UNIVERSITY INTERSCHOLASTIC LEAGUE

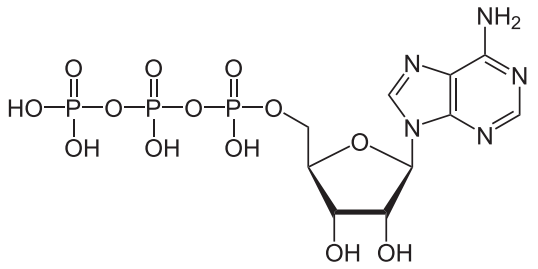
# Science

## District • 2025

**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. Identify the following structure.



A) ATP
B) triglyceride
C) ribose
D) phenylalanine
E) DNA nucleotide

B02. *Plasmodium* infects human red blood cells. The form that infects these cells is called
A) sporozoite.
B) merozoite.
C) gametocytes.
D) oocyst.
E) ookinete.

B03. Which of the following is not an example of unity in diversity of life?
A) The wings of butterflies and the wings of bats.
B) The forearms of mammals.
C) DNA as the inherited genetic information.
D) The use of ribosomes by all cells to build proteins.
E) All of the above are examples of unity in diversity of life.

B04. A biome that is dominated by very low rainfall, extreme temperature fluctuations, and plants and animals adapted to water conservation is
A) tundra.
B) taiga.
C) coniferous forest.
D) tropical rainforest.
E) desert.

B05. Consider the following genetic cross. If 80 progeny were produced, statistically, what percent would be homozygous recessive or both traits? Assume Mendelian genetics.

AaBb x AaBb

A) 0%
B) 5%
C) 6.25%
D) 18.75%
E) 56.25%

B06. In eukaryotic cells, _____ occurs in the nucleus and _____ occurs in the cytoplasm.
A) replication; protein synthesis
B) protein synthesis; transcription
C) transcription; translation
D) protein synthesis; replication
E) translation; transcription

B07. An area of the plasma membrane where phospholipids, sphingolipids, and cholesterol have congregated and distorted the membrane structure is called a/an
A) endomembrane.
B) glycoprotein.
C) leaflet.
D) lipid raft.
E) cholesterol mat.

B08. Hormone is to _____ as electrochemical is to _____.
A) integumentary; endocrine
B) digestive; nervous
C) cardiovascular; integumentary
D) muscular; digestive
E) endocrine; nervous

B09. Which DNA technology would be used to separate fragments based on molecular weight?
A) Northern blot
B) PCR
C) Southern blot
D) gel electrophoresis
E) molecular cloning

B10. According to the World Health Organization, on January 30, 2025, the Ministry of Health of Uganda declared an outbreak of Sudan virus disease (SVD), which belongs to the same family of viruses as
A) Mumps.
B) Ebola.
C) Chikungunya.
D) Zika.
E) HIV.

B11. If a prokaryote is undergoing photosynthesis but using elemental sulfur as the electron donor, this is called
A) aerobic respiration.
B) anaerobic respiration.
C) anoxygenic photosynthesis.
D) oxygenic photosynthesis.
E) fermentation.

B12. All of the proteins, some of which are enzymes, listed below have a role in DNA replication at the molecular level. Of the listed proteins, which one is responsible for keeping the two unwound strands of DNA from reannealing?
A) RNA primases
B) DNA helicase
C) DNA ligase
D) DNA Polymerase III
E) Single-strand binding protein

B13. Columnar, cuboidal, and squamous are cells of _____ ___ tissue.
A) cardiac
B) connective
C) epithelial
D) muscle
E) nervous

B14. In a population at Hardy-Weinberg equilibrium, 1352 express the recessive phenotype out of a population of 2000 individuals. What percent of the population is homozygous recessive?
A) 3.16%
B) 17.8%
C) 29.2%
D) 67.6%
E) 82.2%

B15. In terms of biological hierarchy, which of the following includes all of the other answer choices below?
A) cells
B) biome
C) tissues
D) organism
E) organelles

B16. Crossing over of homologous chromosomes to produce new combinations of alleles occurs during
A) Mitosis
B) Prophase I
C) Telophase I
D) asexual reproduction
E) Prophase II

B17. Which of the following would likely belong to Domain Archaea?
A) hyperthermophile
B) fungi
C) bacteria
D) humans
E) yeast

B18. Which statement about natural selection is not true?
A) Environmental conditions select for advantageous traits.
B) Individuals in a population have differences.
C) Characteristics are passed from parent to offspring.
D) Over time, an advantageous trait increases in the population.
E) Individuals within a population evolve.

B19. The reduction of nitrate to nitrite by bacterial cells occurs using
A) anaerobic respiration.
B) aerobic respiration.
C) fermentation.
D) photosynthesis.
E) glycolysis only.

B20. Mutations in the gene for p53 in humans are commonly associated with
A) mitochondrial defects.
B) muscular dystrophy.
C) Alzheimer's.
D) various types of cancer.
E) neurological defects.

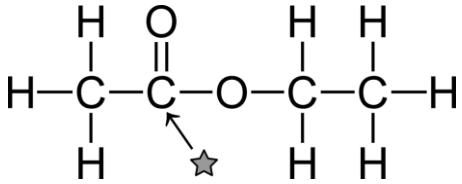
C01. Aqueous solutions of $K_3PO_4$ and $AgNO_3$ are mixed, producing one solid product and one aqueous product. What is the sum of the coefficients when this reaction is balanced using the smallest whole number coefficients?

A) 4 B) 5 C) 6 D) 8 E) 9

C02. If 66.0 g of water at 20.0°C is mixed with 44.0 g of water at 65.0°C, what will the final temperature of the mixture be?

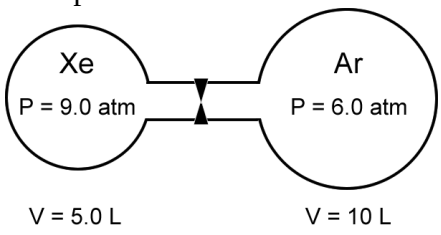
A) 38.0°C B) 47.0 °C C) 60.8°C
D) 42.5°C E) 34.3°C

C03. The molecule shown here is ethyl acetate, $C_4H_8O_2$. Ethyl acetate has a sweet smell and is found in wines, candy, and fruit. It is also used in perfumes, as an industrial solvent, and by entomologists to quickly kill insects in bug jars. What is the orbital hybridization of the carbon atom marked with the star?



A) *sp* B) $sp^2$ C) $sp^3$ D) $dsp^3$ E) $d^2sp^3$

C04. In the following two-bulb gas system at 0°C, the bulb on the left has a volume of 5.0 L and contains 9.0 atm of xenon gas. The bulb on the right has a volume of 10 L and contains 6 atm of argon gas. After the value is opened and the gases are allowed to mix, what will the final pressure be?




