UNIVERSITY INTERSCHOLASTIC LEAGUE

Science

Invitational B • 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. In the Fluid Mosaic Model of biological membranes, which of the following is not correct?
A) The two leaflets of the membrane are symmetrical in both structure and function.
B) Phospholipids can move laterally and flip across to the other leaflet.
C) Glycoproteins are more likely to be embedded within the outer leaflet of the membrane.
D) Enzymes assist in the movement of phospholipids.
E) Phospholipids can congregate and distort the membrane structure.

B02. Glands, such as the thyroid and adrenal glands, secrete chemical messengers that regulate bodily functions. Which bodily system is this?
A) integumentary
B) nervous
C) cardiovascular
D) skeletal
E) endocrine

B03. In terms of numbers, the *majority* of biochemical reactions in the cell use enzymes made of
A) carbohydrates.
B) RNA.
C) DNA.
D) proteins.
E) lipids.

B04. Blood, bone, and alveolar are _______ tissues.
A) epithelial
B) integumentary
C) muscle
D) connective
E) nervous

B05. Which of the following statements about DNA replication is incorrect?
A) DNA replication occurs prior to cell division.
B) The replication of DNA produces RNA transcripts.
C) DNA polymerases replicate DNA.
D) Replication is bidirectional.
E) DNA replication occurs within the nucleus of eukaryotic cells and the nucleoid region of prokaryotic cells.

B06. A biome that is dominated by heavy rainfall, hot temperatures (near the equator), and dense vegetation is
A) temperate deciduous forest.
B) taiga.
C) tundra.
D) desert.
E) tropical rainforest.

B07. Malaria-infected *Anopheles* inject _______ into humans during feeding.
A) gametocytes
B) oocysts
C) ookinete
D) zygotes
E) sporozoites

B08. Birds are most closely related to
A) crocodilians.
B) fish.
C) mammals.
D) salamanders.
E) snails.

B09. Consider the following genetic cross. What percent of the progeny will be heterozygous?

Aa x AA

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

B10. Tapeworms, flukes, and roundworms are examples of
A) endoparasites.
B) ectoparasites.
C) commensals.
D) mutualists.
E) biological vectors.

B11. In oxygenic photosynthesis, ________ is the electron donor.
A) oxygen
B) elemental sulfur
C) water
D) hydrogen sulfide
E) carbon dioxide

B12. Which of the following mutations in DNA of a coding sequence would not result in an altered protein sequence?
A) missense
B) silent
C) frameshift
D) nonsense
E) All of the above result in altered protein sequence.

B13. The Centers for Disease Control and Prevention issued a Food Safety Alert in November 2024 for cucumbers and foods made with contaminated cucumbers, specifically for
A) *Listeria*.
B) *Salmonella*.
C) *Escherichia coli* O27.
D) *Escherichia coli* O157:H7.
E) enterovirus.

B14. Which of the following is a mechanism by which speciation can be prevented?
A) natural selection
B) reproductive isolation
C) recombination
D) gene flow
E) mutation

B15. What major event is occurring in S phase of the cell cycle?
A) Condensation of the chromosomes
B) DNA replication
C) Cellular growth
D) Formation of the spindle apparatus
E) Division of the cytoplasm

B16. Which of the following does not belong to Domain Eukarya?
A) algae
B) mammals
C) hyperthermophiles
D) yeast
E) mushrooms

B17. Consider the F2 generation of Mendel's pea plants. If 16 progeny were produced in this generation from a dihybrid cross, statistically, how many of the 16 would be homozygous recessive for both traits?
- A) 1
- B) 3
- C) 6
- D) 8
- E) 16

B18. Which major macromolecular group does ATP belong?
- A) proteins
- B) carbohydrates
- C) amino acids
- D) lipids
- E) nucleic acids

B19. In a population at Hardy-Weinberg equilibrium, 450 out of 1000 individuals in the population have a recessive phenotype. Which Hardy-Weinberg variable is solved for first?
- A) p^2
- B) p
- C) q^2
- D) q
- E) $2pq$

B20. The 30S ribosomal subunit of prokaryotes includes
- A) 46 proteins plus 28S, 5.8S, and 5S rRNA.
- B) 33 proteins plus 18S rRNA.
- C) 33 proteins plus 23S and 5S rRNA.
- D) 19 proteins plus 16S rRNA.
- E) the 50S ribosomal subunit.

C01. What is the molar mass of aluminum nitrate?

A) 117.01 g/mol
B) 213.01 g/mol
C) 88.99 g/mol
D) 184.99 g/mol
E) 56.99 g/mol

C02. What is the sum of the coefficients when this reaction is balanced using the smallest whole number coefficients?

CH_3OH (ℓ) + O_2(*g*) → CO_2(*g*) + H_2O(*g*)

A) 4 B) 6 C) 8 D) 9 E) 11

C03. Which of these statements is true when an electron in an oxygen atom jumps from n = 2 to n = 5?

A) The oxygen atom is now an ion.
B) The oxygen atom decays into a nitrogen atom.
C) The oxygen atom has absorbed energy from its surroundings.
D) The oxygen atom gives off a photon of light.
E) This can't happen because oxygen is always O_2 and is never just one atom.

