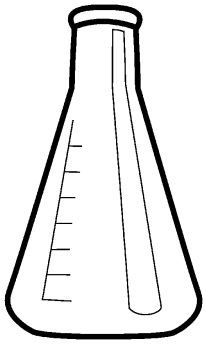
UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

Invitational A • 2019



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.

B01. All organisms within the same Order belong to the same
A) Domain.
B) Genus.
C) Family.
D) Species.
E) All of the above are correct.

B02. If an organism is homozygous recessive for a trait, which of the following is not a possible genotype of the organism's progeny?
A) AA
B) Aa
C) aa
D) Unable to determine.

B03. The light-harvesting pigments of photosynthesis in eukaryotes are typically found within
A) nuclear membranes.
B) the endoplasmic reticula.
C) the plasma membrane.
D) thylakoid membranes.
E) mitochondria.

B04. Which of the following would you not find associated with the plasma membrane of a cell?
A) Transmembrane proteins
B) Phospholipids
C) Integral proteins
D) Selective permeability
E) Ribosomes

B05. With the extinction of dinosaurs nearly 65.5 million years ago, which group of animals adapted and evolved very quickly afterwards?
A) Arthropods
B) Mammals
C) Amphibians
D) Reptiles
E) Aquatic vertebrates

B06. Which organ system has no known function in defense from microbial invaders?
A) Integumentary
B) Lymphatic
C) Immune
D) Nervous
E) All of the above have some defense function.

B07. A Mendelian monohybrid cross would yield a genotypic ratio of ____.
A) 3:1
B) 1:1
C) 1:2:1
D) 9:3:3:1
E) none of the above

B08. Which process specifically generates a protein's primary structure from an mRNA sequence?
A) Gene expression
B) Translation
C) Transcription
D) Replication
E) Transformation

B09. Which of the following is the correct order of phases during the nuclear division portion of the eukaryotic cell cycle for somatic cells?
A) Prophase, Anaphase, Metaphase, Telophase, Cytokinesis
B) Prophase I, Metaphase I, Anaphase I, Telophase I, Cytokinesis, Prophase II, Metaphase II, Anaphase II, Telophase II, Cytokinesis
C) Telophase, Anaphase, Metaphase, Prophase, Cytokinesis
D) Prophase, Metaphase, Anaphase, Telophase, Cytokinesis
E) G_1, S, G_2, mitosis

B10. DNA replication in Domain Bacteria occurs
A) within the nucleus.
B) prior to mitosis.
C) immediately prior to cell division.
D) during gene expression.
E) only for one of the DNA strands in the double helix.

B11. The field of biology that studies characteristics of organisms and attempts to classify them into specific groups is called
A) population biology.
B) phylogeny.
C) biological diversity.
D) ecology.
E) taxonomy.

B12. Consider the cell biology of eukaryotic cells. Which of the following statements is incorrect?
A) Cell walls are present in all eukaryotes.
B) The nucleus contains chromatin.
C) The mitochondria are responsible for glucose oxidation to generate ATP.
D) Lysosomes are digestive organelles.
E) The rough endoplasmic reticulum contains ribosomes.

B13. From August 2014 through September 2018, 386 cases of acute flaccid myelitis (AFM) have been confirmed by the Centers for Disease Control and Prevention (CDC), mostly in children. The cause of the disease has yet to be determined. What disease does AFM mimic?
A) chickenpox
B) measles
C) influenza
D) food poisoning
E) polio

B14. If a mutation occurred that changed a cytosine to an adenine in the DNA sequence, this would be called a
A) deletion.
B) base insertion.
C) base substitution.
D) frameshift mutation.
E) silent mutation.

B15. Organisms within the same geographic area that can mate and produce fertile offspring are part of the same
A) community.
B) population.
C) ecosystem.
D) biosphere.
E) phylum.

B16. In the water cycle, the process of carrying water through plants and exiting leaves as vapor into the atmosphere is termed
A) condensation.
B) precipitation.
C) infiltration.
D) evaporation.
E) transpiration.

B17. According to natural selection, which would occur if a phenotype in 1 out of 100 organisms provided an advantage for acquiring food and reproducing?
A) Organisms with that gene would die out.
B) Organisms with that phenotype would thrive and the allele(s) for that phenotype would increase in the population over time.
C) The phenotype in the population would remain relatively stable.
D) After several generations, the phenotype would still represent 1% in the population.
E) Since it is only 1% of the population, organisms with that phenotype would fail to pass on any useful genes.

B18. A viral disease that causes the parotid salivary glands to swell is called
A) measles.
B) roseola.
C) mumps.
D) rubella.
E) German measles.

