DOUBLE ELIMINATION 6

TOSS-UP

1) Biology - *Multiple Choice* Which of the following is NOT a property of rod cells' response to light that grants human eyes the ability to see?

W) Conformational change in retinal requires just a single photon to occur
X) Signal amplification via the secondary messenger cAMP
Y) Negative feedback termination of rhodopsin **[roh-DOP-sin]** signaling upon activation to allow light adaptation
Z) Lowered release of glutamate neurotransmitter upon detection of light

ANSWER: X) Signal amplification via the secondary messenger cAMP

BONUS

1) Biology - *Short Answer* Identify all of the following four chromosome counts that a hybrid, which is the result of a species with chromosome count 6 crossed with a species with chromosome count 10, can have if its an allopolyploid: 1) 8; 2) 16; 3) 24; 4) 32.

ANSWER: 2 and 4

TOSS-UP

2) Earth and Space - *Short Answer* When the frequency of a wave in an enclosed basin is equal to its resonant frequency, a standing wave can form with an amplitude as large as a few meters. What term is given to these standing waves?

ANSWER: Seiches

BONUS

2) Earth and Space - *Multiple Choice* The distance between the 500 and 1000 millibar pressure surfaces is an important value in meteorology. This is because larger distances between these surfaces correspond to which of the following atmospheric conditions?

W) Colder air
X) Warmer air
Y) More unstable air
Z) More stable air

ANSWER: X) Warmer air

TOSS-UP

3) Math - *Short Answer* Albert writes the 8 prime numbers less than 20 on a circle in increasing order clockwise. He then writes on a new circle the value of each number on the original circle minus the number 3 spots ahead. What is the sum of the 8 numbers on this new circle?

ANSWER: 0

BONUS

3) Math - *Short Answer* How many (possibly empty) subsets of $\{1,2,3,4,5\}$ **[the set 1, 2, 3, 4, 5]** have no two consecutive numbers?

ANSWER: 13

TOSS-UP

4) Physics - *Multiple Choice* On a Minkowski diagram, which of the following represents the worldline for a stationary particle?

W) Horizontal line
X) Vertical line
Y) Line with slope 1
Z) Line with slope -1

ANSWER: X) Vertical line

BONUS

4) Physics - *Short Answer* Identify all of the following four statements that must be true of an inductor in a circuit if its voltage $V(t)$ and current $I(t)$ are to remain finite: 1) V must be continuous; 2) V must be differentiable; 3) I must be continuous; 4) I must be differentiable.

ANSWER: 3 only

TOSS-UP

5) Chemistry - *Multiple Choice* In infrared spectroscopy, which of the following wavenumbers, in inverse centimeters, is closest to the vibrational frequency of a nitrile **[NY-trial]** group?

W) 1700
X) 1900
Y) 2200
Z) 3100

ANSWER: Y) 2200

BONUS

5) Chemistry - *Multiple Choice* Which of the following molecular orbitals of the conjugated pi systems has 3 nodes?

W) HOMO of 1,3-butadiene
X) LUMO of 1,3-butadiene
Y) HOMO of 1,3,5-hexatriene
Z) LUMO of 1,3,5-hexatriene

ANSWER: Z) LUMO of 1,3,5-hexatriene

TOSS-UP

6) Energy - *Short Answer* Researchers in the Gratta group at Stanford are working on detecting neutrinoless double beta decay. This theoretical phenomenon is important because it would prove that neutrinos are what type of fermion, which are defined to be their own antiparticles?

ANSWER: Majorana **[my-ur-AW-nuh]** particles

BONUS

6) Energy - *Multiple Choice* Scientists in the Walbot Lab at Stanford are investigating how homeotic genes create genetic diversity in plants. According to the ABC model of flower development, which of the following sequences shows the arrangement of floral organs, from innermost to outermost, in a mutant where the C gene is suppressed?

