UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

District • 2022

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 major macromolecular groups are paired correctly with their respective monomers except
A) Proteins – amino acids
B) Carbohydrates – polysaccharides
C) Nucleic acids – nucleotides
D) Lipids – fatty acids
E) All of the above are paired correctly

B02. In Mendelian classical genetics and using the following genetic cross, how many individuals would express the dominant phenotype from both traits if 100 progeny were produced?

AABb x aaBb

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

B03. _____ is to bacteria as _____ is to eukaryotic somatic cells.
A) Binary fission; mitosis
B) Mitosis; meiosis
C) Meiosis; mitosis
D) Binary fission; meiosis
E) Mitosis; binary fission

B04. Which of the following techniques is used to amplify a specific sequence of DNA into billions of copies of that exact sequence for further research analysis?
A) Western blotting
B) Polymerase Chain Reaction
C) Southern blotting
D) Northern blotting
E) DNA fingerprinting

B05. All polymerases move down their respective nucleic acid template strands in
A) a 5' to 5' direction.
B) a 3' to 3' direction.
C) a 5' to 3' direction.
D) a 3' to 5' direction.
E) any direction (i.e. the direction is not permanently set).

B06. Transmembrane lipid transporter proteins are located in lipid bilayers, such as the plasma membrane, and assist with movement of lipids from one leaflet of the membrane to the other side. The specific name of the transport protein that moves phospholipids from the exoplasmic leaflet to the cytoplasmic leaflet is
A) flippase.
B) floppase.
C) scramblase.
D) protein kinase.
E) caspase.

B07. Earth is about 4.6 billion years old. When did the Great Oxidation Event occur?
A) ~.6 billion years ago
B) ~3.5 billion years ago
C) ~2.3 billion years ago
D) ~500 million years ago
E) ~2000 years ago

B08. In a population at Hardy-Weinberg equilibrium, 523 out of 1000 individuals in the population have a recessive phenotype. What percent of the population are heterozygotes?
A) 7.7%
B) 27.7%
C) 40.0%
D) 52.3%
E) 72.3%

B09. Land plants belong to Supergroup
A) SAR.
B) Unikonta.
C) Opisthokonta.
D) Chromalveolata.
E) Archaeplastida.

B10. Which of the following pathogens causes primary amoebic meningoencephalitis (brain-eating disease)?
A) *Entamoeba histolytica*
B) *Aspergillus niger*
C) *Ancylostoma duodenale*
D) *Plasmodium falciparum*
E) *Naegleria fowleri*

B11. What binds to a promoter?
A) DNA
B) RNA
C) DNA polymerase
D) RNA polymerase
E) Ribosomes

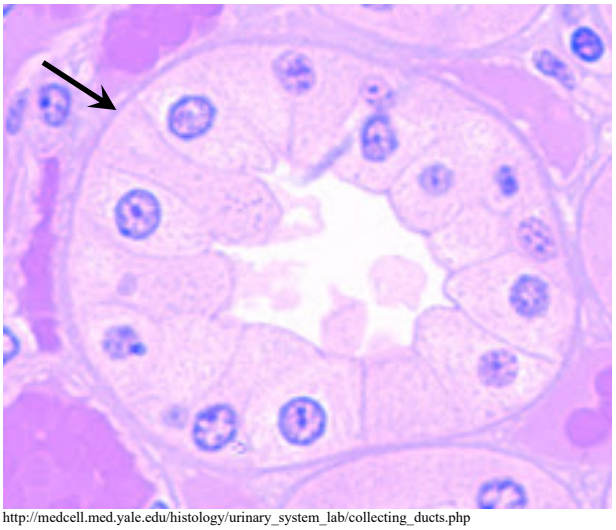
B12. Which of the following statements about the Calvin cycle in photosynthesis is incorrect?
A) The Calvin cycle is an anabolic pathway.
B) The Calvin cycle produces ATP and NADPH.
C) Carbon dioxide fixation occurs during the first step of the cycle with Rubisco as the enzyme.
D) CO_2 enters into the cycle and leaves as a carbohydrate.
E) The starting material is regenerated after molecules enter and leave the cycle.

B13. The Centers for Disease Control and Prevention has identified an outbreak linked to packaged "Power Greens." Which organism has been labeled as the culprit of this outbreak?
A) *Escherichia coli*
B) *Listeria*
C) Viral gastroenteritis
D) *Salmonella*
E) SARS-CoV2

B14. A main function of the urinary system is
A) disposal of metabolic wastes.
B) protection against mechanical injury.
C) locomotion and other movement.
D) food processing.
E) reproduction.

B15. Which major event is occurring in prophase of the mitotic cell cycle?
A) Chromosomes are condensing.
B) Nuclear envelope is disintegrating.
C) Centrioles are replicating.
D) Spindle apparatus is forming.
E) All of the above are occurring.

B16. Examine the microscopic image of the epithelial tissue lining a kidney tubule. This image is a cross-section of a collecting duct. The structure identified by the arrow is the



http://medcell.med.yale.edu/histology/urinary_system_lab/collecting_ducts.php

A) cell wall.
B) connective tissue.
C) basement membrane.
D) cytoplasm.
E) nucleus.

B17. Mosses and other bryophytes have
A) seeds.
B) gametophyte-dominated life cycles.
C) vascular tissue.
D) pollen grains.
E) flowers.

B18. The key mechanism of evolution is
A) genetic similarity.
B) gene flow.
C) homology.
D) natural selection.
E) artificial selection.

B19. Speciation that occurs due to geographic separation is knows as _____ speciation.
A) peripatric
B) parapatric
C) sympatric
D) allopatric

B20. In eukaryotic cells, the Krebs cycle occurs within the
A) cytosol.
B) chloroplast.
C) nucleus.
D) cytosol.
E) mitochondria.

C01. How many oxygen atoms are there in three moles of sodium bromate?

A) 1.81×10^{24}
B) 2.41×10^{24}
C) 3.61×10^{24}
D) 5.42×10^{24}
E) 6.02×10^{23}

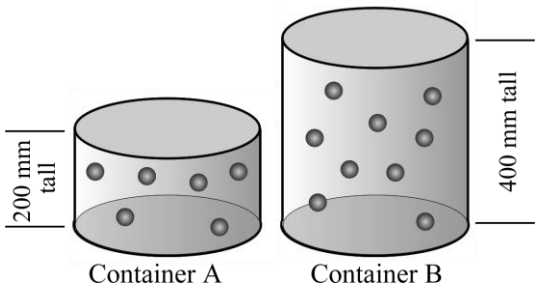
C02. If you have 100.0 g of A_3C (MM: 68.0 g/mol) and 100.0 grams BD_2 (MM: 44.0 g/mol), how many grams of AD (27.0 g/mol) can you form?