B19. The type of tissue found lining the internal surface of the stomach is
A) muscle.
B) nervous.
C) connective.
D) epithelial.

B20. Large polymers made of amino acids that catalyze a majority of chemical reactions are called
A) enzymes.
B) ribozymes.
C) inorganic catalysts.
D) nucleic acids.
E) transmembrane proteins.

C01. What is the molar mass of the mineral magnetite, Fe_3O_4, in grams per mole?

A) 231.55
B) 34
C) 71.85
D) 271.4
E) 37.00

C02. What is the sum of the coefficients in the balanced equation for the complete combustion of butane, C_4H_{10}?

A) 4
B) 9
C) 16.5
D) 22
E) 33

C03. Which of these is the best ground state electron configuration for strontium?

A) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$
B) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^0 5s^2$
C) $1s^2\ 2s^2 p^6\ 3s^2 p^6 d^{10}\ 4s^2 p^6\ 5s^2$
D) $[Kr] 4p^6 5s^2$
E) $[Kr] 4p^6 5s^0$

C04. Which of the following compounds contains exactly one unshared pair of valence electrons?

A) BF_3
B) PH_3
C) H_2S
D) NO_2
E) CCl_4

C05. What is absolute zero (0 K) measured in degrees Fahrenheit?

A) 0
B) 32
C) –273.15
D) –459.67
E) –218.52

C06. In a mercury thermometer, why does the mercury level in the tube go up as the temperature increases?

A) Because that's how thermometers work.
B) Because heat rises, so as the mercury warms up it rises up the tube.
C) Atoms expand in size as they are heated, increasing the volume of the mercury in the tube.
D) The mercury atoms move farther apart as the temperature increases, increasing the volume of the mercury in the tube.
E) Some mercury at the bottom of the tube begins to boil, pushing the mercury above it higher up the tube.

C07. Under which of these conditions does the ideal gas law begin to fail?

A) large volume
B) high temperature
C) high pressure
D) large number of moles
E) when R is not in units of L·atm/mol·K

C08. Which chemical equation below would have the equilibrium expression $K = [A]^2[B]$

A) $2A(aq) \rightleftharpoons B(aq)$
B) $B(aq) \rightleftharpoons 2A(aq)$
C) $A_2B(aq) \rightleftharpoons 2A(aq) + B(aq)$
D) $2A(aq) + B(aq) \rightleftharpoons A_2B(s)$
E) $A_2B(s) \rightleftharpoons 2A(aq) + B(aq)$

C09. The salt concentration in the Dead Sea is 34.2%, almost ten times saltier than the open ocean. What is the boiling point elevation of Dead Sea water due to the NaCl concentration?

A) 9.11°C
B) 4.55°C
C) 2.99°C
D) 5.99°C
E) 16.5°C

C10. Which of the following are all members of the same group on the periodic table?

A) Copper, silver, gold, and platinum
B) Nitrogen, oxygen, fluorine, and neon
C) Uranium, neptunium, plutonium, and mercury
D) Carbon, silicon, tin, and lead
E) Adamantium, vibranium, dilithium, and dalekanium

C11. The reaction

$$2\ NO(g) + 2\ H_2(g) \rightarrow N_2(g) + H_2O(g)$$

is second order with respect to NO and first order with respect to H_2. What is the rate law for the reaction?

A) $\text{rate} = k\frac{[NO]^2[H_2]^2}{[N_2][H_2O]}$
B) rate = $k\ [NO]^2[H_2][N_2][H_2O]$
C) $[N_2][H_2O] = k\ [NO]^2[H_2]$
D) rate = $k\ [NO]^2[H_2]$
E) k = rate $[NO]^2[H_2]$

C12. 1026 kJ of heat increases the temperature of a sample of water at sea level from 40°C to 80°C. If 1026 kJ more heat is added, what will the final temperature of the water be?

A) 120°C because the water will continue to heat up at the same rate.
B) More than 100°C but less than 120°C because some of the heat will be used to boil the water.
C) Less than 100°C because as the water gets hotter, it takes a greater amount of heat to raise the temperature by one degree.
D) 100°C because that's the highest temperature water can reach at 1 atm pressure.
E) The water will all boil away before that much heat can be added.

C13. According to the Arrhenius definition of acids and bases, is carbon dioxide an acid, a base, or neither?

A) Neither, because CO_2 does not contain H or OH in its chemical formula.
B) Neither, because CO_2 does not have the words "acid" or "base" in its name.
C) Neither, because CO_2 is a covalent compound.
D) It is a base, because when you dissolve it in water the pH goes up.
E) It is an acid because when you dissolve it in water the pH goes down.

