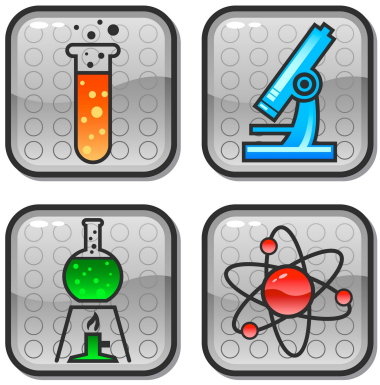
UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

Invitational A • 2021



GENERAL DIRECTIONS:

- **DO NOT OPEN EXAM UNTIL TOLD TO DO SO.**
- Contestants may take up to two hours to complete the contest. 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. Write clearly and legibly!
- You may place as many notations as you desire anywhere on the test paper but not 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.
- The back two pages of this test include a copy of the periodic table of the elements, as well as listings of other scientific relationships. You may use this information during the contest and may detach the back page from the test if you wish.
- A simple scientific calculator is sufficient for the high school Science contest. **The UIL provides a list of approved calculators that meet the criteria for use in the Science contest. No other calculators are permitted during the contest.** The Science Contest Approved Calculator List is available in the current Science Contest Handbook and on the UIL website. Contest directors will perform a brief visual inspection to confirm that all contestants are using only approved calculators. Each contestant may use up to two approved calculators during the contest.

B01. The electron acceptor during the light-dependent reactions of oxygenic photosynthesis is
A) NADPH.
B) $NADP^+$.
C) water.
D) ATP.
E) oxygen.

B02. The organisms that cause malaria, amoebic dysentery, primary amoebic meningoencephalitis, and African sleeping sickness are
A) prokaryotic.
B) protozoa.
C) worms.
D) transmitted via vectors.
E) fungi.

B03. When the ranges of two closely-related species overlap,
A) hybridization can occur.
B) genetic diversity decreases.
C) speciation always occurs.
D) natural selection no longer applies.
E) adaptive radiation will generate new species.

B04. Which of the following is important for skeletal muscle contraction?
A) calcium
B) myosin
C) actin
D) ATP
E) All of the above are important in muscle fiber contraction.

B05. The directed movement of organisms towards an attractant is called
A) conditioning.
B) kinesis.
C) turgor.
D) taxis.
E) a learned response.

B06. Prokaryotic ribosomes contain a ____ large subunit and a _____ small subunit.
A) 80S; 80S
B) 70S; 70S
C) 50S; 30S
D) 60S; 40S
E) 23S; 5S

B07. In terms of biological hierarchy, which scenario most accurately represents a population?
A) A stand of related pine trees.
B) All of the living organisms and their environment in coastal regions.
C) An entire multicellular organism.
D) Plants and animals interacting within a forest.
E) The oceans and land masses of Earth.

B08. RNA polymerase recognizes a/an _____ and begins the process of
A) origin; replication.
B) Shine-Dalgarno; translation.
C) promoter; transcription.
D) promoter; translation.
E) activator site; transcription.

B09. In 1995, 31 wolves were reintroduced into the Greater Yellowstone Ecosystem where they had been missing since the last pack was killed in 1926. The goal of the wolf reintroduction was to increase biodiversity, which it has. This example best demonstrates that the reintroduction of a/an _____ has a significant impact on biodiversity, ecosystem dynamics, and even geology of the region.
A) apex predator
B) secondary consumer
C) prey
D) primary producer
E) hybrid species

B10. In October 2020, the Centers for Disease and Prevention and the U.S. Department of Agriculture's Food Safety and Inspection Service began investigating a multistate outbreak of Listeria monocytogenes linked to
A) spinach.
B) onions.
C) ice cream.
D) milk.
E) deli meats.

B11. Scientists examine layers of rock and sediment that contain fossils. Usually the layer on the bottom
A) contains the fossils that formed most recently.
B) only includes the dinosaurs.
C) represents the oldest fossils.
D) only includes the fossils of mammals.
E) never contains fossils.

B12. The role of leukocytes in the body is to
A) clot blood.
B) transport respiratory gases.
C) store carbohydrates.
D) fight infection.
E) generate more blood cells.

B13. If red (R) is dominant to white (r), what percentage of offspring will be red in the second filial generation (F_2) from the following cross?

RR x rr

A) 0%
B) 25%
C) 50%
D) 75%
E) 100%

B14. Which of the following statements about linked genes is not correct?
A) The distance between linked genes can be measured by recombination frequencies.
B) Linked genes are present, usually very close, on the same chromosome.
C) Linked gene assort independently.
D) Linked genes, more often than not, end up in the same gamete during meiosis.
E) All of the above are correct statements.

