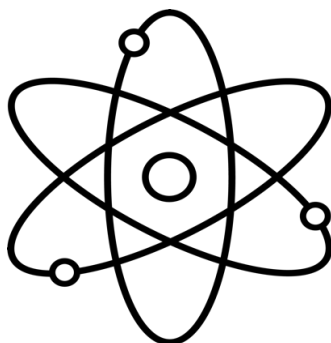




SCIENCE

Invitational A • 2015



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.

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.

UNIVERSITY INTERSCHOLASTIC LEAGUE

Making a World of Difference

Periodic Table of the Elements

1A 1																	8A 18
1 H 1.008	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	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 22.99	12 Mg 24.31	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	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 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)						

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	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 (262)

Some Standard Properties of Water

property	symbol	value
density of water	ρ_{water}	1.000 g cm ⁻³
density of ice	ρ_{ice}	0.9167 g cm ⁻³
specific heats		
ice	C_{ice}	2.09 J g ⁻¹ K ⁻¹
water	C_{water}	4.184 J g ⁻¹ K ⁻¹
steam	C_{steam}	2.03 J g ⁻¹ K ⁻¹
heat of fusion	ΔH_{fus} or L_f	334 J g ⁻¹
heat of vaporization	ΔH_{vap} or L_v	2260 J g ⁻¹
index of refraction	n	1.33
autoionization	K_w	1.0×10^{-14}

Pressure
1 atm = 760 torr
= 101325 Pa
= 14.7 psi
1 bar = 10 ⁵ Pa
= 100 kPa

Energy
1 cal = 4.184 J
1 L atm = 101.325 J
1 Cal = 1 kcal
1 hp = 746 W
1 eV = 1.602 × 10 ⁻¹⁹ J

Various Physical Constants

property	symbol	value
universal gas constant	R	8.314 J mol ⁻¹ K ⁻¹
		62.36 L torr mol ⁻¹ K ⁻¹
		0.08206 L atm mol ⁻¹ K ⁻¹
		1.987 cal mol ⁻¹ K ⁻¹
Planck's constant	h	6.626 × 10 ⁻³⁴ J s
		4.136 × 10 ⁻¹⁵ eV s
Planck's reduced constant	$h/2\pi$	1.054 × 10 ⁻³⁴ J s
		6.582 × 10 ⁻¹⁶ eV s
Boltzmann constant	k_B	1.38 × 10 ⁻²³ J K ⁻¹
Stefan-Boltzmann	σ	5.67 × 10 ⁻⁸ W m ⁻² K ⁻⁴
speed of light	c	3.00 × 10 ⁸ m s ⁻¹
speed of sound (at 20°C)	v_{air}	343 m s ⁻¹
acceleration of gravity	g	9.80 m s ⁻²
gravitational constant	G	6.67 × 10 ⁻¹¹ N m ² kg ⁻²
Avogadro's number	N_A	6.022 × 10 ²³ mol ⁻¹
elementary charge	e	1.602 × 10 ⁻¹⁹ C
Faraday	F	96485 C mol ⁻¹
Coulomb's law constant	k	8.988 × 10 ⁹ N m ² C ⁻²
Rydberg constant	R	2.178 × 10 ⁻¹⁸ J

Some Other Conversion Factors

1 in	=	2.54 cm
1 lb	=	453.6 g
1 mi	=	5280 ft = 1.609 km
1 gal	=	4 quarts = 231 in ³ = 3.785 L

property	symbol	value
electron rest mass	m_e	9.11 × 10 ⁻³¹ kg
		0.000549 u
		0.511 MeV c ⁻²
proton mass	m_p	1.6726 × 10 ⁻²⁷ kg
		1.00728 u
		938.3 MeV c ⁻²
neutron mass	m_n	1.6749 × 10 ⁻²⁷ kg
		1.008665 u
		939.6 MeV c ⁻²
atomic mass unit	u	1.6605 × 10 ⁻²⁷ kg
		931.5 MeV c ⁻²
earth mass		5.972 × 10 ²⁴ kg
earth radius		6.371 × 10 ⁶ m
moon mass		7.348 × 10 ²² kg
sun mass		1.989 × 10 ³⁰ kg
distance earth-moon		3.844 × 10 ⁸ m
distance earth-sun		1.496 × 10 ¹¹ m
permittivity of free space	ϵ_0	8.85 × 10 ⁻¹² F m ⁻¹
permeability of free space	μ_0	4 π × 10 ⁻⁷ T m A ⁻¹

