BASH



Finals 1

TOSS-UP

1. Energy *Short Answer* Students at Montgomery Blair are studying strings in computer science. The minimum length of a computer program to produce an object is referred to as that object's what?

ANSWER: KOLMOGOROV COMPLEXITY

BONUS

1. Energy *Short Answer* Students at Johns Hopkins University are frustrated with how Rohan Garg writes Energy questions without flavor text. Identify all of the following three statements that are key differences between the Einstein and Debye models of heat capacity:

1) The Debye model uses quantum harmonic oscillators while the Einstein model uses phonons
2) At low temperatures, the Debye model predicts a cubic dependence while the Einstein model predicts an exponential dependence for heat capacity
3) The Einstein model introduces a maximum vibrational frequency in a solid

ANSWER: 2 ONLY

TOSS-UP

2. Earth and Space *Multiple Choice* Kian is searching for Walter White in the Bisti Badlands. He notices that the soft bedrock has been heavily eroded, resulting in steep slopes and narrow canyons. Given this, which of the following stream drainage patterns should he expect to find?

W) Dendritic

X) Trellis

Y) Deranged

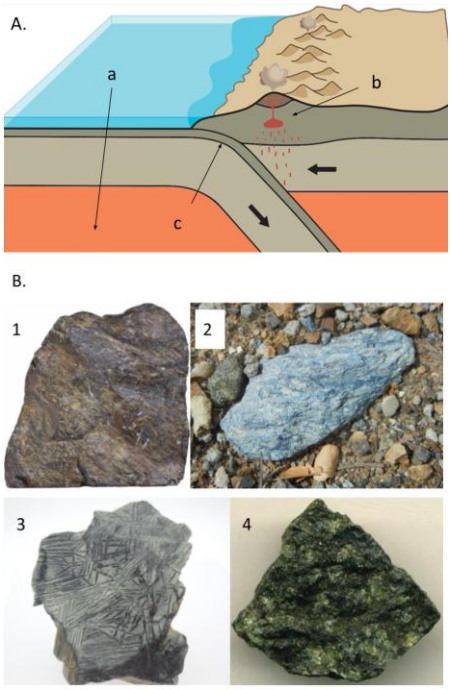
Z) Parallel

ANSWER: Z) PARALLEL

VISUAL BONUS

2. Earth and Space *Short Answer* Shown below are three ocean features and four rock specimens. Answer the following two questions regarding these images.

1) Three of these specimens were formed at one of the features labelled on figure A. Match them.
2) What is the identity of the unmatched specimen?



ANSWER: 1) A4, B1, C2 2) KOMATIITE

TOSS-UP

3. Chemistry *Multiple Choice* Which of the following pairs of conditions would most favor conjugate addition on an enone over 1,2-addition?

W) High temperatures, hard nucleophile

X) High temperatures, soft nucleophile

Y) Low temperatures, hard nucleophile

Z) Low temperatures, soft nucleophile

ANSWER: X) HIGH TEMPERATURES, SOFT NUCLEOPHILE

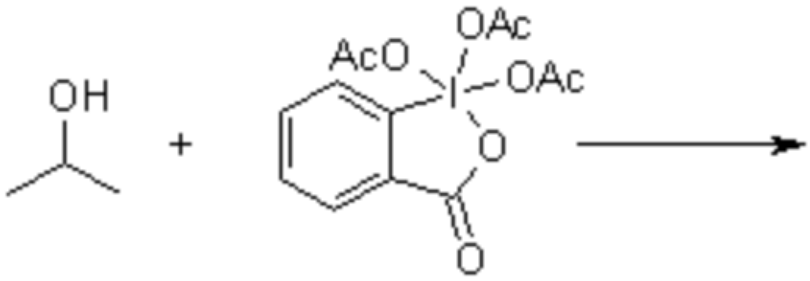
VISUAL BONUS

3. Chemistry *Short Answer* Answer the following three questions about the reaction shown in the image below:

1) What is the name of the name of the iodine-containing reagent shown in this reaction?

