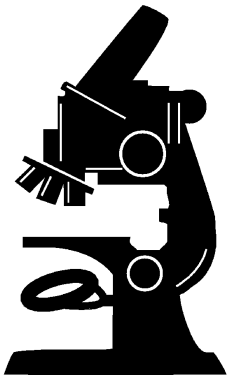
UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

Invitational B • 2018



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**

B01. All of the following would require an energy source except
A) endocytosis.
B) osmosis.
C) exocytosis.
D) active transport.
E) moving from low concentration to high concentration.

B02. Ribosomes are composed of two different types of molecules, each belonging to a different organic macromolecular group. To which two groups do these molecules belong?
A) Protein and Nucleic Acid
B) Carbohydrate and Protein
C) Lipid and Nucleic Acid
D) Carbohydrate and Nucleic Acid
E) Lipid and Protein

B03. In the eukaryotic genome, which structure contains a strand of DNA wrapped around eight histone core proteins?
A) chromatin
B) nucleosome
C) 10 nm fiber
D) 30 nm fiber
E) chromatid

B04. Millions of acres of rainforest are removed each year in a process called deforestation. Which of the following would not be a potential effect of deforestation?
A) Reduced gene flow and species fragmentation.
B) Increased soil erosion.
C) Increased floods.
D) Desertification due to decreased atmospheric water vapor.
E) Decreased atmospheric carbon dioxide concentration.

B05. In the Hardy-Weinberg principle, what is the relationship between p and q?
A) $p - q = 1$
B) $p^2 = q$
C) $p + q = 1$
D) $p/q = 1$
E) $2pq = 1$

B06. The epithelial tissue lining the _____ contains cells that have microscopic projections, called microvilli, to increase surface area.
A) lungs
B) liver
C) bile and pancreatic ducts
D) ureters
E) small intestines

B07. An antibiotic that blocks the A-site of the ribosome would immediately
A) cause dissociation of the ribosome from the mRNA.
B) block the binding of incoming tRNAs carrying amino acids.
C) prevent transcription.
D) cause the mRNA to be misread.
E) inhibit ribosomal translocation.

B08. Which of the following mechanisms can alter allele frequencies within a population?
A) Gene flow
B) Natural selection
C) Genetic drift
D) Sexual selection
E) All of the above alter allele frequencies.

B09. Polymerase Chain Reaction is a molecular biology technique used to
A) amplify a segment of DNA, usually from a very small starting quantity.
B) insert a plasmid into a bacterial cell.
C) determine the sequence of nucleotides on a DNA segment.
D) separate nucleic acids or proteins that differ by their size or charge.
E) digest DNA at specific palindromic sequences.

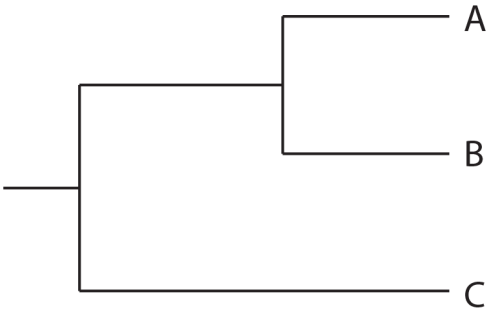
B10. Chickenpox is a disease caused by a/an
A) bacterium.
B) fungus.
C) helminth.
D) virus.
E) protozoan.

B11. What is the maximum theoretical yield of ATP produced per glucose by oxidative phosphorylation alone in aerobic respiration?
A) 4
B) 6
C) 28
D) 32
E) 38

B12. In ecology, an organism that breaks down the remains or waste products of other organisms is called a/an
A) producer.
B) scavenger.
C) consumer.
D) decomposer.
E) synthesizer.

B13. A student discovered a complete skull in an open field. After examining the teeth, the student observed that the pre-molars and molars were flat and broad. The student also noticed the canines were absent. Based on this information, the student predicted the skull was mostly likely from a/an
A) omnivore.
B) scavenger.
C) herbivore.
D) carnivore.
E) nonmammalian vertebrate.

B14. In the phylogentic tree below,



A) A and B are sister taxa.
B) A and B are unrelated.
C) C is called a node.
D) B is the common ancestor to A and C.
E) C is the common ancestor to A and B.

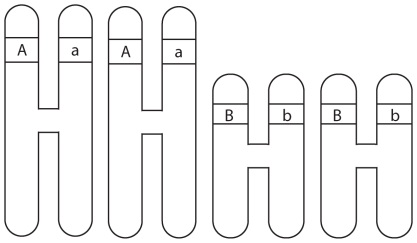
B15. In theory, how many molecules of carbon dioxide are needed to make two molecules of glucose during photosynthesis?
A) 1
B) 3
C) 6
D) 9
E) 12

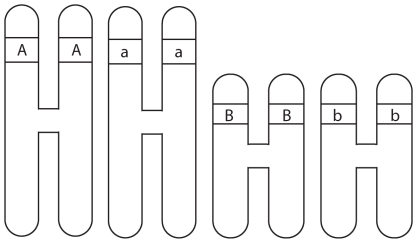
B16. All of the following are multicellular, eukaryotic parasites except
A) liver flukes.
B) tapeworms.
C) fleas.
D) malaria.
E) roundworms.

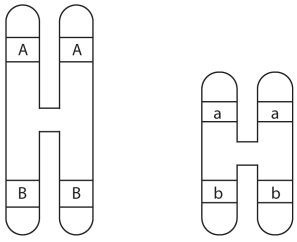
B17. The role of CAP in the regulation of the *lac* operon in some bacteria is to
A) increase the intracellular concentration of cAMP.
B) facilitate the binding of the repressor (LacI) to the *lac* operator sequence.
C) repress the *lac* operon.
D) assist RNA polymerase in binding to the promoter for the *lacZYA* genes.
E) prevent translation of *lacZYA* mRNA.

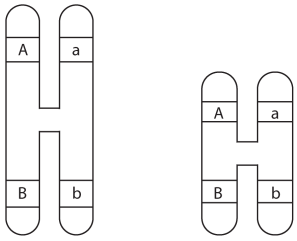
B18. A botanist found a plant that exhibited two dominant phenotypes. Assuming a Mendelian inheritance pattern for both traits, what genotype should the botanist use in a testcross to determine the exact genotype with respect to the two traits of the original plant?
A) AABB
B) AaBB or AABb
C) aabb
D) AaBb
E) aaBB or AAbb

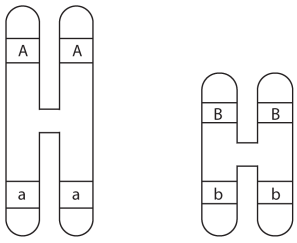
B19. An organism with the genotype AaBb has gene A and gene B located on two different chromosomes. Which of the following images is correct for the arrangement of the genes for this organism in G2 of interphase?

