DASONI

Competitive Division DE 6

TOSS-UP

1) BIOLOGY *Multiple Choice* Which of the following best describes a Robertsonian translocation?

W) Two nonhomologous chromosomes fuse together

X) A piece of a chromosome breaks off and fuses with a nonhomologous chromosome

Y) Two nonhomologous chromosomes swap fragments of DNA

Z) A section of a chromosome breaks off and reattaches in the reverse orientation

ANSWER: W) TWO NONHOMOLOGOUS CHROMOSOMES FUSE TOGETHER [GKD]

BONUS

1) BIOLOGY *Multiple Choice* Which of the following statements about vascular cambium is false?

W) Ray initials give rise to sieve elements and vessel elements

X) Fusiform initials can divide both perpendicular and parallel to the surface of the cambium

Y) Cells formed on the interior of the vascular cambium develop into secondary xylem

Z) Ferns do not have vascular cambium

ANSWER: W) RAY INITIALS GIVE RISE TO SIEVE ELEMENTS AND VESSEL ELEMENTS [GKD]

TOSS-UP

2) CHEMISTRY *Multiple Choice* Which of the following configurations would constitute a strong Jahn-Teller effect?

W) High spin d^4

X) Low spin d^4

Y) High spin d^5

Z) Low spin d^5

ANSWER: X) LOW SPIN D^4 [DC]

BONUS

2) CHEMISTRY *Short Answer* Hydrotris(pyrazolyl)borate, or Tp, is a type of ligand that is tridentate and binds to a metal in a *fac* manner. What is this general class of ligands called?

ANSWER: SCORPIONATE [DC]

TOSS-UP

3) EARTH AND SPACE *Short Answer* There are several important horizons associated with a Reissner-Nordstrom black hole. One is the event horizon, but what other horizon separates spacelike and timelike regions of space?

ANSWER: CAUCHY HORIZON [AC]

BONUS

3) EARTH AND SPACE *Multiple Choice* According to the VMM hypothesis, the minerals in igneous rocks formed at a mid-ocean ridge align themselves with the external magnetic field. Moving away from the mid-atlantic ridge, the first large period of magnetic reversal would correspond with which of the following magnetic chrons?

W) Gilbert

X) Gauss

Y) Matuyama

Z) Brunhes

ANSWER: Y) MATUYAMA [EB]

TOSS-UP

4) MATH *Short Answer* 4 colors are guaranteed to color a plane so that no two adjacent regions have the same color. How many colors guarantee the same on a torus?

ANSWER: 7 [MD]

BONUS

4) MATH *Short Answer* Akshansh has sneaked onto the staff roster and is reading questions. As per usual, he deliberately mispronounces any word he can, and for every question he reads, he has a 5% chance of being caught by Griffin and banned from the competition server. Which of the following best describes the probability Akshansh reads at least 8 questions?

W) 0% - 25%

X) 25% - 50%

Y) 50% - 75%

Z) 75% - 100%

Answer: Y) 50% - 75% [MD]

5) PHYSICS *Short Answer* The vector describing the velocity of a thrown coffee cup can be thought of as a tensor with what rank?

ANSWER: 1 [AC]

BONUS

5) PHYSICS *Short Answer* Name all of the following that are pseudovectors.

1) Electric field

2) Magnetic field

3) Velocity

4) Torque

Answer: 2 AND 4 [AC]

TOSS-UP

6) ENERGY *Short Answer* Davidson HS A Team members are studying the evolution of the universe. Inflation explains many observations that we see now, including which law of electromagnetism?

ANSWER: GAUSS'S LAW OF MAGNETISM [AC]

BONUS

6) ENERGY *Short Answer* Davidson HS A Team members are studying deep carbon and the carbonate-silicate cycle. Ignoring other processes, identify what would happen to atmospheric carbon dioxide concentrations in each of the following three scenarios:

1) Formation of a mountain range

2) Rising global temperatures

3) Decreased rainfall

ANSWER: DECREASE, DECREASE, INCREASE [EB]

TOSS-UP

7) BIOLOGY *Multiple Choice* In real-time PCR, fluorescent probes are allowed to anneal to the DNA sequence of interest. When *Taq* **[TACK]** polymerase reaches the probe, it degrades it, releasing the fluorescent probe. Which of the following activities is most important for this process?

