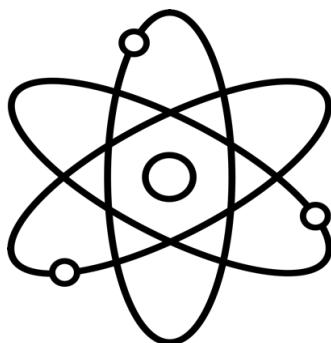




# SCIENCE

Region • 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.



# Periodic Table of the Elements

1A <b>1</b>																8A <b>18</b>				
<b>1</b> <b>H</b> 1.008											3A <b>13</b>		4A <b>14</b>	5A <b>15</b>	6A <b>16</b>	7A <b>17</b>	<b>2</b> <b>He</b> 4.003			
<b>3</b> <b>Li</b> 6.941	<b>4</b> <b>Be</b> 9.012											<b>5</b> <b>B</b> 10.81	<b>6</b> <b>C</b> 12.01	<b>7</b> <b>N</b> 14.01	<b>8</b> <b>O</b> 16.00	<b>9</b> <b>F</b> 19.00	<b>10</b> <b>Ne</b> 20.18			
<b>11</b> <b>Na</b> 22.99	<b>12</b> <b>Mg</b> 24.31	3B <b>3</b>	4B <b>4</b>	5B <b>5</b>	6B <b>6</b>	7B <b>7</b>	8B <b>8</b>	8B <b>9</b>	8B <b>10</b>	1B <b>11</b>	2B <b>12</b>	<b>13</b> <b>Al</b> 26.98	<b>14</b> <b>Si</b> 28.09	<b>15</b> <b>P</b> 30.97	<b>16</b> <b>S</b> 32.07	<b>17</b> <b>Cl</b> 35.45	<b>18</b> <b>Ar</b> 39.95			
<b>19</b> <b>K</b> 39.10	<b>20</b> <b>Ca</b> 40.08	<b>21</b> <b>Sc</b> 44.96	<b>22</b> <b>Ti</b> 47.87	<b>23</b> <b>V</b> 50.94	<b>24</b> <b>Cr</b> 52.00	<b>25</b> <b>Mn</b> 54.94	<b>26</b> <b>Fe</b> 55.85	<b>27</b> <b>Co</b> 58.93	<b>28</b> <b>Ni</b> 58.69	<b>29</b> <b>Cu</b> 63.55	<b>30</b> <b>Zn</b> 65.41	<b>31</b> <b>Ga</b> 69.72	<b>32</b> <b>Ge</b> 72.64	<b>33</b> <b>As</b> 74.92	<b>34</b> <b>Se</b> 78.96	<b>35</b> <b>Br</b> 79.90	<b>36</b> <b>Kr</b> 83.80			
<b>37</b> <b>Rb</b> 85.47	<b>38</b> <b>Sr</b> 87.62	<b>39</b> <b>Y</b> 88.91	<b>40</b> <b>Zr</b> 91.22	<b>41</b> <b>Nb</b> 92.91	<b>42</b> <b>Mo</b> 95.94	<b>43</b> <b>Tc</b> (98)	<b>44</b> <b>Ru</b> 101.07	<b>45</b> <b>Rh</b> 102.91	<b>46</b> <b>Pd</b> 106.42	<b>47</b> <b>Ag</b> 107.87	<b>48</b> <b>Cd</b> 112.41	<b>49</b> <b>In</b> 114.82	<b>50</b> <b>Sn</b> 118.71	<b>51</b> <b>Sb</b> 121.76	<b>52</b> <b>Te</b> 127.60	<b>53</b> <b>I</b> 126.90	<b>54</b> <b>Xe</b> 131.29			
<b>55</b> <b>Cs</b> 132.91	<b>56</b> <b>Ba</b> 137.33	<b>57</b> <b>La</b> 138.91	<b>72</b> <b>Hf</b> 178.49	<b>73</b> <b>Ta</b> 180.95	<b>74</b> <b>W</b> 183.84	<b>75</b> <b>Re</b> 186.21	<b>76</b> <b>Os</b> 190.23	<b>77</b> <b>Ir</b> 192.22	<b>78</b> <b>Pt</b> 195.08	<b>79</b> <b>Au</b> 196.97	<b>80</b> <b>Hg</b> 200.59	<b>81</b> <b>Tl</b> 204.38	<b>82</b> <b>Pb</b> 207.20	<b>83</b> <b>Bi</b> 208.98	<b>84</b> <b>Po</b> (209)	<b>85</b> <b>At</b> (210)	<b>86</b> <b>Rn</b> (222)			
<b>87</b> <b>Fr</b> (223)	<b>88</b> <b>Ra</b> (226)	<b>89</b> <b>Ac</b> (227)	<b>104</b> <b>Rf</b> (261)	<b>105</b> <b>Db</b> (262)	<b>106</b> <b>Sg</b> (266)	<b>107</b> <b>Bh</b> (264)	<b>108</b> <b>Hs</b> (277)	<b>109</b> <b>Mt</b> (268)	<b>110</b> <b>Ds</b> (281)	<b>111</b> <b>Rg</b> (272)	<b>112</b> <b>Cn</b> (285)									

