THE PHYSICS TUTOR

SAMPLE TEST

Science

IMPORTANT INFORMATION:

- DO NOT OPEN EXAM UNTIL TOLD TO DO SO.
- Contestants may take up to two hours to complete the contest.
- 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. Each contestant may use up to two approved calculators during the contest.

Name:

Date:

Grade: 9 10 11 12

Final Score

B01. All of the following are examples of transport proteins except:
A) Channel
B) Pepsin
C) Calcium ATPase
D) Na^+/K^+ Pumps
E) All of the above are correct.

B02. The DTaP vaccine helps build immunity to which of the following diseases?
A) Dengue
B) Taeniasis
C) Whooping Cough
D) Hepatitis A
E) Paronychia

B03. Gel electrophoresis is a molecular biology technique used to
A) create millions of copies of molecular material.
B) separate mixtures of proteins, RNA, or DNA according to its molecular size.
C) verify analyzed molecular material is from humans rather than bacteria.
D) break apart the nucleus and release molecular material into solution.
E) None of the above.

B04. In a sample DNA strand, it consists of 19% guanine. What percentage of the nucleotides is adenine?
A) 19%
B) 38%
C) 62%
D) 50%
E) 31%

B05. The esophagus, small intestine, and anus are all organs part of which organ system?
A) Circulatory
B) Lymphatic
C) Muscle
D) Digestive
E) Respiratory

B06. The alleles in a population exist where blue petals (B) are dominant over white petals and dark green stems (G) are dominant over light green stems. After the following genetic cross, what percentage of the population will have white petals with a dark green stem?

BbGg x bbGG

A) 25%
B) 50%
C) 75%
D) 100%
E) None of the above.

B07. Which of the following is not a polymer?
A) glucose
B) starch
C) cellulose
D) chitin
E) DNA

B08. Lactose is a sugar in milk composed of one glucose molecule joined by glycosidic linkage to one galactose molecule. How is lactose classified?
A) a pentose
B) a hexose
C) a monosaccharide
D) a disaccharide
E) a polysaccharide

B09. Which bonds are created during the formation of the primary structure of a protein?
A) peptide bonds
B) hydrogen bonds
C) disulfide bonds
D) phosphodiester bonds
E) peptide bonds, hydrogen bonds, and disulfide bonds

B10. The fatty acid tails of a phospholipid are _____ because they _____ .
A) hydrophilic; are easily hydrolyzed into their monomers
B) hydrophilic; consist of units assembled by dehydration reactions
C) hydrophobic; dissolve easily in water
D) hydrophobic; have no charges to which water molecules will adhere
E) hydrophobic; consist of units assembled by dehydration

B11. When chemical, transport, or mechanical work is done by an organism, what happens to the heat generated?
A) It is used to power more cellular work.
B) It is lost to the environment.
C) It is used to generate ADP from nucleotide precursors.
D) It is to store energy as more ATP.
E) It is transported to specific organs such as the brain.

B12. Which of the following is most similar in structure to ATP?
A) a pentose sugar
B) a DNA nucleotide
C) an RNA nucleotide
D) an amino acid with three phosphate groups attached
E) a phospholipid

B13. All of the following are part of a prokaryotic cell except
A) DNA.
B) a cell wall.
C) a plasma membrane.
D) ribosomes.
E) an endoplasmic reticulum.

B14. There are 678 organisms in a population at Hardy-Weinberg equilibrium. In this population, the frequency of the recessive allele is 0.34. How many organisms express the dominant phenotype?
A) 78
B) 304
C) 600
D) 447
E) 231

B15. Which organelle often takes up much of the volume of a plant cell?
A) lysosome
B) vacuole
C) mitochondrion
D) Golgi apparatus
E) peroxisome

B16. Which of the following molecules is most likely to passively diffuse across the plasma membrane?
A) CO_2
B) hemoglobin
C) glucose
D) Na^+
E) DNA

B17. Where do the reactions of the citric acid cycle occur in eukaryotic cells?
A) the cytosol
B) the intermembrane space of the mitochondrion
C) the matrix of the mitochondrion
D) the cristae of the mitochondrion
E) Across the inner membrane of the mitochondria

B18. The source of oxygen produced during photosynthesis comes from
A) Water
B) Glucose
C) CO_2
D) Pyruvate
E) O_3

B19. In what phase of mitosis are centrioles beginning to move apart in animal cells?
A) telophase
B) prophase
C) prometaphase
D) metaphase
E) anaphase

B20. An organism with a cell wall would most likely be unable to take in materials through

A) diffusion
B) osmosis
C) active transport
D) phagocytosis
E) facilitated diffusion

C01. If a young scientist has a sample of Zinc which has a mass of 448 grams, how many Zinc atoms are within the sample?

A) 8.79×10^{22} atoms
B) 4.13×10^{23} atoms
C) 1.13×10^{23} atoms
D) 1.76×10^{28} atoms
E) 4.13×10^{24} atoms

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

$$A_2 + BC \rightarrow AC + B_2$$

A) 2
B) 3
C) 4
D) 5
E) 6

C03. What is the molecular shape of a boron trichloride (BCl_3) molecule?

