# SCIENCE
## District 1 • 2010

GENERAL DIRECTIONS:

- DO NOT OPEN EXAM UNTIL TOLD TO DO SO.
- Ninety minutes should be ample time to complete this contest, but since it is not a race, contestants may take up to two hours. If you are in the process of actually writing an answer when the signal to stop is given, you may finish writing that answer.
- Papers may not be turned in until 30 minutes have elapsed. If you finish the test in less than 30 minutes, remain at your seat and retain your paper until told to do otherwise. You may use this time to check your answers.
- All answers must be written on the answer sheet provided. Indicate your answers in the appropriate blanks provided on the answer sheet.
- You may place as many notations as you desire anywhere on the test paper except on the answer sheet, which is reserved for answers only.
- You may use additional scratch paper provided by the contest director.
- All questions have ONE and only ONE correct (BEST) answer. There is a penalty for all incorrect answers.
- If a question is omitted, no points are given or subtracted.
- On the back of this page is printed a copy of the periodic table of the elements. You may wish to refer to this table in answering the questions, and if needed, you may use the atomic weights and atomic numbers from the table. Other scientific relationships are listed also.
- Silent hand-held calculators that do not need external wall plugs may be used. Graphing calculators that do not have built-in or stored functionality that provides additional scientific information are allowed. Small hand-held computers are not permitted. Calculators that accept memory cards or memory sticks are not permitted. Each contestant may bring one spare calculator. All memory must be cleared.
- Answers within 5% of the exact answer will be considered correct.

SCORING:

All questions will receive 6 points if answered correctly; no points will be given or subtracted if unanswered; 2 points will be deducted for an incorrect answer.

**Biology Questions (1 – 20)**

1. Which of the following is NOT part of all cells?
   A) cell membrane
   B) cell wall
   C) ribosomes
   D) DNA
   E) RNA

2. Which of the following is true of plasma membranes?
   A) They have molecules on their surfaces that identify them.
   B) They are essentially impermeable.
   C) They are basically static, nonchanging structures.
   D) They are hydrophilic barriers between cells
   E) All of the above are true.

3. An individual with genotype AaBb is _____ for these genes.
   A) homozygous dominant
   B) heterozygous
   C) heterozygous dominant
   C) homozygous recessive
   D) heterozygous recessive

4. The sequence of processes involved in the breakdown of glucose is _____ .
   A) glycolysis, electron transport chain, Krebs cycle
   B) electron transport chain, glycolysis, Krebs cycle
   C) Krebs cycle, glycolysis, electron transport chain
   D) electron transport chain, Krebs cycle, glycolysis
   E) glycolysis, Krebs cycle, electron transport chain

5. Which of the following is true?
   A) When a person reaches maturity, cell division other than for repair stops.
   B) Cell division in an adult indicates cancer.
   C) Some specific cells throughout the body retain the ability to divide and replace themselves.
   D) Growth continues on throughout the life of an adult.
   E) All cells retain the ability to divide even after the organism reaches maturity.

6. In DNA, complementary base pairing occurs between which of the following?
   A) cytosine and uracil
   B) adenine and guanine
   C) adenine and uracil
   D) adenine and thymine
   E) All of the above

7. The cell walls of fungi contain _____ .
   A) cellulose
   B) lignin
   C) chitin
   D) pectin
   E) protein

8. Which of the following invertebrate groups is characterized by radial symmetry in adults?
   A) Arthropoda
   B) Cnidaria
   C) Platyhelminthes
   D) Chordata
   E) Nematoda

9. Which of the following is NOT true?
   A) All chordates have notochords.
   B) All chordates have pharyngeal pouches or perforations.
   C) All chordates have dorsal tubular nerve cords.
   D) All chordates are vertebrates.
   E) Chordates are found in all major types of environments.

10. Leaves arise _____ .
    A) as part of the periderm
    B) as part of secondary growth
    C) at nodes
    D) as a result of differentiation of cambium cells
    E) from the lateral, not the apical, meristem

11. Which of the following is NOT true?
    A) Flowers often exhibit coevolution with their pollinators.
    B) Seeds often exhibit coevolution with their disseminators.
    C) The pollen grain is a haploid microspore.
    D) Megaspores are part of the female gametophyte generation.
    E) Megaspores and microspores arise through mitosis.

