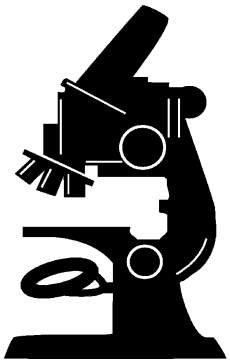
UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

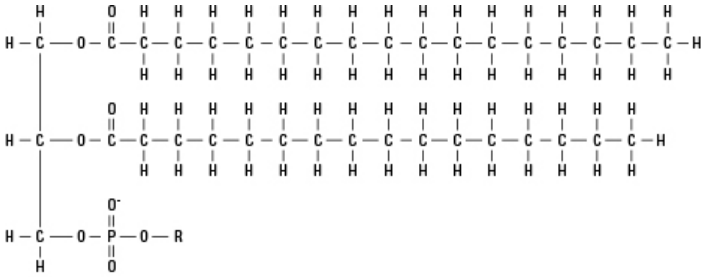
District • 2018



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 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. Examine the image below. This molecule is a/an
A) carbohydrate.
B) protein.
C) lipid.
D) starch.
E) nucleotide.



B02. Chickenpox is primarily transmitted through
A) respiratory droplets.
B) feces.
C) urine.
D) Fomites (inanimate objects: doorknobs, pencils, handrails, cell phones).
E) sexual contact.

B03. Which of the following defines a normal human egg cell?
A) 22 autosomes and 1 X chromosome
B) 44 autosomes and 1 X chromosome
C) 22 autosomes and 1 Y chromosome
D) 44 autosomes and 1 Y chromosome
E) 22 autosomes and 2 X chromosomes

B04. All of the following are evidence for unity in diversity of life except
A) all living organisms are made of cells.
B) DNA is the genetic storage and inheritance molecule of all living organisms.
C) all cell types have a plasma membrane.
D) both eukaryotic and prokaryotic cells have ribosomes.
E) all living organisms have nuclei.

B05. Which of the following statements about translation is incorrect?
A) Incoming tRNAs carrying amino acids bind to the A-site of the ribosome.
B) Peptidyltransferase is the name of the enzymatic activity of the ribosome; it generates the peptide bond.
C) The codons on transfer RNAs are complementary to the anticodons on messenger RNA.
D) The small ribosomal subunit binds to the mRNA before the large subunit binds.
E) AUG is the most common start sequence on mRNA.

B06. Lipid biosynthesis occurs in the _____ of eukaryotic cells.
A) Golgi apparatus
B) lysosome
C) plasma membrane
D) rough endoplasmic reticulum
E) smooth endoplasmic reticulum

B07. Of the following answer choices, a human would be most closely related to a/an
A) dolphin.
B) spider.
C) mold.
D) amoeba.
E) eagle.

B08. What feature do cytochromes in the aerobic electron transport chain have in common with the oxygen-carrying protein of red blood cells?
A) Both structures transport oxygen.
B) Both structures carry high-energy electrons.
C) Both structures are embedded within a membrane.
D) Both structures contain heme.
E) Both structures split water to produce protons and oxygen.

B09. Osteoporosis is a homeostatic imbalance that can occur if the blood _____ concentration is too low for an extended period of time.
A) vitamin C
B) vitamin D
C) calcium
D) glucose
E) folic acid

B10. A molecular biology technique that separates nucleic acids by size is called
A) Polymerase Chain Reaction.
B) gel electrophoresis.
C) DNA cloning.
D) transformation.
E) restriction enzyme digestion.

B11. The immune system relies heavily on the _____ system, as many of the organs in this system serve as the framework for the production, action, or location of numerous white blood cells.
A) cardiovascular
B) integumentary
C) digestive
D) lymphatic
E) nervous

B12. *Escherichia coli* is a bacterium whose genome encodes the *lac* operon. What could you predict would occur if glucose was added to the growth medium as the sole carbon source?
A) The *lac* operon would be induced.
B) The *lac* operon would be repressed.
C) The *lac* operon would be activated.
D) The *lac* operon would be derepressed.
E) Nothing would happen. The *lac* operon has nothing to do with glucose.

B13. Molecule X binds to the allosteric site of an enzyme and prevents the enzyme from catalyzing a chemical reaction. This type of enzyme regulation is called
A) competitive inhibition.
B) allosteric activation.
C) non-competitive inhibition.
D) proteolysis.
E) protein degradation.

B14. The DTaP combination vaccine protects against all of the following, except
A) diphtheria.
B) whooping cough.
C) tetanus.
D) pertussis.
E) polio.

B15. In a population at Hardy-Weinberg equilibrium, the frequency of the dominant allele is 0.672. What is the frequency of the recessive allele in this population?
A) 1.672
B) 0.744
C) 0.451
D) 0.328
E) 0.107

B16. Human immunodeficiency virus (HIV) uses an enzyme called reverse transcriptase to synthesize a DNA copy of its RNA genome prior to gene expression and integration into the host cell's genome. Viruses that use reverse transcriptase are classified as
A) prophages.
B) retroviruses.
C) lysogenic viruses.
D) lytic viruses.
E) oncogenic viruses.

B17. Land plants are part of Supergroup
A) Plantae.
B) Archaeplastida.
C) Opisthokonta.
D) Eukarya.
E) Viridiplantae.

B18. Purple flowers are the dominant phenotype in pea plants. The genes for flower color are also inherited according to Mendelian pattern. A researcher allows a pea plant that is heterozygous for the flower color gene to self-fertilize. If the fertilization resulted in the formation of 8 seeds total, predict how many of those seeds would develop white flowers.
A) 8
B) 6
C) 4
D) 2
E) 1

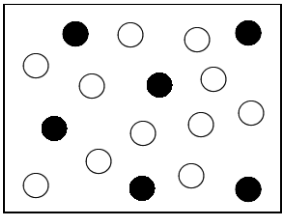
B19. Cytokinesis during plant cell mitosis involves the formation of a/an
A) cell plate.
B) central vacuole.
C) spindle apparatus.
D) chiasma.
E) cleavage furrow.