Some Average Bond Energies (kJ/mol)

C-H	413	C-C	346	C-Cl	339	C-N	305
O-H	463	C=C	602	C-Br	285	N=N	418
N-H	391	C≡C	835	O=O	498	H-H	436
C-O	358	C=O	799	C≡O	1072	Br-Br	193
H-Cl	432	S-H	347	N≡N	945	Cl-Cl	242
H-Br	366	H-I	299	C≡N	887	I-I	151

Biology Questions (1 – 20)

1. Isotopes of the same element have different mass numbers but identical atomic numbers because isotopes of the same element have a
 - A) different number of protons and neutrons.
 - B) different number of protons.
 - C) different structure of electrons residing in electron shells.
 - D) different number of electrons and protons.
 - E) different level of radioactivity.

2. Fatty acids are long hydrocarbon chains with a _____ functional group.
 - A) hydroxyl
 - B) carboxyl
 - C) carbonyl
 - D) sulfhydryl
 - E) amino

3. A molecule made of covalent bonds in which the sharing of electrons is equal is
 - A) polar
 - B) aqueous
 - C) hydrophilic
 - D) hydrophobic
 - E) non polar

4. As the pH of a solution decreases, the hydroxyl ion concentration
 - A) increases
 - B) decreases
 - C) is not affected

5. The process by which particles move from areas of higher concentration to areas of lower concentration is called
 - A) osmosis
 - B) a concentration gradient
 - C) diffusion
 - D) mass movement
 - E) entropy

6. The closest relatives to the land plants are the _____
 - A) green algae
 - B) ferns
 - C) mosses
 - D) aquatic plants
 - E) seedless plants

7. Energy present in a system that is unable to perform work is called
 - A) entropy
 - B) heat
 - C) potential energy
 - D) equilibrium energy
 - E) radiant energy

8. The sum total of all genes in a population is known as
 - A) Hardy-Weinberg equilibrium
 - B) the allele pool
 - C) the gene pool
 - D) the biome
 - E) the genome

9. An autosome is a chromosome that
 - A) is found in all human cells
 - B) is found only in human gametes
 - C) is found only in females
 - D) is found only in males
 - E) determines the gender of humans

10. The three basic plant organs are the _____
 - A) cells, tissues, and meristems
 - B) roots, shoots, and flowers
 - C) roots, stems, and leaves
 - D) xylem, phloem, and roots
 - E) buds, nodes, and internodes

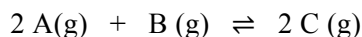
11. Which of the following is an organelle found in a prokaryotic cell?
- A) ribosome
 - B) DNA
 - C) plasma membrane
 - D) All the above
 - E) None of the above
12. Nutrients that cannot be biosynthesized and must be consumed in the diet are known as the _____ nutrients.
- A) limiting
 - B) factorial
 - C) vitaminal
 - D) essential
 - E) required
13. A circulatory system has three basic components: the circulatory fluid, the circulatory vessels, and the _____.
- A) interstitial fluid
 - B) lungs
 - C) heart
 - D) blood
 - E) arteries and veins
14. Bacteria and Archaea are both considered
- A) prokaryotes
 - B) halophytes
 - C) eubacteria
 - D) eukaryotes
 - E) autotrophic
15. The nerve cells that transfer information within the body are known as _____.
- A) neurons
 - B) dendrites
 - C) ganglia
 - D) synapses
 - E) effectors
16. What molecules are produced during translation?
- A) DNA
 - B) RNA
 - C) ribosomes
 - D) peptides
 - E) amino acids
17. The inability to interbreed, known as reproductive isolation, is a central tenet of the _____ species concept.
- A) reproductive
 - B) biological
 - C) recognition
 - D) phylogenetic
 - E) genetic
18. In binomial nomenclature, the first of the two names is the _____ and should be _____.
- A) specific epithet, capitalized
 - B) species; underlined
 - C) species; capitalized
 - D) genus; capitalized
 - E) genus; lower case
19. How many phosphate groups are found in a single nucleotide?
- A) 0 in DNA, 0 in RNA
 - B) 1 in DNA, 1 in RNA
 - C) 1 in DNA, 2 in RNA
 - D) 2 in DNA, 1 in RNA
 - E) 2 in DNA, 2 in RNA
20. The field of biology that identifies and classifies organisms is known as
- A) phylogenetics
 - B) nomenclology
 - C) systems
 - D) biogeography
 - E) taxonomy