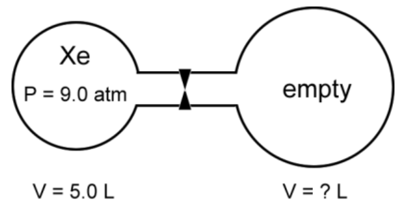
C04. Which of these is not a valid hybridized orbital type in valence bond theory?

A) sp B) sp^2 C) sp^3 D) s^2p^3 E) sp^3d

C05. Only one of these is the correct name of an ionic compound. Which one is correct?

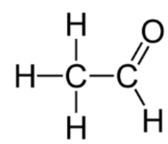
A) Zinc(II) nitrate
B) Copper(I) monochloride
C) Dilithium oxide
D) Silver(I) bromide
E) Lead(II) iodate

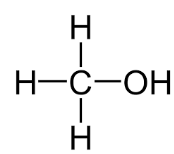
C06. In the following two-bulb gas system, the bulb on the left has a volume of 5.0 L and contains 9.0 atm of xenon gas. The bulb on the right has an unknown volume and is empty. When the valve is opened allowing the xenon gas to fill both bulbs, the final pressure is 3.0 atm. What is the volume of the bulb on the right?

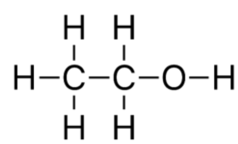


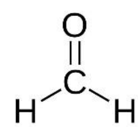
A) 5.0 L B) 7.5 L C) 10.0 L
D) 12.5 L E) 15.0 L

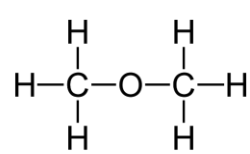
C07. Which of these liquids would you expect to have the highest boiling point?

A) acetaldehyde 

B) methanol 

C) ethanol 

D) formaldehyde 

E) dimethyl ether 

C08. A sample of solid hexamine, $C_6H_{12}N_4$, is burned, generating 3,000. J of heat. How many grams of hexamine were in the sample? The heat of combustion for hexamine is –4200.0 kJ/mol.

A) 100.2 g B) 70.14 g C) 57.26 g
D) 151.63 g E) 95.83 g

C09. A piece of an unknown metal with a mass of 50.14 g is heated to 88.0°C and dropped into 125 grams of water at a temperature of 25.0°C. If the final temperature of the water and the metal is 27.6°C, which of these could be the unknown metal?

A) Chromium B) Tin
C) Titanium D) Tungsten
E) Zinc

C10. When this reaction

$$2W(g) + X(g) \rightarrow Y(g) + Z(s)$$

is allowed to reach equilibrium at 25°C, the amount of each substance at equilibrium is found to be

W = 0.75 atm Y = 1.8 atm
X = 0.85 atm Z = 2.2 grams

What is the value of the equilibrium constant for this reaction at 25°C?

A) 0.27 B) 3.8 C) 2.8 D) 0.12 E) 8.3

C11. If you have 100 mL of 0.10 M $Ba(OH)_2$ and you add 200 mL of water, what is the new pH of the solution?

A) 1.48 B) 1.18 C) 13.00
D) 12.82 E) 12.52

C12. What is the highest concentration of chloride ions you could have in a solution of 0.0010 M $Pb(NO_3)_2$ without forming a precipitate?

A) 0.13 M B) 0.017 M
C) 1.7×10^{-8} M D) 0.25 M
E) 0.095 M

C13. What is the oxidation number on the carbon atom in carbon monoxide?

:C≡O:

A) +2 B) –2 C) 0 D) +1 E) –1

C14. How does a catalyst speed up a chemical reaction?

A) It increases the kinetic energy of the reactants, resulting in more energetic collisions.
B) It creates a new reaction pathway with a lower activation energy.
C) It creates new attractions between the reactants, resulting in more interactions.
D) The presence of a catalyst tells the reactants you are serious about speeding up the reaction so they try harder.
E) It increases the value of the equilibrium constant for the reaction, resulting in the formation of more product.

C15. How many molecules would there be in the gas phase if 325 mL of liquid methanol (CH_3OH) at room temperature is heated to 64.7°C and vaporized at 1 atm pressure? The density of liquid methanol at room temperature is 0.792 g/mL.

A) 1.74×10^{24} molecules
B) 2.29×10^{24} molecules
C) 3.64×10^{24} molecules
D) 4.83×10^{24} molecules
E) 5.09×10^{24} molecules

C16. Consider the following four statements, which may be either true or false:

I. Heat and temperature are the same thing.
II. It is possible to add heat to something without changing its temperature.
III. When you put ice in warm water, heat from the water is transferred to the ice and cold from the ice is transferred to the water.
IV. Heat has negative mass and that is why heat rises.

How many of these statements are true?