A) Trigonal planar
B) Trigonal bipyramidal
C) See-saw
D) Square planar
E) Tetrahedral

C04. If 325 grams of methane (CH_4) undergoes a combustion reaction, how many grams of water vapor are produced?

A) 366 g
B) 183 g
C) 578 g
D) 836 g
E) 731 g

C05. A sample of oxygen gas at STP has a mass of 24.2 grams. What would be the volume of the gas if in a flexible walled container?

A) 37.0 L
B) 33.9 L
C) 16.9 L
D) 18.5 L
E) 22.4 L

C06. Which of the following postulates of Dalton's Atomic Theory have been disproven and shown to be false in some cases?

I. All matter consists of atoms; indivisible particles of an element.
II. Atoms of the same element are identical in all properties.
III. Atoms of different elements have different sizes, masses, and other properties.
IV. Atoms cannot be created or destroyed.
V. Atoms of different elements combine in fixed whole-number ratios.

A) I and II only
B) I and III only
C) I, II, and III only
D) I, II, III, and IV
E) I, II, III, and V
F) All of the postulates have been disproven

C07. What is the formal charge on the sulfur atom in a molecule of sulfur tetrachloride?

A) −2
B) −1
C) 0
D) +1
E) +2

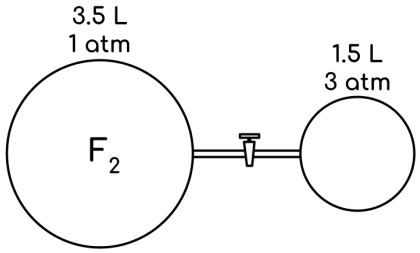
C08. What is the ground state electron configuration for an atom of Ne?

A) $1s^2\ 2s^2\ 3p^6$
B) $1s^2\ 2s^2\ 2p^6$
C) $1s^2\ 2s^2\ 3d^{10}\ 2p^6$
D) $1s^2\ 2s^2\ 3d^{10}\ 3p^6$
E) $[He]\ 2s^2\ 3p^6$

C09. Which of the following correctly describes the flow of electrons in a redox reaction?

A) Cations carry electrons through the salt bridge to the anode
B) Anions carry electrons through the salt bridge to the cathode
C) Through the solution from electrode to electrode
D) From the anode to the cathode
E) More than one answer choice is correct.

C10. A bulb system is set up as shown below. The bigger bulb contains fluorine gas, the smaller bulb is empty, and they are both held at a constant temperature of 20 °C. What is the total pressure of the system after the valve is opened? Assume the tube does not contribute to the volume of the system.



A) 0.9 atm
B) 3.6 atm
C) 0.7 atm
D) 4.0 atm
E) 1.6 atm

C11. What is the pH of a 0.75 M solution of HI?

A) 0.12
B) 5.67
C) 7.00
D) 9.85
E) 13.88

C12. How much energy is required to heat five 12 gram blocks of ice at 0 °C to liquid water at 16 °C?

A) 4.02 kJ
B) 4.81 kJ
C) 16.0 kJ
D) 20.0 kJ
E) 24.1 kJ

C13. Which of the following elements would be expected to have the largest 3rd ionization energy?

A) Na
B) Ca
C) Sr
D) F
E) Cl

C14. Which of the following expressions correctly solves for the K_{sp} of Ag_3PO_4?

A) $K_{sp} = 4x^3$
B) $K_{sp} = 12x^3$
C) $K_{sp} = 27x^4$
D) $K_{sp} = 81x^4$
E) $K_{sp} = 108x^4$

C15. How many mL of water must be added to 200 mL of a 0.985 M solution of NaCl in order to dilute the solution to 0.500 M?

A) 194 mL
B) 200 mL
C) 394 mL
D) 102 mL
E) 594 mL

C16. A student in a lab decides to titrate $HC_2H_3O_2$ using 1.0 M NaOH. Which of the following best predicts the pH of this titration at the equivalence point?

A) pH = 0
B) pH < 7
C) pH = 7
D) pH > 7
E) pH = 14

C17. What would be the K_c of the following balanced gas-phase reaction if the K_p was found to be 0.685 at 30 °C?

