

TOSS-UP

1) PHYSICS *Short Answer* Indicate, by name or number, all of the following 4 conductors for which resistivity decreases when the temperature of the conductor is increased:

- 1: copper wire
- 2: graphite
- 3: gallium-arsenide semiconductor
- 4: superconducting mercury

ANSWER: 2 AND 3

BONUS

1) PHYSICS *Short Answer* A large metal rod 5 m long and 0.25 m^2 in cross-sectional area is subjected to a force of 200 N and is found to stretch .01 m. What is Young's modulus for this metal?

ANSWER: $4 \times 10^5 \text{ Pa}$ (ACCEPT: 400,000 Pa)

TOSS-UP

2) ASTRONOMY *Multiple Choice* On which of the following days would an observer standing directly on the Tropic of Capricorn view the Sun at his zenith at high noon?

- W) vernal equinox
- X) summer solstice
- Y) autumnal equinox
- Z) winter solstice

ANSWER: Z) WINTER SOLSTICE

BONUS

2) ASTRONOMY *Short Answer* By name or number, name all of the following 4 absorption lines that are common in stars of the spectral class A:

- 1: hydrogen
- 2: ionized helium
- 3: calcium
- 4: nitrogen

ANSWER: 1 AND 3

TOSS-UP

3) BIOLOGY *Multiple Choice* Which of the following major classes of proteins involved in DNA replication start the process of DNA unwinding by breaking a single DNA strand, releasing the tension holding the helix in its supercoiled form?

- W) helicases
- X) primases
- Y) DNA ligases
- Z) topoisomerases

ANSWER: Z) TOPOISOMERASES

BONUS

3) BIOLOGY *Short Answer* What mechanism of gene duplication typically arises by crossover between unequally aligned chromatids, either on homologous chromosomes or the same chromosome, and results in one chromosome with the straight-line duplication of a sequence containing a gene and a sequence where the gene is lost?

ANSWER: TANDEM GENE DUPLICATION

TOSS-UP

4) EARTH SCIENCE *Short Answer* Indicate, by name or number, all of the following 3 statements which are attributes of barchan dunes:

- 1: they are the fastest moving of all dunes
- 2: they are widespread in the deserts of Central Asia
- 3: they have sand movement not only toward the slip face, but also around the edges of the crescent

ANSWER: 1, 2, AND 3

BONUS

4) EARTH SCIENCE *Multiple Choice* Which of the following characteristics does NOT apply to loess, a wind-deposited silt formation?

- W) Horizontally stratified
- X) Fine-grained
- Y) Calcareous
- Z) Buff colored

ANSWER: W) HORIZONTALLY STRATIFIED

TOSS-UP

5) CHEMISTRY *Short Answer* Consider a mixture of acetone in chloroform. Indicate, by name or number, all of the following 3 characteristics of negative azeotropes that can be observed in this mixture:

- 1: positive change in enthalpy of mixing
- 2: higher vapor pressure than predicted from Raoult's Law
- 3: higher boiling point than either pure acetone or pure chloroform

ANSWER: 3 ONLY

BONUS

5) CHEMISTRY *Short Answer* Consider the reaction $2 \text{NO(g)} + \text{O}_2\text{(g)} \rightarrow 2 \text{NO}_2\text{(g)}$. When the concentration of NO is doubled, the rate of the reaction increases by a factor of 4. When both the O₂ and the NO concentrations are doubled, the rate increases by a factor of 8. What is the overall order of the reaction?

ANSWER: 3

TOSS-UP

6) MATHEMATICS *Short Answer* Find the limit of the sequence whose n th term is given by $a_n = (1 + \frac{1}{n})^n$.

ANSWER: e

BONUS

6) MATHEMATICS *Short Answer* John's parents have agreed to let John attend a concert performed by his favorite band if he helps out around the house for an average 8 hours per week for 5 weeks. For the first 4 weeks, John spends 6, 13, 7, and 3 hours each week. If he truly wants to attend his favorite band's performance, how many hours should he spend doing his chores during the fifth week?