Chemistry Questions (21 – 40)

21. What is the name for the compound CoSO_3 ?
- copper(II) sulfate
 - cobalt(II) sulfite
 - chromium(I) sulfite
 - cobalt(II) sulfate
 - copper(II) sulfite
22. What is the chemical formula for ammonium iodate?
- Am_2I
 - NH_3I
 - NH_4IO_4
 - NH_4IO_3
 - $(\text{NH}_4)_2\text{IO}_3$
23. What is the molar mass of $\text{Fe}(\text{CH}_3\text{CO}_2)_3$?
- 233.0 g/mol
 - 114.9 g/mol
 - 173.9 g/mol
 - 344.7 g/mol
 - 185.0 g/mol
24. What is the percentage of carbon by mass in caffeine ($\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$)?
- 6.18%
 - 51.0%
 - 49.5%
 - 33.3%
 - 56.2%
25. Which of the following atoms will have the largest atomic radius?
- Li
 - Zn
 - Br
 - Mg
 - Ca
26. Balance the following reaction with whole numbers as coefficients.
- $$\text{C}_4\text{H}_{10}(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$$
- What are the respective coefficients?
- 2 : 13 : 8 : 10
 - 1 : 6 : 4 : 5
 - 1 : 9 : 4 : 5
 - 2 : 14 : 7 : 10
 - 3 : 19 : 12 : 15
27. Refer to the reaction shown in the previous question. What type of reaction is this?
- neutralization
 - precipitation
 - combustion
 - metathesis
 - polymerization
28. Balance the following equation.
- $$\text{BF}_3 + \text{H}_2\text{O} \rightarrow \text{B}_2\text{O}_3 + \text{HF}$$
- What is the maximum number of grams of B_2O_3 that can be formed when 100 g of BF_3 and 50 g of H_2O completely react?
- 64.4 g
 - 51.3 g
 - 94.4 g
 - 48.5 g
 - 72.8 g
29. KNO_3 is a major component of fertilizer and can be made by the following reaction
- $$4 \text{KCl} + 4 \text{HNO}_3 + \text{O}_2 \rightarrow 4 \text{KNO}_3 + 2 \text{Cl}_2 + 2 \text{H}_2\text{O}$$
- How many pounds of KCl are needed to make 500 lbs of KNO_3 ?
- 678 lbs
 - 413 lbs
 - 510 lbs
 - 2000 lbs
 - 369 lbs

