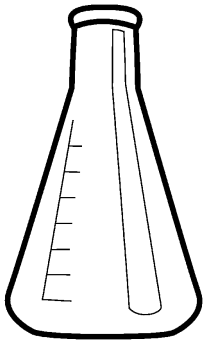
UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

Region • 2019

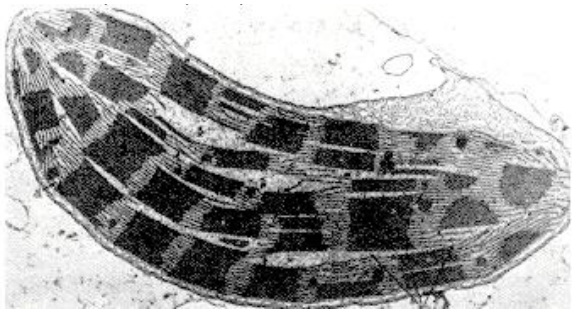


GENERAL DIRECTIONS:

- 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. All of the following are common between DNA replication and transcription except
A) helicase activity is supplied by a separate enzyme.
B) phosphodiester bonds form between adjacent nucleotides.
C) elongation occurs in a 5' to 3' direction relative to the newly synthesized strand.
D) DNA is used as a template.
E) both events occur within the nucleus of some cell types.

B02. Examine this image. Which part would you expect to have the highest concentration of protons if the organelle in this image was functioning correctly?



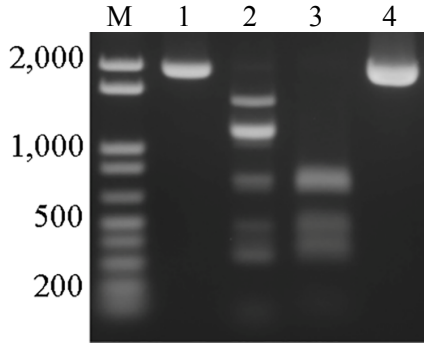
A) intermembrane space
B) matrix
C) stroma
D) thylakoid lumen
E) cytosol

B03. Both dominant genes A and B are required for an organism to exhibit a dominant phenotype for trait A. Given the following genetic cross, if 247 offspring are obtained, about how many will exhibit a dominant phenotype for trait A?

AaBb x AaBb

A) 247
B) 185
C) 139
D) 108
E) 46

B04. A researcher performed PCR to amplify a 1200 base pair segment of DNA from several different DNA templates. The researcher performed agarose gel electrophoresis on the PCR products and the following results were obtained. Examine the image below. Which lane represents a successful experiment?

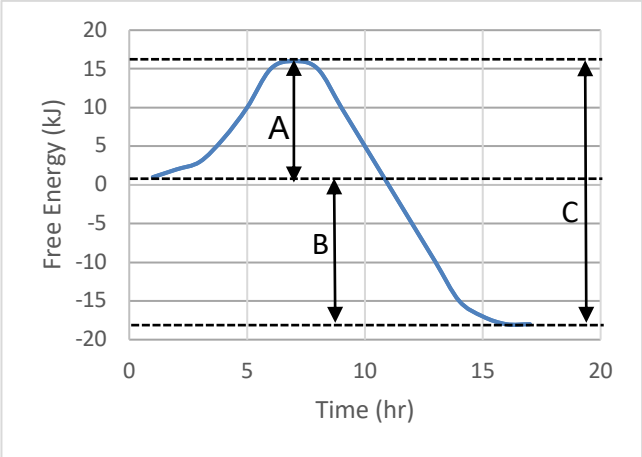


A) Lane M
B) Lane 1
C) Lane 2
D) Lane 3
E) Lane 4

B05. Which of the following is not a function of epithelial cells?
A) secretion of mucus
B) selective absorption
C) protection
D) nutrient supply
E) sensory

B06. Which of the following best explains the concept of tissue tropism in the replication of viruses?
A) Each type of virus can infect many different cell types.
B) Viruses have surface glycoproteins that bind specifically to host cell receptors. Therefore, only specific cells are infected.
C) In general, viruses that infect bacteria are not specific to each bacterial species.
D) Viruses that undergo lysogeny, are more likely to infect specific cells.
E) Animal viruses only infect mammals.

B07. Examine the following graph. Which specific letter on the graph changes in the presence of an enzyme?



A) A
B) B
C) C
D) None of the above would change in response to an enzyme's presence.

B08. Carcinomas *in situ* are defined as
A) non-cancerous cells that have not left the original site of formation.
B) metastatic disease.
C) completely benign abnormal cells.
D) cancerous cells that have invaded nearby regional tissues.
E) cancerous cells that have not left the site of their origin.

B09. On 27 February 2019, the Centers for Disease Control and Prevention issued a final update on the *Salmonella* infections linked to
A) hummus.
B) tahini.
C) raw milk.
D) chicken.
E) raw turkey products.

B10. For vascular plants, the dominant generation is the
A) gametophyte.
B) tracheophyte.
C) sporophyte.
D) multicellular haploid.
E) gamete.

B11. A large population of squirrels, in which the frequency of both the *A* and *a* alleles is 0.5, is decimated by a natural disaster. In the remaining members of the original population, the frequency of the *A* allele is now 0.2. The effect represented in this scenario is most specifically called
A) genetic reassortment.
B) bottleneck effect.
C) founder effect.
D) genetic drift.
E) speciation.

B12. A terrestrial biome that receives high annual precipitation and high annual temperatures would most likely be called a
A) tropical rainforest.
B) subtropical desert.
C) tundra.
D) temperate grassland.
E) temperate rainforest.

B13. The bacterial promoter contains -10 and -35 sequences upstream of the transcriptional start site. What specifically binds to the -10 and -35 sequences?
A) RNA polymerase core enzyme
B) RNA
C) ribosomes
D) sigma factors
E) repressors

B14. Viruses are excluded from the current three Domain system because
A) some virus genome structure includes several strands of RNA.
B) viral genomes are too complex and cannot be sequenced.
C) they are parasitic and rely on other cells for replication.
D) they lack ribosomal RNA.
E) none of the above answers are correct since viruses are not excluded from the three Domain system.

B15. Which of the following would affect the rate of a biochemical reaction?
A) concentration of the substrate
B) concentration of the enzyme or other catalyst
C) temperature
D) the type of solvent in which the reaction is occurring
E) All of the above influence the reaction rate.

