NNHS ROUND 13

TOSS-UP

1) Physics – *Short Answer* What phenomenon, responsible for the blue glow of nuclear reactors, occurs when a charged particle exceeds the speed of light in a medium?

ANSWER: CHERENKOV RADIATION

BONUS

1) Physics – *Short Answer* What thermodynamic effect describes the decrease in temperature of a gas as it is throttled through a valve at constant enthalpy?

ANSWER: JOULE–THOMSON EFFECT

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TOSS-UP

2) Biology – *Multiple Choice* Which of the following structures contains bipolar neurons?

W) Auditory nerve
X) Vagus nerve
Y) Cerebrum
Z) Retina

ANSWER: Z) RETINA

BONUS

2) Biology – *Multiple Choice* ER stress occurs under which of the following conditions?

W) Lack of phospholipid to make vesicles
X) Lack of ribosomes to produce polypeptides
Y) Increased unfolded protein level
Z) Decreased unfolded protein level

ANSWER: Y) INCREASED UNFOLDED PROTEIN LEVEL
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TOSS-UP

3) Earth and Space – *Multiple Choice* Which of the following statements about quasars is correct?

W) Quasars were more common in the early universe
X) Quasars are stellar objects of very low luminosities
Y) Quasars are Seyfert galaxies
Z) Quasars are yet to be observed

ANSWER: W) QUASARS WERE MORE COMMON IN THE EARLY UNIVERSE

BONUS

3) Earth and Space – *Short Answer* In what natural process does radiation gradually destroy a mineral's crystal structure, leaving it amorphous?

ANSWER: METAMICTIZATION (ACCEPT: METAMICTION)

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TOSS-UP

4) Math – *Short Answer* A circle and a square are drawn in the same plane. What is the maximum number of intersections between the two figures?

ANSWER: 8

BONUS

4) Math – *Short Answer* What is the largest possible area of a square that is inscribed in a regular octagon with a side length of 4?

ANSWER: $32 + 16\sqrt{2}$
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TOSS-UP

5) Chemistry – *Short Answer* How many different enantiomers does the compound with molecular formula CH_2FCl have?

ANSWER: 1

BONUS

5) Chemistry – *Short Answer* In catalytic perfection, enzymes catalyze a reaction so efficiently that the rate of the reaction is limited by what process?

ANSWER: DIFFUSION (ACCEPT: SUBSTRATE DIFFUSION; PRODUCT DIFFUSION)

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TOSS-UP

6) Energy – *Multiple Choice* Researchers at Fermilab are looking for weakly-interacting massive particles, or WIMPs, which are a potential candidate of dark matter. Dark matter was originally posited to exist after noticing discrepancies in graphs of which of the following two quantities of a galaxy?

W) Acceleration and rotational velocity
X) Rotational velocity and radius
Y) Radius and gravitational force
Z) Luminosity and distance from the galaxy

ANSWER: X) ROTATIONAL VELOCITY AND RADIUS

BONUS

6) Energy – *Short Answer* Researchers at Fermilab are studying quantum mechanics. The researchers are using Hermitian matrices, which are square matrices whose transpose equals its complex conjugate. Identify all of the following four numbers that could be the element in the first row and first column of a Hermitian matrix: 1) 1; 2) 1/2 + √3/2i; 3) −4; 4) 2i.

ANSWER: 1 AND 3
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TOSS-UP

7) Physics – *Multiple Choice* A spaceship travels at the escape velocity from Earth. Which of the following best describes the shape of the spaceship's trajectory?

W) Circular
X) Elliptical
Y) Parabolic
Z) Hyperbolic

ANSWER: Y) PARABOLIC

BONUS

7) Physics – *Short Answer* A heat pump operates at the maximum possible efficiency between two reservoirs of 27 and 77 Celsius. What is the coefficient of performance of this heat pump?

ANSWER: 7

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TOSS-UP

8) Biology – *Short Answer* What is the primary polysaccharide that makes up the middle lamella?

ANSWER: PECTIN

BONUS

8) Biology – *Multiple Choice* What type of epithelial tissue is found on the lining of the upper respiratory tract?

