TOSS-UP

1) PHYSICS *Multiple Choice* The interference pattern predicted in Young's double slit experiment and actual empirical observation differ slightly due to which of the following discrepancies not accounted for theoretically?

W) The particle like nature of light interfering

X) The superposition of photons on the interference pattern

Y) Rays are treated as parallel theoretically

Z) Diffraction around slit openings

ANSWER: Y) Rays are treated as parallel theoretically

BONUS

1) PHYSICS *Short Answer* A block of mass 10 kilograms is suspended from a roof by three massless ropes at angles of 30 degrees to the horizontal and to the left of the block, directly vertical, and 60 degrees to the horizontal and to the right of the block. If the tension in the vertical rope is 20 newtons, then expressing your answer in simplest radical form, what is the tension in the rightmost rope?

ANSWER: $40\sqrt{3}$

TOSS-UP

2) EARTH AND SPACE *Multiple Choice* What mechanism most likely forms malachite?

W) Magmatic Differentiation

X) Hydrothermal Enrichment

Y) Placer Deposition

Z) Secondary Replacement

ANSWER: X) Hydrothermal Enrichment

BONUS

2) EARTH AND SPACE *Short Answer* Name all of the following 3 statements concerning hydrothermal enrichment that are true:

1. Sedimentary Exhalative deposits are fluvial

2. Skarn is formed with calc alkaline fluids
3. Porphyries are found near Mid ocean ridges

ANSWER: 2 only

TOSS-UP

3) CHEMISTRY *Short Answer* Rank the following three molecules in increasing pK_a:

1. Methanol
2. Ethanol
3. Water

ANSWER: 1 3 2 (Accet 3 1 2)

BONUS

3) CHEMISTRY *Short Answer* Identify all of the following three coordination complexes that exhibit paramagnetism:

1. $Ni(CO)_4$
2. $Fe(SCN)_6^{3-}$
3. $Pt(Cl)_4^{2-}$

ANSWER: 2 and 3

TOSS-UP

4) MATH *Short Answer* Given that $f(x) = x^3 + x + 1$, find the slope of the tangent line of f inverse of x at x = 1.

ANSWER: 1

BONUS

4) MATH *Multiple Choice* Which of the following is closest to the limit as x approaches 1 of the following rational function: $f(x) = \frac{sin(1/x)}{ln(1/x)}$ (READ AS: the fraction with numerator sine of the quantity 1 divided by x close quantity and denominator the natural log of the quantity 1 divided by x close quantity) ?

W) 0

X) 0.5

Y) 1

Z) 2

ANSWER: W) 0

TOSS-UP

5) BIOLOGY *Short Answer* What is the name of the central cavity of sponges?

ANSWER: Spongocoel

BONUS

5) BIOLOGY *Short Answer* For each of the following ions, indicate whether there is a higher concentration inside or outside the cell.

1) Ca2+
2) Na+
3) K+

ANSWER: 1 and 2 outside 3 inside

TOSS-UP

6) EARTH AND SPACE *Multiple Choice* Which of the following is NOT a reason why there is no ekman transport in the atmospheric circulation cells, while it is found in surface ocean currents?

W) circulation cells are driven by pressure gradient force

X) Ocean waves are driven by prevailing winds

Y) Friction has a significantly larger effect in oceans compared to circulation cells

Z) Coriolis has a small, but meaningful contribution to both fluid phenomena

ANSWER: W) Circulation cells are driven by pressure gradient force

BONUS

6) EARTH AND SPACE *Short Answer* What atmospheric phenomenon causes the distinctive Sargassum Seaweed to coalesce into large linear swaths?

ANSWER: Langmuir Circulation

TOSS-UP

7) CHEMISTRY *Multiple Choice* Given that the pK_a of acetylene is 25, the pK_a of ammonia is 37, and the pK_a of water is 15.7, which of the following bases could be used to deprotonate acetylene?

W) Ammonia

X) Sodium amide

Y) Water

Z) Sodium hydroxide

ANSWER: X) Sodium amide

BONUS

7) CHEMISTRY *Short Answer* Identify all of the following three statements that are true of the hydride anion:

1. It is larger than the fluoride anion
2. It can act as a strong base on its own
3. It can act as a strong nucleophile on its own

ANSWER: 1 and 2

TOSS-UP

8) MATH *Short Answer* How many terminal zeroes does 2020! have?

ANSWER: 503

BONUS

8) MATH *Short Answer* In the 2020 Summer Olympics, a total of X athletes will participate. These X athletes can be divided into 3, 4, 5, and 7 rows without a remainder. If there are less than 2020 athletes competing and the value of X is such that it yields the minimum number of athletes remaining when they are divided into 13 rows, what is X?

ANSWER: 1,680

TOSS-UP

9) CHEMISTRY *Short Answer* What intramolecular effect increases the rate of an S_N2 reaction through the interaction of the reaction center with non conjugated lone pairs or pi bonds, leading to the leaving group leaving more easily?

ANSWER: Anchimeric assistance

BONUS

9) CHEMISTRY *Short Answer* Identify the HOMO of each of the following three molecules in their most common state as singlet, doublet, or triplet:

1. O_2^{2-}
2. O_2
3. O_2^{+}

ANSWER: 1. Singlet, 2. Triplet, 3. Doublet

TOSS-UP

10) BIOLOGY Which of the following groups of cnidarians do not possess a medusa stage?