W) 5'-3' **[5 prime to 3 prime]** exonuclease

X) 3'-5' exonuclease

Y) 5'-3' endonuclease

Z) 3'-5' endonuclease

ANSWER: W) 5'-3' EXONUCLEASE [GKD]

BONUS

7) BIOLOGY *Short Answer* Biotin has an extraordinarily high binding affinity for streptavidin **[strep-TA-vih-tin]**, which makes it extremely useful in biotechnology. If the association constant for the binding of biotin to streptavidin is 2×10^{13}, what concentration of biotin is required for 50% of streptavidin molecules to be bound to biotin at equilibrium, expressed in scientific notation with one significant figure?

ANSWER: 5×10^{-14} [GKD]

(SOLUTION: The dissociation constant is the inverse of the association constant, and the dissociation constant is defined as the concentration of ligand at which half the protein molecules are bound to ligand molecules - alternatively, use equilibrium expressions)

TOSS-UP

8) CHEMISTRY *Short Answer* What reaction involves the palladium and copper-mediated cross-coupling reaction between an aryl halide and a termine alkyne?

ANSWER: SONOGASHIRA COUPLING [DC]

BONUS

8) CHEMISTRY *Short Answer* The Wittig reaction is a well-known method to synthesize alkenes. However, it often has poor stereoselectivity. A modification involving a stabilized phosphonate carbanion, rather than a phosphonium ylide (yee-lied), produces predominantly (E)-alkenes. The stabilizing functional group must be electron-withdrawing, like an ester. What is this reaction called?

ANSWER: HORNER-WADSWORTH-EMMONS REACTION (ACCEPT: HWE) [DC]

TOSS-UP

9) EARTH AND SPACE *Short Answer* By name or number, identify all of the following three minerals that have three perpendicular axes of symmetry of equal lengths:

1) Fluorite

2) Pyrite

3) Kyanite

ANSWER: 1 AND 2 (ACCEPT: FLUORITE, PYRITE) [EB]

BONUS

9) EARTH AND SPACE *Short Answer* Name all of the following three types of orbits that have components perpendicular to the plane of the bodies of which they orbit

1) Lyapunov

2) Lissajous

3) Halo

ANSWER: 2 AND 3 (LISSAJOUS, HALO) [AC]

TOSS-UP

10) MATH *Multiple Choice* Griffin is depositing money into a bank that has four interest options. Which will give him the most annual interest?

W) 1.6% per month

X) 3% every other month

Y) 10% twice a year

Z) 20% per year

ANSWER: Y) 10% TWICE A YEAR [MD]

BONUS

10) MATH *Short Answer* A right circular cone has a base of area 25pi and a surface area of 90pi. What is the volume of the cone?

ANSWER: 100pi [AKa]

TOSS-UP

11) PHYSICS *Short Answer* What theorem states that the density of points in phase space of a system remains constant over time?

ANSWER: LIOUVILLE'S THEOREM [AC]

BONUS

11) PHYSICS *Short Answer* The adiabatic index of a gas is 1.222 repeating. How many degrees of freedom does this gas have?

ANSWER: 9 [AC]

TOSS-UP

12) ENERGY *Short Answer* Davidson MS C team members are studying how to shift the frequency of waves. Beat frequencies in acoustic waves are a specific example of what technique of mixing frequencies from two different waves?

ANSWER: HETERODYNING [GKD]

BONUS

12) ENERGY *Short Answer* Davidson HS A Team members are studying the male reproductive system. Humans have two main adaptations to keep the testis at a temperature cooler than body temperature. The first is by keeping them outside the body in the process of testicular descent; the second is the presence of what collection of testicular arteries and veins that function as a countercurrent exchanger?

ANSWER: PAMPINIFORM PLEXUS [GKD]

13) BIOLOGY *Multiple Choice* Which of the following is the most important regulator of breathing when at rest?