A) 

B) 

C) 

D) 

E) 

B20. The duck-billed platypus and the echidna are egg-laying monotremes belonging to
A) Class Mammalia.
B) Phylum Mammalia.
C) Kingdom Chordata.
D) Genus *Homo*.
E) Domain Animalia.

C01. Which of the following molecules has sp^3 hybridization on the central atom?

A) CO_2
B) H_2O
C) BF_3
D) PCl_5
E) SF_6

C02. How many moles of oxygen are there in 5 mol of copper(II) sulfate pentahydrate?

A) 5 moles
B) 9 moles
C) 20 moles
D) 25 moles
E) 45 moles

C03. If a chemical reaction is described as *spontaneous*, that means the reaction:

A) happens rapidly
B) occurs suddenly, without warning
C) results in an overall energy gain
D) results in an overall energy loss
E) occurs only in the forward direction and cannot be reversed

C04. Determine the empirical formula of a compound that has a percent composition of 43.7% P and 56.3% O.

A) P_2O_3
B) P_4O_{10}
C) P_3O_7
D) P_2O_5
E) PO_4

C05. Iron (III) reacts with cyanide ions in water to form $Fe(CN)_6^{3-}(aq)$. If the initial Fe^{3+} concentration is 1.00×10^{-3} M and the initial CN^- concentration is 0.150 M and the reaction goes to completion, what will the final concentration of CN^- be?

A) 0.000 M
B) 0.006 M
C) 0.144 M
D) 0.149 M
E) 0.150 M

C06. Pentaborane, B_5H_9, was once used as an experimental rocket fuel. It was known as *green dragon* because it explodes on contact with air and burns with a green flame. What is the standard enthalpy change of combustion, ΔH_c°, for pentaborane?

$$B_5H_9 \quad + \quad O_2 \quad \rightarrow \quad B_2O_3 \quad + \quad H_2O$$

A) –1623 kJ/mol
B) –3838 kJ/mol
C) –4519 kJ/mol
D) –7675 kJ/mol
E) –9039 kJ/mol

C07. The yellow line in the helium emission spectrum has a wavelength of 588 nm. What is the energy of one mole of 588 nm photons emitted by helium atoms?

A) 3.38×10^{-19} J
B) 1.48×10^{-28} J
C) 1.48×10^{15} J
D) 2.04×10^{5} J
E) 2.04×10^{-4} J

C08. What is the lattice energy of an ionic compound?

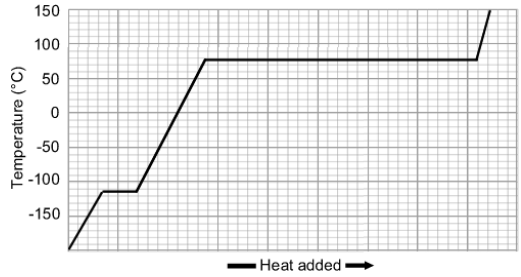
A) The energy given off when oppositely-charged ions in the gas phase combine to form an ionic bond
B) The total bond energy of all the ionic bonds in the crystal
C) The difference between the chemical potential of the crystal and the total bond energy
D) The energy released when a random arrangement of ions aligns itself into a crystal lattice
E) The energy that holds oppositely-charged ions slightly apart from one another in a solid crystal

C09. How many grams of NaCl would have to be added to 1000 grams of water to raise the boiling point to 102.5 °C?

A) 39 g
B) 78 g
C) 120 g
D) 140 g
E) 280 g

C10. Which diagram below best represents the heating curve for ethanol??

A)



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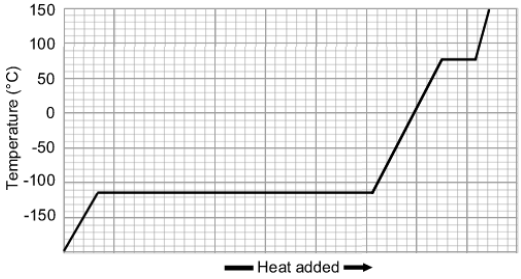
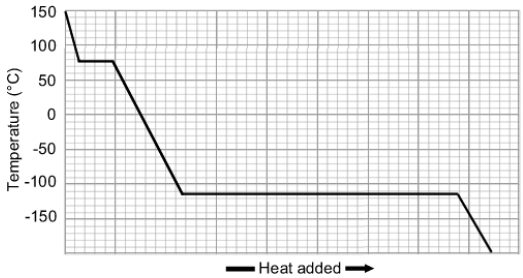
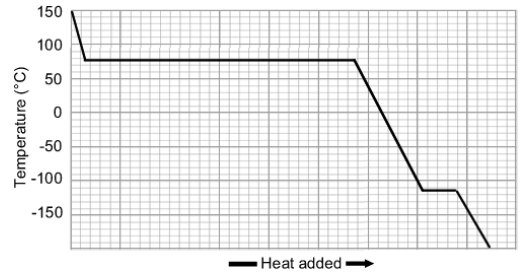


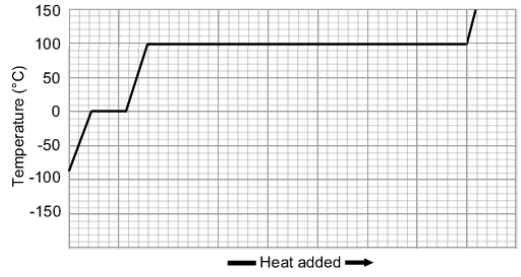
C)



D)



E)



C11. A buffer solution is made in which the concentration ratio of $H_2PO_4^-$ to HPO_4^{2-} is 10 to 1. What is the pH of the solution?

A) 3.16
B) 6.21
C) 7.21
D) 8.53
E) 10.0

C12. Which set of quantum numbers below corresponds to the valence electron that is lost when a sodium atom becomes a sodium ion?