2) What is the oxidation state of the iodine atom in this reagent?

3) What organic molecule is formed from the reaction between isopropanol and this reagent?



ANSWER: 1) DESS-MARTIN PERIODANE (ACCEPT: DMP); 2) +5; 3) ACETONE

TOSS-UP

4. Physics *Short Answer* Order the following three fundamental forces in terms of increasing degrees of freedom in their gauge symmetries:

1) Strong force
2) Weak force
3) Electromagnetic force

ANSWER: 3, 2, 1

BONUS

4. Physics *Multiple Choice* Ivy throws a globe stress ball straight upwards in the presence of air resistance. The force due to air resistance is proportional to the square of the velocity of the ball. As the ball is rising, which of the following functions best describes the velocity of the ball as a function of time?

W) Logarithmic
X) Logistic
Y) Tangent
Z) Hyperbolic tangent

ANSWER: Y) TANGENT

TOSS-UP

5. Math *Short Answer* Axiomatic set theory is founded on 8 main axioms, which include extensionality and pairing. These 8 axioms are known as what set of axioms, which provide the standard axiomatization of modern set theory?

ANSWER: ZERMELO-FRAENKEL AXIOMS (ACCEPT: ZF)

BONUS

5. Math *Short Answer* Let f(n) denote the number of ordered pairs of positive integers (x,y) for which 1/x + 1/y = 1/n. What is the ratio of f(24) to f(12)?

ANSWER: 7/5

TOSS-UP

6. Biology *Multiple Choice* Yunyi is performing a Needleman-Wunsch Algorithm to align a series of long protein sequences isolated from his lab. However, he accidentally assigns a small positive score for indels rather than a negative score. Which of the following mutation types will likely be overrepresented in his final sequence alignments?

W) Frameshift
X) Translocation
Y) Duplication
Z) Nonsense

ANSWER: W) FRAMESHIFT

BONUS

6. Biology *Short Answer* Evan is performing gel electrophoresis on his favorite plasmid, but notices that it runs at different rates when he treats it with certain enzymes. Order the following three scenarios in terms of increasing migration rate on a typical agarose gel:

1) Treating the plasmid with a nicking endonuclease
2) Treating the plasmid with a restriction endonuclease
3) Treating the plasmid with DNA gyrase

ANSWER: 1, 2, 3

TOSS-UP

7. Earth and Space *Short Answer* The time a star spends on the main sequence is approximately proportional to its mass raised to what power?

ANSWER: -2.5

BONUS

7. Earth and Space *Short Answer* Kian is studying a protostar and observes a burst of increased luminosity caused by the accretion of matter onto the star. What phenomenon did he observe?

ANSWER: FU ORIONIS EFFECT (ACCEPT: FU ORI EFFECT)

TOSS-UP

8. Chemistry *Short Answer* Kian is performing a polymerization reaction when, to his dismay, he discovers that he cannot stop it. What is the name of this specific type of chain polymerization that has lost the ability to terminate?

ANSWER: LIVING POLYMERIZATION

BONUS

8. Chemistry *Short Answer* While normal amides overreact with Grignard reagents to form tertiary alcohols, a special class of amides, formed from the condensation of an acyl chloride with a methylated hydroxylamine, will instead react with Grignard reagents to form ketones. What is the name for this class of amides?

ANSWER: WEINREB AMIDES

TOSS-UP

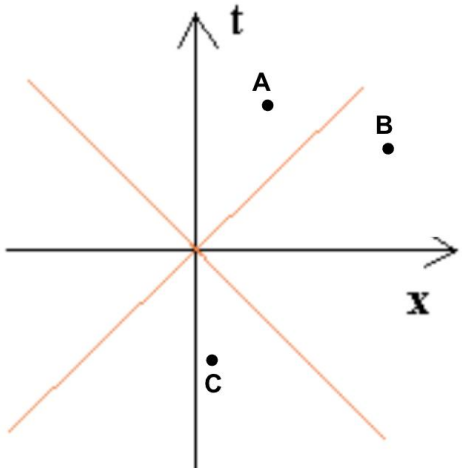
9. Physics *Short Answer* Collective excitations are distinguished from other quasiparticles by their bosonic nature. Identify all of the following three quasiparticles that are considered collective excitations:

1) Phonons
2) Cooper pairs
3) Excitons

ANSWER: ALL

VISUAL BONUS

9. Physics *Short Answer* Consider the Minkowski diagram shown in the image below. By letter, identify all of the following three events that are separated from the origin by a timelike interval.