W) Simple squamous
X) Simple cuboidal
Y) Pseudostratified columnar
Z) Stratified squamous

ANSWER: Y) PSEUDOSTRATIFIED COLUMNAR
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TOSS-UP

9) Earth and Space – *Short Answer* In what layer of the atmosphere does convection primarily occur?

ANSWER: TROPOSPHERE

BONUS

9) Earth and Space – *Multiple Choice* Which of the following is closest to the time it takes for Earth to complete one cycle of precession?

W) 11,000 years
X) 26,000 years
Y) 92,000 years
Z) 240,000 years

ANSWER: X) 26,000 YEARS

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TOSS-UP

10) Math – *Multiple Choice* Which of the following could be the eccentricity of a hyperbola?

W) 0
X) 0.4
Y) 1
Z) 1.7

ANSWER: Z) 1.7

BONUS

10) Math – *Short Answer* An ant starts at one corner of a rectangular prism with side lengths of 3, 5, and 9. The ant wants to crawl on the surface of the prism to the opposite vertex. What is the minimum distance the ant has to crawl?

ANSWER: $\sqrt{145}$
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TOSS-UP

11) Chemistry – *Multiple Choice* What is the hybridization of carbon atoms in graphene?

W) s
X) sp
Y) sp^2
Z) sp^3

ANSWER: Y) sp^2

BONUS

11) Chemistry – *Short Answer* What rule states that the entropy of vaporization of most substances is around the same value?

ANSWER: TROUTON'S RULE

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TOSS-UP

12) Energy – *Multiple Choice* Researchers at Oak Ridge National Lab are studying the use of metal organic frameworks to store natural gas. Which of the following gases is the primary component of natural gas?

W) Methane
X) Hydrogen
Y) Carbon dioxide
Z) Hydrogen sulfide

ANSWER: W) METHANE

BONUS

12) Energy – *Short Answer* Researchers at Oak Ridge National Lab are studying the SARS-COV-2 virus. In particular, they are looking at what physiological reaction in humans, where the innate immune system causes an uncontrolled and excessive release of pro-inflammatory signaling molecules?

ANSWER: CYTOKINE STORM
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TOSS-UP

13) Physics – *Short Answer* An alpha particle accelerates across a 5 volt potential difference. In electron volts, what is the kinetic energy of the particle?

ANSWER: 10

BONUS

13) Physics – *Multiple Choice* A uniform, ideal spring is allowed to hang from its endpoints under the influence of gravity. What is the shape of the spring?

W) Catenary
X) Parabola
Y) Circular arch
Z) Elliptical arch

ANSWER: X) PARABOLA

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TOSS-UP

14) Biology – *Multiple Choice* You find two white roses. After crossing the two flowers, all of the resulting offspring are red, the wild-type phenotype. Which of the following is true?

W) The two mutations are found on the same gene
X) The two mutations are found on different genes
Y) The two mutations are linked with recombination frequency 0.5
Z) An F2 generation would be needed before drawing any conclusion

ANSWER: X) THE TWO MUTATIONS ARE FOUND ON DIFFERENT GENES

BONUS

14) Biology – *Short Answer* Identify all of the following three groups that have dominant sporophytes: 1) Mosses; 2) Ferns; 3) Angiosperms.

ANSWER: 2 AND 3
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TOSS-UP

15) Earth and Space – *Multiple Choice* In which of the following parts of an HR diagram would one expect to find white dwarfs?

W) Top left
X) Top right
Y) Bottom left
Z) Bottom right

ANSWER: Y) BOTTOM LEFT

BONUS

15) Earth and Space – *Short Answer* What kind of trace fossil consists of the petrified remains of dung and is often used to analyze the diet of extinct species?

ANSWER: COPROLITE

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TOSS-UP

16) Math – *Multiple Choice* Which of the following equations is equivalent to the polar equation $r = 3\sin(\theta)$?

W) $x = 3$
X) $y = 3$
Y) $x^2 + y^2 = 3x$
Z) $x^2 + y^2 = 3y$

ANSWER: Z) $x^2 + y^2 = 3y$

BONUS

16) Math – *Short Answer* In radians, what is the phase shift of $\sin(x) + \cos(x)$?

