THUMB: SINGLE ELIMINATION 4

1) Earth and Space – *Multiple Choice* Which of the following best describes how the wet and dry adiabatic lapse rates in a given environment change as the temperature is lowered?

W) They grow closer in magnitude but never intersect
X) They grow closer in magnitude and eventually intersect
Y) They grow further apart in magnitude
Z) The difference between them remains constant

ANSWER: W) They grow closer in magnitude but never intersect [FJ]

2) Physics – *Multiple Choice* Heisenberg's uncertainty principle states that certain pairs of quantities, called conjugate variables, cannot both be precisely known at the same time. Which of the following pairs are NOT conjugate variables?

W) Frequency and time
X) Energy and time
Y) Magnetic field and magnetization
Z) Angular momentum and angular position

ANSWER: Y) Magnetic field and magnetization [AX]

3) Chemistry – *Multiple Choice* Which of the following is NOT a possible ring configuration for cyclohexane?

W) Chair
X) Half Chair
Y) Boat
Z) Half Boat

ANSWER: Z) Half Boat [DS] [SY]

4) Biology - *Multiple Choice* Aryan was stabbed with a rusty nail, which gave him tetanus. After a week, he begins to show symptoms of lockjaw, stopping him from talking, thank God. Which of the following best explains why the preferred treatment includes both an immunoglobin AND antibiotic regimen?

W) Immunoglobins bind the pathogen, antibiotics kill the pathogen
X) Immunoglobins bind the pathogen, antibiotics kill opportunistic infections
Y) Immunoglobins bind the toxin, antibiotics kill the pathogen
Z) Immunoglobins bind the toxin, antibiotics kill opportunistic infections

ANSWER: Y) Immunoglobins bind the toxin, antibiotics kill the pathogen [SY]

5) Math – *Short Answer* Order the following three expressions from smallest to largest:

1) 2^11
2) 3^7
3) 5^5

ANSWER: 1, 2, 3 [AX]

6) Earth and Space – *Short Answer* What principle is often depicted as the final rung on the cosmic distance ladder, allowing astronomers to relate the distance to the most distant galaxies through their recessional velocities?

ANSWER: Hubble's law [FJ]

7) Physics – *Short Answer* Identify all of the following four fundamental particles that interact via the strong force: 1) Electron 2) Muon 3) Tau neutrino 4) Antineutrino

ANSWER: None [FJ]

8) Chemistry - *Multiple Choice* Which of the following effects best explains the covalency of the cobalt-iodine bonds in the complex $\mathrm{CoI_6^{3+}}$?

W) Inductive effect
X) Hyperconjugation
Y) Jahn-Teller effect
Z) Nephelauxetic effect

ANSWER: Z) Nephelauxetic effect [AlX]

9) Biology - *Short Answer* By name or number, rank the following four zones associated with the growth of new bone tissue from closest to the epiphysis to closest to the diaphysis.

1) Zone of ossification
2) Zone of calcification
3) Zone of proliferation
4) Zone of hypertrophy

ANSWER: 3 4 2 1 (ACCEPT Zone of maturation in place of #4)

10) Math – *Short Answer* If you have a very large ***n*** sided die numbered from **1** through ***n***, what is the expected number of rolls you need to do to obtain a sum of at least ***n***?

ANSWER: e (ACCEPT: Euler's number; Do NOT ACCEPT:: Euler's constant) [AX]

11) Earth and Space – *Multiple Choice* At its greatest eastern elongation, Venus appears in which of the following phases as viewed from Earth?

W) Waxing gibbous
X) Waning gibbous
Y) First quarter
Z) Last quarter

ANSWER: Y) First quarter [FJ]

12) Physics – *Short Answer* A parallel-plate air capacitor is connected to a battery and charged to store 10 J of energy. While the capacitor remains connected to the battery, a dielectric slab with dielectric constant 3 is partially inserted so that it covers exactly half of the plate area. What is the new amount of energy, in Joules, stored in the capacitor?

ANSWER: 20 [AX]

13) Chemistry - *Short Answer* By name or number, order the following three ligands by decreasing field strength on the spectrochemical series:

1) CO
2) NH3
3) H2O

Answer: 1, 2, 3 [SY]

14) Biology - *Multiple Choice* Lambda phages face the critical decision of staying lytic or turning lysogenic upon infecting a bacterium. They've evolved to sense the concentrations of other lambda phages in an area. Which of the following best explains a situation where a phage would stay lytic?

W) When phage concentration is low, as this implies poor bacterial fitness
X) When phage concentration is low, as this implies reduced intraspecific competition
Y) When phage concentration is high, as this implies good bacterial fitness
Z) When phage concentration is high, as this implies increased intraspecific competition

ANSWER: X) When phage concentration is low, as this implies reduced intraspecific competition [SY]

15) Math - *Short Answer* Alex learned in calculus that all differentiable functions are continuous, but the reverse is not always true. What function exemplifies this, being continuous at every point but differentiable at none?

