NNHS ROUND 15

TOSS-UP

1) Physics – *Short Answer* Identify all of the following four thermodynamic cycles that contain an adiabatic step: 1) Otto; 2) Carnot; 3) Stirling; 4) Diesel.

ANSWER: 1, 2, 4

BONUS

1) Physics – *Short Answer* Order the following three events by chronological order in the early universe: 1) Beginning of nucleosynthesis; 2) Photon decoupling; 3) Neutrino decoupling.

ANSWER: 3, 1, 2

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TOSS-UP

2) Biology – *Multiple Choice* In which of the following regions of the adrenal cortex is aldosterone synthesized and secreted?

W) Zona glomerulosa
X) Zona fasciculata
Y) Zona reticularis
Z) Zona pellucida

ANSWER: W) ZONA GLOMERULOSA

BONUS

2) Biology – *Short Answer* What hormone converts androgens to estrogens?

ANSWER: AROMATASE
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TOSS-UP

3) Earth and Space – *Multiple Choice* Which of the following terms refers to warm, dry winds that form when air descends on the leeward side of the Rockies?

W) Monsoon
X) Chinooks
Y) Santa Ana winds
Z) Trade winds

ANSWER: X) CHINOOKS

BONUS

3) Earth and Space – *Short Answer* Which astronomer first proposed a namesake number that equaled the number of protons in the universe, and then related this number to the fine structure constant?

ANSWER: ARTHUR EDDINGTON (ACCEPT: EDDINGTON)

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TOSS-UP

4) Math – *Multiple Choice* A square has two vertices at (0,0) and (4, 0). Which of the following could NOT be the x-coordinate of one of the other two vertices?

W) 0
X) $2\sqrt{2}$
Y) $2\sqrt{3}$
Z) 4

ANSWER: Y) $2\sqrt{3}$

BONUS

4) Math – *Short Answer* If r and s are the distinct roots of the polynomial $x^2 - 42x + 217$, then what value of x satisfies the equation 1 divided by the quantity x – r plus 1 divided by the quantity x – s equals 0?

ANSWER: 21
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TOSS-UP

5) Chemistry – *Multiple Choice* When an electron in hydrogen undergoes a spin-flip, it produces the hydrogen line. Which of the following is closest to the wavelength of this light?

W) 2 meters
X) 20 centimeters
Y) 2 centimeters
Z) 200 nanometers

ANSWER: X) 20 CENTIMETERS

BONUS

5) Chemistry – *Short Answer* Identify all of the following three statements that are true about ultraviolet-visible spectroscopy: 1) When a carbon carbon double bond absorbs energy, it undergoes a π to π^* transition; 2) When a carbonyl group absorbs energy, it undergoes a π to π^* transition; 3) Conjugated double bonding increases the energy separation between bonding and antibonding orbitals.

ANSWER: 1 ONLY

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TOSS-UP

6) Energy – *Short Answer* Researchers at Ames National Lab are studying how to make catalysis more precise, reducing waste and energy consumption. The researchers used what type of material, which consists of organic-inorganic links that form a "cage"?

ANSWER: METAL-ORGANIC FRAMEWORK (ACCEPT: MOF)

BONUS

6) Energy – *Short Answer* Researchers at Ames National Lab are studying the accumulation and recycling of plastic waste by looking at how to break down long polymers into smaller pieces, which can be used to create new plastics. What term describes prepolymers that are capable of entering further polymerization through their reactive end groups?

ANSWER: TELECHELIC
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TOSS-UP

7) Physics – *Multiple Choice* Which of the following is NOT an advantage of using a MOSFET transistor over a BJT?

W) Cheaper production costs
X) Faster switching speeds
Y) Increased signal amplification capability
Z) Less input current required

ANSWER: Y) INCREASED SIGNAL AMPLIFICATION CAPABILITY

BONUS

7) Physics – *Short Answer* What equation, which is more accurate than the Cauchy equation, explains chromatic aberration by describing the wavelength dependence of a material's refractive index?

ANSWER: SELLMEIER EQUATION

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TOSS-UP

8) Biology – *Multiple Choice* A rat is put in a Skinner box and given continuous electric shocks until the rat presses down on a lever. Eventually, the rat learns to press down on the lever to remove the electric shocks. Which of the following types of operant conditioning is this considered?

