ESBOT

2023

DE10

Tossup

1) *Biology – Short Answer:* Select all of the following 3 groups of protists that have heteromorphic generations:

    I) Brown Algae
    II) Plasmodium
    III) Paramecium

ANSWER: I and II

Bonus

1) *Biology – Short Answer:* Select all of the following 4 characteristics that are true of frogs:

    I) They utilize negative pressure breathing
    II) They are poikilotherms
    III) They undergo meroblastic cleavage
    IV) They have 3 chambered hearts

ANSWER: II, IV

Tossup

2) *Math – Short Answer:* What is the angle in degrees formed by the minute and hour hands of a clock at 6:30?

ANSWER: 15

Bonus

2) *Math – Short Answer:* Nikhil is planning on walking from his house to the 2023 Genshin Expo. Nikhil lives at (0,0) and the Genshin Expo is at (6,4), and can only walk North or East on lattice points. However, he wants to avoid a patch of grass on the way there, which is located at (4,3). How many ways are there for Nikhil to go to the Genshin Expo without touching grass?

ANSWER: 105

Tossup

3) *Earth and Space – Multiple Choice:* Calcrete most commonly forms in which of the following Koppen climate classifications?

    W) A
    X) B
    Y) C
    Z) D

ANSWER: X) B

Bonus

3) *Earth and Space – Short Answer:* Order the following 3 minerals by increasing melting point:

    1) Anorthite
    2) Albite
    3) Sanidine

ANSWER: 3, 2, 1

Tossup

4) *Energy – Multiple Choice:* Scientists at Princeton University are probing the electronic structures of Iron Germanates under compression in diamond anvil cells at HP-CAT at the Advanced Photon Source in Argonne National Lab. In particular they want to figure out the pressure at which iron in mantel silicates transition from low to high spin. Which of the following techniques do they use to determine this transition?

    W) Mossbauer spectroscopy
    X) X-ray Fluorescence spectroscopy
    Y) Electron back-scattering diffraction
    Z) Positron emission tomography

ANSWER: W) Mossbauer spectroscopy

Bonus

4) *Energy – Short Answer:* Scientists at Idaho National Laboratory are studying thermophilic archaea found in the hot spring and geysers in Yellowstone and their heat shock proteins. What is the name of the atp dependent group II chaperonin that is considered to be the prototypical archeal chaperonin.

ANSWER: Thermosome

Tossup

5) *Physics – Short Answer:* Kaiwen's rocket engine parts have arrived in a box with a total mass of 80 kilograms. He places the box on frictionless wheels and pushes it forwards with a force of 40 Newtons. After 4 seconds of pushing, he accidentally engages the brakes and the box skids away from him with a friction force of 160 Newtons. How far in meters does the box travel after the brakes are engaged?

ANSWER: 1

Bonus

5) *Physics – Multiple Choice:* In a gas, both conduction and convection play a role in heat transfer. What quantity, defined as the kinematic viscosity divided by the conductivity, estimates the relative contributions of each type of heat transfer?

    W) Reynold's number
    X) Prandtl number
    Y) Stokes number
    Z) Poisson number

ANSWER: X) Prandtl number

Tossup

6) *Chemistry – Multiple Choice:* In a molecule of methylamine, electrons in which of the following hybrid orbitals will have the highest S character?

    W) N lone pair
    X) C-H bond
    Y) N-H bond
    Z) C-N bond

ANSWER: W) N lone pair

Bonus

6) *Chemistry – Short Answer:* A certain isomer of 10 annulene is planar. How many of its double bonds are cis?

ANSWER: 3

Tossup

7) *Math – Short Answer:* Sukrith is writing down his square roots. He writes down the square root of some integer n to the nearest thousandth. However, he spilled ink on the integer part of the square root! If all he can see is the fractional part, then what is the smallest value of n when the fractional part is equal to [**point seven three two**]?

ANSWER: 3

Bonus

7) *Math – Short Answer:* Consider an element of the permutation group P^5 **[P five]** that maps the sequence 1, 2, 3, 4, 5 to the sequence 4, 5, 3, 2, 1. What is the order of this element?

ANSWER: 4

Tossup

8) *Earth and Space – Multiple Choice:* Which of the following is responsible for the sporadic variability in luminosity of RS Canum Venaticorum variable Stars?

    W) Eddington Valve
    X) Stellar Surface Features
    Y) Gravitational Lensing
    Z) Planetary Transits

ANSWER: X) Stellar Surface Features

Bonus

8) *Earth and Space – Short Answer:* Which of the following statements is true of our models of galactic formation and evolution?

    W) Top-down theory underestimates the high relative frequency of large galaxies
    X) Bottom-up theory underestimates the high relative frequency of large galaxies
    Y) Top-down theory correctly estimates the high relative frequency of smaller galaxies
    Z) Bottom-up theory correctly estimates the high relative frequency of smaller galaxies

ANSWER: Z) Bottom up theory correctly estimates the high relative frequency of smaller galaxies

Tossup

9) *Biology– Multiple Choice:* Which of the following enzymes is not used in the energy payoff phase of glycolysis?