B20. In a marine community, sea otters are keystone species that prey on sea urchins. Sea urchins primarily consume large amounts of kelp. Predict what would happen in the marine environment if sea otters were removed due to predation or disease.
A) Kelp forests would increase in the community since sea otters do not consume kelp.
B) The absence of sea otters would not impact the abundance of urchins or kelp.
C) The abundancy of kelp forests would not be impacted.
D) The only impact would be to sea urchins, which would increase in numbers.
E) The sea urchin populations would increase and the kelp forest abundance would decrease.

C01. How many grams of oxygen are in 424.0 grams of copper(II) sulfate pentahydrate?

A) 27.24 g
B) 108.7 g
C) 135.8 g
D) 212.0 g
E) 244.5 g

C02. The diagram below represents a solution containing formic acid and formate ions. What is the pH of the solution? The K_a for formic acid is 1.8×10^{-4}.



● = HCOOH, formic acid
○ = $HCOO^-$, formate ion

A) 0.545
B) 4.01
C) 3.74
D) 5.45
E) 9.33

C03. What is the oxidation number of the chlorine atoms in Cl_2?

A) 2
B) 17
C) 35.45
D) –1
E) 0

C04. The reaction A + 2B → C + 2D proceeds according to a four-step mechanism:

$2A + X \rightarrow A_2X$
$A_2X + B \rightarrow A + ABX$
$ABX + B \rightarrow C + Z + X$
$Z \rightarrow 2D$

What is the role of compound X in this reaction?

A) Binding agent
B) Catalyst
C) Intermediate
D) Reactant
E) Spectator

C05. If a 500. mL sample of gas at 25°C and 525 torr is heated to 323°C and allowed to expand to 1.00 L, what will the final pressure be?

A) 4.46 atm
B) 691 atm
C) 525 atm
D) 525 torr
E) 3390 torr

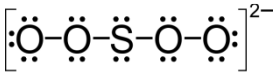
C06. What is the molarity of a 34.0% by mass strontium chloride solution? The density of the solution is 1.3811 g/mL.

A) 4.51 M
B) 3.82 M
C) 1.55 M
D) 2.96 M
E) 5.88 M

C07. An endothermic reaction that results in an increase in entropy is:

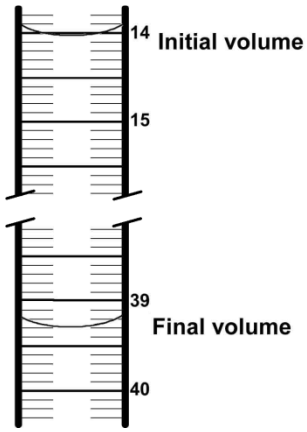
A) spontaneous at high temperatures.
B) spontaneous at low temperatures.
C) spontaneous at all temperatures.
D) nonspontaneous at all temperatures.
E) an equilibrium reaction.

C08. This Lewis dot structure for the sulfate ion, SO_4^{2-}, satisfies the octet rule, but is incorrect. Why is it incorrect?



A) Because it does not include the two extra electrons that give the ion a –2 charge.
B) Because the formal charge on the central sulfur atom in this arrangement is not zero.
C) Because the correct arrangement of atoms has resonance structures that make it more stable than this one.
D) Because opposites attract, therefore the oxygen atoms will bond to the sulfur atom, not to each other.
E) Because putting all the atoms in a line is just stupid.

C09. A clear liquid is dispensed from a burette into a clean beaker and then weighed. The initial and final burette readings are those shown in the image. If the mass of the sample is 22.42 g, which of these liquids is it most likely to be?



A) Benzene
B) Diethyl Ether
C) Ethanol
D) Heptane
E) Trichloroethane

C10. An empty metal gas cylinder has a mass of 54.00 kg and a volume of 44.8 L. When filled to a pressure of 32.0 atm with an unknown monatomic gas at 0°C, the total mass of the filled cylinder is 59.36 kg. Which gas is in the cylinder?

A) Helium
B) Neon
C) Argon
D) Krypton
E) Xenon

C11. If 85.0 g of ice at 0°C is placed in a glass containing 425 g of water at 15.0°C, what mass of ice will remain unmelted when the ice/water mixture reaches thermal equilibrium?

A) 0 grams of ice remains – all of the ice will melt
B) 3.35 g
C) 5.14 g
D) 7.88 g
E) 16.0 g

C12. A galvanic cell is constructed using a magnesium electrode in a 1.0 M $Mg(NO_3)_2$ solution and a silver electrode in a 1.0 M $AgNO_3$ solution. What is the standard potential of the cell at 25°C?

A) –1.57 V
B) –3.17 V
C) +3.17 V
D) –3.97 V
E) +3.97 V

C13. A chemist dissolves 36.76 grams of calcium chloride dihydrate in a 100.0 mL volumetric flask and fills the flask to the mark. She then pipettes 5.00 mL of this solution into a 25.00 mL volumetric flask and dilutes to the mark with water. What is the chloride ion concentration in the final solution?

A) 2.50 M
B) 1.37 M
C) 1.18 M
D) 1.00 M
E) 0.500

C14. Rank these single bonds from least polar to most polar: C-O, H-F, P-S, Br-Br.

A) H-F < C-O < P-S < Br-Br
B) H-F < P-S < C-O < Br-Br
C) Br-Br < H-F < P-S < C-O
D) Br-Br < C-O < P-S < H-F
E) Br-Br < P-S < C-O < H-F

C15. Given this information:

$$6\ Fe_2O_3(s) \rightarrow 4\ Fe_3O_4(s) + O_2(g) \qquad \Delta H^\circ = 471.6\ kJ$$

$$Fe_3O_4(s) \rightarrow 3\ Fe(s) + 2\ O_2(g) \qquad \Delta H^\circ = 1118.4\ kJ$$

Calculate the standard molar enthalpy of formation for $Fe_2O_3(s)$.

