SBL FALL FINALS 2

TOSS-UP

1) Math – *Short Answer* [7] 10 people are standing in a line. How many ways are there to choose 5 people such that no 2 of them are standing next to each other?

ANSWER: 6 [Com - Com]

BONUS

1) Math – *Short Answer* [6] Right triangle ABC is inscribed in a circle centered at point O. Another circle is drawn internally tangent to the previous circle such that it is tangent to the hypotenuse of ABC. Given that the legs of triangle ABC have length 5 and 12, what is the radius of the smaller circle?

ANSWER: 13/4 [Geo - Circ]

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TOSS-UP

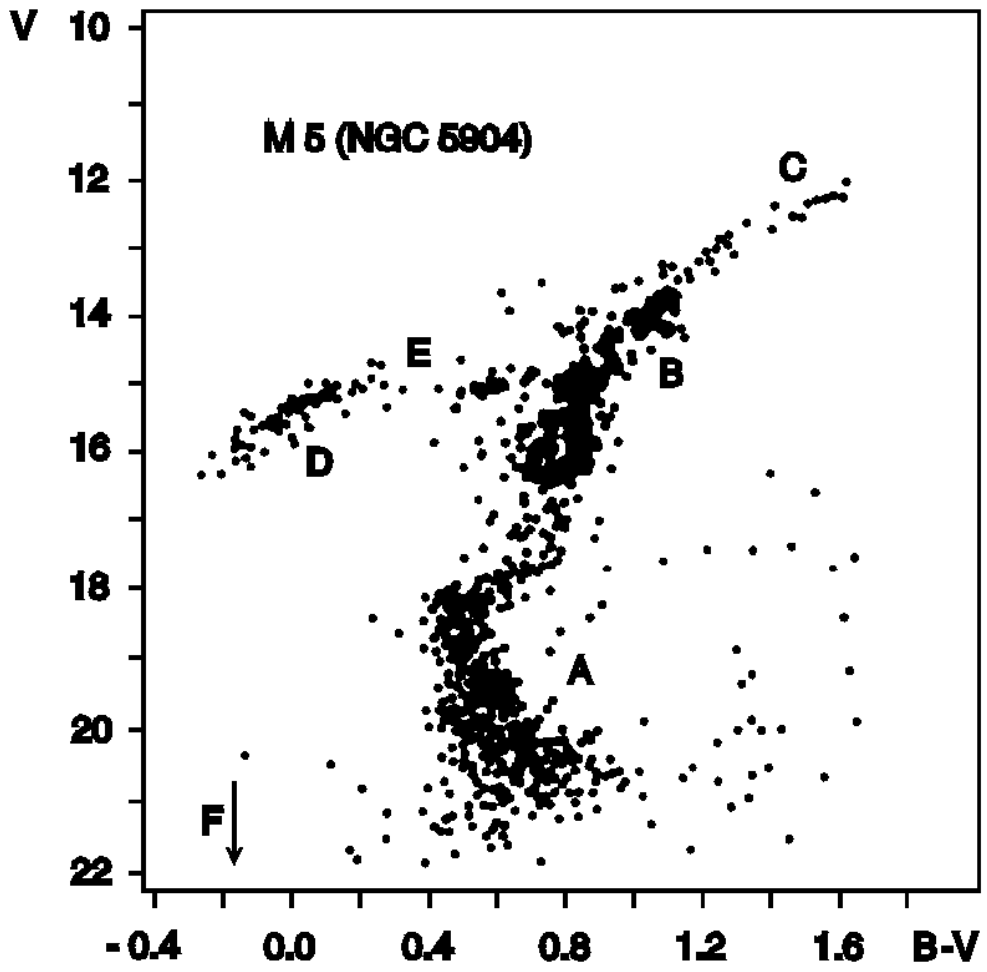
2) Earth and Space – *Multiple Choice* [7] Which of the following statements regarding the speed of sound in seawater is not true?

