

TOSS-UP

1) Math — *Short Answer* What is the partial derivative with respect to y of the expression x^4y^7 ?

ANSWER: $7x^4y^6$

BONUS

1) Math — *Short Answer* Approximating the natural log of 2 as 0.7, and starting with 2048 on a calculator display, how many times must one successively press the natural logarithm button to get a negative value in the display?

ANSWER: 4

TOSS-UP

2) Physics — *Short Answer* A frictionless 2-kilogram cart is moving along the x -axis with a kinetic energy of 100 joules. It collides elastically with a second frictionless cart of mass 6 kilograms that is originally at rest on the x -axis. In joules, what is the final kinetic energy of the two-cart system?

ANSWER: 100

BONUS

2) Physics — *Short Answer* A bob swinging on a pendulum has a tangential [*tan-JEN-chul*] speed of 3 meters per second. If the length of the string is 2 meters and the magnitude of the centripetal force is 18 newtons, then, in kilograms, what is the mass of the bob?

ANSWER: 4

TOSS-UP

3) Biology — *Short Answer* What plant ground-tissue type has thick, lignified cell walls?

ANSWER: SCLERENCHYMA

BONUS

3) Biology — *Multiple Choice* During systole [*SIS-tah-lee*], blood is expelled from the ventricles of the heart. Which of the following is TRUE of the heart during systole?

W) The ventricles are hyperpolarized

X) The pressure in the aorta is higher than the pressure in the left ventricle

Y) The atrioventricular [*ay-tree-oh-ven-TRIK-yoo-lur*] valves are closed

Z) The semilunar valves are closed

ANSWER: Y) THE ATRIOVENTRICULAR VALVES ARE CLOSED

TOSS-UP

4) Chemistry — *Multiple Choice* One hundred millimoles of each of the following compounds is dissolved in a liter of water. Which of them will produce the solution of lowest ionic resistance ?

- W) Hydrochloric acid
- X) Ammonia
- Y) Acetic acid
- Z) Methylamine [*methyl-ah-MEEN*]

ANSWER: W) HYDROCHLORIC ACID

BONUS

4) Chemistry — *Short Answer* Identify all of the following three statements that are true of equilibrium: 1) Increasing the temperature of an exothermic reaction will decrease K ; 2) Increasing the temperature of an endothermic reaction will favor product formation; 3) Decreasing the temperature of an exothermic reaction will shift the equilibrium position toward products.

ANSWER: ALL

TOSS-UP

5) Earth and Space — *Multiple Choice* A monocline is an example of which of the following?

- W) Basin
- X) Fold
- Y) Dome
- Z) Mountain range

ANSWER: X) FOLD

BONUS

5) Earth and Space — *Multiple Choice* Which of the following is closest to the top speed, in miles per hour, of a tsunami?

- W) 60
- X) 100
- Y) 600
- Z) 1,000

ANSWER: Y) 600

TOSS-UP

6) Energy — *Multiple Choice* Scientists at Fermilab are building devices to perform quantum teleportation of qubits [*CUE-bits*] over long distances. Which of the following is a unique property of qubits, compared to classical bits?

- W) Can form entangled states
- X) Can achieve faster-than-light communication
- Y) Are less error-prone than classical bits
- Z) Are cheaper to produce than classical bits

ANSWER: W) CAN FORM ENTANGLED STATES

BONUS

6) Energy — *Multiple Choice* Scientists are using the Advanced Photon Source to study the gumboot chiton [*KYE-tun*]. This organism's teeth contain what element found in santabarbarite?

- W) Zinc
- X) Calcium
- Y) Barium
- Z) Iron

ANSWER: Z) IRON

TOSS-UP

7) Math — *Multiple Choice* A square has an irrational side length. Which of the following **MUST** be true of the length of the diagonal of the square?

