

# Assorted Full Round, Medium-Hard Difficulty

Siddharth Trehan

March 31, 2013

### TOSS-UP

1. BIOLOGY *Short Answer* This protein is commonly used to map evolutionary relationships between lineages of organisms. In the cytosol, it can stimulate Apaf-1, which is responsible for activating cell death. It contains a prosthetic heme group which is important in electron transport for both NADH and FADH<sub>2</sub>. Name this molecule.

ANSWER: CYTOCHROME C

### BONUS

2. BIOLOGY *Multiple Choice* Which of the following is not true of tumor cells?

- (W) They tend to consume higher levels of glucose than surrounding tissue
- (X) They secrete chemicals that promote the growth of blood vessels
- (Y) Most cancer cells have a single mutation that causes them to become cancerous
- (Z) Rb is a tumor-suppressor gene that is mutated in retinoblastomas

ANSWER: Y

---

### TOSS-UP

3. PHYSICS *Multiple Choice* Which of the following is not true of precession?

- (W) Precession is caused by the torque exerted by the weight of a spinning object
- (X) If the direction of rotation of the object is clockwise, then the direction of precession is also clockwise
- (Y) The angular velocity of precession is greatest for high angular velocities of rotation
- (Z) The axis of precession is distinct from both the torque axis and the spin axis

ANSWER: Y

### BONUS

4. PHYSICS *Short Answer* Order the moment of inertias for the following four solids from least to greatest, given that the axis of rotation is through the geometric center of the cylinder along its long axis:

- (1) A solid cylinder
- (2) A solid cylinder with a sphere hollowed out around its center of mass
- (3) A solid cylinder with a sphere hollowed out around a point other than its center of mass
- (4) A solid cylinder with a sphere attached to its end

ANSWER: 3, 2, 1, 4

---

### TOSS-UP

5. CHEMISTRY *Short Answer* In organic chemistry, what reaction uses a triphenyl phosphonium ylide to convert a carbonyl group to an alkene?

ANSWER: WITTIG REACTION

### BONUS

6. CHEMISTRY *Short Answer* What reagent is commonly used to synthesize methyl esters, notable for its release of nitrogen upon reaction?

ANSWER: DIAZOMETHANE

---

### TOSS-UP

7. MATH *Multiple Choice* Which of the following operators transforms a vector function into a vector function?

- (W) Gradient
- (X) Divergence
- (Y) Curl
- (Z) Laplacian

ANSWER: Y

### BONUS

8. MATH *Short Answer* Find the derivative with respect to  $x$  of the following function:  $f(x) = \frac{x^3 - a^3}{x - a}$

ANSWER:  $2X + A$

---

### TOSS-UP

9. EARTH AND SPACE *Short Answer* Which metal is extracted from bauxite?

ANSWER: ALUMINUM

### BONUS

10. EARTH AND SPACE *Multiple Choice* Which of the following mineral ores would not be ferromagnetic?

(W) Cobaltite

(X) Limonite

(Y) Bornite

(Z) Hematite

ANSWER: Y

---

### TOSS-UP

11. ENERGY *Short Answer* This is a common metal used in chemotherapy because it can preferentially bind to guanine bases in DNA. Another element in the same family as this metal is used in heterogeneous catalysts in organic chemistry. This metal itself is also used as a catalyst in some reactions. It is extremely rare in the Earth's crust and is therefore not present in any common mineral ores. In galvanic cells, it is sometimes used as an inert metal in electrodes, although sometimes not used because of it is also one of the most expensive metals on the periodic table. Name this metal.

ANSWER: PLATINUM

### BONUS

12. ENERGY *Multiple Choice* ABC transporters are found on the majority of cancer cells and are responsible for drug resistance. You expect that these transporters are selective for...