30. What is the electron configuration of tin?
- $[\text{Ar}]4s^2 3d^2$
 - $[\text{Ar}]4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^3$
 - $[\text{Ar}]4s^2 3d^{10} 4p^6 5s^1 4d^9 5p^4$
 - $[\text{Ar}]4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^0 6s^2$
 - $[\text{Ar}]4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^2$
31. What is the energy of a photon with a wavelength of 440 nm?
- $5.15 \times 10^{-19} \text{ J}$
 - $6.82 \times 10^{14} \text{ J}$
 - $2.16 \times 10^{-18} \text{ J}$
 - $4.52 \times 10^{-19} \text{ J}$
 - $2.92 \times 10^{-22} \text{ J}$
32. What is the electron dot formula for nitrate?
- $\left[\begin{array}{c} \text{:}\ddot{\text{O}}\text{:} \\ \text{:}\ddot{\text{O}}\text{:N}\text{:}\ddot{\text{O}}\text{:} \end{array} \right]^-$
 - $\left[\begin{array}{c} \text{:}\ddot{\text{O}}\text{:} \\ \text{:}\ddot{\text{O}}\text{:N}\text{:}\ddot{\text{O}}\text{:} \end{array} \right]^-$
 - $\left[\begin{array}{c} \text{:}\ddot{\text{O}}\text{:} \\ \text{:}\ddot{\text{O}}\text{:N}\text{:}\ddot{\text{O}}\text{:} \end{array} \right]^-$
 - $\left[\begin{array}{c} \text{:}\ddot{\text{O}}\text{:} \\ \text{:}\ddot{\text{O}}\text{:O}\text{:}\ddot{\text{O}}\text{:} \end{array} \right]^-$
33. Which of the following molecules is not polar?
- NH_3
 - SF_4
 - BeF_2
 - PH_3
 - CH_2O
34. An exothermic reaction is at equilibrium. As the reaction is slowly heated, which of the following must be true about the reactants and products?
- the products will increase in concentration
 - the reactants will increase in concentration
 - the concentrations of both reactants and products will remain constant
35. 75 mL of hydrochloric acid is titrated to the end point with 21.92 mL of 0.0155 M NaOH. What is the concentration of the hydrochloric acid?
- 0.00453 M
 - 0.00227 M
 - 0.00906 M
 - 0.0530 M
 - 0.0155 M
36. A 5 liter gas container is filled with 10 g of ethane (C_2H_6) at 25°C . What is the pressure of the methane gas in this container?
- 0.137 atm
 - 14.7 atm
 - 8.27 atm
 - 3.91 atm
 - 1.63 atm
37. An evacuated container is filled with equal masses of argon and neon. What is the mole fraction of argon in this mixture?
- 41.1 %
 - 33.6 %
 - 50.0 %
 - 66.4 %
 - 58.9 %
38. What is the molar solubility of $\text{Pb}(\text{OH})_2$ if the value of K_{sp} is equal to 1.43×10^{-20} ?
- $1.20 \times 10^{-10} \text{ mol/L}$
 - $8.46 \times 10^{-11} \text{ mol/L}$
 - $1.53 \times 10^{-7} \text{ mol/L}$
 - $3.72 \times 10^{-8} \text{ mol/L}$
 - $2.43 \times 10^{-7} \text{ mol/L}$
39. What is the pH of a $2.9 \times 10^{-4} \text{ M}$ solution of KOH ?
- 10.46
 - 10.54
 - 3.54
 - 10.76
 - 3.24

40. Which of the equations shown is equal to the equilibrium constant, K_p , for the following gas phase chemical reaction?



- A) $\frac{P_C}{P_A P_B}$ D) $\frac{P_C^2}{P_A^2 P_B}$
 B) $\frac{2P_A P_B}{2P_C}$ E) $\frac{P_A^2 P_B}{P_C^2}$
 C) $\frac{2P_C}{2P_A P_B}$

Physics Questions (41 – 60)

On this contest i, j and k are the unit vectors in the $+x$, $+y$ and $+z$ directions respectively, and unless otherwise indicated, you may neglect air resistance in every problem.

41. According to Tyson, who discovered Pluto?
 A) Venetia Burney
 B) Percival Lowell
 C) Henry Madan
 D) Clyde Tombaugh
 E) Herbert Hall Turner
42. According to Tyson, which of the following discovered in 1789 is the heaviest atom in nature?
 A) lead
 B) mercury
 C) platinum
 D) plutonium
 E) uranium
43. According to Tyson, which scientist led a team of physicists to produce a new element in 1941?
 A) Philip H. Abelson
 B) Percival Lowell
 C) Edwin M. McMillan
 D) Glen T. Seaborg
 E) Herbert Hall Turner
44. According to Tyson, he stated that he believes that Americans love of Pluto is to be blamed on
 A) being discovered by an American astronomer
 B) being named after the roman god of the dead and underworld
 C) the popularity and efficacy of Pluto water
 D) the popularity of Mickey’s dog in a cartoon by Walt Disney
 E) the use of plutonium in the first atomic bomb used in World War II
45. Pirates starting from their home port travel 75.0 m at 60.0° E of N then 57.3 m at 25.0° S of W and finally due south for 25.0 m. With the origin of the coordinate system at their home port and with E and N in the $+x$ and $+y$ directions respectively on their treasure map, where as measured in standard position will the pirates place the X on their treasure map?
 A) 17.5 m, 318°
 B) 36.7 m, 343°
 C) 86.7 m, 323°
 D) 123 m, 318°
 E) 146 m, 318°
46. If you throw a ball upward, at the top of the vertical motion the ball is momentarily motionless. Which of the following is true at this point?
 A) acceleration is zero
 B) acceleration is 9.8 m/s^2 downward
 C) acceleration is 9.8 m/s^2 upward
 D) velocity is constant
 E) velocity is non-zero
47. A roadrunner runs along a straight road from the coyote. While watching you notice that the roadrunner’s coordinate position is described by $x(t) = 23.00 \text{ m} + (7.250 \text{ m/s}^2) t^2$, what is the roadrunner’s displacement from 2.000 s to 3.000 s?
 A) 7.25 m
 B) 29.00 m
 C) 36.25 m
 D) 65.25 m
 E) 140.25 m