A) 6.5 atm B) 8.5 atm C) 7.5 atm
D) 8.0 atm E) 7.0 atm

C05. Thinking in terms of the Bohr model of the atom, which of these statements about the electron energy level spacings in a hydrogen atom is true?

A) The energy differences between adjacent energy levels in a hydrogen atom are all equal, so the transition from $n$=1 to $n$=2 is the same difference in energy as the transition from $n$=8 to $n$=9.
B) The energy differences between adjacent energy levels in a hydrogen atom get increasingly larger as you move farther from the nucleus, so the transition from $n$=1 to $n$=2 is a smaller difference in energy than the transition from $n$=8 to $n$=9.
C) The energy differences between adjacent energy levels in a hydrogen atom get increasingly smaller as you move farther from the nucleus, so the transition from $n$=1 to $n$=2 is a greater difference in energy than the transition from $n$=8 to $n$=9.
D) There is no real pattern to the energy level differences between adjacent energy levels in a hydrogen atom, and the only way to compare two transitions is to do the calculations for each one and then compare the final numbers.
E) The electron energy level spacings in a hydrogen atom cannot be calculated theoretically and can only be measured experimentally.

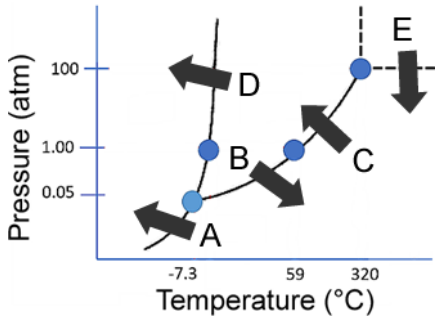
C06. Consider the following ionic compounds KBr $AlCl_3$ FeN $BaCl_2$. Order them from smallest (on the left) to largest (on the right) lattice energy.

A) FeN < KBr < $BaCl_2$ < $AlCl_3$
B) KBr < $BaCl_2$ < $AlCl_3$ < FeN
C) FeN < $BaCl_2$ < KBr < $AlCl_3$
D) KBr < FeN < $BaCl_2$ < $AlCl_3$
E) $AlCl_3$ < $BaCl_2$ < KBr < FeN

C07. A sample of liquid methanol ($CH_3OH$) is burned, generating 1650 kJ of heat. What was the volume of methanol burned? The heat of combustion for methanol is –725.7 kJ/mol. The density of methanol is 0.792 g/cm$^3$.

A) 57.7 mL
B) 108 mL
C) 75.7 mL
D) 92.0 mL
E) Not enough information is provided

C08. Which arrow on this graph represents the phase change deposition?




C09. What is the molar mass of unknown compound $Na_xS_yO_z$ if a 0.0590 mol sample contains 2.71 g of sodium, 3.78 g of sulfur, and 2.83 g of oxygen

A) 142 g/mol
B) 158 g/mol
C) 167 g/mol
D) 175 g/mol
E) 181 g/mol

C10. What happens to the pH of pure water as you increase the temperature?

A) The pH remains 7.0 because $[H^+] = [OH^-]$
B) The pH decreases because $[H^+] > [OH^-]$
C) The pH increases because $[H^+]$ increases
D) The pH decreases because $[H^+]$ increases
E) The pH increases because $[OH^-]$ decreases

C11. If a block of dry ice (solid $CO_2$) with a mass of 1165 g is added to 1325 mL of water at 20 °C and then the whole system is heated to 200°C, how many molecules would be in the gas phase?

A) $6.022 \times 10^{23}$ molecules
B) $6.022 \times 10^{24}$ molecules
C) $6.022 \times 10^{25}$ molecules
D) $6.022 \times 10^{26}$ molecules
E) $6.022 \times 10^{27}$ molecules

C12. If solid $PbCl_2$ is added to water, what will the chloride ion concentration be at equilibrium?

A) 0.0257
B) 0.0162 M
C) 0.00643 M
D) 0.0128 M
E) 0.0324 M

C13. In which of these situations can you add heat to a substance without increasing its temperature?

A) When the substance is very cold
B) When the substance is already very hot
C) When the substance is in the process of melting
D) When the substance is a supercritical fluid
E) None of these. Adding heat always raises the temperature of the thing you're adding heat to.

C14. If you have 100 mL of 1.0 M benzoic acid solution and you add 200 mL of water, what is the new pH of the solution?

A) 2.43
B) 2.34
C) 3.24
D) 3.42
E) 4.23

C15. If sample of propane ($C_3H_8$) with a mass of 7325 grams undergoes complete combustion, how many $CO_2$ molecules will be formed?

A) $3.000 \times 10^{26}$
B) $6.022 \times 10^{23}$
C) $1.807 \times 10^{24}$
D) $3.345 \times 10^{25}$
E) $1.000 \times 10^{26}$

C16. What is the name of the acid formed by adding a hydrogen ion to a chlorite ion?

A) hydrochloric acid
B) hypochlorous acid
C) chlorous acid
D) chloric acid
E) perchloric acid

C17. If 500 grams of solid aluminum is reacted with 500 L of HF gas at STP to form solid $AlF_3$, how many grams of aluminum would remain when the reaction was over?

A) 200 g B) 602 g C) 149 g
D) 78.0 g E) 299 g

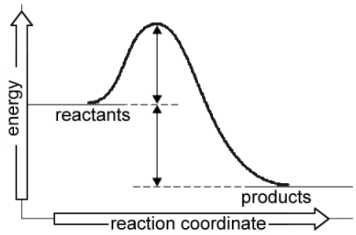
C18. Your lab partner mistakenly pours 375 mL of 0.50 M $CaCl_2$ solution into a jar containing 825 mL of 0.25 M $AlCl_3$. What is the chloride ion concentration in the mixed solution?

A) 0.828 M B) 0.750 M C) 1.75 M
D) 0.994 M E) 1.25 M

C19. In which of these compounds or ions is the metal in the highest oxidation state?

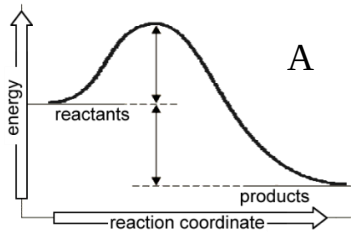
A) $Cr_2O_7^{2-}$
B) $ReO_3$
C) $Fe_2O_3$
D) $MnO_4^-$
E) $VO_4^{3-}$

C20. Shown here is the energy diagram for an uncatalyzed chemical reaction.

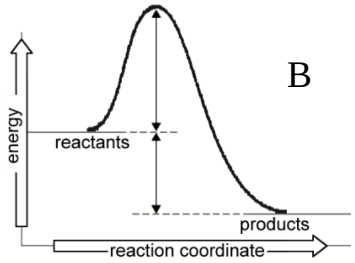



Which of the diagrams below could represent the same reaction with a catalyst added?

