UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

District • 2023

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. Crossing over during ______ is one way that genetic diversity is established in sexual reproduction.
A) Metaphase I
B) Anaphase II
C) Prophase I
D) Prophase II
E) Telophase I

B02. If purple is dominant over white, what percent of offspring from the following cross would be white?

Pp x pp

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

B03. Given the following template strand, the complementary sequence produced after DNA replication would be

3'-GTAACATGC-5'

A) 5'-GCATGTTAC-3'
B) 5'-CATTGTACG-3'
C) 3'-GCATGTTAC-5'
D) 3'-CATTGTACG-5'
E) 5'-CAUUGUACG-3'

B04. Melanoma is a type of skin cancer. From which cell type does this cancer derive?
A) melanocytes
B) basal cells
C) squamous cells
D) mast cells
E) keratinocytes

B05. The Gram-positive etiologic agent of pneumococcal meningitis is
A) *Klebsiella pneumoniae*.
B) *Neisseria meningitidis*.
C) *Staphylococcus aureus*.
D) *Streptococcus pneumoniae*.
E) *Bacillus anthracis*.

B06. An organic macromolecule that contains an $–NH_2$, –COOH, alpha carbon, and an R-group that ranges from a single hydrogen to ring-like structures would best be classified into which major macromolecular group?
A) carbohydrates
B) proteins
C) amino acids
D) nucleic acids
E) disaccharides

B07. A defining characteristic of Supergroup Opisthokonta is
A) the presence of flagellated cells with a single posterior flagellum.
B) an asymmetrical appearance with a feeding groove.
C) the presence of plastids, such as chloroplasts.
D) the shared evolutionary origin of chloroplasts and the presence of cellulose in cell walls.
E) amoeboid organisms with microtubule-supported pseudopodia.

B08. The organ system that is responsible for gamete production is the
A) digestive system.
B) nervous system.
C) urinary system.
D) reproductive system.
E) integumentary system.

B09. What major event occurred 65.5 million years ago?
A) extinction of the dinosaurs
B) the beginning of the diversification of mammals
C) the K-T event
D) extinction of 95% of plant and animal species
E) All of the above occurred.

B10. The domain of life that includes single-celled organisms, the closest relatives to mitochondria and chloroplasts, and many phyla with organisms responsible for human disease is
A) Domain Archaea.
B) Domain Bacteria.
C) Domain Eukarya.
D) Domain Prokarya
E) Domain Archaebacteria.

B11. The _______ zone of a lake or ocean is where the rate of photosynthesis is greater than the rate of cellular respiration by phytoplankton.
A) benthic
B) abyssal
C) photic
D) primary
E) aphotic

B12. How many carbon dioxide molecules are made during the Krebs cycle per glucose molecule?
A) 0
B) 1
C) 2
D) 4
E) 6

B13. Which of the following would be the best choice to counteract a speciation event?
A) gene flow
B) mutation
C) predation
D) selection
E) isolation

B14. Which process produces mRNA, tRNA, and rRNA?
A) replication
B) transduction
C) translation
D) regulation
E) transcription

B15. In a population at Hardy-Weinberg equilibrium, 212 organisms out of 507 express the recessive phenotype. What is the frequency of the recessive allele?
A) 0.125
B) 0.353
C) 0.418
D) 0.457
E) 0.647

B16. The eukaryotic organelle that contains catalase, which converts reactive oxygen species into H_2O_2 and then further oxidizes other compounds, is the
A) nucleus.
B) lysosome.
C) mitochondrion.
D) peroxisome.
E) Golgi apparatus.

B17. During photosynthesis, which molecule serves as the final electron acceptor?
A) oxygen
B) NADPH
C) $NADP^+$
D) chlorophyll
E) ATP

B18. Repressor is to _______ as RNA polymerase is to
A) operator; Shine-Dalgarno.
B) promoter; start codon.
C) activator sequence; promoter.
D) promoter; Shine-Dalgarno.
E) operator; promoter.

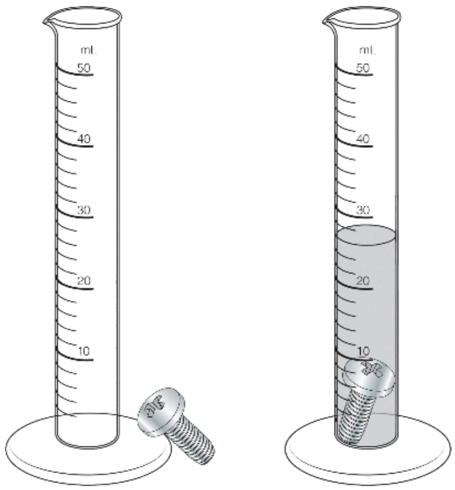
B19. Which of the following techniques uses tagged antibodies against the protein to determine if the protein is expressed or present in the sample?

A) Western blot
B) Northern blot
C) Southern blot
D) CRISPR/Cas9
E) agarose gel electrophoresis

B20. In February 2023, the Food and Drug Administration and the Centers for Disease Control and Prevention coordinated their efforts to investigate a multistate outbreak of ______, linked to the use of artificial tears.

A) MRSA
B) carbapenem-resistant *Pseudomonas aeruginosa*
C) carbapenem-resistant *Enterobacteriaceae*
D) multi-drug resistant *Mycobacterium tuberculosis*
E) *Escherichia coli*

C01. The empty graduated cylinder weighs 172.60 grams and the steel screw weighs 51.35 g. If the cylinder containing both the liquid and the screw weighs 248.38 grams, what is the density of the liquid inside the graduated cylinder? The density of the steel screw is 7.9 g/mL.



A) 0.79 g/mL
B) 0.92 g/mL
C) 1.00 g/mL
D) 1.14 g/mL
E) 1.25 g/mL

C02. When the following equation is balanced using the smallest whole number coefficients, what is the sum of the coefficients?

$$\_\_H_3PO_4(aq) + \_\_Ba(OH)_2(s) \rightarrow \_\_Ba_3(PO_4)_2(s) + \_\_H_2O(\ell)$$

A) 8
B) 10
C) 12
D) 14
E) 16

C03. If you dilute 300.0 mL of 0.015 M solution of hydrochloric acid to twice the original volume, then add 0.15 grams of NaOH, what will the pH of the final solution be? (Assume adding 0.15 g of NaOH does not change the volume.)