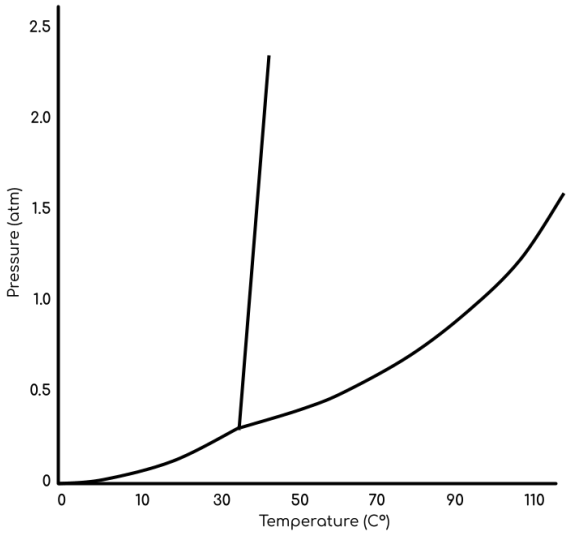
$$3N_2(g) + 6H_2O(g) \rightarrow 4NH_3(g) + 2O_2(g)$$

A) 6.85×10^{-1}
B) 1.05×10^{4}
C) 4.46×10^{-5}
D) 1.46×10^{0}
E) 1.10×10^{10}

C18. Which of the following compounds, when dissolved in water, would have the least effect on changing the freezing point of the water if they are all equal in moles?

A) NaCl
B) $FeCl_2$
C) $NaNO_3$
D) $FeCl_3$
E) $C_6H_{12}O_6$

C19. A compound is found to have a phase diagram as shown below. Based on the diagram, what is the compound's normal boiling point?



A) 12 °C
B) 37 °C
C) 69 °C
D) 97 °C
E) 117 °C

C20. Which of the following sets of quantum numbers is valid?

A) $n = 3 \;\; l = 3 \;\; m_l = -3 \;\; m_s = + ½$
B) $n = 1 \;\; l = 0 \;\; m_l = 1 \;\; m_s = - ½$
C) $n = 3 \;\; l = 1 \;\; m_l = 0 \;\; m_s = + ½$
D) $n = 2 \;\; l = 0 \;\; m_l = -1 \;\; m_s = - ½$
E) $n = 4 \;\; l = 3 \;\; m_l = 4 \;\; m_s = + ½$

P01. *This is a placeholder question reserved for a question from the selected reading for the current school year. On all tests, these questions will be pulled from the selected reading in increasing difficulty for each test.*

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

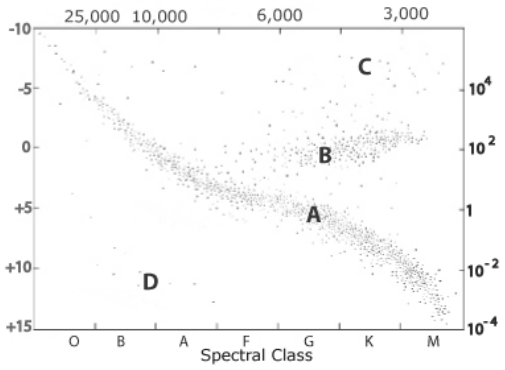
P02. *This is a placeholder question reserved for a question from the selected reading for the current school year. On all tests, these questions will be pulled from the selected reading in increasing difficulty for each test.*

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

P03. *This is a placeholder question reserved for a question from the selected reading for the current school year. On all tests, these questions will be pulled from the selected reading in increasing difficulty for each test.*

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

P04. Which of the following locations would you expect to find a star similar in temperature and luminosity to the sun?



P05. Which International System of Units (SI) measures the luminous intensity of a light wave?

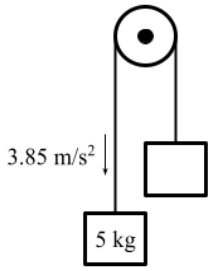
A) Ampere
B) Candela
C) Watt
D) Lumen
E) LUX

P06. A boy stands at the top of a 20.0 meter tall building and throws a ball horizontally at a speed of 13.0 m/s. How far from the base of the building does the ball land?

A) 48.7 m
B) 23.7 m
C) 14.2 m
D) 58.2 m
E) 26.3 m

P07. A simple pulley system is set up as shown. If the mass on the left accelerates downward at a rate of 3.85 m/s^2, what is the mass of the block on the right? Assume the pulley is massless and frictionless.

A) 1.6 kg
B) 2.2 kg
C) 3.8 kg
D) 5.0 kg
E) 11.5 kg

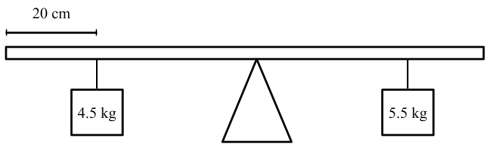


P08. A 17.0 kilogram child sits at rest on top of a 3.5 meter tall frictionless slide. If the child sets off down the slide, what will be their speed when they reach the bottom?

A) 4.1 m/s
B) 5.9 m/s
C) 6.8 m/s
D) 8.3 m/s
E) 11.2 m/s

P09. A meter stick is set up with a 4.5 kilogram mass located at the 20.0 cm mark. If the fulcrum of the system is placed at the 55.0 cm mark, at what mark on the stick should a 5.5 kilogram mass be placed in order to balance the system?

A) 16 cm
B) 29 cm
C) 49 cm
D) 71 cm
E) 84 cm



P10. A 25.0 cm long string under a tension of 15 N has a mass per length ratio of 3.0 g/m. If the string is plucked, what is the frequency of sound heard at 20 °C?

