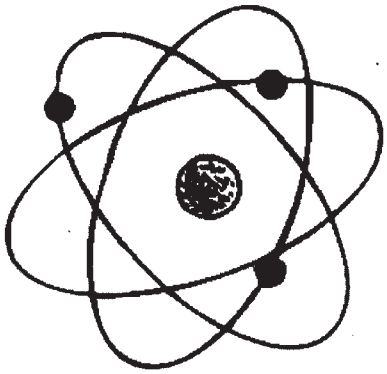
SCIENCE

Regional • 2009



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.

Periodic Table of the Elements

1A																8A
1 H 1.008	2A											3A	4A	5A	6A	7A	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 23.00	12 Mg 24.31	3B	4B	5B	6B	7B	8B			1B	2B	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Ha (262)	106 Unh (263)	107 Uns (262)		109 Une (267)									

Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

See Reverse Page for Other Useful Information

OTHER USEFUL INFORMATION

Avogadro's Number, $N_A = 6.022 \times 10^{23}$ mol^{-1}

Absolute zero = 0 K = −273.15 °C

Atmospheric pressure, 1 atm = 1.013×10^5 N/m^2 = 101.3 kPa = 760.0 Torr = 760.0 mmHg

Standard temperature and pressure (STP) is 0 °C and 1 atm

Gram molecular volume at STP = 22.4 L

Mechanical equivalence of heat, 1 kcal = 1 Cal = 1,000 cal = 4,186 J

Gas constant, R = 1.987 cal/mol•K = 0.08206 atm•L/mol•K = 8.314 J/mol•K

Dulong and Petit's constant = 6.0 amu•cal/gram•K

Faraday's constant, 1 F = 96,485 C/mol

Acceleration of gravity at Earth's surface, g = 9.80 m/s^2

Gravitational constant, $G = 6.67 \times 10^{-11}$ N•m^2/kg^2

Horsepower, 1 hp = 746 W = 550 ft•lbs/s

Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K

Stefan-Boltmann constant, $\sigma = 5.67 \times 10^{-8}$ W/m^2•K^4

Elementary charge, $e = 1.602 \times 10^{-19}$ C

Coulomb's law constant, $k = 1/4\pi\varepsilon_o = 8.988 \times 10^9$ N•m^2/C^2

Permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ C^2/N•m^2

Permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ T•m/A

Electron volt, 1 eV = 1.602×10^{-19} J

Vacuum speed of light, $c = 3.00 \times 10^8$ m/s

Planck's constant, $h = 6.626 \times 10^{-34}$ J·s = 4.136×10^{-15} eV•s

Planck's reduced constant, $\hbar = {}^{h}/_{2\pi} = 1.054 \times 10^{-34}$ J·s = 6.582×10^{-16} eV•s

Atomic mass unit, 1 amu = 1 u = 1.66×10^{-27} kg = 931.5 MeV/c^2

Electron rest mass, $m_e = 9.11 \times 10^{-31}$ kg = 0.000549 u = 0.511 MeV/c^2

Proton Mass = 1.6726×10^{-27} kg = 1.00728 u = 938.3 MeV/c^2

Neutron Mass = 1.6749×10^{-27} kg = 1.008665 u = 939.6 MeV/c^2

Some standard values for water:

- Mass density, $\rho = 1.00$ g/cm^3 = 1,000 kg/m^3
- Heat capacity or Specific heat, c = 1.00 cal/gram•C° = 1.00 kcal/kg•C° = 4186 J/ kg•C°
- Latent heats, $L_F = 79.7$ kcal/kg = 3.33×10^5 J/kg & $L_V = 539$ kcal/kg = 22.6×10^5 J/kg
- Index of refraction, n = 1.33

Biology Questions (1 – 20)

1. Which of the following are NOT true of both cilia and flagella?
   A) they are cellular organelles
   B) they are involved in movement
   C) they have a 9 + 2 arrangement of their microtubules
   D) they are composed mainly of proteins
   E) they have basal bodies

2. Which of the following terms includes all of the others?
   A) sucrose
   B) cellulose
   C) carbohydrate
   D) glycogen
   E) glucose

3. Chromatids attached at their centromeres represent
   A) paternal and maternal chromosomes.
   B) the products of DNA replication.
   C) the end of mitotic activity.
   D) pairs of chromosomes.
   E) None of the above

4. Which of the following releases the most energy in the form of ATP?
   A) aerobic respiration
   B) anaerobic respiration
   C) alcoholic fermentation
   D) lactate fermentation
   E) All of the above release about the same amount of ATP.