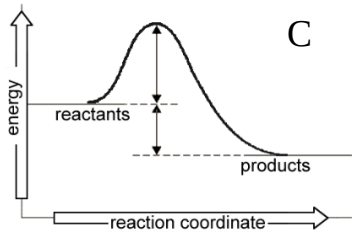
A



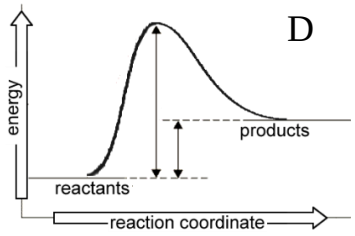

B



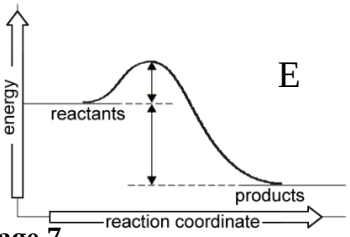

C




D




E



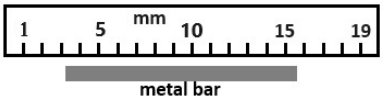
P01. According to Orzel, the mathematician Emmy Noether proved a theorem showing that _____ in physics lead to conserved quantities such as momentum and energy.
A) zeros
B) infinities
C) symmetries
D) relativities
E) probabilities

P02. According to Orzel, an event can cause or be caused by another event only if ...
A) the events are separated by enough time for light to travel between them
B) the events are separated by less time than is needed for light to travel between them
C) the events take place in the same location
D) the events both lie on the light cone
E) the events involve conserved quantities

P03. According to Orzel, as the speed of an object increases, the force required to maintain a constant rate of acceleration will…
A) increase slightly
B) increase dramatically
C) decrease slightly
D) decrease dramatically
E) remain constant

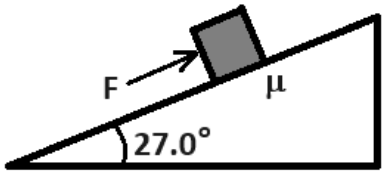
P04. Which moon of Saturn is known for its cryovolcanoes that blast geyser-like plumes of water and other chemicals into space and, thus, supplies most of the material for Saturn's E-ring.
A) Titan
B) Mimas
C) Dione
D) Tethys
E) Enceladus

P05. You measure the length of a bar of metal using a ruler with millimeter markings (as shown). What is the best possible measurement of the bar of metal?
A) 3.2 mm
B) 12 mm
C) 12.5 mm
D) 15.7 mm
E) 16 mm




P06. A car that starts from rest accelerates at $3.30\text{m/s}^2$ for a distance of 22.0m. The car then slows down at a rate of $-1.40\text{m/s}^2$ for a time of 4.75seconds, after which the car travels at a constant speed. What is the final constant speed of the car?
A) 1.87 m/s
B) 5.40 m/s
C) 6.65 m/s
D) 8.52 m/s
E) 12.0 m/s

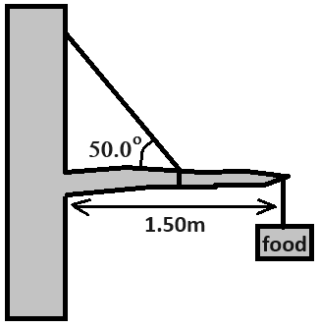
P07. You slide a 90.0kg box of radishes up an incline that is angled at 27.0° above the horizontal (as shown). You push the box with a force of 680.0N and your force is parallel to the incline. The box slides up the incline at a constant speed. What is the coefficient of friction between the box and the incline?
A) 0.865
B) 0.509
C) 0.454
D) 0.356
E) 0.317




P08. A 20.0kg cart is rolling to the right at 4.50m/s when it impacts a stationary 12.0kg wagon. As a result of the collision, the two vehicles lock together and continue to move to the right. What percentage of the original kinetic energy of the cart was converted to heat during the collision?
A) 25.0 %
B) 31.3 %
C) 37.5 %
D) 62.5 %
E) 68.7 %

P09. A 16.0kg food pack is attached to the end of a 1.50m long tree branch. A rope is tied at the exact middle of the branch and extends up to the tree trunk at an angle of 50.0° with respect to the horizontal (as shown). The branch has a mass of 10.0kg that is evenly distributed throughout its length. What is the magnitude of the net force acting at the base of the tree branch, where it connects to the tree trunk?

A) 157 N
B) 235 N
C) 308 N
D) 345 N
E) 379 N
F) 537 N

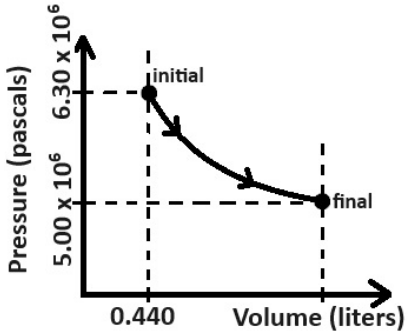



P10. An open-open pipe is supposed to produce an $n = 2$ resonance at 454.0Hz. Unfortunately, the sound is a little flat, producing an $n = 2$ resonance at 449.0Hz. How much length should be cut from the pipe to obtain the correct sound? Assume the air temperature is 20.0°C.

A) 5.61 mm
B) 7.55 mm
C) 8.41 mm
D) 10.5 mm
E) 12.6 mm

P11. A monatomic ideal gas undergoes the isothermal expansion shown on the PV diagram below. If there are 0.910 moles of the gas, then how much work is done by the gas during this expansion?

A) 280 J
B) 640 J
C) 1420 J
D) 2200 J
E) 2770 J

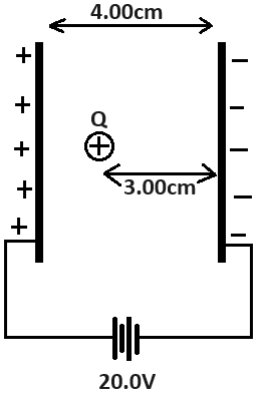



P12. A 2600.0m long wire with a diameter of 1.24mm is connected to a 60.0V power supply. This results in a current of 1.55A flowing in the wire. What is the resistivity of the material from which the wire is made?

A) $1.80 \times 10^{-8}$ Ωm
B) $3.87 \times 10^{-8}$ Ωm
C) $5.72 \times 10^{-8}$ Ωm
D) $7.19 \times 10^{-8}$ Ωm
E) $1.49 \times 10^{-7}$ Ωm

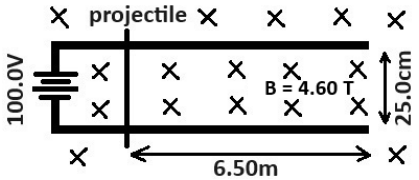
P13. A charge, $Q = +450.0mC$, is placed between two parallel plates. The plates are connected to a 20.0V power supply and are separated by 4.00cm. The charge starts from rest at a location 3.00cm from the negative plate (as shown). The charge has a mass of 2.70μg. How fast is the charge moving when it reaches the negative plate?

