

### **TOSS-UP**

1) BIOLOGY *Short Answer* Give the phenomena by which homologous chromosomes pair during meiosis before crossing over?

ANSWER: Synapsis

### **BONUS**

1) BIOLOGY *Short Answer* By name or number, indicate all of the following that are true concerning adenoviruses

- 1) They are responsible for SARS
- 2) They are responsible for respiratory tract infections of animals
- 3) They are responsible for the common cold

ANSWER: 2

---

### **TOSS-UP**

2) EARTH AND SPACE *Multiple Choice* Which of the following branches of the HR diagram would a star that has just begun helium fusion reside on?

- W) Red giant
- X) Horizontal
- Y) Asymptotic giant
- Z) Turn off

ANSWER: X) Horizontal

### **BONUS**

2) EARTH AND SPACE *Multiple Choice* According to the unified model of active galaxies, which of the following viewing orientations in respect to a black hole would result in a type 2 Seyfert galaxy.

- W) Face on to the torus
- X) Angled to the torus
- Y) Edge on to the torus
- Z) Face on to the event horizon

ANSWER: Y) Edge on to the torus

---

**TOSS-UP**

3) MATH *Short Answer* What is the distance from the point (3,4) to the line  $-6x+5y=12$ ?

ANSWER:  $2\sqrt{61}/61$

**BONUS**

3) MATH *Short Answer* Give the unit direction vector for the line of intersection between the planes  $x+2y=0$  and  $y-z=1$ .

ANSWER:  $\mathbf{i}+\mathbf{j}+\mathbf{k}$

---

**TOSS-UP**

4) PHYSICS *Short Answer* Rank the following three interactions by order of increasing distance.

- 1) Weak force
- 2) Strong force
- 3) Electromagnetic interaction

ANSWER: 1, 2 3

**BONUS**

4) PHYSICS *Multiple Choice* Which of the following is true about the magnitude of the residual strong force?

- W) Decreases with distance  
X) Increases with distance  
Y) Remains constant with distance  
Z) It increases then decreases

ANSWER: Z) It increases then decreases

---

**TOSS-UP**

5) CHEMISTRY *Multiple Choice* Which of the following two equimolar solutions will produce a pH closest to neutral when mixed?

- W) Acetic acid and calcium hydroxide
- X) Acetic acid and ammonia
- Y) Hydrochloric acid and calcium hydroxide
- Z) Hydrochloric acid and ammonia

ANSWER: X) Acetic acid and ammonia

### BONUS

5) CHEMISTRY *Short Answer* A single electron in its ground state is trapped in a 1-dimensional infinite potential well. When subjected to light with a wavelength of 800 nm, it enters its first excited state. Determine the wavelength of light that is required for the electron to enter its second excited state from its ground state.

ANSWER: 300 nm

---

### TOSS-UP

6) BIOLOGY *Multiple Choice* Which of the following neurotransmitters is secreted significantly in the enteric nervous system to control digestion?

- W) Serotonin
- X) Glutamate
- Y) Dopamine
- Z) Norepinephrine

ANSWER: W

### BONUS

6) BIOLOGY *Short Answer* The ependymal cells of the choroid plexus secrete what fluid?

ANSWER: Cerebrospinal Fluid

---

### TOSS-UP

7) EARTH AND SPACE *Multiple Choice* Which of the following mechanisms results in cloud formation on the windward side of mountain ranges?

- W) Orographic lifting
- X) Frontal wedging
- Y) Convection
- Z) Convergence lifting

ANSWER: W) Orographic lifting

### **BONUS**

7) EARTH AND SPACE *Short Answer* Give the common name for all the following features of volcanoes.

- I. Cone shaped accumulations from magma flow separate from the central vent
- II. Incandescent cloud of gas and ash that rushes down the sides of the volcano
- III. Dome of granite that remains after most of the volcano has eroded away

ANSWER: Parasitic cone, pyroclastic flow (nuee ardente), inselberg

---

### **TOSS-UP**

8) MATH *Short Answer* 5 sheep and 1 wolf are arranged in a circle. The wolf either eats the sheep on his left or right with equal probability, and keeps repeating this process with the remaining sheep. What is the probability that the last sheep to be eaten is the sheep initially located diametrically opposite the wolf?

ANSWER: 3/8

### **BONUS**

8) MATH *Short Answer* Arun randomly and uniformly picks a real number in  $[0,10]$ . If the first number he picks is A, he then randomly picks a second real number B in  $[0,A]$ . What is the probability that B is less than 4?

ANSWER: 16/25

---

### **TOSS-UP**

9) PHYSICS *Short Answer* A mass is hanging from a spring and is given a small push. Indicate all of the following choices that would increase the period of oscillation.