W) Carpel, stamen, stamen, sepal
X) Sepal, petal, petal, sepal
Y) Sepal, sepal, stamen, stamen
Z) Carpel, carpel, sepal, sepal

ANSWER: X) Sepal, petal, petal, sepal

TOSS-UP

7) Biology - *Short Answer* In eicosanoid **[eye-COH-suh-noid]** synthesis, phospholipase A2 cleaves what polyunsaturated fatty acid from the plasma membrane to be metabolized by cyclooxygenase or lipooxygenase?

ANSWER: Arachidonic **[uh-rack-uh-DON-ic]** acid

BONUS

7) Biology - *Short Answer* Identify all of the following three aquatic locations in which zooplankton could be found in high abundance: 1) Salt marsh within estuary; 2) Limnetic **[lim-NET-ic]** zone of oligotrophic lake; 3) Benthic zone of Pacific Ocean.

ANSWER: 1 only

TOSS-UP

8) Math - *Short Answer* Let A be a 25x25 matrix such that $A^2x = 25x$ for any 25-vector x. What is the smallest possible rank of A?

ANSWER: 25

BONUS

8) Math - *Short Answer* Evaluate the derivative of $\sin(x^2)\cos(x^2)$ **[sine of x squared times cosine of x squared]** at $x = \sqrt{\pi}$.

ANSWER: $2\sqrt{\pi}$

TOSS-UP

9) Earth and Space - *Short Answer* Asymptotic giant branch stars are thought to produce elements heavier than iron via what process, which involves the growth of nuclei via neutron capture over thousands of years?

ANSWER: s-process

BONUS

9) Earth and Space - *Multiple Choice* Which of the following statements is NOT true regarding sunspots?

W) The magnetic field is approximately vertical at sunspot umbras
X) Light bridges in the sunspot have exceptionally strong magnetic field lines
Y) Sunspots migrate towards lower latitudes over an 11-year cycle
Z) Sunspots form due to magnetic flux tubes in the convective zone

ANSWER: X) Light bridges in the sunspot have exceptionally strong magnetic field lines

TOSS-UP

10) Physics - *Multiple Choice* When a charged particle enters a constant magnetic field in the z direction, where the particle's velocity is not parallel to the field, its path follows a circular helix. How does the particle's trajectory change when a uniform electric field in the x direction is introduced?

W) A lateral drift of constant velocity is introduced
X) The radius of the helix is enlarged
Y) The helix becomes elliptical instead of circular
Z) No change to the trajectory occurs

ANSWER: W) A lateral drift of constant velocity is introduced

BONUS

10) Physics - *Multiple Choice* Daniel has a very large number N of ideal resistors, numbered 1 through N. The k^{th} resistor has resistance k ohms. If he connects all of his resistors in parallel, which of the following is closest to the effective resistance he creates?

W) $\frac{1}{N^2}$ **[1 over the quantity n squared]**
X) $\frac{1}{N \log N}$ **[1 over the quantity n log n]**
Y) $\frac{1}{N}$
Z) $\frac{1}{\log N}$

ANSWER: Z) $\frac{1}{\log N}$

TOSS-UP

11) Energy - *Short Answer* Researchers in the Irwin group at Stanford are creating electromagnetic sensors in frequency ranges previously unusable due to quantum noise. To do this, the researchers are using what type of device, which involves placing a weak barrier between two superconductors that allows a current to flow without an applied voltage?

ANSWER: Josephson junction

BONUS

11) Energy - *Multiple Choice* Scientists at the Stanford Nanofabrication Facility are using vapor deposition to synthesize semiconductors found in colored LEDs. Phosphors are most commonly used in LEDs to create which of the following colors?

W) Red
X) Green
Y) Blue
Z) White

ANSWER: Z) White

TOSS-UP

12) Chemistry - *Short Answer* What is the name for a pair of stereoisomers that differ in absolute configuration at only one stereocenter, such as D-glucose and D-galactose?

