TOSS-UP

1) Physics [2] – *Short Answer* Identify all of the following three forces that are inertial forces: 1) Centripetal; 2) Coriolis; 3) Centrifugal.

ANSWER: 2, 3 [SS, Forces]

BONUS

1) Physics [5] – *Short Answer* Identify all of the following 3 quantities that, when increased, would increase the separation between fringes from a diffraction grating: 1) Distance between light source and diffraction grating; 2) Distance between diffraction grating and wall; 3) Slit separation.

ANSWER: 2 ONLY [GW, Optics]

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TOSS-UP

2) Biology [3] – *Multiple Choice* Which of the following is true regarding both prokaryotic DNA polymerase I and DNA polymerase III?

W) They both add primers from the 5' to the 3' direction.
X) They both replace primers with DNA Nucleotides
Y) They both open up the DNA double helix.
Z) They both have exonuclease activity

ANSWER: Z) THEY BOTH HAVE EXONUCLEASE ACTIVITY [DJ, DNA/RNA]

BONUS

2) Biology [2] – *Short Answer* Identify all of the following three conditions that are X-linked: 1) Duchenne muscular dystrophy; 2) Red-green color blindness; 3) Hemophilia A.

ANSWER: ALL [SS, Genetics]

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TOSS-UP

3) Math [4] – *Short Answer* If f(x) is a monic quadratic polynomial such that f(1)=1 and f(2)=2, what is the value of f(3)?

ANSWER: 5 [SS, Polynomials]

BONUS

3) Math [2] – *Multiple Choice* Which of the following numbers has the largest sum of factors?

W) 150
X) 151
Y) 152
Z) 153

ANSWER: W) 150 [SS, Factors]

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TOSS-UP

4) Earth and Space [3] – *Multiple Choice* Lahars, which are caused by volcanoes, are a type of mass wasting event that belong to which of the following broader types of mass wasting?

W) Slump
X) Debris Flow
Y) Mudflow
Z) Creep

ANSWER: Y) MUDFLOW [BZ, Mass Wasting]

BONUS

4) Earth and Space [4] – *Short Answer* Order the following three minerals in terms of increasing average oxidation state of iron. 1) Pyrite; 2) Goethite; 3) Magnetite.

ANSWER: 1, 3, 2 [SS, Mineralogy]

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TOSSUP

5) Chemistry [3] – *Short Answer* When Aluminum-26 undergoes electron capture, a neutrino is emitted along with what isotope?

ANSWER: MAGNESIUM-26 (ACCEPT: Mg-26) [SS, Nuclear]

BONUS

5) Chemistry [4] – *Short Answer* A vicinal dihalide is treated with sodium amide dissolved in liquid ammonia. What functional group is the major product of this reaction?

ANSWER: ALKYNE (ACCEPT: ALKYNIDE ION) [SS]

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TOSSUP

6) Energy [3] – *Short Answer* Researchers at Lawrence Berkeley National Lab are studying the effect bacteriophages have on *E. coli* receptors. What specific phage is known for infecting *E. coli* and was discovered by Esther Lederberg?

ANSWER: LAMBDA PHAGE (ACCEPT: COLIPHAGE) [DJ, BIO]

BONUS

6) Energy [4] – *Short Answer* Researchers at Lawrence Berkeley National Lab are using cold crystals to study neutrinos. In particular, they are investigating whether or not neutrinos are an example of what type of fermion that is also its own antiparticle?

ANSWER: MAJORANA PARTICLE (ACCEPT: MAJORANA FERMION) [DJ, Physics]

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TOSS-UP

7) Physics [3] – *Short Answer* The change in Helmholtz free energy is equivalent to the expansion work done on a system when what variable is held constant?

ANSWER: TEMPERATURE [BZ, Thermo]

BONUS

7) Physics [5] – Short Answer A spring with a spring constant of 16 Newtons per meter and 0 rest length lies flat on a frictionless surface. A 1-kilogram block is moving at a speed of 9 meters per second away from the center of the spring when it is 3 meters away from the center of the spring. What is the amplitude of oscillations of the spring and block system?

ANSWER: 15/4 (ACCEPT: 3.75) [GW, SHO]

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TOSS-UP
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8) Biology [3] – *Short Answer* After a mass-extinction event, what large-scale evolutionary process occurs, in which new species are created that fill different ecological niches?

ANSWER: ADAPTIVE RADIATION [DJ, EVOLUTION]

BONUS

8) Biology [2] – *Multiple Choice* Which of the following best describes the quaternary structure of hemoglobin?