12. The plant hormone that promotes dormancy in plants and seeds is _____ .
    A) abscisic acid
    B) auxin
    C) gibberellin
    D) ethylene
    E) florigen

13. Which of the following is a junction between two neurons?
    A) Schwann cell
    B) chemical synapse
    C) node of Ranvier
    D) sodium gate
    E All of the above

14. The pancreatic secretions governing glucose levels are precisely controlled by _____ .
    A) neural connections to the pancreas
    B) the blood-brain barrier
    C) cooperative interactions
    D) homeostatic feedback loops
    E) releasing factors

15. In rigor mortis, muscles lose their ability to _____ .
    A) contract
    B) form cross-bridges
    C) bend
    D) relax
    E) flex

16. Which vitamin functions in blood clotting?
    A) A
    B) $B_{12}$
    C) C
    D) E
    E) K

17. Phagocytes are derived from stem cells in the _____ .
    A) spleen
    B) thymus
    C) bone marrow
    D) blood
    E) liver

18. At the end of gastrulation, a fertilized egg has developed into _____ .
    A) a hollow ball of cells
    B) an embryo with germinal layers
    C) an embryo with a heart and blood vessels
    D) a solid ball of cells
    E) a single large cell

19. Speciation occurs _____ .
    A) after populations become reproductively isolated and diverge
    B) when mutations generate observable differences
    C) when transitional forms develop between different populations
    D) when natural selection pressures reach their maximum
    E) when humans intervene and establish new breeds

20. In general, a predator is _____ .
    A) smaller than its host
    B) larger than its host
    C) smaller than its prey
    D) larger than its prey
    E) the largest animal in a community

## Chemistry Questions (21 – 40)

21. Determine the oxidation state of P in $K_2HPO_4$ .
    A) –3
    B) +1
    C) +5
    D) +3
    E) +7

22. The number of valence electrons in the lowest energy state of a lead atom is _____ .
    A) 2
    B) 14
    C) 3
    D) 6
    E) 8

23. What is the energy of the photon at wavelength = 6580 A ?
    A) $3.0 \times 10^{-15}$ ergs
    B) $6.6 \times 10^{-27}$ ergs
    C) $8.0 \times 10^{-13}$ ergs
    D) $3.0 \times 10^{-12}$ ergs
    E) $8.7 \times 10^{-24}$ ergs

24. In an atom, the maximum number of electrons having the quantum numbers n = 6 and l = 2 is ____ .
    A) 5
    B) 8
    C) 72
    D) 10
    E) 6

25. The inner transition metals are elements with partially filled sets of _____ orbitals.
    A) s
    B) p
    C) d
    D) f
    E) g

26. Which of the following would be expected to have the lowest first ionization energy?
    A) O
    B) C
    C) Ne
    D) F
    E) Li

27. The chemical formula of an ionic substance made up of K and S would be
    A) $K_2S$
    B) $KS_2$
    C) $K_2S_3$
    D) $KS_3$
    E) KS

28. The hybrid orbitals of $H_2O$ would be described as _____ .
    A) sp
    B) $sp^2$
    C) $sp^3d^2$
    D) $sp^3d$
    E) $sp^3$

29. Solution A contains HCl and has $[ H_3O^+ ] = 10^{-5}$ M. Solution B contains acetic acid and has $[ H_3O+ ] = 10^{-5}$ M. Which solution is more acidic and which solution has a greater pH?
    A) Both solutions have identical acidities and pH.
    B) Solution B is more acidic and has a greater pH.
    C) Solution A is more acidic, but Solution B has a greater pH.
    D) Solution A is more acidic and has a greater pH.
    E) Solution B is more acidic, but Solution A has a greater pH.

30. Which is USUALLY larger, the heat of vaporization or the heat of fusion?
    A) The heat of vaporization.
    B) The heat of fusion.
    C) Can not be determined.
    D) They are equal.
    E) The answer for water is different than typical substances.