A) $n = 1,\ \ell = 0,\ m_\ell = 0,\ \ m_s = +½$
B) $n = 2,\ \ell = 1,\ m_\ell = 1,\ \ m_s = +½$
C) $n = 3,\ \ell = 0,\ m_\ell = 0,\ \ m_s = -½$
D) $n = 3,\ \ell = 1,\ m_\ell = -1,\ m_s = +½$
E) $n = 3,\ \ell = 1,\ m_\ell = 1,\ \ m_s = -½$

C13. 10 g of nickel(II) iodate is added to 100 mL water. If the equilibrium concentration of iodate ion is 4.55×10^{-2} M, what is the K_{sp} for nickel(II) iodate?

A) 4.71×10^{-5}
B) 3.77×10^{-4}
C) 2.07×10^{-3}
D) 6.83×10^{-2}
E) 2.27×10^{-2}

C14. Phosphorus pentachloride decomposes at high temperatures to form phosphorus trichloride and chlorine gas:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

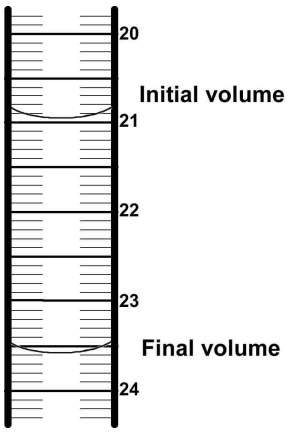
If 1.25 mol of PCl_5 is placed in a 2.0 L container and heated to 425 °C and 0.188 mol of PCl_3 is present at equilibrium, calculate the partial pressure equilibrium constant, K_p, for this reaction at 425 °C.

A) 0.0166
B) 0.579
C) 0.953
D) 6.29
E) 10.1

C15. An average adult human diet is 2000 Calories per day. One watt is 1 J/sec. Both of these are energy units divided by time. Assuming an average diet of 2000 Calories per day, what is the average wattage of an adult human being?

A) 5811 watts
B) 1389 watts
C) 487.3 watts
D) 96.85 watts
E) 21.33 watts

C16. Given the initial and final burette readings in the figure below, what volume was dispensed?



A) 2.5 mL
B) 2.56 mL
C) 2.64 mL
D) 3.36 mL
E) 5.1 mL

C17. Combustion of ammonia in oxygen produces nitrogen dioxide as one of the products. What is the sum of the coefficients in the balanced equation for the reaction of ammonia with oxygen gas?

A) 4
B) 8
C) 12
D) 16
E) 21

C18. The principal ore of lead is lead(II) sulfide, also known by its mineral name, galena. How many tons of lead are in 16.0 tons of galena?

A) 7.43
B) 10.7
C) 13.9
D) 14.4
E) 14.9

C19. If a 10.0-liter sample of neon gas at 760 torr is heated from 25.0 °C to 100 °C and compressed to 5.00 liters, what will the final pressure of the gas be?

A) 760 torr
B) 2.50 atm
C) 8.00 atm
D) 1.90×10^3 atm
E) 6.08×10^3 atm

C20. 100.0 mL of an HCl solution with a pH of 2.00 is added to 100.0 mL of an HCl solution with a pH of 4.0. To the correct number of significant digits, what is the pH of the resulting solution?

A) 2.3
B) 2.30
C) 3
D) 3.0
E) 3.00

P01. According to Tyson, scientists know that the Gravitational constant "big G" used in Newton's equation of gravity has not changed in eons, because if "big-G" had been different in the past then…
A) the energy output of the Sun would have been far more variable than the geological record indicates.
B) the orbital mechanics of the Earth would not have permitted a stable circular orbit.
C) the accretion disk around the Sun would have dispersed before planets formed.
D) the Earth's layers would not have differentiated and the Earth would not have a well-defined core.
E) the spiral arms of the Milky Way galaxy would not have remained stable, and our galaxy would now be an elliptical galaxy.

P02. According to Tyson, what do astrophysicists use to infer the structure and content of the matter in the early universe?
A) the intensity variations of gravitational waves from colliding neutron stars.
B) the temperature variations in the Cosmic Microwave Background.
C) the distribution of small, distant blue spiral galaxies.
D) the distribution of quasars.
E) the calculated intensity fluctuations of dark matter and dark energy.

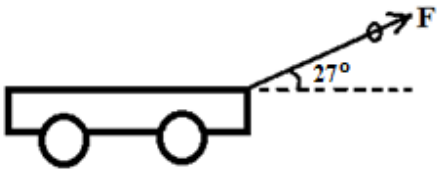
P03. According to Tyson, the light from distant quasars and galaxies has been _____ by objects that happen to fall along the line of sight to Earth's telescopes.
A) absorbed
B) spectrally depleted
C) enhanced
D) redshifted
E) gravitationally lensed

P04. A white dwarf star is primarily composed of what element?
A) Carbon
B) Iron
C) Oxygen
D) Helium
E) Hydrogen

P05. A certain snail you are watching is moving at the exciting speed of 32.0 mm/min. What is the speed of the snail in miles per hour?
A) 3.73×10^{-5} mph
B) 4.70×10^{-4} mph
C) 1.19×10^{-3} mph
D) 3.03×10^{-3} mph
E) 1.43×10^{-2} mph

P06. A golf ball rolls across the roof of a building at 3.00 m/s. It reaches the edge of the roof and flies horizontally off the building at that same speed. The height of the building is 12.50 m. Ignoring air resistance, how far from the base of the building will the golf ball first hit the ground?
A) 1.88 m
B) 3.39 m
C) 4.79 m
D) 6.12 m
E) 7.65 m

P07. A wagon with a mass of 12.0 kg is being pulled as shown by a force of 20.0 N. The force is pulling up at an angle of 27° above the horizontal. Ignoring friction, what is the horizontal acceleration of the wagon?



A) 0.757 m/s^2
B) 0.849 m/s^2
C) 1.00 m/s^2
D) 1.49 m/s^2
E) 1.67 m/s^2

P08. A 100.0g ball of clay is thrown directly upwards with an initial velocity of 8.00 m/s. At a height of 2.70m, the clay impacts a 30.0g dragonfly that is hovering with zero velocity. The dragonfly becomes stuck in the clay. What is the speed of the clay + dragonfly immediately after the collision?
A) 2.56 m/s
B) 3.33 m/s
C) 5.60 m/s
D) 6.15 m/s
E) 7.27 m/s

P09. A coin with a mass of 2.50g and a radius of 9.50mm rolls down the entire length of an inclined plane without slipping. The angle of the incline is 45°, and the length of the incline is 84.8cm. Assuming no losses due to friction, what is the linear velocity of the coin at the bottom of the incline? Note: the rotational inertia for a disk is $I = \frac{1}{2}mr^2$.

