BASH



Double Elimination 7

TOSS-UP

1. Energy *Short Answer* Students at Johns Hopkins University are confused on how to write this flavor text, but hope players enjoy this question. The fastest way to implement Disjoint Set Union for n vertices is using both small to large merging and path compression. When both of these are used, the complexity of uniting two vertices is what named function of n?

ANSWER: INVERSE ACKERMANN FUNCTION

BONUS

1. Energy *Short Answer* BASH is running again in the year 2042! It has 42 teams randomly assigned into 7 groups of 6 teams. Given that two of these teams are South Hollywood and Intralake, what is the probability each of these teams wins their group, assuming each team has an equal chance of winning their group?

ANSWER: 1/41

TOSS-UP

2. Earth and Space *Short Answer* Order the following three regions of a river and the surrounding groundwater by increasing flow speed:

1) Thalweg
2) Hyporheic zone
3) Saturated zone

ANSWER: 3, 2, 1

BONUS

2. Earth and Space *Short Answer* Identify all of the following three treatments that can destroy a mineral's tenebrescence:

1) Heating
2) Reaction with acid
3) Repeated exposure to UV light

ANSWER: 1 AND 2

TOSS-UP

3. Chemistry *Multiple Choice* Boron trifluoride etherate can be added to the Diels-Alder reaction between cyclopentadiene and maleic anhydride. Which of the following best describes the role it plays in this reaction?

W) Increase the steric bulk of maleic anhydride to favor the exo conformation of the product
X) Prevent the dimerization of cyclopentadiene to increase product yield
Y) Lower the LUMO of maleic anhydride to increase reaction rate
Z) Decrease secondary orbital effects to increase endo selectivity

ANSWER: Y) LOWER THE LUMO OF MALEIC ANHYDRIDE TO INCREASE REACTION RATE

VISUAL BONUS

3. Chemistry *Short Answer* Answer the following two questions about the image below:

1) Giving your answer as a number from 1 to 5, which Erlenmeyer flask absorbs light at the longest wavelength?
2) Beaker 1 contains a vanadium ion. What is the oxidation state of vanadium in this ion?



ANSWER: 1. 4; 2. +4

TOSS-UP

4. Physics *Multiple Choice* Which of the following hadrons CANNOT contain a charm quark?

W) J/Psi Meson

X) B Meson

Y) Xi Baryon

Z) Hyperon

ANSWER: Z) HYPERON

BONUS

4. Physics *Multiple Choice* If the total orbital angular momentum of an electron is sqrt(30) times the reduced Planck's constant, then which of the following options is not a possible value for the z-component of the orbital angular momentum?

W) -3 h-bar

X) 0

Y) 4 h-bar

Z) 7 h-bar

ANSWER: Z) 7 H-BAR

TOSS-UP

5. Math *Short Answer* Consider the function f from the set S to itself such that for any two x and y in the set S, f of the quantity x + y is equal to f of x plus f of y. Identify all of the following sets S for which the function must be linear:

1) Real numbers
2) Complex numbers
3) Rational numbers

ANSWER: 3 ONLY

BONUS

5. Math *Short Answer* Students at Montgomery Blair are computing factorials. To the nearest ten, what is the logarithm base 10 of 272! **[272 factorial]**?

ANSWER: 550

TOSS-UP

6. Biology *Short Answer* Rohan is running a thin-layer chromatography to separate a variety of lipoproteins using a hexane mobile phase. Order the following three types of lipoproteins in terms of increasing distance traveled on the plate:

1) Low density lipoproteins
2) High density lipoproteins
3) Chylomicrons

ANSWER: 2, 1, 3

BONUS

6. Biology *Short Answer* Jason found some cysteine in his lab and decided to run a 2D gel electrophoresis on it. Given that cysteine has pKa values of 2, 8, and 11, identify all of the following 3 statements that are true:

1) The sample will equilibrate at a pH of 5
2) If the isoelectric focusing fails and the sample equilibrates at a pH of 12, it will travel faster towards the anode
3) If he treats the sample with an oxidizing agent instead of a reducing agent, it will travel slower towards the anode

ANSWER: ALL

TOSS-UP

7. Earth and Space *Short Answer* What paradox arises when the less-massive star in a binary system evolves into a giant while the more-massive one remains on the main sequence?