A) 50.0 m/s
B) 57.7 m/s
C) 70.7 m/s
D) 81.6 m/s
E) 94.3 m/s




P14. A railgun is being tested for launching satellites into space. The railgun is constructed from two zero-resistance rails that are separated by 25.0cm. The rails are connected to a 100.0V power source, and the magnetic field in the railgun is 4.60T. A 14.0g projectile is placed on the rails, starting from rest at a location 6.50m from the end of the rails. The projectile has a resistance of 0.630Ω. At what speed is the projectile launched from the end of the rails?

A) 80.7 m/s
B) 183 m/s
C) 210 m/s
D) 291 m/s
E) 412 m/s

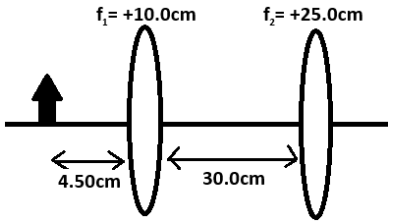


P15. While in deep space, you experiment with a light-based propulsion system. You use a collimated 450.0W laser to produce a spot with a diameter of 8.00cm. You direct the spot onto a perfectly reflective disk whose diameter is 12.0cm. The disk has a mass of 24.0g, and it starts from rest. If the laser pushes the disk for exactly three full days, what is the final speed of the disk?

A) 7.20 m/s
B) 14.4 m/s
C) 16.2 m/s
D) 21.6 m/s
E) 32.4 m/s

P16. A double lens magnifier is built with two converging lenses. The first lens has a focal length of +10.0cm and the second lens has a focal length of +25.0cm. The second lens is placed 30.0cm to the right of the first lens, and the object is located 4.50cm to the left of the first lens. By what factor is the object magnified by the double lens system?

A) 1.82
B) 3.45
C) 7.86
D) 9.21
E) 14.3




P17. You have suddenly been blessed with super strength. You test your strength by throwing a 2.00m long bamboo pole as hard as you can. You manage to throw the pole at the staggering speed of 0.920c (92.0% of the speed of light). As it flies away from you, what is the length of the bamboo pole as measured in your frame of reference?

A) 0.784 m
B) 0.566 m
C) 0.392 m
D) 0.307 m
E) 0.160 m

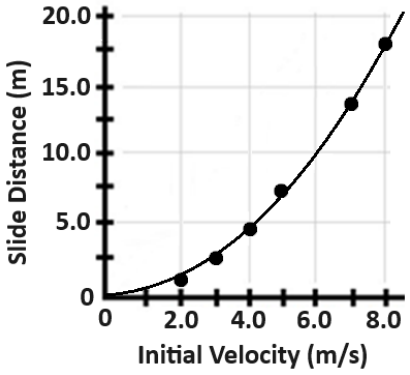
P18. In your physics laboratory, you create a beam of subatomic particles that you call *X-particles*. These particles carry a single unit of positive charge, have a lifetime of about $10^{-15}$ seconds, and decay into a proton, a kaon, and a pion (as illustrated). What is the most likely quark structure for the X particle?

A) $uus$
B) $uuc$
C) $udc$
D) $u\bar{s}$
E) $\bar{d}c$

$$X \rightarrow p^+ + K^- + \pi^+$$

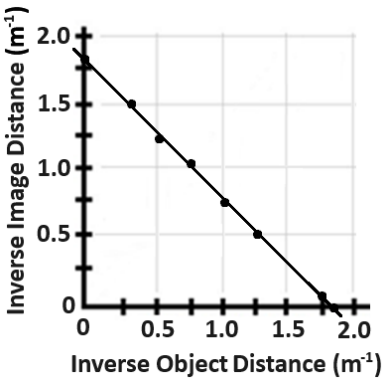
P19. You slide a 5.00kg box across a horizontal floor with different initial velocities. For each velocity, you measure the distance the box slides before coming to rest. The data are plotted below. Using these data, determine the coefficient of friction between the box and the floor.

A) 0.18
B) 0.27
C) 0.36
D) 0.45
E) 0.72




P20. You place an object at different distances in front of a concave mirror. For each placement of the object, you measure the location of the image. You plot the inverse of the image distance (1/q) as a function of the inverse of the object distance (1/p). The plot is shown below. From these data, estimate the radius of curvature of the mirror.

A) 28 cm
B) 55 cm
C) 110 cm
D) 180 cm
E) 200 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
$\Delta H_{fus}$ = 334 J/g
$\Delta H_{vap}$ = 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

### Equilibrium Constants

$K_a$ for benzoic acid $6.3 \times 10^{-5}$

$K_{sp}$ for $PbCl_2$ $1.7 \times 10^{-5}$

*This space intentionally left blank.*

# Physics

## Useful Constants

| quantity | symbol | value |
|---|---|---|
| Free-fall acceleration | g | $9.80\ m/s^2$ |
| Permittivity of Free Space | $\varepsilon_0$ | $8.854 \times 10^{-12}\ C^2/Nm^2$ |
| Permeability of Free Space | $\mu_0$ | $4\pi \times 10^{-7}\ Tm/A$ |
| 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 | $m_p$ | $1.67265 \times 10^{-27}\ kg$<br>$1.007276 amu$ |
| Neutron mass | $m_n$ | $1.67495 \times 10^{-27}\ kg$<br>$1.008665 amu$ |
| Atomic Mass Unit | amu | $1.66 \times 10^{-27}\ kg$<br>$931.5\ MeV/c^2$ |
| Gravitational constant | G | $6.67 \times 10^{-11}\ Nm^2/kg^2$ |
| Stefan-Boltzmann constant | $\sigma$ | $5.67 \times 10^{-8}\ W/m^2K^4$ |
| Universal gas constant | R | $8.314\ J/mol \cdot K$<br>$0.082057\ L \cdot atm/mol \cdot K$ |
| 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 | $R_\infty$ | $1.097 \times 10^{7}\ m^{-1}$ |
| Standard Atmospheric Pressure | 1 atm | $1.013 \times 10^{5}\ Pa$ |
| Density of Pure Water | $\rho_{water}$ | $1000.0\ kg/m^3$ |

**DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!**

# UIL HIGH SCHOOL SCIENCE CONTEST
# ANSWER KEY
# 2025 DISTRICT

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

**CHEMISTRY SOLUTIONS – UIL DISTRICT 2025**

C01. (D) The equation is $K_3PO_4(aq) + 3AgNO_3(aq) \rightarrow Ag_3PO_4(s) + 3KNO_3(aq)$