ANSWER: 11

TOSS-UP

7) PHYSICS *Short Answer* What property, implemented widely in Polaroids and other polarizing filters, is the selective absorption of light where rays having varying polarizations are absorbed in different amounts by the filter?

ANSWER: DICHROISM

BONUS

7) PHYSICS *Multiple Choice* A spaceship flies past Earth at a speed of $0.6c$. If a crew member onboard the spaceship measures its length to be 500 m, what is the observed length of the spaceship from Earth?

- W) 300 m
- X) 320 m
- Y) 400 m
- Z) 440 m

ANSWER: Y) 400 m

TOSS-UP

8) ASTRONOMY *Multiple Choice* The cosmic background radiation that is observed today, with a temperature of roughly 2.7 K, consists of photons which were predominantly active in which of the following time periods following the Big Bang?

- W) singularity
- X) recombination
- Y) dark age
- Z) reionization

ANSWER: X) RECOMBINATION

BONUS

8) ASTRONOMY *Multiple Choice* The cosmological principle implies which of the following conditions of the universe?

- W) anisotropic and heterogeneous
- X) anisotropic and homogeneous
- Y) isotropic and heterogeneous
- Z) isotropic and homogeneous

ANSWER: Z) ISOTROPIC AND HOMOGENEOUS

TOSS-UP

9) BIOLOGY *Multiple Choice* T_4 , thyroxine, and T_3 , triiodothyronine, are two iodine-containing amine hormones secreted by the follicles in the thyroid gland in the lower part of the neck. Persons with low peripheral deiodination can show signs of iodine deficiency even when they have high levels of T_4 . Which of the following differences between T_4 and T_3 best accounts for this?

- W) T_4 is secreted in much larger amounts than T_3
- X) T_4 is converted into T_3 by enzymes in cell plasma membranes
- Y) T_4 has a longer half-life than T_3
- Z) T_4 is much less active than T_3

ANSWER: Z) T_4 IS MUCH LESS ACTIVE THAN T_3

BONUS

9) BIOLOGY *Multiple Choice* Which of the following components of the cell membrane, an example of which is a red blood cell, function primarily to determine the shape of the cell by forming supporting scaffold anchored to the membrane and cytoskeleton of the cell?

- W) glycolipids
- X) glycoproteins
- Y) spectrins
- Z) clathrins

ANSWER: Y) SPECTRINS

TOSS-UP

10) EARTH SCIENCE *Short Answer* By name or number, indicate all of the following 3 choices which is/are accurate conclusions from the Deep Sea Drilling Project, an international program sponsored by several oceanographic institutions in order to gather information about ocean basins and test processes that formed them:

- 1: sediment layers thicken with distance from the continental margins
- 2: youngest oceanic crust is adjacent to continental margins and increases in age towards the ridge
- 3: sediment older than 180 million years does not exist in ocean basins

ANSWER: 3 ONLY

BONUS

10) EARTH SCIENCE *Multiple Choice* Which of the following plate boundaries is a convergent plate boundary?

- W) Antarctic and Pacific
- X) South American and African
- Y) African and Arabian
- Z) Nazca and South American

ANSWER: Z) NAZCA AND SOUTH AMERICAN

TOSS-UP

11) CHEMISTRY *Short Answer* Consider an ionic solid such that the radius of the smaller and larger ions are 50 pm and 150 pm, respectively. What is the likely structure of this ionic solid?

ANSWER: ZINC-BLENDE STRUCTURE

BONUS

11) CHEMISTRY *Short Answer* Acrylonitrile, CH_2CHCN , is used in the synthesis of acrylic fibers. Beginning from the left, what is the hybridization on each carbon atom in acrylonitrile?

ANSWER: sp^2 , sp^2 , sp

TOSS-UP

12) MATHEMATICS *Short Answer* Consider the sequence 3, 7, 11, 15.... What is the 10th term of this sequence?