ANSWER: ALGOL'S PARADOX

BONUS

7. Earth and Space *Short Answer* What is the name for the two diametrically-opposite points on Mercury's surface that reach the highest temperatures at perihelion?

ANSWER: HOT LONGITUDES

TOSS-UP

8. Chemistry *Multiple Choice* Which of the following is not a possible hapticity for the cyclopentadienyl ligand?

W) 1

X) 3

Y) 5

Z) 7

ANSWER: Z) 7

BONUS

8. Chemistry *Short Answer* Kian is approximating a carbon-oxygen single bond as a quantum harmonic oscillator. Identify all of the following three changes that Kian can make to increase the separation between energy levels in his quantum harmonic oscillator:

1) Replacing the single bond with a double bond

2) Replacing the carbon with a nitrogen

3) Replacing the oxygen with a nitrogen

ANSWER: 1 AND 3

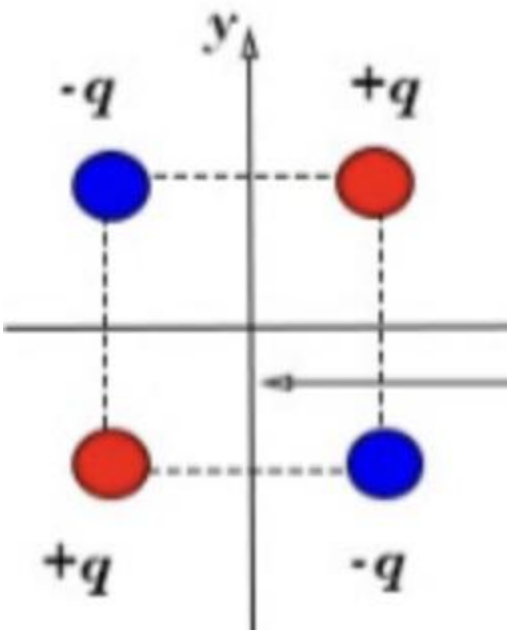
TOSS-UP

9. Physics *Short Answer* The Principle of Least Action in classical mechanics states that particles take trajectories that minimize the total action of the path. Feynman generalized this statement into what principle of quantum mechanics, summing over infinitely many quantum trajectories into a single quantum amplitude?

ANSWER: PATH-INTEGRAL FORMULATION

VISUAL BONUS

9. Physics *Short Answer* Consider the following configuration of charges in the image below. The side length of the square is 2 centimeters. An infinite conducting sheet is placed on the plane z = -1 centimeter. If the electric field at z = 3 meters is 64 Newtons per Coulomb, then in Newtons per Coulomb, what is the electric field at z = 6 meters?



ANSWER: 2

TOSS-UP

10. Math *Short Answer* The Riemann zeta function at an input s is defined to be the sum from n = 1 to infinity of 1/n to the power of s. It is known that zeta of 1 diverges and zeta of 2 is equal to pi squared over 6. However, the function at 3 doesn't have a closed form and is instead known as what constant?

ANSWER: APÉRY'S CONSTANT

VISUAL BONUS

10. Math *Short Answer* Yunyi is playing cup pong on GamePigeon, as shown below. The point value of a given cup is equal to the number of cups in the row, and the probability he has of hitting a given cup is proportional to its point value. Assuming Yunyi never misses the cups, answer the following two questions about the game:

1) What is the expected value of points gained for a given throw?
2) If Yunyi makes three throws, what is the probability he gets a score of 11?