- (W) Hydrophobic substances
- (X) Hydrophilic but uncharged substances
- (Y) Monovalent cation containing-substances
- (Z) Monovalent anion containing-substances

ANSWER: W

---

### TOSS-UP

13. BIOLOGY *Multiple Choice* The reason why replication requires a primer but transcription does not is because DNA polymerase has which of the following activities that RNA polymerase does not?

- (W) Head polymerization
- (X) Methylation
- (Y) Proofreading
- (Z) Endonuclease

ANSWER: Y

### BONUS

14. BIOLOGY *Short Answer* Using words or numbers, identify all of the following four activities that DNA polymerase possesses:

- (1) 3' to 5' polymerase
- (2) 5' to 3' polymerase
- (3) 3' to 5' exonuclease
- (4) 5' to 3' exonuclease

ANSWER: 2 AND 3

---

**TOSS-UP**

15. PHYSICS *Multiple Choice* Which of the following does not imply a lower pressure for an ideal fluid in a pipeline?

(W) Lower cross-sectional area

(X) Higher volumetric flow rate

(Y) Lower height

(Z) Lower velocity

ANSWER: Z

**BONUS**

16. PHYSICS *Short Answer* A large barrel of a height of 40 meters contains a very small hole at the bottom with a cross sectional area of 10 square centimeters. Given that the acceleration due to gravity is  $10 \text{ m/s}^2$  and that the barrel has a cross-sectional area of 5 meters squared, calculate the speed of the fluid through the hole to the nearest integer value.

ANSWER: 20 METERS PER SECOND

---

**TOSS-UP**

17. CHEMISTRY *Multiple Choice* Which sample of water will have the highest water pressure?

(W) 10.0 mL at  $62^\circ \text{C}$

(X) 20.0 mL at  $52^\circ \text{C}$

(Y) 30.0 mL at  $42^\circ \text{C}$

(Z) 40.0 mL at  $32^\circ \text{C}$

ANSWER: W

### BONUS

18. CHEMISTRY *Multiple Choice* For a given spontaneous equilibrium reaction, which of the following statements is true?

(W) The reaction will start without the input of energy  
(X) There is a net input of energy into the reaction from the environment  
(Y) The standard potential for the reaction is negative  
(Z) The equilibrium constant  $K$  will be greater than 1

ANSWER: Z

---

### TOSS-UP

19. MATH *Multiple Choice* In relativity, a reference frame traveling at relativistic speeds will experience which of the following kinds of rotations of spacetime?

(W) An ordinary rotation  
(X) A hyperbolic rotation  
(Y) A parabolic rotation  
(Z) An open rotation

ANSWER: X

### BONUS

20. MATH *Short Answer* Which type of geometric object, although similar to matrices, are more inclusive and describe linear relations between vectors, scalars, and other types of these objects, including the dot product and cross product, have a characteristic order representing the number of dimensions contained in the object, and are used in electromagnetism and relativity to describe quantities that are Lorentz-invariant?

ANSWER: TENSORS

---

### TOSS-UP

21. EARTH AND SPACE *Short Answer* What is the term for a sheet intrusion (or concordant pluton) that has been injected between two layers of sedimentary rock such that the pressure of the magma is high enough that the overlying strata are forced upward, giving it a dome or mushroom-like form with a generally planar base?

ANSWER: LACCOLITH

### BONUS

22. EARTH AND SPACE *Multiple Choice* Which of the following rocks does not commonly compose a batholith?

(W) Muscovite

(X) Quartz

(Y) Olivine

(Z) Diorite

ANSWER: Y

---

### TOSS-UP

23. ENERGY *Short Answer* Using words or numbers, identify all of the following four choices that is or are true of potential energy associated with E and B fields:

(1) The E field has a potential energy associated with translational motion of point charges

(2) The E field has a potential energy associated with rotational motion of dipoles

(3) The B field has a potential energy associated with translational motion of point charges

(4) The B field has a potential energy associated with rotational motion of dipoles

ANSWER: 1, 2, 4

### BONUS



24. ENERGY *Multiple Choice* Which of the following is occurring as a magnet attracts a loop of wire with a current passing through it?