ANSWER: 39

BONUS

12) MATHEMATICS *Short Answer* Simplify the following trigonometric expression

completely: $\frac{\tan^2 x + 1}{1 + \cot^2 x}$

ANSWER: $\tan^2 x$

TOSS-UP

13) PHYSICS *Multiple Choice* Which of the following statements is NOT true regarding damped oscillations?

- W) they are reductions in amplitude caused by dissipative forces
- X) a system takes shorter time to return to equilibrium if it is overdamped
- Y) the mechanical energy during a damped oscillation decreases continuously and eventually reaches zero
- Z) if b , a constant describing the strength of the damping force, is less than the critical value, the system oscillates with steadily decreasing amplitude

ANSWER: X) A SYSTEM TAKES SHORTER TIME TO RETURN TO EQUILIBRIUM IF IT IS OVERDAMPED

BONUS

13) PHYSICS *Multiple Choice* Your friend from Europe gifts you a 960-W toaster, designed to operate on a 240-V line. In order to use it with your USA-standard 120-V, which of the following transformers can you use to make some toast?

- W) a step-up transformer with 4 times as many secondary coils than primary coils
- X) a step-up transformer with 2 times as many secondary coils than primary coils
- Y) a step-down transformer with 4 times as many primary coils than secondary coils
- Z) a step-down transformer with 2 times as many primary coils than secondary coils

ANSWER: X) A STEP-UP TRANSFORMER WITH 2 TIMES AS MANY SECONDARY COILS THAN PRIMARY COILS

TOSS-UP

14) ASTRONOMY *Multiple Choice* Given that Deneb, a star in the constellation Cygnus, is a supergiant, in which of the following luminosity classes would it BEST be classified?

- W) I
- X) II
- Y) III
- Z) IV

ANSWER: W) I

BONUS

14) ASTRONOMY *Short Answer* What infrared space telescope, launched in 2003 by NASA, required cooling by liquid helium in order to function but continued to record observations even after the cryogen was exhausted, and is thus now in the “warm phase” of its mission?

ANSWER: SPITZER SPACE TELESCOPE

TOSS-UP

15) BIOLOGY *Short Answer* In glycolysis, what enzyme phosphorylates fructose 6-phosphate into fructose 1,6-bisphosphate?

ANSWER: PHOSPHOFRUCTOKINASE

BONUS

15) BIOLOGY *Multiple Choice* Two parents are heterozygous for the recessive allele producing albinism. Which of the following best represents the probability that the parents will have one albino child among three children?

W) $\frac{1}{4}$

X) $\frac{3}{4}$

Y) $\frac{27}{64}$

Z) $\frac{37}{64}$

ANSWER: Y) $\frac{27}{64}$

TOSS-UP

16) EARTH SCIENCE *Short Answer* What idea, which was consistent with Wegener’s hypothesis concerning continental drift, was originally formulated to explain the migration of magnetic poles through time, but now refers to the imaginary movement of Earth’s magnetic poles relative to a continent fixed in position?

ANSWER: APPARENT POLAR WANDERING (ACCEPT: POLAR WANDERING)

BONUS

16) EARTH SCIENCE *Short Answer* Order the following three magmatic compositions in terms of increasing tendency to form pyroclastic flows: rhyolitic, basaltic, andesitic

ANSWER: 2, 3, 1

TOSS-UP

17) CHEMISTRY *Multiple Choice* Of the following four oxoacids, which can be predicted to have the lowest pK_a value?

W) hypochlorous acid

X) chlorous acid

- Y) chloric acid
- Z) perchloric acid

ANSWER: Z) PERCHLORIC ACID

BONUS

17) CHEMISTRY *Short Answer* At constant temperature and pressure, order the following 3 gases in terms of increasing mass density: N₂, NH₃, NO₂

ANSWER: 2, 1, 3

TOSS-UP

18) MATHEMATICS *Short Answer* Find the indefinite integral of $h(x) = \tan x \sec^2 x$.