ANSWER: Epimers

BONUS

12) Chemistry - *Short Answer* Phenyl magnesium bromide is being used to carry out a Grignard **[GREEN-yard]** reaction, but unfortunately there is some residual water in the reaction flask that quenches the reaction. What is the unintended organic product formed?

ANSWER: Benzene

TOSS-UP

13) Biology - *Multiple Choice* Sodium is considered the ninth essential micronutrient for C4 and CAM plants, but not for C3 plants. Which of the following processes would sodium be a cofactor for?

W) Production of malic acid
X) Regeneration of phosphoenolpyruvate
Y) Conversion of oxaloacetate to pyruvate
Z) Synthesis of RuBP

ANSWER: X) Regeneration of phosphoenolpyruvate

BONUS

13) Biology - *Multiple Choice* Fish in a pond can have spikes, which is controlled by a single locus with alleles A and B, which display heterozygote advantage. Specifically, fish with genotype AA have no spikes; fish with genotype AB have small spikes which have a relative fitness to the AA genotype of 1.5, and fish with genotype BB have large spikes which have a relative fitness to the AA genotype of 0.9. Assuming Hardy-Weinberg equilibrium, the frequency of the B allele with optimal frequency lies in which of the following ranges?

W) 0 to 0.1
X) 0.3 to 0.5
Y) 0.5 to 0.7
Z) 0.9 to 1

ANSWER: X) 0.3 to 0.5

TOSS-UP

14) Physics - *Short Answer* A monochromatic light source, placed far away, directly illuminates a small circular aperture in an otherwise opaque sheet of material. An imaging plane is placed on the other side of the sheet. What is the name for the bright central region of the resulting interference pattern, named for an English astronomer?

ANSWER: Airy disk (DO NOT ACCEPT: Newton's rings)

BONUS

14) Physics - *Multiple Choice* Which of the following is most accurate regarding the composite wavefunction of two fermions?

W) The spatial part of the wavefunction must be antisymmetric under particle exchange
X) The spin part of the wavefunction must be antisymmetric under particle exchange
Y) Both the spatial part and spin part of the wavefunction must be antisymmetric under particle exchange
Z) Either the spatial part or the spin part of the wavefunction must be antisymmetric under particle exchange

ANSWER: Z) Either the spatial part or the spin part of the wavefunction must be antisymmetric under particle exchange

TOSS-UP

15) Math - *Short Answer* Let a be a product of two complex numbers on the unit circle and b be a quotient of two complex numbers on the unit circle. What is the maximum possible value of $|a-b|$ **[the absolute value of a minus b]**?

ANSWER: 2

BONUS

15) Math - *Short Answer* Region R is defined as the points that satisfy $0 < x < 2$ and $0 < y < 5$. What is the double integral over R of $x^2 y$, dy, dx?

ANSWER: $\frac{100}{3}$

TOSS-UP

16) Chemistry - *Short Answer* Order the following three ligands from lowest to highest denticity: 1) EDTA; 2) Terpyridine; 3) Porphyrin.

ANSWER: 2, 3, 1

BONUS

16) Chemistry - *Multiple Choice* Which of the following best describes the rate law for hydrobromination of alkynes?

W) First order with respect to alkyne and zeroth order with respect to HBr
X) First order with respect to alkyne and first order with respect to HBr
Y) First order with respect to alkyne and second order with respect to HBr
Z) Second order with respect to alkyne and second order with respect to HBr

ANSWER: Y) First order with respect to alkyne and second order with respect to HBr

TOSS-UP

17) Earth and Space - *Short Answer* Identify all of the following statements about western boundary currents that are true: 1) They carry warm water poleward; 2) They are shallow and have relatively low velocities; 3) They rarely create eddy currents.

ANSWER: 1 only

BONUS

17) Earth and Space - *Short Answer* Zircons are useful for radioactive dating because they incorporate almost no lead during their formation. This makes lead an example of what type of element, which includes atoms with high charges or atomic radii that do not easily fit into crystal structures?