W) There exists a depth at which the speed of sound in seawater reaches a minimum
X) The speed of sound in seawater increases as temperature increases
Y) For a given temperature, the speed of sound in seawater is always greater than that of freshwater
Z) The speed of sound in seawater can be expressed as a bivariate function of temperature and salinity

ANSWER: Z) THE SPEED OF SOUND IN SEAWATER CAN BE EXPRESSED AS A BIVARIATE FUNCTION OF TEMPERATURE AND SALINITY [Oceanography, YL]

VISUAL BONUS

2) Earth and Space – *Short Answer* [9] Shown in the image is a color-magnitude diagram of Messier object 5, with individual stars plotted as dots. Answer the following three questions regarding this image: 1) What type of variable star is represented by the population at letter E? 2) What stellar evolutionary stage is represented by stars near letter D? 3) Is M5 an open cluster, a globular cluster, or a galaxy?
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ANSWER: 1) RR LYRAE; 2) HORIZONTAL BRANCH; 3) GLOBULAR CLUSTER
[Astronomy - Stellar, YL]

TOSS-UP

3) Physics – *Short Answer* Real objects do not radiate as much thermal energy as predicted by the Stefan–Boltzmann law. What quantity is equal to the ratio of an object's measured thermal radiation to its ideal thermal radiation?

ANSWER: EMISSIVITY

BONUS

3) Physics – *Short Answer* Electrons can possess magnetic moments due to their spin and orbital angular momentum. What relativistic phenomenon is a result of the interaction between these two?

ANSWER: SPIN–ORBIT COUPLING (ACCEPT: SPIN–ORBIT INTERACTION)

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TOSS-UP

4) Biology – *Short Answer* Rank the following three ions in terms of decreasing concentration in the intracellular fluid of a resting neuron: 1) Na^+; 2) Cl^-; 3) K^+.

ANSWER: 3, 1, 2

BONUS

4) Biology – *Short Answer* Identify all of the following three types of plant ground tissue that possess secondary cell walls: 1) Parenchyma; 2) Collenchyma; 3) Sclerenchyma.

ANSWER: 2 AND 3
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TOSS-UP

5) Chemistry – *Short Answer* How many normal vibrational modes does one molecule of acetylene have?

ANSWER: 7

BONUS

5) Chemistry – *Short Answer* Identify all of the following three carbon dioxide vibrational modes that are considered to be Raman active: 1) Asymmetric C–O stretch; 2) Symmetric C–O stretch; 3) Symmetrical bend in plane.

ANSWER: 2 ONLY

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TOSS-UP

6) Energy – *Short Answer* Scientists at Argonne National Lab are working on new solvent extraction methods that employ magnetic fields to act on paramagnetic metal ions. Identify all of the following three metal ions that are paramagnetic: 1) Na^{+}; 2) Cr^{3+}; 3) Zn^{2+}.

ANSWER: 2 ONLY

BONUS

6) Energy – *Short Answer* Researchers at Fermilab are conducting particle physics experiments in order to ascertain information about the early universe. One of their experiments focuses on the conversion of what particles to electrons without the emission of neutrinos?

ANSWER: MUONS
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TOSS-UP

7) Biology – *Short Answer* Insects secrete what form of nitrogenous waste?

ANSWER: URIC ACID

BONUS

7) Biology – *Short Answer* During inflammation, which class of leukocytes may migrate into the blood to become mast cells and release histamine?

