

High School  
Set 10

TOSS-UP

1) Physics – *Short Answer* An arch supported only by its own strength will be strongest if the shape of the arch follows what mathematical curve?

ANSWER: CATENARY (ACCEPT: INVERTED CATENARY, HYPERBOLIC COSINE; do not accept: PARABOLA)

BONUS

1) Physics – *Short Answer* A theoretical circuit has an infinite number of resistors placed in parallel. The first resistor has a resistance of one ohm, and each following resistor has twice the resistance of the previous one. In ohms, what is the total resistance across the circuit?

ANSWER: 1/2 (ACCEPT: 0.5)

## TOSS-UP

2) Biology – *Short Answer* In brown fat, thermogenin [*thermo-JEN-in*] uncouples the mitochondrial proton gradient from the action of what enzyme?

ANSWER: ATP SYNTHASE

## BONUS

2) Biology – *Short Answer* T cells undergo a process of central tolerance in order to prevent autoimmunity. In what organ does this process occur?

ANSWER: THYMUS

## TOSS-UP

3) Chemistry – *Multiple Choice* Which of the following pairs would have the most exothermic reaction?

- W) Rubidium [*roo-BID-ee-um*] and chlorine
- X) Potassium and chlorine
- Y) Potassium and bromine
- Z) Rubidium and iodine

ANSWER: W) RUBIDIUM AND CHLORINE

## BONUS

3) Chemistry – *Multiple Choice* What color can hexa-aqua-iron (III) appear to be in aqueous solution?

- W) Pink
- X) Green
- Y) Yellow
- Z) Blue

ANSWER: Y) YELLOW

## TOSS-UP

4) Earth and Space – *Multiple Choice* When Karl Jansky noticed a source of radio interference appearing from all directions in the sky, he measured the daily peak strength of the interference. Which of the following best describes how this peak changed each day?

- W) It was one hour earlier each day
- X) It was 4 minutes earlier each day
- Y) It was 4 seconds earlier each day
- Z) It was at the same time each day

ANSWER: X) IT WAS 4 MINUTES EARLIER EACH DAY

## BONUS

4) Earth and Space – *Short Answer* Identify all of the following three types of fusion that are sustainable in a brown dwarf with 75 times the mass of Jupiter: 1) Protium;  
2) Deuterium [*doo-TEER-ee-um*]; 3) Lithium.

ANSWER: 2, 3

## TOSS-UP

5) Energy – *Multiple Choice* Scientists at SLAC National Accelerator Lab are shooting femtosecond electron pulses at samples and measuring their diffraction signals with time resolution. Which of the following phenomena is best probed by this type of experiment?

- W) Protein crystal structures
- X) Nuclear spin environments in molecules
- Y) Chemical kinetics
- Z) Extent of charge-parity asymmetry

ANSWER: Y) CHEMICAL KINETICS

## BONUS

5) Energy – *Short Answer* Scientists supported by the Department of Energy are studying the human pathogen *Pseudomonas aeruginosa* [*soo-doh-MOH-nus air-roo-jin-OH-sah*]. Identify all of the following three statements that are true of this bacterium: 1) It is Gram-negative; 2) It is rod-shaped; 3) It typically infects the immunocompromised.

ANSWER: ALL

## TOSS-UP

6) Math – *Short Answer* What is the absolute value of the product of the two complex numbers  $1 + 3i$  and  $2 - i$ ?

ANSWER:  $5\sqrt{2}$

## BONUS

6) Math – *Short Answer* What are the coordinates of the image of the point  $(-7, 6)$  when it is rotated about the point  $(1, -4)$  by 90 degrees clockwise?

ANSWER:  $(11, 4)$  (ACCEPT:  $x = 11$  AND  $y = 4$ )

## TOSS-UP

7) Physics – *Short Answer* A charge of 2 coulombs is placed at the origin, and a second charge is placed on the  $x$ -axis at  $x = -3$ . In coulombs, for what value of the second charge is there to be no net force on a test charge placed on the  $x$ -axis at  $x = 1$ ?