W) Partial pressure of oxygen in cerebrospinal fluid

X) Partial pressure of oxygen in aortic and carotid bodies

Y) Partial pressure of carbon dioxide in aortic and carotid bodies

Z) Hydrogen ion concentration in cerebrospinal fluid

ANSWER: Z) HYDROGEN ION CONCENTRATION IN CEREBROSPINAL FLUID [GKD]

BONUS

13) BIOLOGY *Multiple Choice* In order for a ligand-gated chloride ion channel to be inhibitory in a neuron, which of the following must be true about the equilibrium potential of chloride in that neuron?

W) It must be more negative than the resting membrane potential

X) It must be the same as the resting membrane potential

Y) It must be more positive than the resting membrane potential

Z) It must be more negative than threshold

ANSWER: Z) IT MUST BE MORE NEGATIVE THAN THRESHOLD [GKD]

TOSS-UP

14) CHEMISTRY *Short Answer* Ladderanes can be synthesized by consecutive [2+2] cycloadditions of cyclobutenes, but must start from bicyclohexene. Bicyclohexene is normally synthesized by treatment of a bicyclic sulfoxide with a strong base in presence of DMSO. What is the name of this reaction?

ANSWER: RAMBERG-BACKLUND REACTION [DC]

BONUS

14) CHEMISTRY *Short Answer* A common organic reaction in the domain of polycyclic aromatic hydrocarbons is the Scholl reaction, which involves the acid-mediated catalysis of arene coupling. For example, hexaphenylbenzene in presence of trifluoroacetic acid yields hexabenzocoronene, one of the simplest nanographenes. Calculate the pi-electron to six-membered ring ratio for hexabenzocoronene.

ANSWER: 42/13 [DC]

TOSS-UP

15) EARTH AND SPACE *Short Answer* Originally thought to be evaporite salt deposits when observed on the Moon, what high-albedo, spoke-like system is made up of streaks of ejecta around an impact crater?

ANSWER: RAY SYSTEM [AC]

BONUS

15) EARTH AND SPACE *Short Answer* What is the focal length in centimeters of an ice sculpture of a refracting telescope, given the objective lens is planoconvex with radius of curvature 2 centimeters, the eyepiece lens is planovex with radius of curvature 1 centimeter, and the index of refraction of ice is 1.3?

ANSWER: 2 [EB]

TOSS-UP

16) MATH *Short Answer* What is 1313 base 7 times 15 base 7? Give your answer in base 7.

ANSWER: 23331 [MD]

BONUS

16) MATH *Short Answer* Evaluate the double integral of the function $x^2y + y^2x$ over the rectangular area bordered by the x axis, the y axis, the line x equals 2, and the line y equals 4

ANSWER: 64 [EB]

TOSS-UP

17) PHYSICS *Short Answer* Name all of the following three theories that are linear.

    1) Classical mechanics

    2) Electromagnetism

    3) Quantum mechanics

ANSWER: 2 AND 3 [AC]

BONUS

17) PHYSICS *Short Answer* System A changes macrostates such that the number of possible microstates goes from 1 to 100. System B changes macrostates such that the number of possible microstates goes from 1 to approximately e * 10^2. In terms of the Boltzmann constant k, what is the difference in delta S between system A and B?

ANSWER: 1 * k [AC]

TOSS-UP

18) ENERGY *Short Answer* Davidson HS A team members are studying protein engineering, a common research and industrial process used to produce biocatalysts. Contrasted with rational design, which engineers proteins via an analysis of structure, what process involves mimicking natural selection and optimizing an enzyme's catalytic properties via subsequent rounds of mutagenesis?

ANSWER: DIRECTED EVOLUTION [DC]

BONUS

18) ENERGY *Short Answer* Davidson HS B Team members are studying random walks. James starts at the origin at time t=0; every second, he randomly chooses to move 1 unit left or 1 unit right. After 10 moves, what is the probability that James is still within 3 units of the origin?

ANSWER: 21/32 [AKa]

TOSS-UP

19) BIOLOGY *Multiple Choice* Which of the following statements is not true about the Lotka-Volterra equations?