ANSWER: 1) 3 2) 32/125

TOSS-UP

11. Biology *Short Answer* Yunyi is studying the mechanism of action of beta-lactamases, and notice that they act as a suicide inactivator for what enzyme that catalyzes the cross-linking of peptidoglycan chains?

ANSWER: TRANSPEPTIDASE

BONUS

11. Biology *Short Answer* Mary and Larry are heterozygous for the mutant allele for both the p53 gene and the Ras gene. What is the probability that their child will have the mutant phenotype for both p53 and Ras?

ANSWER: 3/16

TOSS-UP

12. Energy *Short Answer* Scientists at Amador Valley are staying up to 4 am to write questions while daydreaming about sleep. In stage 2 of NREM sleep, large amplitude waves occasionally interrupt the theta rhythm. What is the name for these waves?

ANSWER: K-COMPLEXES

BONUS

12. Synergy *Short Answer* Yunyi is performing chemical reactions involving Grubbs catalyst in a forest for months on end without stopping. He notices that the leaves of the trees are losing their color and a protective layer of suberin is being formed at the petiole. Identify all of the following three alkenes that Yunyi could be reacting with Grubbs catalyst to lead to this result:

1) Styrene
2) But-2-ene
3) 1-methylcyclohexene

ANSWER: 1 ONLY

TOSS-UP

13. Earth and Space *Multiple Choice* Which of the following seismic discontinuities occurs at the same depth as the D'' **[D double prime]** layer?

W) Conrad

X) Gutenberg

Y) Lehmann

Z) Mohorovicic

ANSWER: X) GUTENBERG

BONUS

13. Earth and Space *Short Answer* The jet stream does not exist at a constant latitude, but instead has several large meanders which are the source of mid-latitude cyclones. These meanders are an example of what kind of wave, which arises because the Coriolis force varies with latitude?

ANSWER: ROSSBY WAVE

TOSS-UP

14. Chemistry *Short Answer* When CO2 is added to RuBP during the Calvin cycle, RuBP tautomerizes so that the electrophilic carbonyl carbon becomes a nucleophilic enol alpha carbon. What term describes this inversion of reactivity?

ANSWER: UMPOLUNG

VISUAL BONUS

14. Chemistry *Short Answer* Answer the following two questions about the molecule shown below:

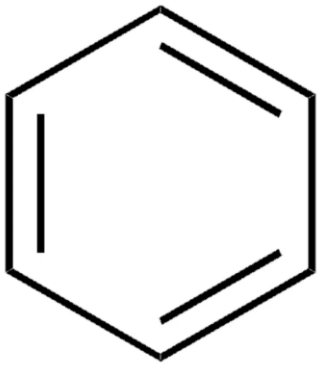
1) What is the point group of this molecule?

2) Identify all of the following three symmetry elements that this molecule contains:

1) Inversion center

2) C2 axis

3) C4 axis



ANSWER: 1) D6h; 2) 1 AND 2

TOSS-UP

15. Physics *Multiple Choice* Which of the following state functions has pressure and temperature as its natural variables?

W) Enthalpy

X) Internal energy

Y) Gibbs free energy

Z) Hemholtz free energy

ANSWER: Y) GIBBS FREE ENERGY

BONUS

15. Physics *Short Answer* A superconductor has a London penetration depth of 2 centimeters and is exposed to an external magnetic field. To one significant figure, what is the ratio of the strength of the magnetic field at the surface to the strength of the magnetic field at a depth of 6 centimeters?

ANSWER: 20

TOSS-UP

16. Math *Short Answer* There is an unknown prime p and Daniel wants to know if 7 is a quadratic residue modulo p. Identify all of the following numbers n for which if Daniel was given the remainder when p was divided by n, he would be able to answer his question with certainty:

1) 7

2) 14

3) 28

ANSWER: 3 ONLY

BONUS

16. Math *Short Answer* How many bijective functions from the set of the first 7 positive integers to itself exist such that applying the function 5 times to any input yields the input itself?

