche cell does not

ANSWER: X) THEY HAVE DIFFERENT ELECTROLYTES

TOSS-UP

11) Earth and Space – *Short Answer* What type of tide has a single high and a single low during a 24-hour period?

ANSWER: DIURNAL

BONUS

11) Earth and Space – *Multiple Choice* In which of the following locations would you expect to find lava with the lowest silica content?

W) The volcanic zones of Iceland

X) Mount Fuji

Y) Mount Saint Helens

Z) Andean volcanic belt

ANSWER: W) THE VOLCANIC ZONES OF ICELAND

TOSS-UP

12) Energy – *Short Answer* Scientists at Savannah River National Lab are working to create a viable fuel cycle for deuterium-tritium fusion. Deuterium and tritium differ only in their number of what subatomic particle?

ANSWER: NEUTRONS

BONUS

12) Energy – *Multiple Choice* In new research at Princeton Plasma Physics Laboratory, scientists have coated the interiors of fusion reactors with boron to prevent contaminants from entering the reaction chamber. In nuclear fission reactors, boron is also used in what component?

W) Coolant

X) Control rods

Y) Neutron source

Z) Electrical conductor

ANSWER: X) CONTROL RODS

TOSS-UP

13) Math – *Short Answer* A 20-by-30 rectangular wall is tiled with 600 unit-square tiles. If the topmost row and the leftmost column are removed, how many of the original tiles remain?

ANSWER: 551

BONUS

13) Math – *Short Answer* A rhombus has diagonals of lengths 14 and 18. To the nearest integer, what is its perimeter?

ANSWER: 46

TOSS-UP

14) Physics – *Short Answer* What theory unified special relativity with gravity?

ANSWER: GENERAL RELATIVITY

BONUS

14) Physics – *Multiple Choice* Which of the following quantities is defined as the rate of change of angular momentum?

W) Translational momentum

X) Kinetic energy

Y) Rotational energy

Z) Torque

ANSWER: Z) TORQUE

TOSS-UP

15) Biology – *Multiple Choice* What genes in *Drosophila* control pattern formation in the larva?

W) Maternal effect genes

X) TATA boxes

Y) Homeotic genes

Z) TLR genes

ANSWER: Y) HOMEOTIC GENES

BONUS

15) Biology – *Multiple Choice* Which of the following plants is most distantly-related to the tomato?

W) Potato

X) Apple

Y) Corn

Z) Mustard

ANSWER: Y) CORN

TOSS-UP

16) Chemistry – *Multiple Choice* Cathode rays are most similar to what type of radiation?

W) Alpha

X) Beta

Y) Gamma

Z) Neutrino

ANSWER: X) BETA

BONUS

16) Chemistry – *Short Answer* Rank the following three elements in order of increasing first ionization energy: 1) Phosphorus; 2) Sulfur; 3) Chlorine.

ANSWER: 1, 2, 3

TOSS-UP

17) Earth and Space – *Multiple Choice* Which of the following minerals is an industrial ore of lead and can be identified by its relative softness and three directions of cleavage?

- W) Bournite
- X) Graphite
- Y) Sphalerite
- Z) Galena

ANSWER: Z) GALENA

BONUS

17) Earth and Space – *Short Answer* Identify all of the following three locations where extratropical cyclones form: 1) Within air masses; 2) Between air masses; 3) At the polar front.

ANSWER: 2, 3

TOSS-UP

18) Energy – *Short Answer* Scientists supported by the Department of Energy are studying lipid synthesis in algae. Specifically, they are studying how algae make what most-common class of lipid found in plants?

ANSWER: TRIGLYCERIDES (ACCEPT: TRIACYLGLYCEROLS)

BONUS

18) Energy – *Short Answer* Ames Lab researchers are creating permanent magnets that have lower cost and higher performance compared to current technologies. Place the following three types of commercial magnets in order of increasing strength as assessed by their typical maximum energy product: 1) Alnico; 2) Ceramic; 3) Neodymium.

ANSWER: 2, 1, 3