B16. Transcribe the following DNA *coding* strand:

5'-ACCGATGCACTTTTAACCGA-3'

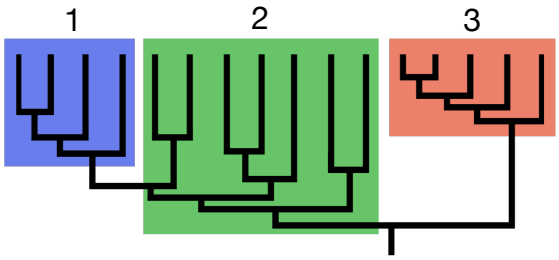
A) 5'-ACCGAUGCACUUUUAACCGA-3'
B) 3'-ACCGAUGCACUUUUAACCGA-5'
C) 3'-UGGCUACGUGAAAAUUGGCU-5'
D) 5'-UGGCUACGUGAAAAUUGGCU-3'
E) 3'-TGGCTACGTGAAAATTGGCT-5'

B17. Teens and young adults, especially those who are living in group housing such as a dorm, are at an increased risk of acquiring bacterial meningitis caused by _____, which is why many colleges require certification that the student has been vaccinated.
A) *Listeria monocytogenes*
B) *Streptococcus pneumoniae*
C) *Neisseria meningitidis*
D) *Mycoplasma* sp.
E) *Haemophilus influenzae* type b

B18. Which of the following, relative to the other answer choices, represents the primary producer in a marine food web?
A) predatory zooplankton
B) zooplankton
C) filter feeders
D) predatory fish
E) phytoplankton

B19. Ribonucleotides are involved in some capacity in all of the following events except
A) ATP synthesis.
B) DNA replication.
C) transcription.
D) translation.
E) Ribonucleotides are involved in all of the above processes.

B20. In this phylogenetic tree, which block represents a paraphyletic relationship?



A) Block 1
B) Block 2
C) Block 3
D) Blocks 1 and 2
E) Blocks 1, 2, and 3

C01. 200.0 g of an unknown metal reacts with excess oxygen to form 357.1 g of a metal oxide. What is the metal oxide?

A) Ag_2O
B) ZrO_2
C) Cr_2O_3
D) V_2O_5
E) U_3O_8

C02. 200.0 L of a 0.200 M copper (II) chloride solution is reacted with 10.0 L of 3.00 M phosphoric acid and 2.850 kg of solid copper phosphate is produced. What is the percent yield of copper phosphate?

A) 56.2%
B) 18.7%
C) 94.8%
D) 49.9%
E) 25.0%

C03. Which of the following species is isoelectronic with cadmium(II)?

A) Zinc(II)
B) Palladium
C) Tin(II)
D) Tin(IV)
E) Mercury(II)

C04. Arrange these molecules in order of decreasing bond angle between the H atoms: BH_3, NH_3, CH_4, H_2O.

A) $CH_4 > BH_3 > NH_3 > H_2O$
B) $H_2O > NH_3 > BH_3 > CH_4$
C) $BH_3 > H_2O > NH_3 > CH_4$
D) $H_2O > BH_3 > NH_3 > CH_4$
E) $BH_3 > CH_4 > NH_3 > H_2O$

C05. What is the pH of a 0.050 M solution of KCN?

A) 10.95
B) 8.75
C) 7.89
D) 6.08
E) 3.04

C06. 44.0 grams of dry ice is crushed into powder and the powder is placed into an uninflated spherical balloon at STP and the neck of the balloon is tied off. When all of the dry ice has sublimed to CO_2 gas, what will the diameter of the balloon be?

A) 17.5 cm
B) 23.1 cm
C) 28.7 cm
D) 35.0 cm
E) 46.1 cm

C07. Why is non-polar paraffin wax a solid at room temperature while hydrogen-bonding water is a liquid?

A) Because wax has a very high molecular weight, and high molecular weight compounds are usually solids.
B) Because hydrogen bonds are stronger in liquids than in solids, and this helps hold water in the liquid state.
C) Because the total of all the dispersion forces between the wax molecules is greater than the strength of the hydrogen bonds in the water.
D) Because paraffin wax is less dense than water, as evidenced by the fact that wax floats in water.
E) Because the 109.5° bond angles in the wax cause the wax molecules to become entangled with one another and this prevents them from flowing freely.

C08. A mad scientist invents a Carbon Bomb made up of a billion billion billion carbon atoms. He lives too far from the coast to test his bomb in the ocean, so he ignites it instead in his next door neighbor's 10,600 gallon (40.0 m^3) swimming pool. If all the heat given off by the Carbon Bomb is absorbed by the water in the pool, how much will the water temperature rise? The $\Delta H_{combustion}$ for carbon is –393.5 kJ/mol.

A) 3.90 °C
B) 28.1 °C
C) 42.5 °C
D) 85.9 °C
E) 163 °C

C09. Rank these compounds in order of highest to lowest Mg^{2+} concentration in the saturated solution: $MgCO_3$, MgF_2, $Mg_3(PO_4)_2$. The K_{sp} value for each one is on the data sheet.

A) $MgF_2 > MgCO_3 > Mg_3(PO_4)_2$
B) $Mg_3(PO_4)_2 > MgF_2 > MgCO_3$
C) $MgCO_3 > MgF_2 > Mg_3(PO_4)_2$
D) $MgF_2 > Mg_3(PO_4)_2 > MgCO_3$
E) $Mg_3(PO_4)_2 > MgCO_3 > MgF_2$

C10. In acidic solution, the dichromate ion oxidizes Fe^{2+} to Fe^{3+} and is reduced to Cr^{3+}. What is the sum of the coefficients in the balanced equation for this reaction?

A) 36
B) 34
C) 32
D) 24
E) 16

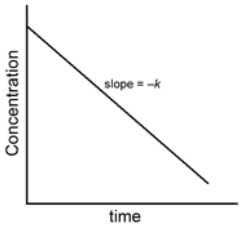
C11. The Réaumur temperature scale (°Ré) is used to measure milk temperatures in some European cheese factories. On the Réaumur scale, water freezes at 0 °Ré and boils at 80 °Ré. If a sample of milk in a Swiss cheese factory is at 1.000 °Ré, what is its temperature in °F?

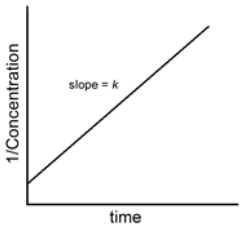
A) 32.44
B) 33.50
C) 34.25
D) 35.44
E) 33.75

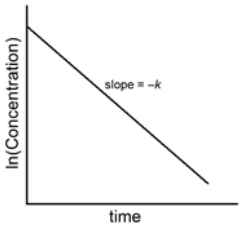
C12. A student has 6.18 g of a solid mixture of KBr and $BaSO_4$. The mixture is 72% KBr and 28% $BaSO_4$ by mass. How much pure KBr and pure $BaSO_4$ would the student need to add to the initial mixture to obtain 10.0 g of a mixture with a composition of 50% KBr and 50% $BaSO_4$ by mass?

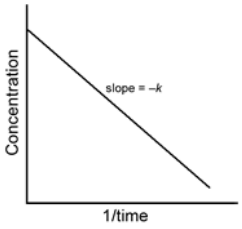
A) 1.91 g of $BaSO_4$ and 1.91 g of KBr
B) 4.45 g of $BaSO_4$ and 1.73 g of KBr
C) 4.45 g of KBr and 1.73 g of $BaSO_4$
D) 1.54 g of KBr and 2.28 g of $BaSO_4$
E) 3.27 g of $BaSO_4$ and 0.55 g of KBr

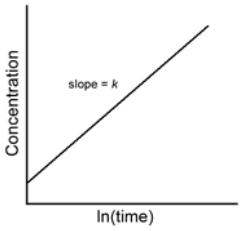
C13. The reaction $2A \rightarrow B + C$ has second order kinetics. Which plot below correctly relates [A] and time?