- 1) Doubling the mass
- 2) Adding another spring in parallel

3) Increasing the gravitational acceleration

ANSWER: 1

**BONUS**

9) PHYSICS *Short Answer* A 4 kg ball is rolling around at the bottom of a hollow hemispherical surface. This surface has a radius of curvature of 1 meter. What is the angular frequency of the ball if it is given a small push, to 1 significant digit? Neglect friction.

ANSWER: 3 (rad/s)

---

**TOSS-UP**

10) CHEMISTRY *Short Answer* Identify all of the following three molecules that have noninteger bond orders:

- I. C<sub>2</sub>
- II. B<sub>2</sub>H<sub>6</sub>
- III. OF<sub>2</sub>

ANSWER: II

**BONUS**

10) CHEMISTRY *Short Answer* Compound A can undergo two parallel reactions to form B and C with rate constants  $k_B = 0.2 \text{ s}^{-1}$  and  $k_C = 0.5 \text{ s}^{-1}$ . To the nearest second, what is the half life of compound A?

ANSWER: 1 second

---

**TOSS-UP**

11) BIOLOGY *Multiple Choice* The pGLO plasmid is induced in the presence of what sugar?

- W) Lactose
- X) Glucose
- Y) Erythrose
- Z) Arabinose

ANSWER: Z

**BONUS**

11) BIOLOGY *Short Answer* The sarcolemma is the plasma membrane of what type of human cell?

ANSWER: Muscle Cell

---

**TOSS-UP**

12) EARTH AND SPACE *Short Answer* How many points are needed to find the epicenter of a earthquake?

ANSWER: 3

**BONUS**

12) EARTH AND SPACE *Short Answer* What type of metamorphism occurs when hydrothermal fluids alter the chemical composition of the rock?

ANSWER: Metasomatism

---

**TOSS-UP**

13) MATH *Multiple Choice* Which of the following expressions is equivalent to  $(\sin x - \cos x)^2 + (\sin x + \cos x)^2$ ?

W)  $1 - 2 \sin(x)$

X)  $1 - \sin(2x)$

Y)  $4 \tan x$

Z) 2

ANSWER: Z) 2

**BONUS**

13) MATH *Short Answer* What is the x value which satisfies the condition of the Mean Value Theorem for  $f(x) = x^3$  on the interval  $[0,2]$ ?

ANSWER:  $2\sqrt[3]{3}/3$

---

## **TOSS-UP**

14) PHYSICS *Short Answer* Give the Gaussian surface associated with application of Gauss's Law for each of the following 3 charge distributions:

- I. Infinite charged plate
- II. Infinitely long wire
- III. Point charge

ANSWER: I. cylinder, II. cylinder, III. sphere

## **BONUS**

14) PHYSICS *Short Answer* What is the resonant angular frequency of an RLC circuit consisting of a 5 H inductor, 5 F capacitor, 35 ohm resistor?

ANSWER: 0.2

---

## **TOSS-UP**

15) CHEMISTRY *Multiple Choice* When the natural log of the equilibrium constant is graphed against 1/T for a certain reaction, the graph is linear with a positive slope and positive y-intercept. Which of the following can be concluded from the graph?

- W) The reaction is always spontaneous
- X) The reaction is never spontaneous
- Y) The reaction is spontaneous at high temperatures
- Z) The reaction is spontaneous at low temperatures

ANSWER: W) The reaction is always spontaneous

## **BONUS**

15) CHEMISTRY *Short Answer* The reversible oxidation of Ce<sup>3+</sup> to Ce<sup>4+</sup>, with standard potential -1.7 V, is performed against a reference hydrogen electrode held at a pH of 0 with an applied potential difference that increases linearly with time. The absorbance of Ce<sup>4+</sup> is monitored throughout the experiment with a spectrophotometer. Identify all of the following three statements that are true:

- I. The absorbance of the solution increases linearly with time
- II. The absorbance is maximal when the applied potential is 1.7 V

III. The pH of the solution increases

ANSWER: None

---

### TOSS-UP

16) BIOLOGY *Short Answer* Which part of the limbic system is central to addiction by being the dopamine center for motivation?

ANSWER: Nucleus Accumbens

### BONUS

16) BIOLOGY *Short Answer* By name or number, indicate all of the following that are true of heat shock.