ANSWER: BASOPHILS

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TOSS-UP

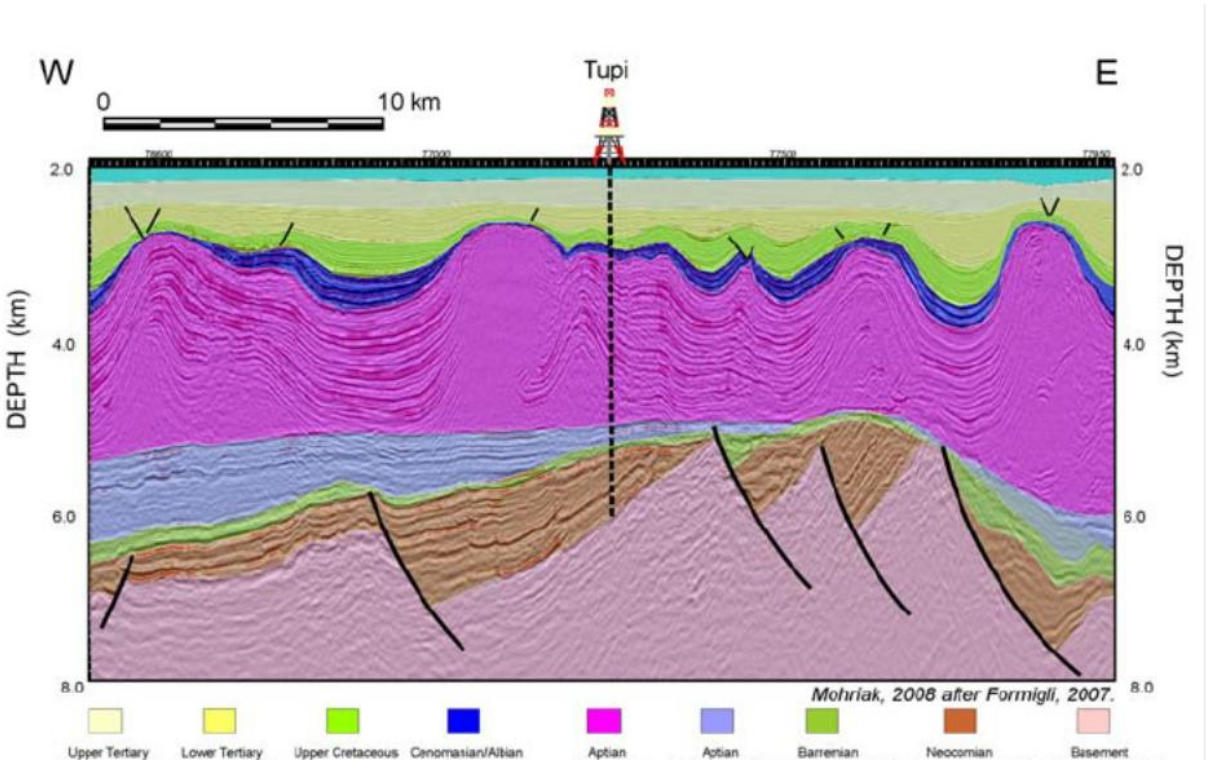
Earth and Space – *Multiple Choice* [7] Galactic fountains are features that spread relatively hot, metal-enriched gas high above the disk of a spiral galaxy. Which of the following best describes how most galactic fountains form?

W) Intense stellar winds and supernovae
X) Tidal forces from a supermassive black hole
Y) Relativistic jets from a neutron star
Z) Tidal forces from orbiting dwarf galaxies

ANSWER: W) INTENSE STELLAR WINDS AND SUPERNOVAE [Astronomy - Other, YL]

VISUAL BONUS

Earth and Space – *Short Answer* [8] Shown in the image is a seismic cross section of the rock under the Santos Basin, located in the South Atlantic. Answer the following two questions regarding the image: 1) Identify the primary mineral of the purple unit; 2) What type of normal fault can be seen near the bottom of the profile?
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ANSWER: 1) HALITE (ACCEPT: SALT); 2) LISTRIC FAULT [Geology - Structural, YL]

TOSS-UP

9) Chemistry – *Multiple Choice* Which of the following compounds is the least suitable nucleophile for an SN2 reaction?

W) Ethanol
X) Methylamine
Y) Sodium iodide
Z) Sodium methoxide

ANSWER: W) ETHANOL

BONUS

9) Chemistry – *Short Answer* Rank the following three liquids in terms of increasing viscosity: 1) Mercury; 2) Water; 3) Diethyl ether.

ANSWER: 3, 2, 1

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TOSS-UP

10) Math – *Short Answer* [7] What is the coefficient of the xy^3 term in the binomial expansion of open parentheses $3x + 2y$ close parentheses to the 4th?

ANSWER: 96 [Alg - idk]

BONUS

10) Math – *Short Answer* [8] Alice estimates the value of the natural log of a large integer n by plotting the graph of $y = \ln(x)$ and performing the Euler method with a step size of 1 starting from the point (1, 0). She notices that, as n grows to infinity, the difference between her estimate and the true value of $\ln(n)$ approaches what constant?

ANSWER: EULER–MASCHERONI CONSTANT [Calc - Der]
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TOSS-UP

11) Energy – *Short Answer* Scientists at Lawrence Berkeley National Lab have been developing methods for performing artificial photosynthesis. In these methods, titanium dioxide is used for the water-splitting reaction that is traditionally catalyzed by what enzyme within photosystem 2 in plants?