W) 2 alpha chains and 2 beta chains
X) 3 alpha chains and 1 beta chains
Y) 1 alpha chain and 3 beta chains
Z) 1 alpha chain and 1 beta chain

ANSWER: W) 2 ALPHA AND 2 BETA CHAINS [DJ, Biomolecules]

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TOSS-UP

9) Math [1] – *Short Answer* What is the dot product of the vectors, $6\boldsymbol{i} + 3\boldsymbol{j}$ and $4\boldsymbol{i} - 7\boldsymbol{j}$?

ANSWER: 3 [SS, Vectors]

BONUS

9) Math [5] – *Short Answer* If f'(x)[***f prime of x***] is strictly decreasing for all $x > 0$, $f(2) = 9$, and $f(3) = 13$, then what is the largest possible integer value of f(1)?

ANSWER: 4 [GW, Functions]

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TOSS-UP

10) Earth and Space [4] – *Multiple Choice* Which of the following metamorphic facies has the highest grade?

W) Blueschist
X) Greenschist
Y) Zeolite
Z) Eclogite

ANSWER: Z) ECLOGITE [SS, Rocks]

BONUS

10) Earth and Space [3] – *Short Answer* Identify all of the following three solar system bodies that are fully differentiated. 1) Callisto; 2) Jupiter; 3) Mercury.

ANSWER: 2 AND 3 [SS]

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TOSS-UP

11) Chemistry [5] – *Short Answer* Order the following three isomers of pentane by increasing enthalpy of combustion: 1) N-pentane; 2) Neopentane; 3) Isopentane.

ANSWER: 1, 3, 2 [SS]

BONUS

11) Chemistry [4] – *Short Answer* A particle in a 1D box has zero-point energy of 1 electronvolt. If the mass of the particle and the length of the box are both doubled, what is the energy of the 4th excited state of the particle in electronvolts?

ANSWER: 25/8 [SS, Quantum]

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TOSS-UP

12) Energy [2] – *Multiple Choice* Researchers at Lawrence Berkeley National Lab are using targeted alpha-particle therapy with antibodies to selectively attack cancerous cells and monitoring the results using positron emission tomography. PET-scans employ the use of what halogen attached to glucose as a radiotracer?

W) Fluorine
X) Chlorine
Y) Bromine
Z) Iodine

ANSWER: W) FLUORINE [DJ, PHYSICS]

BONUS

12) Energy [4] – *Short Answer* Researchers at SLAC National Accelerator are creating a new x-ray based accelerator using strings of magnets that wiggle an electron beam. What insertion devices are being used to create this free electron laser?

ANSWER: UNDULATOR [DJ, PHYSICS]

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TOSS-UP

13) Physics [3] – *Short Answer* A 5 kg mass is moving at 10 meters per second to the right and collides and sticks to a stationary 3 kg mass. What is the coefficient of restitution of the collision?

ANSWER: 0 [SS, Conservation]

BONUS

13) Physics [4] – *Multiple Choice* Which of the following characterizes an electric field produced purely from static charges?

W) Curl-free
X) Divergence-free
Y) Rotational
Z) Radial

ANSWER: W) CURL-FREE [GW, Electromagnets]

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TOSS-UP

14) Biology [4] – *Short Answer* Identify all of the following 3 compounds that are 5 carbon sugars: 1) Dihydroxyacetone; 2) Galactose; 3) Ribulose.

ANSWER: 3 ONLY [DJ, Biomolecules]

BONUS

14) Biology [2] – *Multiple Choice* Which of the following is NOT true regarding miRNA?

W) miRNA binds to complementary mRNA sequences.
X) miRNA is in the RNA-Induced silencing complex.
Y) miRNA is double stranded
Z) miRNA is vitally important in the regulation of gene expression.

ANSWER: Y) MIRNA IS DOUBLE STRANDED [DJ, DNA/RNA]

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TOSS-UP

15) Math [5] – *Short Answer* Evaluate 125 to the power of $\log_{25}(6)$.

ANSWER: 6 ROOT 6 [GW, Logs/Exponents]

BONUS

15) Math [5] – *Short Answer* Find the eigenvalues of the 2x2 matrix with first row 1, 4 and second row 3, 2.

ANSWER: –2 AND 5 [GW, Linear Algebra]

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TOSS-UP

16) Earth and Space [3] – *Short Answer* What are the SI units of Hubble's constant?

ANSWER: HERTZ (ACCEPT: INVERSE SECONDS, 1 OVER SECONDS) [Cosmology, GW]

BONUS

16) Earth and Space [3] – *Multiple Choice* Which of the following best explains why the dust tail of a comet is often more curved than the gas tail?

W) The sun's magnetic field causes the dust tail to accelerate perpendicular to its velocity
X) The dust tail spirals due to increased radiation pressure from the sun
Y) Dust particles are subject to lensing effects
Z) Dust particles individually follow their own orbits

ANSWER: Z) DUST PARTICLES INDIVIDUALLY FOLLOW THEIR OWN ORBITS [Asteroids/Comets]

TOSS-UP

17) Chemistry [3] – *Multiple Choice* Which of the following indicators would be most suitable for a titration of formic acid with potassium hydroxide?

