

ESBOT

2023

DE6

Tossup

1) *Physics – Short Answer:* What is the wave speed in meters per second on a 100 meter long string if its mass is 1 kilogram and a tension of 4 Newtons is exerted on it?

ANSWER: 20

Bonus

1) *Physics – Short Answer:* Identify all of the following 3 statements that are true of neutrinos:

- I) Their flavor can oscillate
- II) A neutrino with a known flavor has a known mass
- III) Neutrinos can only have right-handed chirality

ANSWER: I only

Tossup

2) *Biology – Short Answer:* Select all of the following three statements that are true of cell signaling:

- I) Receptor tyrosine kinases are capable of creating multiple phosphorylation cascades from a single ligand
- II) Cyclic AMP is the most common second messenger in humans
- III) IP3 is used to release calcium from the endoplasmic reticulum

ANSWER: I and III

Bonus

2) *Biology – Short Answer:* What protein supersecondary structure is often used to bind to DNA and involves a central zinc prosthetic group?

ANSWER: Zinc finger

Tossup

3) *Chemistry – Short Answer:* When comparing the atomic radii of elements down a group, the elements Gallium and Germanium have anomalously low radii. What is the name of the effect that causes this?

ANSWER: d block contraction

Bonus

3) *Chemistry – Multiple Choice:* Which of the following best explains why dilute HF is a weak acid and all other hydrogen halides are strong acids?

W) The bond dissociation energy of HF is much higher than the other hydrogen halides

X) The dissolution of HF is very exothermic

Y) The entropy of solvation of F^- is very negative

Z) HF is able to self-conjugate into H_2F^+ and HF_2^-

ANSWER: Y) The entropy of solvation of F^- is very negative

Tossup

4) *Math – Short Answer:* A regular hexagon is inscribed in another regular hexagon. If the outer hexagon has a side length of 2, what is the smallest possible side length of the inner hexagon?

ANSWER: $\sqrt{3}$

Bonus

4) *Math – Short Answer:* Order the following 3 numbers in increasing order:

1) 2^{100}

2) 10^{30}

3) 3^{70}

ANSWER: 2, 1, 3

Tossup

5) *Earth and Space – Short Answer:* What is the primary process responsible for the formation of greywacke?

ANSWER: Turbidity Currents

Bonus

5) *Earth and Space – Short Answer:* Order the following 3 parts of an ocean transgression sequence from deepest to shallowest:

- 1) Conglomerate
- 2) Sandstone
- 3) Limestone

ANSWER: 1, 2, 3

Tossup

6) *Physics – Short Answer:* Colin throws a 0.7 kilogram ball and gives it a kinetic energy of 140 Joules. What is the ball's momentum in kilogram meters per second?

ANSWER: 14

Bonus

6) *Physics – Short Answer:* Kaiwen is building a pendulum for his clock and needs to decide which pendulum to use. Order the following 3 pendulums in order of increasing period:

- 1) Mass of M at the end of a massless rod of length L
- 2) A rod of length $3L$ with mass $3M$
- 3) A rod of length $4L$ with mass M

ANSWER: 1, 2, 3

Tossup

7) *Math – Short Answer:* The KNG 10 math competition consists of 30 multiple-choice questions. Each question has 5 answer choices, in which only 1 is correct. 7 points are awarded for a correct answer, 2.5 points are awarded for no answer, and 0 points are awarded for an incorrect answer. Assuming somebody answers every question at random, what is their expected score?

ANSWER: 42

Bonus

7) *Math – Multiple Choice:* Let A be the set of all prime numbers one less than a power of 2, and let B be the set of all numbers one greater than a factor of 24. Which of the following ordered pairs would be in the set formed by the Cartesian product of A and B?

W) (3, 3)

X) (5, 7)

Y) (1, 2)

Z) (4, 5)

ANSWER: W) (3, 3)

Tossup

8) *Energy – Short Answer:* Researchers at Oak Ridge National Lab are studying a rare insect species called chimera ants. In this species, male worker ants inherit all their genes from their mother, making them haploid. What is this form of sex determination pattern called?

ANSWER: Haplodiploidy

Bonus

8) *Energy – Short Answer:* Chimera ants employ a process called phagogenesis, where they incorporate genes from the organisms they consume into their offspring's genomes. The mechanism by which this occurs is analogous to the process in CRISPR where viral genetic material is added to the host genome. In CRISPR systems, what two enzymes add viral spacers to the bacterial genome?