ANSWER: OXYGEN-EVOLVING COMPLEX (ACCEPT: WATER-SPLITTING COMPLEX)

BONUS

11) Energy – *Short Answer* Researchers at Lawrence Livermore National Lab are using short laser pulses to remove atoms from the surface of metals. Lasers are generated by shooting photons at excited electrons, causing them to relax to their ground state. What is the term for this process?

ANSWER: STIMULATED EMISSION

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TOSS-UP

12) Physics – *Multiple Choice* Most jet engines employ which of the following thermodynamic cycles?

W) Carnot cycle
X) Stirling cycle
Y) Otto cycle
Z) Brayton cycle

ANSWER: Z) BRAYTON CYCLE

BONUS

12) Physics – *Short Answer* Identify all of the following three statements that are true regarding electric field lines: 1) Induced electric field lines form closed loops; 2) Equipotential lines are always parallel to electric field lines; 3) More closely-spaced electric field lines correspond to stronger electric fields.

ANSWER: 1 AND 3
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TOSS-UP

13) Chemistry – *Multiple Choice* How many net pi bonds are formed during a sigmatropic rearrangement?

W) –1
X) 0
Y) 1
Z) 2

ANSWER: X) 0

BONUS

13) Chemistry – *Multiple Choice* When H_2 forms a side-on complex with a tungsten center, which of the following is most likely to occur?

W) The H–H bond strength decreases because tungsten donates electrons into the H–H sigma star orbital
X) The H–H bond strength increases because tungsten donates electrons into the H–H sigma orbital
Y) The H–H bond strength decreases because tungsten donates electrons into the H–H pi star orbital
Z) The H–H bond strength increases because tungsten donates electrons into the H–H pi orbital

ANSWER: W) THE H–H BOND STRENGTH DECREASES BECAUSE TUNGSTEN DONATES ELECTRONS INTO THE H–H SIGMA STAR ORBITAL

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TOSS-UP

14) Biology – *Short Answer* Identify all of the following three organelles that are enclosed by a double membrane: 1) Nucleus; 2) Glyoxysome; 3) Chloroplast.

ANSWER: 1 AND 3

BONUS

14) Biology – *Short Answer* What enzyme in red blood cells is responsible for the rapid conversion of water and carbon dioxide into carbonic acid?

ANSWER: CARBONIC ANHYDRASE
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TOSS-UP

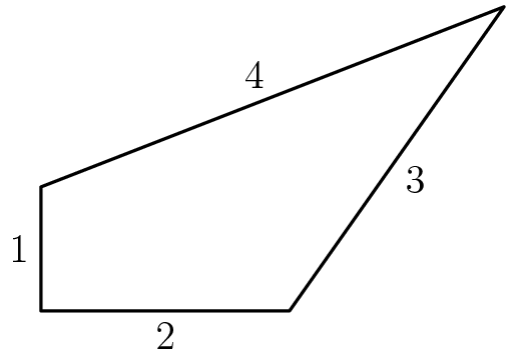
15) Math – *Multiple Choice* [8] A linear map *f* from R squared to R squared maps a region D to another region with the same area. Which of the following best describes the Jacobian determinant of this transformation?

W) Less than 1
X) 1
Y) Between 1 and 2
Z) 2

ANSWER: X) 1 [Calc - Der]

VISUAL BONUS

15) Math – *Short Answer* [8] Shown in the image is a convex quadrilateral which has side lengths of 1, 2, 3, and 4, in that order. In addition, it has a right angle between the sides of lengths 1 and 2. What is the area of this quadrilateral?



ANSWER: 1 PLUS ROOT 11 [Geo - Quad]

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TOSS-UP

Earth and Space – *Multiple Choice* [7] Which of the following statements regarding dynamic tide theory is false?

W) Amphidromic points represent points in the ocean that experience zero tidal range
X) Cotidal lines rotate around amphidromic points
Y) The number of amphidromic points present in the oceans may vary drastically throughout the year
Z) Waves associated with tidal movement have extremely long wavelengths and shallow amplitudes

ANSWER: Y) THE NUMBER OF AMPHIDROMIC POINTS PRESENT IN THE OCEANS MAY VARY DRASTICALLY THROUGHOUT THE YEAR [Oceanography, YL]

BONUS
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Earth and Space – *Short Answer* [8] Identify all of the following three characteristics that would be expected for subtropical gyre circulation in the Northern Hemisphere: 1) Downwelling at the center; 2) Counterclockwise flow; 3) Stronger eastern boundary currents and weaker western boundary currents.