ANSWER: A AND C

TOSS-UP

10. Math *Short Answer* Identify all of the following three numbers which would take on a value of 0 for the Mobius function:

1) 31

2) 32

3) 33

ANSWER: 2 ONLY

BONUS

10. Math *Short Answer* Let r and s be the roots of the quadratic $x^2 - x + 4$. Consider the monic quadratic polynomial with roots r^4 and s^4. What is the sum of the coefficients of that quadratic?

ANSWER: 240

TOSS-UP

11. Biology *Short Answer* Identify all of the following three situations in which blood pH is expected to be lower than usual in a human:

1) Formation of a fistula between stomach and systemic circulation

2) Chloride deficiency in the bloodstream

3) Increased ketogenesis in the liver

ANSWER: ALL

VISUAL BONUS

11. Biology *Short Answer* Shown in the image is a complementation test, in which seven different mutant haploid strains were crossed and the phenotype of the offspring was observed, where a minus denotes a mutant, and a plus denotes a wild-type. Answer the following two questions about this test:

1) Which of the 7 strains possesses a dominant mutation?

2) What is the maximum number of genes on which the 7 mutations can occur?

	A	B	C	D	E	F	G
A	N/A	-	+	-	+	-	+
B		N/A	+	-	+	-	+
C			N/A	+	+	-	+
D				N/A	+	-	+
E					N/A	-	-
F						N/A	-
G							N/A

ANSWER: 1) F, 2) 4

TOSS-UP

12. Energy *Short Answer* Scientists at Amador Valley are studying transport through the nuclear pore complex. What family of GTPases regulates the directional transport of cargo by interacting with nuclear import and export machinery?

ANSWER: RAN GTPASES

BONUS

12. Synergy *Short Answer* Katherine is studying the decomposition of 1-molar of substance A into two products, B and C. The decomposition of A into B is second order and has a rate constant of 0.3 inverse molar seconds. The decomposition of A into C is also second order and has a rate constant of 0.2 inverse molar seconds. If Katherine is in a spaceship traveling at 0.8 times the speed of light relative to the reaction mixture, then after 20 seconds in Katherine's reference frame and in molars as a common fraction, what is the concentration of substance B?

ANSWER: 18/35

TOSS-UP

13. Earth and Space *Short Answer* Identify all of the following three atmospheric phenomena that require wind shear to form:

1) Mesocyclone
2) Lenticular cloud
3) Kelvin-Helmholtz cloud

ANSWER: 1 AND 3

BONUS

13. Earth and Space *Multiple Choice* Which of the following types of volcanic eruption caused the Permian extinction?

W) Plinean
X) Strombolian
Y) Icelandic
Z) Vulcanian

ANSWER: Y) ICELANDIC

TOSS-UP

14. Chemistry *Short Answer* Evan shines a beam of light through a solution of potassium permanganate. If the initial intensity of the light is 6 times 10^{-3} Watts per meter squared, and the final intensity of the light is 3 times 10^{-5} Watts per meter squared, then to one decimal place, what is the absorbance of the solution?

ANSWER: 2.3

BONUS

14. Chemistry *Short Answer* When too much salt is dissolved in water, the activity of the ions can no longer be well approximated by their concentration. Instead, what model should be used to predict the activity of nonideal solutions?