<b>58</b> <b>Ce</b> 140.12	<b>59</b> <b>Pr</b> 140.91	<b>60</b> <b>Nd</b> 144.24	<b>61</b> <b>Pm</b> (145)	<b>62</b> <b>Sm</b> 150.36	<b>63</b> <b>Eu</b> 151.96	<b>64</b> <b>Gd</b> 157.25	<b>65</b> <b>Tb</b> 158.93	<b>66</b> <b>Dy</b> 162.50	<b>67</b> <b>Ho</b> 164.93	<b>68</b> <b>Er</b> 167.26	<b>69</b> <b>Tm</b> 168.93	<b>70</b> <b>Yb</b> 173.04	<b>71</b> <b>Lu</b> 174.97
<b>90</b> <b>Th</b> 232.04	<b>91</b> <b>Pa</b> 231.04	<b>92</b> <b>U</b> 238.03	<b>93</b> <b>Np</b> (237)	<b>94</b> <b>Pu</b> (244)	<b>95</b> <b>Am</b> (243)	<b>96</b> <b>Cm</b> (247)	<b>97</b> <b>Bk</b> (247)	<b>98</b> <b>Cf</b> (251)	<b>99</b> <b>Es</b> (252)	<b>100</b> <b>Fm</b> (257)	<b>101</b> <b>Md</b> (258)	<b>102</b> <b>No</b> (259)	<b>103</b> <b>Lr</b> (262)

## Some Standard Properties of Water

property	symbol	value
density of water	$\rho_{\text{water}}$	1.000 g cm <sup>-3</sup>
density of ice	$\rho_{\text{ice}}$	0.9167 g cm <sup>-3</sup>
specific heats		
ice	$C_{\text{ice}}$	2.09 J g <sup>-1</sup> K <sup>-1</sup>
water	$C_{\text{water}}$	4.184 J g <sup>-1</sup> K <sup>-1</sup>
steam	$C_{\text{steam}}$	2.03 J g <sup>-1</sup> K <sup>-1</sup>
heat of fusion	$\Delta H_{\text{fus}}$ or $L_f$	334 J g <sup>-1</sup>
heat of vaporization	$\Delta H_{\text{vap}}$ or $L_v$	2260 J g <sup>-1</sup>
index of refraction	$n$	1.33
autoionization	$K_w$	$1.0 \times 10^{-14}$

Pressure
1 atm = 760 torr
= 101325 Pa
= 14.7 psi
1 bar = 10 <sup>5</sup> 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 <sup>-19</sup> J

## Various Physical Constants

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

### 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 <sup>3</sup> = 3.785 L

property	symbol	value
electron rest mass	$m_e$	$9.11 \times 10^{-31} \text{ kg}$
		0.000549 u
		$0.511 \text{ MeV c}^{-2}$
proton mass	$m_p$	$1.6726 \times 10^{-27} \text{ kg}$
		1.00728 u
		$938.3 \text{ MeV c}^{-2}$
neutron mass	$m_n$	$1.6749 \times 10^{-27} \text{ kg}$
		1.008665 u
		$939.6 \text{ MeV c}^{-2}$
atomic mass unit	$u$	$1.6605 \times 10^{-27} \text{ kg}$
		$931.5 \text{ MeV c}^{-2}$
earth mass		$5.972 \times 10^{24} \text{ kg}$
earth radius		$6.371 \times 10^6 \text{ m}$
moon mass		$7.348 \times 10^{22} \text{ kg}$
sun mass		$1.989 \times 10^{30} \text{ kg}$
distance earth-moon		$3.844 \times 10^8 \text{ m}$
distance earth-sun		$1.496 \times 10^{11} \text{ m}$
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12} \text{ F m}^{-1}$
permeability of free space	$\mu_0$	$4\pi \times 10^{-7} \text{ T m A}^{-1}$