B15. Which of the following eukaryotic organelles functions in lipid and steroid biosynthesis?
A) mitochondria
B) Golgi apparatus
C) Lysosomes
D) Rough endoplasmic reticulum
E) Smooth endoplasmic reticulum

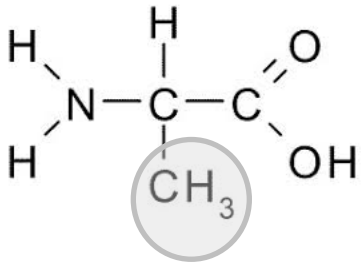
B16. A ribosome is to proteins as _____ is to DNA.
A) RNA polymerase
B) DNA polymerase
C) DNA helicase
D) a nucleus
E) replication

B17. Leguminous plants have root nodules that house soil-dwelling bacteria that
A) reduce nitrate to nitrite.
B) fix dinitrogen gas from the atmosphere.
C) undergo denitrification.
D) undergo anaerobic ammonia oxidation (anammox).
E) decompose plant waste products.

B18. In a virus replication cycle, which of the following actions would best demonstrate the role of host and tissue specificity?
A) Assembly and maturation of virions.
B) Biosynthesis of nucleic acids and proteins.
C) Injection of genetic material into the host cell.
D) Attachment to host cell receptors.
E) Release of mature virions.

B19. A DNA binding protein that binds to a sequence located in between the promoter and the start of the gene's coding sequence (ATG) would most likely be involved in
A) repressing transcription.
B) activating transcription.
C) repressing translation.
D) activating translation.
E) positive control.

B20. The functional group identified by the circle is a/an



A) amino.
B) carboxyl.
C) alcohol.
D) ester.
E) methyl.

C01. In 1793, the first U.S. coin ever minted, known as the *chain cent* or *flowing hair cent*, was just over an inch in diameter, was made of solid copper, and had a mass of 13.5 grams (more than twice the weight of a modern quarter). How many copper atoms were in a chain cent?

A) 5.17×10^{26}
B) 2.83×10^{24}
C) 6.02×10^{23}
D) 1.35×10^{23}
E) 1.28×10^{23}

C02. Which subshell is next highest in energy after the 3*d* subshell?

A) 4*d*
B) 4*s*
C) 3*p*
D) 4*p*
E) 3*f*

C03. How many total electrons are shared in the bonds of a methane molecule?

A) 12
B) 8
C) 6
D) 4
E) 2

C04. What is the volume of 2.6 moles of neon gas at 1 atm pressure and 85 °C?

A) 18.1 L
B) 34.0 L
C) 76.4 L
D) 97.7 L
E) 212.5 L

C05. When solid carbon dioxide (dry ice) sublimates to vapor, what type of intermolecular force must be overcome?

A) hydrogen bonds
B) thermochemical bonds
C) dipole-dipole forces
D) dispersion forces
E) ion-ion attractions

C06. If 65 g of acetylene, C_2H_2, is completely combusted, how many moles of CO_2 would be produced?

A) 5.0
B) 8.7
C) 4.3
D) 2.5
E) 1.3

C07. What are the signs on ΔH and ΔS when solid carbon dioxide (dry ice) sublimates to CO_2 gas?

A) $\Delta H > 0$ and $\Delta S > 0$
B) $\Delta H < 0$ and $\Delta S < 0$
C) $\Delta H < 0$ and $\Delta S > 0$
D) $\Delta H > 0$ and $\Delta S < 0$
E) $\Delta H < 0$ and $\Delta S = 0$

C08. If the following gas phase reaction is at equilibrium and you reduce the volume of the container at constant temperature, what will happen to the reaction?

$$A_2 + 3\ B_2 \rightleftharpoons 2\ AB_3$$

A) More product will be formed
B) More reactants will be formed
C) There will be no change
D) The reaction will stop
E) All of the A_2 will be used up

C09. What volume of 0.325 M HCl is required to neutralize 65.0 mL of 0.750 M NaOH?

A) 50.0 mL
B) 75.0 mL
C) 100 mL
D) 125 mL
E) 150 mL

C10. If the molar solubility of CaF_2 is 0.0011 M, what is the K_{sp} for CaF_2?

A) 2.4×10^{-6}
B) 1.3×10^{-9}
C) 5.3×10^{-9}
D) 1.2×10^{-6}
E) 5.3×10^{-6}

C11. An electrochemical cell has two electrodes, called the

A) inlet and outlet
B) input and output
C) negatode and positode
D) anode and cathode
E) diode and triode

C12. What is the rate law for this reaction, given the reaction mechanism below?