ANSWER: DEBYE-HUCKEL MODEL

TOSS-UP

15. Physics Short Answer Identify all of the following four types of magnetism that exhibit positive magnetic susceptibility:

1) Paramagnetism

2) Diamagnetism

3) Ferromagnetism

4) Antiferromagnetism

ANSWER: 1, 3, 4

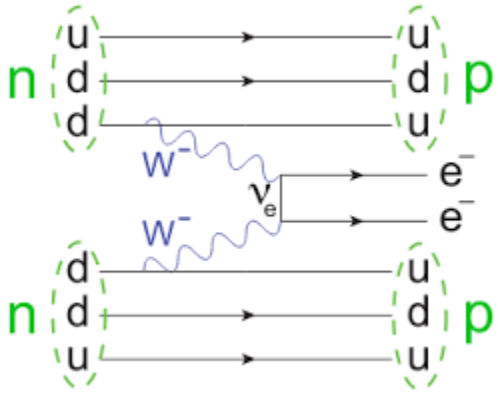
VISUAL BONUS

15. Physics *Short Answer* Answer the following three questions about the nuclear process shown in the image below:

1) What type of diagram, often used to show particle interactions, is depicted in the image?

2) The diagram depicts the neutrinoless version of what specific process, where two neutrons simultaneously convert into two protons?

3) If such a process were to be discovered, it would prove that the neutrino is an example of what kind of fermion, which equals its own antiparticle?



ANSWER: 1) FEYNMANN DIAGRAM; 2) DOUBLE BETA MINUS DECAY; 3) MAJORANA PARTICLE

TOSS-UP

16. Math *Short Answer* Identify all of the following three orders imposed on the set of natural numbers that would be considered a partial order:

1) a is less than or equal to b if a divides b

2) a is less than or equal to b if b/a is at most 2

3) a is less than or equal to b if a is at most b + 1

ANSWER: 1 ONLY

BONUS

16. Math *Short Answer* Edwin has dropped out of college to retake kindergarten! In his class of 24 students, each student likes everyone else except exactly 3 people who they dislike. Let A be the number of love triangles, where each pair of students like each other and B be the number of hate triangles, where each pair of students don't like each other. What is A + B?

ANSWER: 1304

TOSS-UP

17. Biology *Multiple Choice* The glyoxylate cycle is an anabolic pathway similar to the citric acid cycle, but bypasses some of its steps. Which of the following best describes the biochemical purpose of this bypass?

W) To maintain elevated levels of NAD^+ for use in oxidation reactions

X) To prevent carbon loss by skipping decarboxylation steps

Y) To reduce glycolysis inhibition by limiting citrate accumulation

Z) To minimize ATP formation in favor of generating more energy-rich molecules

ANSWER: X) TO PREVENT CARBON LOSS BY SKIPPING DECARBOXYLATION STEPS

VISUAL BONUS

17. Biology *Short Answer* Answer the following two questions about the image shown:

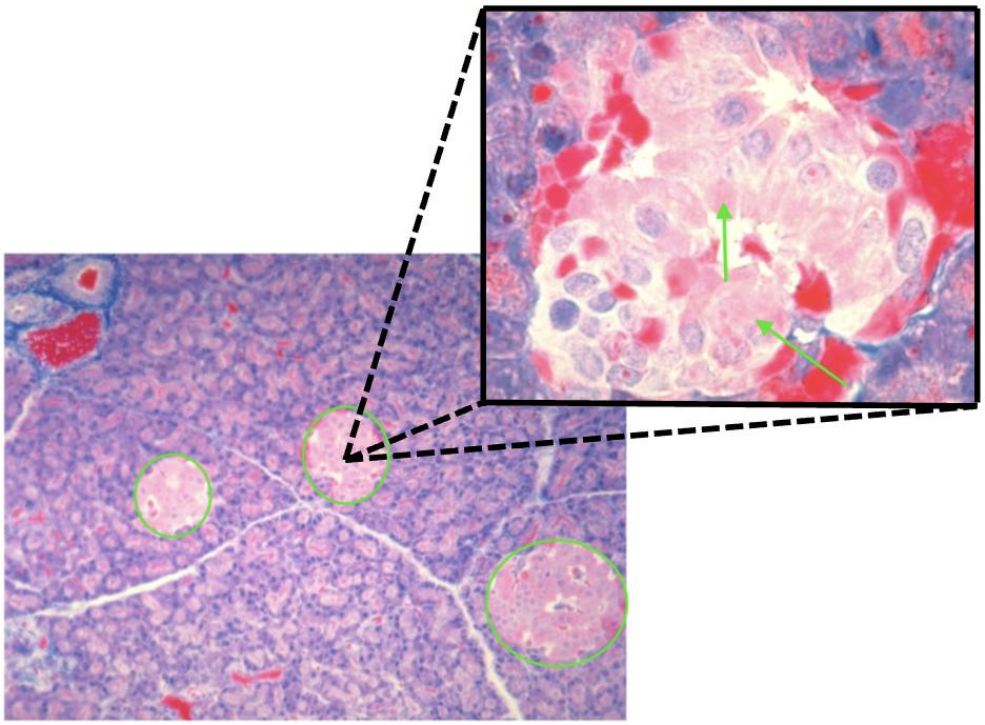
1) What is the name for the specialized endocrine regions contained in the green circles?