X) Positive punishment
W) Negative punishment
Y) Positive reinforcement
Z) Negative reinforcement

ANSWER: Z) NEGATIVE REINFORCEMENT

BONUS

8) Biology – *Short Answer* Identify all of the following three taste receptors that are G-protein coupled receptors: 1) Sweet; 2) Sour; 3) Umami.

ANSWER: 1 AND 3
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TOSS-UP

9) Earth and Space – *Multiple Choice* The dry adiabatic lapse rate of an environment is 10° celsius per kilometer, and the wet adiabatic lapse rate is 5° celsius per kilometer. Which of the following values for the environmental lapse rate would cause conditional instability?

W) 1° celsius per kilometer
X) 4° celsius per kilometer
Y) 7° celsius per kilometer
Z) 11° celsius per kilometer

ANSWER: Y) 7° CELSIUS PER KILOMETER

BONUS

9) Earth and Space – *Short Answer* What effect is responsible for pressure broadening of spectral lines due to charged particles in plasmas?

ANSWER: STARK EFFECT (ACCEPT: STARK BROADENING)

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TOSS-UP

10) Math – *Short Answer* What is the difference between the square of the sum of the first three positive integers and the sum of the squares of the first three positive integers?

ANSWER: 8

BONUS

10) Math – *Short Answer* What base 10 fraction equals the base 3 repeating decimal $0.\underline{012}_3$ ***[0 point 0 1 2 repeating]***?

ANSWER: 5/26
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TOSS-UP

11) Chemistry – *Short Answer* What process converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons?

ANSWER: FISHER–TROPSCH PROCESS

BONUS

11) Chemistry – *Short Answer* What type of sandwich compound consists of two cyclopentadienyl ions bound to a metal center with a +2 oxidation state?

ANSWER: METALLOCENE

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TOSS-UP

12) Energy – *Short Answer* Researchers at Oak Ridge National Lab performed a computational study on lung fluid cells from COVID-19 patients using the Summit supercomputer. The Sars-Cov-2 virus infects cells by attaching to ACE-2 receptors on the cell surface. What is the substrate of ACE-2?

ANSWER: ANGIOTENSIN I (DO NOT ACCEPT: ANGIOTENSIN)

BONUS

12) Energy – *Multiple Choice* Researchers at Oak Ridge National Lab performed a computational study on lung fluid cells from COVID-19 patients using the Summit supercomputer. They found that the bradykinin system appeared to be hyperactive in many COVID-19 patients. Which of the following is an effect of bradykinin on the body?

W) Vasoconstriction
X) Vasodilation
Y) Proliferation of B cells
Z) Proliferation of T cells

ANSWER: X) VASODILATION
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TOSS-UP

13) Physics – *Short Answer* What dimensionless constant characterizes the strength of the electromagnetic interaction between charged particles?

ANSWER: FINE STRUCTURE CONSTANT

BONUS

13) Physics – *Short Answer* Esaki diodes have apparent regions of negative resistance within them that enable very simplistic and stable circuits. What effect causes these regions of negative resistance?

ANSWER: QUANTUM TUNNELING

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TOSS-UP

14) Biology – *Multiple Choice* Which of the following characteristics is shared by both charophytes and embryophytes?

W) Alternation of generations
X) Ring-shaped cellulose-synthesizing proteins
Y) Apical meristems
Z) Multicellular, dependent embryos

ANSWER: X) RING-SHAPED CELLULOSE-SYNTHESIZING PROTEINS

BONUS

14) Biology – *Short Answer* What term refers to the spots under a fern sporophyte's reproductive leaves?

ANSWER: SORI (ACCEPT: SORUS)
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TOSS-UP

15) Earth and Space – *Short Answer* The Crab Nebula is the remnant of what supernova?

ANSWER: SN 1054 (ACCEPT: SN 1054A; CSI+21-05315; PLX 1266; CM TAU)

BONUS

15) Earth and Space – *Short Answer* Rank the following four ions by increasing concentration in typical ocean water: 1) Sodium; 2) Sulfate; 3) Chlorine; 4) Calcium.

ANSWER: 4, 2, 1, 3

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TOSS-UP

16) Math – *Multiple Choice* Which of the following is congruent to the expression 3 times the modular inverse of 4 mod 5?

