

### **Tossup**

1) *Earth and Space – Short Answer:* Identify all of the following 4 which could be used to measure distance on cosmological scales:

- I) Parallax
- II) Cepheid [sef-ee-id] Variables
- III) Mira Stars
- IV) Dwarf Novae

ANSWER: I, II and III

### **Bonus**

1) *Earth and Space – Short Answer:* Which of the following is the correct term for the theory of universe death in which the Higgs Field reaches its absolute minimum?

- W) Heat Death
- X) Big Rip
- Y) Vacuum Decay
- Z) Big Crunch

ANSWER: Y

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### **Tossup**

2) *Chemistry – Short Answer:* What is the anhydride of Barium hydroxide?

ANSWER: BaO

### **Bonus**

2) *Chemistry – Short Answer:* A 0.01 Molar solution of a weak acid has a pH of 3. To two significant figures, what is the value of the  $K_a$  for this acid?

ANSWER:  $1.1 \times 10^{-4}$

### **Tossup**

3) *Energy – Short Answer:* Researchers at the NIH are studying the effects of methanol poisoning. Which of the following is the best treatment for methanol poisoning?

- W) Diethyl Ether
- X) Dopaquinone [READ: **dope-uh-kwi-none**]
- Y) Ethanol
- Z) Glucose

ANSWER: Y) Ethanol

### **Bonus**

3) *Energy – Short Answer:* Researchers at Fermilab are studying quantum computing and the way that quantum bits of information interact with each other, as well as the differences between quantum computing and binary computing. Compute the results of the following bitwise operations: 3 AND 12 XOR 15

ANSWER: 15 (ACCEPT: 1111)

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### **Tossup**

4) *Math – Multiple Choice:* Consider the function  $f(x)$ , which has negative slope and is concave down in the closed interval  $[-2, 5]$ . The value of the integral of  $f(x)$  from -2 to 5 as approximated by a left Riemann sum is:

- W) An overestimate
- X) An underestimate
- Y) An overestimate for large steps and an underestimate for small ones
- Z) An underestimate for large steps and an overestimate for small ones

ANSWER: W) An overestimate

### **Bonus**

4) *Math – Multiple Choice:* Consider a monotonically increasing function  $f(x)$  including the two points  $(3, 7)$  and  $(6, 15)$ . Which of the following is not possible for  $f(x)$  to satisfy?

- W) The value of  $f'(x)$  [READ: **f prime of x**] at  $x = 5$  is equal to 0
- X) The value of  $f(x)$  at  $x = 5$  is equal to 14
- Y) The value of  $f(x)$  at  $x = 5$  is equal to 6
- Z) The value of  $f'(x)$  [READ: **f prime of x**] at  $x = 5$  is equal to 12

ANSWER: Y) The value of  $f(x)$  at  $x = 5$  is equal to 6

**Tossup**

- 5) *Chemistry – Short Answer:* Abhinav performs a titration with NaOH as the titrant and Sulfuric acid as the analyte. How many equivalence points are visible in the titration graph?

ANSWER: 1

**Bonus**

- 5) *Chemistry- Short Answer:* What are the cathode and anode, respectively, of a Zinc-Carbon cell?

ANSWER: Zinc anode, Manganese dioxide cathode

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**Tossup**

- 6) *Earth and Space – Multiple Choice:* Which of the following metamorphic facies [fay-sees] could result from burial metamorphism?

- W) Eclogite [ek-log-ite]
- X) Blueschist
- Y) Hornfels
- Z) Zeolite

ANSWER: Z) Zeolite

**Bonus**

- 6) *Earth and Space – Short Answer:* Identify all of the following 4 rocks which exhibit cleavage:

- I) Metaconglomerate
- II) Slate
- III) Breccia
- IV) Shale

ANSWER: II and IV

### **Tossup**

7) *Math – Short Answer:* What is the smallest positive integer such that its remainder when divided by 7 is 1 and remainder when divided by 5 is 2?

ANSWER: 22

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### **Bonus**

7) *Math – Short Answer:* How many ways are there to seat Annie, Billy, Carol, David, and Emily in a row of 5 seats if Annie and Emily refuse to sit next to each other?

ANSWER: 72

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### **Tossup**

8) *Physics – Short Answer:* Identify all of the following five forces that are not fictitious forces:

- I) Coriolis force
- II) Gravitational force
- III) Tension force
- IV) Centrifugal force
- V) Azimuthal force

ANSWER: II and III

### **Bonus**

8) *Physics – Short Answer:* Thanush puts on Nikhil's glasses. His glasses have convex lenses of focal length 3 cm. Thanush looks at a book of length 30 cm. In centimeters, how long does the book appear to him through Nikhil's glasses?