Overall reaction $A_2 + B_2 \rightarrow 2AB$

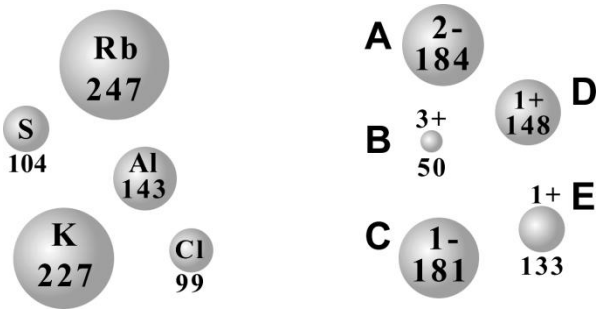
Step 1: $A_2 \rightarrow 2A$ (*slow*)
Step 2: $A + B_2 \rightarrow AB + B$ (*fast*)
Step 3: $A + B \rightarrow AB$ (*fast*)

A) rate = $k[A_2]$
B) rate = $k[A_2][B_2]$
C) rate = $k[B_2]$
D) rate = $k[A][B_2]$
E) rate = $k[A][B]$

C13. What is the mass percent silver in AgCl?

A) 88.15
B) 73.44
C) 50.00
D) 68.34
E) 75.27

C14. This image shows the radii (in pm) of five neutral atoms on the left, along with the radii of their monatomic ions on the right. Which ionic radius on the right corresponds to potassium?



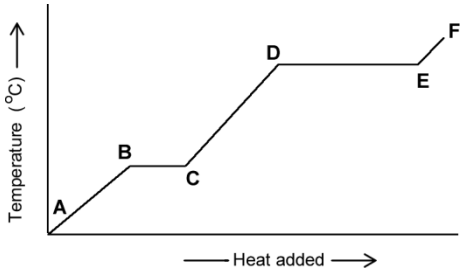
A) A
B) B
C) C
D) D
E) E

C15. What is the sum of the coefficients when this chemical equation is balanced?

$Na_2CO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

A) 5
B) 7
C) 9
D) 11
E) 13

C16. The following graph is a heating curve for an unknown substance, X. Where on this graph could you find liquid X?



A) C–D only
B) A–B, C–D, and E–F
C) B–C and D–E
D) B–C, C–D, and D–E
E) A–E but not E–F

C17. If you heat up a sample of gas in a thick-walled metal canister, which of the below effects will occur?

1. The pressure will increase
2. The volume will increase
3. The number of gas molecules will increase
4. The gas law constant *R* will increase
5. The temperature will increase
6. The average speed of the gas molecules will increase
7. The mass of the sample will increase

A) 1, 2, and 5
B) 1, 5, and 6
C) 2 and 5
D) 1 and 2
E) All except #4

C18. Which of these elements is a transition metal?
A) Copper
B) Tin
C) Lead
D) Magnesium
E) Radium

C19. As a covalent compound, gaseous H_2S is named dihydrogen monosulfide, or often just hydrogen sulfide gas. What is the name for this compound when it is considered an acid?

A) Sulfuric acid
B) Sulfurous acid
C) Hydrosulfuric acid
D) Hydrosulfurous acid
E) Hydrogen sulfide acid

C20. The combustion of 190.3 g of carbon disulfide gives off 4217.4 kJ of heat. What is the heat of combustion for CS_2?

A) 22.16 kJ/mol
B) –1688 kJ/mol
C) 1688 kJ/mol
D) –976.7 kJ/mol
E) 976.7 kJ/mol

P01. According to Rovelli, the General Theory of Relativity, published by Einstein in 1915, is fundamentally a theory of _____.
A) Electromagnetism
B) Waves
C) Thermodynamics
D) Motion
E) Gravity

P02. According to Rovelli, Einstein's equation shows that the expansion of space must have been triggered by the explosion of a young, extremely small, and extremely hot universe: what we now know as the 'Big Bang'. This prediction wasn't widely accepted until the discovery of…
A) time dilation.
B) the cosmic background radiation.
C) the bending of light around the Sun.
D) the electromagnetic field.
E) black holes.