ANSWER: 1 ONLY [Oceanography, YL]

TOSS-UP

17) Energy – *Multiple Choice* Scientists at Brookhaven National Lab are using cryoelectron microscopy to characterize the activated CAS9 guide RNA complex in E. coli. E. coli guide RNA is likely to exhibit sequence specificity for nucleic acids in which of the following organisms?

W) Treponema pallidum
X) T4
Y) Plasmodium falciparum
Z) HIV

ANSWER: X) T4

BONUS

17) Energy – *Short Answer* Researchers at Argonne National Lab have been looking for cost effective ways to enrich molybdenum isotopes. They have developed a method that used parts such as acrylic contractors, which were produced by what technique?

ANSWER: 3D PRINTING

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TOSS-UP

18) Physics – *Short Answer* Curie's law states that the magnetization of a paramagnetic sample is equal to magnetic susceptibility times what quantity?

ANSWER: EXTERNAL MAGNETIC FIELD (ACCEPT: APPLIED MAGNETIC FIELD; MAGNETIC FIELD; H FIELD)

BONUS

18) Physics – *Short Answer* What is the name for devices containing one p–n junction that convert light into electrical current?

ANSWER: PHOTODIODE
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TOSS-UP

19) Math – *Multiple Choice* [8] Which of the following numbers has the highest 2-adic valuation?

W) 62
X) 64
Y) 66
Z) 68

ANSWER: X) 64 [NT - Prim]

BONUS

19) Math – *Short Answer* [8] A polynomial $f(x)$ that has integer coefficients satisfies $f(1) = 1$ and $f(2) = 11$. What is the smallest positive value of $f(10)$?

ANSWER: 19 [Alg - Poly]

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TOSS-UP

20) Earth and Space – *Short Answer* Identify all of the following three solar system bodies that are known to have permanent polar ice caps: 1) Mars; 2) The Earth's moon; 3) Venus.

ANSWER: 1 ONLY

BONUS

20) Earth and Space – *Short Answer* Identify all of the following three features that would usually be associated with an extensional tectonic regime: 1) Graben and horst topography; 2) Normal faulting; 3) Low angle thrust faulting.

ANSWER: 1 AND 2
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TOSS-UP

21) Chemistry – *Short Answer* Esters can be hydrolyzed under acidic conditions to form carboxylic acids and what other functional group?

ANSWER: ALCOHOL

BONUS

21) Chemistry – *Multiple Choice* For which of the following gas-phase reactions is the change in enthalpy the same as the change in internal energy?

W) Dissociation of water vapor to form hydrogen and oxygen gas
X) Formation of ammonia from hydrogen and nitrogen gas
Y) Hydrogenation of ethene to form ethane
Z) Formation of carbon dioxide and hydrogen gas from water vapor and carbon monoxide

ANSWER: Z) FORMATION OF CARBON DIOXIDE AND HYDROGEN GAS FROM WATER VAPOR AND CARBON MONOXIDE

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TOSS-UP

22) Biology – *Short Answer* PYY is a hormone that suppresses the action of what hormone released by the walls of the stomach to increase hunger?

ANSWER: GHRELIN

BONUS

22) Biology – *Short Answer* What two monomers collectively compose the polysaccharide peptidoglycan?

ANSWER: N-ACETYLMURAMIC ACID AND N-ACETYLGLUCOSAMINE (ACCEPT: NAM AND NAG)
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TOSS-UP

23) Physics – *Short Answer* Suppose a charged particle moves with an initial velocity neither parallel nor perpendicular to a uniform magnetic field. What type of curve will be traced out by its resultant motion?

ANSWER: HELICAL

BONUS

23) Physics – *Short Answer* Identify all of the following three statements that are true regarding statistical mechanics: 1) All microstates have equal probability of being occupied: 2) Entropy is proportional to the natural log of the number of microstates; 3) Canonical ensembles have a fixed number of particles.

ANSWER: ALL