

TOSS-UP

1) Biology — *Short Answer* The pineal [*PIN-ee-ul*] gland in the brain is responsible for producing what hormone involved in the sleep-wake cycle?

ANSWER: MELATONIN

BONUS

1) Biology — *Multiple Choice* Proteases [*PRO-tee-aces*] catalyze the cleavage of peptide bonds. In most cases, this reaction is carried out through a single nucleophilic amino acid residue in the protease active site. Which of the following could NOT serve as the catalytic amino acid?

- W) Cysteine [*SIS-teh-een*]
- X) Methionine [*meth-I-OH-neen*]
- Y) Serine [*SEER-een*]
- Z) Threonine [*THREE-ah-neen*]

ANSWER: X) METHIONINE

TOSS-UP

2) Chemistry — *Short Answer* Toluene is reacted with nitric acid and sulfuric acid at high temperature, then purified. The purified product is reacted with hydrogen gas with a palladium-on-carbon catalyst, then a Sandmeyer reaction is performed on the product with copper bromide. What is the name of the organic product of this series of reactions?

ANSWER: 4-BROMO-TOLUENE (ACCEPT: p-BROMOTOLUENE, 1-BROMO-4-METHYLBENZENE, 4-METHYLBROMOBENZENE)

BONUS

2) Chemistry — *Multiple Choice* Which of the following functional groups will be produced if an alkene is exposed to potassium permanganate under alkaline conditions?

- W) Ketone
- X) Aldehyde
- Y) Diol
- Z) Carboxylic acid

ANSWER: Y) DIOL

TOSS-UP

3) Earth and Space — *Multiple Choice* Which of the following best describes the abundance of nearby stars in our location in the Milky Way galaxy?

- W) Dominated by high-mass blue stars
- X) Dominated by white dwarfs
- Y) Dominated by lower-mass red stars
- Z) Dominated by sun-like stars

ANSWER: Y) DOMINATED BY LOWER-MASS RED STARS

BONUS

3) Earth and Space — *Short Answer* What element is the net product formed by the CNO cycle that takes place in hot stars?

ANSWER: HELIUM

TOSS-UP

4) Energy — *Short Answer* Researchers at Ames Lab are developing algorithms to search the space of possible elemental combinations for optimal high-entropy alloys. Their method uses what type of algorithm, which is inspired by mutations and natural selection in biological systems?

ANSWER: EVOLUTIONARY ALGORITHM (ACCEPT: GENETIC ALGORITHM; do not accept: NEURAL NETWORKS, NEAT)

BONUS

4) Energy — *Multiple Choice* Scientists at Thomas Jefferson National Accelerator Facility are trying to form protons that are squeezed into a configuration smaller than their typical one. Which of the following is closest to the typical radius of the proton, in meters?

- W) 10^{-12}
- X) 10^{-13}
- Y) 10^{-14}
- Z) 10^{-15}

ANSWER: Z) 10^{-15}

TOSS-UP

5) Math — *Short Answer* How many diagonals does a 15-sided convex polygon have?

ANSWER: 90

BONUS

5) Math — *Short Answer* A special at a restaurant allows you to get any 3 of 13 possible items, and allows duplicates of the same item. How many different groups of 3 items could you get with this special?

ANSWER: 455

TOSS-UP

6) Physics — *Short Answer* Adam is calculating the electric field that is being produced by a sheet of electric charge. To do so, he draws an imaginary cylinder that passes through the sheet, and uses what law that relates the electric flux passing through the cylinder to the charge within it?

ANSWER: GAUSS'S LAW

BONUS

6) Physics — *Short Answer* Doug pulled a cart 6 meters along the ground with a rope that formed a 60-degree angle with the horizontal. If the tension in the rope was 50 newtons, then in joules, how much work did Doug perform on the cart?

ANSWER: 150

TOSS-UP

7) Biology — *Short Answer* Although it can theoretically affect transcription or splicing, what is the term for a single-base-pair mutation that does not end up changing the encoded amino acid?

ANSWER: SYNONYMOUS (do not accept: silent)

BONUS

7) Biology — *Short Answer* Identify all of the following three reactions in the Krebs cycle that produce NADH: 1) Citrate to isocitrate; 2) Malate [*MAL-ate*] to oxaloacetate [*ox-aloe-ASS-eh-tate*]; 3) Fumarate [*FUME-ah-rate*] to malate.

ANSWER: 2

TOSS-UP

8) Chemistry — *Multiple Choice* Which of the following organic functionalities is considered the most oxidized carbon atom?

W) Alcohol

X) Aldehyde [*AL-deh-hide*]

Y) Carboxylic [*CAR-box-ILL-ik*] acid

Z) Ether [*EE-thur*]

ANSWER: Y) CARBOXYLIC ACID

BONUS

8) Chemistry — *Short Answer* Identify all of the following three molecules that are IR active: 1) O₂; 2) H₂; 3) CO₂.

ANSWER: 3

TOSS-UP

9) Earth and Space — *Multiple Choice* In which of the following regions would one most likely find the oldest stars?

- W) Globular [*GLAW-byoo-lur*] cluster
- X) Open cluster
- Y) Spiral arm
- Z) Dark nebula

ANSWER: W) GLOBULAR CLUSTER

BONUS

9) Earth and Space — *Multiple Choice* Which of the following best explains why Uranus and Neptune have little gaseous ammonia in their atmospheres compared to Jupiter?

- W) They are not massive enough to keep ammonia gravitationally bound in their atmosphere
- X) Their surface temperatures are cold enough for ammonia to freeze
- Y) Ammonia is broken up into nitrogen and hydrogen gas in the harsher atmospheres of Uranus and Neptune
- Z) In the early solar system, much of the ammonia was gravitationally bound to Jupiter, depleting it from the other planets

ANSWER: X) THEIR SURFACE TEMPERATURES ARE COLD ENOUGH FOR AMMONIA TO FREEZE

TOSS-UP

10) Energy — *Multiple Choice* Scientists supported by the Department of Energy are studying explosive compounds like TNT. What is the preferred IUPAC name of TNT?