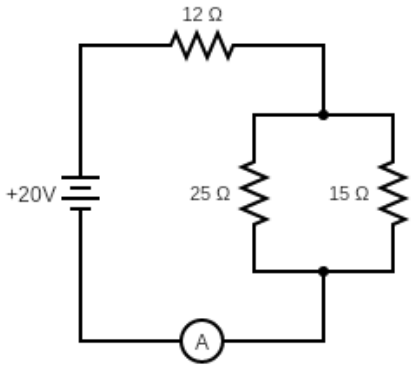
A) 70.7 Hz
B) 85.6 Hz
C) 141 Hz
D) 172 Hz
E) 283 Hz

P11. A diatomic gas is adiabatically compressed from 1.0 atm to 4.0 atm. If the gas is in a flexible walled container with an initial volume of 3.0 L, what is the final volume of the gas? For a diatomic gas $\gamma = 1.4$.

A) 1.1 L
B) 1.8 L
C) 0.43 L
D) 0.58 L
E) 0.75 L

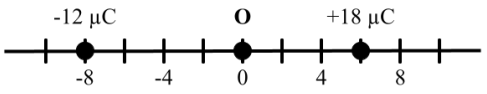
P12. For the circuit shown below, what is the current measured in the ammeter?

A) 260 mA
B) 380 mA
C) 460 mA
D) 940 mA
E) 2200 mA



P13. If a negative 12.0 μC charge is placed at x = -8.0 cm, and a positive 18.0 μC charge is placed at x = 6.0 cm, what is the electric potential measured at point **O**, the origin?

A) -1,350 kV
B) 1,350 kV
C) -4,050 kV
D) 4,050 kV
E) -5,400 kV



P14. A 20.0 cm long solenoid sits in a magnetic field of 600 μT perpendicular to the solenoid. If the solenoid has 30 loops, carries a current of 60.0 A, and has an inner radius of 50.0 mm, what is the torque on the coil?

A) 1.1×10^{-6} Nm
B) 2.0×10^{-3} Nm
C) 8.5×10^{-3} Nm
D) 3.4×10^{-2} Nm
E) 4.2×10^{-2} Nm

P15. If light with an intensity of 4.0×10^{3} W/m^2 moves through a polarizer at an angle of 38° above the horizontal, what is the intensity of the light after passing through the polarizer?

A) 2.5×10^{3} W/m^2
B) 3.2×10^{3} W/m^2
C) 1.5×10^{3} W/m^2
D) 6.4×10^{3} W/m^2
E) 5.1×10^{3} W/m^2

P16. A 2.0 cm tall figure is placed 12.0 cm in front of a diverging lens with a radius of curvature of 24.0 cm. What is the height of the figure after passing through the lens?

A) 1.0 cm
B) 1.3 cm
C) 1.7 cm
D) 3.2 cm
E) 4.0 cm

P17. A hydrogen atom undergoes a transition from the n = 3 state to the n = 1 state. What wavelength of light was produced by this transition?

A) 30 nm
B) 54 nm
C) 78 nm
D) 103 nm
E) 137 nm

P18. An Americium-223 atom undergoes the following chain of decays: alpha, beta, alpha, alpha, gamma, and alpha. What particle remains after this decay chain?

A) Francium-207
B) Radon-206
C) Radon-207
D) Radium-206
E) Radium-207

P19. A toy car travels along a flat stretch of ground and creates a dot plot every 2.0 seconds as shown below. Which of the statements most accurately describes what is happening to the car?

A) The car accelerates rapidly; then the car decelerates at a faster rate than which it accelerated.
B) The car accelerates rapidly; then the car decelerates at a slower rate than which it accelerated.
C) The car rapidly speeds up, slams on its brakes, then speeds off quickly.
D) The car decelerates nearly to a stop; then the car accelerates at a faster rate than which it decelerated.
E) The car decelerates nearly to a stop; then the car accelerates at a slower rate than which it decelerated.

P20. Which of the four fundamental forces is responsible for changing the down quark in a neutron to an up quark–changing the neutron into a proton?

A) Electromagnetic Force
B) Gravitational Force
C) Weak Nuclear
D) Strong Nuclear
E) Magnetic Force

CHEMISTRY USEFUL CONSTANTS

1A 1																	8A 18
1 H 1.01	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	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

Other Information

There is no extra information required to complete this test.

