TOSS-UP

1) PHYSICS *Short Answer* C-P symmetry states that the laws of physics should be the same if a particle were intercharged with its antiparticle, or if the sign of one of its spatial coordinates is changed. The decay of the neutral form of what particle led to the discovery of CP-violation in 1964, which was found to interact through neutral particle oscillations and transform into its two types of mesons through the weak interactions?

ANSWER: KAON (ACCEPT: K MESON)

BONUS

1) PHYSICS *Short Answer* What is the magnitude of the electric field, in N/C to the nearest multiple of ten, that is required to store 1.77×10^{-9} J of electric potential energy in a volume of 1 m^3 in a vacuum?

ANSWER: 20

TOSS-UP

2) EARTH AND SPACE *Multiple Choice* A sample of granite rock contains about 70% silica. Which of the following minerals would have the greatest percent composition by volume in this sample?

W) amphibole
X) muscovite
Y) quartz
Z) orthoclase

ANSWER: Z) ORTHOCLASE

BONUS

2) EARTH AND SPACE *Multiple Choice* Which of the following best describes the cosmic density parameter, Ω_0, if the geometry of the universe is closed?

W) $\Omega_0 = 0$
X) $0 < \Omega_0 < 1$
Y) $\Omega_0 = 1$
Z) $\Omega_0 > 1$

ANSWER: X) $0 < \Omega_0 < 1$

TOSS-UP

3) CHEMISTRY *Short Answer* Leaving radicals unsimplified in your answer, how many times greater is the rate of effusion of carbon dioxide through a porous barrier than xenon gas through the same barrier, assuming gaseous carbon dioxide has a molar mass of 44 g mol^{-1} and gaseous xenon has a molar mass of 132 g mol^{-1}?

ANSWER: $\frac{1}{\sqrt{3}}$ (ACCEPT $\frac{\sqrt{3}}{3}$)

BONUS

3) CHEMISTRY *Short Answer* Permanganate ions react with oxalic acid in acidic aqueous solution to

produce manganese(II) ions and carbon dioxide, in the unbalanced equation $MnO_4^-(aq) + H_2C_2O_4(aq) \rightarrow Mn^{2+}(aq) + CO_2(g)$. Give the balanced equation for the reduction half-reaction.

ANSWER: $MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O$

TOSS-UP

4) BIOLOGY *Short Answer* What salivary gland is actually a pair of glands located beneath the lower jaws, the secretion of which is a mixture of serous fluid and mucus, entering the oral cavity via Wharton's ducts?

ANSWER: SUBMANDIBULAR GLANDS

BONUS

4) BIOLOGY *Short Answer* What nucleoside, commonly found in tRNAs and essential for proper translation of the genetic code in wobble base pairs, is formed when hypoxanthine is attached to a ribose ring via a β-N_9-glycosidic bond?

ANSWER: INOSINE

TOSS-UP

5) ENERGY *Multiple Choice* Which of the following samples of gases can be predicted to have the highest value for gamma, the ratio of heat capacities?

W) CO_2
X) CO
Y) O_2
Z) He

ANSWER: Z) He

BONUS

5) ENERGY *Short Answer* A container is divided into two portions of equal volume V, one of which is evacuated and the other of which contains n moles of an ideal gas at a temperature T. The partition between the two portions is removed and the gas expands to fill both compartments of the container. Presenting your answer in terms of n and R, the ideal gas constant, what is the entropy change accompanying this free-expansion?

ANSWER: $nR \ln (2)$

TOSS-UP

6) MATHEMATICS *Short Answer* A prime number less than twenty is randomly selected. Expressing your answer as a common fraction, what is the probability that the units digit of its square is one?

ANSWER: 1/4

BONUS

6) MATHEMATICS *Short Answer* Find the volume of the solid formed by revolving the region bounded by the graph of $f(x) = \sqrt{\sin x}$ and the lines $x = 0$ and $x = \pi$ about the x-axis.

ANSWER: 2π

TOSS-UP

7) PHYSICS *Multiple Choice* For a parallel-plate capacitor with capacitance C_0, which of the following materials, when used as a dielectric to completely fill the space between the plates, would make for the greatest new capacitance, C?