ANSWER: $-\pi/4$ (ACCEPT: $\pi/4$)
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TOSS-UP

17) Chemistry – *Short Answer* What is the acid anhydride of nitric acid?

ANSWER: N_2O_5 (ACCEPT: DINITROGEN PENTOXIDE)

BONUS

17) Chemistry – *Multiple Choice* Which of the following compounds is most likely to experience the leveling effect in water?

W) H_3O^+
X) H_2N^-
Y) H_2S
Z) O^{2-}

ANSWER: X) H_2N^-

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TOSS-UP

18) Energy – *Multiple Choice* Researchers at Ames National Lab are studying magnetic topological semimetals at the Center for the Advancement of Topological Semimetals. Which of the following elements is a semimetal?

W) Aluminum
X) Phosphorous
Y) Cadmium
Z) Arsenic

ANSWER: Z) ARSENIC

BONUS

18) Energy – *Short Answer* Researchers at Ames National Lab are studying the quality control of graphene, which may have implications for the manufacturing of sensors. What sensor, often used in cameras, consists of an integrated circuit that produces electrical signals from photons incident on its surface?

ANSWER: CHARGE COUPLED DEVICE (ACCEPT: CCD)
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TOSS-UP

19) Physics – *Short Answer* An ideal transformer has 10 coils in the primary winding and 30 coils in the secondary winding. If the source current is 60 amps, then what current does the transformer output?

ANSWER: 20 AMPS

BONUS

19) Physics – *Short Answer* Two speakers are placed a distance of 0.5 meters apart and are facing each other, and both speakers emit sound with a wavelength of 1.0 meters. As a microphone is moved from one speaker to the other, however, the microphone does not observe total destructive interference. What phenomenon is responsible for this effect?

ANSWER: DOPPLER EFFECT (ACCEPT: DOPPLER SHIFT)

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TOSS-UP

20) Biology – *Short Answer* When glucose levels are low in the bacterial cell, cyclic AMP levels are increased. Cyclic AMP binds to what protein that, when bound, serves as an activator for the lac operon?

ANSWER: CATABOLITE ACTIVATOR PROTEIN (ACCEPT: CAP; CYCLIC AMP RECEPTOR PROTEIN; CRP)

BONUS

20) Biology – *Multiple Choice* Nociceptors most directly sense which of the following?

W) Pain
X) Temperature
Y) Heat
Z) Osmolarity

ANSWER: W) PAIN
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TOSS-UP

21) Earth and Space – *Multiple Choice* Which of the following is NOT a cause of tsunamis?

W) Meteor impact
X) Landslide
Y) Volcanic eruption
Z) Mining

ANSWER: Z) MINING

BONUS

21) Earth and Space – *Multiple Choice* According to the Saros cycle, if a lunar eclipse occurred on June 5, 2020, then a lunar eclipse must occur on which of the following days?

W) June 11, 2029
X) June 16, 2038
Y) May 29, 2047
Z) June 12, 2056

ANSWER: X) JUNE 16, 2038

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TOSS-UP

22) Math – *Short Answer* What type of function is characterized by the statement that distinct elements in its domain map to distinct elements in its range?

ANSWER: INJECTIVE (ACCEPT: ONE-TO-ONE; DO NOT ACCEPT: BIJECTIVE; ONE-TO-ONE CORRESPONDENCE; INVERTIBLE)

BONUS

22) Math – *Short Answer* Evaluate the indefinite integral of the fraction with numerator dx and denominator 9 plus 4x squared.

ANSWER: $\frac{1}{6}\tan^{-1}(2x/3) + C$
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TOSS-UP

23) Chemistry – *Multiple Choice* Which of the following properties of nitrogen explains why it has a larger first ionization energy than oxygen?

W) Increased electron shielding
X) Stronger fine structure
Y) Higher energy of antibonding electrons
Z) More stable 2p orbital

ANSWER: Z) MORE STABLE 2P ORBITAL

BONUS

23) Chemistry – *Multiple Choice* In which of the following types of materials would one expect to find nematic and lyotropic phases?

W) Liquid crystal
X) Plasma
Y) Superconductor
Z) Bose-einstein condensate

ANSWER: W) LIQUID CRYSTAL