Constants

R = 0.08206 L·atm/mol·K

R = 8.314 J/mol·K

R = 62.36 L·torr/mol·K

e = 1.602×10^{-19} C

N_A = 6.022×10^{23} mol^{-1}

k = 1.38×10^{-23} J/K

h = 6.626×10^{-34} J·s

c = 3.00×10^{8} m/s

R_H = 2.178×10^{-18} J

m_e = 9.11×10^{-31} kg

$\mathcal{F}$ = 96,485 C/mol e^-

1 amp = 1 C/sec

1 mol e^- = 96,485

PHYSICS USEFUL CONSTANTS

QUANTITY	SYMBOL	VALUE
Free-fall acceleration	g	9.80 m/s^2
Permittivity of Free Space	ε_0	$8.854 \times 10^{-12}\ C^2/Nm^2$
Permeability of Free Space	μ_0	$4\pi \times 10^{-7}\ Tm/A$
Coulomb constant	k	$8.99 \times 10^{9}\ Nm^2/C^2$
Speed of Light (in a vacuum)	c	$3.00 \times 10^{8}\ m/s$
Fundamental Charge	e	$1.602 \times 10^{-19}\ C$
Planck's constant	h	$6.626 \times 10^{-34}\ Js$
Electron mass	m_e	$9.11 \times 10^{-31}\ kg$
Proton mass	m_p	$1.67265 \times 10^{-27}\ kg$ $1.007276\ amu$
Neutron mass	m_n	$1.67495 \times 10^{-27}\ kg$ $1.008665\ amu$
Atomic Mass Unit	amu	$1.66 \times 10^{-27}\ kg$ $931.5\ MeV/c^2$
Gravitational constant	G	$6.67 \times 10^{-11}\ Nm^2/kg^2$
Stefan-Boltzman constant	σ	$5.67 \times 10^{-8}\ W/m^2K^4$
Universal gas constant	R	$8.314\ J/mol \cdot K$ $0.082057\ L \cdot atm/mol \cdot K$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\ J/K$
Speed of Sound (at 20 °C)	v	$343\ m/s$
Avogadro's number	N_A	$6.022 \times 10^{23}\ atoms/mol$
Electron Volts	eV	$1.602 \times 10^{-19}\ J/eV$
Distance conversion	miles → meters	1.00 mile = 1609 meters
Rydberg constant	R_∞	$1.097 \times 10^{7}\ m^{-1}$
Standard Atmospheric Pressure	1 atm	$1.013 \times 10^{5}\ Pa$
Density of Pure Water	ϱ_{water}	$1000.0\ kg/m^3$

THE PHYSICS TUTOR SCIENCE CONTEST

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

THE PHYSICS TUTOR SCIENCE CONTEST
CHEMISTRY

C01. (E) This is a simple stoichiometric relationship. We need to get from grams of Zinc to atoms of Zinc using the railroad track method: $448\ g\ Zn \times \left|\frac{1\ mol\ Zn}{65.38\ g\ Zn}\right| \times \left|\frac{6.022\times10^{23}\ atoms\ Zn}{1\ mol\ Zn}\right|$ = 4.13 x 10^{24} atoms Zn.

C02. (B) When the reaction is balanced you get $1A_2 + 2BC \rightarrow 2AC + 1B_2$. The products of the reaction are what is produced to the right of the arrow, so the sum of the coefficients to the right of the arrow is 3.

C03. (A) Since boron only has 3 valence electrons, each electron will pair with a chlorine leaving no unbonded electrons on the boron atom. No lone pairs and 3 bonds give a molecular shape of trigonal planar.

C04. (E) The balanced combustion reaction for methane is $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$. To stoichiometrically find the grams of water vapor, we do railroad tracks to cancel out units to leave us with grams of the water vapor.
$325\ g\ CH_4 \times \left|\frac{1\ mol\ CH_4}{16\ g\ CH_4}\right| \times \left|\frac{2\ mol\ H_2O}{1\ mol\ CH_4}\right| \times \left|\frac{18\ g\ H_2O}{1\ mol\ H_2O}\right| = 731\ g\ H_2O.$

C05. (C) This is a simple gas law problem in which PV = nRT. At STP, temperature is 273 K and pressure is 1 atm. We do not know the number of moles; however, we can find them by dividing the mass of oxygen by its molar mass. n = $24.2\ g\ O_2 \times \left|\frac{1\ mol\ O_2}{32.0\ g\ O_2}\right| = 0.756\ mol\ O_2$. Now we can plug all of our information into our equation and get (1)V = (0.756)(0.08206)(273). We rearrange and solve for V and get V = $\frac{(0.756)(0.08206)(273)}{1}$ = 16.9 L.

C06. (E) Postulate I was disproved by the discovery of subatomic particles. Postulate II was disproved by the discovery of isotopes. Postulate III was disproved by the discovery that some isotopes of different elements are equal in mass known as isobars (i.e. Carbon-14 and Nitrogen-14). Postulate IV still holds true that atoms cannot be created or destroyed due to the Law of Conservation of Mass. Postulate V does not explain the formation of complex sugars such as $C_{12}H_{22}O_{11}$. It also does not account for allotropes of the same element.

C07. (C) Formal charge can be found using the equation Formal Charge = #VE - #NB - #B. VE is the number of valence electrons, NB is the number of nonbonding electrons, and B is the number of bonds around the atom. For sulfur tetrachloride, the sulfur atom has 6 valence electrons, 2 nonbonding electrons, and 4 bonds attached to the sulfur. So, FC = 6 - 2 - 4 = 0.

