LOST ROUND 13

TOSS-UP

1) PHYSICS – *Short Answer* If a physical system is rotationally symmetric, then what conservation law must it exhibit according to Noether's theorem?

ANSWER: CONSERVATION OF ANGULAR MOMENTUM

BONUS

1) PHYSICS – *Short Answer* What approximation method in quantum mechanics estimates the energy levels of a complicated system by expressing its Hamiltonian as a power series and taking the first few terms?

ANSWER: PERTURBATION THEORY

TOSS-UP

2) BIOLOGY – *Short Answer* Those with Urbach-Wiethe disease typically develop symmetrical calcification in what central portion of the limbic system, leading to reduced emotional responses?

ANSWER: AMYGDALA

VISUAL BONUS

2) BIOLOGY – *Short Answer* The image depicts linear electron flow during the light reaction of photosynthesis in a rose. Answer the following two questions regarding this image:

I. What is the name of the electron carrier labeled A, which functions to shuttle electrons in both linear and cyclic electron flow and what transition metal is coordinated within the protein?
II. What is the name of the reduced form of the pair of central chlorophyll molecules in photosystem II labeled B, which are amongst the most powerful of oxidizing agents in its oxidized?

ANSWER: 1) PLASTOCYANIN AND COPPER; 2) P680 (DO NOT ACCEPT: P680+)

TOSS-UP

3) CHEMISTRY – *Multiple Choice* Which of the following could not describe a normal mode in a centrosymmetric molecule?

W) Both IR and raman active
X) IR active but raman inactive
Y) IR inactive but raman active
Z) Both IR and raman inactive

ANSWER: W) BOTH IR AND RAMAN ACTIVE

VISUAL BONUS

3) CHEMISTRY – *Multiple Choice* When methyl vinyl ketone is treated with a gilman reagent and analyzed using infrared spectroscopy, which of the four IR spectrums shown could be the product?

ANSWER: X

TOSS-UP

4) MATH – *Short Answer* The positive two digit integer AB has 12 divisors. How many divisors does the four digit integer ABAB have?

ANSWER: 24

BONUS

4) MATH – *Short Answer* Robert starts with the polynomial $f(x) = x^2 + x + 1$. Every second, he either adds or subtracts 1 from f. What is the probability that after 2017 seconds, f has a real root?

ANSWER: ½

TOSS-UP

5) EARTH AND SPACE – *Multiple Choice* Which of the following cannot produce an absorption spectra?

W) Ionized hydrogen
X) Singly ionized helium
Y) Doubly ionized oxygen
Z) Doubly ionized sulfur

ANSWER: W) IONIZED HYDROGEN

VISUAL BONUS

5) EARTH AND SPACE – *Short Answer* Displayed is a X-ray photo of the Bullet Cluster, taken by the Chandra Observatory in 2005 and remains one of the most studied clusters due to it providing evidence for the existence of dark matter. Answer the following three questions regarding the bullet cluster:

I. What galactic event is occurring in the Bullet Cluster?
II. The Bullet Cluster provides wide evidence for dark matter by disproving what theory that hypothesizes that gravity acts differently in low acceleration environments?
III. The dark matter within the galaxies is mainly studied via what phenomena which can be measured via the distortion of light coming from behind the Bullet Cluster?

ANSWER: 1) GALACTIC COLLISION (ACCEPT: GALACTIC CANNIBALISM); 2) MOND (ACCEPT: MODIFIED NEWTONIAN DYNAMICS); 3) GRAVITATIONAL LENSING.

TOSS-UP

6) ENERGY – *Short Answer* Scientists at Argonne National Labs have been using solid state fluorine 19 NMR spectroscopy to probe the structures of various materials. In trigonal bipyramidal molecules such as PF_5 at low temperatures, two sets of signals are observed for axial and equatorial fluorine in the fluorine 19 NMR spectrum. However, at high temperatures both signals converge into one signal due to what vibrational effect?

ANSWER: BERRY PSUEDO-ROTATION

BONUS

6) ENERGY – *Short Answer* DOE researchers at Argonne National Labs have been studying the properties of the SARS-COV2 spike protein via the crystallization of different encoded proteins in the two reading frames, termed rep1a and rep1b. Depicted in the image is an image of the virus, along with labeled proteins. Answer the following two questions concerning SARS-COV2:

I. What specific receptor does the spike protein attach to in order to enter cells?
II. Which of the following is the genome of SARS-COV2?