ANSWER: Weierstrass function [AX]

16) Earth and Space – *Short Answer* A region in the Northern Atlantic is cooling despite being in a warming atmosphere. This "cold blob" is primarily due to the weakening of what current system in the Atlantic Ocean?

ANSWER: AMOC (Accept: Atlantic Meridional Overturning Circulation) [FJ]

17) Physics – *Short Answer* In Feynman diagrams, internal lines connecting interaction vertices represent what class of particles that is thought to give rise to the Casimir effect?

ANSWER: Virtual particles [FJ]

18) Chemistry - *Short Answer* Mao is trying to identify a chemical structure with formula C_7H_6O using H1 NMR. He notices one downfield peak with a chemical shift of 10 ppm and a tell-tale cluster of peaks around 7.5 ppm. Knowing the molecule yields a positive result in the Tollen's test, what is the name of this molecule?

ANSWER: Benzaldehyde [SY]

19) Biology - *Short Answer* Lipinski's rule of five is a somewhat archaic law that is used as a guideline to design drugs with good oral pharmacokinetics. By name or number, identify all of the following three conditions that most drugs with good oral pharmacokinetics should have high amounts of:

1) Hydrogen bonding sites
2) Molecular weight
3) Lipid solubility

ANSWER: 3 only [SY]

20) Math – *Multiple Choice* How many solutions does the equation sin(3theta) * cos(2theta) = 1 have on the closed interval 0 to 2pi?

W) 0
X) 1
Y) 2
Z) 3

ANSWER: X) 1 [AX]

21) Earth and Space – *Multiple Choice* Which of the following soil orders is most likely to be found in the Köppen Climate group E?

W) Spodosols
X) Mollisols
Y) Gelisols
Z) Alfisols

ANSWER: Y) Gelisols [FJ]

22) Physics – *Multiple Choice* In Hamiltonian mechanics, the total time derivative of the Hamiltonian must be zero according to the conservation of energy. According to Hamilton's equations, this condition is only met if the Hamiltonian does NOT explicitly depend on which of the following variables?

W) Generalized coordinates
X) Generalized momentum
Y) External force
Z) Time

ANSWER: Z) Time [AX]

23) Chemistry - *Short Answer* Which of the following three metals form superoxides when reacting with oxygen at standard temperature and pressure?
1) Lithium
2) Magnesium
3) Sodium

ANSWER: None [AlX]

24) Biology - *Multiple Choice* The complement system is a component of innate immunity. One complement activation pathway utilizes protein binding to molecules such as mannose, fucose, N-acetylglucosamine, and other foreign carbohydrates to trigger C3 convertase formation. Which of the following complement pathways is being described above?

W) Classical pathway
X) Alternative pathway
Y) Ludwig pathway
Z) Lectin pathway

ANSWER: Z) Lectin pathway [SY]

25) Math – *Short Answer* The Abel-Ruffini theorem shows that there is no general formula to solve all polynomials of what degree or higher?

ANSWER: 5 [AX]

26) Earth and Space – *Multiple Choice* Which of the following entities has the highest observed redshift in the observable universe?

W) First quasars
X) Population III stars
Y) Primordial black holes
Z) Cosmic microwave background

ANSWER: Z) Cosmic microwave background [FJ]

27) Physics – *Multiple Choice* The Poisson spot describes a central bright point that occurs in the shadow of a circular object. Which of the following best describes the mechanism that gives rise to the Poisson spot?

W) Near-field refraction
X) Far-field refraction
Y) Near-field diffraction
Z) Far-field diffraction

ANSWER: Y) Near-field diffraction [FJ]

28) Chemistry - *Multiple Choice* In the Diels-Alder cycloaddition to form cyclohex**ene**, which two molecular orbitals are interacting to form the new bonds?
W) HOMO of butadiene (byoo-tuh-dai-een) and LUMO of ethene
X) HOMO of ethene and LUMO of butadiene
Y) HOMO of butene and LUMO of ethyne
Z) HOMO of ethyne and LUMO of butene

ANSWER: W) HOMO of butadiene and LUMO of ethene [SY]

29) Biology - *Short Answer* (NOTE TO READER: Read somewhat quickly for effect, ENFORCE STALLS) Fully unabbreviate T-A-E in T-A-E buffer, the one used to run gels.

ANSWER: Tris-acetate-ethylene-diamine-tetra-acetic acid (DO NOT ACCEPT tris-acetate-EDTA, or any other answer failing to unabbreviate EDTA) [SY]

30) Math – *Short Answer* Calculate the sum from n equals 1 to 99 of one over **[open parenthesis the square root of the quantity n+1 plus the square root of n close parenthesis]**

ANSWER: 9 [AX]