A) 123 g
B) 119 g
C) 102 g
D) 89.3 g
E) 40.5 g

C03. AT&T and Verizon operate primarily in two radiofrequency bands in the 700 and 800 MHz range. What is the wavelength in inches of a text message sent from a Verizon cell phone operating at 824.2 MHz?

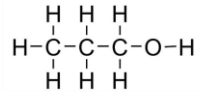
A) 1.18 inches
B) 14.3 inches
C) 37.5 inches
D) 49.9 inches
E) 72.2 inches

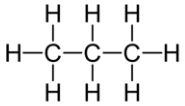
C04. Containers A and B have the same diameter and the same pressure. If the temperature of container A is 300 K, what is the temperature of container B?

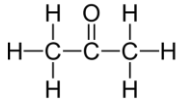


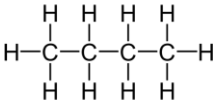
A) 200 K
B) 250 K
C) 300 K
D) 350 K
E) 400 K

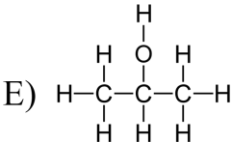
C05. Which of these compounds has the highest vapor pressure?

A) 

B) 

C) 

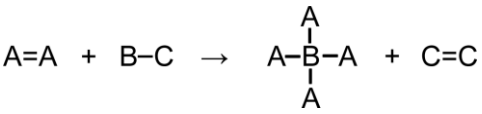
D) 

E) 

C06. What is the shape of a thionyl chloride ($SOCl_2$) molecule?

A) linear
B) trigonal planar
C) trigonal pyramidal
D) tetrahedral
E) square planar

C07. Estimate the ΔH of the reaction below using the bond energies on the data page.



A) –140 kJ
B) +140 kJ
C) –50 kJ
D) +50 kJ
E) +280 kJ

C08. If you had enough energy to melt a pound of ice (454 grams) at 0°C, but decided to use it to vaporize 100°C water instead, how many grams of water could you vaporize?

A) 67.1 g
B) 114 g
C) 228 g
D) 454 g
E) 3072 g

C09. The following chemical reaction is initiated:

$$AB_2(aq) + C_2D\ (aq) \rightleftharpoons 2CB(s) + AD(g)$$

After a few minutes a sample is taken and the following concentration measurements are made

$[AB_2] = 0.15$ M
$[C_2D] = 0.23$ M
$CB = 0.62$ g
$[AD] = 0.073$ moles of gas in a 1 liter volume

What is *Q* at this point in the reaction?

A) 0.47
B) 0.76
C) 1.3
D) 2.1
E) 2.9

C10. Which of these compounds would result in a solution with the highest pH if 0.10 mole of the compound was dissolved in 1.0 kg of water?

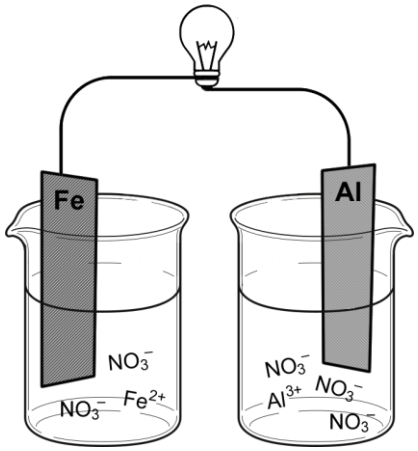
A) $HClO_2$
B) HCN
C) HF
D) HBrO
E) HNO_2

C11. When solid $Al(OH)_3$ is added to water, a small number of moles of $Al(OH)_3$, *x*, will dissolve. Which expression below correctly shows how *x* and the K_{sp} of $Al(OH)_3$ are related?

A) $K_{sp} = 4x^3$
B) $K_{sp} = 108x^5$
C) $K_{sp} = 4x$
D) $K_{sp} = 27x^4$
E) $K_{sp} = x^2$

C12. Which of these atoms or ions would have a ground state electron configuration ending in $3p^5$?
A) Ar^+
B) Br^-
C) Cl^-
D) F
E) S^{2-}

C13. Your friend constructed the electrochemical cell shown here, but when the light bulb didn't light up he realized he forgot to add the salt bridge. He makes a salt bridge containing 2 *M* KCl. When he inserts the salt bridge into the beakers, what will happen?



A) Electrons will flow through the wire from the aluminum to the iron
B) Electrons will flow through the wire from the iron to the aluminum
C) Electrons will not flow because there is no positive voltage.
D) $FeCl_2$ will precipitate out in the left beaker.
E) $AlCl_3$ will precipitate out in the right beaker.

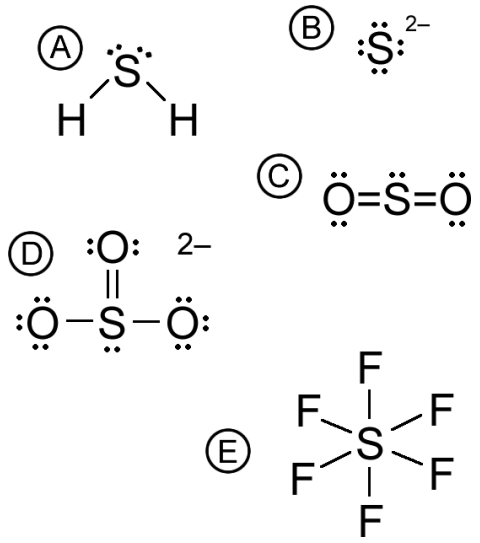
C14. The reaction $A + B_2 + C \rightarrow AB + CB$ is first order with respect to A and second order with respect to B. Which of these initial reactant concentrations will result in the highest initial reaction rate?

Answer Choice	Initial [A]	Initial [B_2]
A	2	1
B	1.25	1.25
C	0.5	2
D	1.5	1
E	1	1.5

C15. How many moles of gas are in an "empty" 2-liter soda bottle at 1 atm pressure and 25°C? An empty 2-liter bottle has a total volume of 2.050 L.

A) 1/6 mole
B) 1/8 mole
C) 1/10 mole
D) 1/12 mole
E) 1/20 mole

C16. In which one of these species is the sulfur atom in the highest oxidation state?