ANSWER: Cas1 and Cas2

Tossup

9) *Earth and Space – Multiple Choice*: Due to its high temperature and pressure at the surface, in which of the following states of matter is the atmosphere of Venus near the surface?

- W) Liquid
- X) Plasma
- Y) Supercritical Fluid
- Z) Gas

ANSWER: Y) Supercritical Fluid

Bonus

9) *Earth and Space – Short Answer*: During the grand unification epoch, the only two forces present in the universe were the electronuclear force and what other force?

ANSWER: Gravity

Tossup

10) *Chemistry – Short Answer*: What are the formal charges on the central atom and outer atoms, respectively, in a triiodide [**tri-io-dide**] ion?

ANSWER: -1, 0

Bonus

10) *Chemistry – Short Answer*: Identify all of the following 3 phenomena that are observed when a small amount of Methyl Lithium is added to liquid water:

- I) Evolution of a gas
- II) Formation of a colorless precipitate
- III) A color change in the solution

ANSWER: I only

Tossup

11) *Math – Short Answer:* Andy, Brandon, and Colin are picking partners. If there is a $\frac{1}{3}$ probability Andy prefers Brandon as his partner and a $\frac{1}{5}$ probability Brandon prefers Colin as his partner, what is the probability that Andy and Brandon both prefer each other as their partners?

ANSWER: $\frac{4}{15}$

Bonus

11) *Math – Short Answer:* If $x + \frac{1}{x} = 3$, what is $x^4 + \frac{1}{x^4}$?

ANSWER: 47

Tossup -

12) *Biology – Short Answer:* What circulatory fluid is found in arthropods instead of blood?

ANSWER: Hemolymph

Bonus

12) *Biology – Short Answer:* Identify all of the following 3 kingdoms of life that are correctly paired with their sister taxon:

- I) Animalia - Choanoflagellates
- II) Plantae - Chlorophyte
- III) Fungi - Nuclearioid

ANSWER: I, III

Tossup

13) *Energy – Multiple Choice:* Researchers at SLAC are using the LINAC coherent light source to study the geometry of transition metal complexes. Which of the following molecular geometries is not correctly paired with its coordination number?

- W) Trigonal prismatic; 6
- X) Pentagonal bipyramidal; 6
- Y) Square pyramidal; 5
- Z) Square antiprismatic; 8

ANSWER: X) Pentagonal bipyramidal; 6

Bonus

13) *Energy – Short Answer:* Scientists at Pacific Northwest National Laboratory are studying volcanism in the western United States. What ancient subducted plate which underlies the western United States is thought to be responsible for much of the volcanism in the area?

ANSWER: Farallon Plate

Tossup

14) *Chemistry – Short Answer:* What effect, which can induce large NMR shifts in aromatic molecules, involves the motion of delocalized electrons around the aromatic ring?

ANSWER: Ring current effect (ACCEPT: Magnetic anisotropy)

Bonus

14) *Chemistry – Multiple Choice:* During a complicated chemical process, Colin must pass a solution over some CaF_2 crystals. If the concentration of calcium in his solution gets too high, the process will be ruined, so he would like to limit the concentration of Ca^{2+} to 2×10^{-5} Molar. If CaF_2 has a solubility product of 4×10^{-11} , which of the following is closest to the molarity of NaF Colin should add to the solution to achieve his goal?

- W) 10^{-5}
- X) 10^{-4}
- Y) 10^{-3}
- Z) 10^{-2}

ANSWER: Y) 10^{-3}

Tossup

15) *Physics – Multiple Choice:* Consider a conducting spherical shell with point A at the center of the shell and point B on the inside surface of the shell. Which of the following best describes the electric potential of the two points when two point charges of unknown magnitude are placed near the shell?

- W) Potential at A is higher than potential at B
- X) Potential at A is lower than potential at B
- Y) Potential at A is equal to the potential at B
- Z) The potentials depend on the external charges

ANSWER: Y) Potential at A is equal to the potential at B

Bonus

15) *Physics – Short Answer:* A Carnot engine is running between two reservoirs with temperatures 150 Kelvin and 500 Kelvin. If the isothermal compression expels 90 Joules of heat, what is the entropy change in the system during isothermal expansion in Joules per Kelvin?

ANSWER: 0.6

Tossup

16) *Biology – Short Answer:* What hypothesis states that the earliest form of genetic elements were self-replicating RNA that got translated into proteins?