ANSWER: 505

TOSS-UP

17. Biology *Short Answer* Evan is using flow cytometry to analyze a variety of leukocytes and receives data on each cell's forward scattering, which represents how much light is blocked when the laser is directed head-on at the cell. Order the following three leukocyte types by increasing forward scattering:

1) Macrophage
2) T cell
3) Basophil

ANSWER: 2, 3, 1

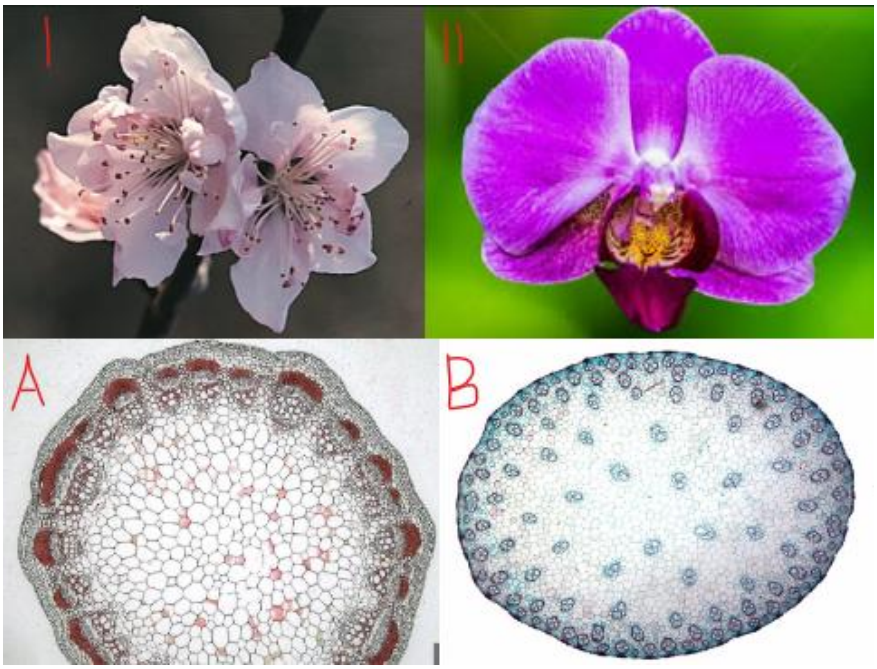
VISUAL BONUS

17. Biology *Short Answer* Answer the following three questions about the images shown:

1) What plant families are depicted in images 1 and 2, respectively?

2) Which cross-section A or B corresponds to the stem of plant 1?

3) What organic polymer is represented by the regions stained red in image A?



ANSWER: 1) ROSACEAE, ORCHIDACEAE, 2) A, 3) LIGNIN

TOSS-UP

18. Earth and Space *Short Answer* Order the following three types of variable stars by increasing pulsation period:

1) Cepheid variables
2) RR Lyrae
3) Mira variables

ANSWER: 2, 1, 3

VISUAL BONUS

18. Earth and Space *Short Answer* The following figure shows a depiction of the Babcock model on the surface of the sun. Answer the following three questions about the Babcock model:

1) The model describes the formation of what surface features, shown at A?

2) What is the name for the arced features made of cool ionized gas shown in figure B?