W) air
X) teflon
Y) polyvinyl chloride
Z) glycerin

ANSWER: Z) GLYCERIN

BONUS

7) PHYSICS *Short Answer* A 300-V power supply is used to charge a 2 μF capacitor. After the capacitor is fully charged, it is disconnected from the power supply and connected across a 500 mH inductor. Assuming the resistance in the circuit to be negligible, what is the angular frequency of the circuit's oscillation, in rad/s?

ANSWER: 1×10^5

TOSS-UP

8) EARTH AND SPACE *Short Answer* What two nuclides can be fused to produce some energy in brown dwarfs above 65 Jupiter masses?

ANSWER: DEUTERIUM (ACCEPT HYDROGEN-2) AND LITHIUM-7

BONUS

8) EARTH AND SPACE *Short Answer* What is the name of an exposed rocky component of a ridge, mountain, or peak, not covered with ice or snow within or at the edge of an ice field or glacier, thus presenting a readily identifiable landmark reference point?

ANSWER: NUNATAK

TOSS-UP

9) CHEMISTRY *Short Answer* What is the term given to the lower energy orbitals in coordination complexes that include the d_{xy}, d_{yz}, and d_{xz} orbitals, and are 2/5 times the ligand field splitting below the average *d*-orbital energy in the complex?

ANSWER: t_{2g}-ORBITAL

BONUS

9) CHEMISTRY *Short Answer* The coordination complex $[Fe(H_2O)_6]^{3+}$ absorbs light with a wavelength of 6.00×10^{-7} m. Presenting your answer in J mol^{-1} to two significant digits, what is the value of the ligand-field splitting?

ANSWER: 2.0×10^5

TOSS-UP

10) BIOLOGY *Multiple Choice* What molecule is formed as a result of the DNA methylation of the base cytosine, and is thought to be involved in the regulation of gene transcription?

W) 5-methylcytidine
X) 5-methylcytosine
Y) 5-methyluracil
Z) 2,2-dimethylthymine

ANSWER: X) 5-METHYLCYTOSINE

BONUS

10) BIOLOGY *Short Answer* Order the following 5 major events in vertebrate development chronologically:

1: gastrulation
2: cell migration
3: formation of blastula
4: neurulation
5: organogenesis

ANSWER: 3, 1, 4, 2, 5

TOSS-UP

11) ENERGY *Short Answer* What future geothermal resource, which is referred to as a near-future investment, is actively being studied by the DOE and includes the implementation of reservoirs of hot water and natural gas locked in deep sedimentary rocks to produce electricity?

ANSWER: GEOPRESSURIZED RESOURCE

BONUS

11) ENERGY *Short Answer* The solar constant, a measure of flux density, is the amount of incoming EM radiation per unit area that would be incident on a plane perpendicular to the rays at a distance of 1 AU. In kW m^{-2} to 2 significant digits, what is the solar constant for Earth, not accounting for atmospheric fluctuations and changes in the distance from the Earth to the Sun?

ANSWER: 1.4

TOSS-UP

12) MATHEMATICS *Short Answer* What is the function whose power series representation is given by $1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots \frac{x^n}{n!} + \ldots ?$

ANSWER: $f(x) = e^x$

BONUS

12) MATHEMATICS *Short Answer* Yash takes 325 distinct pieces of paper and writes the number 1 on

the first paper, 2 on the second, 3 on the third, and so on, until he writes the number 325 on the 325th piece of paper. How many total digits did Yash write?

ANSWER: 867

TOSS-UP

13) PHYSICS *Short Answer* What situation, sometimes described as near-field diffraction, involves both the point source and the screen being relatively close to the obstacle forming the diffraction pattern?

ANSWER: FRESNEL DIFFRACTION

BONUS

13) PHYSICS *Multiple Choice* The Fresnel number, denoted by *F*, is a dimensionless number in optics and is defined to be equal to $\frac{a^2}{L\lambda}$, where *a* is the characteristic size or radius of the aperture, *L* is the distance of the screen from the aperture, and λ is the incident wavelength. For which of the following values of *F* can the situation be predicted to be an example of Fraunhofer diffraction?

W) $F = 0$
X) $F << 1$
Y) $1 < F < 2$
Z) $F >> 2$

ANSWER: X) $F << 1$

TOSS-UP

14) EARTH AND SPACE *Multiple Choice* Which of the following most likely caused the extinction event at the Paleocene-Eocene boundary in the Cenozoic era?