    W) Phosphoglyceromutase **[foss-fo-gliss-er-o-mut-ase]**
    X) Gluconolactonase **[glu-con-o-lac-ton-ase]**
    Y) Enolase
    Z) Triose Phosphate Dehydrogenase

ANSWER: X) Gluconolactonase

Bonus

9) *Biology – Short Answer:* Using the Lineweaver-Burk equation, what is the ratio of the substrate concentration to the Michaelis constant if the fractional saturation of the enzyme is 2/11?

ANSWER: 2/9

Tossup

10) *Physics – Short Answer:* Thanush is examining the wavefunction of his pet electron. He notices that at $t = 0$, his electron has a wavefunction of $\Psi(x)$ **[psi of x].** He wants to determine the uncertainty of his electron's momentum. To do so, he decomposes the electron's wave function into momentum eigenstates. What mathematical operation does he apply to the wave function to achieve this?

ANSWER: Fourier transform

Bonus

10) *Physics – Short Answer:* One mole of a monatomic ideal gas is kept at constant pressure. Its temperature is increased from 100 Kelvin to 200 Kelvin. In terms of physical constants, what is the change in entropy of the gas?

ANSWER: $\frac{5}{2}R \ln(2)$

Tossup

11) *Chemistry – Short Answer:* What quantity, which is approximately equal to the negative of the Mulliken electronegativity, is defined as the partial derivative of internal energy with respect to particle number?

ANSWER: Chemical potential

Bonus

11) *Chemistry – Multiple Choice:* Which of the following functions could represent reactant concentration as a function of time for a reaction governed by the rate law **[rate equals k times square root of the concentration of A]**

  W) **[C equals 3 e to the negative 4 t]**
  X) **[C equals 4 divided by the quantity 2t plus 5]**
  Y) **[C equals open parentheses 3 minus 2t close parentheses squared]**
  Z) **[C equals 1 divided by open parentheses 3t plus 1 close parentheses squared]**

ANSWER: Y) $C = (3 - 2t)^2$

Tossup - Rohit

12) *Earth and Space – Multiple Choice:* According to Andersonian fault theory, which of the following is true of Reverse Faults?

  W) The largest stress is oriented parallel to the direction of strike
  X) The largest stress is oriented parallel to the vertical
  Y) The largest stress is oriented parallel to the direction of dip
  Z) The largest stress is oriented perpendicular to the direction strike and the vertical

ANSWER: X) The largest stress is oriented parallel to the vertical

Bonus - Rohit

12) *Earth and Space – Short Answer:* Order the following 3 locations by increasing difference in water level between high tide and 12 hours 25 minutes after high tide:

  1) Tampa, Florida
  2) San Diego, California
  3) Wilmington, NC

ANSWER: 3, 2, 1

Tossup

13) *Biology – Short Answer:* The coiling of snail shells is regulated by a maternal effect gene, where a right-handed shell D **[big D]** is dominant to a left-handed shell d **[little d]**. If a female snail with genotype Dd **[big D little d]** is crossed with a male snail of genotype dd **[little d little d]**, what is the expected phenotypic ratio of right handed to left handed snails in the F2 generation?

ANSWER: 1:1

Bonus

13) *Biology– Short Answer:* Due to a mutation, the GTPase Ran **[ran]** has stopped functioning. This would most affect the import of molecules into what organelle?

ANSWER: Nucleus

Tossup

14) Energy– *Short Answer:* Scientists at the National Institute of Health and the CDC are studying various antigens with ELISA **[eh - lie - sa]**. Which of the following types of ELISA is considered to be both highly sensitive and highly specific.

    W) Direct
    X) Indirect
    Y) Sandwich
    Z) Competitive

ANSWER: Y) Sandwich

Bonus

14) *Earth and Space – Short Answer:* Scientists at NASA have recently launched the James Webb space telescope which has started to take ultra high resolution images of space. Which of the following is the primary contributor to the loss of resolving power in modern telescopes as determined by the Rayleigh criterion?

    W) Chromatic Aberration
    X) Diffraction through the objective
    Y) Diffraction through the focus
    Z) Lens Impurity

ANSWER: X) Diffraction through the objective

Tossup

15) *Physics – Short Answer:* Identify all of the following 3 pairs of vector quantities that must always be collinear:

       I) Angular velocity and angular momentum
       II) Relativistic force and relativistic acceleration
       III) Velocity and relativistic momentum

ANSWER: III only

Bonus

15) *Physics – Short Answer:* Identify all of the following 3 potential energy functions that could create closed orbits that obey Kepler's second law:

       I) $U = 1/r^2$
       II) $U = r^2$
       III) $U = \arctan(r)$

ANSWER: II and III

Tossup

16) *Math – Short Answer:* If M, A, T, and H are positive integers such that $M^2 + A^2 = 74$ and $T^2 + H^2 = 41$, what is the value of $M + A + T + H$?