C08. (B) The electrons occupy the entire first row ($1s^2$) and the entire second row ($2s^2$ & $2p^6$). Thus, the electron configuration of neon is $1s^2\ 2s^2\ 2p^6$.

C09. (D) In a redox reaction, the electrons flow from the anode to the cathode.

C10. (C) First, we find the total moles of the system using PV = nRT on the left bulb. When we do that we get (1)(3.5) = n(0.08206)(293). When we rearrange and solve for n, we get n = $\frac{(1)(3.5)}{(0.08206)(293)}$ = 0.146 mol F_2. Now, once the value is opened, the gas exists freely in the full volume of both bulbs V_{total} = 3.5 + 1.5 = 5 L. We can now do PV = nRT again, but this time for the full system. When we plug in our values, we get P(5) = (0.146)(0.08206)(293). We rearrange and solve for P, we get P = $\frac{(0.146)(0.08206)(293)}{(5)}$ = 0.7 atm.

C11. (A) Since HI is a strong acid, the pH is equal to the negative log of the H^+ concentration (pH = -log[H^+]). In this problem, since HI is a monoprotic acid, the concentration of the solution is also the concentration of the H^+. So, pH = -log[.750] = 0.13.

C12. (E) Starting out, there are 5 blocks of ice weighing 12 grams each. So, our total mass of ice would be 12(5) = 60 g ice @ 0 °C. To find the energy required to turn this into water, we take q = mΔH_{fus}. In this case, we are melting all 60 grams, so we get q = (60)(334) = 20,040 J required to melt the ice. Now we have 60 g water @ 0 °C. In order to find the energy required to heat the water up to 16 °C, we use the equation q = $mc_{water}\Delta T$. When we set this up we get q = (60)(4.184)(16 - 0) = 4,016.64 J of energy. To find the total energy we simply add these together and get q_{total} = 20,040 + 4,016.64 = 24,056.64 J = 24.1 kJ.

C13. (B) Calcium has the largest 3rd ionization energy because it only wants to lose 2 electrons to become stable. Removing a third electron makes it unstable, thus it would take a significant amount of energy to do so. Calcium has a larger ionization energy than Strontium because it is smaller and it is harder to remove electrons from a smaller atom because of nuclear attraction.

C14. (C) When we set up the K_{sp} reaction, we get $Ag_3PO_4(s) \leftrightharpoons 3Ag^+(aq) + PO_4(aq)$. Using a RICE table as shown to the right, we get our equilibrium expression as follows. $K_{sp} = [3x]^3[x] = 27x^4$.

	$Ag_3PO_4\ (s) \leftrightharpoons$	$3Ag^+(aq)$ +	$PO_4^{-3}(aq)$
R			
I	|	0	0
C	|	+3x	+x
E	|	3x	x

C15. (A) This is a simple dilution where $M_1V_1 = M_2V_2$. In this case M_1 = 0.985 M NaCl, V_1 = 200 mL, and M_2 = 0.500 M NaCl. When we set up our equation, we get (0.985)(200) = (0.500)V_2. When we rearrange and solve for V_2, we get V_2 = $\frac{(0.985)(200)}{(0.500)}$ = 394 mL. This is the total amount of water needed to create this solution, so the amount added would be 394 - 200 = 194 mL of water added.

C16. (D) With a weak acid ($HC_2H_3O_2$) strong base (NaOH) titration, the equivalence point exists at a pH greater than 7 because the number of moles of the strong base is greater than the number of moles of the weak acid.

C17. (B) The way we solve this is using the equation $K_p = K_c(RT)^{\Delta n}$. In this problem, the balanced chemical reaction is $3N_2(g) + 6H_2O(g) \rightarrow 4NH_3(g) + 2O_2(g)$. The sum of the coefficients of the products is 6 and the reactants is 9. Thus $\Delta n = 6 - 9 = -3$. We can plug in our known information to the equation and get $(0.685) = K_c[(0.08206)(303)]^{-3}$. We rearrange and solve for K_c and get $K_c = \frac{(0.685)}{[(0.08206)(303)]^{-3}} = 1.05 \times 10^4$.

C18. (E) Since all are equimolar, the greatest change to the freezing point would come from the compound that dissolved the most ions (largest Van't Hoff factor). Glucose has the smallest Van't Hoff factor since sugars dissolve as a whole molecule, thus their Van't Hoff factor is ~1, and so it will cause the least amount of change to the freezing point of the water.

C19. (D) Looking at the graph, moving from left to right , the regions on the graph move from solid to liquid to gas. Normal boiling point is the transition from liquid to gas at 1 atm (standard atmospheric pressure). If we start at 1 atm, move to the right until we reach the line separating liquid and gas, and then go straight down to the temperature axis, the normal boiling is approximately 97 °C.