2) If the cells depicted by the green arrows, which are the most common type of cell, were overactive, identify all of the following three cellular processes that would have higher activity than usual:

1) Glycolysis

2) Gluconeogenesis

3) Pentose Phosphate Pathway



ANSWER: 1) ISLETS OF LANGERHANS, 2) 1 AND 3

TOSS-UP

18. Earth and Space *Short Answer* Order the following three components of the interstellar medium in order of increasing density:

1) HI **[H one]** regions

2) Intercloud medium

3) Molecular clouds

ANSWER: 2, 1, 3 [EZ]

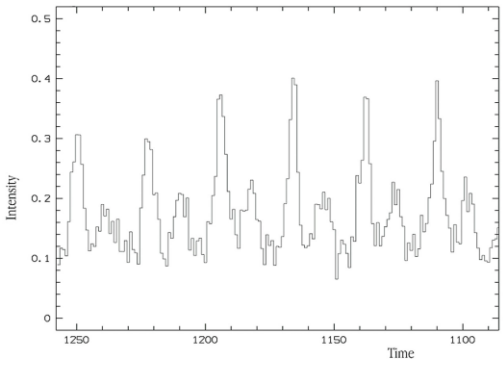
VISUAL BONUS

18. Earth and Space *Short Answer* The following graphs were produced for two stellar objects. Answer the following two questions regarding these graphs:

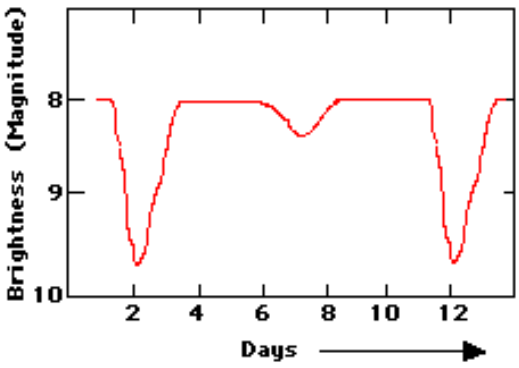
1) What is the general name for these graphs?

2) For each of the graphs A and B, identify the stellar objects they depict, respectively.

A)



B)



ANSWER: 1) LIGHT CURVE 2) MILLISECOND PULSAR (ACCEPT: PULSAR), ECLIPSING BINARY

TOSS-UP

19. Chemistry *Short Answer* Edwin is messing around with germanium when he discovers the very cursed ion $[Ge_9]^{4-}$. This anion involves clusters of germanium atoms and can form salts with group 1 and group 2 metals. What is the general name for such anions?