A)


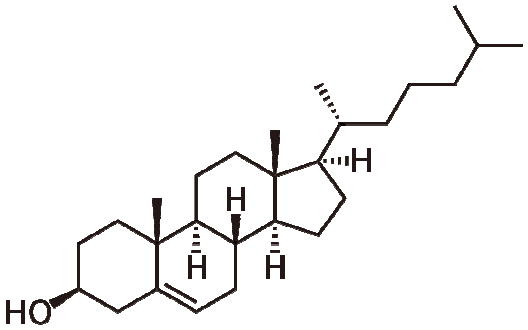
B)


C)


D)


E)


C14. What is the molar mass of cholesterol, below?



A) 390.67
B) 386.64
C) 383.61
D) 381.60
E) 360.43

C15. How many sigma bonds are there in a cholesterol molecule, shown in question C14?

A) 77
B) 73
C) 51
D) 85
E) 68

C16. Metallic iron can be obtained from ore by reacting it with excess carbon monoxide gas at high temperatures:

$$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$$

If this process has an 83.9% yield, how much iron ore is required to obtain 100 g of metallic iron?

A) 129 g
B) 175 g
C) 200 g
D) 243 g
E) 341 g

C17. What is the vapor pressure of ethanol at 5.0 °C?

A) 18.3 torr
B) 20.1 torr
C) 23.5 torr
D) 24.8 torr
E) 26.2 torr

C18. Given the following data, calculate the standard molar enthalpy of formation for C_2H_2 (g).

$$2\ C_2H_2(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2\ H_2O(\ell) \qquad \Delta H° = -2600.0\ kJ$$
$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H° = -393.5\ kJ$$
$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(\ell) \qquad \Delta H° = -571.6\ kJ$$

A) 454.4 kJ
B) –1598 kJ
C) 1635 kJ
D) 227.2 kJ
E) 817.5 kJ

C19. A student titrates 23.45 mL of 0.282 M NaOH into a 5.00 mL solution of H_2SO_4, then realizes he forgot to add phenolphthalein. When he adds the indicator the solution turns bright pink. He dissolves 0.544 grams of KHP in the solution to turn it clear again, then titrates an additional 3.20 mL more to reach the endpoint. What is the H_2SO_4 concentration in the original sample? (KHP molar mass = 204.222 g/mol)

A) 0.091 M
B) 0.364 M
C) 0.485 M
D) 0.750 M
E) 0.970 M

C20. Combustion of a 62.25 g sample of a liquid hydrocarbon compound produces 186.4 g of CO_2. What is the empirical formula for the compound?

A) CH
B) CH_2
C) CH_4
D) C_2H_5
E) C_3H_8

P01. According to Natarajan, omega, the ratio of all matter and energy in the universe to the critical density, was estimated (based on one measurement) to be approximately 1. On what measurement was this estimate based?
A) the masses of all the observed galaxies
B) the fluctuations in the Cosmic Microwave Background
C) the light curves of distant type-Ia supernovae
D) the density of high-Z quasars and galaxies
E) a direct measure of the Cosmological Constant.

P02. According to Natarajan, in 1941 Andrew McKellar determined a temperature of about 3K for molecules in interstellar space. The spectrum of which toxic compound did McKellar study to make this determination?
A) formaldehyde
B) ozone
C) chloronium
D) cyanogen
E) titanium dioxide

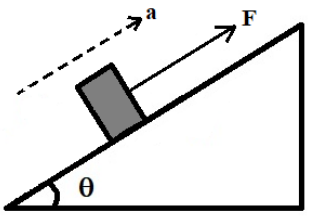
P03. According to Natarajan, one method used to detect exoplanets, which is well suited to finding "hot Jupiters," is to measure…
A) the gravity waves produced by orbiting planets.
B) the brightness of light reflected by the planets.
C) the spectra of light emitted by the hot planets.
D) the brightness of the stars.
E) the radial velocity of the stars.

P04. Which of the gas giant planets orbiting the Sun has the greatest average density?
A) Jupiter
B) Saturn
C) Uranus
D) Neptune
E) They all have the same density.

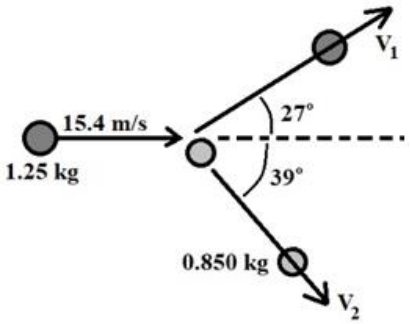
P05. An ionization fan uses electric fields to create air flow by ionizing and accelerating air molecules. If each air ion has a charge of $1e$, and if 10^{12} ions flow from the fan each hour, what is the electric current of air ions flowing from the fan?
A) 44.5 pA
B) 62.4 pA
C) 160 pA
D) 267 pA
E) 427 pA

P06. A booster for an electric train provides a constant acceleration of 15.40m/s^2 for a segment of track that is 15.0m long. If the train has an initial velocity of 25.0m/s, then how long does the acceleration last?
A) 0.228 s
B) 0.518 s
C) 0.630 s
D) 2.45 s
E) 3.76 s

P07. A 50.0kg barrel of ice cream is pulled up an inclined plane by a force of 400.0N oriented parallel to the incline. The angle of the incline is 32.0° and the coefficient of friction between the barrel and the incline is 0.28. What is the acceleration of the barrel?
A) 0.480 m/s^2
B) 1.35 m/s^2
C) 2.81 m/s^2
D) 5.67 m/s^2
E) 8.00 m/s^2

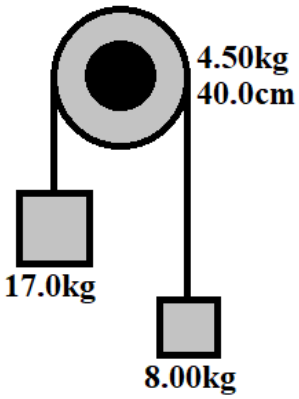


P08. A heavy stone with a mass of 1.25kg is sliding across frictionless ice at a speed of 15.4m/s. It collides with another stone, initially at rest, that has a mass of 0.850kg. After the collision, the stones slide away in different directions as shown. What is the magnitude of the velocity of the second stone, V_2, after the collision?
A) 7.65 m/s
B) 10.6 m/s
C) 11.3 m/s
D) 13.6 m/s
E) 15.6 m/s



P09. An Atwood machine has hanging masses of 8.00kg and 17.0kg (as shown). In addition, the solid disk pulley has a mass of 4.50kg, and a radius of 40.0cm. Assuming the rope moves along the pulley without slipping, what is the acceleration of the hanging masses? Note: the moment of inertia of a solid disk is $I = \frac{1}{2}MR^2$.