A) 2.10 m/s
B) 2.42 m/s
C) 2.80 m/s
D) 3.42 m/s
E) 4.08 m/s

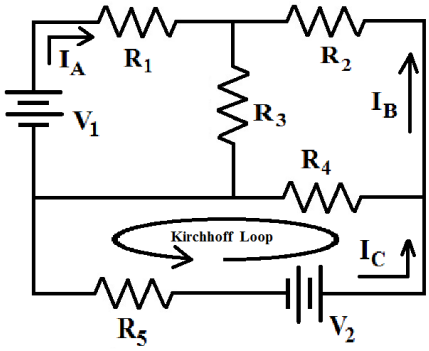
P10. A simple pendulum has a period of 1.75s. You take the pendulum on an elevator, and while the elevator is accelerating you measure the pendulum's period to be 1.62s. What is the acceleration of the elevator?

A) 0.728 m/s^2
B) 0.786 m/s^2
C) 1.40 m/s^2
D) 1.64 m/s^2
E) 3.54 m/s^2

P11. A diatomic gas ($\gamma = 1.4$) starts at a volume of 115cm^3 and a pressure of 3.10atm. The volume is increased adiabatically to 285cm^3. What is the new pressure?

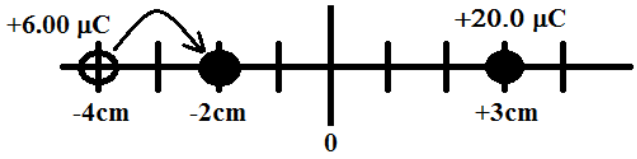
A) 0.680 atm
B) 0.870 atm
C) 1.25 atm
D) 1.62 atm
E) 1.80 atm

P12. For this circuit, determine which loop equation is correct for the Kirchhoff loop indicated. Note that three currents are already labelled.



A) $V_2 - R_4 I_C - R_5 I_C = 0$
B) $V_2 - R_4(I_C + I_A) - R_5 I_C = 0$
C) $V_2 - R_4(I_C - I_B) + R_5 I_C = 0$
D) $V_2 - R_4(I_B - I_C) + R_5 I_C = 0$
E) $V_2 - R_4(I_C - I_B) - R_5 I_C = 0$

P13. Determine the energy needed to move a +6.00μC charge from $x = -4.00cm$ to $x = -2.00cm$ in this system. There is a +20.0μC charge fixed at $x = +3.00cm$.

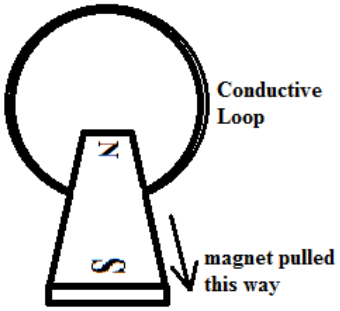


A) 6.18 J
B) 15.4 J
C) 21.6 J
D) 37.0 J
E) 212 J

P14. What is the Meissner effect?

A) The elimination of the magnetic field of a ferromagnetic material by heating.
B) The creation of an aligned magnetic field in a paramagnetic material.
C) The exclusion of a magnetic field from the interior of a superconductor.
D) The deflection of charged particles by a magnetic field.
E) The creation of an electric current by using a changing magnetic field.

P15. A magnet is arranged with its North pole pointed towards a conductive loop of wire (as shown). If the magnet is quickly pulled away from the loop, in which direction will current be induced in the loop?



A) clockwise around the loop.
B) counterclockwise around the loop.
C) from bottom to top, up each side of the loop.
D) from top to bottom, down each side of the loop.
E) no current will be induced in the loop.

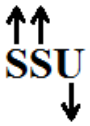
P16. A concave mirror with a radius of curvature of 60.0cm is hung in a bathroom. If a person stands 1.50m away from the mirror, where does the person's image appear to be located?
A) 25.0 cm from the mirror
B) 37.5 cm from the mirror
C) 42.9 cm from the mirror
D) 100 cm from the mirror
E) 158 cm from the mirror

P17. The Balmer lines of Hydrogen are transitions from high energy states down to the n = 2 state. The first three Balmer transitions produce photons with wavelengths given in this table:

Transition	Wavelength
n = 3 to n = 2	656 nm
n = 4 to n = 2	486 nm
n = 5 to n = 2	434 nm

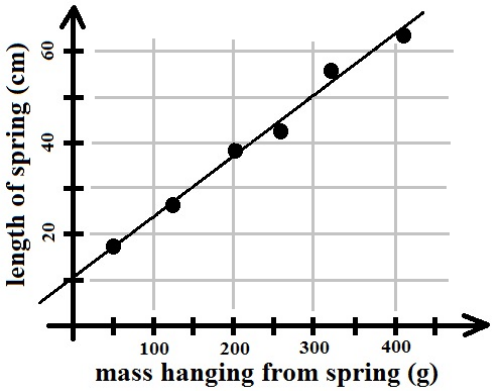
Using this data, determine the wavelength of the photon emitted by a hydrogen atom transitioning from n = 5 to n = 3.
A) 336 nm
B) 684 nm
C) 821 nm
D) 1280 nm
E) 2280 nm

P18. The quark structure of a particle is given by



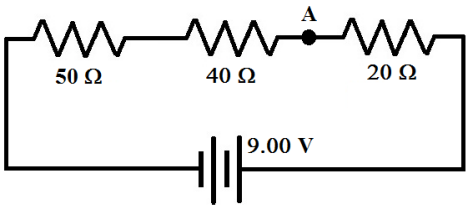
Which description correctly represents this particle?
A) Meson, Charge = 0, Spin = 0, Strangeness = +2
B) Meson, Charge = +1, Spin = 1, Strangeness = -2
C) Baryon, Charge = +2, Spin = $\frac{1}{2}$, Strangeness = +2
D) Baryon, Charge = +1, Spin = $\frac{3}{2}$, Strangeness = -2
E) Baryon, Charge = 0, Spin = $\frac{1}{2}$, Strangeness = -2

P19. You set up a spring so that it hangs vertically. You then hang various known masses from the spring and measure the length of the spring for each mass. The data you collected is graphed below. What is the approximate spring constant of the spring?