5. Color-blindness is an X-linked trait in humans. If a color-blind woman marries a man with normal vision, which of the following would be expected to occur among their children?
   A) All of their daughters would be color-blind, while their sons would have normal color vision.
   B) All of their sons would be color-blind, while all of their daughters would have normal vision but be carriers.
   C) All of their sons and all of their daughters would have normal color vision, but their daughters would be carriers.
   D) All of their children would be color-blind.
   E) All of their children would have normal vision and not be carriers.

6. Which of the following is NOT true of *Escherichia coli*?
   A) It synthesizes vitamins that are essential to its mammalian host.
   B) It can act as a pathogen.
   C) It can prevent colonization of the gut by pathogens.
   D) It is capable of photosynthesis.
   E) It reproduces by binary fission.

7. The primary ecological role of fungi is to
   A) "fix" nitrogen from the air for use by plants.
   B) capture sunlight energy in carbohydrates.
   C) suppress population explosions by parasitizing overproductive animals.
   D) recycle elements in organic matter.
   E) form the base of numerous food chains.

8. Which of the following is NOT true about gymnosperms and angiosperms?
   A) Both are vascular plants.
   B) Both produce seeds.
   C) Gymnosperms are wind-pollinated while many angiosperms are insect-pollinated.
   D) Gymnosperms lack endosperm, while angiosperms have it.
   E) Gymnosperms have swimming sperm, while angiosperms do not.

9. Which of the following is NOT true?
   A) Some perennial plants may have only primary growth.
   B) Cork cambium and vascular cambium form lateral meristems.
   C) Nonwoody plants are herbaceous.
   D) Phloem is formed on the inside of vascular cambium, whereas xylem is formed on the outside.
   E) Sapwood surrounds heartwood.

10. Which of the following elements is a component of chlorophyll and activates enzymes used in photosynthesis, respiration, and protein synthesis?
   A) nitrogen
   B) potassium
   C) sulfur
   D) phosphorus
   E) magnesium

11. Which plant hormone is responsible for phototropism?
   A) indoleacetic acid (IAA)
   B) gibberellin
   C) abscisic acid
   D) ethylene
   E) cytokinin

12. Which of the following is NOT a type of connective tissue?
   A) bone
   B) skeletal muscle
   C) cartilage
   D) collagen
   E) blood

13. Which vitamin is involved in forming blood clots?
   A) A
   B) C
   C) D
   D) E
   E) K

14. An artificial pacemaker supplements the actions of
   A) sympathetic nerves.
   B) the atrioventricular node.
   C) the medulla oblongata.
   D) the sinoatrial node.
   E) the heart muscle itself.

15. Which of the following is NOT true about the peripheral nervous system?
   A) Spinal nerves lead to and from the spinal cord.
   B) There are 31 pairs of spinal nerves.
   C) Cranial nerves lead from the brain directly to the spinal cord.
   D) Some nerves carry only sensory information.
   E) Some nerves are both sensory and motor.

16. The hormone that remains at high levels when the body is suffering from inflammation and stress is
   A) cortisol.
   B) growth hormone.
   C) thyroxine.
   D) adrenaline.
   E) prolactin.

17. The process of filtration in the glomerulus of the kidney is driven by
   A) active transport.
   B) hydrostatic pressure.
   C) osmosis.
   D) diffusion.
   E) sodium-potassium pumps.

18. Which of the following sets serves as an example of convergence?
   A) penguins and porpoises
   B) panthers and tigers
   C) apes and monkeys
   D) sharks, skates, and rays
   E) mice, rats, and gerbils

19. Which of the following is NOT true about ecosystems?
    A) The rate of energy flow depends on the ratio of producers to consumers.
    B) The requirements of an ecosystem change with age.
    C) The larger the ecosystem, the more flexible it is.
    D) The smaller the ecosystem, the more stable it is.
    E) The more efficient the producers are, the more energy must be put in and the more energy is available for the next trophic level.