### 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)

- Post-translational modifications of a polypeptide may include which of the following?
  - condensation reactions
  - hydrolytic reactions
  - hydrostatic reactions
  - A and B
  - A, B and C
- The process of photosynthesis requires carbon, hydrogen and oxygen and sunlight energy. How do plants obtain the oxygen for photosynthesis?
  - from H<sub>2</sub>O in the soil
  - from O<sub>2</sub> in the air
  - from CO<sub>2</sub> in the air
  - from glycolysis in the cytoplasm
  - from sunlight energy
- Which of the following are considered a post-zygotic isolating mechanism in angiosperms?
  - pollen grain unable to germinate on the stigma
  - pollen tube unable to grow through the style
  - sperm nuclei unable to fertilize the egg cell
  - All the above
  - None of the above
- Which of the following can be found in a bacterial chromosome?
  - histone proteins
  - telomeres
  - centromeres
  - DNA
  - All the above
- Allopatric populations and sympatric populations of the same species must differ in their degree of:
  - gene flow
  - directional selection pressure
  - population sizes
  - mutation
  - genetic drift
- Evolutionary change in which a parent species gives rise to many new species driven by availability of ecological niches is called
  - allopatric speciation.
  - sympatric speciation.
  - ecological diversification.
  - adaptive radiation.
  - punctuated adaptation.
- Which is a main difference between cyclic and non-cyclic electron flow in photosynthesis?
  - Reduction of FAD
  - Reduction of NADP+
  - Reduction of ADP
  - Generation of ATP
  - Phosphorylation of ADP
- The eukaryotic gene is divided into coding regions called exons and non-coding regions called introns. What is main difference between exons and introns?
  - Exons are transcribed and translated whereas introns are only transcribed.
  - Introns are transcribed and translated whereas exons are only transcribed.
  - Introns are never transcribed but exons are always transcribed.
  - Exons are located in within a gene whereas introns are located between genes.
  - Exons are RNA and introns are DNA.
- The ecological diversity of insects can be attributed primarily to which of the following adaptations of the insects?
  - Complete and incomplete metamorphosis
  - Rigid exoskeleton made of chitin
  - Specialized mouthparts and hinged appendages
  - Extreme temperature tolerance
  - Ability to digest cellulose
- Taq* polymerase is an enzyme used in PCR that functions best at 75°C. From which group of organisms was the gene for *Taq* isolated?
  - E. coli bacteria
  - Thermophilic bacteria
  - Halophilic bacteria
  - Halophilic archaeans
  - Thermophilic protists

11. Which of the following is a true statement about the main difference between purine and pyrimidine nitrogenous bases?
- purines contain uracil
  - pyrimidines are found in both DNA and RNA, purines are only found in DNA
  - purines have single ring structure whereas pyrimidines have a dual ring structure
  - purines can only form a chemical bond with other purines whereas pyrimidines can form a chemical bond with purines and pyrimidines
  - there are three types of pyrimidines and only two types of purines found in nucleic acids
12. Connective tissue holds together organs and tissues in an extracellular matrix. The matrix consists of a web of fibers embedded in a diverse medium. Which type of fibers can be found in connective tissue?
- fibroblast, macrophage, and platelet
  - pith, soluble and extracellular
  - adipose, elastic and tendon
  - collagenous, reticular, and elastic
  - chondrocyte, erythrocyte and leukocyte
13. Frederick Griffith's 1928 experiments on transformation in Streptococcus pneumonia demonstrated which of the following?
- DNA, not RNA is the genetic material of a chromosome.
  - DNA, not proteins, is the genetic material of a phage.
  - Changes in genotype and phenotype in a cell line can occur by the assimilation of external DNA.
  - The regularity in the ratio of nucleotide bases in DNA.
  - The double helix structure of DNA.
14. Which of the following organelles would be found in great concentration in cells found in the testes or ovaries?
- Rough endoplasmic reticulum
  - Smooth endoplasmic reticulum
  - Ribosomes
  - Golgi apparatus
  - Vacuoles
15. The coupling of the potential energy of a proton gradient to the formation of a phosphoanhydride bond occurs in which of the following?
- mitochondria
  - bacteria
  - nucleus
  - A and B
  - A, B and C
16. Non-protein components of enzymes can be classified as cofactors or coenzymes. The main difference between cofactors and coenzymes is
- cofactors are inorganic ions and coenzymes are organic molecules.
  - coenzymes are not a component of vesicular proteins.
  - cofactors are found in prokaryotes and coenzymes are found in eukaryotes.
  - coenzymes help determine the tertiary structure and cofactors help determine the quaternary structure of proteins.
17. Pyruvate decarboxylase is an enzyme that does which of the following?
- reduces acetaldehyde to alcohol in fermentation
  - removes a COOH group from a pyruvate molecule
  - attaches a carboxyl group to a pyruvate molecule
  - oxidizes a carboxyl group
  - reduces pyruvate
18. In a population under Hardy-Weinberg equilibrium, calculate the frequency of heterozygotes when the dominant allele at the locus is fixed.
- $=2(1)(0)$
  - $=0.5^2$
  - Cannot be determined without knowing the frequency of the recessive allele.
  - $=1$
  - $=2(0.5)(0.5)$
19. A strictly vegan diet excludes meat, dairy, fish, eggs and poultry and all food that contain these animal products. Which of the following essential dietary item is lacking in a vegan diet?
- cellulose
  - hydrolytic enzymes
  - vitamin B-12
  - vitamin C
  - protein

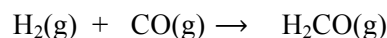
20. When building a phylogeny using molecular homologies, which of the following groupings of taxa is most desired?
- monophyletic
  - paraphyletic
  - polyphyletic
  - analogous
  - heterologous