A) 0.60 N/m
B) 0.75 N/m
C) 1.3 N/m
D) 6.0 N/m
E) 7.4 N/m

P20. In this circuit, you measure the current at point A to be 129mA. This is definitely not what it should be. What could be wrong with the circuit to explain this measurement? (We assume you are using the ammeter correctly).



A) The 50 Ω resistor is shorted (zero resistance)
B) The 50 Ω resistor is open (infinite resistance)
C) The 40 Ω resistor is shorted (zero resistance)
D) The 20 Ω resistor is shorted (zero resistance)
E) The battery is dead (zero volts)

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

Heat of Formation

Compound	ΔH_f° (kJ/mol)
$B_5H_9(l)$	73.2
$B_2O_3(s)$	–1264
$H_2O(l)$	–285.8
$H_2O(g)$	–241.8

Physical Data for Ethanol

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

K_a values for Phosphoric Acid

$K_{a1} = 6.9 \times 10^{-3}$
$K_{a2} = 6.2 \times 10^{-8}$
$K_{a3} = 4.8 \times 10^{-13}$

Energy Unit Conversions

1 Calorie = 1000 calories
1 calorie = 4.184 J

Physics

Useful Constants

quantity	symbol	value
Free-fall acceleration	g	$9.80\ m/s^2$
Permittivity of Free Space	ε_0	$8.854 \times 10^{-12}\ C^2/Nm^2$
Permeability of Free Space	μ_0	$4\pi \times 10^{-7}\ Tm/A$
Coulomb constant	k	$8.99 \times 10^{9}\ Nm^2/C^2$
Speed of light in a vacuum	c	$3.00 \times 10^{8}\ m/s$
Fundamental charge	e	$1.602 \times 10^{-19}\ C$
Planck's constant	h	$6.626 \times 10^{-34}\ Js$
Electron mass	m_e	$9.11 \times 10^{-31}\ kg$
Proton mass	m_p	$1.67265 \times 10^{-27}\ kg$
Neutron mass	m_n	$1.67495 \times 10^{-27}\ kg$
Atomic Mass Unit	u	$1.66 \times 10^{-27}\ kg$
Gravitational constant	G	$6.67 \times 10^{-11}\ Nm^2/kg^2$
Stefan-Boltzmann constant	σ	$5.67 \times 10^{-8}\ W/m^2K^4$
Universal gas constant	R	$8.314\ J/mol \cdot K$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\ J/K$
Speed of Sound (at 20ºC)	v	343 m/s
Distance Conversion	miles → meters	1.00 mile = 1609 meters
Rydberg Constant	R_∞	$1.097 \times 10^{7}\ m^{-1}$

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2018 INVITATIONAL B

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

CHEMISTRY SOLUTIONS – UIL INVITATIONAL B 2018

C01. (B) An atom that is sp^3 hybridized always has four areas of electron density around it (either bonded atoms or non-bonding electron pairs).

C02. (E) $CuSO_4 \cdot 5H_2O$ has 9 moles of oxygen atoms in every mole of compound. Therefore 5 moles of compound will contain $5 \times 9 = 45$ moles of oxygen atoms.

C03. (D) A spontaneous reaction is one that is thermodynamically favorable (has a negative ΔG), meaning there is a net energy loss.

C04. (D) Assume you have 100.0 g of the substance. Then you have 43.7 g of P and 56.3 g of O. Dividing the mass of each element by its molar mass yields 1.411 mol of P and 3.519 mol of O. Divide both mole values by the smaller of the two values to convert at least one of them to an integer – this yields a ratio of 1 P atom for every 2.494 O atoms. Double both of these values to convert them both to integers and the result is 2 P atoms for every 5 O atoms, or P_2O_5. Answer (B), P_4O_{10}, has the same mole ratio, but an empirical formula is always the lowest whole-number ratio of atoms.

C05. (C) Since 6 CN^- react with each Fe^{3+}, if the reaction goes to completion it will consume 6×10^{-3} M CN^-, leaving 0.144 M CN^- unreacted in the solution.

C06. (C) The balanced equation for the reaction is

$$2\ B_5H_9\ +\ 12\ O_2\ \rightarrow\ 5\ B_2O_3\ +\ 9\ H_2O$$

ΔH_{rxn} can be calculated from the heats of formation of the reactants and products:

$$\Delta H_{\text{rxn}} = \sum \Delta H_{\text{f}}\,(products) - \sum \Delta H_{\text{f}}\,(reactants)$$

$$\Delta H_{\text{rxn}} = \left[5 \times \Delta H_{\text{f}}\,(B_2O_3) + 9 \times \Delta H_{\text{f}}\,(H_2O)\right] - \left[2 \times \Delta H_{\text{f}}\,(B_5H_9) + 12 \times \Delta H_{\text{f}}\,(O_2)\right]$$

The ΔH_f values for B_5H_9, B_2O_3, and H_2O (both liquid and gas) are given on the data page. Since ΔH_f refers to the compounds in their standard state (1 atm pressure and 25 °C), the value for H_2O(l) should be used in the calculation, not the value for H_2O(g). ΔH_f for O_2 is not given because ΔH_f for elements in their standard state is 0. Remember to multiply each heat of formation by the s stoichiometric coefficients for each species to get the total heat.

$$\Delta H_{\text{rxn}} = \left[5\ \text{mol}\left(-1264\,\frac{\text{kJ}}{\text{mol}}\right) - 9\ \text{mol}\left(-285.8\,\frac{\text{kJ}}{\text{mol}}\right)\right] - \left[2\ \text{mol}\ \left(73.2\,\frac{\text{kJ}}{\text{mol}}\right) + 12\ \text{mol}\left(0\,\frac{\text{kJ}}{\text{mol}}\right)\right]$$

$$\Delta H_{\text{rxn}} = -8892.2\ \text{kJ} - 146.4\ \text{kJ}$$

$$\Delta H_{\text{rxn}} = -9038.6\ \text{kJ}$$

This is the ΔH_{rxn} for the balanced equation, but the standard enthalpy change of combustion is defined for one mole of the compound. The balanced reaction includes 2 moles of B_5H_9, so the ΔH_{rxn} must be divided by 2 to get the enthalpy of combustion:

$$\Delta H_{\text{comb}} = -4519\ \text{kJ/mol}$$

The ΔH_f for $H_2O(g)$ provided on the data sheet is not used in this calculation. If a student uses that value instead of the ΔH_f for $H_2O(l)$ but otherwise does the problem correctly, they will get –4321 kJ/mol. The only answer close to this is the correct one.