A) 7.00
B) 2.35
C) 1.82
D) 3.12
E) 2.90

C04. Based on the periodic table, which noble gas is most likely to have an isotope that contains 22 neutrons in its nucleus?

A) Ne
B) Ar
C) Kr
D) Xe
E) Rn

C05. If 0.100 moles of neon gas and 5.00 grams of solid CO_2 are placed in a 2.00 liter rigid container at 25.0 °C and then the container is heated to 190.0 °C, what will the final pressure of the gas inside the container be?

A) 1.67 atm
B) 1.90 atm
C) 3.33 atm
D) 4.06 atm
E) 96.9 atm

C06. Which of these compounds has the highest melting point?

A) $AlCl_3$
B) $SiCl_4$
C) PCl_3
D) SCl_2
E) Cl_2

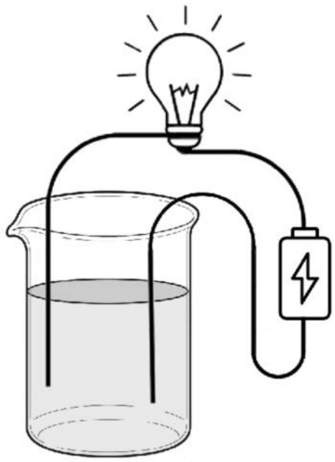
C07. Which of these is an endothermic process?

A) liquid water freezing to ice
B) charging a cell phone battery
C) combustion of natural gas
D) conversion of sugar and oxygen to carbon dioxide and water through respiration
E) a freshly-baked pie cooling off on a table

C08. Enough heat is added to 500 grams of ice at 0°C to melt the ice to water. If the same amount of heat is then added to the water, what will the final temperature of the water be?

A) 79.8 °C
B) 67.0 °C
C) 62.3 °C
D) 55.4 °C
E) 48.2 °C

C09. A sample of a white crystalline solid is added to water, and upon stirring is found to completely dissolve. When the solution is incorporated into an electrical circuit, current flows easily through the solution. What type of bonds most likely held the white solid together?



A) Ionic bonds
B) Covalent bonds
C) Hydrogen bonds
D) Metallic bonds
E) Voltaic bonds

C10. The equilibrium constant K_P for the gas-phase reaction shown below is 2.40×10^3.

$$2A + B \rightleftharpoons 3C + D$$

If the gases A, B, C, and D are pumped into a container at the following pressures, what will happen?

Gas	Pressure (atm)
P_A	0.05
P_B	0.05
P_C	0.50
P_D	0.50

A) The reaction will stop because it is at equilibrium
B) The forward and backward reactions will continue at the same rate
C) The reaction will proceed forward and produce more product
D) The reaction will proceed in the reverse direction and produce more reactant
E) The reaction will proceed until one of the reactants completely runs out.

C11. If you add 25.0 grams of $Ca(OH)_2$ to 9.00 L of water and then dilute it to a final volume of 10.0 L and let it reach equilibrium, what will the pH of the solution be? The K_{sp} for $Ca(OH)_2$ is 5.00×10^{-6}.

A) 13.19
B) 12.33
C) 7.00
D) 1.97
E) 1.67

C12. Which of the compounds below contains an element that is in a +6 oxidation state?

A) Al_2O_3
B) $NaNO_3$
C) $KMnO_4$
D) H_3PO_4
E) H_2SO_4

C13. The following is a three-step mechanism for a reaction. What is the balanced equation for the overall reaction?

Step 1: $3A + 2B \rightarrow AB + C + D$
Step 2: $AB + E \rightarrow Z$
Step 3: $Z + C \rightarrow D + E$

A) $3A + 2B + AB + E + Z + C \rightarrow AB + C + 2D + Z + E$
B) $3A + 2B \rightarrow A_3B_2$
C) $3A + 2B + E \rightarrow 2D + E$
D) $3A + 2B \rightarrow 2D$
E) $A + B \rightarrow C + D$

C14. When a ball of copper wire is added to a concentrated nitric acid solution, the following (unbalanced) redox reaction occurs:

$$Cu(s) + HNO_3(aq) + H^+(aq) \rightarrow Cu^{2+}(aq) + NO_2(g) + H_2O(\ell)$$

What is the sum of the coefficients in the balanced equation?

A) 6
B) 7
C) 8
D) 9
E) 10

C15. How many of the following names and formulas do not match correctly?

Chemical Formula	Chemical Name
SiS_2	silicon disulfate
SO_3	sulfur trioxide
N_2O_4	dinitrogen oxalate
CO	carbon monoxide
OF_2	Oxygen difluorate

A) 1
B) 2
C) 3
D) 4
E) 5

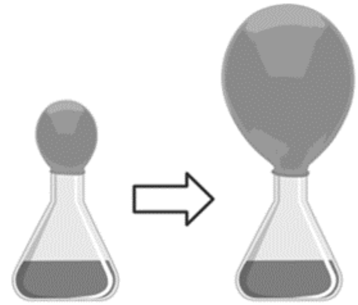
C16. The scientist from Invitational B finishes his titration of a 50.0 mL sample of 0.100 M benzoic acid using 10.0 mL of 0.500 M NaOH. What is the pH of the solution at the equivalence point?
K_a for benzoic acid = 6.3×10^{-5}

A) 2.60
B) 4.90
C) 7.00
D) 8.56
E) 9.06

C17. A 1.5 L bulb and a 2.3 L bulb are connected by a valve. The larger bulb contains Cl_2 gas at 2.8 atm and the smaller bulb contains Cl_2 gas at an unknown pressure. When the valve is opened, the final pressure in the combined system is 4.1 atm. What was the initial pressure of Cl_2 in the smaller bulb before the valve was opened? Assume the volume of the valve tube is negligible.