A) 2.99 m/s^2
B) 3.24 m/s^2
C) 3.53 m/s^2
D) 3.88 m/s^2
E) 4.30 m/s^2



P10. While singing in the shower, you hear two resonances – at frequencies of 280.0 Hz and 360.0 Hz. There are no resonances at frequencies between these two. If you consider the shower to be open at the top and closed at the bottom, and the temperature in the shower to be 20.0°C, then what is the height of the shower?

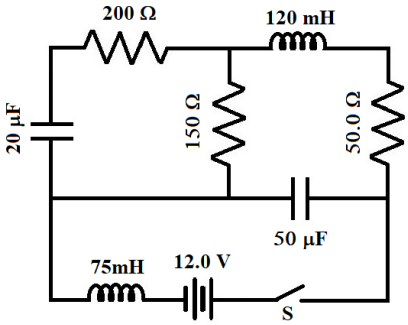
A) 1.86m
B) 2.14m
C) 2.62m
D) 2.76m
E) 3.27m

P11. A diatomic ideal gas ($\gamma = 1.4$) is compressed adiabatically from a volume of 2.80 liters to a volume of 1.20 liters. The initial temperature of the gas is 440.0K. What is the final temperature of the gas?

A) 1440K
B) 1030K
C) 940K
D) 800K
E) 620K

P12. In this DC circuit, the switch S is closed at time $t = 0$. After a long time has passed (that is, as $t \to \infty$), what is the equilibrium DC current flowing in the 150.0Ω resistor? Consider all components to be ideal.

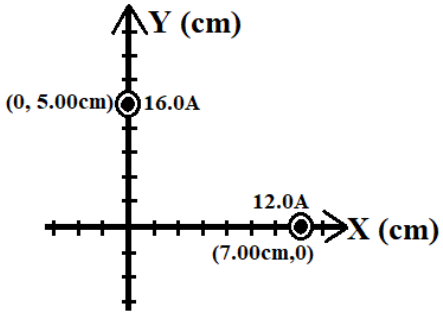
A) 0.00mA
B) 9.87mA
C) 60.0mA
D) 80.0mA
E) 103mA



P13. A 600.0nC point charge sits at the center of a spherical system. The point charge is surrounded by an uncharged, conductive spherical shell. The inner radius of the shell is 2.00cm and the outer radius of the shell is 4.00cm. What is the static electric field at a point 3.00cm from the point charge?

A) 9.00×10^6 N/C
B) 6.00×10^6 N/C
C) 4.00×10^6 N/C
D) 0.00 N/C
E) -2.00×10^6 N/C

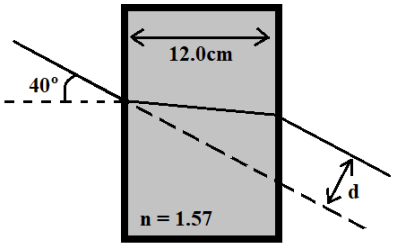
P14. Two long straight wires carry currents of 16.0A and 12.0A in the $+z$-direction (out of the page). The first wire passes through the point (0, 5.00cm), and the second wire passes through the point (7.00cm, 0), as shown. What is the magnitude of the magnetic field at the origin (0, 0) due to these currents?



A) 98.3 μT
B) 72.6 μT
C) 66.3 μT
D) 54.0 μT
E) 29.7 μT

P15. A light ray in air intersects a rectangular slab of glass at an angle of 40.0° with respect to the normal (as shown). The index of refraction of the glass is 1.57. When the ray exits the glass, it returns to a path that is parallel to its original direction, but shifted by a distance *d*. Given that the piece of glass is 12.0cm wide, how far is the ray shifted?

A) 5.4cm
B) 4.7cm
C) 4.1cm
D) 3.6cm
E) 3.0cm



P16. A radio wave with a frequency of 850.0MHz is incident on a metal fence. There are two small gaps in the fence that act like a double slit apparatus. The distance between the gaps is 12.0m. Using a radio receiver as a signal detector, you walk along a path that is 150.0m beyond the fence, but parallel to the line of the fence. As you walk along the path, how far apart are the radio signal maxima?

A) 2.2m
B) 3.4m
C) 4.4m
D) 5.6m
E) 8.8m

P17. A spacecraft is travelling away from Earth at a speed of 0.55c. A beacon on the rear of the spacecraft shines with a green light of wavelength 514nm (as seen by an observer on the spacecraft). To an observer on Earth, what does the wavelength of the beacon appear to be?

A) 615nm
B) 702nm
C) 954nm
D) 1420nm
E) 1770nm

P18. How much input energy is required to complete this endothermic fusion reaction?

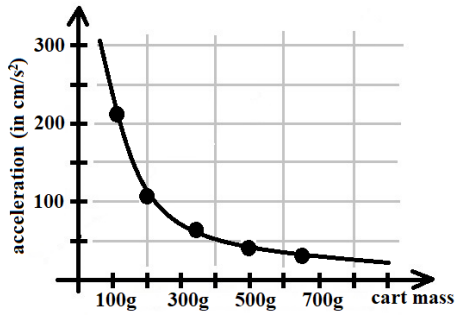
$$^{39}_{19}K + ^{4}_{2}He \rightarrow ^{42}_{21}Sc + ^{1}_{0}n$$

The masses of the isotopes are as follows:
Potassium-39 … 38.96371amu
Helium-4 … …. 4.002602amu
Scandium-42 … 41.965516amu

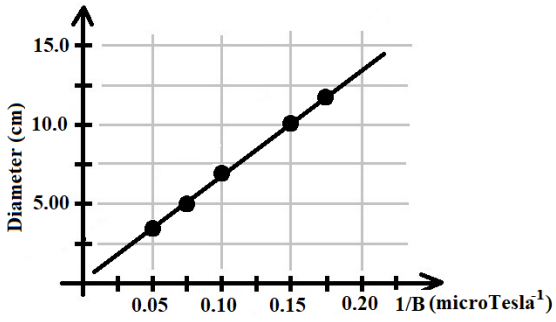
A) 0.743 MeV
B) 6.05 MeV
C) 7.33 MeV
D) 44.2 MeV
E) 934 MeV

P19. A constant, reproducible force is used to accelerate carts of different masses. The acceleration data is graphed below. From this data, determine the magnitude of the force used in the experiment.

A) 1.2 N
B) 0.84 N
C) 0.58 N
D) 0.50 N
E) 0.21 N



P20. A horizontal beam of electrons is directed into a region with a vertical magnetic field. As expected, the electron beam curves into a circle. The diameter of the circular path is measured as the strength of the magnetic field is varied. The diameter is graphed versus the inverse of the magnetic field strength (1/B). From this data, find the velocity of the electron beam.