- 1) Requires calcium chloride
- 2) Used to open adhesion pores
- 3) Cannot be used to introduce plasmids into bacteria

ANSWER: 12

---

### TOSS-UP

17) EARTH AND SPACE *Multiple Choice* By name or number, identify the period for each of the following epochs:

- I. Oligocene
- II. Pennsylvanian
- III. Lopingian

ANSWER: I. Paleogene, II. Carboniferous, III. Permian

### BONUS

17) EARTH AND SPACE *Short Answer* By name or number, indicate all of the following 3 statements which must be true of Artesian wells:

- I. Their height must be below that of the pressure surface
- II. A permeable rock layer must be located between two aquiclude
- III. They can increase the rate of cavern formation in limestone aquifers

ANSWER: All

---

**TOSS-UP**

18) MATH *Short Answer* If John throws a stone and he models the stone's height in meters with the function  $h(t)=5t^2-3t+9$ , what is the horizontal distance from John's position and the point of maximum height in terms of meters.

ANSWER: 3/10

**BONUS**

18) MATH *Short Answer* Find the area bounded by the  $y=x^2$ ,  $y=-x+2$ , and  $x=0$

ANSWER: 7/6

---

**TOSS-UP**

19) PHYSICS *Multiple Choice* A balloon feels a buoyant force of  $F$  when submerged near the water surface. Approximately how far down must we push the balloon so that it feels a force  $\frac{1}{2}F$ ?

W) 2m

X) 5m

Y) 7m

Z) 10m

ANSWER: Z) 10m

**BONUS**

19) PHYSICS *Short Answer* Suppose electrons in a conductor follow the fermi dirac distribution. Which of the following would increase the number of electrons at an energy level of 8J, where the fermi energy is 6J?

- 1) Increase temperature
- 2) Decrease fermi energy
- 3) Increase electrical potential

ANSWER: 1

---

**TOSS-UP**

20) CHEMISTRY *Short Answer* Identify all of the following three models in which the HOMO-LUMO gap increases in energy with increasing principal quantum number:

- I. Bohr hydrogen atom
- II. 1-dimensional box
- III. Spherical potential well

ANSWER: II, III

### BONUS

20) CHEMISTRY *Short Answer* A 1 L sample of helium gas is expanded isothermally to a final volume of 8 L. It is then cooled at constant volume until its entropy is the same as its initial state. If the ratio of the initial to final temperature of the gas is  $\ln k$ , determine  $k$ .

ANSWER: 4

---

### TOSS-UP

21) BIOLOGY *Short Answer* Fermentation is carried out in order to regenerate what molecule?

ANSWER: NAD+ (DO NOT ACCEPT: NADH)

### BONUS

21) BIOLOGY *Short Answer* By name or number, indicate all of the following that are anticoagulants.

- 1) Aspirin
- 2) Heparin
- 3) Warfarin
- 4) Prostacyclin [ $\text{PGI}_2$ ]

ANSWER: all

---

### TOSS-UP

22) EARTH AND SPACE *Multiple Choice* Which of the following characteristics is not true about extreme population II type stars?

- W) They reside in the halo
- X) They have eccentric orbits

- Y) They are the oldest stars
- Z) They are metal rich

ANSWER: Z) They are metal rich

### **BONUS**

22) EARTH AND SPACE *Short Answer* What type of focus utilizes a thin correcting lens above the secondary mirror, ultimately allowing light to escape through a hole at the bottom of the objective mirror?

ANSWER: Schmidt-Cassegrain

---

### **TOSS-UP**

23) MATH *Short Answer* Estimate to three significant digits the following using a first order expansion:  $e^{0.02}$

ANSWER: 1.02

### **BONUS**

23) MATH *Short Answer* What is the surface integral over a closed spherical shell of radius 6 centered at the origin of the function  $xi + yj + zk$ ?

ANSWER:  $1728\pi$

---

### **TOSS-UP**

24) PHYSICS *Multiple Choice* The solution to the twin paradox in special relativity can be explained by what?

- W) Time dilation
- X) Non-inertial reference frames
- Y) The equivalence principle
- Z) Gravitational waves

ANSWER: X) Non-inertial reference frames

### **BONUS**

24) PHYSICS *Multiple Choice* Two events A and B occur at the spacetime coordinates  $(x, ct) = (4, 5)$  for event a and  $(9, 8)$  for event B. These events are:

W) Timelike

X) Spacelike

Y) Lightlike

Z) Pointlike

ANSWER: X) Spacelike

---

### TOSS-UP

25) CHEMISTRY *Short Answer* Rank the following three diatomic molecules in increasing ionization energy:  $N_2$ ,  $O_2$ ,  $F_2$ .

ANSWER: II, III, I

### BONUS

25) CHEMISTRY *Short Answer* There exists a curious electron-rich compound C where the standard reduction potential from the  $+n$  oxidation state to the 0 oxidation state is  $n$  volts. What is the standard reduction potential of the reduction of  $C^{2020+}$  to  $C^{2019+}$ ?

ANSWER: 4039 V