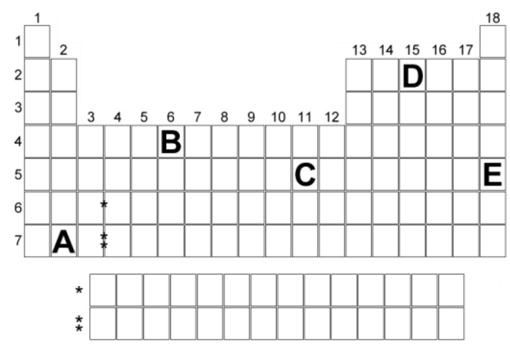
A) 3.3 atm
B) 4.3 atm
C) 5.6 atm
D) 6.1 atm
E) 6.8 atm

C18. Which of the following reactions could be taking place inside the flask at 25°C?



A) $X_2(g) + Y_2(g) \rightarrow 2\ XY(aq)$
B) $2\ XY(aq) \rightarrow X_2(g) + Y_2(g)$
C) $A_2(g) + B_2(g) \rightarrow 2\ AB(g)$
D) $AB(aq) + CD(aq) \rightarrow AD(aq) + CB(s)$
E) None of these reactions would produce the observed result

C19. Consider the outermost electron in each of the elements labeled in the periodic table below. For which one can you know for certain the ground state values for n, ℓ, and m_ℓ?



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

C20. When would an endothermic reaction that results in an increase in entropy for the system be spontaneous?

A) At all temperatures
B) Never at any temperature
C) Above a certain minimum temperature
D) Below a certain maximum temperature
E) It would depend on pressure, not on temperature

P01. According to Feynman, in order to calculate correctly the probability of an event in different circumstances, we have to …
- A) add the arrows for every way that the event could happen.
- B) add the arrows for the most important ways that the event could happen.
- C) multiply the arrows for every way that the event could happen.
- D) multiply the arrows for the most important ways that the event could happen.
- E) use only the arrow for a single way that the event could happen.

P02. According to Feynman, in an experiment in which you direct a beam of light between two blocks, if you push the blocks closer together, what happens to the light?
- A) the light focuses to a single point
- B) the light continues in a narrow beam
- C) the light spreads out
- D) the light does not get through at all
- E) the light beam refracts

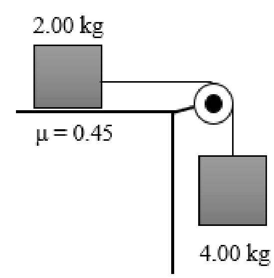
P03. According to Feynman, two successive steps in an event have the following arrows: the first step has a length of 0.2 and is turned towards 2 o'clock; and the second step has a length of 0.3 and is turned toward 5 o'clock. When combined, what is the length and direction for the resulting arrow representing the total event?
- A) length 0.06 direction 3 o'clock
- B) length 0.06 direction 7 o'clock
- C) length 0.1, direction 3 o'clock
- D) length 0.1 direction 7 o'clock
- E) length 0.5, direction 7 o'clock

P04. The habitable zone around a star is the range of distances at which liquid water could exist on the surface of a planet orbiting the star. For the Sun, a class G star, the habitable zone extends from about 1.0 to 1.5 astronomical units. What would be the approximate range of the habitable zone for a class M star?
- A) 0.5 to 0.75 astronomical units
- B) 1.0 to 1.5 astronomical units
- C) 2.0 to 5.0 astronomical units
- D) 8.0 to 12.0 astronomical units
- E) Class M stars cannot sustain a habitable zone

P05. Amanda plans to hike a distance of 2642 miles in a time of 170 days. Assuming she can hike for 10 hours each day, what does Amanda's average hiking speed need to be in meters per minute?
- A) 7.0 meters per minute
- B) 17 meters per minute
- C) 25 meters per minute
- D) 42 meters per minute
- E) 70 meters per minute

P06. From ground level, a soccer ball is kicked with a velocity of 17.0m/s at an angle of 32.0° above the horizontal. The ball hits the top crossbar of the goal. If the ball was kicked from a horizontal distance of 22.0m from the goal, then how far above the ground, vertically, is the crossbar located? Ignore air resistance.
- A) 1.53 m
- B) 2.34 m
- C) 3.42 m
- D) 4.77 m
- E) 5.98 m

P07. A crate with a mass of 4.00 kg hangs by a string that passes over a pulley and is attached to a box of mass 2.00 kg that is sitting on a table (as shown). The coefficient of friction between the table and the 2.00 kg box is 0.45. Assuming that the pulley is massless and frictionless, what is the acceleration of the hanging crate?
- A) 1.80 m/s^2
- B) 3.27 m/s^2
- C) 5.06 m/s^2
- D) 6.53 m/s^2
- E) 9.80 m/s^2



P08. A 600.0g toy car rolls to the right across a horizontal table at a speed of 1.20 m/s. The car collides with a 950.0g toy train that is initially stationary. After the collision, the toy car has bounced directly backwards, and is rolling to the left with a speed of 0.200 m/s. What is the speed of the toy train after the collision? Ignore friction.
- A) 0.126 m/s
- B) 0.379 m/s
- C) 0.632 m/s
- D) 0.758 m/s
- E) 0.884 m/s

P09. A car is going around a circular track that has a radius of curvature of 150.0m. The track is flat (horizontal and unbanked), and the car can travel up to a speed of 45.0m/s without slipping. What is the minimum coefficient of friction that exists between the car tires and the track surface.

A) 0.218
B) 0.300
C) 0.682
D) 0.889
E) 1.38

P10. You are singing while sitting in a tunnel, and you notice that the sound resonates at frequencies of 296Hz and 321Hz. The tunnel is open at both ends and the air temperature is 20.0°C. Assuming that these resonances are adjacent, determine the length of the tunnel.

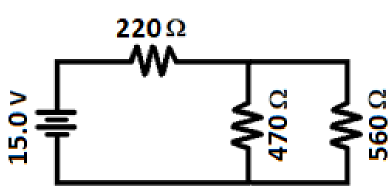
A) 3.43 m
B) 6.86 m
C) 10.3 m
D) 13.7 m
E) 17.2 m

P11. A block of metal weighs 1.50N when in air but appears to weigh only 0.920N when submerged in pure water. What is the density of the metal?