ANSWER: 21

Bonus

16) *Math – Short Answer:* Let a two digit number AB be *nice* if the sum of the product of the digits and the sum of the digits of the number is equal to the number. What is the sum of all nice numbers?

ANSWER: 531

Tossup

17) *Chemistry – Short Answer:* What is the effect in which a radical is stabilized by both an electron donating and electron withdrawing group?

ANSWER: Captodative effect

Bonus

17) *Chemistry – Short Answer:* Identify all of the following 3 hydrides which would be appropriate to reduce a ketone into an alcohol in an aqueous solution:

   I) NaH
   II) $NaBH_4$
   III) $LiAlH_4$

ANSWER: II only

Tossup

18) *Biology – Short Answer:* Identify all of the following three statements that are true of long term potentiation:

   I) Activation of NMDA receptors requires depolarization of neurons by multiple activations of AMPA receptors
   II) At negative resting membrane potentials, NMDA receptors are blocked by Mg2+ ions
   III) NMDA receptors and long term potentiation are linked with the mediation of excitotoxicity

ANSWER: All

Bonus

18) *Biology – Multiple Choice:* Which of the following types of phyllotaxis describes an arrangement where each successive pair of leaves is at a right angle to the previous pair?

   W) Whorled
   X) Opposite
   Y) Decussate
   Z) Distichous

ANSWER: Y) Decussate

Tossup

19) *Energy – Short Answer:* Researchers at Princeton Plasma Physics Laboratory are studying the properties of superconducting materials. Identify all of the following three traits that are characteristic of Type II superconductors:

> I) Most pure element superconductors are Type II
> II) They exhibit a gradual transition to superconductivity as they reach the critical temperature
> III) They generally have high critical temperatures

ANSWER: II and III

Bonus

19) *Energy – Multiple Choice:* Scientists at Brookhaven National Lab are studying black holes. Which of the following spacetime metrics would be most appropriate for analyzing a charged, rotating black hole?

> W) Schwarzchild
> X) Kerr
> Y) Kerr-Newman
> Z) Reissner-Nordstrom

ANSWER: Y) Kerr-Newman

Tossup

20)   *Physics – Multiple Choice:* Thanush is holding a stopwatch in his hand and begins to throw it. He's been hitting the gym quite often, so his throw involves a period of constant acceleration to a relativistic speed and then a period of zero acceleration after he releases the stopwatch. Which of the following best describes how the clock's ticking speed changes over the course of the throwing motion?

    W) Always speeds up
    X) Always slows down
    Y) Slows down, then speeds up
    Z) Slows down, then remains constant

ANSWER: Z) Slows down, then remains constant

Bonus

20)   *Physics – Short Answer:* An ideal 2 Volt source is connected in series with a 200 Ohm resistor. A 600 Ohm resistor is connected in parallel with a 0.02 Amp current source, and both of these components are connected in series with the existing circuit so the current source is directed out of the positive voltage terminal. What is the Thevenin equivalent voltage and resistance, respectively, of the whole system?

ANSWER: 14 Volts, 800 Ohms

Tossup

21)   *Chemistry – Short Answer:* Identify all of the following three properties that occur in cholesteric liquid crystals:

    I) Optical activity
    II) Two distinct melting points
    III) Contains well-defined layers

ANSWER: I and II

Bonus

21)   *Chemistry – Short Answer:* Colin is dissolving sodium in a strange liquid. After he adds some sodium, it turns a deep shade of blue. What color does this solution turn after much more sodium is added?

ANSWER: Bronze/Gold/Metallic/Yellow (ACCEPT: Anything metallic or gold)

Tossup

22) *Math – Short Answer:* The Feng family has 10 children total, 6 who are boys and 4 who are girls. A surveyor asks each of the 10 children how many brothers they have. Then, the surveyor asks each of them how many sisters they have. What is the average of all of the responses the surveyor was given?

ANSWER: 9/2 (ACCEPT: 4.5)

Bonus

22) *Math – Short Answer:* What is the divergence of the vector field $xy\hat{i} + z\hat{j} + 4xyz\hat{k}$?

ANSWER: $y + 4xy$

Tossup - Rohit

23) *Earth and Space – Short Answer:* What is the primary cause for the periodicity in the cosmic microwave background radiation?

ANSWER: Baryon Acoustic Oscillations

Bonus - Rohit

23) *Earth and Space – Short Answer:* Identify all of the following 3 phenomena which are occurring as a result of the tidal acceleration of the Moon:

I) The Earth's rotational period is slowing
II) The Moon is falling towards the earth
III) The Moon's rotational period is slowing

ANSWER: I and III