A) –471.6 kJ/mol
B) –824.2 kJ/mol
C) –1590.0 kJ/mol
D) +1590.0 kJ/mol
E) –4945.2 kJ/mol

C16. What is the concentration of Ni^{2+} in a saturated solution of nickel(II) phosphate if the K_{sp} for nickel(II) phosphate is 4.74×10^{-32}? (Ignore any reaction between the phosphate ions and water.)

A) 6.39×10^{-7} M
B) 5.43×10^{-7} M
C) 2.13×10^{-7} M
D) 1.24×10^{-7} M
E) 1.24×10^{-6} M

C17. Chlorine gas reacts with chloroform to form carbon tetrachloride and hydrogen chloride gas:

$$Cl_2(g) + CHCl_3(g) \rightarrow HCl(g) + CCl_4(g)$$

The following time and concentration data were collected for this reaction.

Time (s)	$[CCl_4]$ (M)
7.00	0.167
148.0	0.374

What is the average rate of the reaction?

A) 0.0132 M/s
B) 0.0238 M/s
C) 0.00147 M/s
D) 0.00253 M/s
E) 0.00349 M/s

C18. What is the work function (φ) of a metal?

A) The amount of energy required to remove an electron from the surface of the metal in a vacuum
B) The amount of energy that can be removed from the metal without changing its temperature
C) The amount of force that can be applied to the metal without altering its shape
D) A unitless measure of the metal's resistance to corrosion
E) The density of the metal relative to the density of pure iron at the same temperature

C19. When this equation is balanced, what is the sum of the coefficients?

$$Au^{3+}(aq) + I^-(aq) \rightarrow Au(s) + I_2(s)$$

A) 5
B) 2
C) 13
D) 9
E) 7

C20. Determine the molar mass of an unknown acid, H_2A, if a 12.11-g sample of the acid requires 38.38 mL of 5.000 M NaOH to neutralize it.

A) 63.10 g/mol
B) 94.65 g/mol
C) 112.2 g/mol
D) 126.2 g/mol
E) 189.3 g/mol

P01. According to Tyson, Fritz Zwicky made an observation about the galaxies in the Coma cluster that implied the existence of a large amount of dark matter in the cluster. What did Zwicky observe?
A) the galaxies appeared dimmer than expected.
B) the galaxies had higher velocities than expected.
C) the galaxies were more redshifted than expected.
D) the galaxies were all smaller than expected.
E) the galaxies had less gas and dust than expected.

P02. According to Tyson, in 2016 a discovery was made that adds even more support to Einstein's theory of General Relativity. What was this discovery?
A) the cosmological constant
B) the Higgs Boson
C) dark matter
D) gravitational lensing
E) gravitational waves

P03. According to Tyson, the most accurate measurements to date reveal that dark energy is responsible for _____ percent of all mass-energy in the universe.
A) 5 percent
B) 27 percent
C) 42 percent
D) 68 percent
E) 95 percent

P04. The color of a main sequence star is determined by…
A) its chemical composition.
B) its location in the galaxy.
C) its temperature.
D) its surface pressure.
E) its age.

P05. For this formula, F is in Newtons, m is in kilograms, L is in meters, and the units of ξ are $\frac{m}{kg\ s}$. What are the units of the constant α?

$$\xi = \alpha\sqrt{FLm}$$

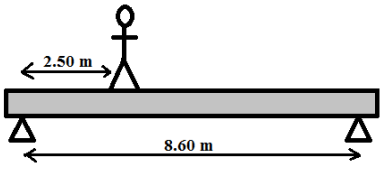
A) $\frac{1}{kg^2}$
B) $\frac{m\ s}{kg}$
C) $\frac{1}{m\ kg\ s}$
D) $\frac{m^2}{kg^2}$
E) $\frac{1}{s\ kg^2}$

P06. A ball is launched from ground level upwards at an angle of 32.0º above the horizontal. The ball lands back on the ground at a distance of 17.5m from where it was launched. What was the initial velocity of the ball? You may ignore air resistance.
A) 10.9 m/s
B) 13.8 m/s
C) 17.5 m/s
D) 19.5 m/s
E) 20.6 m/s

P07. A box is sliding down an inclined plane angled at 28º with respect to the horizontal. If the block slides at a constant speed, what is the coefficient of friction between the block and the inclined plane?
A) 0.054
B) 0.19
C) 0.28
D) 0.53
E) 1.00

P08. A box with a mass of 750.0g slides to the right at a speed of 2.50 m/s across a frictionless surface. A disk with a mass of 550.0g slides at 4.50 m/s to the left directly towards the box. They collide head-on. After the collision, the box has a velocity of 1.50 m/s to the left. What is the final velocity of the disk?
A) 5.86 m/s to the right
B) 3.14 m/s to the left
C) 2.45 m/s to the left
D) 1.36 m/s to the right
E) 0.95 m/s to the right

P09. A log is placed symmetrically on two concrete blocks (as shown) to make a simple bridge. The log has a mass of 20.0kg and the distance between the concrete blocks is 8.60m. The log rests horizontally. A person with a mass of 60.0kg is standing 2.50m from the leftmost block (as shown). What is the downward force on the leftmost block?



A) 269 N
B) 319 N
C) 367 N
D) 515 N
E) 613 N

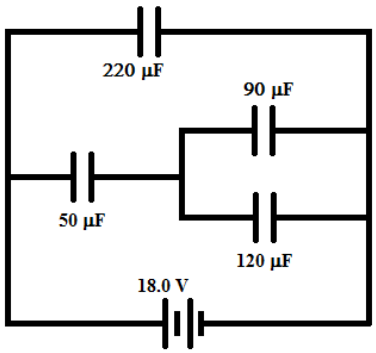
P10. A resonance tube is a rigid vertical tube with an adjustable amount of water in it. The empty part of the tube (the air column) changes length as the water level is raised or lowered. It is found that the air column is resonant with a tuning fork when the air column is 80.0cm long. The next resonance is found when the air column is 60.0cm long. Assuming that the temperature is 20ºC, determine the frequency of the tuning fork.