A) 1630 kg/m^3
B) 2110 kg/m^3
C) 2590 kg/m^3
D) 3660 kg/m^3
E) 5180 kg/m^3

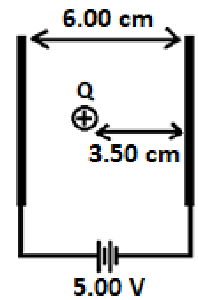
P12. Determine the current flowing in the 470 Ω resistor in this circuit.

A) 68.2 mA
B) 31.5 mA
C) 26.8 mA
D) 17.1 mA
E) 14.4 mA



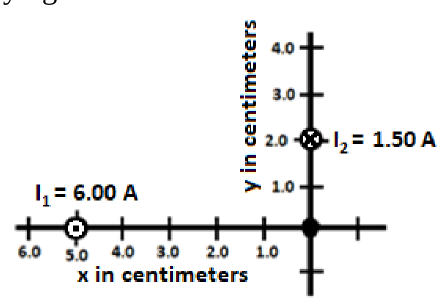
P13. Two parallel plates, separated by 6.00cm, are connected to a 5.00V power supply, as shown. A charged piece of fluff starts at rest between the two plates, at a distance of 3.50cm from the negative plate. The charge on the piece of fluff is +8.00μC and the mass of the piece of fluff is 55.0mg. The piece of fluff accelerates to the negative plate; how fast is it moving when it impacts the negative plate? Ignore air resistance.

A) 0.509 m/s
B) 0.848 m/s
C) 0.921 m/s
D) 1.21 m/s
E) 1.45 m/s



P14. Two long straight wires carry currents in the z-direction. The first wire carries the current I_1 = 6.00A in the positive z-direction. This wire crosses through the x-y plane at the point (-5.00cm, 0.0), as shown. The second wire carries the current I_2 = 1.50A in the negative z-direction. This wire crosses the x-y plane at the point (0.0, 2.00cm). What is the magnitude of the magnetic field at the origin (0.0, 0.0) due to these two current carrying wires?

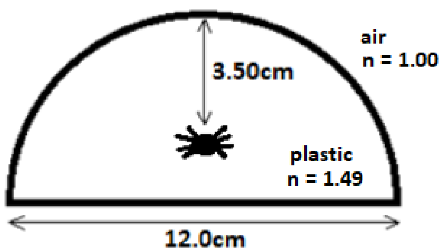
A) 9.00 μT
B) 15.0 μT
C) 24.0 μT
D) 28.3 μT
E) 39.0 μT



P15. An unpolarized light beam has an intensity of 1200W/m^2. The beam first passes through a vertical polarizer, and then it passes through a second polarizer whose axis is oriented at 40.0° with respect to vertical. What is the intensity of the light beam that emerges from the second polarizer?

A) 350 W/m^2
B) 460 W/m^2
C) 600 W/m^2
D) 700 W/m^2
E) 920 W/m^2

P16. A spider has been sealed in a solid plastic hemisphere to create a decorative paperweight, as shown. The diameter of the hemisphere is 12.0cm, and the index of refraction of the plastic is 1.49. If the spider is placed 3.50cm below the curved surface of the plastic, how far into the plastic hemisphere does the spider *appear* to be located?



A) 3.86cm into the plastic
B) 2.91cm into the plastic
C) 2.60cm into the plastic
D) 2.21cm into the plastic
E) 1.97cm into the plastic

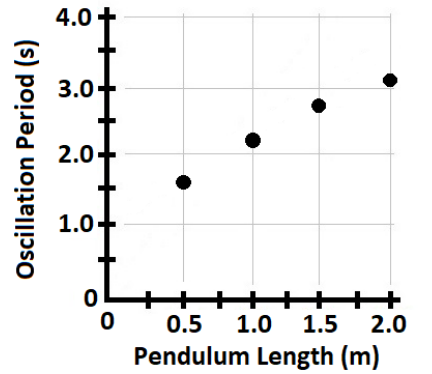
P17. Light with an unknown wavelength is directed onto a photoelectric metal surface. The workfunction of the metal is 1.34 eV, and the photoelectrons emitted from the surface have a velocity of 7.22×10^5 m/s. What is the wavelength of the light shining on the surface?
A) 288nm
B) 364nm
C) 439nm
D) 605nm
E) 837nm

P18. The Rho-meson (ρ) was first discovered in 1961. It is a very short-lived particle, with an average lifetime of 4.5×10^{-24} seconds. Regardless of its charge, the Rho-meson decays into two pions:

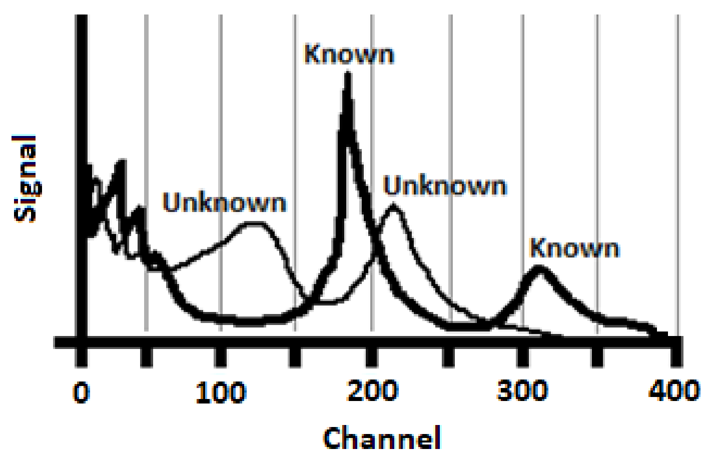
$$\rho \rightarrow \pi + \pi.$$

What fundamental force is responsible for the decay of the Rho-meson?
A) Gravitational Force
B) Higgs Force
C) Weak Force
D) Electromagnetic Force
E) Strong Force

P19. While visiting an alien planet, you make some pendulums of varying lengths; and you measure the period of oscillation of each pendulum as a function of the length of the pendulum. The data are plotted below. What is the approximate gravitational acceleration on this alien planet?
A) 1.2 m/s^2
B) 4.1 m/s^2
C) 6.0 m/s^2
D) 7.8 m/s^2
E) 9.8 m/s^2



P20. The gamma ray spectrum of an unknown isotope (thinner line) is shown below, along with the gamma ray spectrum of a known isotope (thicker line). The known isotope has peaks in its gamma ray spectrum at energies of 1.61MeV and 3.20MeV. Determine the energies of the peaks in the gamma ray spectrum of the unknown isotope.