C14. The number of atoms in one formula unit of potassium dichromate is

A) 3
B) 8
C) 11
D) 12
E) 14

C15. What is the difference between an electrolytic cell and a galvanic cell?

A) An electrolytic cell contains electrolytes and a galvanic cell does not.
B) Galvanic cell is an older term for electrolytic cell.
C) A galvanic cell generates a positive voltage and an electrolytic cell does not.
D) Electrolytic cells give off light as well as voltage.
E) Electrolytic cells have a cell wall and galvanic cells have a cell membrane.

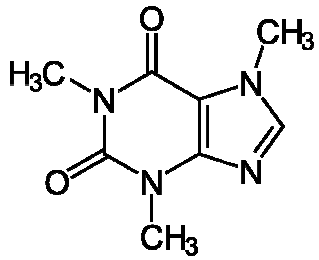
C16. Which of these is not a valid empirical formula?

A) CH
B) CH_2
C) CH_3
D) CH_4
E) C_2H_4

C17. What is the silver ion concentration in a saturated solution of silver oxalate, $Ag_2C_2O_4$? $K_{sp} = 5.4 \times 10^{-12}$.

A) 1.11×10^{-4} *M*
B) 2.21×10^{-4} *M*
C) 1.16×10^{-6} *M*
D) 1.64×10^{-6} *M*
E) 2.32×10^{-6} *M*

C18. What is the molar mass of caffeine, shown below, in grams per mole?



A) 194.22
B) 193.21
C) 169.19
D) 133.16
E) 121.14

C19. How many π bonds are in the caffeine molecule shown in question C18?

A) 3
B) 4
C) 6
D) 8
E) 12

C20. Our current periodic table lists 118 elements. Is it possible that there are still any undiscovered elements in between the elements listed in the periodic table?

A) Yes, but to avoid detection for this long they would have to exist in very small quantities or not occur on Earth at all.
B) Yes, but they would have to be totally non-reactive so they are never found in compounds.
C) Yes, but they would have to be radioactive with extremely short half-lives so they decay before they can be detected.
D) No, because all the boxes in the periodic table are already filled.
E) No, because the atomic number is the number of protons in the nucleus and we have accounted for all possibilities from 1 through 118.

P01. According to Natarajan, the Babylonians recorded the motion of a celestial object that, after two years of normal motion, would reverse its motion for about 90 days. Which celestial object were they observing?
A) Mars
B) Venus
C) The Moon
D) Jupiter
E) Mercury

P02. According to Natarajan, Cepheid variable stars can be used to measure astronomical distances out to about five million light years. However, Edwin Hubble used a different "standard candle" star to measure distances to galaxies that were even farther away. What did he use?
A) Supernovae
B) Red supergiant stars
C) Bright O and B stars
D) White dwarf stars
E) T-Tauri variable stars

P03. According to Natarajan, a modern technology that relies heavily on Einstein's theories of special and general relativity is…
A) The International Space Station.
B) Medical X-Ray devices.
C) Magnetic Resonance Imaging.
D) The Global Positioning System.
E) Atomic clocks.

P04. Which planet in our solar system has an axis of rotation that is nearly perpendicular to the axis of its orbital plane?
A) Venus
B) Mars
C) Jupiter
D) Saturn
E) Uranus

P05. An object accelerates at a rate of 285 inches/minute^2. What is this acceleration in cm/s^2?
A) 0.0312 cm/s^2
B) 0.0792 cm/s^2
C) 0.201 cm/s^2
D) 1.87 cm/s^2
E) 4.75 cm/s^2

P06. A tennis ball, initially travelling at 42.0m/s West, is returned by Serena Williams. After being hit by Serena's racquet, the ball has a velocity of 30.0m/s East. If the racquet was in contact with the ball for a total time of 0.650sec, what was the average acceleration of the ball caused by the racquet?
A) 18.5 m/s^2
B) 46.2 m/s^2
C) 64.6 m/s^2
D) 72.0 m/s^2
E) 111 m/s^2

P07. While cleaning the library, Belle pushes a 21.0kg box of books across a frictionless floor. She pushes with a force of 35.0N angled downward at 20.0° below the horizontal. What is the acceleration of the box of books?
A) 1.77 m/s^2
B) 1.67 m/s^2
C) 1.57 m/s^2
D) 0.639 m/s^2
E) 0.570 m/s^2