- W) It is irrational
- X) It is rational
- Y) It could be rational and it could be irrational
- Z) It is $\sqrt{3}$ times the length of a side

ANSWER: Y) IT COULD BE RATIONAL AND IT COULD BE IRRATIONAL

BONUS

7) Math — *Short Answer* Express the fraction with numerator $\frac{17 + 9i}{1 + 2i}$ and denominator $\frac{1 + 2i}{1 + 2i}$ in standard $a + bi$ form.

ANSWER: $7 - 5i$

TOSS-UP

8) Physics — *Short Answer* Identify all of the following three changes that would increase the period of a simple pendulum:

1) Increasing the length of the string; 2) Increasing the mass of the bob; 3) Decreasing the mass of the bob.

ANSWER: 1

BONUS

8) Physics — *Short Answer* A 0.6-kilogram mass is attached to a vertical spring, and the spring is stretched by 1.5 centimeters when the system reaches equilibrium. In newtons per meter and to two significant figures, what is the spring constant of the spring?

ANSWER: 390

TOSS-UP

9) Biology — *Short Answer* What is the term for the growth of a plant stem upward against the pull of gravity?

ANSWER: GRAVITROPISM (ACCEPT: GEOTROPISM, NEGATIVE GRAVITROPISM, NEGATIVE GEOTROPISM)

BONUS

9) Biology — *Short Answer* The activity of enterokinase [*en-tur-o-KYE-nase*] directly results in the production of what active protein?

ANSWER: TRYPSIN

TOSS-UP

10) Chemistry — *Multiple Choice* Which of the following oxygen-containing compounds has the highest mass percentage of oxygen?

- W) CaO
- X) BaCO₃
- Y) Sr₂SO₄
- Z) Al₂O₃

ANSWER: Z) Al₂O₃

BONUS

10) Chemistry — *Multiple Choice* One proposed solution for carbon capture is to use the reaction of calcium oxide with carbon dioxide to form calcium carbonate. Which of the following is true regarding this process?

- W) This reaction requires large quantities of thermal energy to proceed
- X) This reaction is entropically [*en-TRAW-pik-ah-lee*] favorable
- Y) Increasing the amount of carbon dioxide while holding the calcium oxide amount constant will always increase the amount of calcium carbonate produced
- Z) This reaction is spontaneous at low temperatures

ANSWER: Z) THIS REACTION IS SPONTANEOUS AT LOW TEMPERATURES

TOSS-UP

11) Earth and Space — *Short Answer* Apart from its ice caps, Mars also has large amounts of water frozen in a subsurface layer of what type of ground?

ANSWER: PERMAFROST

BONUS

11) Earth and Space — *Multiple Choice* Which of the following asterisms would be most helpful in locating the general vicinity of the Andromeda Galaxy?

- W) Orion's belt
- X) Southern cross
- Y) The Sickle
- Z) Great Square of Pegasus

ANSWER: Z) GREAT SQUARE OF PEGASUS

TOSS-UP

12) Energy — *Short Answer* Scientists supported by the Department of Energy are studying a quasiparticle that can be thought of as a quantized sound wave. What is the term for this quasiparticle?

ANSWER: PHONON

BONUS

12) Energy — *Multiple Choice* Scientists supported by the Department of Energy are studying semimetals. Which of the following best describes a semimetal?

- W) A material with no overlap between the valence band and the conduction band
- X) A material with a complete overlap between the valence band and the conduction band
- Y) A material with a slight overlap between the valence band and the conduction band
- Z) A material with a reversed ordering of the valence band and the conduction band

ANSWER: Y) A MATERIAL WITH A SLIGHT OVERLAP BETWEEN THE VALENCE BAND AND THE CONDUCTION BAND

TOSS-UP

13) Math — *Short Answer* If the graph of y equals open parenthesis $x + 5$ close parenthesis squared $- 4$ is translated 2 units to the right and 6 units up, what are the coordinates of the vertex of the image?

ANSWER: $(-3, 2)$ (ACCEPT: $x = -3$ AND $y = 2$)

BONUS

13) Math — *Short Answer* What is the quadratic polynomial with integer coefficients and smallest possible positive leading coefficient that has the same sum and product of all its complex zeroes as $4x^3 + 8x^2 - 5x - 7$?