A) 429 Hz
B) 643 Hz
C) 858 Hz
D) 1287 Hz
E) 1716 Hz

P11. A rod of silver that is 80.0cm long is attached to a rod of lead that is 220cm long while at room temperature (20ºC). The metals are then heated to 100ºC. What is the total increase in length of the connected rods at the higher temperature? Note: the coefficients of thermal expansion are $\alpha = 19 \times 10^{-6}\ \frac{1}{°C}$ for silver and $\alpha = 29 \times 10^{-6}\ \frac{1}{°C}$ for lead.

A) 0.16 cm
B) 0.52 cm
C) 0.58 cm
D) 0.63 cm
E) 0.79 cm

P12. Given this capacitor network, determine the charge stored on the 120 μF capacitor.

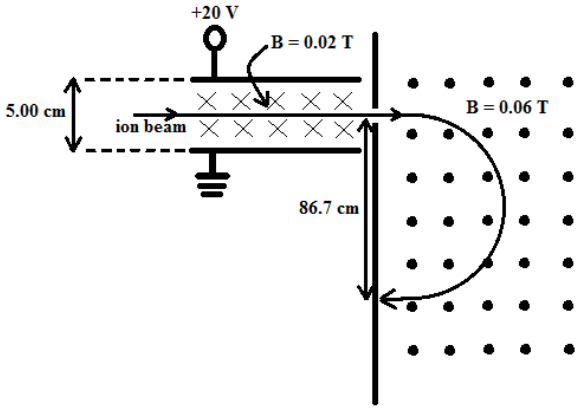


A) 310 μC
B) 420 μC
C) 730 μC
D) 2200 μC
E) 4700 μC

P13. Two flat metal plates are set up side by side to form a parallel plate capacitor. The plates are separated by 12.0cm and charged up to a potential difference of 10.2 volts. A speck of dust located 1.00cm from the negative plate has a charge of +15.0μC and a mass of 2.00g. Ignoring air resistance, and if the speck starts from rest, with what speed does the speck strike the negative plate?

A) 39.1 cm/s
B) 11.3 cm/s
C) 8.00 cm/s
D) 2.77 cm/s
E) 1.28 cm/s

P14. A beam of singly charged particles enters a velocity selector and then a mass spectrometer as shown. The velocity selector plates are separated by 5.00 cm and have a potential difference of 20.0 V between them. The magnetic field in the velocity selector is 0.020 T. The magnetic field in the mass spectrometer is in the opposite direction and has a magnitude of 0.060 T. If the diameter of the circle traced out by the beam in the mass spectrometer is 86.7 cm, what is the mass of the ions in atomic mass units?



A) 130 amu
B) 180 amu
C) 230 amu
D) 250 amu
E) 500 amu

P15. A conductive ring has a diameter of 45.0cm and a resistance of 0.250 Ω. A magnetic field of 9000.0μT is passing through the ring, perpendicular to the ring itself. If the strength of the magnetic field decreases to 3000.0μT over a time of 0.15sec, what is the magnitude of the current induced in the ring?

A) 8.09 mA
B) 12.7 mA
C) 25.4 mA
D) 38.2 mA
E) 102 mA

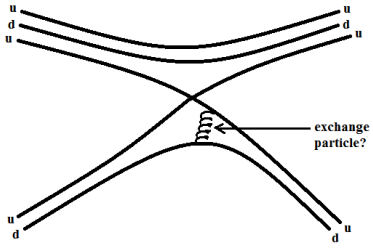
P16. An object is located a distance X in front of a concave mirror. The radius of curvature of the mirror is R. What type of image will be formed if 2X < R?

A) an upright virtual image
B) an upright real image
C) an inverted virtual image
D) an inverted real image
E) an image will not be formed

P17. A charged pi-meson (π+, π-) has an average rest lifetime of 2.6×10^{-8} s. Suppose you have a beam of pi-mesons in a linear particle accelerator moving at 0.9995c (99.95% of the speed of light). What is the average lifetime of the fast-moving pi-mesons as measured by a stationary observer?

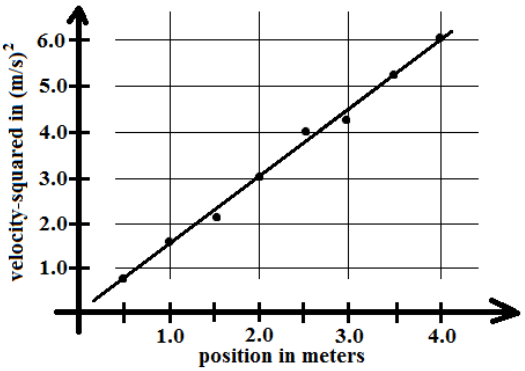
A) 5.2×10^{-5} s
B) 2.6×10^{-5} s
C) 1.2×10^{-6} s
D) 8.2×10^{-7} s
E) 2.6×10^{-8} s

P18. This Feynman diagram shows the interaction of a proton with a pion. Which of these choices could be the exchange particle indicated in the diagram?



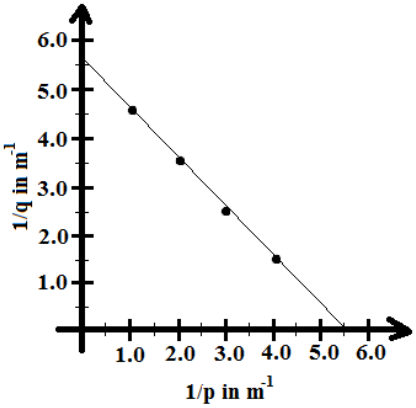
A) Higgs boson
B) W^+ boson
C) W^- boson
D) K meson
E) gluon

P19. An experiment is conducted with a self-propelled toy car in which the velocity of the toy car is measured at different points along its path. The data is graphed as velocity-squared versus position. Given this graph, determine the acceleration of the toy car.



