

# Assorted Full Round, Medium-Hard Difficulty

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### TOSS-UP

1. BIOLOGY *Multiple Choice* Which of the following modifications to RuBisCO would be most helpful in minimizing photorespiration and increasing its turnover rate?

(W) Replacing the active magnesium ion with a calcium ion  
(X) Biotinylating one of the lysine residues  
(Y) Operating the enzyme at a higher temperature  
(Z) Adding a subunit containing coenzyme A

ANSWER: X

### BONUS

2. BIOLOGY *Multiple Choice* A hypothetical enzyme in animals replaces the carboxyl group of a fatty acid with an amine. Which of the following would be least likely to be true of this enzyme?

(W) The carboxyl group will be released as a molecule of acetyl CoA that can only be used for catabolism  
(X) Pyridoxyl phosphate will be required to transfer an amine from glutamine or glutamate to the fatty acid  
(Y) The reaction is an oxidation that produces a molecule of NADPH rather than NADH  
(Z) The product of this reaction can still undergo omega oxidation but not alpha or beta oxidation

ANSWER: Y

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### TOSS-UP

3. PHYSICS *Short Answer* A simple pendulum can be treated as a physical pendulum, where the moment of inertia is found using the parallel axis theorem, with a few assumptions. Which of the following assumptions must be made?

(1) The mass of the object is zero  
(2) The mass of the string is zero

- (3) The string is directly attached to the center of mass of the object
- (4) The object has a radius of zero

ANSWER: 2, 3, 4

### BONUS

4. PHYSICS *Short Answer* For an object with a moment of inertia of the form  $cmr^2$ , assuming the object can be treated as a physical pendulum, the period of oscillation is dependent on which of the following:

- (1) Mass
- (2) Acceleration due to gravity
- (3) Amplitude
- (4) Distance from pivot to center of mass

ANSWER: 2, 4

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### TOSS-UP

5. ENERGY *Multiple Choice* As particles accelerate in a cyclotron...

- (W) Angular frequency increases and radius increases
- (X) Angular frequency increases and radius decreases
- (Y) Angular frequency decreases and radius increases
- (Z) Angular frequency decreases and radius decreases

ANSWER: Y

### BONUS

6. ENERGY *Short Answer* Antiprotons are produced by the bombardment of a single proton with a ray of protons. Using conservation of baryon number, in terms of the speed of light  $c$  and the mass of the antiproton  $m$ , find the minimum bombardment energy of the proton beam.

ANSWER:  $6MC^2$

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**TOSS-UP**

7. MATH *Short Answer* A 45-45-90 triangle is inscribed in a circle of radius 1. Find the area of the triangle.

ANSWER:  $1/2$

**BONUS**

8. MATH *Short Answer* A 30-60-90 triangle with a hypotenuse of 2 is circumscribed around a circle. What is the radius of this circle?

ANSWER:  $\frac{1}{1+\sqrt{3}}$

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**TOSS-UP**

9. CHEMISTRY *Multiple Choice* Which of the following reactions always preserves stereochemistry?

(W) SN1

(X) SN2

(Y) E1

(Z) E2

ANSWER: Z

**BONUS**

10. CHEMISTRY *Short Answer* Arrange the following substances in terms of increasing molar entropy at standard room temperature and pressure: Ca(s), Cl<sub>2</sub>(g), Cl<sub>2</sub>(l), CaCl<sub>2</sub>(s)

ANSWER: CA(S), CaCl<sub>2</sub>(S), Cl<sub>2</sub>(L), Cl<sub>2</sub>(G)

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### TOSS-UP

11. EARTH AND SPACE *Short Answer* What is the term for the torus-shaped region outside of Earth's atmosphere that is influenced by the Earth's magnetic field and captures charged particles by functioning similarly to a magnetic bottle?