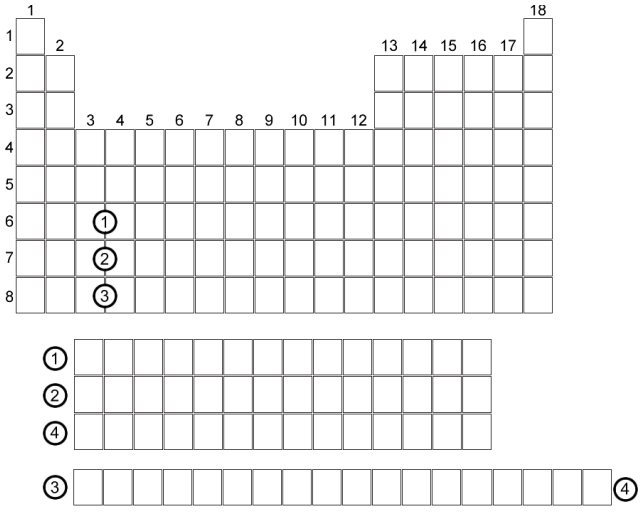
C17. How many grams of oxygen are there in 100.0 grams of $CuSO_4 \cdot 5H_2O$?

A) 32.03
B) 40.09
C) 57.66
D) 11.11
E) 9.00

C18. If you dissolve 100. grams of solid $CaCl_2$ in 750 g of water, what will the molality of the chloride ions be in the final solution?

A) 0.60 *m*
B) 1.20 *m*
C) 2.40 *m*
D) 3.60 *m*
E) 4.80 *m*

C19. Our current periodic table ends with element 118. The periodic table shown below goes 50 elements further, to element 168. Which subshell is represented by the row of elements at the very bottom of this future table?



A) 1*g*
B) 3*g*
C) 4*g*
D) 5*g*
E) 7*g*

C20. Which of these is not a colligative property of solutions?

A) An increase in entropy
B) Vapor pressure lowering
C) Boiling point elevation
D) Osmotic pressure
E) Freezing point depression

P01. According to Kaku, one of the inelegant things about Schrodinger's equation was that it treated space and time separately. Which physicist combined the two to create a compact and elegant quantum equation with four-dimensional symmetry?
A) Einstein
B) Planck
C) Born
D) Heisenberg
E) Dirac

P02. According to Kaku, the method of renormalization is a mathematical procedure for…
A) calculating system probabilities.
B) rotating the axes of a system.
C) cancelling infinities.
D) solving a differential equation.
E) solving a complex integral.

P03. According to Kaku, our best representation of the strong nuclear force is Quantum Chromodynamics. This theory is the combination of Gell-Mann's three quark symmetry and the renormalized solution of …
A) the Schrodinger equation.
B) the Yang-Mills field.
C) the Higgs field.
D) the Electroweak field.
E) Maxwell's electromagnetism.

P04. When a main sequence star expands into a red giant star, how and where is the energy generated that causes the star to expand?
A) helium fusion in the central core
B) helium fusion in a shell around the core
C) hydrogen fusion in the central core
D) hydrogen fusion in a shell around the core
E) carbon/oxygen fusion in the central core

P05. In the following equation, Q is electric charge in Coulombs, ε_0 is the permittivity of free space, v is velocity is m/s, and U is energy in Joules. What are the units of H?

$$H = \varepsilon_0 \frac{Uv}{Q}$$

A) Volts
B) Newtons / Coulomb
C) Teslas
D) Coulombs
E) Amperes

P06. A softball is thrown from an outfielder to third base. The distance between the players is 42.0m. If the ball was initially thrown at an angle of 27.0° above the horizontal, what was the initial speed at which it was thrown? You may assume the ball was thrown and caught at the same vertical height.
A) 4.75 m/s
B) 11.5 m/s
C) 16.0 m/s
D) 22.6 m/s
E) 31.9 m/s

P07. A tokoloshe is stealing an 11.4kg box of tools. The tokoloshe pulls with a horizontal force of 80.0N, and the coefficient of friction between the box of tools and the floor is 0.170. Assuming that it starts from rest, what is the horizontal velocity of the box of tools after being pulled for 2.50seconds.
A) 1.67 m/s
B) 5.35 m/s
C) 13.4 m/s
D) 15.6 m/s
E) 17.5 m/s

P08. An 18.0 kg crate of oranges is pushed up against a horizontal spring that has a spring constant of 930.0 N/m. The crate compresses the spring by 35.0cm. Once the crate is released, it is launched horizontally by the spring and slides a total distance of 3.95m across the floor before coming to rest. What is the coefficient of friction between the crate and the floor?
A) 0.0817
B) 0.164
C) 0.234
D) 0.323
E) 0.801

P09. A 12.3 kg solid cylinder of aluminum rolls down an inclined plane without slipping. The diameter of the cylinder is 16.0cm, and it starts from rest at a vertical height of 87.0cm above the floor. What is the linear speed of the rolling cylinder when it reaches the floor? Note: the rotational inertia of a solid cylinder is $I = \frac{1}{2}MR^2$.
A) 2.53 m/s
B) 3.37 m/s
C) 4.13 m/s
D) 5.84 m/s
E) 8.53 m/s

P10. A guitar string is 70.0cm long and has a mass of 2.30g. A standing wave, exactly as shown, is set up on the string. The frequency of the wave is 514 Hz. What is the tension in the string?

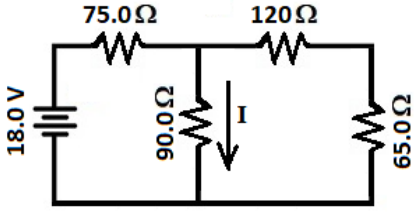
A) 122 N
B) 106 N
C) 49.1 N
D) 34.7 N
E) 24.3 N

P11. 2.00 moles of an ideal diatomic gas are initially at a pressure of 210 kPa and a volume of 35.0L. The gas is expanded adiabatically until the volume is 60.0L. What is the final temperature of the gas?

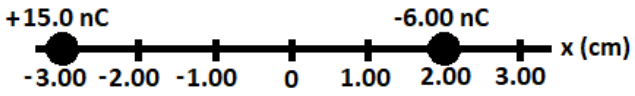
A) 208 K
B) 356 K
C) 442 K
D) 516 K
E) 758 K

P12. Determine the current, I, flowing through the 90.0 Ω resistor in this circuit.

