



## DOUBLE ELIMINATION 1

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### TOSS-UP

1) Energy - *Short Answer* Researchers at Stanford's Hoover Institution are developing policy recommendations for pressurized water nuclear reactors. Identify all of the following three parts of a pressurized water reactor that are made up of water: 1) Coolant; 2) Fuel; 3) Moderator.

ANSWER: 1 and 3

### BONUS

1) Energy - *Multiple Choice* Researchers in the Airan Lab at Stanford are using perfluorocarbon [**per-FLOR-oh-car-bin**] emulsions in certain non-invasive drug therapies. Which of the following compounds is a perfluorocarbon?

W)  $C_4H_9F$

X)  $C_4H_6F_6$

Y)  $C_4F_{10}$

Z)  $C_4F_{12}$

ANSWER: Y)  $C_4F_{10}$

### TOSS-UP

2) Math - *Multiple Choice* Let  $S$  be a square with side length 2. What is the positive difference between the areas of the circumcircle of  $S$  and the incircle of  $S$ ?

W)  $\pi/2$

X)  $\pi$

Y)  $\sqrt{2}\pi$

Z)  $2\pi$

ANSWER: X)  $\pi$

### BONUS

2) Math - *Short Answer* Express the following 12-digit binary number in hexadecimal: **[read slowly]** 101001101111.

ANSWER: A6F

### TOSS-UP

3) Chemistry - *Multiple Choice* Which of the following statements is true regarding integrated rate laws?

W) The first-order rate constant has units of inverse molar

X) The rate of decay versus time plot for a first-order reaction is nonlinear

Y) Plotting the inverse concentration of a second-order reaction with respect to time gives a linear plot with a negative slope

Z) The rate constant does not appear in a zeroth-order integrated rate law equation

ANSWER: X) The rate of decay versus time plot for a first-order reaction is nonlinear

### BONUS

3) Chemistry - *Multiple Choice* Which of the following is the highest occupied molecular orbital in  $\text{NO}_2$ ?

W) Sigma bonding

X) Sigma antibonding

Y) Pi bonding

Z) Pi antibonding

ANSWER: Z) Pi antibonding

### TOSS-UP

4) Earth and Space - *Multiple Choice* As stars on the Hayashi track evolve, they most directly move in which of the following directions on the HR diagram?

- W) Up
- X) Down
- Y) Left
- Z) Right

ANSWER: X) Down

### BONUS

4) Earth and Space - *Multiple Choice* Which of the following statements is true regarding globular clusters?

- W) They have relatively low metallicity
- X) They are primarily located within the spiral arms of galaxies
- Y) They are mostly observed on infrared wavelengths
- Z) They are composed of stars that formed at around the same time

ANSWER: W) They have relatively low metallicity

## TOSS-UP

5) Biology - *Short Answer* When a sperm cell combines with two polar nuclei, a triploid [**TRIP-loyd**] nucleus forms in a large cell within the female gametophyte [**guh-MEE-toh-fight**] that eventually develops into what multicellular food-storing tissue in the seeds of angiosperms?

ANSWER: Endosperm

## BONUS

5) Biology - *Multiple Choice* Which of the following genetic variations is most strongly associated with differences in susceptibility to malaria between individuals?

W) Single nucleotide polymorphism

X) Chromosomal translocation

Y) Copy number variation

Z) Tandem repeat expansion

ANSWER: W) Single nucleotide polymorphism

### TOSS-UP

6) Physics - *Multiple Choice* Consider a graph of net force versus displacement for the motion of a particle. The change in which of the following quantities is equal to the area under the curve of the graph between two points?

- W) Potential energy
- X) Kinetic energy
- Y) Linear momentum
- Z) Angular momentum

ANSWER: X) Kinetic energy

### BONUS

6) Physics - *Short Answer* What is the moment of inertia of a uniform solid sphere with mass  $M$  and radius  $R$  about an axis passing through a point on its surface?

ANSWER:  $\frac{7}{5}MR^2$

## TOSS-UP

7) Chemistry - *Multiple Choice* The azimuthal [**az-uh-MUH-thul**] quantum number most directly dictates which of the following properties of an electron orbital in an atom?