W) ssRNA
X) ssDNA
Y) dsRNA
Z) dsDNA

ANSWER: 1) ACE II RECEPTOR; 2) W) SSRNA.

TOSS-UP

7) PHYSICS – *Multiple Choice* A lamp sits near the earth emitting electromagnetic radiation of a certain wavelength. An observer rests 10 km above the lamp. When the observer sees the light, it is gravitationally redshifted by 1nm. If we repeat this experiment near the moon where the gravitational field is ⅛ that of earth and the observer now sits 20 km above the lamp, what is the new redshift?

W) 0.1λ
X) 0.3λ
Y) λ
Z) 2λ

ANSWER: X) 0.3λ

BONUS

7) PHYSICS – *Multiple Choice* The wavelength that a detector measures from a light source moving towards it is 500 nm. The light source is traveling ½ c in the detector's reference frame. What is the proper wavelength emitted by the source?***

W) 500 nm
X) 682 nm
Y) 866 nm
Z) 920 nm

ANSWER: Y) 866 NM

TOSS-UP

8) BIOLOGY – *Short Answer* The plasmids of what bacterial species do scientists exploit to transfer foreign DNA into plant cultures?

ANSWER: AGROBACTERIUM TUMEFACIENS

BONUS

8) BIOLOGY – *Short Answer* By name or number, identify all the following three changes that would occur to a Lineweaver–Burk plot after you add an uncompetitive inhibitor: 1) Slope increases; 2) Y-intercept decreases; 3) X-intercept decreases.

ANSWER: 3 ONLY

TOSS-UP

9) CHEMISTRY – *Multiple Choice* Which of the following protecting groups can not be removed under acidic conditions?

W) Boc ***[Bok]***
X) Fmoc ***[F-mok]***
Y) Acetals
Z) Orthoesters

ANSWER: X) FMOC

VISUAL BONUS

9) CHEMISTRY – *Short Answer* Shown is a catalytic cycle for an organometallic coupling reaction, with the intermediates labelled 1 through 4. Answer the following three questions:

I. What is the general name of this class of coupling reactions?
II. What mechanistic step is represented by the transformation of intermediate 3 to 4?
III. What is the oxidation state of palladium in intermediate 3?

ANSWER: 1) SUZUKI COUPLING; 2) TRANSMETALLATION; 3) +2

TOSS-UP

10) MATH – *Short Answer* Compute the sum of the squares of the eigenvalues of the matrix with first row 4, –1, and second row 1, 1.

ANSWER: 15

BONUS

10) MATH – *Short Answer* A positive integer is called an *imposter* if it can be expressed in the form $2^a + 2^b$ where a and b are distinct non-negative integers. How many positive integers less than 2020 are *imposters*?

ANSWER: 55

TOSS-UP

11) EARTH AND SPACE – *Multiple Choice* Which of the following would best indicate a late-stage desert?

W) Bajadas
X) Ventifacts
Y) Inselbergs
Z) Desert pavement

ANSWER: Y) INSELBERGS

BONUS

11) EARTH AND SPACE – *Short Answer* Magnetic fields on the Sun and other G type stars demonstrate strong emission lines of what ionized element that scientists use to study magnetic fields on other Sun-like stars?

ANSWER: CALCIUM

TOSS-UP

12) ENERGY – *Multiple Choice* Scientists at Brookhaven National Laboratory used the Sloan Digital Sky Survey to make detailed measurements of more than two million galaxies and quasars over 11 billion years of cosmic time. The survey confirmed once again the flat nature of the universe. Which of the following statements correctly describes the density of the universe for it to be flat?

W) It is below the critical density
X) It is above the critical density
Y) It is at the critical density
Z) It used to be below the critical density and is now above the critical density

ANSWER: Y) IT IS AT THE CRITICAL DENSITY

BONUS

12) ENERGY – *Multiple Choice* Scientists at Lawrence Berkeley National Laboratory are developing mono and poly-cationic lipids called lipitoid to create synthetic vectors. Which of the following is not a benefit of using cationic lipitoid as vectors?

W) Lipitoid micelles protect the plasmid DNA inside from degradation
X) Lipitoid micelles are as small as most viruses
Y) Lipitoids easily form complexes with DNA
Z) Lipitoids are naturally degraded after DNA transfer has occurred

ANSWER: Z) LIPITOIDS ARE NATURALLY DEGRADED AFTER DNA TRANSFER HAS OCCURRED

TOSS-UP

13) PHYSICS – *Short Answer* What addition to Ampere's law implied the existence of electromagnetic waves and involves the surface integral of a time varying electric field?