20. Which of the following combinations of organisms could be expected to survive in isolation from other forms of life available?
    A) producers and decomposers
    B) producers and carnivores
    C) carnivores and decomposers
    D) herbivores, carnivores, and decomposers
    E) herbivores and decomposers

Chemistry Questions (21 – 40)

21. Which reactants will generate a precipitated product?
    A) $AgNO_3 + CH_3COONa$
    B) $FeCl_2 + Na_2SO_4$
    C) $(NH_4)_2SO_4 + KOH$
    D) $BaCl_2 + Na_2SO_4$
    E) $NaH + H_2O$

22. The principal concept used to separate positive ions in a mass spectrometer is _____ .
    A) bombardment with alpha particles
    B) deflection in a gravitational field
    C) deflection in a magnetic field
    D None of the preceding
    E) neutron capture

23. What is the wavelength of an electron traveling one tenth the speed of light?
    A) 7.3×10^{-7} m
    B) 1.6×10^{-19} m
    C) 3.0×10^{8} m
    D) 2.4×10^{-15} m
    E) 2.4×10^{-11} m

24. The sets of possible values of m_l for n=3 are _____ .
    A) 0, 1, 2
    B) –2, –1, 0, +1, +2
    C) 0; -1, 0, +1; -2, -1, 0, +1, +2
    D) –1, 0, +1; –2, –1, 0, +1, +2
    E) –3, –2, –1, 0, +1, +2, +3

25. What is the oxidation number of oxygen in potassium superoxide ?
    A) –1
    B) –2
    C) +1
    D) 0
    E) –1/2

26. How many oxygen atoms are present in a formula unit of calcium acetate?
    A) 4
    B) 5
    C) 2
    D) 3
    E) 1

27. The geometrical arrangement of 5 pairs of electrons around a central atom is a(an) _____ .
    A) square pyramid
    B) trigonal bipyramid
    C) none of the other choices are correct
    D) tetrahedron
    E) octahedron

28. How many milliliters of 0.250 M HCl are needed to neutralize 5.00 g of Na_2CO_3 ?
    $2\ HCl + Na_2CO_3 \rightarrow 2\ NaCl + CO_2 + H_2O$
    A) 377 mL
    B) 189 mL
    C) Impossible to calculate with the information available.
    D) 94.3 mL
    E) 754 mL

29. Consider the reaction
$CuSO_4(aq) + Zn(s) \rightarrow Cu(s) + ZnSO_4(aq)$
If you want to produce 0.5 moles of Zn^{2+}, how many moles of $CuSO_4$ will be consumed?
A) 2.0 mole
B) 0.5 mole
C) 1.0 mole
D) 0.25 mole
E) 0.75 mole

30. If liquid metallic zinc (Zn) has a vapor pressure of 40 torr at 673°C and 100 torr at 736°C, what is the normal boiling point of zinc ?
A) 1250 K
B) 1450 K
C) 1180 K
D) 1080 K
E) 906 K

31. Solution A contains 1 mole of NaBr dissolved in 1000 grams of water and solution B contains 1 mole of sugar dissolved in 1000 grams of water. Which of the following is false?
A) The vapor pressure of solution B is about 55.5/56.5 times that of pure water.
B) The boiling point of solution A is higher than that of solution B.
C) The freezing point of solution A is lower than that of solution B.
D) The vapor pressure of solution A is higher than that of solution B.
E) The osmotic pressure of solution A is higher than that of solution B.

32. For the reaction $A(aq) + B(aq) \rightarrow C(aq)$
$\Delta G° = -245$ kJ/mole and $\Delta H° = -284$ kJ/mole
Which of the following statements is TRUE?
A) If 1 mole of A is mixed with 1 mole of B, there will be no A remaining when equilibrium is reached.
B) The reaction is spontaneous in the direction as written.
C) When the reaction is run under adiabatic conditions, the final temperature will be lower than the initial temperature of the solution.
D) If a catalyst is present, all answers to this question are true.
E) The reaction is fast because of the large negative $\Delta G°$.