(W) The magnetic field from the magnet does work on the electrons in the wire  
(X) The magnetic field from the magnet does work on the solid lattice of the conductor  
(Y) The electric field inside the conductor does work on the electrons in the wire  
(Z) The electric field inside the conductor does work on the solid lattice of the conductor

ANSWER: Z

---

### TOSS-UP

25. BIOLOGY *Short Answer* Which coenzyme is found in pyruvate dehydrogenase, where it is commonly present in its pyrophosphate form that catalyzes reactions of carbanions?

ANSWER: THIAMINE

### BONUS

26. BIOLOGY *Multiple Choice* Which of the following enzymes of the citric acid cycle is most similar to pyruvate dehydrogenase, which catalyzes the link reactions?

(W) Citrate synthase  
(X)  $\alpha$ -ketoglutarate dehydrogenase  
(Y) Succinyl-CoA synthetase  
(Z) Malate dehydrogenase

ANSWER: X

---

### TOSS-UP

27. PHYSICS *Short Answer* Using words or numbers, identify all of the following three statements that is or are true:

- (1) Rolling without slipping requires that velocity at any point on the solid is given by radius times angular velocity
- (2) A cone is the only solid that can turn while rolling without slipping
- (3) A solid will roll down an incline about an axis such that the angular velocity about this axis is the same at all points

ANSWER: 1, 2, 3

### BONUS

28. PHYSICS *Short Answer* Two parallel plate capacitors are traveling at the same relativistic speed in your frame of reference. Capacitor A is oriented such that its electric field is parallel to its velocity, and capacitor B is oriented such that the plates are parallel to its velocity. For capacitor A and B, indicate whether the E-field will be weaker, stronger, or the same as if they were both at rest in your frame of reference.

ANSWER: A: SAME, B: STRONGER

---

### TOSS-UP

29. CHEMISTRY *Multiple Choice* Decarboxylation involves the removal of a carboxyl group and its replacement with a hydrogen. The carboxyl group is removed as

- (W) Formaldehyde
- (X) Carbon dioxide
- (Y) Carbon monoxide
- (Z) Formic acid

ANSWER: X

### BONUS

30. CHEMISTRY *Short Answer* You are told that a chloride containing compound has a molecular mass of 78.5 g/mol. Its H-NMR shows two signals, one which is split into 7 peaks and the other into 2 peaks. What is the compound?

ANSWER: I HAVE NO CLUE.

---

### TOSS-UP

31. MATH *Short Answer* Tyrone has a drinking problem. Everyday, he rolls a pair of dice, and the product of the numbers on the dice is the number of beers he will consume that day. What is the expected value of the number of beers that Tyrone will consume on a given day? Express your answer as a fraction in lowest terms.

ANSWER:  $49/4$

### BONUS

32. MATH *Short Answer* Tyrone beats his wife. If she is disobedient, he beats her three times a day. If she is obedient, he beats her two times a day. Over the course of 7 days, his wife is disobedient for  $D$  days, obedient for  $O$  days, and leaves home for  $L$  days such that Tyrone is unable to beat his wife. Given that Tyrone's wife was found to have 10 bruise marks by the end of the month, what is the maximum possible value of  $D$  times  $O$  times  $L$ ?

ANSWER: 12

---

### TOSS-UP

33. ENERGY *Multiple Choice* A loop of wire with a current flowing through it is oriented such that its area vector points in the positive  $z$  direction. It produces a steady magnetic field. Along the plane of the loop, in which direction does energy transfer in the form of electromagnetic radiation occur?

(W) Radially inward

(X) Radially outward

(Y) In the positive  $z$  direction

(Z) In the negative  $z$  direction

ANSWER: X

### BONUS

34. ENERGY *Short Answer* Using words or numbers, identify all of the following three choices that increase the efficiency of an Otto cycle:

- (1) Increasing the pressure differences between the isochors
- (2) Increasing the compression ratio
- (3) Using a diatomic instead of monatomic gas

ANSWER: 2 ONLY

---

### TOSS-UP

35. BIOLOGY *Short Answer* These birds are a group of long-legged wading bird belonging to the family Threskiornithidae. They often live in trees, with spoonbills or herons. These birds were named after their name in Ancient Egyptian. Name these birds.