W) 1
X) 2
Y) 3
Z) 4

ANSWER: X) 2

BONUS

16) Math – *Short Answer* Given that x and y are real numbers such that $8x + 15y = 10$, what is the minimum possible value of $x^2 + y^2$?

ANSWER: 100/289
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TOSS-UP

17) Chemistry – *Short Answer* What equation, similar to the Arrhenius equation, is derived from transition state theory and is used to calculate reaction rates as a function of temperature?

ANSWER: EYRING EQUATION (ACCEPT: EYRING–POLANYI EQUATION)

BONUS

17) Chemistry – *Short Answer* Answer the following two questions about Fisher esterification: 1) What type of catalyst, acid or base, is used? 2) What specific intermediate is formed in the reaction?

ANSWER: 1) ACID; 2) OXONIUM ION

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TOSS-UP

18) Energy – *Multiple Choice* Researchers at Fermilab are using their linear accelerator, or LINAC, to study high-energy particle physics. The researchers accelerate which of the following particles in the LINAC?

W) Proton
X) Neutron
Y) Electron
Z) Positron

ANSWER: W) PROTON

BONUS

18) Energy – *Short Answer* Researchers at Fermilab are using high-performance computing to calculate the properties of particles that contain quarks and gluons. In order to study these systems, the researchers are building on what well-established non-perturbative gauge theory?

ANSWER: LATTICE QCD (ACCEPT: LATTICE QUANTUM CHROMODYNAMICS)
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TOSS-UP

19) Physics – *Short Answer* Identify all of the following three statements that are true in RLC circuits: 1) The voltage across the inductor lags the current; 2) The voltage across the capacitor leads the current; 3) The SI unit of reactance is the Henry.

ANSWER: NONE

BONUS

19) Physics – *Short Answer* A 2-kilogram particle travels at 0.6 times the speed of light and experiences a 25-newton force. To two significant figures, what is the acceleration of the particle?

ANSWER: 6.4 METERS PER SECOND SQUARED

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TOSS-UP

20) Biology – *Multiple Choice* According to the species-area curve, graphing the logarithm of the number of species found in a habitat to which of the following functions of area generates a straight line?

W) Reciprocal
X) Square
Y) Square root
Z) Logarithm

ANSWER: Z) LOGARITHM

BONUS

20) Biology – *Short Answer* You and your first cousin are going on a beach trip! Unfortunately, your cousin jumps into the water before realizing that he can't swim. You are debating on whether it is evolutionarily favorable to save your cousin. Assuming you and your cousin are expected to have the same number of offspring, then to the nearest tenth, what is the maximum percent chance of death you can risk in saving your cousin?

ANSWER: 12.5%
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TOSS-UP

21) Earth and Space – *Short Answer* What structures, built perpendicular to the shoreline, are designed to prevent the loss of sand through longshore currents?

ANSWER: GROINS

BONUS

21) Earth and Space – *Short Answer* What is the term for the locations on a HR diagram where protostars become detectable at visible wavelengths because their cocoons have disappeared?

ANSWER: BIRTHLINE

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TOSS-UP

22) Math – *Short Answer* What is the trace of the five by five identity matrix?

ANSWER: 5

BONUS

22) Math – *Short Answer* Let A equal the set {0, 1, 4, 5, 10} and B equal the set {1, 2, 4, 10, 15}. What is the symmetric difference of A and B?

ANSWER: {0, 2, 5, 15}
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TOSS-UP

23) Chemistry – *Multiple Choice* Which of the following statements about coordination complexes is true?

W) EDTA has a denticity of four
X) Square planar complexes have D_{4h} ***[D sub 4h]*** point group symmetry
Y) Tetraamminedichlorocobalt(III) has three isomers
Z) Iron has an oxidation state of +2 in the thiocyanatoiron complex ion

ANSWER: X) SQUARE PLANAR COMPLEXES HAVE D_{4h} POINT GROUP SYMMETRY

BONUS

23) Chemistry – *Short Answer* Identify all of the following three statements that are true about the Haber–Bosch process: 1) It is the principle method of generating nitric acid; 2) At high temperatures, the reaction equilibrium is shifted towards the products; 3) The catalyst typically requires an sulfur-based promotor.

ANSWER: 1 ONLY