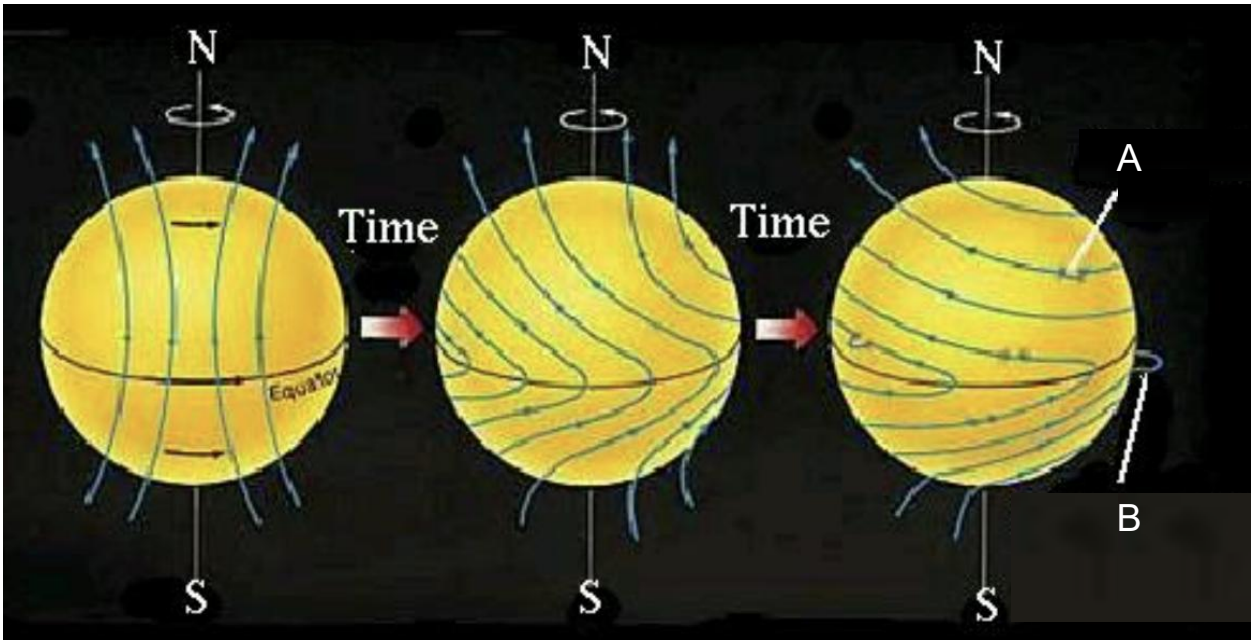
3) Which of the following best describes the driving force in the Babcock model?

W) Nucleosynthesis

X) Differential rotation

Y) Temperature gradient

Z) Magnetic reversals



ANSWER: 1) SUNSPOTS 2) PROMINENCE 3) X) DIFFERENTIAL ROTATION

TOSS-UP

19. Chemistry *Short Answer* The Karplus relationship relates the coupling strength between two protons and the dihedral angle. Order the following three dihedral angles between two hydrogen atoms in order of increasing coupling constant:

1) 30 degrees
2) 90 degrees
3) 120 degrees

ANSWER: 2, 3, 1

BONUS

19. Chemistry *Multiple Choice* Which of the following liquid crystal phases has a helical structure?

W) Lyotropic
X) Cholesteric
Y) Nematic
Z) Smectic

ANSWER: X) CHOLESTERIC

TOSS-UP

20. Physics *Short Answer* In classical mechanics, conjugate quantities such as momentum and position can be interconverted by what mathematical tool?

ANSWER: LEGENDRE TRANSFORMATION

BONUS

20. Physics *Short Answer* A precessing top weighs 50 Newtons and precesses in a circle of radius 10 meters. Given that the top rotates about its central axis at 25 radians per second, and the moment of inertia of the top about its central axis is 200 kilogram meters squared, then to two significant figures and in seconds, what is the period of precession?

ANSWER: 63

TOSS-UP

21. Math *Short Answer* Rohan has a polynomial P in one variable. He finds there are 3 solutions to the congruence P(x) is congruent to 3 modulo 7. When he changes 7 to any other power of 7, he finds there are still 3 solutions. This is due to what lemma, which says that any root of a modular congruence lifts to a unique root modulo a higher power of that prime?

ANSWER: HENSEL'S LEMMA

BONUS

21. Math *Short Answer* The sequence a is defined such that a sub 0 is 2, a sub 1 is 5, and a sub n is 5 times a sub quantity n - 1 minus 6 times a sub quantity n - 2 for n at least 2. What is the remainder when a sub 1000 is divided by 100?