ANSWER: VAN ALLEN RADIATION BELT

### BONUS

12. EARTH AND SPACE *Multiple Choice* Which of the following does not have a magnetic field?

(W) Jupiter

(X) Earth

(Y) Venus

(Z) Earth's moon

ANSWER: Y

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### TOSS-UP

13. BIOLOGY *Short Answer* The light reactions of photosynthesis are one of the most efficient processes on the planet. However, even these reactions don't have 100% efficiency. Using words or numbers, identify all of the following 3 choices that is or are reasons why photosynthesis does not have 100% efficiency:

(1) Generation of reactive oxygen species

(2) Diffusion time for components of the photosystems

(3) Low absorbance of photons by reaction center complex

ANSWER: 1 ONLY

### BONUS

14. BIOLOGY *Short Answer* In the evolution of photosystems, which photosystems was probably the first to abstract electrons from an external electron donor to replenish those in its reaction center, and what was the most probable identity of this electron donor?

ANSWER: PHOTOSYSTEM I, SULFATE

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### TOSS-UP

15. PHYSICS *Multiple Choice* A household has two hot wires at 120 volts each and a neutral wire. At one end of the household circuit is a 10-amp circuit breaker. Which of the following is true?

(W) The total power output of all devices cannot exceed 1200 watts, regardless of whether they are attached in series or parallel

(X) Connecting the two hot wires will produce a circuit at 0 volts

(Y) The circuit breaker is placed on the neutral wire to maximize safety

(Z) High power-electrical devices are placed between one of the hot wires and the neutral wire

ANSWER: W

### BONUS

16. PHYSICS *Multiple Choice* Which of the following types of circuits would be analogous to a chemical equilibrium of the form  $A \rightleftharpoons B$  where the equilibrium constant and both rate constants are finite and non-zero?

(W) Two capacitors in series with a resistor

(X) Two capacitors in parallel, with a resistor in series with both

(Y) Two inductors in series with a resistor

(Z) Two inductors in parallel, with a resistor in series with both

ANSWER: X

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### TOSS-UP

17. ENERGY *Short Answer* Which quantum number, related to the strong interaction, was first proposed from the observation that the proton and the neutron have similar mass and interact equivalently with the strong force, and leads to symmetries such as the baryon octet?

ANSWER: ISOSPIN

### BONUS

18. ENERGY *Multiple Choice* Which of the following does not occur as a result of relativistic motion?

(W) Linear momentum is larger than linear momentum at rest

(X) The acceleration vector is not always parallel to the net force vector

(Y) Force is not equal to the time derivative of linear momentum

(Z) Kinetic energy becomes infinite as velocity approaches the speed of light

ANSWER: Y

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### TOSS-UP

19. MATH *Short Answer* Using words or numbers, identify all of the following three theorems that apply only to cyclic polygons:

(1) Ptolemy's theorem

(2) Brahmagupta's formula

(3) Heron's formula

ANSWER: ALL OF THEM

### BONUS

20. MATH *Short Answer* Given that  $\frac{dy}{dx} = x + y$ , evaluate the indefinite integral of the following expression:  $\frac{xdx+dy}{2x+y}$

ANSWER: X

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### TOSS-UP

21. CHEMISTRY *Short Answer* How many hydrogen peaks (excluding bond-neighbor effects) would the molecule 3-ethyl-2-methylpentane show in its H-NMR?

ANSWER: 5

### BONUS

22. CHEMISTRY *Multiple Choice* A carboxylic acid anhydride and hydrochloric acid are produced from a reaction between which two reactants?

(W) Water and acid chloride

(X) Acid chloride and RCOOH

(Y) Cl<sub>2</sub> and ROH

(Z) Cl<sub>2</sub> and RNH<sub>2</sub>

ANSWER: X

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### TOSS-UP

23. EARTH AND SPACE *Short Answer* A red giant star is emitting radiation with a frequency of 8 MHz. The star is traveling at a speed of 0.6c towards the Earth. To two significant digits, what is the frequency of the star's emitted light as seen from an observer on Earth?

ANSWER: 1.6 MHZ

### BONUS

24. EARTH AND SPACE *Short Answer* In sediments on the ocean floor, bacteria break down organic matter to produce methane, which, under enormous pressure and low temperature, dissolves and becomes locked in water molecules to form crystals. These crystals cement together the ocean sediments into solid layers what, which can extend down into the sea floor?

ANSWER: METHANE HYDRATES

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### TOSS-UP

25. BIOLOGY *Multiple Choice* A human eating which two of the following foods can absorb all of the essential amino acids?

