Assorted Full Round, Hard Difficulty

Siddharth Trehan

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TOSS-UP

1. BIOLOGY *Short Answer* A cell is found to be missing either DNA polymerase I, DNA polymerase III, DNA ligase, or DNA primase. Given the following description, identify which of these enzymes is missing: The cell has an abnormally high mutation rate on the lagging strand. You extract the nucleoplasm and place it in a vial with DNA and find that there is no 5' to 3' exonuclease activity. Furthermore, you note that there is some RNA-DNA base pairing during the G1 phase. Which enzyme is missing?

   ANSWER: DNA POLYMERASE I

BONUS

2. BIOLOGY *Short Answer* For each of the following, identify whether the polymer is composed of DNA or RNA:

   (1) The primers used in PCR

   (2) The probes used in nucleic acid probing

   (3) The primers used in cDNA synthesis

   ANSWER: 1. DNA, 2. RNA, 3. RNA

TOSS-UP

3. PHYSICS *Multiple Choice* Which of the following types of cycles would form a rectangle on a TS diagram?

   (W) Otto cycle

   (X) Carnot cycle

   (Y) Sterling cycle

   (Z) Rankine cycle

   ANSWER: X

BONUS

4. PHYSICS *Short Answer* A genie grants you three wishes, and your first wish is that the ideal gas law was $PV = 2nRT$ instead of $PV = nRT$. Using words or numbers, identify all of the following four changes that would occur once the genie grants this wish:

(1) Heating or cooling would occur more rapidly in adiabatic processes

(2) Isothermal processes would undergo more rapid changes in pressure

(3) Otto cycles would be more efficient

(4) Constant value heat capacity would increase

ANSWER: 1, 3

TOSS-UP

5. MATH *Multiple Choice* Which of the following fourth-degree Taylor series corresponds to $f(x) = \sin x/x$?

(W) $x - x^3/2$

(X) $1 - x^2/6$

(Y) $x - x^3/6$

(Z) $1 - x^2/2$

ANSWER: X

BONUS

6. MATH *Short Answer* Evaluate the following integral: definite integral from $x = 1$ to $x = e$ of $\ln dx$.

ANSWER: 0

TOSS-UP

7. CHEMISTRY *Multiple Choice* Which of the following is a plausible set of quantum numbers for an electron in the the 3d orbital of an atom?

(W) 3, 1, 0, 1/2

(X) 3, 2, 1 1/2

(Y) 2, 3, 2 -1/2

(Z) 2, 2, 1 -1/2

ANSWER: X

BONUS

8. CHEMISTRY *Short Answer* Which reagent is used for weak reductions, such as that of xylose to xylitol?

ANSWER: SODIUM BOROHYDRIDE

TOSS-UP

9. ENERGY *Multiple Choice* Which of the following hormones multiplies the countercurrent gradient in the loop of Henle?

(W) ADH

(X) ANP

(Y) Cortisol

(Z) Oxytocin

ANSWER: W

BONUS

10. ENERGY *Short Answer* Using words or numbers, identify all of the following three processes that exhibit saturation:

(1) Filtration

(2) Reabsorption

(3) Secretion

ANSWER: 2 AND 3

TOSS-UP

11. BIOLOGY *Short Answer* All mammals must mount an innate immune response before mounting an adaptive immune response. Using words or numbers, identify all of the following three choices that is or are true:

(1) This is a direct consequence of antigen presentation

(2) This ensures that the source of the antigen also possesses a PAMP to ensure it is an antigen

(3) If the adaptive immune response were eliminated, the mammal could still fight the infection but the secondary immune response would be identical to the primary immune response

ANSWER: 1, 2, 3

BONUS

12. BIOLOGY *Multiple Choice* Which cell-surface proteins on lymphocytes, which normally link the cell to the extracellular matrix, allows them to squeeze through the walls of the capillaries in and out of lymph nodes via cell-to-cell adhesion?

(W) Selectins

(X) Integrins

(Y) Fibronectins

(Z) Angionectins

ANSWER: X

TOSS-UP

13. PHYSICS *Multiple Choice* According to the Faraday effect, the plane of polarization of light will be rotated if the magnetic field is oriented...