25. Under standard conditions, which one of the following reactions will have a value of  $\Delta H$  that is equal to the enthalpy of formation for the compound formed?
- $4\text{Al(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)}$
  - $\text{N}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{NO(g)}$
  - $\text{Pb}^{2+}\text{(aq)} + 2\text{Cl}^-\text{(aq)} \rightarrow \text{PbCl}_2\text{(s)}$
  - $\text{H}_2\text{O(l)} + \text{CO}_2\text{(g)} \rightarrow \text{H}_2\text{CO}_3\text{(aq)}$
  - $\frac{1}{2}\text{N}_2\text{(g)} + \frac{3}{2}\text{H}_2\text{(g)} \rightarrow \text{NH}_3\text{(g)}$

**Chemistry Questions (21 – 40)**

21. 

26. Estimate the value for  $\Delta H$  for the following gas phase reaction producing formaldehyde:

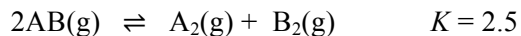


- 390 kJ
- 183 kJ
- +296 kJ
- +324 kJ
- 117 kJ

22. In general, double bonds are \_\_\_\_\_ and \_\_\_\_\_ than single bonds.

- longer ; stronger
- longer ; weaker
- shorter ; weaker
- shorter ; stronger
- none of the above

27. Consider the following reaction and its value for  $K$ .



Each of the three gases is currently at a pressure of 1.5 bar. Which of the following best describes what will happen next?

- reaction will reverse to make more AB
- reaction will go forward to make more  $\text{A}_2$  and  $\text{B}_2$
- reaction does nothing because it is at equilibrium
- reaction will go forward to make more AB
- reaction will reverse to make more  $\text{A}_2$  and  $\text{B}_2$

23. The limits of the human eye can detect light with a minimum total energy of  $3.8 \times 10^{-17}$  J. If we assume that the light has a wavelength of 575 nm, how many photons does this correspond to?

- 125
- 85
- 110
- 175
- 330

28. The vapor pressure of pure benzene ( $\text{C}_6\text{H}_6$ ) at  $25^\circ\text{C}$  is 100 torr. A solution is made by dissolving 12.68 g of compound X (63.40 g/mol) into 100 g of benzene. What is the vapor pressure of this solution?

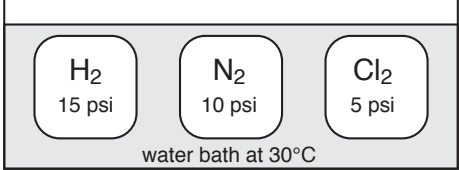
- 88.7 torr
- 15.1 torr
- 86.5 torr
- 92.6 torr
- 67.9 torr

24. Which of the following compounds is capable of hydrogen-bonding?

- $\text{CH}_3\text{CH}_2\text{CH}_3$
- $\text{CH}_3\text{CH}_2\text{COOH}$
- HBr
- $\text{BeH}_2$
- KF