A) 43.5 mA
B) 77.3 mA
C) 89.3 mA
D) 111 mA
E) 133 mA

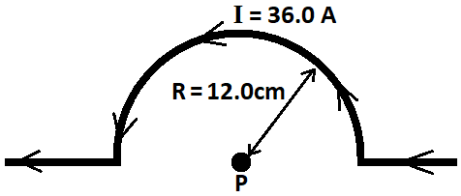


P13. Two charges are located on the x-axis as shown. A +15.0nC charge is located at $x = -3.00cm$ and a −6.00nC charge is located at $x = +2.00cm$. What is the magnitude of the electric field at the origin ($x = 0$) due to these two charges?



A) 7.20×10^3 N/C
B) 1.50×10^4 N/C
C) 1.35×10^5 N/C
D) 1.50×10^5 N/C
E) 2.85×10^5 N/C

P14. A current of 36.0A flows along a semicircular wire as shown. The radius of the semicircle is 12.0cm. What is the magnitude of the magnetic field at the center of the semicircle (point P) produced by the current in the wire?

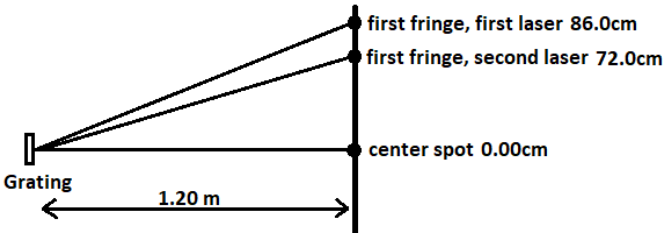


A) 30.0 μT
B) 47.1 μT
C) 60.0 μT
D) 94.2 μT
E) 188 μT

P15. You use a 2660 MW laser to launch a 1.25kg rocket into space. The bottom of the rocket is perfectly reflective and larger in diameter than the laser beam. Assuming you launch the rocket from the surface of the Earth, and ignoring air resistance, what is the initial acceleration of the rocket?

A) 4.39 m/s^2
B) 14.2 m/s^2
C) 8.87 m/s^2
D) 9.80 m/s^2
E) 0.930 m/s^2

P16. A red laser with a known wavelength of 630.0nm is directed through a diffraction grating and onto a wall that is 1.20m from the grating. On the wall, the first order fringes are 86.0cm from the central spot. You switch out the red laser with a different laser. The first order fringes for the second laser are only 72.0cm from the central spot. What is the wavelength of the second laser?



A) 486 nm
B) 527 nm
C) 556 nm
D) 585 nm
E) 713 nm

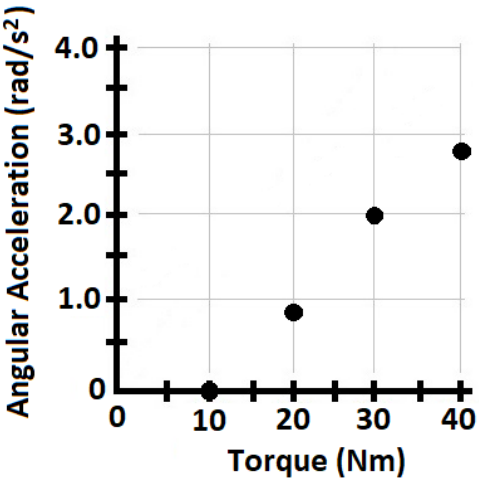
P17. While exploring the cosmos with your home-built telescope, you observe an asteroid that is moving with a velocity of 0.91c. The width of the asteroid along the direction of motion, as seen from the Earth's reference frame, is 1.20 km. If you were to land on the asteroid, how wide would it be in its own reference frame?

A) 1.20 km
B) 2.89 km
C) 4.00 km
D) 6.98 km
E) 13.3 km

P18. You discover a new isotope of Fermium while working in a research laboratory. Initially, you produce 16 atoms of this new isotope. After 17.0seconds, you have only 5 atoms remaining. What is the approximate half-life of this newly discovered isotope?

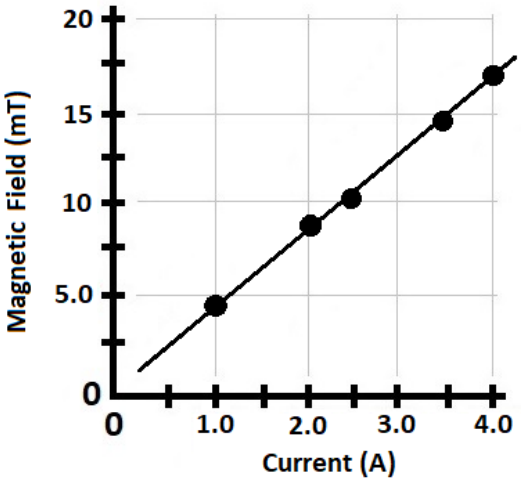
A) 3.1 seconds
B) 6.8 seconds
C) 10 seconds
D) 15 seconds
E) 17 seconds

P19. You measure the angular acceleration of a heavy door for different values of torque applied to the door. The data is plotted below. Based on this data, what is the approximate rotational inertia of the door?



A) 5.0 kgm^2
B) 10 kgm^2
C) 15 kgm^2
D) 20 kgm^2
E) 25 kgm^2

P20. You measure the magnitude of the magnetic field inside a solenoid for different currents flowing in the solenoid. The data is plotted below. Given that the solenoid is 15.0cm long, about how many turns of wire (loops) are in the solenoid?



A) 10,000 turns
B) 5000 turns
C) 1000 turns
D) 500 turns
E) 100 turns

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)

Water Data

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*

Constants

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

Conversion Factors

1 lb = 454 g
1 inch = 2.54 cm

Bond Energies

Bond	Bond energy (kJ/mol)
A-A	250
A=A	520
B-C	210
B-A	240
C-C	300
C=C	630

Weak acid dissociation constants

Acid	Formula	K_a
chlorous acid	$HClO_2$	1.2×10^{-2}
hydrocyanic acid	HCN	6.2×10^{-10}
hypobromous acid	HBrO	2.0×10^{-9}
hydrofluoric acid	HF	6.3×10^{-4}
nitrous acid	HNO_2	4.0×10^{-4}

Standard Reduction Potentials

Half-Reaction	$E^o_{reduction}$
$Fe^{2+} + 2e^- \rightarrow Fe$	−0.44 V
$Al^{3+} + 3e^- \rightarrow Al$	−1.66 V