P08. To maintain a constant running speed, Gaston exerts a constant force of 320.0 N. If Gaston runs a total distance of 5.00km in 30.0minutes, what is Gaston's average power output?
A) 1600 W
B) 889 W
C) 470 W
D) 167 W
E) 53.3 W

P09. A meter stick is hung horizontally with a pivot exactly at the stick's center of mass (the 50.0cm mark). A 150.0g object is attached to the meter stick at the 30.0cm mark and is balanced by another object (of unknown mass) attached at the 90.0cm mark. What is the mass of the unknown object?
A) 300 g
B) 150 g
C) 113 g
D) 75.0 g
E) 50.0 g

P10. A 500.0g mass is hung from a spring. When pulled and released, the mass on the spring oscillates with a period of 0.390sec. What is the spring constant of the spring?
A) 130 N/m
B) 83.3 N/m
C) 32.2 N/m
D) 8.06 N/m
E) 3.29 N/m

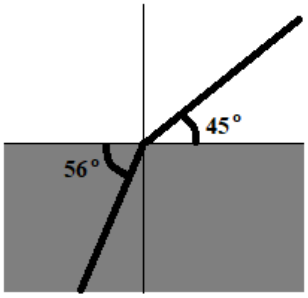
P11. You dive into a vat of cooking oil (which has a density of 0.91g/cm^3) to retrieve your dropped cell phone. The depth of the oil is 3.80m. What is the gauge pressure at the bottom of the vat?
A) 0.237 atm
B) 0.335 atm
C) 0.368 atm
D) 0.404 atm
E) 0.473 atm

P12. Two resistors, a 27.0Ω and a 47.0Ω, are placed in series and connected to a 12.0V battery. Once connected, what is the current passing through the 27.0Ω resistor?
A) 700 mA
B) 600 mA
C) 444 mA
D) 255 mA
E) 162 mA

P13. A balloon holding a charge of -12.0nC is placed with its center 45.0cm from the center of a Van de Graff generator with a charge of +90.0μC. What is the magnitude of the electric force on the balloon?
A) 0.022 N
B) 0.040 N
C) 0.048 N
D) 0.053 N
E) 0.097 N

P14. A beam of electrons moving at a velocity of 4.50×10^5 m/s is directed into a region with a perpendicular magnetic field. If the electron beam traces out a circle with a radius of 22.0cm, then what is the magnitude of the magnetic field?
A) 8.62 μT
B) 11.6 μT
C) 14.7 μT
D) 21.3 μT
E) 27.8 μT

P15. A light ray travelling in air enters an unknown liquid at an angle of 45.0° with respect to the liquid's surface (as shown). The refracted ray makes an angle of 56.0° with respect to the liquid's surface. What is the index of refraction of the unknown liquid?



A) 1.79
B) 1.41
C) 1.26
D) 1.17
E) 0.85

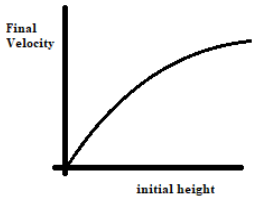
P16. A converging lens is used to form an image of a neon sign. The sign is 2.20m from the lens, and the focal length of the lens is 80.0cm. At what distance from the lens is the image formed?
A) 3.46 m
B) 2.26 m
C) 1.40 m
D) 1.26 m
E) 0.59 m

P17. A hydrogen atom is excited into the $n = 5$ state. It subsequently transitions down to the $n = 3$ state. What is the wavelength of the photon emitted in this transition?
A) 2280 nm
B) 1282 nm
C) 821 nm
D) 683 nm
E) 603 nm

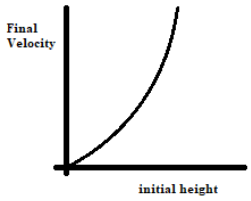
P18. A subatomic particle classified as a meson, such as the pion, is composed of …
A) three quarks
B) two quarks
C) a quark and an anti-quark
D) a quark and a lepton
E) and anti-quark and a lepton

P19. You do an experiment in which you drop an object from different heights and measure the final velocity of the object when it reaches the ground. The object is always at rest when it is released. You then graph the final velocity, v, as a function of the initial height, h. What would you expect the graph to look like?