ANSWER: Incompatible

TOSS-UP

18) Energy - *Multiple Choice* Researchers at Stanford's TomKat Center for Sustainable Energy are developing new methods for the production of fuels via the Fischer-Tropsch process. This process requires the water-gas shift reaction to balance the concentration of various gases. Which of the following ratios of gas concentrations would the water-gas shift reaction be used to change?

W) Concentration of H_2O to concentration of CO
X) Concentration of CO to concentration of H_2
Y) Concentration of H_2 to concentration of CO_2
Z) Concentration of CO_2 to concentration of O_2

ANSWER: X) Concentration of CO to concentration of H_2

BONUS

18) Energy - *Short Answer* Scientists in the COFFIES group at Stanford are studying the differential rotation of the Sun's interior. Their research aims to understand what transition region in the Sun, which separates the cohesively rotating radiative zone from the variably rotating convective zone?

ANSWER: Tachocline

TOSS-UP

19) Math - *Short Answer* What is the modular inverse of 9 mod 17?

ANSWER: 2

BONUS

19) Math - *Short Answer* Calculate the determinant of the inverse of the 3x3 matrix $\begin{bmatrix} 2 & 3 & 3 \\ 1 & 5 & 5 \\ -3 & 1 & 0 \end{bmatrix}$ **[first row 2 3 3, second row 1 5 5, third row -3 1 0]**.

ANSWER: $-\frac{1}{7}$

TOSS-UP

20) Chemistry - *Short Answer* What is the name of the kinetic theory that uses activation energies of elementary reactions, or delta *G* double dagger, to quantify reaction rates?

ANSWER: Transition state theory

BONUS

20) Chemistry - *Short Answer* What is the sum of all the coefficients in the balanced reaction for the zinc carbon battery where manganese dioxide gets reduced to manganese (III) oxide and zinc is oxidized to zinc hydroxide?

ANSWER: 6

TOSS-UP

21) Physics - *Multiple Choice* Consider a system containing two electrons. Which of the following best explains the method by which these electrons could be distinguished?

W) Measuring physical properties such as spin
X) Keeping track of their spatial trajectories over time
Y) Keeping track of the global wavefunction phase upon exchange
Z) The electrons cannot be distinguished

ANSWER: Z) The electrons cannot be distinguished

BONUS

21) Physics - *Multiple Choice* Consider a particle trapped in the 1-dimensional infinite potential well with total width $2d$, so that the potential is zero for $|x| < d$ and infinite otherwise. Which of the following is true about the symmetry of the allowed wavefunctions in the well, with respect to $x = 0$?

W) All wavefunctions must be even
X) All wavefunctions must be odd
Y) All wavefunctions must be either even or odd
Z) Wavefunctions do not have to be either even or odd

ANSWER: Z) Wavefunctions do not have to be either even or odd

TOSS-UP

22) Biology - *Short Answer* What biological technique studies protein interactions by analyzing the proximity of a donor fluorophore **[FLOOR-oh-for]** to an acceptor fluorophore from observations of light emission at different wavelengths?

ANSWER: FRET (ACCEPT: Fluorescence Resonance Energy Transfer, Förster Resonance Energy Transfer)

BONUS

22) Biology - *Short Answer* Order the following three reactions by increasing free energy released into the surroundings: **[read slowly]** 1) G3P to 1,3-bisphosphoglycerate; 2) DHAP to G3P; 3) PEP to pyruvate.

ANSWER: 1, 2, 3

TOSS-UP

23) Earth and Space - *Multiple Choice* Which of the following types of black hole is characterized as being charged and non-rotating?

W) Schwarzschild
X) Reisnner-Nordstrom
Y) Kerr
Z) Kerr-Newman

ANSWER: X) Reisnner-Nordstrom

BONUS

23) Earth and Space - *Short Answer* A star has the unique property that any change in its radius is counteracted by a change in temperature such that its luminosity remains the same. The temperature of this star must be proportional to its radius raised to what power?

ANSWER: $-\frac{1}{2}$