29. A 0.084 M solution of a weak acid is 4.2% ionized. What is the pH of this solution?

- 3.11
- 1.45
- 1.08
- 2.45
- 1.23

30. Which of the following combinations will make 100 mL of a working buffer?
- 65 mL of 0.1 M  $\text{NH}_4\text{Cl}$  + 35 mL of 0.1 M NaOH
  - 50 mL of 0.1 M HCl + 50 mL of 0.1 M NaOH
  - 75 mL of 0.1 M HCOOH + 25 mL of 0.1 M HCl
  - 50 mL of 0.1 M  $\text{NH}_3$  + 50 mL of 0.1 M HCl
  - 40 mL of 0.1 M KOH + 60 mL of 0.1 M  $\text{HNO}_3$
31.  $\text{ZnCO}_3$  is fairly insoluble in water. Which of the following solutions could be added to water in order to help completely dissolve the  $\text{ZnCO}_3$ ?
- a solution of sodium carbonate
  - a 50/50 mix of ethanol and water
  - a solution of potassium hydroxide
  - a solution of hydrochloric acid
  - a solution of silver nitrate
32. For the second order reaction  $\text{X} \rightarrow 2\text{Y}$ , it took 3 hours for 0.425 M X to drop to 0.108 M. What is the rate constant for this reaction?
- $6.39 \times 10^{-4} \text{ M}^{-1} \text{ s}^{-1}$
  - $1.27 \times 10^{-4} \text{ M}^{-1} \text{ s}^{-1}$
  - $1.34 \times 10^{-5} \text{ M}^{-1} \text{ s}^{-1}$
  - $5.12 \times 10^{-4} \text{ M}^{-1} \text{ s}^{-1}$
  - $2.94 \times 10^{-5} \text{ M}^{-1} \text{ s}^{-1}$
33. Which of the following elements is diamagnetic in its ground state electron configuration?
- F
  - Na
  - Si
  - Pb
  - Sr
34. Drops of 1.0 M KOH are added to a solution of a weak acid, HX, until the pH has been brought to exactly 5. The  $K_a$  value for HX is  $3.2 \times 10^{-5}$ . Which of the following solution species has the maximum concentration in this solution?
- HX
  - $\text{OH}^-$
  - $\text{X}^-$
  - $\text{H}_3\text{O}^+$
  - $\text{H}_2\text{X}^+$
35. Three identical containers are each filled with hydrogen gas, nitrogen gas, and chlorine gas while submerged in a water bath held at  $30^\circ\text{C}$ . The pressures are adjusted as shown.
- 
- Which container has the gas with the highest average kinetic energy per mole of gas?
- the  $\text{H}_2$  container
  - the  $\text{N}_2$  container
  - the  $\text{Cl}_2$  container
  - they all have the same kinetic energy
36. A solution of sodium sulfate can be electrolyzed to produce oxygen gas and hydrogen gas at the two electrodes. Which of the following is true for this electrolytic cell at the surface of the anode?
- $\text{H}_2$  gas is produced and the pH is raised
  - $\text{O}_2$  gas is produced and the pH is lowered
  - $\text{H}_2$  gas is produced and the pH is lowered
  - $\text{O}_2$  gas is produced and the pH is raised
37. Under standard thermodynamic conditions, which of the following is the correct mathematical relationship comparing enthalpy ( $H$ ) to internal energy ( $U$ ) for any given system?
- $H = U$
  - $H = 1/U$
  - $H < U$
  - $H < 0 < U$
  - $H > U$
38. Consider the molecular structure for the chloroformate ion,  $\text{ClCO}_2^-$ . The two carbon-oxygen bonds have \_\_\_\_\_ bond strengths and \_\_\_\_\_ bond lengths.
- different ; the same
  - different ; different
  - the same ; the same
  - the same ; different



39. All of the following chemical species have the same molecular geometry except one. Which one is different?
- A)  $\text{CO}_3^{2-}$       C)  $\text{SO}_3$       E)  $\text{CCl}_2\text{O}$   
 B)  $\text{PO}_3^{3-}$       D)  $\text{NO}_3^-$
40. According to atomic theory, what is the maximum number of electrons can have a principle quantum number of  $n = 4$ , and a magnetic quantum number of  $m_l = +1$  ?
- A) 6                      C) 1                      E) 15  
 B) 7                      D) 3
43. According to Tyson, which of the following is not included in the IAU's criterion for a planet?
- A) is in orbit around a star, but may orbit a spot that is exterior to the object  
 B) is in orbit around a star, but not in orbit around another planet  
 C) it has cleared its orbit of wayward debris  
 D) large enough for its own force of gravity to shape it into a sphere  
 E) not so large that it would trigger fusion in its core
44. According to Tyson, which scientist is attributed with saying "the stated authority of a thousand is not worth the humble reasoning of a single individual"?
- A) Nicolaus Copernicus  
 B) Galileo Galilei  
 C) David Jewitt  
 D) Bill Nye the Science Guy®  
 E) Neil DeGrasse Tyson

**Physics Questions (41 – 60)**

On this contest  $\mathbf{i}$ ,  $\mathbf{j}$  and  $\mathbf{k}$  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, in the Planet Zone of the Hall of the Universe at the Rose Center which of the following is NOT included as one of the five classes of objects that orbit our Sun?
- A) asteroid belt  
 B) dwarf planets  
 C) gas giant planets  
 D) Kuiper Belt  
 E) terrestrial planets
42. According to Tyson, who opined "The great thing about [the Pluto] debate is that it has gotten people everywhere thinking about planets and our place among them."?
- A) David Levy  
 B) Bill Nye the Science Guy®  
 C) Geoff Marcy  
 D) Mark Sykes  
 E) Neil DeGrasse Tyson
45. A rocket is launched straight up from rest at ground level with a constant acceleration of  $23 \text{ m/s}^2$  for 35 s until the engine runs out of fuel. After 35 s, the rocket continues to rise upward moving now in free fall. What is the highest point above ground level reached by the rocket?
- A)  $1.4 \times 10^4 \text{ m}$   
 B)  $1.9 \times 10^4 \text{ m}$   
 C)  $2.8 \times 10^4 \text{ m}$   
 D)  $3.2 \times 10^4 \text{ m}$   
 E)  $4.7 \times 10^4 \text{ m}$
46. Two figure skaters, Kate with a mass of 95 kg and Robert with a mass of 150 kg, are at rest in the middle of the ice rink. If Robert pushes Kate with an average force of 26 N for 2.0 s, then what is the speed of Robert after he finishes pushing Kate? You may neglect friction between the skaters and the ice.
- A) 0.00 m/s  
 B) 0.21 m/s  
 C) 0.27 m/s  
 D) 0.35 m/s  
 E) 0.55 m/s