ANSWER: 77

TOSS-UP

22. Biology *Short Answer* Dr. Edwin is treating patients with various heart-related issues and each of their pulse pressures. Order the following three conditions by increasing observed pulse pressure:

1) Aortic stenosis
2) Atherosclerosis
3) Atrial fibrillation

ANSWER: 1, 3, 2

VISUAL BONUS

22. Biology *Short Answer* Shown in the image is a Manhattan plot depicting kidney stone disease in a population. Answer the following 2 questions about this plot:

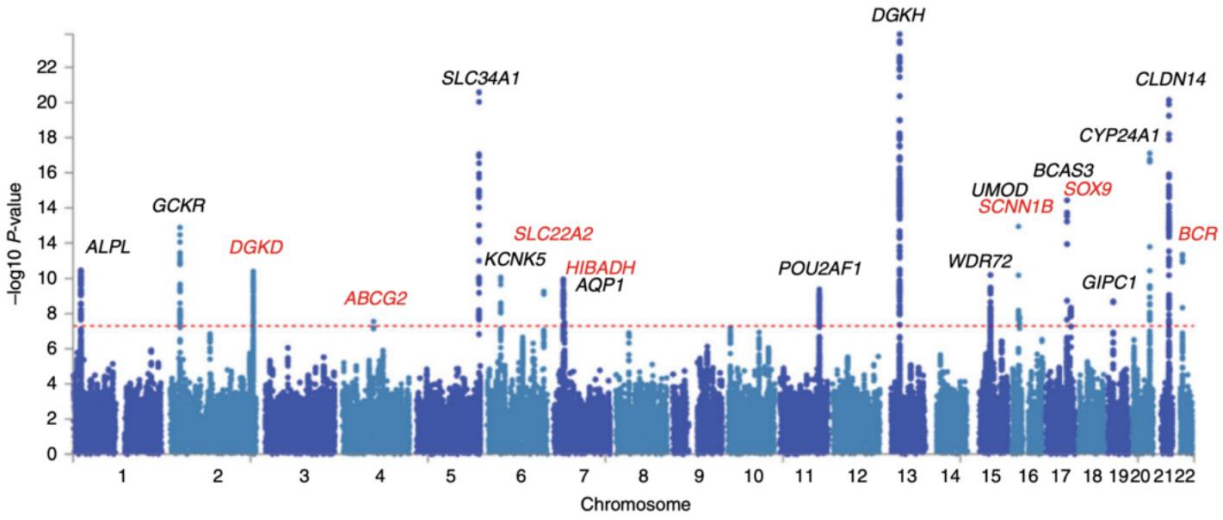
1) What is the name for this general class of observational studies in which statistical associations between disease risk and a large number of DNA loci are analyzed?

2) Identify all of the following three statements that can be definitively concluded from the data in the plot:

1) DGKH is a gene responsible for the formation of kidney stones

2) Kidney stone disease is a polygenic trait

3) Multiple SNPs on chromosome 11 are significantly associated with kidney disease



ANSWER: 1) GENOME WIDE ASSOCIATION STUDIES (ACCEPT: GWAS), 2) 2 and 3

TOSS-UP

23. Energy *Short Answer* Scientists at Montgomery Blair are studying reactions involving aryl diazonium ions. Which reactions use copper halides to install halogens onto aromatic rings via these ions?

ANSWER: SANDMEYER REACTIONS

BONUS

23. Synergy *Short Answer* Ritwik has a spring with spring constant 4 Newtons per meter. He places a mass of 1 kilogram on the spring and stretches it 4 meters from its resting state. He then lets it oscillate and wants to measure its position at t = 4. He uses a Maclaurin Series expansion of the position function and wants to estimate it with an error of at most 0.5. What degree Maclaurin series does he need to use for this?

ANSWER: 4