P03. According to Rovelli, two great physicists carried on a dialogue for years about the validity and nature of quantum theory. Who were they?
A) Bohr and Einstein
B) Bohr and Heisenberg
C) Einstein and Heisenberg
D) Einstein and Planck
E) Heisenberg and Planck

P04. The final manned mission to the Moon included astronaut Gene Cernan, who was the last human on the Moon. In what year did this mission occur?
A) 1969
B) 1972
C) 1982
D) 1995
E) 2003

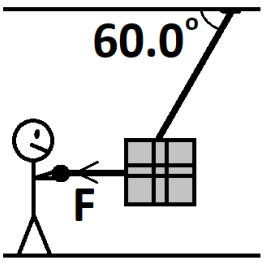
P05. In this equation, v is given in [meters/second], m is in [kilograms], and t is in [seconds]. What are the units of Z?

$$Z = \frac{mv}{t}$$

A) [Newtons]
B) [Joules]
C) [Newtons / meter]
D) [kilogram * meter / second]
E) [Watts]

P06. A horse-drawn chariot is moving at 12.0m/s when it encounters a rough stretch of road. The driver directs the horses to slow down, reducing the speed of the chariot to 5.00m/s. While it is slowing down, the chariot travels a distance of 45.0m. What is the acceleration of the chariot while it is slowing down?
A) -0.78 m/s^2
B) -0.95 m/s^2
C) -1.32 m/s^2
D) -1.56 m/s^2
E) -2.78 m/s^2

P07. A heavy crate with a mass of 190.0kg is hanging from a cable attached to the ceiling. The crate is pulled to one side by a factory worker using a horizontal chain (as shown). What is the force, F, exerted by the factory worker?



A) 1080 N
B) 1860 N
C) 2150 N
D) 3230 N
E) 3720 N

P08. You are lying on the ground, in a grassy field, in the shade of a large oak tree. You throw a baseball directly upward and notice that the ball just barely reaches the top branch of the oak before coming back down. Knowing that the branch is 12.5m above the ground, determine the speed with which you initially threw the baseball.
A) 5.00 m/s
B) 7.83 m/s
C) 11.1 m/s
D) 15.7 m/s
E) 22.1 m/s

P09. A power drill is used to spin a disk saw. To work properly, the disk saw needs to spin at an angular speed of 600.0 rpm. The drill can provide an angular acceleration of 35.0 rad/s^2. Starting from rest, how long will it take for the drill to bring the saw up to the proper angular speed?

A) 0.285 sec.
B) 1.80 sec.
C) 2.72 sec.
D) 8.55 sec.
E) 17.1 sec.

P10. A 50.0kg child sits on a swing that is held by chains that are 2.20m long. You have the task of pushing the child each time that she swings back to you. How many times per minute must you push the swinging child?

A) 45 pushes/minute
B) 40 pushes/minute
C) 28 pushes/minute
D) 20 pushes/minute
E) 14 pushes/minute

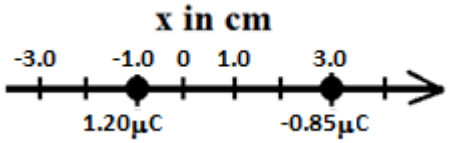
P11. A plastic toy floats in methanol (a liquid with a density of 792 kg/m^3). Approximately 20% of the toy shows above the surface of the liquid. What is the density of the plastic toy?

A) 792 kg/m^3
B) 634 kg/m^3
C) 475 kg/m^3
D) 317 kg/m^3
E) 158 kg/m^3

P12. You are testing a potato slice for electrical conductivity. The potato slice is 14.5cm long and has a square cross section that is 0.40cm by 0.40cm. When connected to a 12.0V power supply, the current flowing through the potato slice is 127μA. What is the resistivity of the potato slice?

A) 0.117 Ωm
B) 1.06 Ωm
C) 10.4 Ωm
D) 26.1 Ωm
E) 94.5 Ωm

P13. Two charges are located as shown. A 1.20μC charge is at x = -1.0cm, and a -0.85μC charge is at x = +3.0cm. What is the electric potential at the origin (x = 0) due to these two charges?



A) 2.25×10^5 V
B) 8.24×10^5 V
C) 9.94×10^5 V
D) 1.08×10^6 V
E) 1.33×10^6 V

P14. A ferromagnetic material that is exposed to an external magnetic field can become permanently magnetized. This permanent magnetization can be removed by _____.

A) heating the material to a high temperature.
B) cooling the material to a low temperature.
C) exposing the material to infrared light.
D) exposing the material to X-rays.
E) flowing a DC current through the material.

P15. A vertically polarized laser beam has an intensity of 600.0 W/m^2. The beam passes through a polarizer whose polarization axis is oriented at an angle of 40.0° with respect to vertical. What is the intensity of the beam after it passes through the polarizer?