A) 0.67 m/s^2
B) 0.75 m/s^2
C) 1.0 m/s^2
D) 1.3 m/s^2
E) 1.5 m/s^2

P20. An experimental setup using a light source, a converging lens, and a screen is constructed on an optics bench. The lens is fixed at one location, but the light source is moved to various locations and the screen is adjusted until a focused image forms. The distance from the source to the lens (p) and from the screen to the lens (q) is recorded for each image, and a graph is made of $\frac{1}{q}$ versus $\frac{1}{p}$. From this graph, determine the focal length of the lens.



A) -1.0 cm
B) 5.5 cm
C) 18 cm
D) 81 cm
E) 130 cm

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

Densities of Organic Solvents

Solvent	Density (g/mL)
heptane	0.684
diethyl ether	0.713
ethanol	0.789
methanol	0.792
benzene	0.877
trichloroethane	1.34

Standard Reduction Potentials

$Ag^+ + e^- \rightarrow Ag(s)$ $\quad E^o_{red} = 0.80$ V

$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$ $\quad E^o_{red} = -2.37$ V

Physics

Useful Constants

quantity	symbol	value
Free-fall acceleration	g	$9.80\ m/s^2$
Permittivity of Free Space	ε_0	$8.854 \times 10^{-12}\ C^2/Nm^2$
Permeability of Free Space	μ_0	$4\pi \times 10^{-7}\ Tm/A$
Coulomb constant	k	$8.99 \times 10^{9}\ Nm^2/C^2$
Speed of light in a vacuum	c	$3.00 \times 10^{8}\ m/s$
Fundamental charge	e	$1.602 \times 10^{-19}\ C$
Planck's constant	h	$6.626 \times 10^{-34}\ Js$
Electron mass	m_e	$9.11 \times 10^{-31}\ kg$
Proton mass	m_p	$1.67265 \times 10^{-27}\ kg$
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
Avogadro's number	N_A	$6.022 \times 10^{23}\ atoms/mol$
Electron Volts	eV	$1.602 \times 10^{-19}\ J/eV$
Distance Conversion	miles → meters	1.00 mile = 1609 meters
Rydberg Constant	R_∞	$1.097 \times 10^{7}\ m^{-1}$
Standard Atmospheric Pressure	1 atm	$1.013 \times 10^{5}\ Pa$

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2018 DISTRICT

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

CHEMISTRY SOLUTIONS – UIL DISTRICT 2018

C01. (E) Molar mass of $CuSO_4 \cdot 5H_2O$ = 249.72 g/mol

$$\frac{424.0\text{ g}}{249.72\text{ g/mol}} = 1.6979\text{ mol } CuSO_4 \cdot 5H_2O$$

$$1.6979\text{ mol } CuSO_4 \cdot 5H_2O \times \frac{9\text{ mol O}}{1\text{ mol } CuSO_4 \cdot 5H_2O} = 15.2811\text{ mol O}$$

$$15.2811\text{ mol O} \times \frac{16.00\text{ g O}}{1\text{ mol O}} = 244.5\text{ g O}$$

C02. (B)

$$K_a = \frac{[H^+][HCOO^-]}{[HCOOH]}$$

$$1.8 \times 10^{-4} = \frac{[H^+][11]}{[6]}$$

$$[H^+] = \frac{(6)(1.8 \times 10^{-4})}{11} = 9.8 \times 10^{-5}$$

$$pH = -\log(9.8 \times 10^{-5}) = 4.01$$

C03. (E) The oxidation state of any atom in its elemental form is 0.

C04. (B) A catalyst appears in the mechanism first as a reactant and later as a product, and does not appear in the overall equation for the reaction.

C05. (D) P_1 = 525 torr, V_1 = 500 mL (0.500 L), T_1 = 25°C (298 K).
P_2 = ?, V_2 = 1.00 L, T_2 = 323°C (596 K).

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$P_2 = \frac{P_1V_1T_2}{V_2T_1} = \frac{(525\text{ torr})(0.500\text{ L})(596\text{ K})}{(1.00\text{ L})(298\text{ K})} = 525\text{ torr}$$

(The temperature and volume were both doubled, so the pressure remained the same.)

C06. (D) Assume you have 1.000 L of solution. The mass of the solution is 1.3811 g/mL × 1000 mL = 1381.1 g. The mass of the $SrCl_2$ is 1381.1 g × 0.340 = 469.57 g. Divide by the molar mass of $SrCl_2$ to get moles of $SrCl_2$ in 1 L of solution:

$$\frac{469.57\text{ g }SrCl_2}{158.52\frac{\text{g}}{\text{mol}}SrCl_2} = 2.96\text{ mol }SrCl_2$$

This is the number of moles in 1 liter, so the molar concentration is 2.96 M.

C07. (A) $\Delta G = \Delta H - T\Delta S$ For an endothermic reaction that results in an increase in entropy, ΔH is positive and ΔS is also positive. In order for ΔG to be negative (so that the reaction is spontaneous), the $T\Delta S$ term must be larger than the ΔH term. This happens at high temperatures.

C08. (C)

C09. (A) Volume = 39.59 mL – 14.01 mL = 25.58 mL. Mass = 22.42 g.
Density = mass/volume = 22.42 g/25.58 mL = 0.876 g/mL.
This is closest to the density of benzene, 0.877.

C10. (D) mass of the gas = 59.36 kg – 54.00 kg = 5.36 kg = 5360 g.
PV = nRT, so n = PV/RT = (32.0)(44.8)/(0.08206)(273) = 63.99 moles
5360 g/ 63.99 mol = 83.76 g/mol. This is closest to krypton, with a molar mass of 83.80 g/mol

C11. (C) First calculate how much heat is lost when cooling 425 g of water from 15°C to 0°C, then calculate how much ice will melt with that quantity of heat.
To cool the water, $q = mc\Delta T$ = (425 g)(4.184 J/g°C)(15°C) = 26,673 J.
To melt the ice, (26,673 J) / (334 J/g) = 79.86 g of ice will melt. 85.0 g – 79.86 g = 5.14 g of ice remains.