(W) Perpendicular to the E-field

(X) Perpendicular to the B-field

(Y) Parallel to the light ray

(Z) Oriented radially around the light ray

ANSWER: Y

BONUS

14. PHYSICS *Short Answer* For your second wish with the genie, you wish that the gravitational force was an inverse cube law instead of an inverse square law. In terms of the gravitational constant G, what is the new escape velocity for a planet with a radius of 400 meters and a mass of 75 million kilograms in meters per second?

ANSWER: $12.5\sqrt{3G}$

TOSS-UP

15. MATH *Multiple Choice* The natural numbers closed over addition is most specifically an example of...

(W) A category

(X) A monoid

(Y) A group

(Z) An abelian group

ANSWER: X

BONUS

16. MATH *Short Answer* This specific type of mapping is a type of homomorphism between categories that is said to obey two laws: one dealing with the mapping of identity elements between the two categories, and the other dealing with the composition of operations from one category to another with another category as the intermediate of the composed operations. One example of this type of mapping is the application of a function over all elements of a list, which transforms it from a list of one type to a list of another. What is the name for this type of mapping?

ANSWER: FUNCTOR

TOSS-UP

17. CHEMISTRY *Short Answer* Using words or numbers, identify all of the following four molecules that have a permanent dipole:

(1) NH3

(2) CCl4

(3) H2O

(4) BH3

ANSWER: 1, 3

BONUS

18. CHEMISTRY *Multiple Choice* The product of the zero order reaction X + Y $\rightarrow$ Z will

(W) Increase linearly

(X) Decrease linearly

(Y) Increase exponentially

(Z) Decrease exponentially

ANSWER: W

TOSS-UP

19. ENERGY *Short Answer* The parabola given by $y-2=3x^2$ is sketched on the xy coordinate plane and a spinner is placed at its vertex. What is the probability that the ray of the spinner intersects with the parabola?

ANSWER: $1/2$

BONUS

20. ENERGY *Short Answer* The parabola given by $y=x^2$ is sketched on the xy coordinate plane and a spinner is placed at the point $(1/2, 1/4)$. What is the probability that the spinner's ray is parallel to the curve of the parabola to the left of the point $(1/2, 1/4)$?

ANSWER: $3/8$

TOSS-UP

21. BIOLOGY *Short Answer* The synthesis of fatty acids from acetyl CoA and a growing fatty acid chain occurs via which type of condensation from organic chemistry?

ANSWER: CLAISEN CONDENSATION

BONUS

22. BIOLOGY *Short Answer* Which intermediate compound formed in fatty acid synthesis is similar to acetyl CoA, but is a β-ketothioester?

ANSWER: MALONYL COA

TOSS-UP

23. PHYSICS *Multiple Choice* A laser uses which of the following processes to increase the proportion of atoms in the excited state rather than in the lower energy states?

(W) Population inversion

(X) Spontaneous emission

(Y) Stimulated emission

(Z) Both spontaneous and stimulated emission

ANSWER: W

BONUS

24. PHYSICS *Short Answer* For your third and final wish with the genie, you wish that magnetic monopoles existed. Using words or numbers, identify all of the following three changes that would occur:

(1) Gauss's law for electricity and for magnetism would both be nonzero

(2) Induced magnetic fields would not form closed loops

(3) The magnetic field could do work on charged particles

ANSWER: 1 ONLY

TOSS-UP

25. MATH *Short Answer* Find the sum of the coefficients when the following is expanded: $(x + 2y)^8$

ANSWER: 6561

BONUS

26. MATH *Short Answer* Solve the followoing differential equation: $x^2 \frac{dy}{dx} + x = 1$, taking the value of the added constant to be zero.

ANSWER: $Y = \mathrm{LN}\, X/X$

TOSS-UP

27. CHEMISTRY *Short Answer* In which specific type of Claisen condensation does a single diester, instead of two separate esters, forms a β-ketoester?