48. A man pulls a 650 N crate by pulling on a rope at an angle of 30.0° above the horizontal. The coefficient of kinetic friction between the crate and the horizontal floor is 0.370. How hard does the man have to pull to keep the crate moving with a constant velocity?
- A) 208 N
 B) 229 N
 C) 293 N
 D) 325 N
 E) 650 N
49. While crossing a river a boat heads due north at a speed of 40 km/hr relative to the water. If the river flows from west to east at 18 km/hr relative to the shore then what is the velocity of the boat relative to shore?
- A) 22 km/hr, 24° E of N
 B) 44 km/hr, 24° E of N
 C) 44 km/hr, 66° W of N
 D) 58 km/hr, 24° W of N
 E) 58 km/hr, 66° E of N
50. A 75.0 kg man rides a Ferris wheel with a diameter of 20.0 m and the wheel makes one revolution in 12.0 s. What is the apparent weight of the man at the top of the Ferris wheel? You may assume the seat remains upright during the ride.
- A) 206 N
 B) 268 N
 C) 529 N
 D) 735 N
 E) 941 N
51. A particle that moves in the xy -plane undergoes a displacement of $\Delta\mathbf{r} = (3.0\mathbf{i} + 2.0\mathbf{j})$ m while being acted upon by a constant force $\mathbf{F} = (4.0\mathbf{i} + 4.0\mathbf{j})$ N. What is the work done by this force during the displacement?
- A) 4.0 J
 B) 20 J
 C) $(7.0\mathbf{i} + 6.0\mathbf{j})$ J
 D) $(12\mathbf{i} - 8.0\mathbf{j})$ J
 E) $(12\mathbf{i} + 8.0\mathbf{j})$ J
52. A neutron travels at 2.6×10^7 m/s collides head on with a carbon nucleus that is initially at rest. Given that a neutron has an approximate mass of 1.0 u and a carbon nucleus has an approximate mass of 12 u. What is the magnitude of the velocity of the neutron after the collision if the collision is elastic and one-dimensional?
- A) 0.0 m/s
 B) 4.0×10^6 m/s
 C) 2.2×10^7 m/s
 D) 3.0×10^7 m/s
 E) 3.2×10^7 m/s
53. An old school record player rotates at 5600 rev/min. How much time does it take a record with a diameter of 25 cm to rotate through 180° ?
- A) 8.9×10^{-5} s
 B) 2.7×10^{-3} s
 C) 5.4×10^{-3} s
 D) 1.1×10^{-2} s
 E) 3.2×10^{-1} s
54. A weight W at the end of a string of length L swings from a ceiling hook. If T is the tension found in the string then what is the magnitude of the net torque about the hook when the string makes an angle ϕ with vertical?
- A) WL
 B) $WL \cos\phi$
 C) $WL/(T \cos\phi)$
 D) $WL \sin\phi$
 E) $WL/(T \sin\phi)$
55. A 6.00 m long cable is used to lift very heavy objects. When a crate of 500 kg is lifted then the cable has a cross sectional area of 0.250 cm^2 and stretches by 0.570 cm. What is Young's modulus for the cable?
- A) 4.85×10^{-12} Pa
 B) 9.50×10^{-4} Pa
 C) 1.29×10^2 Pa
 D) 1.96×10^8 Pa
 E) 2.06×10^{11} Pa