ANSWER: 10/3

**Tossup**

9) *Biology – Short Answer:* What secondary growth tissue is responsible for creating bark in woody plants?

ANSWER: Cork cambium

**Bonus**

9) *Biology – Short Answer:* Identify all of the following 4 cells not correctly matched with what they produce:

- 1) Beta cells - insulin
- 2) Delta cells - somatostatin **[som-a-to-stat-in]**
- 3) Epsilon cells - ghrelin **[grel-in]**
- 4) Alpha cells - glucagon

ANSWER: None

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**Tossup**

10) *Math – Short Answer:* An imaginary convex simple polyhedron has 57 faces and 85 vertices. How many edges does this polyhedron have?

ANSWER: 140

**Bonus**

10) *Math – Short Answer:* If  $x^3 - 9x^2 + 5x - 30$  has distinct roots a, b, and c, what is the value of the expression  $1 - a - b - c$ ?

ANSWER: -8

### **Tossup**

- 11) *Physics – Short Answer:* Consider an electric dipole of length 0.2 millimeters pointing along the x axis. If the force from the dipole at the point  $x = 3$  meters on a charge is 400 N, what is the force on the same charge at  $x = 6$  meters to the nearest Newton?

ANSWER: 50 N

### **Bonus**

- 11) *Physics – Multiple Choice:* Consider a ball of mass  $m$  attached to a string. The other end of the string is attached to a square pole stuck in the ground. If the ball is hit at a velocity  $v$  and begins to wrap around the pole, what quantity is conserved as the ball wraps around the pole?

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

ANSWER: Z) Kinetic energy

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### **Tossup**

- 12) *Energy – Short Answer:* Scientists at Sandia National Laboratory are studying the production of karyotypes in aneuploidies. In the production of a karyotype, cells are arrested at what phase of mitosis?

ANSWER: Metaphase (ACCEPT: Prometaphase)

### **Bonus**

- 12) *Energy – Short Answer:* Researchers at Oak Ridge National Laboratory are studying the use of aromatic compounds as coolants for solar energy production. One of the compounds they are focused on studying is naphthalene, which is formed by fusing two benzene rings so they share a bond. What is the degree of unsaturation of naphthalene?

ANSWER: 7

### **Tossup**

13) *Chemistry – Multiple Choice:* Which of the following is true of catalysts?

- W) Catalysts change the rate of reaction by making products more favorable
- X) Catalysts change the rate of reaction by increasing free energy for activation
- Y) Catalysts provide alternative, lower energy reaction paths
- Z) Catalysts increase only the forward reaction rate

ANSWER: Y) Catalysts provide alternative, lower energy reaction paths

### **Bonus**

13) *Chemistry – Multiple Choice:* The energy profile of a certain reaction has two peaks and ends at a spot lower than it begins. What is the molecularity of the rate determining step?

- W) Bimolecular
- X) Unimolecular
- Y) Trimolecular
- Z) It is impossible to tell from the given information

ANSWER: Z) It is impossible to tell from the given information

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### **Tossup**

14) *Biology – Multiple Choice:* In which of the following conditions is the effectiveness of Batesian mimicry reduced?

- W) Population of the model rapidly increases
- X) Population of the mimic rapidly increases
- Y) Model becomes more noxious
- Z) The number of species using this coloring pattern decreases

ANSWER: X) Population of mimic rapidly increases

### **Bonus**

14) *Biology – Short Answer:* Order the following 3 genetic elements in order of increasing distance from the protein coding gene:

- 1) Enhancer
- 2) Promoter
- 3) 5'UTR [READ: 5 prime U T R]

ANSWER: 3, 2, 1

### **Tossup**

- 15) *Earth and Space– Short Answer:* What is the name for asteroids that orbit Jupiter's Lagrange points?

ANSWER: Trojan Asteroids

### **Bonus**

- 15) *Earth and Space– Short Answer:* The Earth and Jupiter were last in opposition in August of 2021. To the nearest month, when is our next opposition with Jupiter?

ANSWER: September 2022

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### **Tossup**

- 16) *Math – Short Answer:* What is the value of the expression  $\cos(14\pi/50) / \sin(-11\pi/50)$   
[READ: cosine of 14 pi over 50 divided by sine of negative 11 pi over 50]?

ANSWER: -1

### **Bonus**

- 16) *Math – Multiple Choice:* What is the length of the shortest altitude of a triangle with side lengths 75, 100, and 125?

- W) 50
- X) 60
- Y) 75
- Z) 100

ANSWER: X

### **Tossup**

17) *Physics – Multiple Choice:* A tank circuit is a name for an AC circuit commonly used to produce resonance. Which of the following circuits would be considered a tank circuit?