A) 0.85MeV and 2.0MeV
B) 1.0MeV and 2.2MeV
C) 1.3MeV and 2.2MeV
D) 1.6MeV and 2.7MeV
E) 1.9MeV and 3.0MeV

Chemistry

1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8	8B 9	10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1 H 1.01																	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											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
$\mathscr{F}$ = 96,485 C/mol e$^-$
1 amp = 1 C/sec
1 mol e$^-$ = 96,485 C

$Ca(OH)_2$ $K_{sp} = 5.00 \times 10^{-6}$

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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
2023 DISTRICT

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

CHEMISTRY SOLUTIONS – UIL DISTRICT 2023

C01. (E) The mass of the liquid is the total mass minus the mass of the empty cylinder and the screw.
Mass of the liquid = 248.38 g – 172.60 – 51.35 = 24.43 g.
The volume of the liquid is 26.0 mL – the volume of the screw. The volume of the screw is 51.35 g / 7.9 g/mL = 6.50 mL. The volume of the liquid is 26.0 – 6.50 = 19.50 mL.
Density of the liquid = 24.43 g / 19.5 mL = 1.25 g/mL

C02. (C) The balanced equation is $2\ H_3PO_4\,(aq) + 3\ Ba(OH)_2(s) \rightarrow 1\ Ba_3(PO_4)_2(s) + 6\ H_2O(\ell)$

C03. (E) This is an acid-base neutralization reaction. Calculate which one is in excess and what the resulting $[H^+]$ or $[OH^-]$ is, then calculate pH.
Moles of H^+ = 0.300 L × 0.015 mol/L = 0.0045 mol H^+
Moles of OH^- = 0.15 g × (1 mol / 40.0 g) = 0.00375 mol OH^-
H^+ is in excess, with 0.0045 – 0.00375 = 0.00075 moles H^+ remaining.
The volume is now 600.0 mL, so $[H^+]$ = 0.00075 mol/0.600 L = 0.00125 M
pH = –log$[H^+]$ = –log(0.00125) = 2.90

C04. (B) The molar mass of argon is 39.95, which is very close to 40, and the number of protons is 18.
40 – 18 = 22 neutrons.

C05. (D) Moles of CO_2 in the sample = 5.00 g / 44.01 g/mol = 0.1136 moles. Total moles of gas = 0.100 + 0.1136 = 0.214 mol. PV = nRT so P = nRT/V = (0.214)(0.08206)(190+273)/2.00 = 4.06 atm.

C06. (A) Ionic compounds generally have higher melting points than covalent compounds, and the other answer choices are all covalent compounds. These are the melting points according to Wikipedia: $AlCl_3$: 192.4°C, $SiCl_4$: −68.74°C, PCl_3: −93.6°C, SCl_2: −121.0 °C, Cl_2: −101.5 °C.

C07. (B) An endothermic process absorbs energy as it occurs. A, C, D, and E all give off energy, but you have to put energy into a cell phone battery to recharge it.

C08. (A) The heat required to melt 500 g of ice is $q = m\Delta H_{fus}$ = (500 g)(334 J/g) = 167,000 J. The heat required to raise the temperature of water is $q = mc\Delta T$, where c = 4.184 J/g°C. Rearranging to solve for ΔT,
$\Delta T = q/mc$ = 167,000 J / (500 g × 4.184 J/g°C) = 79.8 °C.

C09. (A) Since the solution conducts electricity easily, it contains dissolved ions, so the solid compound is most likely held together by ionic bonds. (Some covalent compounds such as HCl are also strong electrolytes, but these compounds are not solid at room temperature.)

C10. (C) Plugging the given pressures into the equilibrium expression yields

$$Q = \frac{C^3D}{A^2B} = \frac{(0.50)^3(0.50)}{(0.05)^2(0.05)} = 500$$

Since Q < K, there is not enough product relative to the amount of reactant present, so the reaction will proceed forward toward an equilibrium ratio.

C11. (B) $K_{sp} = [Ca^{2+}][OH^-]^2 = 4x^3$, where $x = [Ca^{2+}]$. $x = [Ca^{2+}] = \left(\frac{K_{sp}}{4}\right)^{1/3} = \left(\frac{5.00\times10^{-6}}{4}\right)^{1/3} = 0.010772\ M$

$[OH^-] = 2\times[Ca^{2+}]$ = 2 × 0.010772 M = 0.021544 M. pOH = –log(0.021544) = 1.67.
pH = 14 – pOH = 14 – 1.67 = 12.33

C12. (E) The sulfur in H_2SO_4 is in a +6 oxidation state.

C13. (D) E, Z, and C are all either catalysts or intermediates and do not appear in the overall equation for the reaction.

C14. (E) The balanced equation is $Cu(s) + 2HNO_3(aq) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(\ell)$

C15. (C)

Chemical Formula	Chemical Name
SiS_2	silicon ~~disulfate~~ **disulfide**
SO_3	sulfur trioxide
N_2O_4	dinitrogen **tetr**oxide
CO	carbon monoxide
OF_2	~~Monoxygen difluorate~~ **oxygen difluoride**

C16. (D) At the equivalence point all of the moles of benzoic acid have been converted to the conjugate base form (the benzoate ion, *Benz*$^-$). Moles of benzoate = (0.050 L)(0.100 M) = 0.0050 moles Benz$^-$. The total volume at the equivalence point is 50.0 mL + 10.0 mL = 60.0 mL = 0.0600 L The benzoate concentration is therefore 0.0050 mol/0.060 L = 0.083 M. $K_b = K_w/K_a = 1\times10^{-14}/6.3\times10^{-5} = 1.59 \times 10^{-10}$

$$K_b = \frac{[OH^-][HBenz]}{[Benz^-]} = \frac{x^2}{(0.083 - x)}$$

Assume x << 0.100 (less than 5%)

$$K_b = \frac{x^2}{0.083}, so\ x = [OH^-] = \sqrt{K_b \times 0.083} = \sqrt{1.59 \times 10^{-10} \times 0.083} = 3.63 \times 10^{-6}$$

Assumption is good: $x = 3.63 \times 10^{-6}$ and is well under 5% of 0.083.
$[H^+][OH^-] = 1\times10^{-14}$, $[H^+] = 1\times10^{-14}/3.63 \times 10^{-6} = 2.76 \times10^{-9}$

$$pH = -\log[H^+] = -\log(2.76 \times 10^{-9}) = 8.56$$

Not making the assumption that $[OH^-]$ << 0.083 and solving for x using the quadratic formula yields the same result.