47. Find the angle between vectors  $\mathbf{A}$  and  $\mathbf{B}$  given  $\mathbf{A} = 3.0\mathbf{i} + 5.0\mathbf{j}$  and  $\mathbf{B} = -4.0\mathbf{i} + 3.0\mathbf{j}$ .
- A)  $21^\circ$   
 B)  $53^\circ$   
 C)  $59^\circ$   
 D)  $84^\circ$   
 E)  $90^\circ$
48. A solid, uniform sphere with a mass of 2.7 kg and a diameter of 20 cm rotates about an axis tangent to the surface of the sphere at a constant 50 rev/min. What is the rotational kinetic energy of the sphere?
- A) 0.10 J  
 B) 0.15 J  
 C) 0.52 J  
 D) 0.70 J  
 E) 1.4 J
49. A projectile of mass  $m$  is launched with an initial velocity  $v_0$  and at an angle  $\theta$  above the horizontal. In a coordinate system with the origin at the launch point and oriented such that the plane of the motion is described by  $\mathbf{i}$  and  $\mathbf{j}$  with  $\mathbf{i}$  pointing in the horizontal direction of motion and with  $\mathbf{j}$  pointing vertically upward. What is the time rate of change of the angular momentum vector about the launch point as a function of the time from launch,  $t$ ?
- A)  $[-mgt \sin\theta]\mathbf{i}$   
 B)  $[-mgtv_0 \sin\theta]\mathbf{k}$   
 C)  $[-mgtv_0 \cos\theta]\mathbf{k}$   
 D)  $[mgt \sin\theta]\mathbf{i}$   
 E)  $[mgv_0 \cos\theta]\mathbf{i}$
50. A steel wire is under tension of 47.0 N. The wire is 0.150 mm in diameter and has a length under tension of 40.0 cm. Given that the elastic or Young's modulus of steel is 200 GPa, then what is the length of the wire without any tension?
- A) 39.0 cm  
 B) 39.5 cm  
 C) 40.0 cm  
 D) 41.0 cm  
 E) 52.5 cm
51. Water at  $20^\circ\text{C}$  undergoes laminar flow in a horizontal pipe that has a radius of 2.0 cm and length of 20 m with a pressure drop 22 kPa across the ends of the pipe. Given that the viscosity of water at  $20^\circ\text{C}$  is  $1.00 \text{ mPa}\cdot\text{s}$ , then what is the speed of water flowing through the pipe? You may treat the water as incompressible and Newtonian.
- A)  $5.5 \times 10^1 \text{ m/s}$   
 B)  $1.4 \times 10^2 \text{ m/s}$   
 C)  $4.4 \times 10^2 \text{ m/s}$   
 D)  $3.5 \times 10^3 \text{ m/s}$   
 E)  $1.1 \times 10^4 \text{ m/s}$
52. Two tuning forks are struck and the sounds from each fork reach your ears simultaneously with equal intensities. One fork has a frequency of 243 Hz and the second fork has a frequency of 245 Hz. What is the frequency (or pitch) of the tone that is heard?
- A) 2 Hz  
 B) 243 Hz  
 C) 244 Hz  
 D) 245 Hz  
 E) 488 Hz
53. For a molecular gas which of the following quantities is determined solely by the average translational kinetic energy of the molecules of the gas?
- A) enthalpy  
 B) entropy  
 C) internal energy  
 D) pressure  
 E) temperature
54. The volume charge density,  $\rho$ , of a solid, non-conducting sphere of radius  $R$  varies with radial distance  $r$  as given by  $\rho(r) = A/r$ , where  $A$  is constant. What is the total charge of the sphere?
- A)  $A \ln(R)$   
 B)  $A/(2R^2)$   
 C)  $4\pi A$   
 D)  $\pi AR^2$   
 E)  $2\pi AR^2$