33. Consider the two step reaction mechanism
$A + M \rightarrow A^* + M \quad k_1$
$A^* + M \rightarrow A + M \quad k_{-1}$
$A^* \rightarrow B + C \quad k_2$
If $k_2 >> k_1 >> k_{-1}$, the observed rate law will be _____ .
A) cannot be determined from the information given
B) $d[C]/dt = (k_1 k_2 / k_{-1})[A]$
C) $d[C]/dt = -k_1 [A]$
D) $d[C]/dt = k_1 [A][M]$
E) $d[C]/dt = -k_2 [A^*]$

34. What is the form of the equilibrium constant for the reaction $2\ HgO(s) \rightarrow 2\ Hg(l) + O_2(g)$?
A) $K_c = [Hg]^2 [O_2]$
B) $K_c = [O_2]$
C) none of the other answers is correct
D) $K_c = [O_2]/[HgO]^2$
E) $K_c = [Hg]^2 [O_2]] / [HgO]^2$

35. 0.50 moles of HCN are added to a liter of water. What is the pH if K_a for HCN = 4.0×10^{-10} ?
A) 5.35
B) 4.85
C) 9.40
D) 4.35
E) 4.69

36. What quantity of 0.100 M NaOH would be required to titrate 300 ml of a 0.0200 M solution of H_2SO_3 to the equivalence point corresponding to the formation of HSO_3^- ?
For H_2SO_3 , $K_{a1} = 1.2 \times 10^{-2}$, $K_{a2} = 6.2 \times 10^{-8}$
A) 60 ml.
B) 1500 ml.
C) 120 ml.
D) 30 ml.
E) 240 ml.

37. What is the concentration of Pb^{2+} and F^- in a saturated solution of PbF_2 ?
$K_{sp} = 3.7 \times 10^{-8}$

	$[Pb^{2+}]$	$[F^-]$
A)	2.1×10^{-3}	4.2×10^{-3}
B)	1.9×10^{-4}	3.8×10^{-4}
C)	2.1×10^{-3}	2.1×10^{-3}
D)	3.3×10^{-3}	6.6×10^{-3}
E)	9.6×10^{-5}	1.9×10^{-4}

38. The electrolysis of an aqueous sodium chloride solution using inert electrodes produces a gas at one electrode. At the other electrode, a different gas is produced and the solution becomes basic around that electrode. Which of the following is the equation for the anode half-reaction in this electrolytic cell?

A) none the the other answers listed is correct
B) $H_2 + 2\ OH^- \rightarrow 2\ H_2O + 2\ e^-$
C) $Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$
D) $2\ Cl^- \rightarrow Cl_2 + 2\ e^-$
E) $2\ H_2O + 2\ e^- \rightarrow H_2 + 2\ OH^-$

39. You mix 199.4 grams of oxygen gas with 189.1 grams of argon gas. What will be the final volume (in liters) at STP of the gas mixture?

A) 172 L
B) 442 L
C) 246 L
D) 541 L
E) 98 L

40. A solution is prepared by adding 2.0 mole of acetic acid and 1.0 mole of sodium acetate to enough water to make 1.0 L of solution. Finally, that solution was diluted to a final volume of 5.0 L. What is the pH of the final solution?

For acetic acid $K_a = 1.8 \times 10^{-5}$.

A) 2.6
B) 4.0
C) 4.4
D) 5.0
E) 7.5

Physics Questions (41 – 60)

41. This UT physicist has served as Acting Director of the Center for Statistical Mechanics and Complex Systems since 1974. From 1971 to 1973 he/she was a Fulbright-Hays Research Scholar at Free University of Brussels and has authored several books. His/her research is on quantum transport theory, the transition to chaos in classical and quantum mechanical conservative systems and stochastic chaos theory.

A) Jacques Distler
B) Alan MacDonald
C) Michael Marder
D) Linda Reichl
E) Gennady Shvets

42. Who is generally recognized as the "father" of statistical thermodynamics due to his derivation of the relationship between entropy S and thermodynamic probability W often written as $S = k \ln W$, where k is a constant named in his honor?

A) Daniel Bernoulli
B) Ludwig Boltzmann
C) S. N. Bose
D) Rudolf Clausius
E) J. Willard Gibbs

43. A basic assumption in statistical mechanics (or statistical thermodynamics) is that each possible microstate is equally likely. Therefore the number of possible microstates corresponding to a particular macrostate out of the total number of possible microstates gives the probability of the occurrence of that macrostate. If you flip a fair coin four times in a row and record the outcomes of each flip (the microstate), then what is the probability that you will get exactly two heads and two tails (the macrostate)?

A) 6.0%
B) 16%
C) 25%
D) 38%
E) 50%

44. A 637 N crate is to be moved up a 35.0° incline. The coefficient of kinetic friction between the crate and the incline is 0.300. If the force is applied parallel to the surface of the incline and the crate moves at a constant speed, then what is the required magnitude of the force?