ANSWER: $\frac{1}{2} \tan^2 x + C$

BONUS

18) MATHEMATICS *Multiple Choice* By name or number, indicate all of the following intervals for which the function $f(x) = \frac{2(x^2 - 9)}{x^2 - 4}$ is decreasing:

- 1: $(-\infty, -2)$
- 2: $(-2, 0)$
- 3: $(0, 2)$
- 4: $(2, \infty)$

ANSWER: 1 AND 2

TOSS-UP

19) PHYSICS *Multiple Choice* Which of the following particles is NOT a product of the beta-plus decay of a proton?

- W) electron
- X) positron
- Y) neutrino
- Z) neutron

ANSWER: W) ELECTRON

BONUS

19) PHYSICS *Short Answer* A Carnot engine takes in 3000 J of heat from a reservoir at 600 K, does some work, and discards heat to a reservoir at 480 K. How much work does this Carnot engine do?

ANSWER: 600 JOULES

TOSS-UP

20) ASTRONOMY *Short Answer* What explosion event marks the beginning of the triple alpha process, and occurs when the density of the star's core reaches 1 million g/cm³?

ANSWER: HELIUM FLASH

BONUS

20) ASTRONOMY *Short Answer* Indicate, by name or number, all of the following 3 solar features that are thought to occur primarily in the photosphere, as opposed to other layers of the sun:

- 1: granules
- 2: spicules
- 3: flares

ANSWER: 1 ONLY

TOSS-UP

21) BIOLOGY *Short Answer* What repeating structure, the smallest subunit of muscle contraction, is bounded by discs of protein, or Z lines, and is composed of long, fibrous proteins that slide past each other when muscles contract and relax?

ANSWER: SARCOMERE

BONUS

21) BIOLOGY *Short Answer* Indicate, by name or number, all of the following 4 actions that are isotonic contractions:

- 1: swinging a bat
- 2: holding a heavy ball in place at arm's length
- 3: carrying a box
- 4: pushing against a stationary truck

ANSWER: 1 AND 3

TOSS-UP

22) EARTH SCIENCE *Multiple Choice* Which of the following periods of geologic time saw the adaptation of lobe-finned fish to terrestrial environments, eventually evolving into air-breathing amphibians?

- W) Ordovician
- X) Silurian
- Y) Devonian
- Z) Mississippian

ANSWER: Y) DEVONIAN

BONUS

22) EARTH SCIENCE *Short Answer* Given the following 5 principal groups of climate types, match them to the capital letters A, B, C, D, and E as classified by the Koppen system of climate classification:

- 1: dry
- 2: humid middle-latitude, with mild winters
- 3: humid tropical
- 4: polar
- 5: humid middle latitude, with severe winters

ANSWER: 1: B; 2: C; 3: A; 4: E; 5: D

TOSS-UP

23) CHEMISTRY *Short Answer* What phase of liquid crystals includes molecules that lie parallel to one other and form sheets, resembling soldiers lining up on parade and forming orderly layers?

ANSWER: SMECTIC PHASE

BONUS

23) CHEMISTRY *Short Answer* What volume of 6.0 M HNO_3 would be needed to make 60 mL of 0.50 M solution?

ANSWER: 5 mL

TOSS-UP

24) MATHEMATICS *Short Answer* Differentiate the following hyperbolic function:

$$\frac{d}{dx}[\sinh(x^2 - 3)]$$

ANSWER: $2x \cosh(x^2 - 3)$

BONUS

24) MATHEMATICS *Short Answer* What is the product of the two smallest prime factors of 250?

ANSWER: 10

TOSS-UP

25) PHYSICS *Short Answer* What behavior, characteristic of permanent magnets, is exhibited when a material magnetized to saturation while the external field is reduced to

zero has some remaining magnetization, and requires a magnetic field in the reverse direction in order to reduce the magnetic field to zero?

ANSWER: HYSTERESIS

BONUS

25) PHYSICS *Short Answer* The maximum centripetal acceleration that your car can sustain without skidding out of a curved path is 8 ms^{-2} . If your car is traveling at a constant 20 ms^{-1} on level ground, what is the radius of the tightest unbanked curve that your car can travel?

ANSWER: 50 METERS