C20. (C) Quantum numbers exist where n = #, $\ell = 0 \ldots n - 1$, $m_\ell = -\ell \ldots +\ell$, and $m_s = \pm ½$. The only answer choice that satisfies all of these rules is C where n = 3, ℓ falls in the range $0 \ldots n - 1$, and m_ℓ falls in the range $-\ell \ldots +\ell$.

THE PHYSICS TUTOR SCIENCE CONTEST
PHYSICS

P01. (#) [PAGE:] *Reserved for book questions. There will be a detailed explanation of the answer to the questions with corresponding citations directly from the book to ensure accuracy throughout the tests.*

P02. (#) [PAGE:] *Reserved for book questions. There will be a detailed explanation of the answer to the questions with corresponding citations directly from the book to ensure accuracy throughout the tests.*

P03. (#) [PAGE:] *Reserved for book questions. There will be a detailed explanation of the answer to the questions with corresponding citations directly from the book to ensure accuracy throughout the tests.*

P04. (A) The Sun is a main sequence star. A star with similar temperature and luminosity would also be considered a main sequence star.

P05. (B) In the International System of Units (SI), the unit used to measure the luminous intensity of a light wave is the Candela.

P06. (E) This problem is a standard projectile motion problem with no tricks. The ball's vertical displacement is modeled by the equation $d_y = ½(9.8)t^2 + v_{0y}t + h_0$. The ball is thrown horizontal, so there is no initial vertical velocity that must be accounted for. This simplifies the equation to $0 = -4.9t^2 + h_0$. When we substitute in given values, we get $0 = -4.9t^2 + 20.0$. Rearranging and solving for t yields $t = \sqrt{\frac{20.0}{4.9}} = 2.02$ seconds. Using the horizontal displacement equation $d_x = v_{0x}t$ we can solve where $d_x = (13.0)(2.02) = 26.3$ m.

P07. (B) Newton's second law says that $\Sigma F = ma$. In this problem, the block on the left (m_1) is experiencing the downward (-) force of gravity and the upward (+) force of tension. This can be modeled by the equation $m_1a = T - m_1g$. When we substitute in given values noting that acceleration is in the negative y direction, we get $(5)(-3.85) = T - (5)(9.8)$. Rearranging and solving for T yields $T = (5)(-3.85) + (5)(9.8) = 29.8$ N. For the block on the right (m_2), $m_2a = m_2g - T$. Note that tension is negative and the gravitational force is positive because we have to have consistency in the signs of up and down throughout the whole system. When we substitute known values, we get $(-3.85)m_2 = (9.8)m_2 - 29.8$. When we simplify and solve for m_2, we get $m_2 = \frac{29.8}{13.7} = 2.2$ kg.

P08. (D) This problem is a simple conservation of energy problem. Initially, all of the energy is in the form of gravitational potential modeled by the equation $E_p = mgh$. At the end, all of the energy has been transformed into kinetic energy modeled by the equation $E_k = ½mv^2$. Since there is no friction, there is no energy lost to heat so all the potential energy has to equal the kinetic. This means $E_p = E_k = mgh = ½mv^2$. Subbing in known values and solving for velocity yields $v = \sqrt{2(9.8)(3.5)} = 8.3$ m/s.

P09. (E) In order for the stick to balance, the torque generated by both boxes has to sum to zero. We know that $\tau = F\sin\Theta r$. For the block on the left, the distance from the fulcrum (r_1) is 55 - 20 = 35 cm = 0.35 m. Since the torques must equal, we can set up the equation $F\sin\Theta r_1 = F\sin\Theta r_2$. The force generated for both blocks is gravitational force $F = mg$.

Subbing this in, we get $m_1 g \sin\Theta r_1 = m_2 g \sin\Theta r_2$. Knowing $\Theta = 90$, we can substitute in all known values and solve for r_2. We get $r_2 = \frac{(4.5)(0.35)}{5.5} = 0.29$ m = 29 cm. This is the distance from the fulcrum to the point in which the block needs to be hung, so to find the marking on the meter stick, we add the marking that the fulcrum is placed at to the distance from the fulcrum needed. We get 55 + 29 = 84 cm.

P10. (C) The tension on a string is modeled by the equation $T = \mu v^2$ where μ is the mass per unit length density of the string (kg/m). Since there are no nodes given in the problem, this is the fundamental frequency in which $\lambda = 2L = 2(0.25) = 0.50$. When we substitute our known values into the equation, we get $15 = (0.003)v^2$. When we solve for v, we get $v = \sqrt{\frac{15}{0.003}} = 70.7$ m/s. We know that $v = \lambda f$, we rearrange and solve for frequency and get $f = \frac{70.7}{0.50} = 141$ Hz.

P11. (A) For adiabatic processes, no heat is transferred in or out of the system. This process is modeled by the equation $PV^\gamma = PV^\gamma$. When we substitute in the known values, we get $(1)(3)^{1.4} = (4)V^{1.4}$. We rearrange and solve for V and get $V = \sqrt[1.4]{\frac{(1)(3)^{1.4}}{4}} = 1.1$ L.