C02. (A) Normally when solving problems of this type you would use "heat lost by the hot = heat gained by the cold" $-m_H c_H \Delta T_H = m_C c_C \Delta T_C$, but when the hot and cold are the same substance and there is no phase change, you can solve it using the idea of conservation of energy: the energy of the cold plus the energy of the hot equals the total energy, where energy is expressed as mass times temperature: $m_C T_C + m_H T_H = m_{TOTAL} T_{FINAL}$ (This only works if the two substances are the same, because the specific heat is factored out and canceled.)

$$T_{FINAL} = \frac{m_C T_C + m_H T_H}{m_{TOTAL}} = \frac{(66.0)(20.0) + (44.0)(65.0)}{(66 + 44)} = 38.0℃$$

C03. (B) There are three regions of electron density surrounding that carbon atom: the single bond to the left to another carbon atom, the single bond to the right to an oxygen atom, and the double bond oriented up to another oxygen atom. Since there are three regions of electron density around that carbon atom, three hybrid orbitals are involved in the bonding: *s*, *p*, and *p*, are hybridized into three $sp^2$ hybrid bonds.

C04. (E) Pressure times volume is an energy unit, so the law of conservation of energy says that the energy in the left bulb plus the energy of the right bulb equals the energy of the total system, or stated as an equation, $P_1V_1 + P_2V_2 = P_{Final}V_{Final}$
We know $P_1$, $V_1$, $P_2$, $V_2$, and $V_{Final}$, so we can just rearrange and solve for $P_{Final}$
$P_{Final} = (P_1V_1 + P_2V_2)/V_{Final} = (9.0\times5.0 + 6.0\times10)/15 = 105/15 = 7.0$ atm.

C05. (C) In our solar system the distance between two adjacent planets gets larger with each step away from the sun, and the energy level spacings in an atom are the opposite – the difference in energy between $n$=8 and $n$=9 is much smaller than the difference between $n$=1 and $n$=2.

C06. (B) Lattice energy is strongly affected by the Coulombic attraction between the two ions. The attraction is largest for ions with the largest charge and smallest size, with charge being the more important factor. To a first approximation you can multiply the absolute values of the ionic charges to rank the compounds and then use ionic radius to break any ties (there are no ties in this case). KBr: 1×1=1; $AlCl_3$: 3×1 = 3; FeN: 3×3 = 9; $BaCl_2$: 2×1 = 2. Thus the ranking would be 1 < 2 < 3 < 9, or KBr < $BaCl_2$ < $AlCl_3$ < FeN.

C07. (D) 1650 kJ / 725 kJ/mol = 2.274 moles of methanol. 2.274 mol × 32.05 g/mol = 72.871 g of methanol. 72.871 g / 0.792 g/mL = 92.0 mL methanol.

C08. (A) Deposition is going directly from a gas to a solid without becoming liquid in between.

C09. (B) This is just a molar mass calculation disguised as an empirical formula problem. Add the masses of all the elements and divide by the number of moles: 2.71 + 3.78 + 2.83 = 9.32 g / 0.059 mol = 157.966 = 158 g/mol. (The compound is sodium thiosulfate, $Na_2S_2O_3$.)

C10. (D) When you increase the temperature, water molecules break up more readily, so $[H^+]$ increases and therefore pH decreases. $[OH^-]$ also increases and $[H^+]$ is still equal to $[OH^-]$, but pH is based only on the $H^+$ concentration, not on the $OH^-$ concentration. Since $[H^+]$ increases with temperature, the pH of neutral water goes down when the temperature increases. Neutral water has a pH of 7.00 only at 25°C.

C11. (C) The initial and final temperatures don't matter other than at 200°C all of the molecules are in the gas phase, so the question is really just asking how many total molecules are in the problem. For $CO_2$, 1165 g / 44.01 g/mol = 26.47 mol × $6.022 \times 10^{23}$ = $1.594 \times 10^{25}$ molecules. For water, 1325 g / 18.02 g/mol = 73.53 mol × $6.022 \times 10^{23}$ = $4.4279 \times 10^{25}$ molecules. The total is $1.594 \times 10^{25} + 4.4279 \times 10^{25} = 6.022 \times 10^{25}$ molecules.

C12. (E) $K_{sp} = [Pb^{2+}][Cl^-]^2 = (x)(2x)^2 = 4x^3$, so $x = (K_{sp}/4)^{⅓} = (1.7\times10^{-5}/4)^{⅓} = 0.0162$ M = $[Pb^{2+}]$. $[Cl^-] = 2 \times [Pb^{2+}] = 2 \times 0.0162$ M = 0.0324 M

C13. (C) Adding heat to a substance undergoing a phase change does not raise the temperature of the substance because all of the added heat energy is used to overcome intermolecular attractions.

C14. (B) After adding 200 mL of water the new concentration is $M_2 = (M_1V_1)/V_2 = (1.0)(100)/(300) = 0.333$ M. The pH of a 0.333 M solution of benzoic acid is

$$[H^+] = \sqrt{K_a C_{acid}} = \sqrt{(6.3 \times 10^{-5})(0.333)} = 0.00458$$
$$pH = -\log[H^+] = -\log(0.00458) = 2.34$$

C15. (A) 7325 g / 44.11 g/mol = 166.06 mol $C_3H_8$ From the balanced equation $1\ C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$, 3 moles of $CO_2$ are produced for every mole of $C_3H_8$, so moles of $CO_2$ = 498.19. Multiply this by $6.022 \times 10^{23}$ Avogadro's number to get molecules, and the answer is $3.000 \times 10^{26}$.

C16. (C) When an acid is formed from a polyatomic ion ending in *-ite*, the acid name ends with *-ous acid*. When an acid is formed from a polyatomic ion ending in *-ate*, the acid name ends with *-ic acid*.

C17. (E) $2\ Al(s) + 6\ HF(g) \rightarrow 2\ AlF_3(s) + 3\ H_2(g)$ You don't actually need a balanced equation for the reaction as long as you realize that to form $AlF_3$ you need three moles of HF for every mole of Al. First calculate moles of HF available, then moles of Al that react, then grams of Al that reacted, leaving grams of aluminum in excess. Moles HF = $n = PV/RT$ = (1 atm)(500 L)/(0.08206)(273) = 22.319 moles HF. 22.319 mol HF × (1 mol Al/3 mol HF) = 7.4396 mol Al reacted × 26.98 g/mol = 200.722 grams of Al reacted. The grams remaining = 500 – 200.722 = 299.28 g = 299 grams of Al remaining.