- W) Energy level
- X) Shape
- Y) Orientation
- Z) Spin

ANSWER: X) Shape

## BONUS

7) Chemistry - *Multiple Choice* At equilibrium, which of the following statements is true about the relationship between delta G and the equilibrium constant?

- W) Delta G of the system is at its maximum, and  $\Delta G$  [**delta G**] =  $RT \ln k$
- X) Delta G of the system is at its minimum, and  $\Delta G = -RT \ln k$
- Y) Delta G of the system is zero, and  $\Delta G^\circ$  [**delta G nought**] =  $-RT \ln K$
- Z) Delta G of the system is positive, and K is greater than 1

ANSWER: Y) Delta G of the system is zero, and  $\Delta G^\circ = -RT \ln K$



### TOSS-UP

8) Energy - *Short Answer* Researchers at the SLAC-Stanford Battery Center are testing sodium-ion batteries because they may be more reliable than lithium-ion batteries for energy storage. Identify all of the the following three statements that are true comparing lithium and sodium: 1) Lithium is more reactive than sodium; 2) Lithium has a higher electronegativity than sodium; 3) Lithium has a higher metallic character than sodium.

ANSWER: 2 only

### BONUS

8) Energy - *Short Answer* Researchers at SLAC are using the Stanford Synchrotron Radiation Lightsource to study how mercury accumulated in fish becomes toxic. This toxicity is primarily due to the synthesis of what biologically-derived mercury compound by microbes in fish?

ANSWER: Methylmercury

## TOSS-UP

9) Biology - *Multiple Choice* Which of the following best explains how microRNA acts to block protein synthesis?

- W) Prevents tRNA anticodon binding to mRNA
- X) Blocks large and small ribosome subunit joining
- Y) Enables proteasome [**PROH-tee-oh-sohm**] recruitment to degrade emerging peptide sequences
- Z) Facilitates mRNA recognition in protein complexes that cleaves mRNA

ANSWER: Z) Facilitates mRNA recognition in protein complexes that cleaves mRNA

## BONUS

9) Biology - *Multiple Choice* Caspases [**CAS-pay-siz**] initiate apoptosis [**ay-pop-TOH-sis**] by acting via which of the following enzymatic mechanisms?

- W) Kinase [**KY-nase**]
- X) Protease [**PROH-tee-ase**]
- Y) Ubiquitinase [**you-BIK-wuh-tin-ase**]
- Z) Nuclease [**NEW-klee-ase**]

ANSWER: X) Protease

### TOSS-UP

10) Math - *Short Answer* What is the greatest possible product of a collection of positive integers that sum to 8?

ANSWER: 18

### BONUS

10) Math - *Short Answer* What is the volume of the 3D solid obtained by rotating an isosceles triangle with side lengths 13, 13, and 10 about its axis of symmetry?

ANSWER:  $100\pi$

## TOSS-UP

11) Earth and Space - *Multiple Choice* Wadati-Benioff [**wuh-DAW-tee BEN-ee-off**] zones are located at which of the following types of plate boundaries?

- W) Continental-continental convergent
- X) Oceanic-continental convergent
- Y) Continental-continental divergent
- Z) Oceanic-oceanic divergent

ANSWER: X) Oceanic-continental convergent

## BONUS

11) Earth and Space - *Multiple Choice* Which of the following conditions is most commonly associated with the formation of low velocity zones in Earth's upper mantle?

- W) High pressure from overlying rock
- X) Low pressure from overlying rock
- Y) High degree of partial melting
- Z) Low tectonic plate velocity

ANSWER: Y) High degree of partial melting

### TOSS-UP

12) Physics - *Multiple Choice* A superposition of waves is created such that the value of each component is zero at  $x = 0$  and  $x = 1$ . If  $n$  is a positive integer, which of the following describes the allowed components of this superposition?