C12. (C) Since the reduction of $Ag^+(aq)$ to $Ag(s)$ has a higher potential than the reduction of $Mg^{2+}(aq)$ to $Mg(s)$, $Ag^+(aq)$ will be reduced at the cathode in a galvanic cell. (You could also determine this from the activity series if reduction potentials were not provided.) $Mg(s)$ will therefore be oxidized at the anode.

$$E^{\circ}_{\text{cell}} = E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}} = 0.80\text{ V} - (-2.37\text{ V}) = 3.17\text{ V}$$

C13. (D) Molar mass of $CaCl_2{\cdot}2H_2O$ = 147.02 g/mol. (36.76 g) / (147.02 g/mol) = 0.2500 moles.
(0.2500 mol) / (0.100 L) = 2.500 M $CaCl_2$ in the initial solution.
2.500 M $CaCl_2$ × (5 mL/25 mL) = 0.500 M $CaCl_2$ in the diluted solution, but the question asks for the chloride ion concentration, which is twice the $CaCl_2$ concentration, so $[Cl^-]$ = 1.00 M.

C14. (E). Br-Br is the least polar, and H-F is the most polar, so the choices are reduced to (D) or (E). C-O is a more polar bond than P-S, so the answer is (E).

C15. (B)

$4\ Fe_3O_4(s) + O_2(g) \rightarrow 6\ Fe_2O_3(s)$ $\quad \Delta H^\circ = -471.6$ kJ

$\underline{12\ Fe(s) + 8\ O_2(g) \rightarrow 4\ Fe_3O_4(s)}$ $\quad \Delta H^\circ = -1118.4$ kJ × 4 = –4473.6 kJ

$12\ Fe(s) + 8\ O_2(g) \rightarrow 6\ Fe_2O_3(s)$ $\quad \Delta H^\circ = -471.6$ kJ + –4473.6 kJ = –4945.2 kJ

ΔH_f° is defined as the enthalpy of reaction for the formation of one mole of compound from its

elements, so –4945.2 kJ must be divided by 6 moles to get kJ/mol:

$$\frac{-4945.2\ \text{kJ}}{6\ \text{mol}\ Fe_2O_3} = -824.2\ \text{kJ/mol}$$

C16. (A) $Ni_3(PO_4)_2(s) \rightleftharpoons 3\ Ni^{2+}(aq) + 2\ PO_4^{3-}(aq)$ $K_{sp} = 4.74 \times 10^{-32} = [Ni^{2+}]^3[PO_4^{3-}]^2$
If x amount of $Ni_3(PO_4)_2(s)$ dissolves, $[Ni^{2+}] = 3x$ and $[PO_4^{3-}] = 2x$.
Therefore $K_{sp} = [3x]^3[2x]^2 = (27x^3)(4x^2) = 108x^5$

$$\left(\frac{4.74 \times 10^{-32}}{108}\right)^{1/5} = 2.130 \times 10^{-7} = x$$

$$[Ni^{2+}] = 3x = (3)(2.130 \times 10^{-7}) = 6.39 \times 10^{-7}\ \text{M}$$

C17. (C)

$$\text{Average rate} = \frac{\Delta[CCl_4]}{\Delta t} = \frac{0.374\ \text{M} - 0.167\ \text{M}}{148.0\ \text{s} - 7.00\ \text{s}} = \frac{0.2070\ \text{M}}{141.0\ \text{s}} = 0.00147\ \text{M/s}$$

C18. (A)

C19. (C) $2\ Au^{3+}(aq) + 6\ I^-(aq) \rightarrow 2Au(s) + 3I_2(s)$

C20. (D) 126.2 g/mol
Moles of NaOH = 0.03838 L × 5.000 M = 0.1919 mol
Because H_2A is diprotic, the moles of NaOH is twice the number of moles of acid.
Moles of acid = 0.09595 mol. 12.11 g/0.09595 mol = 126.2 g/mol

PHYSICS SOLUTIONS – UIL DISTRICT 2018

P01. (B) page 77: "The Coma cluster, as we call it, is an isolated and richly populated ensemble of galaxies about 300 million light-years from Earth …. Using the motions of a few dozen galaxies as tracers of the gravity field that binds the entire cluster, Zwicky discovered that their average velocity had a shockingly high value."

P02. (E) page 96: "Every few years, lab scientists devise ever more precise experiments to test the theory [of General Relativity] …. A modern example… comes from 2016, when gravitational waves were discovered by a specially designed observatory tuned for just this purpose."

P03. (D) page 107: "The most accurate measurements to date reveal dark energy as the most prominent thing in town, currently responsible for 68 percent of all the mass-energy in the universe…"

P04. (C) Stars radiate according to Wien's Law, which states that the peak frequency (color) in the emission spectrum is determined by the temperature of the star. None of the other factors affect the color, except age – but by the time a star ages enough to change color, it is no longer classified as a main sequence star.

P05. (A) We can take the formula $\xi = \alpha\sqrt{FLm}$ and convert it into units: $\frac{m}{kg\ s} = \alpha\sqrt{N\ m\ kg}$. Recalling that a Newton can be broken down: $N = \frac{kg\ m}{s^2}$, we can see: $\frac{m}{kg\ s} = \alpha\sqrt{\frac{kg\ m}{s^2}\ m\ kg} = \alpha\sqrt{\frac{kg^2\ m^2}{s^2}} = \alpha\frac{kg\ m}{s}$
This leads to the units of α: $\alpha = \frac{m}{kg\ s}\cdot\frac{s}{kg\ m} = \frac{1}{kg^2}$

P06. (B) This is a projectile motion problem, for which $a_x = 0$, and $a_y = -9.8\ m/s^2$. Let's call the initial velocity v_0, so that the components of the initial velocity are: $v_{0x} = v_0\cos(32)$, and $v_{0y} = v_0\sin(32)$. Then, using a kinematic equation for the horizontal: $x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 = 0 + v_0\cos(32)\,t + 0 = 17.5$. Simplifying gives us the relation: $v_0 t = 20.6356$. Now, using the vertical direction kinematic equation: $y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 = 0 + v_0\sin(32)\,t - 4.9t^2 = 0$. Using the value of $v_0 t$ from the first part and substituting it into the second equation allows us to solve for time:
$v_0\sin(32)\,t - 4.9t^2 = 20.6356\sin(32) - 4.9t^2 = 10.935 - 4.9t^2 = 0$, or $4.9t^2 = 10.935$, so $t = 1.494$s.
Now, going back to the first part: $v_0 t = 20.6356 = v_0(1.494)$, or $v_0 = 13.8$ m/s.