A) 6.0×10^4 m/s
B) 1.2×10^5 m/s
C) 1.3×10^5 m/s
D) 2.6×10^5 m/s
E) 3.0×10^5 m/s

Chemistry

1A												3A	4A	5A	6A	7A	8A
1												13	14	15	16	17	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*
Density: assume 1.00 g/mL

<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

Volume of a sphere $= \frac{4}{3}\pi r^3$

<u>Physical Data for Ethanol</u>

T_{mp} = –114.14 °C
T_{bp} = 78.24 °C
ΔH_{fus} = 4.9 kJ/mol
ΔH_{vap} = 38.56 kJ/mol
$c_{liquid\ ethanol}$ = 111.5 J/mol·K
$c_{solid\ ethanol}$ = 112.4 J/mol·K
$c_{gaseous\ ethanol}$ = 78.28 J/mol·K

<u>K_a values</u>

HCN	6.2×10^{-10}

<u>K_{sp} values</u>

$MgCO_3$	3.5×10^{-8}
MgF_2	3.7×10^{-8}
$Mg_3(PO_4)_2$	1.0×10^{-10}

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	$1.013 \times 10^{5}\ Pa$

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2019 REGIONAL

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

CHEMISTRY SOLUTIONS – UIL REGIONAL 2019

C01. (D) Moles of oxygen added to the compound = (357.1 g – 200.0 g)/(16.00 g/mol) = 9.82 mol O. Divide the mass of unknown metal by the molar mass of each metal to determine how many moles of metal are present, then use the formula stoichiometry to determine how many moles of oxygen are necessary to combine with that many moles of metal to form the compound.
V_2O_5 : 200 g/50.94 g/mol = 3.93 mol V. 3.93 mol V × (5 mol O/2 mol V) = 9.82 mol O

C02. (A) The balanced equation is 3 $CuCl_2$ + 2 H_3PO_4 → $Cu_3(PO_4)_2$ + 6 HCl
200.0 L × 0.200 M = 40.0 moles Cu × 1 mol $Cu_3(PO_4)_2$/3 mol $CuCl_2$ = 13.33 moles $Cu_3(PO_4)_2$
10.0 L × 3.00 M = 30.0 moles H_3PO_4 × 1 mol $Cu_3(PO_4)_2$/2 mol H_3PO_4 = 15.00 moles $Cu_3(PO_4)_2$
$CuCl_2$ is the limiting reagent.
13.33 moles $Cu_3(PO_4)_2$ × 380.59 grams/mole = 5074.5 grams $Cu_3(PO_4)_2$ theoretical yield
Percent yield = (2.850 kg/5.0745 kg) × 100% = 56.2%

C03. (D) Cadmium(II) loses two electrons from the 5*s* orbital and has a resulting electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10}$. Tin(IV) loses two electrons from the 5*p* orbital and two from the 5*s* orbital and has the same electron configuration as cadmium(II).

C04. (E) Nonbonding electron pairs have stronger repulsions than bonding electron pairs do, and tend to "squash" the other bond angles a little. BH_3 is trigonal planar (120°), and the bond angles are 109.5° in CH_4, 107° in NH_3, and 104.5° in H_2O.

C05. (A) K_a for HCN = 6.2×10^{-10}, so the K_b for CN^- = K_w/K_a = 1.6×10^{-5}. You can construct a RICE table, or recognize that K_b is sufficiently small and the initial CN^- concentration is sufficiently high that x « 0.050 M, and the math simplifies to
$x = [OH^-] = \sqrt{C_{initial} K_b} = \sqrt{0.050 \times 1.6 \times 10^{-5}} = 8.944 \times 10^{-4}\ M$
pOH = 3.05. pH = 14 – pOH = 10.95

C06. (D) 44.0 g CO2 is 1.00 mole, which takes up 22.4 L at STP.

$$\text{Volume of a sphere} = \frac{4}{3}\pi r^3$$

The volume must be converted to cm^3 for the radius to come out in cm.

$$r = \left(\frac{3V}{4\pi}\right)^{\frac{1}{3}} = \left(\frac{3 \times 22{,}400\ \text{cm}^3}{4\pi}\right)^{\frac{1}{3}} = 17.5\ \text{cm}$$

Diameter = 2 × radius, so the diameter of the balloon = 2 × 17.5 = 35.0 cm.

C07. (C)

C08. (A) A billion billion billion atoms = 1×10^{27} atoms, or 1660.58 moles of carbon. $q = mc\Delta T$.
1660.58 moles C × –393.5 kJ/mol = 653,437 kJ given off. The volume of water = 40.0 m^3 = 40,000,000 mL. Assume a density of 1.00 g/mL for the water, m = 40,000,000 g.

$$\Delta T = \frac{q}{mc} = \frac{653{,}437{,}000\ \text{J}}{(4.00 \times 10^7 \text{g})(4.184\ \text{J/g} \cdot \text{K})} = 3.90\ ^\circ\text{C}$$

C09. (B) For $MgCO_3$ $K_{sp} = 3.5 \times 10^{-8} = x^2$, $x = [Mg^{2+}] = 1.87 \times 10^{-4}$ M
For MgF_2, $K_{sp} = 3.7 \times 10^{-8} = 4x^3$, $x = [Mg^{2+}] = 2.10 \times 10^{-3}$ M
For $Mg_3(PO_4)_2$, $K_{sp} = 1.0 \times 10^{-10} = (3x)^3(2x)^2 = 108x^5$, $x = 3.92 \times 10^{-3}$ M, $[Mg^{2+}] = 3x = 1.18 \times 10^{-2}$ M

C10. (A) The balanced equation is $Cr_2O_7^{2-} + 6\ Fe^{2+} + 14\ H^+ \rightarrow 2\ Cr^{3+} + 6\ Fe^{3+} + 7\ H_2O$.

C11. (C) A difference of 80 degrees on the Réaumur scale equals a difference of 180 degrees on the Fahrenheit scale, and the freezing point of water on the Réaumur scale is offset by -32 degrees from the Fahrenheit scale. Therefore °F = (180/80)°Ré + 32. °F = (180/80)(1) + 32 = 34.25 °F.

C12. (E) The student needs 5.00 grams of each component in the final mixture, and currently has $6.18 \times 0.28 = 1.73$ grams of $BaSO_4$, and $6.16 \times 0.72 = 4.45$ grams of KBr. So the student needs 3.27 grams of $BaSO_4$ and 0.55 grams of KBr to have 5.00 grams of each.

C13. (B) A plot of 1/Concentration vs time is linear for second order reactions.

C14. (B) The chemical formula is $C_{27}H_{46}O$.

C15. (A) Either draw in all the missing bonds and count them all, or do the math: 27 C atoms = 108 bonds, plus 46 H atoms = 46 bonds, plus 1 O atom = 2 bonds, for a total of 156, but divide by 2 because each bond is counted twice (once for each atom). This gives 78 total bonds in the molecule, minus one for the pi bond, leaving 77 sigma bonds.

C16. (E) 200 g Fe / 55.85 g/mol = 3.58 mol Fe. 3.58 mol Fe × (1 mol Fe_2O_3/2 mol Fe) = 1.79 mol Fe_2O_3 needed if the reaction had a 100% yield. The reaction is only 83.9% efficient, so this calculation underestimates the amount of reactant needed. The actual amount necessary is 1.79 mol Fe_2O_3/0.839 = 2.13 mol Fe_2O_3. 2.13 mol Fe_2O_3 × 159.7 g/mol = 341 g Fe_2O_3.