W)  $\sin(\pi nx)$  [sine of the quantity pi n x]

X)  $\sin(2\pi nx)$  [sine of the quantity 2 pi n x]

Y)  $\sin(\pi x/n)$  [sine of the quantity pi x over n]

Z)  $\sin(2\pi x/n)$  [sine of the quantity 2 pi x over n]

ANSWER: W)  $\sin(\pi nx)$

### BONUS

12) Physics - *Multiple Choice* A disk starts from rest and rotates about a fixed axis due to a constant net torque. The work done by the torque during the second revolution is how many times the work done during the first revolution?

W) 0.5

X) 1

Y) 2

Z) 4

ANSWER: X) 1

### TOSS-UP

13) Chemistry - *Multiple Choice* Which of the following correctly states the correct number of sigma and pi bonds between the central carbon-carbon bond in acetylene [**uh-SEE-tul-een**]?

W) 2 sigma bonds, 1 pi bond

X) 1 sigma bond, 2 pi bonds

Y) 1 sigma bond, 1 pi bond

Z) 1 sigma bonds, 3 pi bonds

ANSWER: X) 1 sigma bond, 2 pi bonds

### BONUS

13) Chemistry - *Short Answer* Identify all of the following three intermolecular forces that are present in acetonitrile [**uh-see-toh-NY-tri-uhl**], which has chemical formula  $\text{CH}_3\text{CN}$ : 1) London dispersion forces; 2) Dipole-dipole interactions; 3) Hydrogen bonding.

ANSWER: 1 and 2

### TOSS-UP

14) Biology - *Multiple Choice* The tympanic [**tim-PAN-ic**] membrane within the ear is attached to which of the following bones?

W) Stapes [**STAY-pees**]

X) Incus

Y) Malleus

Z) Modiolus

ANSWER: Y) Malleus

### BONUS

14) Biology - *Short Answer* Identify all of the following three blood types a recipient with A minus blood would accept: 1) O minus; 2) AB plus; 3) B minus.

ANSWER: 1 only

## TOSS-UP

15) Earth and Space - *Multiple Choice* A synodic [**sih-NOH-dic**] day on Earth defines a day relative to which of the following reference points?

- W) The Sun
- X) The Moon
- Y) The stars
- Z) The ecliptic

ANSWER: W) The Sun

## BONUS

15) Earth and Space - *Multiple Choice* Which of the following processes causes the difference in area between Martian shield volcanos and Earth's volcanic island chains?

- W) Eustatic [**yoo-STAT-ic**] adjustment
- X) Crustal contraction
- Y) Tectonic activity
- Z) Isostatic [**iso-STAT-ic**] rebound

ANSWER: Y) Tectonic activity



## TOSS-UP

16) Energy - *Multiple Choice* Scientists at the Stanford Amyloid [AM-uh-loyd] Center are studying Alzheimer's disease. Which of the following statements is NOT true regarding Alzheimer's disease?

W) Tau proteins accumulate in the brains of Alzheimer's patients

X) Acetylcholine deficiency in the substantia niagra is the main cause of Alzheimer's

Y) Some individuals possess a higher risk for Alzheimer's due to genetic factors

Z) Some individuals with high amyloid plaque buildup in their brain will not have the disease

ANSWER: X) Acetylcholine deficiency in the substantia niagra is the main cause of Alzheimer's

## BONUS

16) Energy - *Short Answer* Researchers in the Kavli Institute at Stanford are studying the polarization of light as it passes through neutral hydrogen structures. What term is given to clouds of neutral hydrogen in the interstellar medium?

ANSWER: HI [H-one] regions

### TOSS-UP

17) Chemistry - *Short Answer* What is the name of the spectral series that corresponds to the hydrogen atom's electronic transitions to its first energy level?

ANSWER: Lyman series (ACCEPT: Lyman)

### BONUS

17) Chemistry - *Short Answer* Several hydrocarbons are combusted in the presence of excess oxygen. If one mole of each hydrocarbon is present, order the following three molecules by increasing number of gas molecules produced: 1) Propane; 2) Butyne [**BYOO-tine**]; 3) Pentene.