ANSWER: DISPLACEMENT CURRENT

VISUAL BONUS

13) PHYSICS – *Short Answer* Shown in the diagram is an electrical circuit consisting of a voltage source, resistor, capacitors and inductors. Answer the following three questions about this circuit.

I. At the resonant frequency, what quantity is maximized?
II. Determine the resonant frequency of this circuit.
III. If the amplitude of oscillation of the voltage across C1 is 10V, what is the energy contained in the circuit?

ANSWER: I) IMPEDANCE; 2) ¼; 3) 400J.

TOSS-UP

14) BIOLOGY – *Multiple Choice* Which of the following groups of animals have an incomplete septum within the heart?

W) Birds
X) Frogs

Y) Alligators
Z) Turtles

ANSWER: Z) TURTLES

VISUAL BONUS

14) BIOLOGY – *Short Answer* Shown in the image is the exocytosis of a vesicle containing acetylcholine at a neuromuscular junction. Answer the following three questions about the image:

I. What is the name of the protein marked A?
II. What are the SNARE protein subtypes that the purple and pink strands represent respectively?
III. Give whether protein A, pink, or purple SNARE protein detects calcium ion influx to trigger vesicle fusion.

ANSWER: 1) SYNAPTOTAGMIN; 2) PURPLE IS v-SNARE, PINK IS t-SNARE; 1) A

TOSS-UP

15) CHEMISTRY – *Short Answer* Identify all of the following three substituents that, when substituted at the alpha carbon to a carbonyl group, will decrease the stretching band frequency of the carbonyl group: 1) Amino; 2) Chloro; 3) Carboxyl.

ANSWER: 1 AND 3

BONUS

15) CHEMISTRY – *Short Answer* A sample of chlorobenzene is prepared such that the chlorinated carbon is radiolabeled by a carbon-14 isotope. The sample is reacted under high temperature and pressure with sodium hydroxide. The product is then isolated and analyzed. Identify all of the following three statements that are true: 1) In the ^{1}H-NMR spectrum of the product, 5 distinct signals are produced; 2) In the product, 100% of the carbon-14 is found to be ortho to the original position; 3) The reaction proceeds through a mechanism involving a radical intermediate.

ANSWER: NONE

TOSS-UP

16) MATH – *Short Answer* A function f satisfies $f(x+y) = 3f(x)f(y)$ for all real x and y. If $f(3) = 18$, what is $f(1)$?

ANSWER: $\sqrt[3]{3}$ (CUBE ROOT 3)

VISUAL BONUS

16) MATH – *Short Answer* Depicted in the image are two circles, labeled ω_1 and ω_2, which intersect at points P and Q. A line is drawn through Q such that it intersects ω_1 at R and ω_2 at S. Given that angle PQS measures 60 degrees and the radius of ω_1 is twice that of ω_2, find the ratio of the lengths of segments PR to PS.

ANSWER: 2:1

TOSS-UP

17) EARTH AND SPACE – *Multiple Choice* Which of the following best describes the difference between adaptive optics and active optics?

W) Adaptive optics correct for the Earth's rotation while active optics correct for seeing
X) Adaptive optics correct seeing while active optics correct for telescope defects
Y) Adaptive optics correct for telescope defects while active optics correct for the Earth's rotation
Z) Adaptive optics correct the Earth's rotation while active optics correct for proper motion

ANSWER: X) ADAPTIVE OPTICS CORRECT SEEING WHILE ACTIVE OPTICS CORRECT FOR TELESCOPE DEFECTS

VISUAL BONUS

17) EARTH AND SPACE – *Short Answer* Shown in the image is a cross section of the Grand Canyon. Answer the following two questions regarding this image:

I. The red circles highlight two unconformities. Give all the types of unconformities that S could be and R could be.
II. Order F through K from youngest to oldest given that J is older than F

ANSWER: I) S IS ANGULAR AND NONCONFORMITY; R IS DISCONFORMITY; II) G, H, I, F, J, K

TOSS-UP

18) ENERGY – *Multiple Choice* Scientists at the National Renewable Energy Laboratory are studying the composition of algae in pursuit of alternative fuels. In algae, what is the primary method of energy storage?
W) Starch
X) Glycogen
Y) Triglyceride
Z) Wax

ANSWER: Z) WAX

BONUS

18) ENERGY – *Short Answer* Scientists at Princeton Plasma Physics Laboratory are interested in diocotron instability because it can wreak havoc in plasma required for fusion reactions, reducing the efficiency of experiments. Diocotron instability occurs because of shear velocities that give rise to electron vortices. To what type of instability in fluid dynamics is diocotron instability most similar to?