31. For a certain process at 127°C, $\Delta G = -16.20$ kJ/mol and $\Delta H = -17.0$ kJ/mol. What is the entropy change for this process at this temperature?
    A) –6.2 J/mol K
    B) –2.0 J/mol K
    C) +2.0 J/mol K
    D) +6.2 J/mol K
    E) –8.1 J/mol K

32. A and B react to form C. Given the following initial rates of formation of C in the table, what are the values of the orders of [ A ] and [ B ] ?

| $[ A ]_0$ | $[ B ]_0$ | $\Delta[ C ] / \Delta t$ |
|---|---|---|
| 0.1 M | 0.1 M | $4.0 \times 10^{-4}$ (M/s) |
| 0.2 M | 0.1 M | $1.6 \times 10^{-3}$ (M/s) |
| 0.1 M | 0.2 M | $4.0 \times 10^{-4}$ (M/s) |

| | Order of A | Order of B |
|---|---|---|
| A) | 2 | 2 |
| B) | 2 | 0 |
| C) | 1 | 2 |
| D) | 1 | 1 |
| E) | 2 | 1 |

33. Mixing 50. ml of 0.010 M barium hydroxide(aq) and 150. mL of 0.010 M nitric acid(aq) will result in a solution with a pH of _____ .

A) 13.70
B) 2.60
C) 0.30
D) 11.70
E) 2.30

34. How many grams of Cu metal will be plated out of a $Cu(NO_3)_2$ solution by passing a current of 3.00 amperes for 11 minutes?

A) 0.072
B) 0.65
C) 1.3
D) 1.7
E) 2.6

35. For the reaction
? Al + ? $CuSO_4$ ➔ ? $Al_2(SO_4)_3$ + ? Cu,
a maximum of ____ grams of $Al_2(SO_4)_3$ could be formed from 6.859 grams of Al and 5.914 grams of $CuSO_4$.

A) 3.0
B) 1.7
C) 4.2
D) 7.6
E) 9.3

36. What volume of 0.215 molar sodium hydroxide solution would be required to neutralize completely 41.8 mL of a 0.110 molar sulfuric acid solution?

A) 94.4 mL
B) 42.8 mL
C) 77.2 mL
D) 60.1 mL
E) 17.2 mL

37. A 7.78 g gas sample occupies 1.25 L at STP. What is the molecular weight of the sample?

A) 139 g/mol
B) 251 g/mol
C) 307 g/mol
D) 195 g/mol
E) 56 g/mol

38. We have an aqueous solution that contains 37.9 percent (by mass) of a hypothetical solute Z. The formula weight of the solute Z is 222.5 g/mol. The density of the solution is observed to be 1.302 g/mL. What is [ Z ] in this solution?

A) 3.1 mol/L
B) 1.5 mol/L
C) 4.0 mol/L
D) 4.9 mol/L
E) 2.2 mol/L

39. Given:
$H_3O^+(aq) + NO_2^-(aq) \rightarrow HNO_2(aq) + H_2O$ ,
$K_c = 3.78 \times 10^3$ at T = 298 K .
Calculate $K_c$ for the reaction :
$NO_2^-(aq) + H_2O(l) \rightarrow HNO_2(aq) + OH^-(aq)$.

A) $0.30 \times 10^{-11}$
B) $0.83 \times 10^{-9}$
C) $0.57 \times 10^{-9}$
D) $0.15 \times 10^{-10}$
E) $0.38 \times 10^{-10}$

40. What is the pOH of a .687 M solution of NaOH at 298 K?

A) 0.08
B) 0.12
C) 0.16
D) 0.24
E) 0.32

**Physics Questions (41 – 60)**

41. According to Feynman which science is most affected by physics?

A) astronomy
B) biology
C) chemistry
D) geology
E) mathematics

42. According to Feynman which one of the following sciences helped physics in the discovery of conservation of energy?

A) astronomy
B) biology
C) chemistry
D) geology
E) mathematics

43. This Texas physicist is interested in cataclysmic variable research, modeling non-linear phenomena and physics education. He/she has received several teaching awards including the Piper Professor Award. He/she received his/her Ph.D. from Purdue University.
    A) Tikhon Bykov
    B) Margaret Cheung
    C) Jodi Cooley
    D) Richard Olenick
    E) Christopher Pope

44. What is a cataclysmic variable?
    A) A variable that becomes infinite as you approach a fixed value.
    B) A parameter used in the description of a collision.
    C) A star whose intensity irregularly changes from bright to dim.
    D) A variable that describes a supercritical fission reaction.
    E) A variable used in the description of the big bang.