55. Two point charges with a positive charge,  $+q$ , are located at  $(+a, 0)$  and  $(-a, 0)$ . What are the values of the net electric field and the net electric potential at the origin? You may take the electric potential to be zero infinitely far from the charges.
- A)  $\Sigma \mathbf{E} = 0$  and  $\Sigma V = 0$   
 B)  $\Sigma \mathbf{E} = 0$  and  $\Sigma V = 2kq/a$   
 C)  $\Sigma \mathbf{E} = (2kq/a^2)\mathbf{i}$  and  $\Sigma V = 0$   
 D)  $\Sigma \mathbf{E} = (2kq/a^2)\mathbf{i}$  and  $\Sigma V = 2kq/a$   
 E) none of the above
56. A parallel-plate capacitor has a dielectric material inserted between the conductive plates such that it completely fills the space between the plates. The area of each plate is  $250 \text{ cm}^2$  and the plates are  $0.300 \text{ mm}$  apart. If a battery charges the capacitor to a potential difference of  $120 \text{ V}$  and places equal amounts of opposite free charge of magnitude  $150 \text{ nC}$  on each plate, then what is the magnitude of the bound charge induced on each dielectric surface?
- A)  $0.00 \text{ nC}$   
 B)  $61.5 \text{ nC}$   
 C)  $75.0 \text{ nC}$   
 D)  $88.5 \text{ nC}$   
 E)  $150 \text{ nC}$
57. An alpha particle with charge  $+2e$  travels in a circular path with a radius of  $1.25 \text{ m}$  in a uniform magnetic field with a magnitude of  $0.25 \text{ T}$ . Given that the mass of an alpha particle is  $6.65 \times 10^{-27} \text{ kg}$ , what is the period of the circular motion?
- A)  $3.3 \times 10^{-9} \text{ s}$   
 B)  $4.2 \times 10^{-8} \text{ s}$   
 C)  $1.0 \times 10^{-8} \text{ s}$   
 D)  $5.2 \times 10^{-7} \text{ s}$   
 E)  $1.7 \times 10^{-7} \text{ s}$
58. Two long, straight wires lie in a horizontal plane and carry equal currents in opposite directions. If the wire that has the current that flows east is located north of the wire that has the current that flows west, then at a point halfway between the wires in the horizontal plane what is the direction of the net magnetic field from the wires? You may neglect the magnetic field of the Earth.
- A) vertically down  
 B) vertically up  
 C) north  
 D) south  
 E) zero
59. A long, thin wire carries a current of  $10 \text{ A}$ . A long, hollow, cylindrical conductor is oriented so that it is coaxial to the wire and has an inner radius of  $1.5 \text{ mm}$  and an outer radius of  $3.0 \text{ mm}$ . The cylindrical conductor carries a current of  $12 \text{ A}$  that is uniformly distributed over its cross-sectional area and flows in the opposite direction as the current in the wire. What is the magnitude of the magnetic field at a distance of  $2.0 \text{ mm}$  from the common central axis of the wire and the cylinder?
- A)  $2.0 \times 10^{-4} \text{ T}$   
 B)  $6.9 \times 10^{-4} \text{ T}$   
 C)  $1.0 \times 10^{-3} \text{ T}$   
 D)  $2.0 \times 10^{-3} \text{ T}$   
 E)  $2.2 \times 10^{-3} \text{ T}$
60. The objective lens of a compound optical (or light) microscope has a focal length of  $22.0 \text{ mm}$ . It forms an image of a specimen at a distance of  $18.0 \text{ cm}$  beyond the focal point located on the same side as the image. How far from the objective lens is the specimen? You may neglect the thickness of the lens and use the thin lens approximation.
- A)  $2.20 \text{ cm}$   
 B)  $2.47 \text{ cm}$   
 C)  $18.0 \text{ cm}$   
 D)  $20.2 \text{ cm}$   
 E)  $44.4 \text{ cm}$