A) 208 N
B) 522 N
C) 556 N
D) 637 N
E) 5110 N

45. A projectile is launched at an angle of 53° above the horizontal. If it was launched 12 m above a long flat firing range and lands 50 m from the launch point (the horizontal range), then with what speed was it launched? You may neglect air resistance for this problem.

A) 21 m/s
B) 23 m/s
C) 32 m/s
D) 44 m/s
E) 53 m/s

46. An airplane is flying at a constant speed v in a horizontal circle of radius r. If the lift force on the wings (due to the air) is perpendicular to the wings, then at what angle to the vertical, θ, must the wings be banked? You may neglect air resistance for this problem.

A) $\theta = \tan^{-1}\left(\frac{v^2}{gr}\right)$
B) $\theta = \tan^{-1}\left(\frac{gr}{v^2}\right)$
C) $\theta = \frac{1}{2}\sin^{-1}\left(\frac{v^2}{gr}\right)$
D) $\theta = \frac{1}{2}\sin^{-1}\left(\frac{gr}{v^2}\right)$
E) $\theta = 45°$

47. A spring gun with a spring constant of 28 N/m horizontally fires a 56 g ball from a height of 1.4 m above the ground. The spring is initially compressed from its equilibrium length by 18 cm when the ball is in the loaded position. When fired the ball leaves the gun and loses contact with the spring while the spring is still compressed by 12 cm. What is the speed of the ball just before it hits the ground 1.4 m below the gun? You may neglect the mass of the spring, rotation of the ball, air resistance and any friction between the ball and the barrel while it is being fired.

A) 3.0 m/s
B) 5.2 m/s
C) 6.0 m/s
D) 6.6 m/s
E) 600 m/s

48. A chain pulls tangentially on a 40.6 kg uniform cylindrical gear with a net tension of 72.5 N. The chain is attached along the outside radius of the gear at 0.650 m from the axis of rotation. If it takes 1.70 s to reach a rotational speed of 1.35 rev/s after starting from rest, then what is the magnitude of the frictional torque opposing the motion of the gear? You may assume that the gear rotates about its center of mass and that the only torques are from friction and the chain.

A) 4.33 m•N
B) 38.5 m•N
C) 42.8 m•N
D) 47.1 m•N
E) 85.6 m•N

49. A garden hose with an inner radius of 1.0 cm has a nozzle attached that has an opening with a 0.20 cm radius. If the water in the hose flows at 2.0 m/s and the nozzle is held horizontally, then what is the speed of the water as it exits the nozzle? You may treat the water as an incompressible fluid and neglect viscous effects for this problem.

A) 0.080 m/s
B) 0.28 m/s
C) 7.1 m/s
D) 10 m/s
E) 50 m/s

50. For an isotropic sound wave without attenuation. The intensity of the sound wave that travels directly from the source is:
    A) directly proportional to the distance from the source.
    B) inversely proportional to the distance from the source.
    C) directly proportional to the square of the distance from the source.
    D) inversely proportional to the square of the distance from the source.
    E) none of the above since it is proportional to the cube of the distance from the source.

51. If the furnace turns on and raises the temperature inside a house from 16.0°C to 20.0°C, then what fraction of the air molecules in the house are forced out of the house? You may treat the air as an ideal gas and consider that the volume and pressure of the house (which is not 100% airtight) are constant.
    A) 0.0136
    B) 0.136
    C) 0.200
    D) 0.250
    E) 0.360

52. Given the following data: when 31.15 kJ of heat is added to 0.500 kg of a solid at 21°C it becomes all liquid at its melting point of 327°C. If the specific heat of the solid is 129 J/(kg•C°), then what is the latent heat of fusion of the substance? You may assume that no heat is transferred to or from the environment in this process.
    A) 1.14×10^4 J/kg
    B) 2.28×10^4 J/kg
    C) 3.12×10^4 J/kg
    D) 3.95×10^4 J/kg
    E) 6.23×10^4 J/kg

53. A static electric charge placed on a conductor of arbitrary shape is:
    A) uniformly distributed throughout the volume.
    B) dispersed throughout the volume of the object and distributed according to the shape of the object.
    C) mostly on the outer surface, but is not uniformly distributed.
    D) entirely on the surface and uniformly distributed.
    E) entirely on the surface and is distributed according to the shape of the object.