C17. (D) $P_1V_1 + P_2V_2, = P_{FINAL}V_{TOTAL}$. V_{TOTAL} = 1.5 L + 2.3 L = 3.8 L $P_1 = (P_{FINAL}V_{TOTAL} - P_2V_2) / V_1$
P_1 = ((4.1)(3.8) – (2.8)(2.3)) / (1.5) = (15.58 – 6.44)/1.5 = 9.14/1.5 = 6.1 atm

C18. (B) The reaction causes the volume to expand at constant temperature, so the reaction is generating more moles of gas than it is using up. The only answer choice that does this is B.

C19. (A) You know the ground state value of n and the value of ℓ for the outermost electron in each of these elements based on the element's position in the periodic table, but m_ℓ refers to the particular orbital within the subshell, and since the orbitals within a subshell are equal in energy we can't specify for certain what the m_ℓ value of the outermost electron is, except for element A. Element A has ℓ = 0, so the only possible value for m_ℓ is also 0. For elements B and C m_ℓ could possibly be –2, –1, 0, +1, or +2, and for elements D and E m_ℓ could possibly be –1, 0, or +1.

C20. (C) ΔG = ΔH – TΔS. A reaction is spontaneous when ΔG < 0. If ΔH is (+) (endothermic) and ΔS is also (+) (increase in entropy), then ΔG = (+) – (+), and is negative only when TΔS > ΔH, which only happens above a certain minimum temperature.

PHYSICS SOLUTIONS – UIL DISTRICT 2023

P01. (A) page 49: "And in order to calculate correctly the probability of an event in different circumstances, we have to add the arrows for *every way* that the event could happen – not just the ways we think are the important ones!"

P02. (C) pages 54-55: "Let's investigate this core of light more closely by putting a source at S, a photomultiplier at P, and a pair of blocks between them…. Let's put a second photomultiplier at Q, below P…. But as we push the blocks closer together, at a certain point, the detector at Q starts clicking! … So, when you try to squeeze light too much to make sure it's going in only a straight line, it refuses to cooperate and begins to spread out."

P03. (B) page 61: "Now, to combine the amplitudes for both steps, we shrink and turn *in succession*. First, we shrink the unit arrow from 1 to 0.2 and turn it from 12 to 2 o'clock; then we shrink the arrow further, from 0.2 down to three-tenths of that, and turn it by the amount from 12 to 5 – that is, we turn it from 2 o'clock to 7 o'clock. The resulting arrow has a length of 0.06 and is pointed towards 7 o'clock."

P04. (A) Class M stars are red dwarfs, so they have a lower luminosity than our Sun. Consequently, a planet would need to be closer to the class M star than the Earth is to the Sun in order to have liquid water on its surface. Earth is 1.0 astronomical unit from the Sun. The only choice that is closer to the class-M star is choice A: 0.5-0.75 astronomical units.

P05. (D) First, we convert the distance to meters: $(2642\ miles)\frac{(1609\ meters)}{(1.00\ mile)} = 4250978\ meters$. Now we convert the time into minutes: $(170\ days)\frac{(10\ hours\ of\ hinking)}{(1.0\ day)}\frac{60\ min}{1\ hour} = 102000\ min$. Dividing, we obtain the speed: $\frac{4250978\ meters}{102000\ min} = 41.7\frac{m}{min} \approx 42\ meters/minute$.

P06. (B) We begin with the horizontal: the initial velocity in the horizontal direction is $v_{ix} = v_i \cos\theta$, which gives: $v_{ix} = (17.0)\cos 32.0 = 14.4$ m/s. There is no acceleration in the horizontal, so we can easily find the time for the ball to reach the goal: $t = \frac{\Delta x}{v_{ix}} = \frac{22.0m}{14.4} = 1.526$ sec. Now we examine the vertical, starting with the initial vertical velocity: $v_{iy} = v_i \sin\theta = (17.0)\sin 32.0 = 9.01$m/s. Finally, we determine the final vertical position of the ball, which is the height at which the ball hits the crossbar: $y = y_i + v_{iy}t + \frac{1}{2}a_y t^2 = 0 + (9.01)(1.526) - (0.5)(9.80)(1.526)^2 = 2.34$m.

P07. (C) The force diagram for the box on the table includes four forces: gravity ($m_1 g$, directed downward), the normal force (F_N, directed upward), friction (F_f, directed to the left), and tension (T, directed to the right). This box moves to the right, so there is no motion in the vertical direction. Thus, for this box, the forces in the vertical direction sum to zero:
$\sum F_{1y} = F_N - m_1 g = 0 \;\rightarrow\; F_N = m_1 g = (2.00)(9.80) = 19.6$N. Now we know the Normal force, which allows us to determine the frictional force: $F_f = \mu F_N = (0.45)(19.6) = 8.82$N. This box accelerates to the right, so for the horizontal, we get: $\sum F_{1x} = T - F_f = m_1 a \;\rightarrow\; T = 2.00a + 8.82$. Now we examine the hanging crate. The force diagram for the crate only has two forces: gravity ($m_2 g$, directed downward) and tension (T, directed upward). There are no horizontal forces acting on the crate. The crate accelerates at the same rate as the box, but downward. So, for the vertical we get: $\sum F_{2y} = m_2 g - T = m_2 a \;\rightarrow\; (4.00)(9.80) - T = 4.00a \;\rightarrow\; T = 39.2 - 4.00a$.
Setting the two expressions for the tension equal, we obtain $T = 2.00a + 8.82 = 39.2 - 4.00a$.
This leads to $6.00a = 30.38 \;\rightarrow\; a = 5.06$m/s^2

P08. (E) Because there is a collision, we will use conservation of momentum to solve this problem. We will choose "to the right" to be positive, and object 1 will be the toy car while object 2 will be the toy train. The initial momentum is: $p_i = m_1 v_{1i} + m_2 v_{2i} = (0.600kg)(1.20m/s) + (0.950kg)(0.0m/s) = 0.72$kgm/s, and the final momentum is given by: $p_f = m_1 v_{1f} + m_2 v_{2f} = (0.600)(-0.200) + (0.950)v_{2f} \rightarrow$ $p_f = -0.12 + 0.950v_{2f}$. By conservation of momentum, the initial and final momenta must be equal ($p_i = p_f$). Thus, $= -0.12 + 0.950v_{2f} = 0.72$. This leads to $0.950v_{2f} = 0.84 \rightarrow$ $v_{2f} = 0.884$m/s.