C17. (C)

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{\text{vap}}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

T_1 = normal BP for ethanol = 78.24 °C = 351.39 K. P_1 = 1 atm. T_2 = 5.0 °C = 278.15 K. P_2 = ?
ΔH_{vap} = 38.56 kJ/mol

$$\ln\left(\frac{P_2}{1}\right) = \frac{38{,}560\ \text{J/mol}}{8.314\,\text{J/mol}\cdot\text{K}}\left(\frac{1}{351.39} - \frac{1}{278.15}\right)$$

$$P_2 = 0.03095\ \text{atm} \times \frac{760\ \text{torr}}{1\ \text{atm}} = 23.5\ \text{torr}$$

C18. (D) Reverse equation 1, multiply equation 2 by 4, and add equation 3. Then divide by 2 to get one mole of product formed:

$4\ CO_2(g)\ +\ 2\ H_2O(\ell) \rightarrow 2\ C_2H_2(g)\ +\ 5\ O_2(g)$	$\Delta H° = 2600.0$ kJ
$4\ C(s)\ +\ 4\ O_2(g) \rightarrow 4\ CO_2(g)$	$\Delta H° = -393.5$ kJ × 4
$2H_2(g)\ +\ O_2(g) \rightarrow\ 2\ H_2O(\ell)$	$\Delta H° = -571.6$ kJ
$4\ C(s) + 2\ H_2(g) \rightarrow 2\ C_2H_2(g)$	$\Delta H° = 454.4$ kJ
$2\ C(s) +\ H_2(g) \rightarrow C_2H_2\ (g)$	$\Delta H°_f = 227.2$ kJ

C19. (C) Total moles NaOH added = (0.02345 L × 0.282 mol/L) + (0.00320 L × 0.282 mol/L) = 7.515×10^{-3} moles. Moles of KHP = (0.544 g / 204.222 g/mol) = 2.664×10^{-3} moles. Moles of NaOH that reacted with the H_2SO_4 = 7.515×10^{-3} moles – 2.664×10^{-3} moles = 4.851×10^{-3} moles. Moles H_2SO_4 = moles NaOH/2 = 2.426×10^{-3} moles H_2SO_4.
2.426×10^{-3} moles H_2SO_4 / 0.00500 L = 0.485 M H_2SO_4.

C20. (E) 186.4 g CO2 is 4.235 mol CO2, so the sample contains 4.235 moles, or 50.867 grams, of carbon. The remaining 11.38 grams of sample is hydrogen (11.29 moles). The mole ratio of H to C is 11.29/4.235 = 2.66:1. Multiply by 3 to get integer values, 8:1 H:C, or C_3H_8

PHYSICS SOLUTIONS – UIL REGIONAL 2019

P01. (B) pages 138-139: "But there is another approach to independently measure the total omega…. Measurements of the fluctuations in the CMBR [Cosmic Microwave Background Radiation] detected by COBE in 1990 gave the answer that omega is equal to 1."

P02. (D) page 170: "In 1941, the Canadian physicist Andrew McKellar had measured the temperature of the universe without realizing it….While studying the spectra of molecules in interstellar space to understand their function and origin, McKellar determined that the poisonous cyanogen molecules were extremely cold – in fact, around three kelvins…"

P03. (E) pages 218-219: "The most popular search strategy, which revealed the hot Jupiters, is to measure radial velocity – the wobble of the stars caused by the pull of their planet companions….Hot Jupiters are the easiest to detect via this wobble… "

P04. (D) While all of the gas giants have low densities compared to the inner planets, they do have some significant differences from one another. Jupiter and Saturn are primarily composed of hydrogen and helium, with very little else – thus they have the lowest densities. Saturn has a density less than that of water (so it would float if you had an ocean big enough).

Both Uranus and Neptune have large quantities of heavier molecules, such as ammonia and methane. However, thanks to its position in the very outer reaches of the solar system, Neptune has a much thicker core of water ice, dry ice, and liquid ammonia and methane. Thus, the average density of Neptune, which is 1.64 g/cm^3, is the greatest of all the gas giants.

P05. (A) Current is charge flow per unit time, so $I = \frac{\Delta Q}{\Delta t}$. We have the number of ions and the charge of each, so we can find the total charge: $\Delta Q = Ne = (1.0 \times 10^{12})(1.602 \times 10^{-19}) = 1.602 \times 10^{-7}$ C.
Now, the time just needs to be converted to seconds: $t = (1\ hr)\left(60\ \frac{min}{hr}\right)\left(60\ \frac{sec}{\text{min}}\right) = 3600$ s.
Dividing gives the current: $I = \frac{1.602 \times 10^{-7}}{3600} = 4.45 \times 10^{-11}$ A $= 44.5$ pA.

P06. (B) Since a distance is given, I will use the kinematic equation: $x = x_0 + v_0 t + \frac{1}{2}at^2$. Plugging in the values that are provided: $15 = 0 + (25)t + (0.5)(15.40)t^2$. This does leave us with a quadratic equation: $7.7t^2 + 25t - 15 = 0$, but that is solved easily enough. Plugging these values into the quadratic formula gives us: $t = \frac{-25 \pm \sqrt{625+462}}{15.4} = \frac{-25 \pm 32.97}{15.4} = 0.518s, -3.76s$. Since negative time doesn't make any sense, the correct choice must be the positive result: $t = 0.518$s.

P07. (A) First, we need to consider all of the forces: we have the applied force, F, oriented up the plane. We also have gravity (mg) pointed directly downward, and we have friction, F_f, oriented down the plane. There is also the normal force, F_N, oriented up and left, perpendicular to the plane.

As usual with an inclined plane, we tilt our coordinate system, so that the x-direction is up and right, parallel to the plane, and the y-direction is up and left, perpendicular to the plane. By doing this, we guarantee that the applied force is in the positive x-direction, while friction is in the negative x-direction. Likewise, the normal force is in the positive y-direction. The gravitational force must be broken into components: directed down the plane (in the negative x-direction) is $mgsin\theta$, while the component directed down and right, perpendicular to the plane (in the negative y-direction) is $mgcos\theta$.

Applying Newton's second law: $\sum F_x = F - F_f - mgsin\theta = ma_x$, and $\sum F_y = F_N - mgcos\theta = ma_y$. There is no acceleration in the y-direction, so $a_y = 0$, which gives: $F_N - mgcos\theta = 0$,
or $F_N = mgcos\theta = (50)(9.8)\cos(32) = 415.5$N. Since we know the coefficient of friction between the barrel and the plane, we can now determine the frictional force: $F_f = \mu F_N = (0.28)(415.5) = 116.4$N.
Plugging this all into the x-direction equation gives:
$F - F_f - mgsin\theta = 400 - 116.4 - (50)(9.8)\sin(32) = (50)a_x$, which simplifies to
$283.6 - 259.7 = 23.9 = 50a_x$, resulting in an acceleration of $a_x = \frac{23.9}{50} = 0.480$ m/s^2.