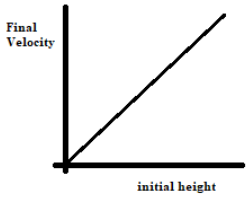
A)



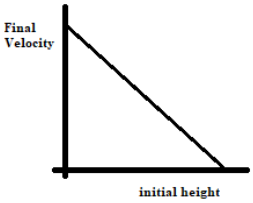
B)



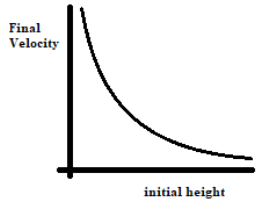
C)



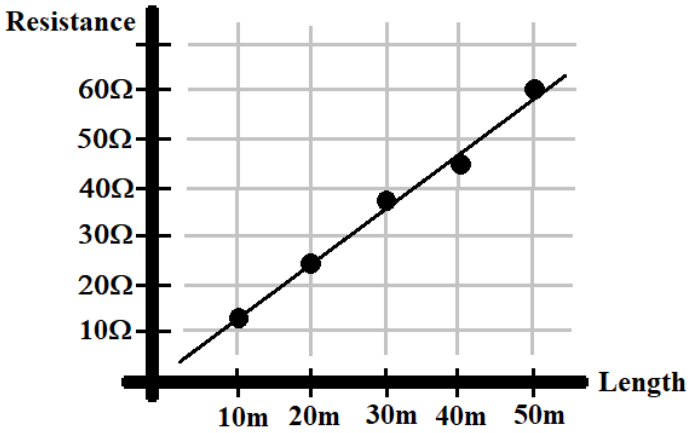
D)



E)



P20. The resistance of a type of wire is measured as a function of its length. Based on the graph of the data, and knowing that the diameter of the wire is 0.40mm, determine the resistivity of the wire metal.



A) 5.8×10^{-7} Ωm
B) 4.4×10^{-7} Ωm
C) 2.9×10^{-7} Ωm
D) 1.4×10^{-7} Ωm
E) 1.1×10^{-7} Ωm

Chemistry

1A 1												3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1 H 1.01	2A 2																2 He 4.00
3 Li 6.94	4 Be 9.01											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	8	8B 9	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 65.38	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 138.9	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 (281)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (293)	118 Og (294)

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
90 Th 232.0	91 Pa 231.0	92 U 238.0	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)

<u>Water Data</u>

T_{mp} = 0°C
T_{bp} = 100°C
c_{ice} = 2.09 J/g·K
c_{water} = 4.184 J/g·K
c_{steam} = 2.03 J/g·K
ΔH_{fus} = 334 J/g
ΔH_{vap} = 2260 J/g
K_f = 1.86 °C/*m*
K_b = 0.512 °C/*m*

<u>Constants</u>

R = 0.08206 L·atm/mol·K
R = 8.314 J/mol·K
R = 62.36 L·torr/mol·K
e = 1.602×10^{-19} C
N_A = 6.022×10^{23} mol^{-1}
k = 1.38×10^{-23} J/K
h = 6.626×10^{-34} J·s
c = 3.00×10^{8} m/s
R_H = 2.178×10^{-18} J
m_e = 9.11×10^{-31} kg

Physics

Useful Constants

quantity	symbol	value
Free-fall acceleration	g	$9.80\ m/s^2$
Permittivity of Free Space	ε_0	$8.854 \times 10^{-12}\ C^2/Nm^2$
Permeability of Free Space	μ_0	$4\pi \times 10^{-7}\ Tm/A$
Coulomb constant	k	$8.99 \times 10^{9}\ Nm^2/C^2$
Speed of light in a vacuum	c	$3.00 \times 10^{8}\ m/s$
Fundamental charge	e	$1.602 \times 10^{-19}\ C$
Planck's constant	h	$6.626 \times 10^{-34}\ Js$
Electron mass	m_e	$9.11 \times 10^{-31}\ kg$
Proton mass	m_p	$1.67265 \times 10^{-27}\ kg$
Neutron mass	m_n	$1.67495 \times 10^{-27}\ kg$
Atomic Mass Unit	u	$1.66 \times 10^{-27}\ kg$
Gravitational constant	G	$6.67 \times 10^{-11}\ Nm^2/kg^2$
Stefan-Boltzmann constant	σ	$5.67 \times 10^{-8}\ W/m^2K^4$
Universal gas constant	R	$8.314\ J/mol \cdot K$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\ J/K$
Speed of Sound (at 20ºC)	v	343 m/s
Avogadro's number	N_A	$6.022 \times 10^{23}\ atoms/mol$
Electron Volts	eV	$1.602 \times 10^{-19}\ J/eV$
Distance Conversion	Meters → inches	1.00 meter = 39.37 inches
Rydberg Constant	R_∞	$1.097 \times 10^{7}\ m^{-1}$
Standard Atmospheric Pressure	1 atm	$1.013 \times 10^{5}\ Pa$