45. Non-linear systems often give rise to chaotic phenomena in which the behavior of the system is highly sensitive to initial conditions. This sensitivity is popularly referred to as what?
    A) the Poincaré map
    B) the butterfly effect
    C) the Wolfram effect
    D) a Lyapunov condition
    E) a strong attractor

46. A dog's hair has been cut and is now getting 1.04 mm longer each day. With winter coming on, this rate of hair growth is steadily increasing, by 0.132 mm/day every week. By how much will the dog's hair grow during 5 weeks?
    A) 45.6 mm
    B) 48.0 mm
    C) 52.6 mm
    D) 60.2 mm
    E) 602 mm

47. A firefighter, a distance d from a burning building, directs a stream of water from a fire hose at an angle $\theta$ above the horizontal. If the initial speed of the stream is $v_0$, at what height h above the nozzle does the water strike the building? You may neglect air resistance.
    A) $d \tan\theta$
    B) $d - (gd^2)/(2v_0^2)$
    C) $d + (gd^2)/(2v_0^2)$
    D) $d \tan\theta - (gd^2)/(2v_0^2 \cos^2\theta)$
    E) $d \tan\theta + (gd^2)/(2v_0^2 \cos^2\theta)$

48. A helicopter is lifting two crates simultaneously. The first crate has a mass of 200 kg and is attached to the helicopter by a cable. The second crate has a mass of 100 kg and is attached to the first crate by a cable and hangs directly below the first crate. As the helicopter accelerates upward at a rate of 1.00 $m/s^2$, what is the magnitude of the tension in each of the two cables? You may neglect air resistance and the weight of the cables themselves.
    A) $T_{first} = 2.00 \times 10^2$ N & $T_{second} = 1.00 \times 10^2$ N
    B) $T_{first} = 3.00 \times 10^2$ N & $T_{second} = 1.00 \times 10^2$ N
    C) $T_{first} = 2.64 \times 10^3$ N & $T_{second} = 8.80 \times 10^2$ N
    D) $T_{first} = 2.94 \times 10^3$ N & $T_{second} = 9.80 \times 10^3$ N
    E) $T_{first} = 3.24 \times 10^3$ N & $T_{second} = 1.08 \times 10^3$ N

49. A skier of mass 70.0 kg is pulled up a frictionless incline by a motor-driven cable. How much work is required to pull the skier a distance of 60.0 m up a 30.0° incline at a constant speed of 2.00 m/s? You may neglect air resistance.
    A) $3.43 \times 10^2$ J
    B) $6.86 \times 10^2$ J
    C) $1.03 \times 10^4$ J
    D) $2.06 \times 10^4$ J
    E) $4.12 \times 10^4$ J

50. A helium filled balloon is tied to a 4.0 m long, 0.10 kg uniform string. The balloon is spherical with a radius of 0.40 m. When released, it lifts a length h of string and then remains in equilibrium. Determine the value of h. Given the following: the mass of the empty balloon is 0.25 kg, the density of helium is 0.179 kg m$^{-3}$ and the density of air is 1.29 kg/m$^{3}$.
A) 0.22 m
B) 1.1 m
C) 1.9 m
D) 2.2 m
E) 3.8 m

51. The amplitude of a system moving in simple harmonic motion is doubled. By what factor has the total energy of the system changed?
A) 1/4
B) 1/2
C) 1
D) 2
E) 4

52. Calculate the length of a pipe that has a fundamental frequency of 240 Hz at 20.0°C if the pipe is closed at one end.
A) 0.175 m
B) 0.285 m
C) 0.357 m
D) 0.570 m
E) 0.714 m

53. According to the kinetic theory of a gas, what is the root-mean-square speed of an oxygen molecule at 20.0°C?
A) 125 m/s
B) 239 m/s
C) 338 m/s
D) 478 m/s
E) 676 m/s