P08. (C) Although this is a two-dimensional problem, it is still just conservation of momentum, so it isn't too difficult. The basic equations are that momenta in both the x- and y- directions are conserved: $p_{xi} = p_{xf}$ and $p_{yi} = p_{yf}$.

Let's begin with the x-direction. Initially the second stone is at rest, so it has no initial momentum. The initial momentum of the first stone is entirely in the x-direction.
Thus, we have: $p_{xi} = p_{1xi} + p_{2xi} = m_1 v_{1i} + 0 = (1.25)(15.4) = 19.25$ kgm/s. The final momentum in the x-direction is non-zero for both stones. They are moving at angles, so we have to decompose the velocities into components: $v_{1xf} = V_1 \cos(27) = 0.891V_1$ and $v_{2xf} = V_2 \cos(-39) = 0.777V_2$. So, the final momentum in the x-direction is: $p_{xf} = p_{1xf} + p_{2xf} = (1.25)(0.891V_1) + (0.850)(0.777V_2)$. This gives $p_{xf} = 1.114V_1 + 0.6605V_2 = p_{xi} = 19.25$.

Now consider the y-direction: The initial velocity of the first stone is entirely in the x-direction, so it has no initial momentum in the y-direction. The second stone starts at rest, so it also has no initial momentum in the y-direction. Thus, $p_{yi} = 0$. They both, however, have momenta in the y-direction after the collision. Once again, we need to decompose the final velocities into components: $v_{1yf} = V_1 \sin(27) = 0.454V_1$ and $v_{2yf} = V_2 \sin(-39) = -0.629V_2$. So, the final momentum in the y-direction is: $p_{yf} = p_{1yf} + p_{2yf} = (1.25)(0.454V_1) + (0.850)(-0.629V_2)$. This gives $p_{yf} = 0.5675V_1 - 0.5347V_2 = p_{xi} = 0$.

Now the problem is reduced to algebra: using the y-direction equation: $0.5675V_1 = 0.5347V_2$ gives: $V_1 = 0.9422V_2$. Plugging this into the x-direction equation gives: $1.114(0.9422V_2) + 0.6605V_2 = 19.25 = 1.71V_2$. Thus, the final velocity of the second stone is $V_2 = \frac{19.25}{1.71} = 11.3$ m/s.

P09. (B) To begin, we must consider the force diagram for each block, and for the pulley. For the heavy block the forces are tension (T_1, up) and gravity ($m_1 g$, down). For the lighter block, the forces are also tension (T_2, up) and gravity ($m_2 g$, down). At the pulley, the forces cause torques, both counterclockwise ($T_1 R$) and clockwise ($T_2 R$). Note that because the rope does not slip on the pulley, then the tensions T_1 and T_2 are not the same magnitude. Also, since the forces act on the pulley's edge, the torque arm is the radius of the pulley, R.

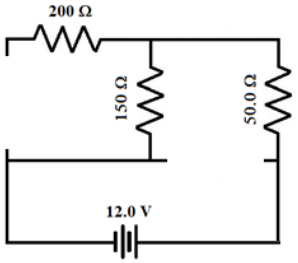
The acceleration of the heavy block is down, while the acceleration of the lighter block is up. The pulley will accelerate in the counterclockwise direction. Using Newton's second law, we can write the equations:
$\sum F_1 = m_1 g - T_1 = m_1 a = (17)(9.8) - T_1 = (17)a = 166.6 - T_1 = 17a$.
$\sum F_2 = T_2 - m_2 g = m_2 a = T_2 - (8)(9.8) = (8)a = T_2 - 78.4 = 8a$.
And using the equivalent equation for torques:
$\sum \tau = T_1 R - T_2 R = I\alpha = (T_1 - T_2)R = \frac{1}{2} M R^2 \alpha$. Here we can use the fact that $a = R\alpha$ to simplify this equation to $T_1 - T_2 = \frac{1}{2} M a = (0.5)(4.50)a = 2.25a$.

We have reduced this problem to the equations: $166.6 - T_1 = 17a$, $T_2 - 78.4 = 8a$, and $T_1 - T_2 = 2.25a$. Adding the first two equations gives: $166.6 - 78.4 + T_2 - T_1 = 17a + 8a = 25a = 88.2 - (T_1 - T_2)$. Now plugging in from the second equation: $88.2 - (2.25a) = 25a \rightarrow 88.2 = 27.25a \rightarrow a = 3.24$ m/s^2.

P10. (B) The shower can be considered to be an open-closed pipe, so the frequencies of resonances are given by the equation: $f_n = \frac{nv}{4L}$ for odd integer n values. In this equation v is the speed of sound, which at 20°C is given as $v = 343$ m/s. The two resonances are adjacent, that is they can be represented as $f_n = 280$Hz, and $f_{n+2} = 360$Hz. (We must go to n+2 for the second one because we can only have odd integer values). Subtracting these: $f_{n+2} - f_n = 360 - 280 = 80 = \frac{(n+2)v}{4L} - \frac{nv}{4L} = \frac{2v}{4L} = \frac{2(343)}{4L}$. This allows us to determine the length of the "pipe" to be: $80(4L) = 686 \rightarrow L = \frac{686}{320} = 2.14$m.

P11. (E) There are a variety of equations for the adiabatic process, the most widely-known of which is: $P_1V_1^{\gamma} = P_2V_2^{\gamma}$. However, we do not know the pressure (initial or final), so we must modify this equation by using the ideal gas law: $PV = nRT \rightarrow P = \frac{nRT}{V}$. Plugging this into the adiabatic equation gives: $\frac{nRT_1}{V_1}V_1^{\gamma} = \frac{nRT_2}{V_2}V_2^{\gamma}$. Simplifying gives another important adiabatic equation: $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$. Now we can plug in our known values: $(440)(2.80)^{1.4-1} = T_2(1.20)^{1.4-1}$, which gives $664.23 = 1.076T_2$, and a final temperature of $T_2 = 618\ K \approx 620\ K$.

P12. (C) A long time after the switch is closed this DC circuit will reach a state of equilibrium and all transient signals will have damped out. At that point, capacitors are fully charged and behave like open switches; and inductors simply behave like wires.
Replacing these elements in the circuit leaves a purely resistive network (as shown). The only complete loop has the 12.0V battery and two resistors (150Ω and 50Ω) in series. Thus, the current in the 150Ω resistor is:
$I = \frac{12}{(150+50)} = 0.0600\ A = 60.0\ mA$.

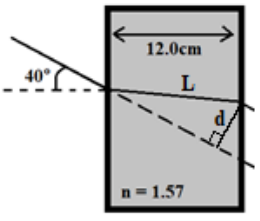


P13. (D) Since the point charge is at the center of the shell, then any distance from the point charge that is between 2.00cm and 4.00cm will be located inside the conductive material itself. So, a location that is 3.00cm from the point charge is inside the conductive material of the shell. Because charges are free to move inside of conductors, the charges will rearrange in such a way as to eliminate any static electric fields in a conductor. You may even have this fact memorized: the static electric field inside a conductor is always zero.