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2019 INVITATIONAL A

Biology	Chemistry	Physics
B01. A	C01. A	P01. A
B02. A	C02. E	P02. C
B03. D	C03. A	P03. D
B04. E	C04. B	P04. E
B05. B	C05. D	P05. C
B06. D	C06. D	P06. E
B07. C	C07. C	P07. C
B08. B	C08. E	P08. B
B09. D	C09. A	P09. D
B10. C	C10. D	P10. A
B11. E	C11. D	P11. B
B12. A	C12. D	P12. E
B13. E	C13. E	P13. C
B14. C	C14. C	P14. B
B15. B	C15. C	P15. C
B16. E	C16. E	P16. D
B17. B	C17. B	P17. B
B18. C	C18. A	P18. C
B19. D	C19. B	P19. A
B20. A	C20. E	P20. D

CHEMISTRY SOLUTIONS – UIL INVITATIONAL A 2019

C01. (A) The molar mass = (3 × 55.85) + (4 × 16.00) = 231.55 g/mol

C02. (E) $2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$

C03. (A)

C04. (B)

C05. (D)

C06. (D)

C07. (C) At high pressures and at low temperatures intermolecular forces become significant and a gas behaves less like an ideal gas.

C08. (E) $A_2B(s)$ is not included in the equilibrium expression because it is a solid.

C09. (A) $\Delta T_b = ik_bm$. i for NaCl = 2, k_b = 0.512 °C/m, m = moles NaCl/kg solvent.
Assume 100.0 g of Dead Sea water. At 34.2% NaCl, 100 g of Dead Sea water contains 34.2 g NaCl and 65.8 g H_2O. Moles of NaCl = (34.2 g)/(58.44 g/mol) = 0.5852 moles.
m = (0.5852 mol NaCl)/(0.0658 kg H_2O) = 8.894 mol/kg
$\Delta T_b = ik_bm$. = (2)(0.512°C/m)(8.894 m) = 9.11°C.

C10. (D) Carbon, silicon, tin, and lead are all in Group 14 (IVA) in the periodic table.

C11. (D)

C12. (D)

C13. (E)

C14. (C) Potassium dichromate is $K_2Cr_2O_7$.

C15. (C)

C16. (E) C_2H_4 is not a valid empirical formula because the subscripts can be reduced to CH_2 without changing their ratio.

C17. (B) $K_{sp} = 5.4 \times 10^{-12} = [Ag^+]^2[C_2H_4^{2-}]$ Let $[C_2H_4^{2-}] = x$. $[Ag^+] = 2 \times [C_2H_4^{2-}] = 2x$.
$5.4 \times 10^{-12} = [2x]^2[x] = 4x^3$. $x = 1.105 \times 10^{-4}$, so $[Ag^+] = 2.21 \times 10^{-4}\ M$

C18. (A) The chemical formula is $C_8H_{10}N_4O_2$, so the molar mass is 194.22 g/mol.

C19. (B) Each single bond is a sigma bond, and each double bond is made up of one sigma bond and one pi bond.

C20. (E)

PHYSICS SOLUTIONS – UIL INVITATIONAL A 2019

P01. (A) page 4: "The strangest thing was that about every two years it reversed its motion entirely for some ninety days and then switched back to its eastward journey. The Babylonians recorded this object and its peculiar backpedaling. We now understand this apparent motion of Mars to be a result of … "

P02. (C) page 52: "Cepheids could not be spotted easily and studied if they lay beyond about five million light-years, even with the unprecedented reach of the hundred-inch telescope. Hubble pushed out farther by using classes of some of the brightest stars – the O and B stars – as standard candles."

P03. (D) page 76: "He [Einstein] could not have anticipated our current reliance on his theory of general relativity to get our bearings. GPS [Global Positioning System] technology is built entirely on Einsteinian gravity…. This is no mean task, as it requires taking into account corrections predicted by both of Einstein's theories – the special and the general theory of relativity."

P04. (E) The obliquity of a planet is the angle between the axis of the orbital plane of the planet and the axis of rotation of the planet. These angles are usually small: for example, the Earth's obliquity is about 23° (this is responsible for the seasons we experience). Uranus, however, has an obliquity of 98° -- its axis of rotation is very nearly perpendicular to the axis of its orbital plane. It essentially rotates "on its side".