P07. (D) The most important piece of information here is that the speed of the box is constant. That means that the acceleration is zero! As usual, we take the coordinate system to be tilted so that the x-direction is down the plane and the y-direction is perpendicular to the plane. The forces are then the weight (mg) pointed straight down; the normal force (F_n) in the +y direction, and friction (f) in the −x direction. Looking at the forces in the y-direction: we have a component of the weight ($mgcos\theta$) and the normal force (F_n). The acceleration in the y-direction is zero, so $mgcos\theta = F_n$. We also know how friction relates to the normal force: $f = \mu F_n$. Now, looking at the forces in the x-direction (down the plane), we have a component of the weight ($mgsin\theta$), and the frictional force (f). Again, there is no acceleration, so we know $f = mgsin\theta$.
Therefore: $mgsin\theta = f = \mu F_n = \mu\, mgcos\theta$.
Solving for the coefficient of friction: $\mu = \frac{mgsin\theta}{mgcos\theta} = tan\theta = \tan(28) = 0.53$.

P08. (E) This is a one-dimensional conservation of momentum problem. First, let's establish that "to the right" is positive. Then the initial momentum of the box is $p_{10} = m_1 v_{10} = (0.75)(2.50) = 1.875\ kgm/s$. Also, the initial momentum of the disk is $p_{20} = m_2 v_{20} = (0.55)(-4.50) = -2.475\ kgm/s$. Thus, the total initial momentum is $p_0 = 1.875 - 2.475 = -0.600\ kgm/s$.
After the collision, we know the velocity of the box, so we can get its final momentum:
$p_{1f} = m_1 v_{1f} = (0.75)(-1.50) = -1.125\ kgm/s$. We do not know the final momentum of the disk, but we do know that momentum must be conserved. Therefore, $p_0 = p_f = p_{1f} + p_{2f} = -0.600 = -1.125 + p_{2f}$.
So, $p_{2f} = 0.525 = m_2 v_{2f} = (0.55)v_{2f}$, which gives $v_{2f} = 0.95\ m/s$. This is positive, so it is to the right.

P09. (D) This is a typical statics problem, but in this case all of the forces are vertical. Each concrete block exerts a normal force on the log (N_1 and N_2, directed upward). The log's weight and the person's weight are both directed downward (W_L and W_P). Both the sum of the forces and the sum of the torques must equal zero. First, the forces: $\sum F = N_1 + N_2 - W_L - W_P = 0$, or $N_1 + N_2 = W_L + W_P = m_L g + m_P g = (20)(9.8) + (60)(9.8) = 784$N. To evaluate the torques, we must select a pivot point. I choose to select the leftmost concrete block as the pivot point. Torques are forces multiplied by the distances from the pivot point. Conveniently, all of our forces are perpendicular to the log, so we don't have to break down any forces into components. We take clockwise torques to be negative – both of the weights produce clockwise torques, while N_2 produces a counterclockwise torque. N_1 produces no torque since it is at the pivot point. Mathematically,
$\sum \tau = N_1(0) - W_P(2.5) - W_L(4.3) + N_2(8.6) = 0 = -(60)(9.8)(2.5) - (20)(9.8)(4.3) + N_2(8.6) = 0$
This gives: $N_2 = 269\ N$. Plugging this into the force equation: $N_1 + 269 = 784$, so $N_1 = 515\ N$.

P10. (C) The air column in a resonance tube acts like an open-closed pipe, for which the resonances are related to the total length of the pipe. This problem is easier than that, however, because we are given two adjacent resonances. In any pipe, adjacent resonances are separated by exactly one-half of a wavelength of the resonant sound wave. Therefore $\frac{1}{2}\lambda = R_1 - R_2 = 80cm - 60cm = 20cm$, so the wavelength is $\lambda = 40.0cm$.
The temperature is 20ºC, so we know the speed of sound is 343 m/s. Thus, $\lambda f = v = 343 = (0.4)f$.
This gives the frequency as $f = 858\ Hz$.

P11. (D) The total increase in length will be the sum of the individual increases in length.
So, for silver: $\Delta L = \alpha L_0 \Delta T = (19 \times 10^{-6})(80)(100 - 20) = 0.1216\ cm$.
And for lead: $\Delta L = \alpha L_0 \Delta T = (29 \times 10^{-6})(220)(100 - 20) = 0.5104\ cm$
So the total increase in length is $\Delta L = 0.1216 + 0.5104 = 0.63\ cm$.

P12. (B) First, we need to reduce the capacitor network down to a single equivalent capacitance. Starting with the two middle capacitances in parallel: $C_1 = 90 + 120 = 210\ \mu F$. Then we can combine this with the other middle capacitor: $C_2 = (\frac{1}{210} + \frac{1}{50})^{-1} = 40.38\ \mu F$. Finally, we can get the total combined capacitance: $C_3 = 40.38 + 220 = 260.38\ \mu F$. From this we can get the total charge stored: $Q_3 = C_3 V_3 = (260.38)(18) = 4687\ \mu C$. Since the top and middle branches are in parallel, their voltages are the same, and equal to the voltage of the battery, so the charge stored on the middle branch is $Q_2 = C_2 V_2 = (40.38)(18) = 727\ \mu C$. This charge is the same for capacitors in series, so this same charge is stored on the 50 μF and the 210 μF equivalent capacitance, so $Q_1 = Q_2 = 727\ \mu C$. From this we can get the voltage across the middle parallel branch: $V_1 = \frac{Q_1}{C_1} = \frac{727}{210} = 3.46\ V$. Now the charge stored on the 120 μF capacitor is given by: $Q = CV = (120)(3.46) = 415\ \mu C \approx 420\ \mu C$.