54. A steam engine operates between 500°C and 270°C. What is the maximum possible efficiency of this steam engine?
A) 29.7%
B) 42.3%
C) 46.0%
D) 70.2%
E) 85.2%

55. A positively charged particle is free to move in a region with a nonzero electric field E. Which statement must be TRUE:
A) The particle is accelerating in the direction perpendicular to E.
B) The particle is accelerating in the direction of E.
C) The force on the particle is opposite the direction of E.
D) The particle is moving in the direction of E.
E) The particle is moving opposite the direction of E.

56. Two point charges, $q_1 = +2.0$ pC and $q_2 = -2.0$ pC, are separated by 4.0 μm. What is the magnitude of the dipole moment of this pair of charges?
A) $8.0 \times 10^{-21}$ C·m
B) $8.0 \times 10^{-18}$ C·m
C) $1.6 \times 10^{-17}$ C·m
D) $8.0 \times 10^{-15}$ C·m
E) $1.6 \times 10^{-14}$ C·m

57. A solenoid that is 2.7 m long has a radius of 0.85 cm and is comprised of 600 turns. It carries a current of 2.5 A. What is the magnitude of the magnetic field B at the center of the solenoid far from either end?
A) $5.9 \times 10^{-5}$ T
B) $1.9 \times 10^{-4}$ T
C) $7.0 \times 10^{-4}$ T
D) $1.9 \times 10^{-3}$ T
E) $2.2 \times 10^{-1}$ T

58. For light that is incident upon a certain substance in air, the angle at which the light reflected from the surface is totally polarized (a.k.a. Brewster's angle) is 60°. What is the angle of refraction of the light ray incident upon the surface at this angle?
A) 30°
B) 45°
C) 60°
D) 75°
E) 90°

59. An object is placed in front of a convex mirror, and the size of the image is one-fourth that of the object. What is the ratio of the object distance to the focal length of the mirror?

A) + 3/4
B) + 1
C) + 5/4
D) – 3
E) + 5

60. What are the colors of the dots that make up a standard CRT (cathode ray tube) color television screen?

A) red, green & blue
B) magenta, yellow & cyan
C) red, yellow & blue
D) magenta, green & cyan
E) red, green & cyan

# UIL HIGH SCHOOL SCIENCE CONTEST
# ANSWER KEY

## DISTRICT 1 • 2010

| | | | | | |
|---|---|---|---|---|---|
| 1. | B | 21. | C | 41. | C |
| 2. | A | 22. | A | 42. | B |
| 3. | C | 23. | D | 43. | D |
| 4. | E | 24. | D | 44. | C |
| 5. | C | 25. | D | 45. | B |
| 6. | D | 26. | E | 46. | B |
| 7. | C | 27. | A | 47. | D |
| 8. | B | 28. | E | 48. | E |
| 9. | D | 29. | A | 49. | D |
| 10. | C | 30. | A | 50. | C |
| 11. | E | 31. | B | 51. | E |
| 12. | A | 32. | B | 52. | C |
| 13. | B | 33. | B | 53. | D |
| 14. | D | 34. | B | 54. | A |
| 15. | D | 35. | C | 55. | B |
| 16. | E | 36. | B | 56. | B |
| 17. | C | 37. | A | 57. | C |
| 18. | B | 38. | E | 58. | A |
| 19. | A | 39. | E | 59. | D |
| 20. | D | 40. | C | 60. | A |