P09. (E) The force diagram for the car includes three forces: gravity (mg, directed downward), the normal force (F_N, directed upward), and friction (F_f, directed horizontally towards the center of the circular path). Because the car is moving in a circle, the sum of the forces directed towards the center of the circular path is equal to the centripetal force. In this case, only one force – friction – contributes to the centripetal force. Mathematically, we have: $\sum F_c = \frac{mv^2}{r} = F_f$. Plugging in some values, and the formula for the frictional force, we get: $\frac{mv^2}{r} = \frac{m(45.0)^2}{150} = F_f = \mu F_N \rightarrow \frac{\mu F_N}{m} = 13.5$. To find the normal force, we examine the forces in the vertical. There is no motion in the vertical direction, so the vertical forces must sum to zero: $\sum F_y = F_N - mg = 0 \rightarrow F_N = mg$. Substituting this into the previous equation gives: $\frac{\mu F_N}{m} = \frac{\mu mg}{m} = \mu g = 13.5 \rightarrow \mu = \frac{13.5}{9.8} = 1.38$. Notice that the mass of the car is not needed. This value represents the minimum coefficient of friction needed to safely drive at that speed on that curve; it is possible for a car with good tires on a dry road to have an effective coefficient of friction that is this large.

P10. (B) Resonances in an open-open tube occur at frequencies of $f = \frac{nv}{2L}$ where n is an integer. Thus, two adjacent resonances are separated in frequency by $\Delta f = \frac{(n+1)v}{2L} - \frac{nv}{2L} = \frac{v}{2L}$. The temperature is 20.0°C, so we know that the speed of sound is $v = 343$m/s. Putting it all together with the given resonance frequencies: $\Delta f = 321Hz - 296Hz = 25Hz = \frac{343}{2L}$. This gives a tunnel length of: $L = \frac{343}{2(25)} = 6.86$m.

P11. (C) The weight of the metal in air is $mg = 1.50N$, so the mass of the metal is $\frac{1.50N}{9.80m/s^2} = 0.1531$kg. When placed is water, the weight of the metal is partially offset by the buoyant force. The magnitude of the buoyant force is $F_B = W_{air} - W_{water} = 1.50N - 0.920N = 0.580N$. The buoyant force equals the density of the liquid multiplied by the volume of the block of metal and the acceleration due to gravity. Mathematically, $F_B = \rho_w V_M g = (1000kg/m^3)V_M(9.80m/s^2) \rightarrow 9800V_M = 0.580$. This allows us to find the volume of the block of metal: $V_M = 5.918 \times 10^{-5}m^3$. Finally, by using the mass and volume of the metal, we can determine the density of the metal: $\rho_M = \frac{M_M}{V_M} = \frac{0.1531\ kg}{5.918 \times 10^{-5}m^3} = 2587 \approx 2590$kg/m^3.

P12. (D) First, we need to reduce the resistors in the circuit to a single equivalent resistance. We start by combining the 470Ω and the 560Ω, which are in parallel. Resistors in parallel are combined using the formula: $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \rightarrow \frac{1}{R_p} = \frac{1}{470} + \frac{1}{560} \rightarrow R_p = 255.5\Omega$. This parallel group is in series with the 220Ω resistor. Series resistances add, so the total equivalent resistance is: $R_T = R_p + R_3 = 255.5 + 220 = 475.5\Omega$. Now we use Ohm's Law to find the current produced by the battery: $I_0 = \frac{V}{R_T} = \frac{15.0}{475.5} = 0.0315A$. The currents in objects in series are all equal, so this same current flows through the 220Ω resistor and through the parallel equivalent 255.5Ω resistance. Using Ohm's Law, we can find the voltage across the parallel group: $V_p = I_0 R_p = (0.0315A)(255.5\Omega) = 8.06V$. The voltages across objects in parallel are all equal, so this voltage is the same across each of the two resistors in parallel, the 560Ω and the 470Ω. Thus, finally, we can use Ohm's Law one more time to find the current flowing through the 470Ω resistor: $I_1 = \frac{V_p}{R_1} = \frac{8.06V}{470\Omega} = 0.0171A = 17.1mA$.

P13. (C) There are different ways to work this problem, but I will use a straightforward approach. First, we find the magnitude of the electric field between the plates: $|E| = \frac{V}{d} = \frac{5.00V}{0.06m} = 83.3$V/m. Now we can find the force exerted on the charged piece of fluff:
$F = qE = (8.00 \times 10^{-6}C)(83.3V/m) = 6.67 \times 10^{-4}$N. From this, we determine the acceleration of the piece of fluff: $a = \frac{F}{m} = \frac{6.67 \times 10^{-4}N}{55.0 \times 10^{-6}kg} = 12.1$m/s^2. Lastly, we use kinematics to find the velocity of the piece of fluff when it reaches the negative plate: $v_f^2 = v_i^2 + 2a\Delta x = 0 + 2(12.1m/s^2)(0.0350m)$. This gives a final velocity of $v_f = \sqrt{0.848} = 0.921$m/s.

