

TOSS-UP

1) Earth and Space – *Multiple Choice* The Sun's temperature is highest at its core and decreases with increasing distance from the core until its temperature reaches a minimum and increases throughout the Sun's atmosphere. Which of the following layers of the Sun is closest to where this minimum occurs?

- W) Convective zone
- X) Chromosphere
- Y) Transition zone
- Z) Corona

ANSWER: X) CHROMOSPHERE

BONUS

1) Earth and Space – *Short Answer* Place the following three photon emissions from hydrogen in order of increasing wavelength: 1) Electron transition from $n = 3$ to $n = 2$; 2) Electronic spin transition from parallel to antiparallel relative to protium nucleus; 3) Electronic transition from $n = 2$ to $n = 1$.

ANSWER: 3, 1, 2

TOSS-UP

2) Energy – *Short Answer* Scientists at Argonne National Lab are studying a quasiparticle that is the collective excitation of electron spin in a lattice. What is the term for this quasiparticle?

ANSWER: MAGNON

BONUS

2) Energy – *Short Answer* Scientists at Lawrence Berkeley National Lab recently reported a study of methanol emission by leaves during different stages of the leaf life cycle. They performed a statistical test to determine if the population means of young, mature, and old leaves were equal using the law of total variance. This test is a part of what family of hypothesis tests?

ANSWER: ANOVA (ACCEPT: ANALYSIS OF VARIANCE)

TOSS-UP

3) Math – *Short Answer* What is the least common multiple of 21 and 33?

ANSWER: 231

BONUS

3) Math – *Short Answer* In a right triangle, the altitude to the hypotenuse divides the hypotenuse into segments of lengths 12 and 13. What is the length of the longer leg?

ANSWER: $5\sqrt{13}$

TOSS-UP

4) Physics – *Short Answer* The Milky Way has a diameter of 10^5 light years. In seconds to one significant figure, what is the proper time measured by a photon that travels along a diameter of the Milky Way?

ANSWER: 0

BONUS

4) Physics – *Short Answer* A 9-meter steel beam of mass 4000 kilograms and non-uniform density is held up by a force of 23,520 newtons on its left end, and a force of 15,680 newtons on its right end. If the beam is in static equilibrium, then, in meters, how far from the left end of the beam is its center of mass?

ANSWER: $18/5$ (ACCEPT: $3 \frac{3}{5}$, 3.6)

TOSS-UP

5) Biology – *Short Answer* What is the term for the transfer of genetic material from one genome to another via plasmids, transposable elements, or viral infection?

ANSWER: HORIZONTAL GENE TRANSFER (ACCEPT: LATERAL GENE TRANSFER)

BONUS

5) Biology – *Short Answer* Place the following four events in chronological order in the sequence of a skeletal muscle contraction:
1) Troponin undergoes a conformational change; 2) T-tubules depolarize; 3) Calcium is released from the sarcoplasmic reticulum; 4) Acetylcholine is released into the synaptic cleft.

ANSWER: 4, 2, 3, 1

TOSS-UP

- 6) Chemistry – *Multiple Choice* When plotting the temperature dependence of volume for a sample of an ideal gas on a graph, the slope of the line is most dependent on what aspect of the sample?
- W) Molecular weight
 - X) Amount of gas
 - Y) Density
 - Z) The deviation from ideality

ANSWER: X) AMOUNT OF GAS

BONUS

- 6) Chemistry – *Short Answer* Consider a particle in a three-dimensional box. How many degenerate states are there for the third excited state?

ANSWER: 3

TOSS-UP

7) Earth and Space – *Multiple Choice* The northern and southern polar ice caps on Mars have a distinct carved spiral shape. Which of the following is thought to cause this shape?

W) Wind patterns

X) Ancient ocean currents

Y) Meteor impacts

Z) Tectonic forces

ANSWER: W) WIND PATTERNS

BONUS

7) Earth and Space – *Short Answer* Place the following three geologic environments in order of increasing geothermal gradient: 1) Stable continent; 2) Accretionary prism; 3) Collisional mountain belt.

ANSWER: 2, 1, 3

TOSS-UP

8) Energy – *Short Answer* Scientists supported by the Department of Energy are studying dark energy. Dark energy is thought to be related to what term in Einstein’s field equations?

ANSWER: COSMOLOGICAL CONSTANT (ACCEPT: LAMBDA)

BONUS

8) Energy – *Multiple Choice* Scientists supported by the Department of Energy are studying hexokinase, a well-known “housekeeping” enzyme. In this context, what does “housekeeping” mean?

- W) Its expression is relatively constant across many contexts
- X) It performs a process required for the cell to live
- Y) It plays a role in DNA synthesis
- Z) It prepares basic biochemical building blocks

ANSWER: W) ITS EXPRESSION IS RELATIVELY CONSTANT ACROSS MANY CONTEXTS

TOSS-UP

9) Math – *Short Answer* What is the derivative with respect to x of arctangent x at $x = 6$?

ANSWER: $1/37$

BONUS

9) Math – *Short Answer* According to the rational root theorem, how many different numbers are possible rational roots of the equation $8x^5 - 5x^4 + 3x^2 - 12 = 0$?