C07. (D) $E = hv$, and $v\lambda = c$. These equations can be combined to yield $E = hc/\lambda$, which is the energy of one photon of a given wavelength. To get the energy of a mole of photons, the energy of one photon must be multiplied by Avogadro's number. If we are using a value for c that is in meters per second, λ must also be in meters.

$$E = \frac{(6.626 \times 10^{-34}\text{J} \cdot \text{sec})(3.00 \times 10^{8}\ \text{m/sec})}{588 \times 10^{-9}\ \text{m}} \times 6.022 \times 10^{23}/\text{mol} = 2.04 \times 10^{5}\ \text{J}$$

C08. (A) Lattice energy is defined as the energy given off when oppositely-charged gas phase ions combine to form an ionic bond.

C09. (D) The expression for boiling point elevation is $\Delta T = K_b \cdot m \cdot i$, where K_b is the boiling point elevation constant for water (0.512 °C/m), m is the solute concentration in molality (moles of solute per kilogram of solvent), and i is the van't Hoff factor for the solute, which in this case is 2. Solve for molality using the boiling point elevation expression, then multiply by kg of solvent to get moles of NaCl, then multiply by the molar mass of NaCl to get grams of NaCl.

C10. (A) The temperatures in graphs C and D are going *down* as heat is added, so those are incorrect. The boiling point and melting point in graph E don't match those of ethanol, so graph E does not represent ethanol. Graphs A and B differ in the lengths of the horizontal lines. The lengths of these lines are proportional to the heats of fusion and of vaporization for the compound. For ethanol, ΔH_{vap} (38.56 kJ/mol) is about eight times the value of ΔH_{fus} (4.9 kJ/mol), so the line representing boiling should be about eight times the length of the line representing freezing. This is true in Graph A. The specific heat data is not necessary to solve this problem, but correlates to the slopes of the lines for heating each phase. A lower specific heat corresponds to a steeper slope.

C11. (B) Since $[H_2PO_4^-]$ is 10 times $[HPO_4^-]$, the 10 to 1 ratio can be substituted into the K_a expression:

$$K_{a_2} = \frac{[H^+][HPO_4^-]}{[H_2PO_4^-]} = \frac{[H^+][1]}{[10]} = 6.2 \times 10^{-8}$$

Therefore $[H^+] = 6.2 \times 10^{-7}$, and the pH is 6.21.

C12. (C) Sodium's outermost electron is in the 3*s* orbital. Therefore n = 3 and $\ell = 0$, so only answer C can be correct. (For $\ell = 0$, m_ℓ always = 0, and the value of m_s could be either +½ or –½ because this electron is unpaired.)

C13. (A) Nickel iodate is $Ni(IO_3)_2$. There are two IO_3^- ions for every Ni^{2+} ion, so the Ni^{2+} concentration is half the IO_3^- concentration: $[Ni^{2+}] = ½(4.55 \times 10^{-2}\ M) = 2.275 \times 10^{-2}\ M$.
$K_{sp} = [Ni^{2+}][IO_3^-]^2 = [2.275 \times 10^{-2}][4.55 \times 10^{-2}]^2 = 4.71 \times 10^{-5}$.

C14. (C) First calculate K_C, then calculate K_P from that. Moles of PCl_5 = 1.25 – 0.188 = 1.062. Moles of PCl_3 = moles of Cl_2 = 0.188. The gases are in a 2 L container, so the molar concentrations are 0.531 M for PCl_5 and 0.0940 for PCl_3 and Cl_2.

$$K_C = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{[0.0940][0.0940]}{[0.531]} = 1.664 \times 10^{-2}$$

$$K_P = K_C(RT)^{\Delta n}$$

R = 0.08206 L·atm/mol·K, T = 425 °C + 273 = 698 K. There are two moles of gas products in the balanced equation and only one mole of reactant gas, so Δn = 2 – 1 = 1:

$$K_P = 1.664 \times 10^{-2}(0.08206 \times 698)^1 = 0.953$$

C15. (D)

$$\frac{2000 \text{ Calories}}{1 \text{ day}} \times \frac{1000 \text{ cal}}{1 \text{ Calorie}} \times \frac{4.184 \text{ J}}{1 \text{ cal}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 96.85 \frac{\text{J}}{\text{sec}} = 96.85 \text{ watts}$$

C16. (C) Volume dispensed = final volume – initial volume. The final volume is 23.60 mL and the initial volume is 20.96 mL. 23.60 – 20.96 = 2.64 mL.

C17. (E) The balanced equation is $4\ NH_3 + 7\ O_2 \rightarrow 4\ NO_2 + 6\ H_2O$.

C18. (C) Calculate the mass percent lead in PbS, then multiply that by the mass of the sample to determine the mass of lead in the sample.

$$\text{Mass percent Pb in Pbs} = \frac{\text{molar mass of Pb}}{\text{molar mass of PbS}} = \frac{207.20}{207.20 + 32.07} = 0.86597$$

$$0.86597 \times 16.0 \text{ tons} = 13.9 \text{ tons}$$

C19. (B)

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}, \text{ so } P_2 = \frac{P_1V_1T_2}{T_1V_2}$$

Most of the answers are given in atm, so convert P_1 from 760 torr to 1 atm before doing the calculation so that the answer comes out in atm. Also convert the temperatures from °C to kelvins. T_1 = 298 K and T_2 = 373 K.

$$P_2 = \frac{P_1V_1T_2}{T_1V_2} = \frac{(1 \text{ atm})(10.0 \text{ L})(373 \text{ K})}{(298 \text{ K})(5.00 \text{ L})} = 2.50 \text{ atm}$$

C20. (A) pH is a log scale, therefore you cannot simply average the two pH values. Calculate total moles of H^+ and total volume, then calculate the resulting $[H^+]$ concentration.

For the pH 2.00 solution, $[H^+] = 10^{-2.00} = 1.0 \times 10^{-2}$ M.
1.0×10^{-2} M × 0.1000 L = 1.0×10^{-3} moles of H^+

For the pH 4.0 solution, $[H^+] = 10^{-4.0} = 1 \times 10^{-4}$ M.
1×10^{-4} M × 0.1000 L = 1×10^{-5} moles of H^+

Total moles of $H^+ = 1.0 \times 10^{-3} + 1 \times 10^{-5} = 1.01 \times 10^{-3}$ moles
Total volume = 0.1000 L + 0.1000 L = 0.2000 L
Final $[H^+] = 1.01 \times 10^{-3}$ mol /0.2000 L = 5.05×10^{-3} M
Final pH = $-\log(5.05 \times 10^{-3}) = 2.3$

We can keep only one significant digit in the final answer because there is only one significant digit in the least precise measurement, which is the given pH 4.0 value. (In a log value only the digits after the decimal point are significant.)