(W) Rice and soy beans  
(X) Corn and rice  
(Y) Tomatoes and soy beans  
(Z) Cabbage and rice

ANSWER: W

### BONUS

26. BIOLOGY *Multiple Choice* A farmer refers to his grains of rice as “rice fruits”, and another ridicules him. Which farmer is right?

(W) The first: since rice is a grain, its fruit coat is fused with its seed coat, and what is commonly called a rice grain is actually a fruit  
(X) The second: the fruit of rice is a small, dehiscent structure that releases its seeds at maturity, and so what is commonly called a rice grain is actually a seed  
(Y) The first: the fruit wall of rice is used to store food, and is reabsorbed into the seedling at maturity, and so what is commonly called a rice grain is actually a fruit  
(Z) The second: rice is a gymnosperm and does not produce fruits

ANSWER: W

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### TOSS-UP

27. PHYSICS *Multiple Choice* In a spring, the force of friction that causes dampening...

(W) Leads the position by 90 degrees  
(X) Lags the position by 90 degrees  
(Y) Is in phase with the position  
(Z) Is out of phase with the position by 180 degrees

ANSWER: X

### BONUS

28. **PHYSICS** *Short Answer* For each of the following, determine whether the source voltage is in phase, leads, or lags in comparison to the current:

- (1) Capacitor voltage
- (2) Inductor voltage
- (3) Resistor voltage

ANSWER: LAGS, LEADS, IN PHASE

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### TOSS-UP

29. **ENERGY** *Short Answer* Which nuclear disaster is the second-largest in history and was initially caused by earthquake damage to boiling water reactors?

ANSWER: FUKUSHIMA-DAIICHI DISASTER

### BONUS

30. **ENERGY** *Short Answer* Although this inequality is often applied to nuclear fusion reactors, it can be associated with any sort of fuel. The minimum value of this inequality is equal to the product of confinement time and temperature, and is important to determine the conditions needed for the fusion reactor to maintain its temperature against total power losses. Name this inequality.

ANSWER: LAWSON CRITERION

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### TOSS-UP

31. **MATH** *Short Answer* You roll three die numbered zero to six. How many ways can the numbers on the die add up to seven?

ANSWER: 42

### BONUS

32. MATH *Multiple Choice* Which of the following functions has a point of inflection at  $x=2$ ?

(W)  $\frac{1}{3}x^3 - 3x^2 + 8x + 4$

(X)  $x^3 + 3x^2 + 8x + 4$

(Y)  $x^3 + 3x^2 + 8x - 10$

(Z)  $\frac{1}{3}x^3 + x^2 + x - 12$

ANSWER: W

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### TOSS-UP

33. CHEMISTRY *Multiple Choice* Which of the following is not true of the colligative properties of solutions?

(W) The origin of the boiling point elevation is entropic and can be explained in terms of the vapor pressure or chemical potential of the solvent

(X) A linear relationship exists between the temperatures at which two solutions exert the same vapor pressure

(Y) Boiling point elevation and freezing point depression can be used to determine the molar concentration of solution

(Z) Boiling point elevation and freezing point depression are independent of the van't Hoff factor

ANSWER: Z

### BONUS

34. CHEMISTRY *Short Answer* In which type of crystal structure do each of the two atom types forms a separate face-centered cubic lattice, with the two lattices interpenetrating so as to form a 3D checkerboard pattern?

ANSWER: ROCK SALT

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### TOSS-UP

35. EARTH AND SPACE *Short Answer* What is the Hubble type for a perfectly spherical galaxy?

ANSWER: E0

### BONUS

36. EARTH AND SPACE *Multiple Choice* Which of the following is not a spiral galaxy?

- (W) Pinwheel galaxy
- (X) Tringulum galaxy
- (Y) Starburst galaxy
- (Z) Whirlpool galaxy

ANSWER: Y

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### TOSS-UP

37. BIOLOGY *Multiple Choice* Which of the following is not true of the cell cycle?

- (W) If irreversible damage to DNA is detected at the G2 checkpoint, the cell exits the cell cycle and enters G0
- (X) Most cells in the body, with the exception of stem cells, are in G0
- (Y) Cells lacking growth factors will exit the cell cycle, but will re-enter if the proper growth factors are provided
- (Z) Cells that lack signals for the S phase will halt at the G1 checkpoint but continue to enlarge in the presence of growth factors

ANSWER: W

### BONUS

38. BIOLOGY *Short Answer* Also known as the G1 checkpoint, give the name for the irreversible point in G1 in mammals in which a cell either exits the cell cycle into G1 or becomes committed to DNA synthesis.