ANSWER:  $-32$

## BONUS

7) Physics – *Short Answer* Identify all of the following three quantities that, according to the Einstein field equations, affect the curvature of spacetime in a given place and time: 1) Energy density; 2) Momentum density; 3) Mass density.

ANSWER: ALL

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## TOSS-UP

8) Biology – *Short Answer* During mitosis, spindle fibers attach to what protein structures located on the centromeres [*SEN-troh-meers*] of chromosomes?

ANSWER: KINETOCHORES

## BONUS

8) Biology – *Multiple Choice* Which of the following statements about vertebrates is false?

- W) All reptiles are tetrapods
- X) All gnathostomes [*NAY-tho-stohmes*] are vertebrates
- Y) All tetrapods are amniotes
- Z) All vertebrates are chordates [*KOR-dates*]

ANSWER: Y) ALL TETRAPODS ARE AMNIOTES



## TOSS-UP

9) Chemistry – *Short Answer* When oxygen is photolyzed, it breaks into two oxygen atoms with unpaired electrons. What is the term for this type of species?

ANSWER: FREE RADICAL (ACCEPT: RADICAL)

## BONUS

9) Chemistry – *Short Answer* What is the IUPAC [*EYE-you-pack*] name of the major organic product of the reaction of propene with hydrogen gas in the presence of Raney nickel?

ANSWER: PROPANE

## TOSS-UP

10) Earth and Space – *Multiple Choice* Marine sediment in the North Atlantic is primarily calcareous [*kal-CARE-ee-us*] ooze, while marine sediment in the North Pacific is primarily pelagic [*peh-LAJ-ik*] clay. Which of the following best explains why?

- W) The North Pacific has a higher pH than the North Atlantic
- X) The North Pacific is deeper than the North Atlantic
- Y) The North Pacific has a lower pH than the North Atlantic
- Z) The North Pacific has more dissolved oxygen than the North Atlantic

ANSWER: Y) THE NORTH PACIFIC HAS A LOWER pH THAN THE NORTH ATLANTIC

## BONUS

10) Earth and Space – *Short Answer* Identify all of the following three statements about the fossil record that are true: 1) The earliest evidence of multi-cellular life is in the Paleozoic; 2) Shelly fossils first appeared in the Mesozoic; 3) Most trilobites [*TRY-low-bites*] went extinct near the end of the Cambrian.

ANSWER: 3

## TOSS-UP

11) Energy – *Short Answer* Scientists at Brookhaven National Lab are studying the protein that gives coronaviruses the shape they were named for and are their interface with host cells. What is the name for this protein?

ANSWER: SPIKE PROTEIN (ACCEPT: CORONAVIRUS SPIKE PROTEIN, S PROTEIN)

## BONUS

11) Energy – *Short Answer* Scientists at Argonne National Lab are studying the structure of antibodies. Identify all of the following three antibodies that are typically monomeric: 1) IgG; 2) IgM; 3) IgE.

ANSWER: 1, 3



## TOSS-UP

12) Math – *Short Answer* What is  $f'$  prime of 2 for the function  $f$  of  $x = x^3$  times  $e$  to the  $x$ ?

ANSWER:  $20e^2$

## BONUS

12) Math – *Short Answer* What is the cross product of vectors  $\mathbf{i} + 3\mathbf{j} - 2\mathbf{k}$  and  $\mathbf{i} + 2\mathbf{j}$ ?

ANSWER:  $4\mathbf{i} - 2\mathbf{j} - \mathbf{k}$

## TOSS-UP

13) Physics – *Short Answer* The de Broglie **[da-BROY]** wavelength of an object is equal to Planck's constant divided by what property of the object?