ANSWER: KELVIN-HELMHOTZ INSTABILITY

TOSS-UP

19) PHYSICS – *Multiple Choice* Which of the following does NOT provide evidence for the particle nature of light?

W) Photoelectric effect
X) Compton scattering
Y) Blackbody radiation
Z) Malus's law

ANSWER: Z) MALUS'S LAW

BONUS

19) PHYSICS – *Short Answer* A torsion pendulum with moment of inertia 28 kilogram meters squared is rotated through an angle of 0.3 radians. If the restoring torque is 21 newton meters, give the period of oscillations in seconds.

ANSWER: $2\pi\sqrt{(2/5)}$

TOSS-UP

20) BIOLOGY – *Short Answer* What glycoprotein secreted by the parietal cells of the stomach is required for the absorption of vitamin B12?

ANSWER: INTRINSIC FACTOR

BONUS

20) BIOLOGY – *Short Answer* By name or number, identify all the following three statements that are true about the immune system: 1) CD8+ cells can bind to MHC class I molecules; 2) Interleukin 2 is the main cytokine responsible for plasma cell and cytotoxic T cell proliferation; 3) IgD is the only membrane bound antibody.

ANSWER: ALL

TOSS-UP

21) CHEMISTRY – *Short Answer* Order the following three substituents in increasing activation of an aromatic ring towards electrophilic aromatic substitution: 1) Nitro; 2) Methoxy; 3) Acetyl.

ANSWER: 1, 3, 2

BONUS

21) CHEMISTRY – *Short Answer* By number, identify all of the following three statements that are true regarding carbenes: 1) Alpha-elimination produces singlet carbenes; 2) Carbenes undergo pericyclic reactions with alkenes; 3) Triplet carbenes have a smaller bond angle than singlet carbenes.

ANSWER: ALL

TOSS-UP

22) MATH – *Short Answer* There are 4 houses on a street, with 2 on each side, and each house can be painted one of 5 different colors. Find the number of ways that the houses can be painted such that no two houses on the same side of the street are the same color and not all the houses are different colors.

ANSWER: 280

VISUAL BONUS

22) MATH – *Short Answer* Evaluate the definite integral depicted in the image.

ANSWER: $\pi/4$

TOSS-UP

23) EARTH AND SPACE – *Multiple Choice* In which of the following Köppen climate designations would one most expect to experience collision-coalescence based rain?

W) A
X) B
Y) C
Z) D

ANSWER: W) A

BONUS

23) EARTH AND SPACE – *Short Answer* By name or number, identify all the following three phenomena that are spiral tracers: 1) OB associations; 2) Emission nebula; 3) Planetary nebula.

ANSWER: 1 AND 2

TOSS-UP

24) ENERGY – *Multiple Choice* Researchers at SLAC use the Linac Coherent Light Source to image protein structures. Through which mechanism do free-electron lasers like the LCLS produce light?

W) Synchrotron radiation
X) Spontaneous emission
Y) Electric dipole transitions
Z) Optical pumping

ANSWER: W) SYNCHROTRON RADIATION

BONUS

24) ENERGY – *Short Answer* Scientists at Lawrence Livermore National Laboratory have recently discovered the protein lanmodulin, a naturally occurring solution to heavy metal

contamination that binds to rare earth elements. What protein analog in smooth muscles serve a similar function by binding to calcium ions to begin signalling cascades?

ANSWER: CALMODULIN

TOSS-UP

25) PHYSICS – *Short Answer* The dispersion relation of a matter wave connects which two of its properties?

ANSWER: ENERGY AND MOMENTUM (ACCEPT: FREQUENCY AND WAVELENGTH)

VISUAL BONUS

25) PHYSICS – *Short Answer* The following drawing depicts the phase diagram of a superconductor. Answer the following three questions about the material depicted.

I. What type of superconductor is represented here?
II. What is the name for the vortices formed in phase A which allow magnetic field lines through?
III. In superconductors, what is the term that describes the distance which a magnetic field can penetrate into its surface?

ANSWER: 1) TYPE-II; 2) QUANTUM VORTICES (ACCEPT ABRIKOSOV VORTICES); 3) LONDON PENETRATION DEPTH.