54. A spherical conductor with a radius of 75.0 cm has a negative net charge. If the magnitude of the electric field just outside the surface of the conductor is 8.40×10^5 V/m, then what is the value of the electric potential just outside the surface of the conductor? You may assume that the potential goes to zero as you move infinitely far away from the sphere.
    A) -1.12×10^6 V
    B) -6.30×10^5 V
    C) 0.00 V
    D) $+6.30 \times 10^5$ V
    E) $+1.12 \times 10^6$ V

55. In a mass spectrometer a singly charged ion is accelerated through a potential difference of 7.0 kV before entering a uniform magnetic field of magnitude 1.2 T oriented perpendicular to the velocity of the ion. If the ion moves in a circle of radius 12.5 cm, then what is the mass of the ion?
    A) 2.57×10^{-18} kg
    B) 2.57×10^{-21} kg
    C) 2.57×10^{-22} kg
    D) 2.57×10^{-25} kg
    E) 2.57×10^{-26} kg

56. The speed of an electromagnetic wave in a vacuum depends upon which of the following?
    A) The amplitude of the electric field, but not the amplitude of the magnetic field.
    B) The amplitude of the magnetic field, but not the amplitude of the electric field.
    C) The amplitude of both the electric and magnetic fields.
    D) The frequency and wavelength of the wave.
    E) None of the above.

57. An insect is trapped in a piece of amber with index of refraction n = 1.546. When viewed in air from directly above, the insect appears to be 7.00 mm below the smooth surface of the amber. How far below the surface is the insect?
    A) 2.47 mm
    B) 3.82 mm
    C) 4.53 mm
    D) 7.00 mm
    E) 10.8 mm

58. For a particular grating, red light of wavelength 630 nm has a third-order maximum at the exact same location as the fourth-order maximum of blue light. What is the wavelength of the blue light?
    A) 470 nm
    B) 840 nm
    C) Need to know the angle θ from the center of the grating to the location on the screen.
    D) Need to know the distance between successive slits (or the grating parameter).
    E) Need to know the index of refraction.

59. Two spaceships A & B are moving directly toward each other with relative velocity 0.900c. If an astronaut on spaceship A measures the length of his ship to be 30.0 m, then according to an astronaut on spaceship B what is the length of spaceship A?
    A) 9.49 m
    B) 13.1 m
    C) 30.0 m
    D) 68.8 m
    E) 94.9 m

60. A 3.0×10^{19} Hz x-ray photon Compton scatters off of a free electron initially at rest. If the observed scattering angle for the photon is 90°, then what is the frequency of the scattered x-ray photon?
    A) 0.0 Hz
    B) 4.1×10^{11} Hz
    C) 2.4×10^{19} Hz
    D) 3.0×10^{19} Hz
    E) 4.1×10^{20} Hz

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY

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

41. (D) Linda Reichl has served as Acting Director of the Center for Statistical Mechanics and Complex Systems at UT one year after she was hired in 1973. She is the author of *A Modern Course in Statistical Physics*, which is a widely used textbook on statistical mechanics.

42. (B) Ludwig Boltzmann made major contributions in statistics mechanics and statistical thermodynamics including the relationship between the entropy of a system and the thermodynamic probability, which is engraved on his tombstone in the Zentralfriedhof in Vienna.

43. (D) The macrostate 2H & 2T is made up of the following possible microstates: HHTT, HTHT, THHT, HTTH, THTH & TTHH or 6 possibilities (or from combinatorial mathematics ${}_4C_2$, i.e., choose 2 H out of 4 possible H) out of $2^4 = 16$ possible options. Thus the probability is 6/16 = 0.375 or 38%.

44. (B) From the Newton's 2nd Law and the free-body diagram of the problem:
$F_A = F_G\sin35° + F_{frk} = 637\sin35° + 0.300(637)\cos35° = 522$ N

45. (A) From the horizontal position equation: $t = 50/(v_o\cos53°)$ & from the vertical position equation: $0 = 12 + (v_o\sin53°)\,t + ½(-9.80)\,t^2 \Rightarrow 0 = 12 + (v_o\sin53°)[50/(v_o\cos53°)] + ½(-9.80)[50/(v_o\cos53°)]^2$
$\Rightarrow v_o = \{[4.90(50)^2]/[(12+50\tan53°)(\cos53°)^2]\}^{½} = 20.77$ m/s