A) 500 W/m^2
B) 460 W/m^2
C) 390 W/m^2
D) 350 W/m^2
E) 250 W/m^2

P16. A candle is placed 27.0cm in front of a concave mirror. The mirror has a radius of curvature of 80.0cm. If the candle is 3.50cm tall, how tall is the image of the candle as seen in the mirror?

A) 2.09cm
B) 3.50cm
C) 5.28cm
D) 7.26cm
E) 10.8cm

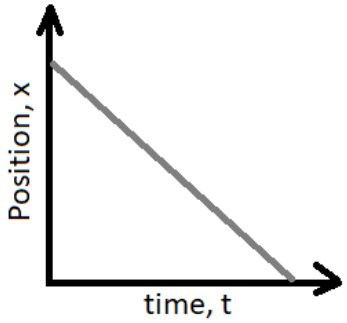
P17. A hydrogen atom undergoes a transition from the $n = 7$ state to the $n = 3$ state. What is the wavelength of the photon emitted during this transition?

A) 479.0 nm
B) 827.0 nm
C) 1005 nm
D) 2672 nm
E) 3650 nm

P18. The first evidence for the bottom-quark was found at Fermilab in 1977 with the discovery of the ϒ-particle (Upsilon-particle). The lifetime of the ϒ-particle is about 1.2×10^{-20} seconds, and its decay produces two photons: $\Upsilon \rightarrow \gamma + \gamma$. What fundamental force is primarily responsible for the decay of the ϒ-particle?

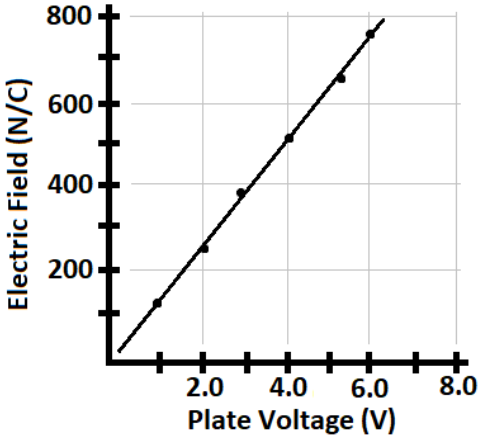
A) Electromagnetic Force
B) Gravitational Force
C) Higgs Force
D) Strong Force
E) Weak Force

P19. Shown below is the position-versus-time graph for a toy train moving in one dimension. Which statement best describes the motion of the train?



A) The train moves backward at constant speed.
B) The train moves backward with constant acceleration.
C) The train moves forward at constant speed.
D) The train moves forward with constant acceleration.
E) The train is stationary.

P20. The electric field between two parallel plates is measured as the voltage across the plates is varied. The data is plotted below. From this graph, determine the separation distance of the parallel plates.



A) 5.0 mm
B) 6.3 mm
C) 8.0 mm
D) 11.3 mm
E) 12.5 mm

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
$e = 1.602 \times 10^{-19}$ C
$N_A = 6.022 \times 10^{23}$ mol^{-1}
$k = 1.38 \times 10^{-23}$ J/K
$h = 6.626 \times 10^{-34}$ J·s
$c = 3.00 \times 10^{8}$ m/s
$R_H = 2.178 \times 10^{-18}$ J
$m_e = 9.11 \times 10^{-31}$ kg

There is no test-specific data for this exam.

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	$1.67265 \times 10^{-27}\ kg$ $1.007276 amu$
Neutron mass	m_n	$1.67495 \times 10^{-27}\ kg$ $1.008665 amu$
Atomic Mass Unit	amu	$1.66 \times 10^{-27}\ kg$ $931.5\ MeV/c^2$
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	$8.314\ J/mol \cdot K$ $0.082057\ L \cdot atm/mol \cdot K$
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	miles → meters	1.00 mile = 1609 meters
Rydberg Constant	R_∞	$1.097 \times 10^{7}\ m^{-1}$
Standard Atmospheric Pressure	1 atm	$1.013 \times 10^{5}\ Pa$
Density of Pure Water	ρ_{water}	$1000.0\ kg/m^3$

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2021 INVITATIONAL A

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

CHEMISTRY SOLUTIONS – UIL INVITATIONAL A 2021

C01. (E) (13.5 g)/(63.55 g/mol) × 6.022 ×10^{23} atoms/mol = 1.28 × 10^{23} atoms

C02. (D) The subshells fill in the order 1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d* 4*p*

C03. (B) Methane, CH_4, has four single bonds, for 8 shared electrons.

C04. (C) $PV = nRT$, so $V = nRT/P$ = (2.6)(0.08206)(85+273)/1 = 76.4 L

C05. (D) CO_2 is a nonpolar molecule and only has dispersion forces in the solid state.