ANSWER: $4x^2 + 8x + 7$

TOSS-UP

14) Physics — *Multiple Choice* Which of the following pairs of fundamental forces are the most important for modeling the behavior of nucleons in a carbon-12 nucleus?

- W) Strong and weak
- X) Strong and electromagnetic
- Y) Weak and electromagnetic
- Z) Strong and gravity

ANSWER: X) STRONG AND ELECTROMAGNETIC

BONUS

14) Physics — *Short Answer* Benzene has an index of refraction of 1.501. In meters per second and in scientific notation with two significant figures, what is the speed of light in benzene?

ANSWER: 2.0×10^8

TOSS-UP

15) Biology — *Short Answer* In mammals, most non-shivering heat production happens in what specialized adipose [*AD-ih-pohss*] tissue?

ANSWER: BROWN FAT (ACCEPT: BROWN)

BONUS

15) Biology — *Short Answer* What photosensitive receptor protein family is thought to be conserved across all animal species?

ANSWER: RHODOPSIN (ACCEPT: OPSIN)

TOSS-UP

16) Chemistry — *Multiple Choice* What is the formula of the ionic compound composed of the zinc cation [*CAT-eye-on*] and sulfite anion [*AN-eye-on*]?

W) ZnSO_3

X) Zn_2SO_3

Y) $\text{Zn}(\text{SO}_3)_2$ [*Z-n-S-oh-3-2*]

Z) $\text{Zn}_3(\text{SO}_3)_2$ [*Z-n-3-S-oh-3-2*]

ANSWER: W) ZnSO_3

BONUS

16) Chemistry — *Multiple Choice* Which of the following is NOT true for the behavior of gases according to kinetic molecular theory?

W) At the same temperature, all gases have the same average kinetic energy

X) As gas particles collide, they do not lose energy

Y) The gas particles do not exert forces on one another

Z) Gases with larger molar masses have greater root mean square speeds than smaller gases

ANSWER: Z) GASES WITH LARGER MOLAR MASSES HAVE GREATER ROOT MEAN SQUARE SPEEDS THAN SMALLER GASES

TOSS-UP

17) Earth and Space — *Multiple Choice* The wet bulb of a psychrometer [*sigh-KRAW-met-er*] is used to measure which of the following properties of the atmosphere?

- W) Air temperature
- X) Air pressure
- Y) Humidity
- Z) Wind chill

ANSWER: Y) HUMIDITY

BONUS

17) Earth and Space — *Multiple Choice* Long after ocean crust is formed and transported away from the mid-ocean ridge, the crust will become more dense and sink lower into the mantle. Which of the following is primarily responsible for this effect?

- W) Accumulation of marine sediment
- X) Cooling of the crust
- Y) Tectonic compression
- Z) Water infiltration into the crust

ANSWER: X) COOLING OF THE CRUST

TOSS-UP

18) Energy — *Multiple Choice* Scientists supported by the Department of Energy are developing novel semiconductors. Which of the following materials is an example of a semiconductor?

- W) Gallium [*GAL-ee-um*] arsenide
- X) Brass
- Y) Calcium carbide
- Z) Dinitrogen monoxide

ANSWER: W) GALLIUM ARSENIDE

BONUS

18) Energy — *Multiple Choice* Scientists at Brookhaven National Lab are studying how pairs of Higgs bosons interact. Which of the following phenomena is most directly explained by the existence of the Higgs boson?

- W) Gravitational lensing
- X) Proton decay
- Y) Supersymmetry breaking
- Z) Mass of W and Z bosons

ANSWER: Z) MASS OF W AND Z BOSONS

Before we leave, let's confirm the team's score. What score does the Official Scorekeeper have? And what is the final score in the Chat Box? Does anyone disagree?

I'd like to remind the Scorekeeper to submit the official scoresheet. Best of luck to the team and thanks for competing in today's event.