ANSWER: RNA world hypothesis

Bonus

16) *Biology – Multiple Choice:* An orchid mantis is a species of mantis native to southeast Asia that is known for resembling an orchid flower, which allows it to hunt prey without being recognized. What type of mimicry does the orchid mantis use?

- W) Batesian mimicry
- X) Aggressive mimicry
- Y) Rewarding mimicry
- Z) Mullerian mimicry

ANSWER: X) Aggressive mimicry

Tossup

17) *Earth and Space – Short Answer:* Identify all of the following 3 eruptive styles which commonly result from cinder cones:

- I) Hawaiian
- II) Vulcanian
- III) Plinian

ANSWER: II only

Bonus

17) *Earth and Space – Multiple Choice:* Which of the following best describes the change in flow of the Somali current between July and January?

- W) It flows northward in July and weakens in January
- X) It flows southward in July and weakens in January
- Y) It flows northward in July and southward in January
- Z) It flows southward in July and northward in January

ANSWER: Y) It flows northward in July and southward in January

Tossup

18) *Physics – Multiple Choice:* Kaiwen is sending a wave down a transmission line with a certain impedance Z . If the wave suddenly reaches a new section of the line with a different impedance, which of the following best describes what happens to the wave?

- W) Some wave energy is dissipated as heat at the junction
- X) Some wave energy is reflected back up the line
- Y) Some wave energy is dissipated outwards from the transmission line
- Z) The wave continues with the same energy, but phase shifted

ANSWER: X) Some wave energy is reflected back up the line

Bonus

18) *Physics – Multiple Choice:* Consider a proton traveling at a speed of $0.01c$ and an electron traveling at an unknown speed. Assuming that a proton is 2000 times more massive than the electron and giving your answer to one significant figure, how many times faster should the electron be traveling so that both particles have the same total energy?

ANSWER: 100

Tossup

19) *Math – Short Answer:* Identify all of the following 4 equilateral polygons that do not have their area uniquely determined by their side length:

- I) Triangle
- II) Rhombus
- III) Pentagon
- IV) Hexagon

ANSWER: II, III, IV

Bonus

19) *Math – Short Answer:* How many ways are there to jump up 6 stair steps if each jump can cover 1 or 3 stair steps?

ANSWER: 6

Tossup

20) *Chemistry – Short Answer:* In terms of R, what is the constant-pressure heat capacity of an ideal gas with 9 degrees of freedom?

ANSWER: $11R/2$

Bonus

20) *Chemistry – Multiple Choice:* In Debye-Huckel theory, ions are assumed to be spherical point charges with zero dipole moment. Which of the following ions would be worst approximated by Debye-Huckel theory?

- W) NH_4^+
- X) SO_3^{2-}
- Y) PO_4^{3-}
- Z) Hg_2^{2+}

ANSWER: X) SO_3^{2-}

Tossup

21) *Biology – Short Answer:* Identify all of the following 3 plant hormones that are involved with regulation of apical dominance:

- I) Auxins
- II) Cytokinins
- III) Strigolactones

ANSWER: All

Bonus

21) *Biology – Short Answer:* Antidiuretic hormone affects water retention in the kidneys by increasing the amount of aquaporins present in what part of the nephron?

ANSWER: Collecting duct (ACCEPT: distal tubule)

Tossup

22) *Earth and Space – Multiple Choice*: Which of the following types of stars lacks hydrogen in its spectra?

- W) Wolf-Rayet
- X) Mira Variable
- Y) Heavy-Metal-Oxide
- Z) Peculiar A

ANSWER: W) Wolf-Rayet

Bonus

22) *Earth and Space – Multiple Choice*: Which of the following statements is true of the rate of expansion of spacetime since the end of the inflationary epoch?

- W) It has monotonically increased
- X) It has monotonically decreased
- Y) It decreased, then increased
- Z) It increased, then decreased

ANSWER: Y) It decreased, then increased

Tossup

23) *Energy – Short Answer*: Researchers at Fermilab are studying potential dark matter candidates. One of the candidates for dark matter is a spin 0, massful boson that can decay into two photons, and can also serve as a solution to the strong CP problem. What is the name of this particle?

ANSWER: Axion

Bonus

23) *Energy – Short Answer*: Researchers at Fermilab are studying quantum chromodynamics and the different types of interactions in baryons. The sigma and sigma star baryons consist of the same quarks, but differ from each other due to different values of mass and what other property?

ANSWER: Spin (ACCEPT: Angular momentum, DO NOT ACCEPT: Isospin)