# UIL HIGH SCHOOL SCIENCE CONTEST

## Contestant Answer Sheet

Contestant # \_\_\_\_\_

9 10 11 12  
CONTESTANT GRADE LEVEL

A 2A 3A 4A 5A  
CONFERENCE

**PLEASE WRITE ANSWERS WITH CAPITAL LETTERS**

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

**BIOLOGY SCORE**

**CHEMISTRY SCORE**

**PHYSICS SCORE**

**OVERALL SCORE:**

UIL HIGH SCHOOL SCIENCE CONTEST  
ANSWER KEY

REGION • 2015

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

**PHYSICS KEY for Science Contest • Region • 2015**

41. (B) “Five classes of objects orbit our Sun. ... Beyond the outer planets is the **Kuiper Belt** of comets, a disk of small icy worlds including Pluto.”
42. (B) The quote is from Bill Nye the Science Guy® which is found in Chapter 5.
43. (A) This is not one of the IAU’s criteria for a planet as discussed in Chapter 6.
44. (B) “As is often cited (and attributed to Galileo), the stated authority of a thousand is not worth the humble reasoning of a single individual.”
45. (E) By kinematics for the first 35 s:  $(y - y_0)_1 = v_0t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(+23)(35)^2 = 1.41\text{E}+4 \text{ m}$  &  $v = v_0 + at = 0 + (+23)(35) = 805 \text{ m/s}$ . Then for the free fall part of the motion:  $(y - y_0)_2 = [v^2 - v_0^2]/[2a] = [0^2 - 805^2]/[2(-9.8)] = 3.31\text{E}+4 \text{ m} \Rightarrow h = (y - y_0)_1 + (y - y_0)_2 = 1.41\text{E}+4 + 3.31\text{E}+4 = 4.7\text{E}+4 \text{ m}$
46. (D) By  $\Delta p = (\Sigma F)_{\text{avg}}\Delta t \Rightarrow v = (26)(2)/(150) = 0.346 \text{ m/s}$
47. (D) By the formula for the dot product:  $\theta = \cos^{-1}([\mathbf{A} \cdot \mathbf{B}]/[AB]) = \cos^{-1}([(3)(-4)+(5)(3)]/[ \{(3)^2+(5)^2 \}^{1/2} \{(-4)^2+(3)^2 \}^{1/2}]) = 84^\circ$
48. (C) By the parallel axis theorem:  $I = I_{\text{com}} + Md^2 = (2/5)MR^2 + MR^2 = (7/5)MR^2$ , and  $KE_{\text{rot}} = \frac{1}{2}I\omega^2 = \frac{1}{2}[(7/5)(2.7)(0.1)^2][(50)(2\pi/60)]^2 = 0.52 \text{ J}$
49. (C) With  $\mathbf{r}(t) = [(v_0 \cos\theta)t]\mathbf{i} + [(v_0 \sin\theta)t - \frac{1}{2}gt^2]\mathbf{j} \Rightarrow \mathbf{p}(t) = m\{[(v_0 \cos\theta)]\mathbf{i} + [(v_0 \sin\theta) - gt]\mathbf{j}\} \Rightarrow \mathbf{L}(t) = \mathbf{r}(t) \times \mathbf{p}(t) = [-\frac{1}{2}mgt^2v_0 \cos\theta]\mathbf{k} \Rightarrow (d/dt)\mathbf{L}(t) = [-mgtv_0 \cos\theta]\mathbf{k}$ , which is also equal to the net torque that is produced solely by the gravitational force.
50. (B) By  $F/A = Y\Delta L/L_0 \Rightarrow L_0 = L\{F/(YA)+1\}^{-1} = (0.40)\{(47)/[\pi(0.075\text{E}-3)^2(200\text{E}+9)]+1\}^{-1} = 0.395 \text{ m}$
51. (A) By Poiseuille’s law:  $\Delta P = [(8\eta L)/(\pi r^4)]Q$ , where the volume flowrate  $Q = Av = (\pi r^2)v \Rightarrow v = [(r^2\Delta P)/(8\eta L)] = [(0.02)^2(22\text{E}+3)]/[8(1\text{E}-3)(20)] = 55 \text{ m/s}$
52. (C) The frequency that is heard is the average of the two individual frequencies  $f = (243+245)/2 = 244 \text{ Hz}$ . Note that the intensity of this frequency is modulated by the beat frequency.
53. (E) By definition the temperature of a molecular gas is the average translational kinetic energy of the molecules of the gas.
54. (E)  $Q = \int \rho(r) dV$ , where  $dV = (4\pi r^2) dr \Rightarrow Q = \int_0^R (A/r) (4\pi r^2) dr = 2\pi AR^2$
55. (B) At the midpoint between two identical charges the net electric field is zero and the electric potential from each charge add to give  $\Sigma V = 2kq/a$
56. (B) Without the dielectric  $C_0 = \epsilon_0 A/d = (8.85\text{E}-12)(250\text{E}-4)/(0.3\text{E}-3) = 8.85\text{e}-8 \text{ F}$  and thus  $Q_0 = C_0V = (8.85\text{E}-8)(120) = 88.5 \text{ nC} \Rightarrow Q_{\text{bound}} = Q - Q_0 = 150 - 88.5 = 61.5 \text{ nC}$
57. (D) By N2L in the centripetal direction:  $\Sigma F_c = F_B = |q|vB \sin 90^\circ = mv^2/r$  and with  $v = 2\pi r/T$   
 $\Rightarrow T = [2\pi m]/[|q|B] = [2\pi(6.65\text{E}-27)]/[2(1.602\text{E}-19)(0.25)] = 5.2\text{E}-7 \text{ s}$
58. (A) By the right hand circulation rule, the direction of both magnetic fields from the wires and therefore the net magnetic field is vertically down.
59. (B) By Ampere’s law:  $\int_{\text{loop}} \mathbf{B} \cdot d\mathbf{s} = \mu_0 i_{\text{enclosed}} \Rightarrow B(2\pi r) = \mu_0 \{i_{\text{wire}} - i_{\text{cylinder}}[\pi(r^2 - r_{\text{inner}}^2)]/[\pi(r_{\text{outer}}^2 - r_{\text{inner}}^2)]\}$   
 $\Rightarrow B = (4\pi\text{E}-7)/[2\pi(0.002)]\{10 - 12[(0.002^2 - 0.0015^2)/(0.003^2 - 0.0015^2)]\} = 6.9\text{E}-4 \text{ T}$
60. (B) The objective lens of a compound microscope is a converging lens that will form a real image that is then viewed by the eyepiece. Thus  $f = +2.2 \text{ cm}$  and  $d_i = 18+2.2 = +20.2 \text{ cm}$ , which by  $1/f = 1/d_o + 1/d_i \Rightarrow d_o = 2.47 \text{ cm}$