C18. (A) Moles of chloride in the $CaCl_2$ = (0.375 L)(0.50 M)×2 = 0.375 mol. Moles of chloride in the $AlCl_3$ = (0.825 L)(0.25 M)×3 = 0.61875 mol. Total moles = 0.99375 moles $Cl^-$. Total volume = 0.375 L + 0.825 L = 1.200 L. 0.99375 mol/1.200 L = 0.828 M.

C19. (D) The Mn is in a +7 oxidation state. The others are Cr(VI), Re(VI), Fe(III) and V(V).

C20. (E) A catalyst reduces the activation energy for the reaction by providing a new reaction pathway, but the energy difference between the reactants and products does not change. A is the same graph only wider, B has a higher activation energy, C has a different energy for the products, D changes the reaction from exothermic to endothermic.

**PHYSICS SOLUTIONS – UIL DISTRICT 2025**

P01. (C) page 104: "This was made especially clear in 1915 when German mathematician Emmy Noether proved a mathematical theorem showing that symmetries in physics lead to conserved quantities like momentum and energy."

P02. (A) page 116: "The critical limit is the speed of light: one event can cause or be caused by another event only if the two are separated by enough time to allow light to travel between them."

P03. (B) page 143: "The important thing is that the force required to accelerate an object increases dramatically as the speed of that object increases."

P04. (E) In 2005, the *Cassini* spacecraft revealed cryovolcanoes on Saturn's sixth largest moon, Enceladus. The cryovolcanoes blast geyser-like plumes of water vapor and other volatile compounds from the moon. Since then, more than one hundred cryovolcanoes in total have been identified on Enceladus.

P05. (C) Measurements using an analog tool, such as a ruler, should be estimated to one digit below the smallest markings on the tool. For this ruler, the smallest markings are millimeters, so we should estimate the measurement to the tenths of a millimeter. The left end of the bar is located at about 3.2mm, and the right end of the bar is located at about 15.7mm. The total length of the bar is then $L = 15.7 - 3.2 = 12.5$mm. No rounding is needed since this is already indicated to one tenth of a millimeter.

P06. (B) There are two parts to this problem: speeding up and slowing down. Let's start by finding the speed of the car after the initial acceleration. We know the acceleration and the distance traveled, so we'll use $v_1^2 = v_0^2 + 2a\Delta x$. This gives $v_1^2 = (0)^2 + 2(3.30)(22.0) = 145.2 \;\rightarrow\; v_1 = 12.05$ m/s. This is the maximum speed reached by the car. Now it begins to slow down. For this part, we are given the time, so we'll use $v_2 = v_1 + at$. This gives $v_2 = 12.05 + (-1.40)(4.75) = 5.40$m/s. This is the final speed of the car.

P07. (D) We begin with a free body force diagram. There are four forces: gravity ($mg$, directed downward), the normal force ($F_N$, directed up and left perpendicular to the plane), friction ($F_f$, directed down and left parallel to the plane), and the applied force ($F$, directed up and right parallel to the plane). As usual for inclined planes, we will tilt our coordinate system, so that the x-axis is parallel to the plane and the y-axis is perpendicular to the plane. Thus, the normal force is in the positive y-direction, friction is in the negative x-direction and the applied force is in the positive x-direction. The gravitational force must be broken into components. In the negative x-direction is the component $mg\sin\theta$ and in the negative y-direction is the component $mg\cos\theta$. The motion of the box is entirely in the positive x-direction, so the forces in the y-direction must sum to zero, giving: $\sum F_y = F_N - mg\cos\theta = 0 \;\rightarrow\; F_N = mg\cos\theta \;\rightarrow\; F_N = (90.0)(9.80)\cos(27.0) = 785.9$N. Now, we consider the x-direction. The box moves in the x-direction, but at a constant speed, which means that the acceleration in the x-direction is zero. Thus, summing the forces gives: $\sum F_y = F - F_f - mg\sin\theta = ma_x = m(0) = 0$. This leads to $680.0 - F_f - (90.0)(9.8)\sin(27.0) = 0 \;\rightarrow\; 680.0 - F_f - 400.4 = 0 \;\rightarrow\; F_f = 279.6$N. Finally, the coefficient of friction relates the frictional force to the normal force: $F_f = \mu F_N \;\rightarrow\; (279.6) = \mu(785.9) \;\rightarrow\; \mu = 0.356$.

P08. (C) We begin with conservation of momentum, $p_i = p_f \;\rightarrow\; m_c v_{ci} + m_w v_{wi} = m_c v_{cf} + m_w v_{wf}$. Since the cart and wagon are locked together after the collision, their final velocities will be the same: $v_{cf} = v_{wf}$. We will call that velocity $v_f$. Putting in the known quantities, we get $(20.0)(4.50) + (12.0)(0) = (20.0)v_f + (12.0)v_f \;\rightarrow\; 90.0 = 32.0v_f \;\rightarrow\; v_f = 2.81$m/s. Now we consider the kinetic energy before and after the collision. Before the collision, the kinetic energy is $KE_i = \frac{1}{2}m_c v_{ci}^2 + \frac{1}{2}m_w v_{wi}^2 = (0.5)(20.0)(4.50)^2 + (0.5)(12.0)(0)^2 = 202.5\,J$. After the collision, the kinetic energy is $KE_f = \frac{1}{2}(m_c + m_w)v_f^2 = (0.5)(20.0 + 12.0)(2.81)^2 = 126.3\,J$.

Thus, the kinetic energy converted to heat is $\Delta KE = KE_i - KE_f = 202.5 - 126.3 = 76.2\,J$. As a percentage of the initial kinetic energy, the energy converted to heat is $\%\Delta KE = \frac{\Delta KE}{KE_i} = \frac{76.2}{202.5} = 0.375 = 37.5\%$.