W) Anthozoans
X) Scyphozoans
Y) Cubozoans
Z) Hydrozoans
ANSWER: W

BONUS

10) BIOLOGY *Short Answer* What is the name for a group of cephalopods with external shells?

ANSWER: Natulises

TOSS-UP

11) PHYSICS *Multiple Choice* According to BCS theory, superconductivity is caused by the interaction between what two particles?

W) Electron and electron hole

X) Electron hole and phonon

Y) Phonon and exciton

Z) Electron and phonon

ANSWER: Z) Electron and phonon

BONUS

11) PHYSICS *Short Answer* A particle in a one dimensional box contains 64 particles. If the number of particles in the box is halved while the length of the box is doubled, by what factor will the zero point energy and the highest occupied energy state change by, respectively?

ANSWER: Zero point energy: ¼ , Highest energy state: 1/16

TOSS-UP

12) EARTH AND SPACE *Short Answer* The ability for carbonates to form varies with depth. What is the name for the most rapid change in the such ability, found near the mixed layer?

ANSWER: Lysocline

BONUS

12) EARTH AND SPACE *Short Answer* Name all of the following gemstone - mineral pairs which are correctly paired together:

1. Peridot - olivine
2. Opal - Quartz
3. Ruby - Corundum

ANSWER: All

TOSS-UP

13) CHEMISTRY *Short Answer* What is the oxidation number of the central carbon of isopropanol?

ANSWER: 0

BONUS

13) CHEMISTRY *Short Answer* The $Mn^{2+}/Mn(s)$ couple has a standard reduction potential of -1.2 volts, while the $Mn^{3+}/Mn(s)$ couple has a standard reduction potential of +1.5 volts. What is the standard reduction potential of the Mn^{3+}/Mn^{2+} couple?

ANSWER: -0.3 volts

TOSS-UP

14) MATH *Short Answer* What is the sum of the first 12 perfect cubes?

ANSWER: 6,084

BONUS

14) MATH *Short Answer* Determine the slope of the tangent to the function f(x) = cosh(1/x) (f of x equals hyperbolic cosine of the quantity 1 divided by x close quantity) at the point (1, cosh(1)).

ANSWER: 0

TOSS-UP

15) BIOLOGY *Short Answer* What is the term for a crown of ciliated tentacles that function in feeding, and are found in a namesake major clade of Bilateria?

ANSWER: Lophophore

BONUS

15) BIOLOGY *Short Answer* By name or number, indicate all of the following that are formed by the cleavage of Phosphatidylinositol- 4,5 bisphosphate by phospholipase c.

1) IP3
2) Diacylglycerol
3) cAMP
4) Phosphodiesterase

ANSWER: 12

TOSS-UP

16) PHYSICS *Short Answer* Identify all of the following three particles that would follow fermi dirac statistics:

1. Muon
2. Gluon
3. Neutron

ANSWER: 1 and 3

BONUS

16) PHYSICS *Short Answer* Identify all of the following three statements that are true about work in an isothermal process:

1. The amount of work done in an irreversible process is always greater than in a reversible process
2. The amount of work done in an isothermal process is equal in magnitude to the change in heat
3. Free expansion is an irreversible process and does no work

ANSWER: 2, 3

TOSS-UP

17) EARTH AND SPACE *Short Answer* Order the following 3 stages of a star's life from first to last:

1. White Dwarf
2. Red Giant
3. Yellow Dwarf

ANSWER: 3 2 1

BONUS

17) EARTH AND SPACE *Short Answer* What specific type of proton proton chain sequence is the most energetic and helium 3 directly captures a proton to form helium 4 in the last step?

ANSWER: Proton Proton chain 4

TOSS-UP

18) CHEMISTRY *Multiple Choice* Which of the following is nonaromatic?

W) $C_8H_8^+$

X) C_8H_8

Y) $C_8H_8^-$

Z) $C_{18}H_{18}$

ANSWER: X) C_8H_8

BONUS

18) CHEMISTRY *Multiple Choice* Which of the following crown ethers is best for sequestering the Mg^{2+} cation?

W) 12-crown-4

X) 15-crown-5

Y) 18-crown-6

Z) 21-crown-7

ANSWER: W) 12-crown-4

TOSS-UP

19) MATH *Short Answer* What is the remainder when 4^{2020} is divided by 3?

ANSWER: 1

BONUS

19) MATH *Multiple Choice* Which of the following powers of 10 is closest to 4^{300}?

W) 175

X) 180

Y) 185

Z) 190

ANSWER: X) 180

TOSS-UP

20) CHEMISTRY *Multiple Choice* Which of the following nuclides would decay via electron capture?

W) Carbon 11

X) Boron 11

Y) Nitrogen 12

Z) Nitrogen 15

ANSWER: W) Carbon 11

BONUS

20) CHEMISTRY *Multiple Choice* Which of the following is used to remove the BOC protecting group from amines?

W) Carbamic acid

X) Methanimidic acid

Y) Tetra-n-butylammonium fluoride

Z) Trifluoroacetic acid

ANSWER: Z) Trifluoroacetic acid