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P05. (C) This is a simple, though multi-step conversion:

$$285\,\frac{inches}{minute^2} * 2.54\,\frac{cm}{inch} * \left(\frac{1\ minute}{60\ seconds}\right)^2 = 0.201\,\frac{cm}{s^2}$$

P06. (E) Average acceleration is defined as the change in velocity divided by the change in time. In other words: $\bar{a} = \frac{\Delta v}{\Delta t}$. Considering the direction East to be positive, then we have an initial velocity that is negative and a final velocity that is positive: $v_i = -42.0$ m/s and $v_f = +30.0$ m/s. Then $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{(30-(-42))}{0.65} = 111$ m/s^2.

P07. (C) Since the floor is frictionless, we only have three forces present: gravity (downward), the normal force (upward), and the applied force (angled at 20.0° below the horizontal). We must first break up the applied force into horizontal and vertical components: $A_x = Acos\theta = (35.0)\cos(20.0) = 32.9\ N$ and $A_y = Asin\theta = (35.0)\sin(20.0) = 12.0\ N$.

The box only slides horizontally, so all of the vertical forces cancel out: $\sum F_y = F_N - mg - A_y = 0$. Since there is no vertical acceleration, we need look at that direction no more. Now, considering the horizontal forces, we have only one: $\sum F_x = A_x = 32.9 = ma = 21.0a$. Solving for acceleration: $a = \frac{32.9}{21.0} = 1.57$ m/s^2.

P08. (B) First, consider the work done by Gaston: $W = Fd = (320N)(5000m) = 1.60 \times 10^6\ J$. Now we can calculate his power output, which is work divided by time: $P = \frac{W}{t} = \frac{1.60 \times 10^6\ J}{30\ minutes} = \frac{1.60 \times 10^6\ J}{1800\ seconds} = 889\ W$.

P09. (D) Since it is balanced, we know that the torques must sum to zero. The torques in each case equal the force (mg) multiplied by the "torque arm". Torque arms are measure from the pivot, which is at the 50.0cm mark. Thus, $r_1 = 50 - 30 = 20.0cm = 0.200m$. The other torque arm is $r_2 = 90 - 50 = 40.0cm = 0.400m$. Conveniently, the forces are perpendicular to the meter stick, so we don't need to worry about any angles. Also, one torque is directed clockwise (negative) and the other counterclockwise (positive). Thus, the total torque due to the two hanging masses is: $\sum \tau = m_1 g r_1 - m_2 g r_2 = 0$. Plugging in values and solving: $(.150kg)(9.8)(0.200m) - (m_2)(9.8)(0.400m) = 0$, or $m_2 = \frac{(0.150)(9.8)(0.200)}{(9.8)(0.400)} = 0.075kg = 75.0g$.

P10. (A) The period of oscillation of a mass-spring system is $T = 2\pi\sqrt{\frac{m}{k}}$. Plugging in the given values:

$T = 0.390 = 2\pi\sqrt{\frac{0.500kg}{k}}$, This gives: $0.06207 = \sqrt{\frac{0.500kg}{k}}$, and $259.6 = \frac{k}{0.500}$. So, $k = 129.8 \approx 130$N/m.

P11. (B) Gauge pressure means that we get to ignore the pressure caused by the atmosphere – we need only consider the pressure created by the oil. We do need to convert the units on the density given. $\rho = 0.91\frac{g}{cm^3} = 910\frac{kg}{m^3}$. The pressure due to depth in a stationary fluid is given by: $P = \rho gh$. So, $P = (910)(9.8)(3.80) = 33890\ Pa$. Converting to atmospheres: $P = \frac{33890Pa}{101300Pa/atm} = 0.335\ atm$.

P12. (E) Resistors in series combine by simply adding them, so the total resistance in the circuit is $R_0 = R_1 + R_2 = 27.0 + 47.0 = 74.0\ \Omega$. Then using Ohm's Law, we can get the total current: $I_0 = \frac{V_0}{R_0} = \frac{12.0}{74.0} = 0.162A = 162\ mA$. For a series circuit, the current in each resistor is the same as the total current, so $I_1 = I_2 = I_0 = 162mA$.

P13. (C) Utilizing Coulomb's Law: $F = \frac{kQ_1Q_2}{r^2} = \frac{(8.99\times10^9)(-12.0\times10^{-9})(90.0\times10^{-6})}{(0.450)^2} = -0.048\ N$. The negative sign indicates the force is attractive, but the magnitude of the force is just: $|F| = 0.048\ N$.

P14. (B) The velocity and the magnetic field are perpendicular, so we can use the following equation for the radius of the circle traced by the beam: $r = \frac{mv}{|q|B}$. The beam is made of electrons, whose mass and charge are known. Thus, $r = 0.220 = \frac{(9.11\times10^{-31})(4.50\times10^5)}{(1.602\times10^{-19})B}$, which gives: $B = \frac{4.10\times10^{-25}}{3.52\times10^{-20}} = 1.16\ \times\ 10^{-5}\ T = 11.6\ \mu T$.