P09. (E) This system is in equilibrium, so all forces and torques sum to zero. There are five forces acting on the branch – the weight of the food pack ($m_f g$, downward, acting at the end of the branch), the weight of the branch ($m_b g$, downward, acting at the middle of the branch), the tension ($T$, up and left at an angle, acting at the middle of the branch), a vertical force at the base of the branch ($F_v$, downward, acting at the base of the branch) and a horizontal force at the base of the branch ($F_h$, right, acting at the base of the branch).
We will begin by exploring the torque. First, we choose the pivot point. It could be anywhere, but it is best to choose the pivot point to be at the base of the tree branch where it meets the tree trunk. Torque is defined as a force multiplied by the length of the torque arm multiplied by the sine of the angle between the force and the torque arm (that is $\tau = Fr\sin\theta$). Torques oriented clockwise are negative, while counterclockwise torques are positive. The sum of all of the torques in this system, with a pivot point at the base of the branch, is:
$\sum \tau = -m_f g(L)\sin 90° - m_b g\left(\frac{1}{2}L\right)\sin 90° + T\left(\frac{1}{2}L\right)\sin 50° + F_v(0)\sin 90° + F_h(0)\sin 0° = 0 \;\rightarrow$
$-(16.0)(9.80)(1.50)(1) - (10.0)(9.80)(0.750)(1) + T(0.750)(0.7660) + 0 + 0 = 0$
This leads to $-235.2 - 73.5 + 0.5745T = 0$, which gives the tension in the rope of
$308.7 = 0.5745T \;\rightarrow\; T = 537.3\,N$.
Now, we consider the sums of forces, with downward forces being negative and upward forces being positive. Because it acts at an angle, the tension must be broken into components. In the vertical, we have $\sum F_{vertical} = -m_f g - m_b g + T\sin\theta - F_v = 0 \;\rightarrow$
$-(16.0)(9.80) - (10.0)(9.80) + (537.3)\sin 50° - F_v = 0 \;\rightarrow\; -156.8 - 98.0 + 411.6 - F_v = 0.$
This gives a vertical force at the base of the tree branch of $F_v = 156.8\,N$. In the horizontal, we have $\sum F_{horizontal} = -T\cos\theta + F_h = 0 \;\rightarrow\; -(537.3)\cos 50° + F_h = 0$. This gives a horizontal force at the base of the tree branch of $F_h = 345.4\,N$. Thus, the total force acting at the base of the tree branch is $F = \sqrt{F_v^2 + F_h^2} = \sqrt{(156.8)^2 + (345.4)^2} = 379\,N$.

P10. (C) An open-open pipe resonates at frequencies given by $f_n = \frac{nv}{2L}$ where *n* is an integer, *v* is the speed of sound, and *L* is the length of the pipe. At 20.0℃, the speed of sound is 343.0m/s. For the frequency we want, we need: $f_2 = 454.0 = \frac{(2)(343)}{2L} \;\rightarrow\; L = 0.75551$m. The "slightly flat sounding" pipe has a length of: $f_2' = 449 = \frac{(2)(343)}{2L'} \;\rightarrow\; L' = 0.76392$m. The difference in the lengths equals the amount that needs to be cut from the pipe: $\Delta L = L' - L = 0.76392 - 0.75551 = 0.00841m = 8.41$mm.

P11. (B) First, we need the final volume of the ideal gas. Since the process is isothermal, we use Boyle's Law: $P_1V_1 = P_2V_2 \;\rightarrow\; (6.30\times10^6)(0.440) = (5.00\times10^6)V_2 \;\rightarrow\; V_2 = 0.554$ liters. Now, we convert the volumes into m$^3$: $V_1 = 0.440\times10^{-3}m^3 = 4.40\times10^{-4}m^3$, and $V_1 = 0.554\times10^{-3}m^3 = 5.54\times10^{-4}m^3$. Next, we'll use the ideal gas law to find the temperature of the isothermal process. We can use either the initial or final points: $P_1V_1 = nRT \;\rightarrow$ $(6.30\times10^6)(4.40\times10^{-4}) = (0.910)(8.314)T \;\rightarrow\; T = 366.4\,K$. Finally, the work done by the process is: $W = nRT\left(\ell n\left(\frac{V_2}{V_1}\right)\right) = (0.910)(8.314)(366.4)\left(\ell n\left(\frac{5.54\times10^{-4}}{4.40\times10^{-4}}\right)\right) = 639 \approx 640\,J$.

P12. (A) We begin with Ohm's Law to find the resistance of the wire: $V = IR \;\rightarrow\; 60.0 = (1.55)R \;\rightarrow$ $R = 38.7\Omega$. This resistance relates to the resistivity by the equation $R = \frac{\rho L}{A}$. Here, *L* is the length of the wire, and *A* is the cross-sectional area of the wire.
The radius of the wire is $r = \frac{d}{2} = \frac{1.24mm}{2} = 0.62mm = 6.20\times10^{-4}m$, which gives a cross-sectional area of $A = \pi r^2 = \pi(6.20\times10^{-4})^2 = 1.21\times10^{-6}\,m^2$. Putting it all together, we find the resistivity:
$R = \frac{\rho L}{A} \;\rightarrow\; 38.7\Omega = \frac{\rho(2600.0m)}{1.21\times10^{-6}m^2} \;\rightarrow\; \rho = 1.80\times10^{-8}\Omega m.$

P13. (C) First, we must find the magnitude of the electric field between the plates: $E = \frac{V}{d} = \frac{20.0V}{4.00cm} = 5.00\frac{V}{cm} = 500.0\frac{V}{m}$. Now, we calculate the magnitude of the electric force acting on the charge: $F = qE = (450 \times 10^{-9}C)\left(500.0\frac{V}{m}\right) = 2.25 \times 10^{-4}N$. From this, we determine the acceleration of the charge towards the negative plate. Noting that the mass needs to be in kilograms, and using Newton's Second Law, we get: $F = ma \;\rightarrow\; 2.25 \times 10^{-4}N = (2.70 \times 10^{-9}kg)a \;\rightarrow\; a = 8.33 \times 10^{4}\frac{m}{s^2}$. Finally, since we know the charge starts from rest and we know its distance from the negative plate, we use kinematics to find the speed of the charge when it reaches the plate: $v_f^2 = v_i^2 + 2a\Delta x \;\rightarrow\; v_f^2 = (0)^2 + 2\left(8.33 \times 10^{4}\frac{m}{s^2}\right)(0.03m) \;\rightarrow\; v_f^2 = 5000 \;\rightarrow\; v_f = 70.7\frac{m}{s}$.

P14. (E) First, we need the current flowing through the projectile; this can be found by using Ohm's Law: $V = IR \;\rightarrow\; 100.0V = I(0.630\Omega) \;\rightarrow\; I = 158.7A$. Now we determine the magnetic force acting on the projectile by using $F = I\ell B\sin\theta$. Here $\ell$ is the length of the projectile in which current flows, which equals the distance between the rails. Also, since the magnetic field is oriented perpendicular to the direction of the current, the angle $\theta$ is 90.0°, and $\sin\theta = \sin(90.0) = 1$. Thus, the force is $F = I\ell B = (158.7A)(0.25m)(4.60T) = 182.5N$. Noting that the mass needs to be in kilograms, and using Newton's Second Law, we get:$F = ma \;\rightarrow\; 182.5N = (0.0140kg)a \;\rightarrow\; a = 1.30 \times 10^{4}\frac{m}{s^2}$. Finally, since we know that the projectile starts from rest, and the distance it travels before launching from the rails, we use kinematics to find its final velocity: $v_f^2 = v_i^2 + 2a\Delta x \;\rightarrow$ $v_f^2 = (0)^2 + 2\left(1.30 \times 10^{4}\frac{m}{s^2}\right)(6.50m) \;\rightarrow\; v_f^2 = 1.70 \times 10^{5} \;\rightarrow\; v_f = 412\frac{m}{s}$.