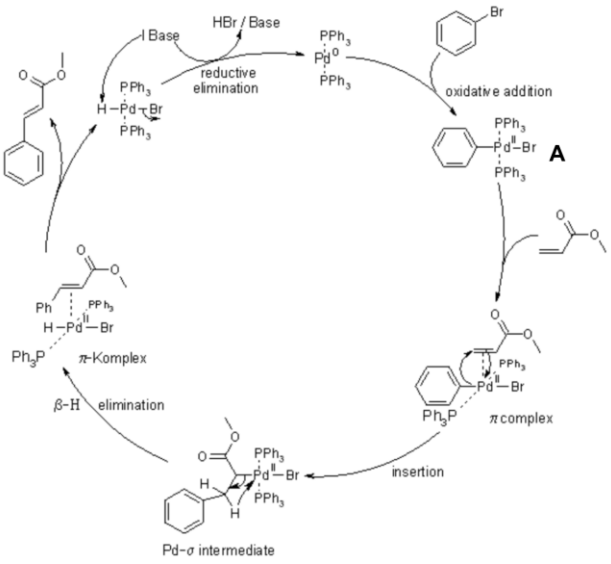
ANSWER: ZINTL IONS

VISUAL BONUS

19. Chemistry *Short Answer* Answer the following two questions about the organometallic coupling reaction shown in the image below:

1. This organometallic reaction couples an alkene to an aryl halide. What is the name for this reaction?

2. Given that palladium is a group 10 metal, what is the total electron count of the palladium complex labelled A?



ANSWER: 1. HECK COUPLING; 2. 16

TOSS-UP

20. Physics *Short Answer* The Penrose process is a method of extracting energy from black holes, and involves shooting a photon into the rotating ergosphere to take advantage of frame dragging. Identify all of the following four types of black holes that can be used in the Penrose process:

1) Kerr
2) Schwarzschild
3) Reissner-Nordstrom
4) Kerr-Newman

ANSWER: 1 AND 4

BONUS

20. Physics *Short Answer* Identify all of the following three particles that are considered tensor bosons:

1) Gluon
2) Higgs boson
3) Kaon

ANSWER: NONE

TOSS-UP

21. Math *Short Answer* Consider the line 4x - 3y = 12. The distance from the line to the origin is measured. The line is then moved one unit up, and the distance is measured. What is the ratio of the new distance to the old distance?

ANSWER: 3/4

BONUS

21. Math *Short Answer* The polynomial $n^2 + n + 41$ has the property that for each n from n = 0 to n = 39, the polynomial takes a prime value. This is because the discriminant, -163, is the negative of what type of number?

ANSWER: HEEGNER NUMBER

TOSS-UP

22. Biology *Short Answer* Identify all of the following three proteins that would be transported by kinesin in the axon of a motor neuron:

1) Nicotinic receptors
2) Ubiquitinated SNARE proteins
3) Synaptotagmins

ANSWER: 3 ONLY

BONUS

22. Biology *Short Answer* Order the following types of mutant alleles in terms of increasing likelihood to be eliminated from a population through natural selection:

1) Dominant harmful allele located close to a recessive beneficial allele
2) Dominant harmful allele located close to a recessive harmful allele
3) Recessive harmful allele located close to a dominant beneficial allele

ANSWER: 3, 1, 2

TOSS-UP

23. Energy *Multiple Choice* Students at Montgomery Blair are studying red tides to better understand lacustrine biomes. Which of the following does NOT contribute to red tide formation?

W) Nonpoint source runoff from surrounding land

X) Heavy precipitation caused by nor'easters

Y) Intensified Langmuir circulation

Z) Anoxic conditions within the epilimnion during summertime

ANSWER: Z) ANOXIC CONDITIONS WITHIN THE EPILIMNION DURING SUMMERTIME

VISUAL BONUS

23. Synergy *Short Answer* Answer the following three questions about the galaxy shown in the figure below:

1) What is the term for such galaxies, which are thought to have formed from galaxy mergers and have high rates of star formation?

2) Identify all of the following four hydrogen transition series whose energies lie in the same region of the electromagnetic spectrum as the majority of the radiation emitted by this galaxy:

1) Lyman

2) Balmer

3) Paschen

4) Brackett

3) For star formation to occur, the insides of the stars must meet what criterion, which allows for fusion with net energy gain?



ANSWER: 1) STARBURST; 2) 3 AND 4; 3) LAWSON'S CRITERION