SELECTED PHYSICS SOLUTIONS – UIL INVITATIONAL B 2018

P01. (A) page 40: "…if big G had been even slightly different in the past, then the energy output of the Sun would have been far more variable than anything the biological, climatological, or geological records indicate."

P02. (B) page 58: "By studying these temperature variations in the CMB [Cosmic Microwave Background] … we can infer what the structure and content of the matter was in the early universe."

P03. (E) page 72: "…where space is curved it can mimic the curvature of an ordinary glass lens and alter the pathways of light that pass through. Indeed, distant quasars and whole galaxies have been 'lensed' by objects that happen to fall along the line of sight to Earth's telescopes."

P04. (A) A white dwarf star is the husk of the core left behind when a low or medium mass star (like the Sun) dies. These smaller stars are unable to fuse heavier elements in their core, and thus only fuse up to the element Carbon, which is the primary element left behind as the white dwarf.

P05. (C) This conversion requires both the distance and the time to be converted. I'll do it all in one step: $32.0\ \frac{mm}{min} * \frac{1.0\ cm}{10.0\ mm} * \frac{1.0\ inch}{2.54\ cm} * \frac{1.0\ foot}{12.0\ inches} * \frac{1.0\ mile}{5280\ feet} * \frac{60.0\ min}{1.0\ hour} = 1.19 \times 10^{-3}\ \frac{miles}{hour}$.

P06. (C) This is a straightforward projectile problem, simplified by the fact that the initial velocity is entirely horizontal. First we need to find the time that the golf ball is flying through the air – this is just the time required for it to reach the ground. Using $y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$, noting the initial height of the ball, and that the velocity in the y-direction starts at zero, we get: $0 = 12.5 + 0 + \frac{1}{2}(-9.8)t^2$. Solving gives: $t^2 = 2.55$ or $t = 1.60\ sec$. Now we can find the horizontal distance travelled in that time. The initial velocity is entirely horizontal, and the horizontal acceleration is zero, so the distance travelled in the x-direction is simply: $x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 = 0 + (3.00)(1.60) + 0 = 4.79\ m$.

P07. (D) Since we are only looking for horizontal acceleration, we need only consider the horizontal component of the applied force: $F_x = Fcos\theta = (20.0)\cos(27) = 17.82\ N$. There is no friction, so this is the net horizontal force. Using Newton's second Law: $F = ma = 17.82 = (12)a$ gives $a = 1.49\ m/s^2$.

P08. (A) First, we need to find the velocity of the clay just before it impacts the dragonfly. It is easiest to do this with energy: $E_{initial} = \frac{1}{2}m_c v_0^2 = E_1 = m_c g h_1 + \frac{1}{2}m_c v_1^2$. This gives: $\frac{1}{2}(0.1)(8)^2 = (0.1)(9.8)(2.7) + \frac{1}{2}(0.1)v_1^2$. Solving for the velocity before impact: $v_1 = 3.33$ m/s. The impact with the dragonfly is perfectly inelastic, since they stick together afterwards. So, using conservation of momentum: $m_c v_1 = (m_c + m_d)v_f$. This gives: $(0.1)(3.33) = (0.1 + 0.03)v_f = (0.13)v_f$, resulting in $v_f = 2.56$ m/s.

P09. (C) Since the coin rolls without slipping, we must consider its rotation as well as its linear velocity. I think this problem is most easily solved with energy, but I will need the height of the starting point. To get the height of the inclined plane requires just a little trigonometry: $h = Lsin\theta = (84.8cm)\sin(45) = 60.0cm$. Now we can use conservation of energy, but we must also include rotational kinetic energy: $E_0 = mgh = E_f = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ Inserting the formula for the rotational inertia of a disk: $mgh = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}mr^2\right)\omega^2 = \frac{1}{2}mv^2 + \frac{1}{4}mr^2\omega^2$. Now recall that $v = r\omega$, so we get: $mgh = \frac{1}{2}mv^2 + \frac{1}{4}mv^2 = \frac{3}{4}mv^2$. Cancelling the mass and solving for velocity gives: $v^2 = \frac{4}{3}gh = \frac{4}{3}(9.8)(0.6) = 7.84$, and a final linear velocity of $v = \sqrt{7.84} = 2.80$ m/s.

P10. (D) We can use the initial period of the pendulum to get the length of the pendulum: $T = 2\pi\sqrt{\frac{L}{g}} = 1.75 = 2\pi\sqrt{\frac{L}{9.8}}$, which gives $L = 0.760$ m. In the elevator, the g in the period formula must also include the acceleration of the elevator: $T' = 2\pi\sqrt{\frac{L}{g+a}} = 1.62 = 2\pi\sqrt{\frac{0.76}{9.8+a}}$. It takes a bit of algebra, but solving for acceleration gives $9.8 + a = 11.44$, or $a = 1.64$ m/s^2.

P11. (B) This is relatively simple, if you remember the formula for an adiabatic process: $P_1V_1^{\gamma} = P_2V_2^{\gamma}$. This is <u>not</u> the same as the Boyle's law formula for an isothermal process. Using the adiabatic formula, and noting that we don't even need to convert units: $(3.10)(115)^{1.4} = P_2(285)^{1.4}$. This gives $P_2 = 0.870$ atm.

P12. (E) Kirchhoff's rules are critically important to solving many circuit problems, but writing the equations can often be the hardest part. The loop rule states that the sum of the voltage changes around a closed loop will be zero. A voltage change occurs whenever a circuit element (resistor, battery, etc…) is encountered as you journey around the loop. In this problem, the loop indicated is the one at the bottom of the circuit. There are three elements encountered along the loop: battery V_2, and resistors R_4 and R_5. The path indicated is counterclockwise around the loop, which is the same direction as I_C along the bottom part of the path.