41. (C) "The science which is perhaps the most deeply affected by physics is chemistry." Keep in mind that according to Feynman "Mathematics is not a science from our point of view, the sense that it is not a *natural* science. The test of its validity is not experiment."
42. (B) "There was an interesting early relationship between physics and biology in which biology helped physics in the discovery of the *conservation of energy*, which was first demonstrated by Mayer in connection with the amount of heat taken in and given out by a living creature."
43. (D) Dr. Richard Olenick, Professor and Chair of the Department of Physics at the University of Dallas, is interested in cataclysmic variable research, modeling non-linear phenomena and physics education.
44. (C) A cataclysmic variable is a star that irregularly increases in brightness by a large factor, then drops back down to a quiescent state.
45. (B) Sensitivity to initial conditions is popularly known as the "butterfly effect," so called because of the title of a paper given by Edward Lorenz in 1972 to the American Association for the Advancement of Science in Washington, D.C. entitled *Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?*
46. (B) Watch your units convert: 0.132 mm/day/week × [(1 week)/(7 day)] = 0.019286 mm/day$^2$, then just use the kinematic equations: length = $1.04[5(7)] + ½\,(0.019286)[5(7)]^2 = 48.0$ mm
47. (D) In the horizontal direction: $t = d/(v_0 \cos\theta)$ and in the vertical direction: $h = 0 + v_0 \sin\theta\, t + ½\,(-g)\, t^2$ then plug in for t and simplify to get $h = d\tan\theta - (gd^2)/(2v_0^2 \cos^2\theta)$
48. (E) By Newton's second law for the 2nd crate: $T_{second} - m_2 g = m_2 a \Rightarrow T_{second} = m_2(g+a) = 1080$ N & similarly for the 1st crate: $T_{first} - T_{second} - m_1 g = m_1 a \Rightarrow T_{first} = (m_1 + m_2)(g+a) = 3240$ N.
49. (D) Since the speed is constant and there is no friction the cable only needs to balance the gravitational component that points down the slope. So, $W = Fd\cos\theta = (mg\sin\theta)\, d\cos 0° = 2.06\times10^4$ J
50. (C) Since it is in equilibrium then the bouyant force must be equal to the weight of the helium gas in the balloon, the balloon material and the length of string that was lifted. Thus, $\rho_{air} g V_{balloon} = \rho_{He} g V_{balloon} + m_{balloon} g + h(m_{string}/L_{string})g \Rightarrow h = [(\rho_{air} - \rho_{He})(4/3)\pi r^3 - m_{balloon}]/[(m_{string}/L_{string})]$ $= [(1.29 - 0.179)(4/3)\pi(0.4)^3 - 0.25]/[(0.10/4.0)] = 1.9$ m
51. (E) Since $E_{SHO} = ½\, kA^2$, thus if you double the amplitude then you will quadruple the total energy.
52. (C) For a pipe closed at one end the fundamental frequency is: $f = v/(4L) \Rightarrow L = v/(4f) = 343/[4(240)] = 0.357$ m
53. (D) $KE_{avg} = ½\, m(v^2)_{avg} = 3/2\, k_B T \Rightarrow v_{rms} = [(v^2)_{avg}]^{½} = [3k_B T/m]^{½} =$ $[3(1.38\times10^{-23})(20.0+273.15)/(2(16.0)(1.66\times10^{-27})]^{½} = 478$ m/s
54. (A) The Carnot (or ideal) efficiency of a heat engine is $e_{ideal} = (T_H - T_L)/T_H$, where T is in Kelvin. $T_H = 500+273.15 = 773.15$ K & $T_L = 270+273.15 = 543.15$ K $\Rightarrow (773.15 - 543.15)/773.15 = 0.297$ or 29.7%
55. (B) Since the charge is positive, then the force and acceleration are in the direction of E. Which way the charge moves depends upon the initial motion.
56. (B) The dipole moment is given by: $p = qd = (2\times10^{-12})(4\times10^{-6}) = 8\times10^{-18}$ C·m
57. (C) For a solenoid: $B = \mu_0 nI = \mu_0(N/L)I = 4\pi\times10^{-7}(600/2.7)2.5 = 7.0\times10^{-4}$ T
58. (A) The reflected light is totally polarized when the reflected and refracted (transmitted) light rays are perpendicular to one another. Thus, the angle of refraction is 30°.
59. (D) With $m = h_i/h_o = 1/4 = -d_i/d_o$ (note: for a convex mirror the magnification can only be positive). Thus, $d_i = -¼\, d_o \Rightarrow 1/f = 1/d_o + 1/d_i = 1/d_o - 4/d_o \Rightarrow d_o/f = -3$
60. (A) The colors that make up a standard color television screen are the additive primary colors: red, green & blue.