P15. (E) The magnitude of the radiation pressure on an object depends on the reflectivity of the object. Since the disk is perfectly reflective, the magnitude of the radiation pressure is maximized, and is given by the equation $P = \frac{2I}{c}$. Here, $I$ is the intensity of the light shining on the disk, which equals the laser power divided by the area of the laser spot. The force acting on the disk can be found from the pressure. The pressure is force divided by area, which in this case is also the area of the laser spot. Putting this together will simplify the mathematics by letting us cancel the area: $P = \frac{F}{A} = \frac{2}{c}I = \frac{2}{c}\frac{Power}{A}$. This gives $F = \frac{2}{c}(Power) = \frac{2}{3.00 \times 10^{8}}(450.0) = 3.00 \times 10^{-6}$ N. The diameters of the disk and spot don't really matter as long as the spot fits entirely on the disk – which it does in this situation. Now, we use Newton's second law to find the acceleration: $F = ma \;\rightarrow\; 3.00 \times 10^{-6} = (24 \times 10^{-3})a \;\rightarrow\; a = 1.25 \times 10^{-4}$ m/s$^2$. We also need to convert the time to seconds: $t = 3.00days * \frac{24\ hrs}{1\ day} * \frac{60\ min}{1\ hr} * \frac{60\ sec}{1\ min} = 259200\ sec$. Finally, we determine the final velocity using kinematics: $v = v_0 + at = 0 + (1.25 \times 10^{-4})(259200) = 32.4$ m/s.

P16. (B) In a compound lens system, we treat each lens separately, with the image from the first lens becoming the object for the second lens. We use $\frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{f_1}$ to find the first image location. Plugging in the given values gives $\frac{1}{4.50} + \frac{1}{q_1} = \frac{1}{10} \;\rightarrow\; q_1 = -8.18cm$. Since it is negative, we know that this is a virtual image. The first magnification is $M_1 = -\frac{q_1}{p_1} = -\frac{-8.18}{4.50} = 1.82$. At this point, we switch to the second lens. The image from the first lens becomes the object for the second lens: $p_2 = D - q_1 = 30 — 8.18 = 38.18cm$. Now, we use the lens equations again, this time for the second lens. The second image location is found using $\frac{1}{p_2} + \frac{1}{q_2} = \frac{1}{f_2} \;\rightarrow\; \frac{1}{38.18} + \frac{1}{q_2} = \frac{1}{25.0} \;\rightarrow$ $q_2 = 72.42cm$. The second magnification is $M_2 = -\frac{q_2}{p_2} = -\frac{72.42}{38.18} = -1.90$. Finally, the total magnification of the double lens system is given by $M = M_1M_2 = (1.82)(-1.90) = -3.45$. Thus, the object is magnified by a factor of 3.45 (and the image is inverted).

P17. (A) Relativistic length contraction is described by the equation $L' = \frac{L_0}{\gamma}$ where $\gamma$ is the Lorentz factor given by $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$, and $L_0$ is the uncontracted length of the pole. Plugging in the velocity with which you threw the bamboo pole, we obtain a Lorentz factor of $\gamma = \frac{1}{\sqrt{1-\frac{(0.92c)^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{0.8464c^2}{c^2}}} = \frac{1}{\sqrt{1-0.8464}} = \frac{1}{\sqrt{0.1536}} = 2.552.$ Thus, in your (stationary) frame of reference, the bamboo pole measures to have a length of $L' = \frac{2.00}{2.552} = 0.784\text{m}$.

P18. (C) First, because the decay products include a proton, we know that particle X is a baryon. That means that it will consist of three quarks. This eliminates choices D and E. Second, the total charge of the decay products is $Q = +1 - 1 + 1 = +1$. By conservation of charge, the original particle must also have a $+1$ charge. Choice B has a charge of +2, so it cannot be the correct answer. Finally, the decay is too slow to rely exclusively on the Strong force (Strong force decays have lifetimes around $10^{-24}$seconds). The decay products do not include photons, so we can also exclude a purely Electromagnetic decay. This means that the decay involves the Weak force, which means that there is at least one quark flavor change. The decay products include up and down quarks and one strange quark (the negative Kaon is composed of a strange quark and an up anti-quark). This suggests that the original particle must include either two strange quarks, or a higher flavor (c, b, t) quark. Choice A is insufficient to decay into those products. Thus, the logical choice is C: the X particle must be composed of an up quark, a down quark, and a charm quark. This satisfies all three conditions: it is composed of three quarks, has a charge of +1, and involves a Weak force flavor change ($c \rightarrow s$) to produce the decay products shown.

P19. (A) There is more than one way to solve this problem, but I choose to use work and energy. Three forces act on the box: gravity ($mg$, directed downward), the normal force ($F_N$, directed upward), and friction ($F_f$, directed horizontally, opposite to the motion of the box). There is no motion in the vertical, so we conclude that the vertical forces balance: $F_N = mg$. Friction is the only horizontal force, so the work done on the horizontal motion of the box equals the force of friction multiplied by the distance traveled: $W = F_f d$. Recalling the relationship between the normal force and friction, we get: $W = F_f d = \mu F_N d = \mu mgd$. Now we turn to conservation of energy. The box has an initial velocity, so it has an initial kinetic energy: $KE_i = \frac{1}{2}mv_i^2$. Once the box slides to a stop, all of that kinetic energy has been converted to heat by friction. By conservation of energy: $KE_i - W = 0 \rightarrow \frac{1}{2}mv_i^2 - \mu mgd = 0 \rightarrow \frac{1}{2}v_i^2 = \mu gd$. Notice that the mass cancels out – the mass of the box does not matter in this experiment. The plot does not trace out a straight line, so we will use a point on the curve to complete our calculations. I'll use the point (6.0m/s, 10.0m). Plugging in our numbers gives $\frac{1}{2}(6.0)^2 = \mu(9.80)(10.0) \rightarrow 18 = 98.0\mu \rightarrow \mu = 0.18$ is the coefficient of friction.

P20. (C) For this experiment, the relevant equation is $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$. Rearranging terms to match the plot, we get $\left(\frac{1}{q}\right) = \frac{1}{f} - \left(\frac{1}{p}\right)$. From this we can see that the line should have a slope of $-1$, which it does. We can also see that the y-intercept is equal to $\frac{1}{f}$. From the plot, the y-intercept is approximately 1.8m$^{-1}$. This gives a focal length of $f = \frac{1}{1.8} = 0.556\text{m}$. Now, the radius of curvature of the mirror can be found by using $f = \frac{R}{2} \rightarrow 0.556 = \frac{R}{2} \rightarrow R = 1.11m = 111cm \approx 110cm.$