C06. (A) Moles C_2H_2 = (65 / 26.04) = 2.496 mol.
Each C_2H_2 will produce 2 CO_2, so moles CO_2 = 2.496 × 2 = 5.0 mol

C07. (A) Sublimation is an endothermic process, so $\Delta H > 0$, and entropy increases going from a solid to a gas, so $\Delta S > 0$.

C08. (A) If you reduce the volume at constant temperature, you are increasing the pressure. According the LeChatelier's principle, the reaction will respond in a way that decreases the pressure. There are fewer gas phase moles of product than there are reactant, so more product will be formed.

C09. (E) $M_{HCl}V_{HCl} = M_{NaOH}V_{NaOH}$. $V_{HCl} = M_{NaOH}V_{NaOH}/M_{HCl}$ = (0.750)(65)/(0.325) = 150 mL

C10. (C) $K_{sp} = [Ca^{2+}][F^-]^2$ $[Ca^{2+}] = 0.0011$ and $[F^-] = 2[Ca^{2+}] = 0.0022$.
$K_{sp} = (0.0011)(0.0022)^2 = 5.3 \times 10^{-9}$

C11. (D)

C12. (A) The rate is determined by the rate-limiting step in the reaction.

C13. (E) % Ag = (107.87)/(107.87 + 35.45) × 100% = 75.27%

C14. (E) Of the atoms on the left, Rb and K both form 1+ ions. Rubidium's outer electrons are one energy level higher than potassium's, so Rb is both the larger atom and the larger 1+ ion. The smaller 1+ ion is therefore K^+.

C15. (B) The balanced reaction is $Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + H_2O + CO_2$

C16. (D) On line B–C solid and liquid are present, C–D is entirely liquid, and on D–E liquid and vapor are present.

C17. (B) The volume will not increase because it is a thick-walled metal container.

C18. (A)

C19. (C) A binary acid such as H_2S, HF, and HCl is named *hydro*– [element stem] –*ic acid*.

C20. (B) 190.3 g / 76.15 g/mol = 2.499 mol. 4217.4 kJ / 2.499 mol = 1688 kJ *given off*, so
ΔH = –1688 kJ/mol

PHYSICS SOLUTIONS – UIL INVITATIONAL A 2021

P01. (E) page 3: "Finally, in November 1915, he committed to print an article giving the complete solution: a new theory of gravity, which he called 'The General Theory of Relativity', his masterpiece and the 'most beautiful of theories', according to the great Russian physicist Lev Landau."

P02. (B) page 9: "The same equation predicts that the expansion ought to have been triggered by the explosion of a young, extremely small and extremely hot universe: by what we now know as the 'Big Bang'. Once again, no one believed this at first, but the proof mounted up until *cosmic background radiation* – the diffuse glare that remains from the heat generated by the original explosion – was actually observed in the sky. The prediction arising from Einstein's equation turned out to be correct."

P03. (A) page 17 "Patiently, Bohr explained the new ideas to Einstein. Einstein objected. He devised mental experiments to show that the new ideas were contradictory … In the end Bohr always managed to find an answer with which to rebut these objections. For years, their dialogue continued by way of lectures, letters, articles…"

P04. (B) Apollo 17, the last manned mission to the Moon, launched on December 7, 1972. Gene Cernan and Harrison Schmitt landed on the Moon on December 11. The two men, along with pilot Ron Evans, returned to Earth on December 19, 1972. This was the last time that a human walked on the surface of the Moon.

P05. (A) Examining the units of the terms in this equation gives

$$[Z] = \frac{kilogram*meters\ /\ second}{second} = \frac{kilogram*meter}{second*second} = \frac{kilogram*meter}{second^2}.$$

This is the definition of a Newton, the unit of force. You can also tell that this equates to a mass times an acceleration. So, the units of Z is [Newtons].

P06. (C) Since we know the initial and final velocities, as well as the distance travelled while accelerating, we should use the equation $v_f^2 = v_i^2 + 2a(x_f - x_i)$. Plugging in the values that we are given leads to $(5.00)^2 = (12.0)^2 + 2a(45.0) \rightarrow 25.0 = 144 + 90a \ \rightarrow 90a = -119 \ \rightarrow a = -\frac{119}{90} = -1.32$ m/s^2.