W) Phenolphthalein
X) Methyl red
Y) Bromothymol blue
Z) Bromocrescol green

ANSWER: W) Phenolphthalein [BZ, Acid/Base]
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BONUS

17) Chemistry [4] – *Short Answer* What equation of state approximates the volume and pressure of a gas as a power series of density?

ANSWER: VIRIAL EQUATION [SS, States of Matter]

TOSS-UP

18) Energy [1] – *Short Answer* Researchers at Lawrence Berkeley National Lab are studying the use of polydiketoenamine for cyclic recycling of plastics. In their research, triketones and amines react, expelling a water molecule and forming a linkage in what general type of reaction?

ANSWER: CONDENSATION (ACCEPT: DEHYDRATION SYNTHESIS) [DJ, CHEM]

BONUS

18) Energy [4] – *Multiple Choice* Researchers at Pacific Northwest National Lab are using AlphaFold2 from Deepmind to study the protein folding process using neural networks. Which of the following types of neural networks would you most likely use for image classification and recognition of a protein?

W) Fully connected neural networks
X) Recurrent neural networks
Y) Convolutional neural networks
Z) Generative adversarial networks

ANSWER: Y) CONVOLUTIONAL NEURAL NETWORKS [DJ, OTHER]

TOSS-UP

19) Physics [3] – *Short Answer* A ball is dropped off of the top of a 10 meter cliff. What is the speed of the ball right before it hits the ground, in meters per second?

ANSWER: 14 METERS PER SECOND [GW, Kinematics]

BONUS

19) Physics [] – *Multiple Choice* A toy car goes around a flat curve of radius 8 centimeters at an angular speed of 14 radians per second. What is the minimum coefficient of friction between the tires and the road for the toy car to make the turn?

W) 1.6

X) 2.0
Y) 2.4
Z) 2.8

ANSWER: W) 1.6 [GW, Circles]

TOSS-UP

20) Biology [5] – *Short Answer* What name is given to the specialized cotyledons in grasses such as maize and wheat?

ANSWER: SCUTELLUM [SS]

BONUS

20) Biology [4] – *Multiple Choice* Which of the following best explains the function of guide RNA in CRISPR?

W) They modify the genomic DNAs histones
X) They form Watson-Crick base pairs with genomic DNA.
Y) Takes a long mRNA strand to help recognize it's genomic target
Z) They recruit an exonuclease to find genomic DNA

ANSWER: X) THEY FORM WATSON-CRICK BASE PAIRS WITH GENOMIC DNA [DJ, BIOTECH]

TOSS-UP

21) Math [2] – *Multiple Choice* A triangle is inscribed in a circle such that it contains the center of the circle within its area. Which of the following must be true regarding the triangle?

W) It is acute
X) It is obtuse
Y) It is scalene
Z) It is isosceles

ANSWER: W) IT IS ACUTE [SS]

BONUS

21) Math [6] – *Multiple Choice* The Lucas sequence is defined as L_0 (***l-sub-0***) equals 2, L_1 (***l-sub-1***) equals 1, and $L_n = L_{n-1} + L_{n-2}$ for all $n \geq 2$. What is the remainder when the 40th Lucas number, L_{40}, is divided by 11?

W) 1
X) 2

Y) 3
Z) 4

ANSWER: X) 2 [GW, Sequences]

TOSS-UP

22) Earth and Space [5] – *Multiple Choice* The area of sea ice in the arctic is at a minimum in which of the following months?

W) January
X) April
Y) September
Z) December

ANSWER: Y) SEPTEMBER [SS, Meteo]

BONUS

22) Earth and Space [3] – *Short Answer* A secondary mirror reflects light back through a hole in the primary mirror in what kind of telescope arrangement?

ANSWER: CASSEGRAIN FOCUS (ACCEPT: CASSEGRAIN REFLECTOR, CASSEGRAIN TELESCOPE, CASSEGRAIN) [Telescopes, GW]

TOSS-UP

23) Chemistry [3] – *Short Answer* The pre-exponential factor for a particular reaction has units of inverse seconds. What is the order of the reaction?

ANSWER: 1 [SS, Kinetics]

BONUS

23) Chemistry [3] – *Multiple Choice* Which of the following atomic orbitals has the fewest number of radial nodes?

W) 5*p*
X) 5*s*
Y) 6*f*
Z) 6*d*

ANSWER: Y) 6*f* [BZ, Quantum]

Chem avg: 3.625

Bio avg: 3.125
Math avg: 3.75
Physics avg:
Energy avg: 3
ESS avg: 3.5