W) intense heating by the greenhouse gas methane
X) impact from an asteroid
Y) eruption of basaltic lavas from volcanoes
Z) expansive glaciation and consequent global cooling

ANSWER: W) INTENSE HEATING BY THE GREENHOUSE GAS METHANE

BONUS

14) EARTH AND SPACE *Short Answer* What early evolutionary track of protostars, which precedes the Hayashi track on the H-R diagram, involves the cooling of a protostar, which causes a drop in the pressure and an overall shrinking of the star, heating up the core and moving the protostar slightly to the left in the H-R diagram?

ANSWER: KELVIN-HELMHOLTZ CONTRACTION PHASE

TOSS-UP

15) CHEMISTRY *Multiple Choice* When filling its molecular orbitals, for which of the following diatomic molecules does the energy of the σ_{2p} orbital drop below that of the two π_{2p} orbitals?

W) B_2
X) C_2
Y) N_2
Z) O_2

ANSWER: Z) O_2

BONUS

15) CHEMISTRY *Multiple Choice* A buffer is prepared with equal molar concentrations of the conjugate acid and base. Which of the following conjugate acid/base pairs would be a good choice for the pH of the buffer to be close to 2?

W) $H_2PO_4^-$ and HPO_4^{2-}
X) CH_3COOH and CH_3COO^-
Y) HNO_2 and NO_2^-
Z) $HClO_2$ and ClO_2^-

ANSWER: Z) $HClO_2$ and ClO_2^-

TOSS-UP

16) BIOLOGY *Short Answer* In the procedure known as a Southern blot, DNA from a sample of cloned genes may be used as a probe to identify the same or a similar gene in another sample. After the cleavage of the restriction fragments, spreading by gel electrophoresis, and denaturation of each fragment into single strands, the gel is blotted with a sheet or membrane composed of what compound, which happens to be highly flammable and is known as guncotton when used as a propellant or low-order explosive?

ANSWER: NITROCELLULOSE

BONUS

16) BIOLOGY *Multiple Choice* Which of the following steps occurs first in the DNA sequencing "chain termination" technique developed by Frederick Sanger?

W) addition of nucleotides to single-stranded DNA by DNA polymerase
X) combination of primed DNA fragment with DNA polymerase
Y) addition of primer to one end of a single-stranded DNA
Z) visualization of gel pattern on X-ray film by radioactive label

ANSWER: Y) ADDITION OF PRIMER TO ONE END OF A SINGLE STRANDED DNA

TOSS-UP

17) ENERGY *Multiple Choice* What enzyme converts glucose 6-phosphate into its isomer fructose 6-phosphate in glycolysis, a step in cellular respiration?

W) hexokinase
X) phosphoglucoisomerase
Y) phosphofructokinase
Z) aldolase

ANSWER: X) PHOSPHOGLUCOISOMERASE

BONUS

17) ENERGY *Multiple Choice* Which of the following statements is not true about biodiesel?

W) it is produced from oils or fats through transesterification
X) it consists mostly of fatty acid methyl esters, or FAMEs
Y) it can be synthesized by hydrocracking biological oil feedstocks
Z) it is an oxygenated fuel

ANSWER: Y) IT CAN BE SYNTHESIZED BY HYDROCRACKING BIOLOGICAL OIL FEED-STOCKS

TOSS-UP

18) MATHEMATICS *Short Answer* Sid started with $18. He wants to buy enough candy and soda for everyone on his Science Bowl team. After his purchase, his remaining money was 80% of what he had spent on the candy and soda. How much money did Sid spend, in dollars?

ANSWER: $10

BONUS

18) MATHEMATICS *Short Answer* Evaluate $\int_0^1 x(x^2 + 1)^3 \, dx$.

ANSWER: $\frac{5}{8}$

TOSS-UP

19) PHYSICS *Multiple Choice* Which of the following forms of radioactive decay would not result in a decrease in atomic number?