P15. (C) This is a simple Snell's Law problem, but the angles given are not the ones to use. We need the angles from the normal – the angles from the line perpendicular to the surface. It happens to be the same for the incident angle, but not for the refracted angle: $\theta_i = 90.0° - 45.0° = 45.0°$, and $\theta_r = 90.0° - 56.0° = 34.0°$. Now we can use Snell's Law: $n_i sin\theta_i = n_r sin\theta_r = (1.00)\sin(45.0) = n_r \sin(34.0)$. This gives: $n_r = \frac{0.7071}{0.5592} = 1.26$.

P16. (D) Since the lens is converging, the focal length is positive. Using the lens equation: $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, we can get the image location, q. Putting everything in meters: $\frac{1}{2.20} + \frac{1}{q} = \frac{1}{0.800}$. Solving gives $\frac{1}{q} = 0.795$, or $q = 1.26m$.

P17. (B) First, we should find the energy difference between the levels involved in this transition. There are various formulas for this, but one of the easiest is: $\Delta E = (13.6\ eV)\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$. For $n_i = 5$ and $n_f = 3$ we get an energy difference of $\Delta E = (13.6)\left(\frac{1}{9} - \frac{1}{25}\right) = 0.967\ eV$. Now the wavelength of the photon with this energy can be found by using: $\lambda = \frac{1240\ eV\cdot nm}{\Delta E} = \frac{1240}{0.967} = 1282\ nm$.

P18. (C) Mesons are subatomic particles that consist of one quark bonded with one anti-quark. For example, a positive pion is composed of an up-quark and an anti-down-quark.
A combination of three quarks is classified as a Baryon (for example, a proton). The other combinations (two quarks, a quark and a lepton, or an anti-quark and a lepton) are not color-neutral combinations, and thus would not be allowed to exist due to the nature of the strong force.

P19. (A) We can analyze this experiment using conservation of energy. When the object is released, it has gravitational potential energy. When it reaches the ground, it has kinetic energy. Ignoring air resistance, we would set these two energies equal: $GPE = mgh = KE = \frac{1}{2}mv^2$. Solving for velocity gives us the formula: $v = \sqrt{2gh}$. So, a graph of velocity as a function of height would give a graph resembling $y = \sqrt{x}$. The only choice resembling this kind of curve is choice A.

P20. (D) The resistance depends on the length of the wire according to the equation $R = \rho\frac{L}{A}$. The graph of resistance, R, as a function of length, L is linear as expected. Furthermore, we see from examining the equation that the line should have a slope equal to $slope = \frac{\rho}{A}$. We have the diameter, so we can calculate the radius, and the cross-sectional area of the wire: $A = \pi r^2 = \pi(0.200\ \times\ 10^{-3})^2 = 1.26\ \times\ 10^{-7}$ m^2. We can also go to the graph and determine the slope: $slope \approx \frac{(58\Omega - 12\Omega)}{(50m - 10m)} = \frac{46\Omega}{40m} = 1.15\frac{\Omega}{m}$. Then, solving for resistivity, we get: $\rho = (slope)A = (1.15)(1.26\ \times\ 10^{-7}) = 1.4\ \times\ 10^{-7}\ \Omega m$.

UIL Science Contest Answer Sheet

Conference _____ **Grade Level** _____ **Contestant #** _____

Biology	Chemistry	Physics
B01 _____	C01 _____	P01 _____
B02 _____	C02 _____	P02 _____
B03 _____	C03 _____	P03 _____
B04 _____	C04 _____	P04 _____
B05 _____	C05 _____	P05 _____
B06 _____	C06 _____	P06 _____
B07 _____	C07 _____	P07 _____
B08 _____	C08 _____	P08 _____
B09 _____	C09 _____	P09 _____
B10 _____	C10 _____	P10 _____
B11 _____	C11 _____	P11 _____
B12 _____	C12 _____	P12 _____
B13 _____	C13 _____	P13 _____
B14 _____	C14 _____	P14 _____
B15 _____	C15 _____	P15 _____
B16 _____	C16 _____	P16 _____
B17 _____	C17 _____	P17 _____
B18 _____	C18 _____	P18 _____
B19 _____	C19 _____	P19 _____
B20 _____	C20 _____	P20 _____
B Score ☐	**C Score** ☐	**P Score** ☐

Grader Initials _____ _____ _____ **OVERALL SCORE** ☐