46. (A) In the vertical direction the y-component of the lift force balances out the weight of the plane:
$F\cos\theta - mg = 0 \Rightarrow F = mg/\cos\theta$ and in the horizontal direction:
$F\sin\theta = mv^2/r \Rightarrow (mg/\cos\theta)\sin\theta = mv^2/r \Rightarrow \theta = \tan^{-1}(v^2/gr)$

47. (C) From conservation of energy: $\Delta KE = -\Delta PE = -(\Delta PE_G + \Delta PE_S)$
$\Rightarrow ½(0.056)v^2 - 0 = -\{[0 - 0.056(9.80)1.4] + ½(28)[(0.12)^2 - (0.18)^2]\}$
$\Rightarrow v = \{2(9.80)1.4 + (28/0.056)\,[(0.18)^2 - (0.12)^2]\}^{½} = 6.04$ m/s

48. (A) From Newton's 2nd law for rotations: $\Sigma\tau = \tau_A - \tau_{fr} = I\alpha = (½\,mr^2)\,[(\omega - \omega_0)/t]$
$\Rightarrow \tau_{fr} = (0.650)72.5 - [½(40.6)(0.650)^2]\{[1.35(2\pi) - 0]/1.70\} = 4.33$ m•N

49. (E) From the continuity equation for incompressible fluids: $A_1v_1 = A_2v_2$
$\Rightarrow v_2 = \{[\pi(0.01)^2](2.0)\}/[\pi(0.002)^2] = 50$ m/s

50. (D) Since $I = P/A = P/(4\pi r^2)$ for an isotropic sound wave without attenuation, then $I \propto 1/r^2$.

51. (A) From the ideal gas law: $N_1T_1 = PV/k = N_2T_2 \Rightarrow N_2 = (T_1/T_2)N_1 \Rightarrow (N_2 - N_1)/N_1 = (T_1/T_2) - 1 =$
$[(273.15+16)/(273.15+20) - 1 = 0.0136$

52. (B) $Q = mc\Delta T + mL_f \Rightarrow L_f = (Q + mc\Delta T)/m = [31150 - (0.5)129(327 - 21)]/0.5 = 22800$ J/kg

53. (E) In electrostatics the electric field inside a conductor is zero. Thus the charge on a conductor can only reside on the surface of the conductor and is arranged so that the electric field in the interior of the conductor is zero. The charge is arranged according to the shape of the object with more charge located on the surface at regions with a small radius of curvature.

54. (B) For charge Q uniformly distributed on a spherical conductor Gauss' Law says that the electric field and thus the electric potential outside the sphere are the same as from a point charge Q located at the center of the sphere. Thus $V = -rE = -0.75(8.40 \times 10^5) = -6.30 \times 10^5$ V (– because Q is negative)

55. (D) By conservation of Energy: $\Delta KE = -\Delta PE = -q\,\Delta V \Rightarrow v = \{[2(-q)\Delta V]/m\}^{½}$ & by Newton's 2nd Law for circular motion: $F_B = qvB = mv^2/r \Rightarrow m = [(-q)B^2r^2]/(2\Delta V) =$
$[1.60\times10^{-19}(1.2)^2(0.125)^2]/[2(7\times10^3)] = 2.57 \times 10^{-25}$ kg

56. (E) The speed of an electromagnetic wave is a constant 3.00×10^8 m/s in a vacuum.

57. (E) $d_{apparent} = (n_{viewer}/n_{object})\,d_{actual} \Rightarrow d_{actual} = (1.546/1.000)\,7.00$ mm = 10.8 mm

58. (A) $m_r\lambda_r = d\sin\theta = m_b\lambda_b \Rightarrow \lambda_b = (3/4)\,630$ nm = 470 nm

59. (B) $L = L_o/\gamma = [1 - (0.900c)^2/c^2]^{½}\,30.0$ m = 13.1 m

60. (C) $\lambda' - \lambda = [h/(m_ec)](1-\cos\theta) \Rightarrow f' = \{[h/(m_ec^2)](1-\cos\theta) + 1/f\}^{-1} =$
$\{[6.63\times10^{-34}/(9.11\times10^{-31}[3.00\times10^8]^2)](1-0) + 1/3.0\times10^{19}\}^{-1} = 2.4 \times 10^{19}$ Hz