ANSWER: DIECKMANN CONDENSATION

BONUS

28. CHEMISTRY *Short Answer* Using words or numbers, identify all of the following that may be reactants in a Claisen condensation:

(1) A carbonyl

(2) An alcohol

(3) A strong base

(4) A strong acid

ANSWER: 1, 3

TOSS-UP

29. ENERGY *Short Answer* The apparent brightness of a star is 6.43 Watts per meters squared. What is the apparent magnitude, to the nearest half unit?

ANSWER: 1.5

BONUS

30. ENERGY *Short Answer* The apparent magnitude of a star is 4.35. What is the apparent brightness to the nearest half Watt per meter squared?

ANSWER: 4.5

TOSS-UP

31. BIOLOGY *Short Answer* Which class of antimicrobials found in plants is released upon infections and is important for mounting the hypersensitive response?

ANSWER: PHYTOALEXINS

BONUS

32. BIOLOGY *Short Answer* Resin is mainly composed of which class of secondary compounds produced by plants?

ANSWER: TERPENES

TOSS-UP

33. PHYSICS *Multiple Choice* Which of the following does not have a definite value?

(W) Isochoric molar heat capacity

(X) Isothermal molar heat capacity

(Y) Adiabatic molar heat capacity

(Z) Isobaric molar heat capacity

ANSWER: Y

BONUS

34. PHYSICS *Short Answer* In a universe with 4 space dimensions, what would be the constant volume and constant pressure molar heat capacities for an ideal diatomic gas?

ANSWER: $3R$ AND $4R$

TOSS-UP

35. MATH *Short Answer* If the square root of the complex number $2 + 2\sqrt{3}i$ is taken, give the argument of the resultant complex number.

ANSWER: 30 DEGREES

BONUS

36. MATH *Short Answer* Find the square root of the complex number $2 + 2\sqrt{3}i$ in a + bi form.

ANSWER: $\sqrt{3} + I$

TOSS-UP

37. CHEMISTRY *Multiple Choice* The reduction of a 3° alcohol produces what type of structure?

(W) an aldehyde

(X) an alkyne

(Y) an alkane

(Z) a 2° alcohol

ANSWER: Y

BONUS

38. CHEMISTRY *Short Answer* What is the major intermolecular force in the following compound, given that the difference in boiling point between its two stereoisomers is less than 3%: CH3CH=CHCH2CH3

ANSWER: LONDON DISPERSION

TOSS-UP

39. ENERGY *Short Answer* Which quantity is a measure of the total mechanical energy of a system? It is used in the Schrodinger wave equation and is derived from Lagrangian mechanics.

ANSWER: HAMILTONIAN

BONUS

40. ENERGY *Multiple Choice* Which of the following quanitites is maximized in any physical process?

(W) The difference between kinetic and potential energies

(X) The sum of kinetic and potential energies

(Y) The change in momentum per unit time

(Z) The negative change in potential energy per unit time

ANSWER: W

TOSS-UP

41. PHYSICS *Short Answer* You are traveling towards the star Aldebaran, which is located 200 meters next to the star Rigel, with a constant velocity of 1000 meters per second in a straight line. Currently, at time 1, you see 30 degrees between Rigel and Aldebaran. Some time later, at time 2, you see 60 degrees between Rigel and Aldebaran. Using words or numbers, name all of the following four choices that is or are equal and nonzero:

(1) The total angular momentum at time 1 in the reference frame where you are stationary

(2) The total angular momentum at time 2 in the reference frame where you are stationary

(3) The total angular momentum at time 1 in the reference frame where Rigel is stationary

(4) The total angular momentum at time 2 in the reference frame where Rigel is stationary

ANSWER: ALL OF THEM

BONUS

42. PHYSICS *Multiple Choice* Particle A is spinning around particle B. Particle B's mass is small enough such that particle B rotates as well. Which of the following describes the velocity of particle A with respect to particle B?

(W) In phase

(X) Out of phase by 180 degrees

(Y) Leads by 90 degrees

(Z) Lags by 90 degrees

ANSWER: X

TOSS-UP