ANSWER: 24

TOSS-UP

10) Physics – *Multiple Choice* Which of the following is not equivalent to the second law of thermodynamics?

W) Heat cannot flow spontaneously from a colder object to a hotter object

X) No heat engine can have an efficiency exceeding that of the Carnot engine

Y) No thermodynamic process can decrease the entropy of the universe

Z) It is impossible for a thermodynamic system to return to the same state twice

ANSWER: Z) IT IS IMPOSSIBLE FOR A THERMODYNAMIC SYSTEM TO RETURN TO THE SAME STATE TWICE

BONUS

10) Physics – *Short Answer* Jack is pacing around a room at a constant speed. The x -component in meters of his motion as a function of time t in seconds can be described as $x = 5 \sin(\text{open parenthesis } 3t \text{ close parenthesis})$. In meters per second, what is Jack's speed?

ANSWER: 15

TOSS-UP

11) Biology – *Multiple Choice* Raspberry is an aggregate fruit, meaning that it develops from which of the following?

- W) A flower without carpels
- X) A single carpel of one flower
- Y) Many carpels of one flower
- Z) Many carpels of many flowers

ANSWER: Y) MANY CARPELS OF ONE FLOWER

BONUS

11) Biology – *Short Answer* Identify all of the following three organisms that follow the haplo-diploid system of sex determination:

- 1) Crows; 2) Ants; 3) Bees.

ANSWER: 2, 3

TOSS-UP

12) Chemistry – *Multiple Choice* Which of the following best describes the bonding of the highest occupied molecular orbital set of a neutral dioxygen molecule?

- W) Sigma-bonding
- X) Sigma-antibonding
- Y) Pi-bonding
- Z) Pi-antibonding

ANSWER: Z) PI-ANTIBONDING

BONUS

12) Chemistry – *Multiple Choice* What type of orbital is the LUMO in ground state ethylene?

- W) Sigma
- X) Sigma star
- Y) Pi
- Z) Pi star

ANSWER: Z) PI STAR

TOSS-UP

13) Earth and Space – *Short Answer* A satellite is in a circular orbit around the Earth with kinetic energy K . As a multiple of K , what is the satellite's total mechanical energy?

ANSWER: NEGATIVE K

BONUS

13) Earth and Space – *Short Answer* Carbon deflagration occurs when carbon burning commences on what type of celestial object?

ANSWER: WHITE DWARF

TOSS-UP

14) Energy – *Short Answer* Scientists supported by the Department of Energy are studying pions. These particles carry what fundamental force in the nucleus?

ANSWER: STRONG

BONUS

14) Energy – *Short Answer* Scientists at Argonne National Lab are studying platinum. Most platinum (II) tetracoordinate complexes have what geometry?

ANSWER: SQUARE PLANAR

TOSS-UP

15) Math – *Short Answer* What compass direction is the result of a 90-degree clockwise turn from north-northwest?

ANSWER: EAST-NORTHEAST (ACCEPT: E-N-E)

BONUS

15) Math – *Short Answer* What is the integral from 0 to 1 of e to the x times, open parenthesis $x^2 + 3x + 5$ close parenthesis, dx ?

ANSWER: $6e - 4$

TOSS-UP

16) Physics – *Multiple Choice* Which of the following statements is true of the Hamiltonian for a point particle in a gravitational field in three dimensions?

- W) It is equal to kinetic energy minus potential energy
- X) It is a function of three variables
- Y) It depends on both position and momentum
- Z) Its time integral is the action

ANSWER: Y) IT DEPENDS ON BOTH POSITION AND MOMENTUM

BONUS

16) Physics – *Short Answer* Identify all of the following three types of fields that can impart a non-zero net force onto a stationary electrical dipole, assuming that the fields do not change with time: 1) Uniform electric field; 2) Non-uniform electric field; 3) Uniform magnetic field.

ANSWER: 2

TOSS-UP

17) Biology – *Multiple Choice* What is the term for the phenomenon by which antibodies binding to antigens on the surface of a bacterium promotes phagocytosis of that bacterium?

- W) Neutralization
- X) Activation of the MAC
- Y) Opsonization
- Z) Complementation

ANSWER: Y) OPSONIZATION

BONUS

17) Biology – *Multiple Choice* Which of the following statements does NOT accurately describe allosteric regulation of enzyme activity?

- W) An allosteric regulator binds covalently at an enzyme's catalytic site
- X) Allosteric regulation can increase or decrease protein activity
- Y) Binding of an allosteric regulator induces a conformational change in a protein
- Z) The binding of hemoglobin to oxygen is an example of positive allosteric regulation

ANSWER: W) AN ALLOSTERIC REGULATOR BINDS COVALENTLY AT AN ENZYME'S CATALYTIC SITE

TOSS-UP

18) Chemistry – *Short Answer* According to the Rydberg equation, the energy of the ground state in a one-electron atom is linearly related to the number of protons in the atom raised to what power?

ANSWER: TWO

BONUS

18) Chemistry – *Short Answer* For a single molecule of butane, rank the following three rotational conformations in order of increasing energy: 1) Gauche; 2) Anti; 3) Eclipsed.

ANSWER: 2, 1, 3