ANSWER: 2, 3, 1

### TOSS-UP

18) Physics - *Multiple Choice* A particle with kinetic energy  $E$  is surrounded by an annulus of potential  $2E$ . Which of the following best describes how the position of the particle is constrained in classical and quantum mechanics?

- W) Trapped in the ring in both classical and quantum mechanics
- X) Trapped in the ring in classical but not quantum mechanics
- Y) Trapped in the ring in quantum but not classical mechanics
- Z) Not trapped in the ring in either quantum or classical mechanics

ANSWER: X) Trapped in the ring in classical but not quantum mechanics

### BONUS

18) Physics - *Multiple Choice* Which of the following is most accurate about the period of a simple pendulum with amplitude  $\theta$  [**theta**]?

- W) It is independent of  $\theta$
- X) It increases with  $\theta$ , up to a constant value at  $\theta = \pi/2$
- Y) It increases with  $\theta$ , up to a constant value at  $\theta = \pi$
- Z) It increases with  $\theta$ , diverging as  $\theta$  approaches  $\pi$

ANSWER: Z) It increases with  $\theta$ , diverging as  $\theta$  approaches  $\pi$

## TOSS-UP

19) Earth and Space - *Multiple Choice* The D'' [**D double prime**] layer, often described as a "plate graveyard," is located in which of the following regions of Earth?

- W) Upper mantle
- X) Lower mantle
- Y) Outer core
- Z) Inner core

ANSWER: X) Lower mantle

## BONUS

19) Earth and Space - *Multiple Choice* Which of the following statements is most accurate regarding conditional instability in Earth's atmosphere?

- W) The atmosphere is stable for unsaturated air parcels only
- X) The atmosphere becomes unstable in the presence of slight disturbances
- Y) The environmental lapse rate is less than the moist adiabatic lapse rate
- Z) The dry adiabatic lapse rate is less than the moist adiabatic lapse rate

ANSWER: W) The atmosphere is stable for unsaturated air parcels only

### TOSS-UP

20) Math - *Short Answer* Given that the product of two positive integers  $a$  and  $b$  is 224, what is the smallest possible value of  $a + b$ ?

ANSWER: 30

### BONUS

20) Math - *Short Answer* How many ways are there to rearrange the letters in "STANFORD" if the first and last letters must be vowels?

ANSWER: 1440

### TOSS-UP

21) Physics - *Short Answer* What name is given to the group of highly unstable particles composed of an equal number of quarks and antiquarks?

ANSWER: Mesons [MEE-zawns]

### BONUS

21) Physics - *Short Answer* Emily is standing on flat ground and has a potato gun that can launch a potato at 10 meters per second. If she launches the potato at an angle of 75 degrees above the ground, then to the nearest meter, how far will the potato travel horizontally?

ANSWER: 5

## TOSS-UP

22) Biology - *Short Answer* When sugar levels become low during exercise, fatty acids are broken down by the body to produce energy. What metabolic process cleaves two carbons from fatty acid ends to produce the needed energy through substrate-level phosphorylation?

ANSWER: Beta oxidation

## BONUS

22) Biology - *Multiple Choice* When a population of elephants is introduced into a new environment, which of the following best describes the population size when the population growth rate starts to decrease?

W) The growth rate will decrease when the population size is around one fourth of the carrying capacity

X) The growth rate will decrease when the population size is around one half of the carrying capacity

Y) The growth rate will decrease when the population size is around three fourth of the carrying capacity

Z) The growth rate will decrease when the population size reaches carrying capacity

ANSWER: X) The growth rate will decrease when the population size is around one half of the carrying capacity

### TOSS-UP

23) Math - *Short Answer* Let  $a$ ,  $b$ , and  $c$  be integers such that the mean of  $a$  and  $b$  is 4, the mean of  $b$  and  $c$  is 5, and the mean of  $c$  and  $a$  is 6. Find the mean of  $a$ ,  $b$ , and  $c$ .

ANSWER: 5

### BONUS

23) Math - *Short Answer* What is the largest integer less than 100 that has exactly 10 positive factors?

ANSWER: 80