56. If a glass of water is left outside to freeze into ice thus lowering the entropy of the glass of water and if we only consider energy exchange between the glass of water and the surrounding air, then which of the following is true of this process
- The entropy of the surrounding air stays the same.
 - The entropy of both the glass of water and the surrounding air decrease.
 - The absolute value of the change in entropy of the glass of water is equal to the absolute value of the change in entropy of the surrounding air.
 - The absolute value of the change in entropy of the glass of water is more than the absolute value of the change in entropy of the surrounding air.
 - The absolute value of the change in entropy of the glass of water is less than the absolute value of the change in entropy of the surrounding air.
57. A point charge $q_1 = +4.00 \mu\text{C}$ is located on the positive y -axis at $y = 0.300 \text{ m}$ and a second charge $q_2 = +4.00 \mu\text{C}$ is located at the origin. Find the magnitude of the total force that q_1 and q_2 exert on a third charge $q_3 = +6.00 \mu\text{C}$ located on the x -axis at $x = 0.500 \text{ m}$.
- 0.326 N
 - 1.08 N
 - 1.32 N
 - 1.44 N
 - 1.50 N
58. Determine the rms speed of the following group of molecules. The molecules have speeds of 300 m/s, 400 m/s, 450 m/s, 500 m/s, 650 m/s, and 750 m/s.
- 450 m/s
 - 508 m/s
 - 530 m/s
 - 750 m/s
 - 281250 m/s
59. A copper wire has a diameter of 0.96 mm and a cross sectional area of $7.2 \times 10^{-7} \text{ m}^2$. If the wire has a resistance of 1.2Ω at 23°C then what is the resistance of the wire at 100°C ? The resistivity of copper is $1.7 \times 10^{-8} \Omega\cdot\text{m}$ at 23°C and the temperature coefficient of resistivity of copper is $0.0039/\text{K}$
- $4.7 \times 10^{-3} \Omega$
 - $3.6 \times 10^{-1} \Omega$
 - $5.8 \times 10^{-1} \Omega$
 - 1.6Ω
 - 1.8Ω
60. An electron moves at high (non-relativistic) speed through a magnetic field that is oriented perpendicular to its direction of travel. Which of the following will change?
- acceleration and velocity
 - acceleration and kinetic energy
 - charge and mass
 - kinetic energy and velocity
 - total energy