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
2022 DISTRICT

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

CHEMISTRY SOLUTIONS – UIL DISTRICT 2022

C01. (D) 3 mol $NaBrO_3$ × (3 mol O/1 mol $NaBrO_3$) = 9 mol O atoms.
9 mol O atoms × 6.02 ×10^{23} atoms/mole = 5.42 × 10^{24} atoms

C02. (B) First you need a balanced equation for the reaction. $A_3C + BD_2 \rightarrow AD + B_xC_y$. In order to create AD from A_3C and BD_2, the coefficients on those compounds must be $2\ A_3C + 3\ BD_2 \rightarrow 6\ AD + B_xC_y$. We have 2C and 3B left over, so B_xC_y is B_3C_2, but that doesn't matter because it's not needed to solve the problem.

$$100.0\text{ g } A_3C \times \frac{1\text{ mol } A_3C}{68.0\text{ g } A_3C} \times \frac{6\text{ mol AD}}{2\text{ mol } A_3C} \times \frac{27.0\text{ g AD}}{1\text{ mol AD}} = 119.1\text{ g AD}$$

$$100.0\text{ g } BD_2 \times \frac{1\text{ mol } BD_2}{44.0\text{ g } BD_2} \times \frac{6\text{ mol AD}}{3\text{ mol } BD_2} \times \frac{27.0\text{ g AD}}{1\text{ mol AD}} = 122.7\text{ g AD}$$

A_3C is the limiting reactant, so 119.1 g of AD will form.

C03. (B) $\lambda = c/\nu$. $\lambda = (3.0 \times 10^8\text{ m/s})/(824.2 \times 10^6\text{ s}^{-1}) = 0.36399$ m = 36.399 cm.
36.399 cm × (1 in/2.54 cm) = 14.33 inches

C04. (E) Temperature, volume, and moles are all changing in this problem. To get an equation that relates those three variables, take a ratio of the ideal gas law for both containers and cancel out the variables that do not change (*P* and *R*):

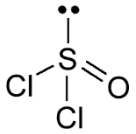
$$\frac{P_AV_A}{P_BV_B} = \frac{n_ART_A}{n_BRT_B} \qquad \frac{V_A}{V_B} = \frac{n_AT_A}{n_BT_B}$$

Then rearrange to solve for T_B. The ratio of volumes is equal to the ratio of heights for the containers.

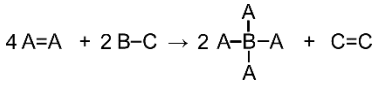
$$T_B = \frac{n_AT_AV_B}{n_BV_A} = \frac{(6)(300)(400)}{(9)(200)} = 400\ K$$

C05. (B) The one with the highest vapor pressure will be the one with the weakest intermolecular forces. A and E have hydrogen bonding, and C has dipole-dipole forces. B and D have only dispersion forces, but B is a smaller molecule with fewer dispersion forces, so B will have the highest vapor pressure.

C06. (C) Thionyl chloride has four regions of electron density around the central sulfur atom, giving it tetrahedral electronic geometry. Since one of those regions of electron density is a lone pair, the molecular shape is trigonal pyramidal.



C07. (C) Balance the equation, then count the bonds broken and the bonds formed. The heat of reaction is the sum of the bond energies for the bonds broken minus the sum of the bond energies for the bonds formed:



$$\Delta H_{\text{rxn}} = \sum nB.E._{\text{reactants}} - \sum nB.E._{\text{products}}$$

$$\Delta H_{\text{rxn}} = (4 \times 520) + (2 \times 210) - (8 \times 240) - (1 \times 630)$$
$$\Delta H_{\text{rxn}} = (4 \times 520) + (2 \times 210) - (8 \times 240) - (1 \times 630)$$
$$\Delta H_{\text{rxn}} = 2500 - 2550 = -50\text{ kJ}$$

C08. (A) The heat required to melt 454 g of ice is $q = m\Delta H_{\text{fus}}$ = 454 g × 334 J/g = 151,636 J. Applying that heat to vaporizing water, $q = m\Delta H_{\text{vap}}$, so $m = q/\Delta H_{\text{vap}}$ = 151,636 J / 2260 J/g = 67.1 g.

C09. (D) The equilibrium constant K is the lowest energy (most stable) ratio of products to reactants, and Q is the ratio of products to reactants at any point during the reaction. We saw last time that the equilibrium expression for this reaction is

$$K_{\text{eq}} = \frac{[\text{AD}]}{[\text{AB}_2][\text{C}_2\text{D}]}$$

and that is also the expression for Q.

$$Q = \frac{[\text{AD}]}{[\text{AB}_2][\text{C}_2\text{D}]} = \frac{(0.073)}{(0.15)(0.23)} = 2.12$$

C10. (B) These are all weak acids and will all drive the pH of water down, so the one with the highest pH will be the weakest acid, which lowers the pH by the smallest amount. The weakest acid is the one with the smallest K_a, which is hydrocyanic acid, HCN.

C11. (D) If x moles dissolves, then $[Al^{3+}] = x$ and $[OH^-] = 3x$. Plugging these into the K_{sp} expression, $K_{sp} = [Al^{3+}][OH^-]^3 = (x)(3x)^3 = 27x^4$.

C12. (A) The ground state electron configuration for a neutral Ar atom ends in $3p^6$, so removing one electron results in $3p^5$.

C13. (A) As soon as the circuit is complete, electrons will flow. Since aluminum has a more negative standard reduction potential than iron, the solid aluminum electrode will oxidize and iron ions in solution will be reduced at the iron electrode.

C14. (E). If the rate is first order with respect top A and second order with respect to B, then the rate law is rate =k[A][B]^2, and the rate is proportional to [A]×[B]^2, so whichever condition has the highest product will have the highest rate. That is 2.25, answer choice E.

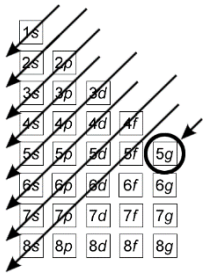
C15. (D) PV = nRT, so n = PV/RT. P = 1 atm, V = 2.050 L, R = 0.08206, and T = 298 K.
n = (1.00)(2.050)/(0.08206)(298) = 0.0838 mol
1/0.0838 = 11.9 mol^{-1}, or 0.0838 × 12 = 1.006 mol, so 0.0838 mol = 1/12 mol.

C16. (E) The oxidation states of the sulfur atoms are A) –2; B) –2; C) +4; D) +4, E) +6.