P07. (A) The free body diagram for this situation has three forces: the gravitational force (mg) directed downward, the force exerted by the factory worker (F) directed to the left, and the tension in the cable (T) directed up and to the right. Since the crate is in static equilibrium, then all of the forces must add up to zero.
The only force at an angle is the tension. Since we know the angle, then the x-component of the tension is $T_x = Tcos(60)$ to the right and the y-component is $T_y = Tsin(60)$ upward. Summing up the forces in the x-direction gives: $\sum F_x = Tcos(60) - F = 0$ and summing up the forces in the y-direction gives: $\sum F_y = Tsin(60) - mg = 0$.
From the y-direction equation we can solve for the tension:
$Tsin(60) = mg \ \rightarrow \ T(0.8660) = (190)(9.8) = 1862N \ \rightarrow \ T = 2150N.$
Now we can use the x-direction equation to determine the force exerted by the factory worker:
$F = Tcos(60) = (2150)(0.5) = 1075N \approx 1080N.$

P08. (D) When you threw the baseball, it was at ground level ($h_i = 0$). At that point, it had only kinetic energy. When it reached the branch, the ball was briefly stationary ($v_f = 0$). At that point it had only gravitational potential energy. Since no external forces acted on the baseball (air resistance is negligible), then by conservation of energy the kinetic energy at the start must be equal to the gravitational potential energy at the end. Mathematically: $KE_i = GPE_f$. Putting in the expressions for these forms of energy gives: $\frac{1}{2}mv_i^2 = mgh_f$. Notice that mass cancels. Solving for the initial velocity gives: $v_i^2 = 2gh_f \;\rightarrow\; v_i = \sqrt{2gh_f} = \sqrt{2(9.8)(12.5)} = \sqrt{245} = 15.7$m/s.

P09. (B) The initial angular speed is zero, and we need to achieve a final angular speed of 600.0rpm. First, we convert this speed into radians per second: $\omega = 600rpm = 600 * 2\pi\frac{rad}{min} = 600 * \frac{2\pi}{60}\frac{rad}{sec}$. This gives a final angular speed of $\omega_f = 20\pi = 62.83\, rad/sec$. The acceleration is in the proper units, so we use the kinematic equation: $\omega_f = \omega_i + \alpha t \;\rightarrow\; 62.83 = 0 + (35.0)t \;\rightarrow\; t = 1.80$sec.

P10. (D) The child on the swing is, in effect, a simple pendulum. The period of a simple pendulum is given by the equation: $T = 2\pi\sqrt{\frac{\ell}{g}}$. Since we know the pendulum length (the length of the chains), we can calculate the period for one complete oscillation: $T = 2\pi\sqrt{\frac{2.20}{9.80}} = (6.28)(0.4738) = 2.98$seconds. The child will need one push for each complete oscillation. Thus, the total number of oscillations (and pushes) that will occur in one minute is $N = \frac{60\ seconds}{T} = \frac{60}{2.98} = 20.1 \approx 20$ pushes/minute.

P11. (B) Since the toy is floating, we know that the buoyant force (acting upward) on the toy must equal the gravitational force (acting downward) on the toy. The buoyant force is related to the volume of the toy underneath the surface, and is given by: $F_B = (\rho_{liquid})(g)(V_{under})$. Since 20% of the toy is above the surface, then 80% is below the surface, meaning $V_{under} = 0.8V_{toy}$. This means that the buoyant force is: $F_B = (792)(9.8)(0.8V_{toy}) = 6209V_{toy}$. This equals the gravitational force, which can be written as $F_g = mg = (\rho_{toy})(V_{toy})(g)$, using the definition of density. Setting these equal and plugging in for g: $6209V_{toy} = (\rho_{toy})(V_{toy})(9.8) \;\rightarrow\; \frac{6209}{9.8} = (\rho_{toy})\frac{V_{toy}}{V_{toy}} = (\rho_{toy}) = 634$ kg/m^3.

P12. (C) First, we use the voltage and current to find the resistance of the potato slice. Using Ohm's Law, we get $R = \frac{V}{I} = \frac{12.0}{127 \times 10^{-6}} = 94488\ \Omega$. Now we can relate this to the resistivity by using the equation: $R = \frac{\rho L}{A}$. To use this equation, we will need to convert the length into meters (0.145m) and find the cross-sectional area of the slice. The cross section is 0.400cm by 0.400cm, so the area is: $A = (0.400)(0.400) = 0.16\ cm^2 = 1.6\ \times\ 10^{-5}$ m^2. Now, $R = 94488 = \frac{\rho L}{A} = \frac{\rho(0.145)}{1.6 \times 10^{-5}} = (9062.5)\rho$, which gives a resistivity of $\rho = \frac{94488}{9062.5} = 10.4\ \Omega$m.