- W) RL Circuit
- X) RC Circuit
- Y) RI Circuit
- Z) LC Circuit

ANSWER: Z) LC Circuit

### **Bonus**

17) *Physics – Short Answer:* A block sits on a track with potential energy modeled by the function  $U(x) = 4 + (x - 2)^2$  [READ: U of x equals 4 plus open parenthesis x minus 2 close parenthesis squared]. If the block begins at rest and moves from  $x = -2$  to  $x = 1$  under a constant 2 Newton friction force, what is its kinetic energy at  $x = 1$ ?

ANSWER: 9 J

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### **Tossup**

18) *Earth and Space – Multiple Choice:* Which of the following is closest to the salinity of ocean water?

- W) 35 PPM
- X) 35 percent
- Y) 35 PSU
- Z) 35 PPB

ANSWER: Y) 35 PSU

### **Bonus**

18) *Earth and Space – Multiple Choice:* Which of the following ions is least prevalent in seawater?

- W)  $\text{Be}^{2+}$
- X)  $\text{Mg}^{2+}$
- Y)  $\text{Ca}^{2+}$
- Z)  $\text{Sr}^{2+}$

ANSWER: X)  $\text{Be}^{2+}$

### **Tossup**

19) *Biology – Short Answer:* Citrate is a product of the Krebs cycle that is used to regulate what key enzyme, called the pacemaker of glycolysis?

ANSWER: Phosphofructokinase (Accept PFK)

### **Bonus**

19) *Biology – Short Answer:* Let  $2n$  denote the number of chromosomes and let  $s$  denote the total nuclear genetic material of a cell in G0 phase. What is the number of chromosomes and total genetic material, in terms of  $n$  and  $s$  respectively, of a cell in Anaphase?

ANSWER:  $4n$ ,  $2s$

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### **Tossup**

20) *Chemistry – Multiple Choice:* Which of the following compounds is a Lewis acid, but NOT a Bronsted-Lowry acid?

- W) HCl
- X) NaF
- Y) KOH
- Z) BH<sub>3</sub>

ANSWER: Z) BH<sub>3</sub>

### **Bonus**

20) *Chemistry – Short Answer:* Two liquids, A and B, are miscible [**miss-i-ble**] in each other. They form an azeotrope at 0.6 mole fraction of A. Identify all of the following 3 concentrations where the two liquids would not fully mix:

- I) 0.4 mol fraction B
- II) 0.6 mol fraction B
- III) 0.8 mol fraction B

ANSWER: None

### **Tossup**

21) *Biology – Short Answer:* Guard cells regulate the opening and closing of stomata through the flow of what ion to regulate the cells' turgor pressure?

ANSWER: Potassium (ACCEPT: K+)

### **Bonus**

21) *Biology – Multiple Choice:* A long day plant has a critical period of 13 hours in an environment with 15 hour night periods. Which of the following sequences of red and far red flashes of light during night would result in the plant flowering?

- W) Flashes of far-red light every hour
- X) A flash of red light immediately followed by a flash of far red light every hour
- Y) One flash of red light one hour into the night period
- Z) A flash of far red light immediately followed by a flash of red light every hour

ANSWER: Z) A flash of far red light immediately followed by a flash of red light every hour

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### **Tossup**

22) *Energy – Short Answer:* Researchers at Lawrence-Berkeley National Lab are studying the effects of solubility between different solvents. Which of the following ionic compounds is insoluble in water?

- W) Sodium Sulfate
- X) Sodium Hydroxide
- Y) Calcium Sulfate
- Z) Calcium Hydroxide

ANSWER: Y) Calcium Sulfate

### **Bonus**

22) *Energy – Short Answer:* Scientists at Oak Ridge National Laboratory are studying mechanisms of delivering vitamins to patients using nanotechnology delivery systems. These delivery systems require that the vitamins are water-soluble. Identify all of the 4 following vitamins that are water-soluble:

- I) Niacin
- II) Retinal
- III) Cobalamin
- IV) Tocopherol

ANSWER: I, III

### **Tossup**

23) *Physics – Multiple Choice:* Two identical balls on a table, one with velocity  $v$  and one at rest, collide elastically with each other such that both balls deflect off of one another and continue moving with a nonzero speed. What is the angle between the final velocities of the two balls?

- W) 0 degrees
- X) 30 degrees
- Y) 90 degrees
- Z) 180 degrees

ANSWER: Y) 90 degrees

### **Bonus**

23) *Physics – Short Answer:* Thanush and Nikhil are testing their physics knowledge by throwing a tennis ball back and forth in a parabolic trajectory. If Thanush throws a tennis ball at 10 meters per second at a 60 degree angle to the horizontal, how far, to the nearest meter, must Nikhil be from Thanush in order to catch the ball?

ANSWER: 9