C17. (C) The molar mass of copper sulfate pentahydrate is 63.55+32.07+(4×16.00)+(10×1.01)+(5×16.00)= 249.72 g/mol. 100.0 grams is 100.0 g / 249.72 g/mol = 0.4004 moles of copper sulfate pentahydrate. There are 9 moles of O in each mole of $CuSO_4 \cdot 5H_2O$, so moles of O = 0.4004 × 9 = 3.60 mol × 16.00 g/mol = 57.66 grams of O.

C18. (C) Molality (m) is moles of solute per kilogram of water. 100 g $CaCl_2$ / 110.98 g/mol = 0.90106 moles $CaCl_2$ × 2 mol Cl^- / mol $CaCl_2$ = 1.802 mol Cl^-. 1.802 mol Cl^- / 0.750 kg = 2.40 m.

C19. (D) The subshell that comes after the 8s is the 5g. (This periodic table goes through the 8p subshell.)



C20. (A) Although it's true that the entropy usually increases when a solvent and solute are combined to form a solution, the increase in entropy is not a colligative property. Colligative properties are certain properties of a liquid that change when the pure liquid becomes a solution. B, C, D, and E are the four colligative properties.

PHYSICS SOLUTIONS – UIL DISTRICT 2022

P01. (E) page 63: "One of the things that was inelegant about the Schrodinger equation was that it treated space and time separately and hence calculations were often tedious and time-consuming. But Dirac's theory combined the two and had a four-dimensional symmetry, so it was also beautiful, compact, and elegant."

P02. (C) pages 81-82: "If we assume that the original bare mass and charge were actually infinite to start with, and then calculate the infinite quantum corrections, we find that these two infinite numbers can cancel each other out, leaving a finite result! In other words, infinity minus infinity equals zero! … This method is called renormalization theory. The procedure, however, is arduous, complex and mind-numbing."

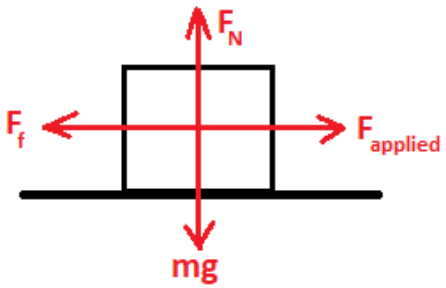
P03. (B) pages 95-96: "Finally, an enterprising Dutch grad student, Gerard 't Hooft, had the courage and raw stamina to plow through this thicket of infinite terms and, via brute force, renormalize the Yang-Mills field….. To do this, one needed quarks coming in three types, or colors, obeying Gell-Mann's three-quark symmetry. So a new theory of the strong force began to gain wide acceptance. This new theory was christened quantum chromodynamics (QCD)…"

P04. (D) When a main sequence star exhausts the hydrogen fuel in the central core, what remains in the core is helium. The helium core begins to contract, and, because of gravitational energy, it heats up. The helium in the core does not undergo fusion, but the excess energy does heat up a shell of hydrogen around the core sufficiently to start hydrogen fusion in the shell. The energy generated by the hydrogen fusion in the shell is significantly larger than when the star was on the main sequence. This excess energy from the shell flows to the upper layers of the star, causing the entire star to expand – creating a red giant.

P05. (E) From the page of constants, we can find the units for the permittivity of free space: $[\varepsilon_0] = \frac{C^2}{Nm^2}$. Now we can put it all together: $[H] = \frac{C^2}{Nm^2}\frac{Jm/s}{C} = \frac{CJ}{Nms}$. Recalling that a Joule is a Newton*meter, we get $[H] = \frac{CNm}{Nms} = \frac{C}{s}$. A Coulomb per second is the definition of an Ampere, so the units of H are Amperes.

P06. (D) Let us first consider the horizontal motion: the component of the initial velocity in the x-direction is given by $v_{xi} = v_i \cos\theta = v_i \cos 27 = 0.891v_i$. There is no acceleration in the horizontal, so we can relate this to the horizontal distance by the kinematic equation: $x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$. This gives $42.0 = 0 + 0.891v_i t + 0 \;\rightarrow\; v_i t = 47.14$. This may not look useful, but you will soon see that it is.
For the vertical motion, the initial velocity in the y-direction is $v_{yi} = v_i \sin\theta = v_i \sin 27 = 0.454v_i$. We know that the initial height and the final height are equal, and that the vertical acceleration is due to gravity, so we can use the same kinematic equation: $y_f = y_i + v_{yi}t + \frac{1}{2}a_y t^2$. Putting in the values gives: $0 = 0.454v_i t + \frac{1}{2}(-9.8)t^2$. Now we can use the result that we got for $v_i t$ from the horizontal direction: $0 = 0.454(47.14) - 4.9t^2 \;\rightarrow\; 21.4 = 4.9t^2 \;\rightarrow\; t = \sqrt{4.37} = 2.09s$. Finally, we can get the initial speed: $v_i t = v_i(2.09) = 47.14 \;\rightarrow\; v_i = 22.6$ m/s.

P07. (C) The force diagram for the box of tools is shown. Since there is no motion in the y-direction, we know that the normal force (F_N) and the weight (mg) cancel one another. Thus, $F_N - mg = 0 \rightarrow F_N = mg$. So, the normal force is $F_N = (11.4)(9.8) = 111.7$ N. From this we can determine the frictional force, $F_f = \mu F_N$. Thus, $F_f = (0.170)(111.7) = 19.0$ N.



In the horizontal direction, there is a net acceleration to the right, so by the acceleration law: $F_{app} - F_f = ma$. Putting in the values that we know: $80.0 - 19.0 = (11.4)a$, which gives an acceleration of $11.4a = 61.0 \rightarrow a = 5.35$ m/s^2. Finally, we can get the velocity by using a kinematic equation: $v_f = v_i + at = 0 + (5.35)(2.50) = 13.4$ m/s.

P08. (A) The system starts with elastic potential energy stored in the compressed spring. This energy is entirely converted to heat via the work done by friction. The initial elastic potential energy is: $U = \frac{1}{2}kx^2 = (0.5)(930)(0.350)^2 = 56.96$ J. The work done by friction is equal to the frictional force multiplied by the distance that the crate slides. Thus, $W = F_f d$. Equating the work and the initial energy gives the frictional force: $F_f d = 56.96 = F_f(3.95) \rightarrow F_f = 14.42$ N. Finally, similar to problem P07, the normal force acting on the crate will equal the weight of the crate. In other words: $F_N = mg = (18.0)(9.80) = 176.4$ N. Knowing the forces allows us to calculate the coefficient of friction: $\mu = \frac{F_f}{F_N} = \frac{14.42}{176.4} = 0.0817$.