P12. (D) For a standard DC circuit, $V = IR_T$. To solve for the total resistance (R_T), we have to add up the resistance of all of the resistors in the circuit. For the resistors in parallel to each other $\frac{1}{R_{||}} = \frac{1}{R_1} + \frac{1}{R_2}$. When we substitute in the known values, we get $\frac{1}{R_{||}} = \frac{1}{25} + \frac{1}{15}$ where $R_{||} = 9.375\ \Omega$. In order to get the total resistance, we add the resistors in series together $R_T = R_{||} + R = 9.375 + 12 = 21.375\ \Omega$. The current measured in the ammeter is simply the current that the battery produces, so $I = \frac{V}{R_T} = \frac{20}{21.375} = 0.940$ A = 940 mA.

P13. (B) Electric potential is modeled by the equation $V = \frac{kq}{r}$. Since electric potential is a scalar quantity, we do not have to worry about vectors and directions, only signs. For the charge on the left (q_1), we get the equation $V_1 = \frac{(8.99\times10^9)(-12\times10^{-6})}{0.08} = -1{,}348{,}500$. For the charge on the right (q_2), we get the equation $V_2 = \frac{(8.99\times10^9)(18\times10^{-6})}{0.06} = 2{,}697{,}000$. To get the total electric potential we add the different voltages together: $V_T = V_1 + V_2 = -1{,}348{,}500 + 2{,}697{,}000 = 1{,}348{,}500$ V = 1,350 kV.

P14. (C) The torque on a solenoid is modeled by the equation $\tau = NIAB\sin\Theta$ where N is the number of loops, I is the current, A is the area of one coil, B is the magnitude of the magnetic field, and Θ is the angle the magnetic field makes with the solenoid. In order to get A, we solve using the radius and get $A = \pi(0.05)^2 = 7.85 \times 10^{-3}$ m^2. Plugging in our known values, we get $\tau = (30)(60)(7.85 \times 10^{-3})(600 \times 10^{-6})\sin(90) = 8.5 \times 10^{-3}$ Nm.

P15. (A) The equation for a polarizer is $I_f = I_i\cos^2\Theta$ where I_f is the intensity after passing through the polarizer, I_i is the initial intensity of the light, and Θ which is the angle the polarizer makes with the horizontal. When we substitute in our known values, we get $I_f = (4.0 \times 10^3)\cos^2(38) = 2.5 \times 10^3$ W/m^2.

P16. (A) For a thin lens, the equation used it $\frac{1}{f} = \frac{1}{do} + \frac{1}{di}$. For a diverging lens, the focal length is negative and half of the radius of curvature so $f = -\frac{24}{2}$ = -12 cm. Substituting on our known values into the equation we get $\frac{1}{-12} = \frac{1}{12} + \frac{1}{di}$. When we range and solve we get that d_i = -6.0 cm. Magnification of a lens is modeled by the equation $m = -\frac{di}{do} = -\frac{-6}{12}$ = 0.5. In order to find the height of the image, we multiply the magnification times the original height and get $h_i = mh_o$ = (0.5)(2) = 1.0 cm.

P17. (D) This transition can be solved using the Rydberg equation $\frac{1}{\lambda} = R(\frac{1}{n_2^2} - \frac{1}{n_1^2})$ where n_2 is the final energy level, n_2 is the initial energy level, and R is the Rydberg constant. When we substitute in the known values, we get $\frac{1}{\lambda} = (1.097 \times 10^7)(\frac{1}{1} - \frac{1}{3^2})$ = 9.75 x 10^6. To find wavelength, we inverse this value and get $(\frac{1}{\lambda})^{-1}$ = $(9.75 \times 10^6)^{-1}$ = 1.03 x 10^{-7} m = 103 nm.

P18. (E) The decay that the Americium undergoes is as follows:

$$^{223}_{95}Am \rightarrow {}^{4}_{2}He + {}^{0}_{-1}e + {}^{4}_{2}He + {}^{4}_{2}He + {}^{0}_{0}\gamma + {}^{4}_{2}He + X$$

In this case, the leftover particle (X) has to preserve both mass and atomic number. Due to the decay particles, 16 amu's were taken from the atoms mass, and the atomic number decreased by 7. This means the atomic number of the left over particle would have an atomic number of 95 - 7 = 88. The atom with this atomic number is Radium. Since 16 amu's were taken from the mass, this means the new mass would be 223 - 16 = 207. Thus the answer is Radium-207.

P19. (D) When dots in the dot plot appear closer together, that means the car is moving at a slower rate. For this dot plot, we can see the dots getting closer together, indicating deceleration to a near stop. We can see after a brief pause, the dots get further apart, indicating acceleration. Since the dots after the pause are further apart than the dots before the pause, the car moves away at a faster rate than when it slowed down.

P20. (C) The weak force is the fundamental force that is responsible for the interaction between subatomic particles. Due to its nature, it has the ability to change one quark into another quark which, in this case, is responsible for a neutron changing into a proton.