- W) 2-methyl-1,3,5-tri-nitro-benzene
- X) 2-hydroxy-1,3,5-tri-nitro-benzene
- Y) 2-methyl-1,3,5-tri-amino-benzene
- Z) 2-hydroxy-1,3,5-tri-amino-benzene

ANSWER: W) 2-METHYL-1,3,5-TRI-NITRO-BENZENE

BONUS

10) Energy — *Short Answer* Scientists supported by the Department of Energy are studying artificial neural networks. In an artificial neural network, what is the term for layers of neurons whose inputs and outputs are only connections to other neurons?

ANSWER: HIDDEN

TOSS-UP

11) Math — *Short Answer* A right triangular region has a leg of length 4 lying along the x -axis, and its other leg is of length 6. If the region is rotated about the x -axis, what is the volume of the resulting shape?

ANSWER: 48π

BONUS

11) Math — *Short Answer* What is the largest possible difference between two 4-digit palindromes each divisible by 6?

ANSWER: 6666

TOSS-UP

12) Physics — *Multiple Choice* A student in a boat floating in a pool takes a steel anchor from within the boat, releases it into the water, and waits until it rests at the bottom of a pool. Which of the following happens to the water level in the pool?

- W) It goes up
- X) It goes down
- Y) It remains the same
- Z) It depends on the material that the boat is made out of

ANSWER: X) IT GOES DOWN

BONUS

12) Physics — *Multiple Choice* A solid, spherical object is floating in equilibrium in water with two-thirds of the object's volume submerged. The object is then pushed down until it is completely submerged. What is the ratio of the magnitude of the buoyant force on the object to the magnitude of the force of gravity on the object while it is submerged?

- W) $1/3$
- X) $2/3$
- Y) 1
- Z) $3/2$

ANSWER: Z) $3/2$

TOSS-UP

13) Biology — *Short Answer* What primary mineralocorticoid [*mineralo-CORE-deh-KOYD*] hormone produced by the adrenal glands increases sodium reabsorption and potassium excretion in the kidneys?

ANSWER: ALDOSTERONE

BONUS

13) Biology — *Multiple Choice* Which of the following is an example of a pair of homoplastic traits?

- W) Prokaryotic flagella and eukaryotic flagella
- X) Mitochondria and chloroplasts
- Y) Photosynthesis and cellular respiration
- Z) Human eyes and bird eyes

ANSWER: W) PROKARYOTIC FLAGELLA AND EUKARYOTIC FLAGELLA

TOSS-UP

14) Chemistry — *Multiple Choice* Which of the following benzene derivatives contains an amino group?

W) Phenol

X) Anisole

Y) Aniline [*AN-ih-lin*]

Z) Benzonitrile [*benzo-NYE-trial*]

ANSWER: Y) ANILINE

BONUS

14) Chemistry — *Short Answer* Rank the following three substances in order of increasing boiling point: 1) Butane; 2) Ethane; 3) Propane.

ANSWER: 2, 3, 1

TOSS-UP

15) Earth and Space — *Short Answer* Limestone can undergo diagenesis to form dolostone [**DOH-low-stone**]. During this chemical alteration, calcium is replaced with what other element?

ANSWER: MAGNESIUM

BONUS

15) Earth and Space — *Short Answer* Identify all of the following three statements about oceanic crust that are true: 1) Oceanic crust is, on average, denser than continental crust; 2) Oceanic crust off the west coast of the United States is older than oceanic crust off the east coast of the United States; 3) Oceanic crust is, on average, older than continental crust.

ANSWER: 1

TOSS-UP

16) Energy — *Multiple Choice* Scientists supported by the Department of Energy are studying hadrons. What quantum number do hadrons have that is dependent on the up and down quark content of the hadron?

- W) Spin
- X) Isospin
- Y) Color charge
- Z) Lepton number

ANSWER: X) ISOSPIN

BONUS

16) Energy — *Multiple Choice* Scientists at the Thomas Jefferson National Accelerator Facility are studying how hadrons contribute to the magnetic moment of the muon. Which of the following best describes how this phenomenon occurs?

- W) Muons are hadrons
- X) Leptons can oscillate [*OSS-ih-late*] into hadrons and vice-versa
- Y) Muons can interact with virtual hadrons
- Z) Muon decay necessarily creates hadrons

ANSWER: Y) MUONS CAN INTERACT WITH VIRTUAL HADRONS

TOSS-UP

17) Math — *Short Answer* What is the sum of the largest prime number less than 90 and the smallest prime number greater than 90?

ANSWER: 186

BONUS

17) Math — *Short Answer* Given that cosine of 16 equals -0.9577 , and expressing your answer to two decimal places, what is the integral from 0 to 2 of $x^3 \sin(x^4) dx$?

ANSWER: 0.49

TOSS-UP

18) Physics — *Short Answer* An ideal monatomic gas is adiabatically [*ad-ee-ah-BAT-ik-lee*] compressed to one-eighth of its original volume. What is the ratio of the final pressure to the initial pressure?

ANSWER: 32 (ACCEPT: 32 TO 1)

BONUS

18) Physics — *Multiple Choice* A non-relativistic electron in a uniform magnetic field is moving in a circular orbit. Which of the following best describes how its orbital period changes if the kinetic energy of the electron is increased?

- W) Increases
- X) Decreases
- Y) Stays the same
- Z) Depends on the direction of the magnetic field

ANSWER: Y) STAYS THE SAME