P14. (B) The formula for the magnetic field due to a current-carrying long straight wire is $|B| = \frac{\mu_0 I}{2\pi r}$. Here I is the current in the wire, and r is the distance from the wire to the point of interest (the origin in our case). The constant μ_0 is the permeability of free space. Using this, we can get the magnitude of the field caused by each current:
$|B_1| = \frac{\mu_0 I_1}{2\pi r_1} = \frac{(4\pi \times 10^{-7})(16.0)}{2\pi(0.05)} = 6.40 \times 10^{-5}\ T = 64.0\ \mu T$.
$|B_2| = \frac{\mu_0 I_2}{2\pi r_2} = \frac{(4\pi \times 10^{-7})(12.0)}{2\pi(0.07)} = 3.43 \times 10^{-5}\ T = 34.3\ \mu T$.
Magnetic fields are vectors, so at this point we must consider the direction of each of these fields. Magnetic field lines go in circles around current-carrying long straight wires: Using the right-hand rule, we can determine that the fields in both cases are oriented counterclockwise around the wires (both currents are in the same direction, so the fields are oriented similarly). Looking at the figure, and tracing a counterclockwise circle around the first wire, we see that the magnetic field at the origin due to the 16.0A current is pointed in the $+x$-direction. Similarly, we can see that the magnetic field at the origin due to the 12.0A current is pointed in the $-y$-direction.

Conveniently, this means that the two fields we have calculated are exactly perpendicular to one another. Therefore, we can combine them using the Pythagorean theorem. Working in microTeslas, the magnitude of the total magnetic field at the origin is then
$|B| = \sqrt{|B_1|^2 + |B_2|^2} = \sqrt{(64.0)^2 + (34.3)^2} = 72.6\ \mu T$.

P15. (D) Following the light ray though the glass, we first need to find the angle of refraction of the ray upon entering the glass: $n_1 sin\theta_1 = n_2 sin\theta_2 = (1)\sin(40) = 0.6438 = 1.57 sin\theta_2$ which gives $\theta_2 = sin^{-1}(0.4094) = 24.17°$. This allows us to find the length of the ray's path through the glass: $\cos(24.17) = \frac{12.0cm}{L} \rightarrow L = \frac{12.0}{\cos(24.17)} = 13.15cm$.
Now, consider the right triangle with L as its hypotenuse and d as one leg (as shown). The small angle, opposite to d, is $\phi = 40 - \theta_2 = 40 - 24.17 = 15.83°$. From this, we can get the shift distance, d. $sin\phi = \frac{d}{L} = \sin(15.83) = \frac{d}{13.15cm}$, which gives: $d = (13.15)(.2728) = 3.59cm \approx 3.6cm$.



P16. (C) The equation for the maxima from a double slit is $dsin\theta = m\lambda$. So, first we need the wavelength of the radio waves: $\lambda = \frac{c}{f} = \frac{3.00 \times 10^8}{850.0 \times 10^6} = 0.353$m. Since we are concerned about the distance between adjacent maxima, we will use $m = 1$. Plugging this into the double slit equation, along with the distance between the gaps: $dsin\theta = (12.0)sin\theta = (1)(0.353) \rightarrow sin\theta = \frac{0.353}{12} = 0.02942$. So, the angle between adjacent maxima is approximately $\theta = sin^{-1}(0.02942) = 1.69°$. The distance between maxima can then be found from: $X = Ltan\theta = (150.0)\tan(1.69) = 4.4$m.

P17. (C) The doppler shift for light, or relativistic doppler shift, is usually described by the equation: $f_{observed} = f_{source}\sqrt{\frac{1+\beta}{1-\beta}}$, where $\beta = \frac{v}{c}$ (defined as positive for a source moving towards the observer.) Converting this equation to wavelength by using $\lambda = \frac{c}{f}$, we get a similar equation: $\lambda_{observed} = \lambda_{source}\sqrt{\frac{1-\beta}{1+\beta}}$. Now we can plug in our numbers, taking care to note that since our source is moving away from the observer, then β will be negative. Thus, $\beta = -\frac{0.55c}{c} = -0.55$.
So, $\lambda_{observed} = (514)\sqrt{\frac{1-(-0.55)}{1+(-0.55)}} = (514)\sqrt{3.44} = 954$nm.

P18. (C) We begin by finding the total mass associated with each side of the reaction. On the left we have potassium-39 and helium-4: $M_L = 38.96371 + 4.002602 = 42.966312$amu. The mass on the right side (Scandium-42 plus a neutron) is $M_R = 41.965516 + 1.008665 = 42.974181$amu. The difference in the masses is then: $\Delta M = M_R - M_L = 42.974181 - 42.966312 = 0.007869$amu. This mass represents the amount of energy needed to complete this reaction. Converting this mass into an energy value: $E = \Delta Mc^2 = (0.007869)(931.5) = 7.33$ MeV.

P19. (E) The important equation here is simply Newton's second law: $F = ma$, but since we have a graph of acceleration versus mass, we see the inverse relationship of the rearranged equation: $a = \frac{F}{m}$. This graph is non-linear, so we are reduced to considering individual data points. First let's use (200g, 105cm/s^2), which gives a force of $F = ma = (0.200kg)(1.05m/s^2) = 0.21$ N. Then we can consider another data point, such as (500g, 45.0cm/s^2), which gives a force of $F = ma = (0.5kg)\left(\frac{0.45m}{s^2}\right) = 0.225$ N. In both cases, it is clear that the best answer choice is E) 0.21N.

P20. (A) The equation that describes the circular motion of charged particles in the presence of a perpendicular magnetic field is $r = \frac{mv}{qB}$. From this we can clearly see the inverse relationship between the radius of the beam's circular path and the strength of the magnetic field. Since the graph is the diameter (2r) versus the inverse of the field (1/B), we end up with a linear plot. Rearranging the formula shows the linear relationship: $r = \left(\frac{mv}{q}\right)\frac{1}{B}$. Multiplying by 2 gives us the diameter on the left side: $2r = d = \left(\frac{2mv}{q}\right)\frac{1}{B}$. Now we can see that the slope of the line shown on the graph should be $slope = \frac{2mv}{q}$. We know both the charge and the mass of an electron, so from the slope we can acquire the velocity of the electron beam, provided we are careful with the units of the slope. To get the slope from the graph, we choose two points on the line, such as (0.03μT^{-1}, 2.5cm) and (0.2μT^{-1}, 13.5cm). Then the slope is calculated to be: $slope = \frac{13.5-2.5}{0.2-0.03} = 64.7cm \cdot \mu T = 6.47 \times 10^{-7} Tm$. Now we can use this to acquire the velocity of the beam: $slope = 6.47 \times 10^{-7} = \frac{2mv}{q} = \frac{2(9.11 \times 10^{-31})v}{1.602 \times 10^{-19}}$. This gives a beam velocity of $v = 5.7 \times 10^4 \approx 6.0 \times 10^4$ m/s.

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** ☐