P09. (B) We can use conservation of energy to solve this, but we must account for both the linear and rotational kinetic energies at the bottom of the inclined plane. Initially, the cylinder has only gravitational potential energy: $U_i = mgh = (12.3)(9.80)(0.870) = 104.9$ J. By conservation of energy, the final energy at the bottom of the inclined plane will equal this initial energy. At the bottom, the cylinder has both linear and rotational kinetic energies: $U_f = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$. The rotational inertia is $I = \frac{1}{2}mr^2$, and since the cylinder rolls without slipping, the angular velocity is related to the linear velocity by $\omega = \frac{v}{r}$. Combining these allows us to rewrite the rotational kinetic energy: $\frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{1}{2}mr^2\right)\left(\frac{v}{r}\right)^2 = \frac{1}{4}mv^2$. Thus, for this system, the total final energy is $U_f = \frac{1}{2}mv^2 + \frac{1}{4}mv^2 = \frac{3}{4}mv^2$. By conservation of energy, $U_f = U_i \rightarrow \frac{3}{4}mv^2 = 104.9$
Solving for the linear velocity: $(0.75)(12.3)v^2 = 104.9 \rightarrow v = \sqrt{11.4} = 3.37$m/s.

P10. (D) From the image, we can see seven anti-nodes, which means that this wave is the $n = 7$ harmonic. Thus, the wavelength of the standing wave is $\lambda = \frac{2L}{n} = \frac{(2)(0.70)}{7} = 0.20$m. Now we can determine the velocity of the wave: $v = \lambda f = (0.20m)(514Hz) = 102.8$ m/s.
We also need the mass per length of the string, which is: $\mu = \frac{m}{L} = \frac{2.30 \times 10^{-3}kg}{0.70m} = 3.286 \times 10^{-3}$ kg/m.
Finally, the wave velocity is related to the tension by: $v = \sqrt{\frac{T}{\mu}} \rightarrow 102.8 = \sqrt{\frac{T}{3.286\times10^{-3}}}$. This leads to $T = (3.286 \times 10^{-3})(102.8)^2 = 34.7$N.

P11. (B) Since the expansion is adiabatic, we can use the equation $P_1V_1^\gamma = P_2V_2^\gamma$. The gas is diatomic, thus $\gamma = 1.4$. Putting in the known values: $(210\ kPa)(35.0\ L)^{1.4} = P_2(60.0\ L)^{1.4}$ gives us the final pressure: $P_2 = 98.74$ kPa. The final temperature can now be found using the ideal gas law: $P_2V_2 = nRT_2$. Putting our values into proper units, this gives: $(98740Pa)(0.060m^3) = (2.00mol)(8.314\ J/molK)T_2$, which leads to the temperature: $T_2 = 356$ K.

P12. (C) First, we will need to simplify the circuit by combining the resistances. The first pair to combine are the 120Ω and the 65.0Ω, which are in series. That gives a combination of $R_s = 120 + 65 = 185\Omega$. This combination is in parallel with the 90.0Ω resistor. Putting together that parallel group leads to an equivalent resistance of $\frac{1}{R_p} = \frac{1}{185} + \frac{1}{90.0} \rightarrow R_p = 60.55\Omega$. Finally, this parallel group is in series with the 75.0Ω resistor, giving a total equivalent resistance for the circuit of $R_T = 60.55 + 75.0 = 135.5\Omega$. Using Ohm's Law, we can find the total current produced by the battery: $I_T = \frac{V_T}{R_T} = \frac{18.0\,V}{135.5\,\Omega} = 0.1328\text{A}$. Because of the series combination, this same current flows through the 75.0Ω resistor and through the parallel combination R_p. In other words, $I_p = I_{75} = I_T = 0.1328\text{A}$. Using this, we can calculate the voltage across the parallel group: $V_p = I_p R_p = (0.1328)(60.55) = 8.04\text{V}$. For resistances in parallel, the voltage across each branch is the same as the voltage across the group. In other words, $V_s = V_{90} = V_p = 8.04\text{V}$. Lastly, since we know the voltage across the 90.0Ω resistor, we can calculate the current through that branch using Ohm's Law. This is the current we are seeking: $I_{90} = \frac{8.04\,V}{90.0\,\Omega} = 0.0893A = 89.3mA$.

P13. (E) An electric field is a vector, so it has both magnitude and direction. The magnitude of an electric field produced by a single charge is given by: $|E| = \left|\frac{kQ}{r^2}\right|$. For the first charge, we have $Q_1 = 15.0\text{nC}$, and the distance to the origin is $r_1 = 3.00cm = 0.0300m$. This gives an electric field magnitude from the first charge of $|E_1| = \frac{kQ_1}{r_1^2} = \frac{(8.99\times10^9)(15.0\times10^{-9})}{(0.0300)^2} = 149833\ N/C$. For the second charge, we have $Q_2 = -6.00\text{nC}$, and the distance to the origin is $r_1 = 2.00cm = 0.0200m$. This gives an electric field magnitude from the second charge of $|E_2| = \left|\frac{kQ_2}{r_2^2}\right| = \frac{(8.99\times10^9)(6.00\times10^{-9})}{(0.0200)^2} = 134850\ N/C$.
Now for the directions: the first charge is positive, so the electric field points away from the charge. Thus, at the origin, the field from the first charge would point to the right. The second charge is negative, so its electric field points towards the charge. At the origin, the field from the second charge would also point to the right. Thus, both fields point in the same direction at the origin – to the right. Therefore, the total electric field would be the sum of the two individual fields: $|E| = |E_1| + |E_2| = 149833 + 134850 = 284683 = 2.85\times10^5$ N/C.

P14. (D) Because of the direction of the currents in the straight sections of wire – current going directly towards, or directly away from, the point P – those sections do not produce any magnetic field at the point P. Thus, only the semicircle produces a magnetic field at the point P. A full circle of current produces a magnetic field at its center according to the equation $|B| = \frac{\mu_0 I}{2R}$. Unsurprisingly, the field at the center of a semicircle is exactly half of the field of the full circle. Thus, $|B| = \frac{\mu_0 I}{4R}$ at the center of a semicircle. Inserting the given values, we get: $|B| = \frac{(4\pi\times10^{-7})(36.0)}{4(0.120)} = 9.42\times10^{-5}\,T = 94.2\,\mu T$.