W) when radium-226 undergoes alpha decay
X) when a carbon-11 nucleus captures an electron
Y) when cobalt-57 undergoes beta-plus decay
Z) when thorium-234 undergoes beta-minus decay

ANSWER: Z) WHEN THORIUM-234 UNDERGOES BETA-MINUS DECAY

BONUS

19) PHYSICS *Short Answer* What experiment, performed in 1922, showed that when neutral atoms were passed through a nonuniform magnetic field, they were deflected according to the orientation of their magnetic moments with respect to the field? The experiment is used to demonstrate that electrons and atoms have intrinsically quantum properties and measurement in quantum mechanics affects the system being measured.

ANSWER: STERN-GERLACH EXPERIMENT

TOSS-UP

20) EARTH AND SPACE *Short Answer* Assume the Hubble constant, H_0, can be approximated to be 70 km/s/Mpc. In terms of H_0, what expression represents the amount of time taken for any galaxy to reach its present distance from Earth?

ANSWER: $1/H_0$

BONUS

20) EARTH AND SPACE *Short Answer* By name or number, indicate all of the following 5 igneous rocks that display phaneritic texture:

1: gabbro
2: diorite
3: andesite
4: granite
5: rhyolite

ANSWER: 1, 2, AND 4

TOSS-UP

21) CHEMISTRY *Multiple Choice* For a first-order reaction, which of the following graphs will produce a line with a slope equal to *-k?*

W) [A] vs time
X) $[A]^2$ vs time
Y) ln[A] vs time
Z) 1/[A] vs time

ANSWER: Y) ln[A] vs time

BONUS

21) CHEMISTRY *Multiple Choice* Polarizability measures the ease with which an electron cloud can be distorted. Which of the following choices best describes the periodic trend for polarizability?

W) increasing left to right along a period and increasing down a group
X) decreasing left to right along a period and increasing down a group
Y) increasing left to right along a period and decreasing down a group
Z) decreasing left to right along a period and decreasing down a group

ANSWER: X) DECREASING LEFT TO RIGHT ALONG A PERIOD AND INCREASING DOWN A GROUP

TOSS-UP

22) BIOLOGY *Multiple Choice* What basic form of bacteria is long and helically shaped, does not generally form associations with other cells, and has a complex structure within its cell membranes that allow it to spin its corkscrew-shaped body and propel it forward?

W) bacillus
X) coccus
Y) spirillus

Z) vibrius

ANSWER: Y) SPIRILLUS

BONUS

22) BIOLOGY *Multiple Choice* Which of the following protists is not an example of a heterotroph?

W) amoebas
X) radiolarians
Y) dinoflagellates
Z) forams

ANSWER: Y) DINOFLAGELLATES

TOSS-UP

23) ENERGY *Short Answer* In a fluidized bed combustor, crushed coal is mixed with what material before being suspended on jets of air inside the boiler, which acts like a sponge by capturing 90% of the organic sulfur that is released when the coal is burned?

ANSWER: LIMESTONE

BONUS

23) ENERGY *Short Answer* What type of vertical-axis wind turbine, used for converting the force of wind into torque on a rotating shaft, consists of a number of aerofoils usually vertically mounted on a rotating shaft or framework, and was invented by its namesake Finnish engineer in 1922? It is generally used when cost or reliability is more important than efficiency.

ANSWER: SAVONIUS TURBINE

TOSS-UP

24) MATHEMATICS *Multiple Choice* Replace each of the variables a, b, and c with a different digit selected from the set {2, 3, 5, 6, 8}. What is the greatest possible value of the expression $a^b + c$ that is less than 100?

W) 17
X) 40
Y) 72
Z) 96

ANSWER: Y) 72

BONUS

24) MATHEMATICS *Short Answer* Solve the differential equation $y' = \frac{2x}{y}$.

ANSWER: $y^2 - 2x^2 = C$

TOSS-UP

25) PHYSICS *Multiple Choice* Which of the following statements is not true for diamagnetic materials?

W) magnetic susceptibility is negative
X) relative permeability is less than unity
Y) magnetic susceptibility is dependent on temperature
Z) relative permeability is extremely close to 1 for solids and liquids

ANSWER: Y) MAGNETIC SUSCEPTIBILITY IS DEPENDENT ON TEMPERATURE

BONUS

25) PHYSICS *Short Answer* Assuming the permeability of free space is 1.26×10^{-6} T m A^{-1}, calculate the permeability of paramagnetic uranium to 2 significant digits if it has a magnetic susceptibility of 4×10^{-4}.

ANSWER: 1.3 X 10^{-6}