

## TOSS-UP

1) Physics – *Short Answer* A block of unknown mass accelerates at 8 meters per second when a 56-newton force is applied to it. In kilograms, what is the mass of the block?

ANSWER: 7

## BONUS

1) Physics – *Short Answer* Gravitational potential energy is directly proportional to the distance between two gravitationally-bound bodies raised to what power?

ANSWER: NEGATIVE ONE

## TOSS-UP

2) Biology – *Multiple Choice* Which of the following statements does NOT correctly describe the adaptive immune system?

- W) T cells finish maturation in the bone marrow
- X) B cells generate antibodies through VDJ recombination
- Y) T cells recognize and destroy infected cells
- Z) Maternal antibodies can cross the placenta

ANSWER: W) T CELLS FINISH MATURATION IN THE BONE MARROW

## BONUS

2) Biology – *Multiple Choice* Eudicots are more closely related to monocots than which of the following dicot plants?

- W) Magnolia
- X) Maple
- Y) Rose
- Z) Apple

ANSWER: W) MAGNOLIA

### TOSS-UP

3) Chemistry – *Multiple Choice* Which of the following types of polymers is made via SN2?

W) Polyether

X) Polyamide

Y) PVC

Z) Paraformaldehyde

ANSWER: W) POLYETHER

### BONUS

3) Chemistry – *Short Answer* Rank the following three cubic lattices in order of increasing nearest-neighbor distance: 1) FCC; 2) BCC; 3) Simple cubic.

ANSWER: 1, 2, 3

## TOSS-UP

4) Earth and Space – *Short Answer* What river has the largest drainage basin in the United States?

ANSWER: MISSISSIPPI

## BONUS

4) Earth and Space – *Multiple Choice* Which of the following statements about surface seawater salinity is true?

- W) Salinity is highest at the equator and lowest in the subtropics
- X) Salinity is highest in the subtropics and lowest at high latitudes
- Y) Salinity is highest at the poles and lowest in the subtropics
- Z) Salinity is uniform

ANSWER: X) SALINITY IS HIGHEST IN THE SUBTROPICS AND LOWEST AT HIGH LATITUDES

## TOSS-UP

5) Energy – *Multiple Choice* Scientists at SLAC are studying a model of cosmological inflation. Which of the following problems in physics can be directly addressed by inflationary theory?

- W) Flatness problem
- X) Matter-antimatter asymmetry
- Y) Nature of dark matter
- Z) Quark confinement

ANSWER: W) FLATNESS PROBLEM

## BONUS

5) Energy – *Short Answer* Scientists at Fermilab are studying neutrinos from SN1987A, which occurred 170,000 lightyears from Earth. To one significant figure and in scientific notation, how many seconds does it take for neutrinos from SN1987A to reach Earth?

ANSWER:  $5 \times 10^{12}$

### TOSS-UP

6) Math – *Short Answer* What is the amplitude of the graph of  $y \equiv$  the second derivative of cosine of  $3x$ ?

ANSWER: 9

### BONUS

6) Math – *Short Answer* A set of 14 points has 3 that are collinear and another 4 that are collinear. Otherwise, no three points in the set are collinear. How many lines contain at least two of the 14 points?

ANSWER: 84

## TOSS-UP

7) Physics – *Multiple Choice* Which of the following effects is primarily responsible for separating the colors in a rainbow?

- W) Refraction
- X) Interference
- Y) Dispersion
- Z) Diffraction

ANSWER: Y) DISPERSION

## BONUS

7) Physics – *Short Answer* Identify all of the following three orbital eccentricities for which Kepler's second law holds: 1) 0; 2) 0.5; 3) 1.5.

ANSWER: ALL

### TOSS-UP

8) Biology – *Short Answer* Bacterial cell walls contain what polymer composed of sugars cross-linked by polypeptides?

ANSWER: PEPTIDOGLYCAN (ACCEPT: MUREIN)

### BONUS

8) Biology – *Multiple Choice* Which of the following combinations of nutrients results in the greatest increase of ocean primary production?

- W) Nitrogen, phosphorus, iron
- X) Nitrogen, molybdenum, magnesium
- Y) Nitrogen, iron, magnesium
- Z) Phosphorus, magnesium, molybdenum

ANSWER: W) NITROGEN, PHOSPHORUS, IRON

### TOSS-UP

9) Chemistry – *Short Answer* What is the term for the ions that appear on both sides of an equation during a precipitation reaction?

ANSWER: SPECTATOR IONS

### BONUS

9) Chemistry – *Multiple Choice* Which of the following halides is the best leaving group in an  $S_N2$  reaction?