ANSWER: IBISES

### BONUS

36. BIOLOGY *Short Answer* To which order do woodpeckers belong?

ANSWER: PICIFORMES

---

### TOSS-UP

37. PHYSICS *Short Answer* Which theorem in fluid mechanics states that the speed of a fluid coming out of the bottom of a bottle is independent of the area of the cap region and can be treated as though a particle were in free fall?

ANSWER: TORICELLI'S THEOREM

### BONUS

38. PHYSICS *Short Answer* A bucket containing water is spun at a constant angular velocity. As expected, the surface of the water curves inward in a parabolic shape. The curve describing this shape can be found by equating which of the following?

- (1) Gravitational potential energy
- (2) Potential due to centripetal force
- (3) Kinetic energy

ANSWER: 1, 2, AND 3

---

### TOSS-UP

39. CHEMISTRY *Multiple Choice* A carbonyl carbon acts an electrophile because

- (W) The difference in electronegativity between oxygen and carbon is enough to polarize the bond
- (X) It has sp<sup>2</sup> hybridization
- (Y) Oxygen can donate electron density to stabilize the positively-charged electrophile
- (Z) All carbon atoms act as electrophiles

ANSWER: W

### BONUS

40. CHEMISTRY *Multiple Choice* RNA can be seen to degrade if left at room temperature for too long, while DNA does not have this issue. The major reason for this is that

- (W) The DNA backbone provides additional stability that the RNA backbone does not provide.
- (X) The replacement of thymine with uracil decreases the stability of the RNA molecule.
- (Y) DNA is wound more tightly around itself in a different manner than RNA, providing it increased stability.
- (Z) DNA is a more stable molecule than RNA

ANSWER: W

---

### TOSS-UP

41. MATH *Short Answer* On the closed interval  $[0, 8\pi]$ , how many times will the function  $f(x) = \sin(x - \pi/8) \tan x$  cross the x-axis?

ANSWER: 12

### BONUS

42. MATH *Short Answer* Using words or numbers, identify all of the following three series that converge to a value smaller than the value the series  $2 + 1 + 1/2 + 1/4 \dots$  converges to:

(1)  $2 - 1 + 1/2 - 1/4 \dots$

(2)  $1/0! + 1/1! + 1/2! + 1/3! \dots$

(3)  $6 + 2 + 2/3 + 2/9 \dots$

ANSWER: I AND II

---

### TOSS-UP

43. ENERGY *Short Answer* According to supersymmetry, which two groups of particles are associated in a one-to-one relationship?

ANSWER: BOSONS AND FERMIONS

### BONUS

44. ENERGY *Short Answer* Using words or numbers, identify all of the following three quantities that is or are possessed by E and B fields in a vacuum:

(1) Energy

(2) Momentum

(3) Angular momentum

ANSWER: 1, 2, AND 3

---

### TOSS-UP

45. PHYSICS *Multiple Choice* The determination of the precise steps needed for the Carnot cycle was done by...
- (W) Maximizing the area on a PV diagram
  - (X) Maximizing the area on a TS diagram
  - (Y) Eliminating all steps without constant entropy
  - (Z) Setting the conditions the same as those for Helmholtz free energy

ANSWER: X

### BONUS

46. PHYSICS *Multiple Choice* In an adiabatic process, pressure varies inversely with volume raised to the power of...
- (W) The proportion of heat that goes into work
  - (X) The proportion of heat that goes into internal energy
  - (Y) The ratio of isobaric to isochoric molar heat capacities
  - (Z) The ratio of entropies in the forward and reverse processes

ANSWER: W

---

### TOSS-UP