P14. (D) The magnitude of the magnetic field due to a long straight wire is given by $|B| = \frac{\mu_0 I}{2\pi r}$ where μ_0 is the permeability of free space. For the first current, the magnetic field produced at the origin has a strength of $|B_1| = \frac{\mu_0 I_1}{2\pi r_1} = \frac{(4\pi \times 10^{-7}Tm/A)(6.00A)}{2\pi(0.05m)} = 2.40 \times 10^{-5}T = 24.0\mu T$. Similarly, for the second current, the magnetic field produced at the origin has a strength of
$|B_2| = \frac{\mu_0 I_2}{2\pi r_2} = \frac{(4\pi \times 10^{-7}Tm/A)(1.50A)}{2\pi(0.02m)} = 1.50 \times 10^{-5}T = 15.0\mu T$. Magnetic fields are vectors, so to combine them we must also consider their direction. A current coming out of the page will produce a magnetic field that goes in counterclockwise circles around the wire. This means that the field produced by the first current will, at the origin, be directed in the positive y-direction. Likewise, a current going into the page will produce a magnetic field that goes in clockwise circles around the wire. This means that the field produced by the second current will, at the origin, be directed in the negative x-direction. We conclude, then, that the fields produced by the two currents are, at the origin, perpendicular to one another. Since they are perpendicular, we can find the magnitude of the total magnetic field at the origin by using the Pythagorean Theorem to combine the individual fields:
$|B_{total}| = \sqrt{B_1^2 + B_2^2} = \sqrt{(24.0)^2 + (15.0)^2} = 28.3\mu T$.

P15. (A) When unpolarized light passes through a polarizer, its intensity is reduced by half. Thus, after the first polarizer, the intensity of the light is $I_1 = \frac{1}{2}I_0 = \frac{1}{2}(1200) = 600W/m^2$. The intensity may be less, but this light is now entirely polarized in the vertical direction. To find the intensity after going through the second polarizer, we use Malus' Law: $I_2 = I_1(\cos\theta)^2$. Here θ is the angle between the first and the second polarizations of the light.
For our case: $I_2 = (600)(\cos 40.0)^2 = 352\frac{W}{m^2} \approx 350\frac{W}{m^2}$.

P16. (B) The image is formed by a single refracting surface – the upper curved surface of the plastic. The spider is the object, with an object location of $p = 3.50cm$. The magnitude of the radius of curvature of the plastic is half of the diameter, so $|R| = \frac{1}{2}(12.0cm) = 6.00cm$. From the perspective of the object (the spider), the curved surface is concave, which means that the radius of curvature of the surface will be negative. Thus, $R = -6.00cm$. Because the object is in the plastic, we begin with $n_1 = 1.49$ and end (in the air) with $n_2 = 1.00$. The equation for image formation at a refracting surface is: $\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$.
Plugging in the known quantities, we get: $\frac{1.49}{3.50cm} + \frac{1.00}{q} = \frac{1.00-1.49}{-6.00cm} \rightarrow 0.4257 + \frac{1}{q} = 0.08167$.
This gives an image location of $q = -2.91cm$. That is, the image appears $2.91cm$ into the plastic hemisphere.

P17. (C) First, we use the velocity of the photoelectrons to determine the energy of the photoelectrons. Their velocity is much less than the speed of light, so we can use the classical formula for kinetic energy: $E_e = \frac{1}{2}mv^2 = (0.5)(9.11 \times 10^{-31}kg)(7.22 \times 10^5)^2 = 2.37 \times 10^{-19}J \;\rightarrow\; E_e = 1.48\text{eV}$. Now we find the energy of the incoming photon: $E_\gamma = E_e + \phi = 1.48 + 1.34 = 2.82\text{eV}$. Finally, we use the photon energy to find the wavelength of these photons: $\lambda = \frac{hc}{E_\gamma} = \frac{1240eVnm}{2.82eV} = 439nm.$

P18. (E) The decay of the Rho meson is very fast, which eliminates the Weak Force as the cause of the particle decay since Weak Force decays are always slow. The fact that the decay is the same regardless of the charge of the Rho meson eliminates the Electromagnetic Force as the cause of the particle decay. There is no such thing as a "Higgs Force" and the Gravitational Force has not been connected to any known particle decay. Thus, the Strong Force is the best choice as the force responsible for the decay of the Rho meson. Note: although we made additional arguments, the speed of the decay ($\sim 10^{-24} seconds$) gives away the answer – only the Strong Force can cause a particle decay to be that rapid.

P19. (D) These points do not actually form a straight line, so we won't be using slopes or intercepts to answer the question. We simply estimate the answer based on one or two of the data points themselves: I'll check using the first and fourth points: The first point is about (0.5m, 1.6s) and the fourth point is about (2.0m, 3.1s). The formula for the period of a pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$. Solving for g in this equation gives: $\frac{T^2}{(2\pi)^2} = \frac{L}{g} \;\rightarrow\; g = \frac{4\pi^2 L}{T^2}$. Entering the values for the points that we have chosen, we obtain a gravitational acceleration of $g_1 = \frac{4\pi^2(0.5)}{(1.6)^2} = 7.7\text{m/s}^2$, or $g_2 = \frac{4\pi^2(2.0)}{(3.1)^2} = 8.2\text{m/s}^2$. For either point, the closest (and best) of our choices is $g \approx 7.8\text{m/s}^2$.

P20. (A) This question is all about calibration. Using the known peaks, we must first determine the energy step associated with a single channel. To begin, we identify the channel numbers of the known peaks: Known peak 1 is at about channel 185 and Known peak 2 is at about channel 310. The difference in channel number is $310 - 285 = 125$channels, and their energy difference is $3.20 - 1.61 = 1.59$MeV. Thus, each channel corresponds to an energy step of $\frac{1.59MeV}{125channels} = 0.01272$MeV/channel. Now we look at the channel numbers of the unknown peaks: Unknown peak 1 is at about channel 125 and Unknown peak 2 is at about channel 215. Measuring from the first Known peak, we see that Unknown peak 1 is $185 - 125 = 60$channels below Known peak 1. Similarly, Unknown peak 2 is $215 - 185 = 30$channels above Known peak 1. Thus, these unknown peaks correspond to energies of $1.61MeV - 60channels\left(0.01272\frac{MeV}{channel}\right) = 0.85MeV$, and $1.61MeV + 30channels\left(0.01272\frac{MeV}{channel}\right) = 2.0MeV$. Therefore, the energies of the Unknown peaks are $0.85MeV$ and $2.0MeV$.