W) Fluoride

X) Chloride

Y) Bromide

Z) Iodide

ANSWER: Z) IODIDE

### **TOSS-UP**

10) Earth and Space – *Short Answer* In the Archaean Eon, the Sun was about 25 percent less luminous, and Earth's day about 50 percent as long as it is today. All other things being equal, the radiative flux at any one point on Earth during this time would be what percent of the modern radiative flux?

ANSWER: 75

### **BONUS**

10) Earth and Space – *Short Answer* Identify all of the following three orbital properties that are equal at Earth's perihelion and aphelion: 1) Velocity; 2) Kinetic energy; 3) Angular momentum.

ANSWER: 3

### TOSS-UP

11) Energy – *Short Answer* Scientists at Pacific Northwest National Lab have developed a method to convert captured carbon dioxide into the lightest hydrocarbon. What is the preferred IUPAC name of this hydrocarbon?

ANSWER: METHANE

### BONUS

11) Energy – *Short Answer* Researchers at Los Alamos National Lab are studying how to convert sugars to fuels. Giving your answer as a preferred IUPAC name, what four-carbon alkane is produced by one of the sets of reactions they are studying?

ANSWER: BUTANE

### **TOSS-UP**

12) Math – *Short Answer* What is the altitude of an equilateral triangle with sides of length 42?

ANSWER: 26

### **BONUS**

12) Math – *Short Answer* Express as a fraction the repeating decimal 0.3181818, with repeating part one-eight.

ANSWER:  $7/22$

## TOSS-UP

13) Physics – *Multiple Choice* Which of the following is approximately true for an ideal pendulum at small angles, but not at large angles?

- W) Frequency is independent of amplitude
- X) Energy is conserved
- Y) Frequency is independent of mass
- Z) Momentum is conserved

ANSWER: W) FREQUENCY IS INDEPENDENT OF AMPLITUDE

## BONUS

13) Physics – *Short Answer* On Earth, Mera weighs 27 pounds. On a newly-discovered planet, she weighs 6 pounds. To two significant figures, and in meters per second squared, what is the acceleration due to gravity on this planet?

ANSWER: 2.2

## TOSS-UP

14) Biology – *Multiple Choice* Which of the following segments of an mRNA molecule is not translated into protein?

W) Start codon

X) Exon

Y) Coding segment

Z) Stop codon

ANSWER: Z) STOP CODON

## BONUS

14) Biology – *Short Answer* what mammalian order are dogs a part of?

ANSWER: CARNIVORA (ACCEPT: CARNIVORANS; DO NOT ACCEPT: CARNIVORES)

## TOSS-UP

15) Chemistry – *Multiple Choice* J.J. Thomson invented a prototype mass spectrometer that enabled him to measure what property of the electron?

W) Mass

X) Spin

Y) Mass-to-charge ratio

Z) Excited state lifetime

ANSWER: Y) MASS-TO-CHARGE RATIO

## BONUS

15) Chemistry – *Short Answer* Rank the following three elements in order of increasing electronegativity: 1) Scandium; 2) Calcium; 3) Potassium.

ANSWER: 3, 2, 1

## TOSS-UP

16) Earth and Space – *Short Answer* What planet in our solar system has the shortest rotational period?

ANSWER: JUPITER

## BONUS

16) Earth and Space – *Multiple Choice* Which of the following stars is the bluest?

W) Arcturus

X) Sirius

Y) Rigel

Z) Barnard's Star

ANSWER: Y) RIGEL

## TOSS-UP

17) Energy – *Multiple Choice* Scientists at Lawrence Berkeley National Lab are studying metallic protoplanets. Which of the following objects is the largest M-type asteroid and was once thought to be the core of a protoplanet?

- W) Ceres
- X) Psyche
- Y) Pallas
- Z) Vesta

ANSWER: X) PSYCHE

## BONUS

17) Energy – *Short Answer* Scientists at Thomas Jefferson National Accelerator Facility are studying particles that contain heavy quarks. Rank the following three quark flavors in order of increasing mass: 1) Up; 2) Bottom; 3) Strange.

ANSWER: 1, 3, 2

### **TOSS-UP**

18) Math – *Short Answer* How many four-digit numbers have exactly the same digits as 2020?

ANSWER: 3

### **BONUS**

18) Math – *Short Answer* A jar contains 8 blue marbles and 8 red marbles. Five marbles are drawn without replacement. What is the probability that the 5 marbles drawn are NOT all the same color?

ANSWER: 38/39