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY

INVITATIONAL A • 2015

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

PHYSICS KEY for Science Contest • Invitational A • 2015

41. (D) “At about four in the afternoon on February 18, 1930, 24-year-old Clyde W. Tombaugh, a farm boy and amateur astronomer from Illinois, discovered on the sky what would be shortly named for the Roman god of the underworld.”
42. (E) “By 1789, just eight years after Herschel discovered Uranus, Martin Klaproth, of Germany, discovered the heaviest atom in nature. In need of a name, and with the planet Uranus fresh on people’s minds, the element uranium would ultimately land at slot 92 on the periodic table...”
43. (D) “Eleven years later, in 1941, a team of physicists led by Glen T. Seaborg manufactured a new element for the periodic table ... while working at the University of California at Berkeley’s cyclotron – one of the world’s preeminent atom smashers.”
44. (D) “Whether or not Walt Disney was thinking about the cosmos when he named his dog is not important here. What matters is that the seeds were sown for planet Pluto to receive a level of attention from the American public that far exceeds its astrophysical significance in the solar system.”
45. (A) Adding by components gives: $R_x = +75\sin(60^\circ) - 57.3\cos(25^\circ) = +13.02\text{m}$ &
 $R_y = +75\cos(60^\circ) - 57.3\sin(25^\circ) - 25 = -11.72\text{m} \Rightarrow R = [(13.02)^2 + (-11.72)^2]^{1/2} = 17.5\text{m}$ &
 $\theta = \tan^{-1}(-11.72/13.02) = -41.98^\circ + 360^\circ = 318^\circ$
46. (B) The acceleration throughout the entire motion is a constant 9.8m/s^2 down.
47. (C) $\Delta x = [23 + 7.25(3)^2] - [23 + 7.25(2)^2] = +36.25\text{ m}$
48. (B) From the FBD & N2L: (vertically) $+F_N + F_T \sin(30^\circ) - F_G = 0 \Rightarrow F_N = 650 - F_T \sin(30^\circ)$
 (horizontally) $+F_T \cos(30^\circ) - F_{\text{frk}} = 0$ & with $F_{\text{frk}} = \mu_k F_N = \mu_k [650 - F_T \sin(30^\circ)]$
 $\Rightarrow F_T = \mu_k(650)/[\cos(30^\circ) - \mu_k \sin(30^\circ)] = 229\text{ N}$
49. (B) By relative velocity addition: $v = [40^2 + 18^2]^{1/2} = 44\text{km/hr}$ at $\theta = \tan^{-1}(18/40) = 24^\circ$ E of N
50. (C) From the FBD & N2L: (radially) $+F_G - F_N = m(+a_c) \Rightarrow F_N = m(g - v^2/r)$
 where $v = 2\pi r/T = 2\pi(10)/(12) = 5.236\text{ m/s} \Rightarrow F_N = 75[9.8 - 5.236^2/10] = 529\text{ N}$
51. (B) $W = \mathbf{F} \cdot \Delta \mathbf{r} = (4)(3) + (4)(2) = 20\text{ J}$
52. (C) By conservation of momentum: $(1.0)(+2.6\text{E}+7) + 0 = (1.0)(+v_1') + (12)(+v_2')$ & for a 1-D elastic collision by the relative velocity equation: $(+2.6\text{E}+7) - (0) = (+v_2') - (+v_1')$
 $\Rightarrow v_1' = -11(+2.6\text{E}+7)/13 = -2.2\text{E}+7\text{ m/s}$
53. (C) Note: 180° is $1/2$ of a revolution and will take $1/2$ of the period to complete. So,
 $t = 1/2 T = 1/2[(1\text{ min})/(5600\text{ rev})][(60\text{ s})/(1\text{ min})] = 5.4\text{E}-3\text{ s}$
54. (D) From the FBD the torque about the hook from the tension in the string is zero, thus the net torque is due to the gravitational force: $\Sigma \tau = \tau_G = \pm r F_G \sin \theta = \pm L W \sin \varphi$
55. (E) By $Y = \text{Stress/strain} = (F/A)/(\Delta L/L_0) = [(750)(9.8)(6)]/[(0.25\text{E}-4)(0.57\text{E}-2)] = 2.06\text{E}+11\text{ Pa}$
56. (E) By the second law of thermodynamics for an irreversible process the total entropy of an isolated system must increase, or $\Delta S \geq 0$. Thus the absolute value of the change in entropy of the glass of water must be less than the absolute value of the change in entropy of the surrounding air.
57. (D) The magnitudes of the electric forces are: $F_{23} = (8.99\text{E}+9)(4\text{E}-6)(6\text{E}-6)/(0.5)^2 = 0.8630\text{ N}$ &
 $F_{13} = (8.99\text{E}+9)(4\text{E}-6)(6\text{E}-6)/(0.3^2 + 0.5^2) = 0.6346\text{ N}$ from the diagram the angle for F_{13} is
 $\theta = \tan^{-1}(0.3/0.5) = 30.96^\circ$ and the net force is found by vector addition of these two force vectors:
 $\Sigma F_x = +0.8630 + 0.6346 \cos 30.96^\circ = 1.4072\text{ N}$ & $\Sigma F_y = +0 - 0.6346 \sin 30.96^\circ = -0.3265\text{ N}$
 $\Rightarrow \Sigma F = [(1.4072)^2 + (-0.3265)^2]^{1/2} = 1.44\text{ N}$
58. (C) By definition an rms average is the square root of the average of the squares of the values, thus
 $v_{\text{rms}} = [(300^2 + 400^2 + 450^2 + 500^2 + 650^2 + 750^2)/6]^{1/2} = 530\text{ m/s}$
59. (D) By $R = R_0[1 + \alpha \Delta T] = 1.2[1 + (0.0039)(100 - 23)] = 1.6\ \Omega$
60. (A) A charged particle moving perpendicularly through a magnetic field moves in uniform circular motion. Thus both the velocity and acceleration vectors will change directions during the motion.