ANSWER: RESTRICTION POINT

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### TOSS-UP

39. PHYSICS *Short Answer* Using words or numbers, identify all of the following three conservation laws that are broken in  $\beta^-$  decays:

- (1) Conservation of strangeness
- (2) Conservation of lepton number
- (3) Conservation of baryon number

ANSWER: 1 ONLY

### BONUS

40. PHYSICS *Multiple Choice* Which of the following has a baryon number of zero?

- (W)  $\pi^0$  meson
- (X) Strange quark
- (Y) Proton
- (Z) Anti-neutron

ANSWER: W

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### TOSS-UP

41. ENERGY *Multiple Choice* The catalytic rotor of ATP synthase is important because it ensures that synthesis of ATP is strongly favored over hydrolysis. It consists of three subunits, each of which has a high affinity for a particular molecule. As these subunits rotate, the affinity of ATP synthase switches to the next molecule. Which of the following is not one of

those subunits?

(W) ATP-binding subunit

(X) ADP-binding subunit

(Y) Inorganic phosphate-binding subunit

(Z) Empty subunit

ANSWER: Y

### BONUS

42. ENERGY *Multiple Choice* Which of the following membranes is the most porous?

(W) ER membrane

(X) Mitochondrial outer membrane

(Y) Mitochondrial inner membrane

(Z) Chloroplast inner membrane

ANSWER: X

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### TOSS-UP

43. MATH *Short Answer* Find the derivative of the following function:  $f(x) = \ln x \sin x$

ANSWER:  $F(X) = \sin X/X + \ln X \cos X$

### BONUS

44. MATH *Short Answer* You are trying to differentiate the function  $f(x) = u_0(x)v_0(x)w_0(x)$ , where the derivative of  $u_0(x)$  is  $u_1(x)$ , the derivative of  $u_1(x)$  is  $u_2(x)$  and so on for  $u$ ,  $v$ , and  $w$ . Suppose you have taken 10 derivatives of  $f(x)$ . How many terms contain  $u_3$ ?

ANSWER: 8

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### TOSS-UP

45. CHEMISTRY *Multiple Choice* Which of the following molecules does not have a permanent dipole?

(W)  $\text{NH}_3$   
(X)  $\text{CH}_2\text{Cl}_2$   
(Y)  $\text{H}_2\text{O}$   
(Z)  $\text{BH}_3$

ANSWER: Z

### BONUS

46. CHEMISTRY *Short Answer* Calculate the strength of the dipole moment for a molecule  $\text{AB}_2$ , where the bond order is 1, the bond angle is 120 degrees, the bond distance is 2.5 nm, the partial charge of A is +0.5 C, and the partial charge of B is 0.25 C.

ANSWER: 0.75 CM

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### TOSS-UP

47. EARTH AND SPACE *Short Answer* What is the term for when an object, such as the Earth or the Moon, makes its closest approach to the body it is orbiting?

ANSWER: PERIGEE

### BONUS

48. EARTH AND SPACE *Short Answer* Order the eccentricities of the following four astronomical objects from the least to the greatest: Earth, Pluto, Mercury, Triton

ANSWER: TRITON, EARTH, MERCURY, PLUTO

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### TOSS-UP

49. ENERGY *Short Answer* Calculate the coefficient of performance for a refrigerator that transfers 800 J from a cold to a hot reservoir using 200 J of mechanical work.

ANSWER: 4

### BONUS

50. ENERGY *Multiple Choice* Which of the following is not true of compression ratios in internal combustion engines?

(W) Knocking in engines using the Otto cycle is due to pre-ignition after compression

(X) Fuels with higher octane ratings allow for a higher compression ratio

(Y) Diesel cycles do not have fuel for most of the compression strokes, they can afford higher compression ratios

(Z) Higher compression ratios do not increase the thermal efficiency, but rather the rate at which heat is converted to mechanical energy

ANSWER: Z

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### TOSS-UP