However, I_C is not the current flowing through R_4. We need to use Kirchhoff's node rule at the node beside (to the right of) R_4 to get this current. Let's label the current through R_4 as I_4 and have it travelling to the left (out from the node). Using the node rule then gives $I_C = I_B + I_4$. Therefore $I_4 = I_C - I_B$. Now we can write the loop rule terms: passing from the negative side to the positive side of the battery is a positive step up in voltage, so our first term is $+V_2$. Passing through R_4, we are going in the same direction as I_4, so it is a step down in voltage, so our second term is $-R_4I_4 = -R_4(I_C - I_B)$. Then we get to the last element in the loop: we are travelling in the same direction as I_C, so it is a step down in voltage. Our final term is $-R_5I_C$. These terms must sum to zero, so our Kirchhoff equation is $V_2 - R_4(I_C - I_B) - R_5I_C = 0$.

P13. (A) To solve this problem, we need to calculate the potential difference across which the moving charge travels. The potential is created by the +20.0μC charge, so the potential at $x = -4.00cm$ is given by: $V_1 = \frac{kQ}{r} = \frac{(8.99\times10^9)(20.0\times10^{-6})}{(0.03-(-0.04))} = 2.57\times10^6\ V$.
And the potential at $x = -2.00cm$ is given by: $V_2 = \frac{kQ}{r} = \frac{(8.99\times10^9)(20.0\times10^{-6})}{(0.03-(-0.02))} = 3.60\times10^6\ V$.
Therefore, the potential difference is $\Delta V = V_2 - V_1 = 1.03\times10^6\ V$.
And the energy needed to move the charge is $U = q\Delta V = (6.00\times10^{-6})(1.03\times10^6) = 6.18\ J$.

P14. (C) The Meissner effect is the exclusion of a magnetic field from a superconductor. Tiny currents set up on the surface of the superconductor and cancel any fields attempting to penetrate the superconducting material.

P15. (A) Analysis of this problem requires Lenz' Law, which states that currents are induced to oppose changes in the magnetic flux. Before the magnet is moved, the north pole is towards the loop – therefore the magnetic flux is initially directed into the page. When the magnet is pulled away, the magnetic flux will decrease. Therefore, by Lenz' Law, the current induced will produce a field to replace that lost flux. In other words, the induced current will create a magnetic field in the same direction that the bar magnet produced before it was pulled away – a field directed into the page. By the right-hand-rule, you can point your right thumb in the direction of the induced field (into the page), and your fingers will curl in the direction of the induced current – clockwise.

P16. (B) The focal length for a concave mirror is positive and equal to half the radius of curvature. In other words, $f = \frac{R}{2} = \frac{60}{2} = 30cm$. The object is at $p = 1.5m = 150cm$. Using the mirror equation, we can get the location of the image: $\frac{1}{p} + \frac{1}{q} = \frac{1}{f} = \frac{1}{150} + \frac{1}{q} = \frac{1}{30}$. This leads to $\frac{1}{q} = \frac{1}{30} - \frac{1}{150} = \frac{4}{150}$, or $q = \frac{150}{4} = 37.5cm$.

P17. (D) You must use energy to solve this problem – so first we need to convert some of the Balmer lines into energy differences. What we really need are the energy differences for the n = 3 →2 transition and for the n = 5 → 2 transition. For the n = 3 to n = 2 transition: $\Delta E_{3\to2} = \frac{1240\ eVnm}{\lambda} = \frac{1240}{656} = 1.89\ eV$. And for the n = 5 to n = 2 transition: $\Delta E_{5\to2} = \frac{1240\ eVnm}{\lambda} = \frac{1240}{434} = 2.86\ eV$. Now, we know that transitions, or combinations of transitions, that start and end at the same energy level undergo the same energy differences, so that $\Delta E_{5\to2} = \Delta E_{5\to3} + \Delta E_{3\to2}$. Thus $2.86 = \Delta E_{5\to3} + 1.89$, giving us $\Delta E_{5\to3} = 2.86 - 1.89 = 0.97\ eV$. Then the wavelength for this transition is $\lambda_{5\to3} = \frac{1240\ eVnm}{\Delta E} = \frac{1240}{0.97} = 1280\ nm$.

P18. (E) This particle has three quarks, so that means it is a Baryon (a Meson has a quark and an anti-quark). Strange quarks have a charge of $\frac{-1}{3}$ and up quarks have a charge of $\frac{+2}{3}$, so two strange quarks and an up quark have a total charge of $\frac{-1}{3}+\frac{-1}{3}+\frac{+2}{3}=0$. All quarks have a spin of $\frac{1}{2}$, but it can be oriented up or down. Clearly the two strange quarks are spin-up and the up quark is spin-down (confused yet?). This means the total spin is $\frac{1}{2}+\frac{1}{2}-\frac{1}{2}=\frac{1}{2}$. Finally, note that there are two strange quarks. A single strange quark carries a strangeness of -1, so two strange quarks will give a total strangeness of -2.

P19. (E) In this experiment, the gravitational force of the mass is balanced by the Hooke's Law force of the spring. Mathematically, $kx=mg$. On the graph, we have the length of the spring, L. This is related to the amount the spring is stretched: $L=x+L_0$ where L_0 is the length of the spring when no mass is hanging from it.
So, $k(L-L_0)=mg$, or $kL=mg+kL_0$, which gives the linear equation: $L=\frac{g}{k}m+L_0$. This is the equation of the line of best fit drawn on the graph. From this we can see that the slope of the line is $slope=\frac{g}{k}$.
The approximate slope of the best fit line on the graph is $\frac{50cm-30cm}{300g-150g}=\frac{20cm}{150g}=\frac{0.2m}{0.15kg}=1.33\ m/kg$.
Now, the spring constant is $k=\frac{g}{slope}=\frac{9.8\ m/s^2}{1.33\ m/kg}=7.35\ \frac{kg}{s^2}\approx 7.4\ \frac{N}{m}$.

P20. (C) Since this is a series circuit, the current at one point is the same current throughout the circuit. Thus, the total current in the circuit is 129mA. Since we know the total voltage supplied to the circuit, we can use Ohm's Law to get the equivalent resistance of the circuit: $R=\frac{V}{I}=\frac{9.0\ V}{129\ mA}=70\ \Omega$. Resistors in series add, so if all of the resistors were functioning properly, then we would expect an equivalent resistance of 110 Ω. Clearly, one of the resistors is bad. If a resistor were open, or if the battery was dead, then no current would flow, which is obviously incorrect. The only choices remaining are that a resistor is shorted.
The only way to sum two of the three resistors and get 70 Ω is with the 50 Ω resistor plus the 20 Ω resistor – so it is likely that those two resistors are functioning properly. Therefore, we may conclude that, most likely, the 40 Ω resistor is shorted.
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