W) It is based on the logistic model

X) If interspecific competition is less important than intraspecific competition, the Lotka-Volterra equations predict a stable equilibrium

Y) If one species has a zero isocline greater than the other at all points, it will outcompete the other species

Z) If one species outcompetes the other, the winning species will have dN/dt greater than zero

ANSWER: Z) IF ONE SPECIES OUTCOMPETES THE OTHER, THE WINNING SPECIES WILL HAVE DN/DT GREATER THAN ZERO [GKD]

BONUS

19) BIOLOGY *Short Answer* There is an allele in a phoenix population that causes male phoenixes to display mating structures in which they are either dominant or subordinate. A wild phoenix that is neither dominant nor subordinate will have an average of 1.4 offspring, but when two phoenixes team up in a dominant and subordinate pair, the reproductive success of the dominant phoenix increases to 8 while the subordinate phoenix will not have any offspring. If two half-brothers have this allele, how many extra copies of the allele will be passed to the next generation if they display this mating structure?

ANSWER: 0.125 [GKD]

20) CHEMISTRY *Multiple Choice* Which of the following constants is not a constituent of lattice energy based on the Born-Landé (lon-DAY) equation?

W) Permittivity of free space

X) Madelung (mad-ih-lung) constant

Y) Avogadro's constant

Z) Landé factor

ANSWER: Z) LANDÉ FACTOR [GKD]

BONUS

20) CHEMISTRY *Short Answer* Suppose that you have two chambers A and B, each with identical volume but filled with a different kind of gas molecule. They are initially separated by a boundary which is then removed. Given that there were 0.5 moles of each gas in each chamber, what is the entropy resulting from the eventual mixture of the two gasses? Express your answer in terms of R and to the nearest three significant figures.

ANSWER: -0.693R [DC]

21) EARTH AND SPACE *Short Answer* Name all of the following that are true of S Doradus variables?

1) Eta carinae is a unusually dim S Doradus star

2) Temperature and luminosity increase in an outburst

3) S Doradus stars could undergo a pair-instability supernova if they do not lose enough mass by the end of their life

ANSWER: 3 ONLY [AC]

21) EARTH AND SPACE *Short Answer* What phenomenon, thought to lead to buildup of stress in a fault zone under certain circumstances, is characterized by prolonged, low-frequency seismic waves and temporary perceived reversals in crustal motion?

ANSWER: EPISODIC TREMOR AND SLIP [EB]

TOSS-UP

22) MATH *Short Answer* The function f is of the form $f(x)=ax^2+bx+c$. Given that $f(0)=7$, $f(1)=9$, and $f(2)=5$, what is $f(3)$?

ANSWER: -5 [AKa]

BONUS

22) MATH *Short Answer* What fraction of the numbers in the infinite Pascal's triangle are odd?

ANSWER: 0 (ACCEPT: Infinitely Small, Infinitesimally Small) [MD]
(Solution: The mod 2 infinite Pascal's triangle forms Sierpinski's triangle, with odds as the lines and evens as the spaces. Since lines take up 0% of the area, the odd numbers make up 0% of the numbers in the infinite Pascal's triangle. Note this is similar to how the fraction of real numbers that are rational numbers is 0)

TOSS-UP

23) PHYSICS *Multiple Choice* Which of the following is false of Elitzur-Vaidman bomb-testers?

W) A quantum superposition involving different paths of a photon is always initially created

X) A photon must interfere with itself for a bomb to be declared live

Y) One detector is oriented such that it is impossible to know the status of the bomb is a photon is detected there

Z) The bomb-tester has a 50% chance to explode a live bomb

ANSWER: X) A PHOTON MUST INTERFERE WITH ITSELF FOR A BOMB TO BE DECLARED LIVE [AC]

BONUS

23) PHYSICS *Short Answer* A dipole with charge 3 coulombs and distance 1 centimeter between charges is rotated in a constant electric field of 5 volts per meter. If it is rotated from an angle of 30 degrees to 90 degrees in the electric field, how much work is done on the dipole, in joules?

ANSWER: -0.15*sqrt(3) [AC]