P13. (B) The electric potential produced by a point charge is given by $V = \frac{kQ}{r}$. Thankfully, electric potential is not a vector, so we can simply add together the potentials produced by each individual charge. Converting the distances from the charges to the origin into meters, and plugging in both the Coulomb constant, k, and the values of the charges gives us:

$$V = \frac{kQ_1}{r_1} + \frac{kQ_2}{r_2} = \frac{(8.99\ \times\ 10^9)(1.20\ \times\ 10^{-6})}{0.01} + \frac{(8.99\ \times\ 10^9)(-0.85\ \times\ 10^{-6})}{0.03}$$

Calculating, we get $V = 1.079 \times 10^6 - 2.547 \times 10^5 = 8.24 \times 10^5$ V.

P14. (A) There are a number of ways to remove the permanent magnetization of a ferromagnetic material – through physical shock, such as hammering; by flowing an AC current through it; or by heating it above the Curie temperature. Exposure to electromagnetic waves does not work, unless you use low frequency radio waves, and neither cooling nor DC current will remove the magnetization. Thus, the only one of these choices that works is to heat the material to a high temperature.

P15. (D) The intensity of a polarized beam that gets through another polarizer is given by Malus' Law: $I = I_0 cos^2\theta$, where θ is the angle between the polarization of the beam and the axis of the polarizer. In this case, we have $I = (600.0)cos^2(40.0°) = 350$ W/m^2.

P16. (E) Since the mirror is concave, we know the radius of curvature, and the focal length, are positive. We find the focal length by: $f = \frac{R}{2} = \frac{80.0}{2} = 40.0$cm. Now we can find the location of the image of the candle. Keeping everything in centimeters, we get: $\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \rightarrow \frac{1}{27.0} + \frac{1}{q} = \frac{1}{40.0}$. This gives an image location of $q = -83.1$cm. Since the image location is negative, we know that it is a virtual image. Now, to find the size of the image, we need the magnification: $M = -\frac{q}{p} = -\frac{-83.1}{27} = 3.08$. Multiplying this magnification by the object height will give us the image height: $h' = Mh = (3.08)(3.50) = 10.8$cm tall.

P17. (C) The wavelength of the photon emitted during a transition in a hydrogen atom can be found using the Rydberg formula: $\frac{1}{\lambda} = R_\infty\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$. Here, n_i and n_f are the initial and final states of the atom, respectively; and R_∞ is the Rydberg constant. Putting in all of the values that we are given: $\frac{1}{\lambda} = R_\infty\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = (1.097 \times 10^7)\left(\frac{1}{(3)^2} - \frac{1}{(7)^2}\right) = (1.097 \times 10^7)\left(\frac{1}{9} - \frac{1}{49}\right) = 995011$ m^{-1}. This gives a wavelength of $\lambda = \frac{1}{995011} = 1.005 \times 10^{-6}$m $= 1005$nm.

P18. (A) The quark structure of the ϒ-particle is $b\bar{b}$, so the decay process that produces two photons is essentially a matter-antimatter annihilation of the bottom quark and the bottom antiquark. This kind of interaction (and essentially any other interaction involving the production of photons) is mediated by the Electromagnetic Force. The lifetime is also indicative of this: for a massive particle like the ϒ, Strong Force interactions are much faster (about 10^{-24} seconds), and Weak Force interactions are much slower (about 10^{-12} seconds). Furthermore, the Higgs Force isn't even a real force, and no particle decays have ever been attributed to the Gravitational Force.

P19. (A) First, notice that this is a one-dimensional position-time graph. For this type of graph, the slope of the curve represents the speed of the object. Since the graph of the train traces out a straight line, we know that the slope, and hence the speed, is constant. This eliminates choices B and D, since constant speed means we have no acceleration. Also, the slope is not zero, so the train is not stationary. This eliminates choice E.
Finally, the slope is negative – that is, the position is decreasing as time increases – so we know that the train is moving backward. This eliminates choice C.

Therefore, the correct choice (A) is that the train is moving backward at a constant speed.

P20. (C) The equation describing the relationship of the electric field between two parallel plates to the voltage across the plates is $E = \frac{V}{d}$. So, a graph of *E* versus *V* would produce a straight line (as we see) with a slope of $\frac{1}{d}$. Turning our attention to the graph, we can choose a pair of points on the line with which to determine the slope. Estimating from the graph, I choose (1.5V, 200N/C) and (4.8V, 600N/C). So, the slope is $slope = \frac{600-200}{4.8-1.5} = \frac{400}{3.3} = 120$ m^{-1}. Now we can determine the distance between the plates: $d = \frac{1}{slope} = \frac{1}{120} = 0.0083$m $= 8.3$mm ≈ 8.0mm.

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** ☐