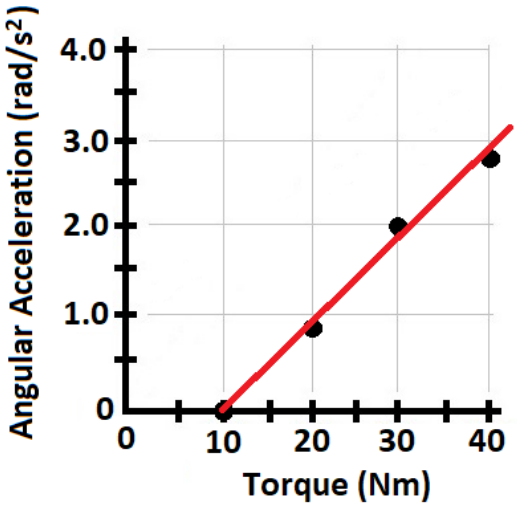
P15. (A) The radiation pressure due to light shining on a reflective surface is $Pressure = \frac{2I}{c}$ where I is the light intensity. Pressure is force per unit area, and intensity is power per unit area. Since the bottom of the rocket is larger than the laser beam, the area for both the pressure and intensity is simply the area of the laser spot. We don't need to know a value for this area, just that it is the same for both quantities: $Pressure = \frac{Force}{Area} = \frac{2(Intensity)}{c} = \frac{2(Power)}{c(Area)}$. Multiplying both sides by the area of the laser spot, we find: $Force = \frac{2(Power)}{c} \rightarrow F = \frac{2(2660\times10^6)}{3.00\times10^8} = 17.73$ N. This is the upward force due to radiation pressure. There is also the downward force of gravity: $F_g = mg$, which gives $F_g = (1.25)(9.8) = 12.25$ N. Thus, the net force on the rocket is $\sum F = 17.73 - 12.25 = 5.48$ N. Finally, we can use Newton's Second Law to find the acceleration: $\sum F = ma \rightarrow 5.48 = (1.25)a \rightarrow a = 4.39\text{m/s}^2$.

P16. (C) We can use the known laser to find the grating spacing for the diffraction grating. The equation for a bright spot produced by a diffraction grating is $d \sin\theta = m\lambda$. We are working with the first order fringes, so $m = 1$. As for the angle, we use the distances given: $L = 1.20m$ and $y_1 = 0.86m$. So, $\tan\theta_1 = \frac{y_1}{L} = \frac{0.86}{1.20}$. This leads to an angle of $\theta_1 = \tan^{-1}\left(\frac{0.86}{1.20}\right) = \tan^{-1}(0.7167) = 35.6°$. Now we can solve for the grating spacing: $d \sin 35.6° = (1)(630nm) \rightarrow d = 1082nm$.
We use this grating spacing, and the same process, to determine the wavelength of the second laser. The angle for the second laser: $\tan\theta_2 = \frac{0.72}{1.20} = 0.60 \rightarrow \theta_2 = \tan^{-1}(0.60) = 31.0°$. Thus, the wavelength of the second laser is $d \sin\theta_2 = m\lambda_2 \rightarrow (1082nm)\sin 31.0° = (1)\lambda_2 \rightarrow \lambda_2 = 556nm$.

P17. (B) This is an example of relativistic length contraction. In the Earth's reference frame, you observe the contracted length of the asteroid, $L = 1.20km$. In the frame of the asteroid, it will appear wider by a factor of $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$. Calculating this factor gives: $\gamma = \frac{1}{\sqrt{1-\frac{(0.91c)^2}{c^2}}} = \frac{1}{\sqrt{1-0.8281}} = \frac{1}{\sqrt{0.1719}} = 2.41$.
So, the width of the asteroid in its own reference frame is $L_0 = \gamma L = (1.20km)(2.41) = 2.89km$.

P18. (C) Although this is a small number of atoms, it is still approximately correct to use the exponential formula for half-life calculations: $N = N_0 e^{-\lambda t} \rightarrow 5 = 16e^{-\lambda t} \rightarrow 0.3125 = e^{-\lambda t} \rightarrow -\lambda t = \ell n(0.3125) = -1.163$. This gives a decay constant of $\lambda = \frac{1.163}{17sec} = 0.06842sec^{-1}$. Now we can determine the half-life from the decay constant: $T_{1/2} = \frac{\ell n(2)}{\lambda} = \frac{0.693}{0.06842} = 10.13 \approx 10$ seconds.

P19. (B) The equation relating torque to angular acceleration is $\tau = I\alpha$. This clarifies that the relationship is linear, and that we can obtain the rotational inertia from the slope of the best-fit line. The first thing you need to do is sketch in a best-fit line. This is shown to the right. Because the torque is plotted on the x-axis, and the angular acceleration is plotted on the y-axis, the slope of the best fit line will equal the inverse of the rotational inertia. That is, $slope = \frac{1}{\mathrm{I}}$, or $\mathrm{I} = \frac{1}{slope}$.
To obtain the slope, I must choose two points on the best fit line. Specifically, I chose (20Nm, 0.95rad/s^2) and (40Nm, 2.95rad/s^2). This gives a slope of: $slope = \frac{2.95-0.95}{40-20} = \frac{2.0}{20} = 0.1$ (kgm^2)$^{-1}$. Finally, this gives a rotational inertia of $I = \frac{1}{0.1} = 10$ kgm^2. Note: The non-zero intercept is likely due to static friction.



P20. (D) The equation describing the magnetic field inside a solenoid is $B = \mu_0 nI$, where $n = \frac{N}{L}$ is the number of turns per unit length of the solenoid. We can see that the relationship between B and I is linear, which is also obvious from the plot. Conveniently, a best-fit line is already provided. From the equation we determine that the slope of the best fit line relates to the geometry of the solenoid by $slope = \mu_0 n$. To calculate the slope, I must choose two points on the best-fit line. I chose the points (1.1A, 5.0mT) and (3.0A, 12.5mT), which give a slope of: $slope = \frac{12.5-5.0}{3.0-1.1} = 3.95$ mT/A. Relating this to the geometry of the solenoid, and putting in the value for the permeability of free space, gives: $slope = 3.95 \times 10^{-3}$ T/A $= (4\pi \times 10^{-7}$ Tm/A$)n$. Thus, the turns per length is $n = 3140$ m^{-1}. Finally, since we know the length of the solenoid, we can determine the total number of turns in the solenoid: $N = nL = (3140)(0.15) = 470 \approx 500$ turns.