ANSWER: MOMENTUM (ACCEPT: RELATIVISTIC MOMENTUM, LINEAR MOMENTUM)

## BONUS

13) Physics – *Multiple Choice* A positively-charged particle is moving in the vicinity of a long current-carrying wire. For which of the following directions of the initial velocity will the particle be repelled from the wire?

- W) Directly towards the wire
- X) Directly away from the wire
- Y) In the same direction as the current
- Z) Opposite the direction of the current

ANSWER: Z) OPPOSITE THE DIRECTION OF THE CURRENT

## TOSS-UP

14) Biology – *Short Answer* What pigmented compound is the result of hemoglobin degradation and is often found to be elevated in individuals with hepatitis?

ANSWER: BILIRUBIN (ACCEPT: INDIRECT BILIRUBIN, UNCONJUGATED BILIRUBIN)

## BONUS

14) Biology – *Multiple Choice* Which of the following chromatographic methods is likely to be the most effective for isolating large protein aggregates from smaller protein complexes?

- W) Strong cation exchange chromatography
- X) Anion exchange chromatography
- Y) Reverse phase chromatography
- Z) Gel filtration chromatography

ANSWER: Z) GEL FILTRATION CHROMATOGRAPHY

## TOSS-UP

15) Chemistry – *Multiple Choice* Which of the following catalysts is typically used for hydrogenating unsaturated oils?

- W) Iron
- X) Vanadium [*vah-NAY-dee-um*] oxide
- Y) Copper
- Z) Nickel

ANSWER: Z) NICKEL

## BONUS

15) Chemistry – *Short Answer* Consider the compound cis [*sis*]-1-chloro-3-tert-butylcyclohexane [*BYOO-til cyclo-HEX-ane*]. Identify all of the following three statements that are TRUE of the most stable chair conformation: 1) Chlorine is axial; 2) Tert-butyl is equatorial; 3) All carbon-carbon bonds sit in a single plane.

ANSWER: 2

## TOSS-UP

16) Earth and Space – *Multiple Choice* Which of the following most directly determines whether a rock will develop foliation during metamorphism?

- W) Temperature regime
- X) Grain size of primary mineral assemblage
- Y) Water content
- Z) Presence of differential pressure

ANSWER: Z) PRESENCE OF DIFFERENTIAL PRESSURE

## BONUS

16) Earth and Space – *Multiple Choice* Which of the following would lead to the formation of an emergent coast?

- W) Sea ice formation
- X) Continental ice sheet formation
- Y) Intense storm activity
- Z) Increased continental weathering

ANSWER: X) CONTINENTAL ICE SHEET FORMATION



## TOSS-UP

17) Energy – *Short Answer* Scientists at Pacific Northwest National Lab are studying antibiotic resistance in the bacterial genus *Mycobacterium*. One strain of *Mycobacterium* causes a disease in humans in which it replicates within nerve cells or macrophages, eventually causing the loss of the extremities in which it replicates. What is the name of this disease?

ANSWER: LEPROSY (ACCEPT: HANSEN'S DISEASE)

## BONUS

17) Energy – *Multiple Choice* Scientists at Pacific Northwest National Lab are developing sodium-ion batteries. Which of the following best explains why graphite is not used as the anode in these batteries?

- W) Graphite is used as the cathode
- X) Graphite is dissolved by the electrolytes used in these batteries
- Y) Graphite has significant reactivity to sodium ions
- Z) Graphite cannot store appreciable amounts of sodium ions

ANSWER: Z) GRAPHITE CANNOT STORE APPRECIABLE AMOUNTS OF SODIUM IONS

## TOSS-UP

18) Math – *Short Answer* In a triple-elimination tournament, each game is played by two teams, there are no ties, and teams are eliminated when they have lost 3 times. What is the maximum number of games played if 53 teams enter?

ANSWER: 158

## BONUS

18) Math – *Short Answer* In base 8, what is five-six times two-seven?

ANSWER: TWO-ZERO-FOUR-TWO (ACCEPT: 2042)