P13. (B) This is a kinematic problem, with the acceleration provided by the electric field, so first we need to find the magnitude of the electric field. For a parallel plate capacitor, the electric field is based on the voltage across the plates and the distance between them: $|E| = \frac{V}{d} = \frac{10.2}{0.12} = 85\ N/C$. Then the force on the speck of dust is given by: $F = qE = (15 \times 10^{-6})(85) = 1.275 \times 10^{-3}\ N$. From this we can get the acceleration of the speck: $a = \frac{F}{m} = \frac{1.275 \times 10^{-3}}{2.00 \times 10^{-3}} = 0.6375\ m/s^2$. Now we can use kinematics to get the velocity at the plate: $v^2 = v_0^2 + 2a\Delta x = 0 + 2(0.6375)(0.01) = 0.01275$, so $v = \sqrt{0.01275} = 0.113\ m/s = 11.3\ cm/s$.

P14. (A) Let's deal with the velocity selector first: the electric field between the parallel plates in the velocity selector is given by $E = \frac{V}{d} = \frac{20}{.05} = 400\ V/m$. Then the velocity of ions that get through the selector is $v = \frac{E}{B} = \frac{400}{.02} = 2.0{\times}10^4\ m/s$. Now we can consider the mass spectrometer itself. The radius of the circle traced out by ions is given by $r = \frac{mv}{QB}$. Solving for mass gives $m = \frac{QBr}{v}$. The ions are singly charged, so $Q = 1.6{\times}10^{-19}\ C$, and $r = \frac{0.867}{2} = 0.4335\ m$. Then, $m = \frac{(1.6{\times}10^{-19})(0.06)(0.4335)}{2.0{\times}10^4} = 2.08{\times}10^{-25}\ kg$.
Converting to atomic mass units: $m = \frac{2.08{\times}10^{-25}}{1.66{\times}10^{-27}} = 125\ u\ \approx 130\ u$.

P15. (C) This problem requires the use of Faraday's Law, which states that the induced EMF (voltage) is related to the change in magnetic flux through the ring. Mathematically: $|\mathcal{E}| = \frac{\Delta\phi}{\Delta t}$. The magnetic flux is $\phi = B \cdot A$. This is technically a dot product, but since the magnetic field passes through the ring perpendicular to the ring itself, then this just becomes a product: $\phi = BA$. Now the diameter of the ring is 45.0cm, so the radius is 22.5cm. This gives an area of $A = \pi r^2 = \pi(0.225)^2 = 0.159$ m^2. The area doesn't change, so the change in flux is based entirely on the change in the magnetic field:
$\Delta\phi = B_1 A - B_2 A = A(B_1 - B_2) = 0.159(9000 \times 10^{-6} - 3000 \times 10^{-6}) = 9.54 \times 10^{-4}$ Tm^2.
We know the time in which this flux changes, so we can get the induced voltage:
$|\mathcal{E}| = \frac{\Delta\phi}{\Delta t} = \frac{9.54 \times 10^{-4}}{0.15} = 0.00636\,V$. By Ohm's Law, the current is $I = \frac{|\mathcal{E}|}{R} = \frac{0.00636}{0.25} = 0.0254\,A = 25.4\,mA$.

P16. (A) The mirror is concave, so it is capable of producing both real and virtual images. Note the condition, $2X < R$, could be written as $X < \frac{R}{2}$. $\frac{R}{2}$ is the focal length of a spherical mirror. Therefore, the condition is $X < f$. That is, the object is located *inside* the focal point. For a concave mirror, if the object is inside the focal point, then the image is virtual. If there is only a single optical element, then a virtual image will be upright. So, the image is upright and virtual.

P17. (D) The lifetime of a fast-moving particle will be extended by time dilation. Using the formula for time dilation: $\Delta t' = \frac{\Delta t}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{2.6 \times 10^{-8}}{\sqrt{1-\frac{(0.9995c)^2}{c^2}}} = \frac{2.6 \times 10^{-8}}{\sqrt{1-0.999000}} = \frac{2.6 \times 10^{-8}}{\sqrt{9.9975 \times 10^{-4}}} = \frac{2.6 \times 10^{-8}}{0.03162} = 8.2 \times 10^{-7}$ s.

P18. (E) First, notice that the exchange particle goes between two quarks, but does not change their identities. This means that the exchange particle is not charged – eliminating the W boson options. The K meson is not an exchange particle, so it can't be the correct answer. And the Higgs does not manifest itself as an exchange particle due to its extreme mass. Thus, the only viable answer is the gluon, which is a neutral particle that mediates the strong force and binds quarks together.

P19. (B) This graph is based on the equation $v^2 = v_0^2 + 2a\Delta x$. As seen from the graph, the initial velocity is near zero, the x-axis is Δx and the y-axis is v^2. Then we have $v^2 = 2a(\Delta x)$. Clearly, this is a straight line with a slope of 2a. From the graph, I chose a couple of points for the slope: (3.0m, 4.5(m/s)^2) and (1.3m, 2.0(m/s)^2). Then the slope is $\frac{4.5-2.0}{3.0-1.3} = \frac{2.5}{1.7} = 1.5\ \frac{m}{s^2} = 2a$. From this we get the acceleration, $a = 0.75\ m/s^2$.

P20. (C) This is another linear experimental graph, based this time on the lens equation: $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$. Here the x-axis is $\frac{1}{p}$ and the y-axis is $\frac{1}{q}$. Writing the lens equation as a linear equation: $\left(\frac{1}{q}\right) = \frac{1}{f} - \left(\frac{1}{p}\right)$. From this we can see that the slope of this line will be -1, and the y-intercept will be $\frac{1}{f}$. So, for once, we don't care about the slope, but are most concerned with the intercept. From the graph, the intercept is approximately 5.5 m^{-1}. This means that the focal length is $f = \frac{1}{slope} = \frac{1}{5.5} = 0.18m = 18cm$.

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