A) None of them
B) One of them
C) Two of them
D) Three of them
E) All of them

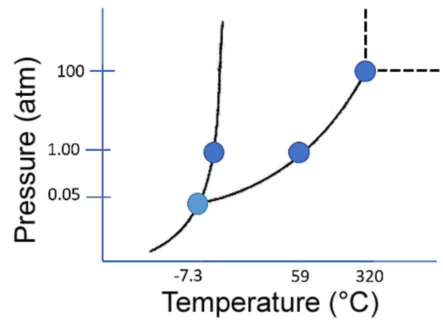
C17. What is the coefficient in front of O_2 when the chemical equation for the complete combustion of propane (C_3H_8) is balanced using the smallest integer coefficients?

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

C18. Your lab partner mistakenly pours 310 mL of 1.15 M NaCl solution into a jar containing 925 mL of 0.95 M KCl. What is the chloride ion concentration in the mixed solution?

A) 0.95 M
B) 1.00 M
C) 1.05 M
D) 1.10 M
E) 1.15 M

C19. What is the name of the point that appears at 320°C and 100 atm on this phase diagram?



A) Absolute point
B) Boiling point
C) Critical point
D) Demarcation point
E) Extremity point

C20. If you had 165 grams of solid aluminum and you wanted to turn it all into AlF_3 by reacting it with HF gas, how many liters of HF gas would you need at STP to complete the reaction?

A) 6.12 L
B) 18.3 L
C) 45.7 L
D) 137 L
E) 411 L

P01. According to Orzel, the results from both Maxwell's equations and the Michaelson-Morley experiment forced physicists to reconsider some deeply held notions. The most fundamental notion that had to be abandoned was the idea of...
A) an absolute frame
B) the aether
C) simultaneous length measurement
D) relative velocity
E) universal time

P02. According to Orzel, a particular type of subatomic particle that is created by cosmic rays in the upper atmosphere has a very short lifetime and should decay before reaching the ground. However, due to the high speed of these particles, and the clock-slowing effects of relativity, these particles are able to reach the surface of the Earth where they are detected in substantial numbers. What are these particles?
A) muons
B) electrons
C) pions
D) D-mesons
E) tauons

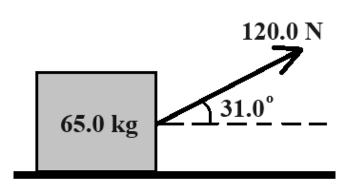
P03. According to Orzel, measuring the length of an object moving at relativistic speeds can be reduced to a problem of....
A) the length measurement tools
B) reference frame correlation
C) reference frame acceleration
D) the synchronization of clocks
E) multiple observers

P04. Uranus and Neptune are called "ice giants" because of their large mantle regions composed of warm, dense ice. This ice makes up about 80% of the mass of these planets. What are the primary three compounds that form the ice in Uranus and Neptune?
A) water, ammonia, methane
B) water, carbon dioxide, ammonia
C) water, hydrogen, methane
D) ammonia, hydrogen, methane
E) ammonia, hydrogen, carbon dioxide

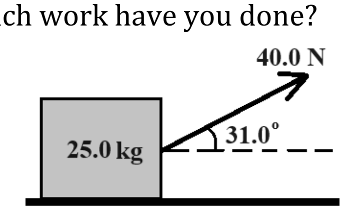
P05. An electric field lies entirely in the x-y plane. The electric field is oriented at an angle of 35.0° with respect to the positive x-axis, and the component of the field in the x-direction has a magnitude of 140.0 N/C. What is the magnitude of the total electric field?
A) 140 N/C
B) 171 N/C
C) 200 N/C
D) 244 N/C
E) 345 N/C

P06. A truck starting from rest accelerates at a constant rate of 2.25m/s^2 until it reaches a speed of 30.0m/s. The truck then travels at constant speed for 5.00 seconds. At that point, how far has the truck traveled in total?
A) 150 m
B) 200 m
C) 350 m
D) 400 m
E) 550 m

P07. You pull a 65.0kg crate to the right with a 120.0N force, as shown. Your force acts on the crate at an angle of 31.0° above the horizontal, and the floor on which the crate slides is frictionless. What is the acceleration of the crate?
A) 0.542 m/s^2
B) 0.951 m/s^2
C) 1.11 m/s^2
D) 1.58 m/s^2
E) 1.85 m/s^2

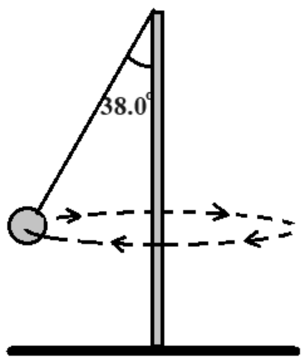


P08. You decide the crate from problem P07 is too heavy, so you switch to pulling a 25.0kg crate. You pull with a force of 40.0N, at an angle (once again) of 31.0°. The floor is frictionless. If you pull the crate a horizontal distance of 45.0m, how much work have you done?
A) 927 J
B) 1082 J
C) 1543 J
D) 1800 J
E) 3857 J



P09. A 3.40kg ball is attached to the end of a 1.50m long rope that is connected to the top of a vertical pole. The ball is kicked so that it spins around the pole in a circle (as shown). While spinning, the rope makes an angle of 38.0° with respect to the pole. What is the angular velocity of the ball as it spins around the pole?

A) 2.88 rad/s
B) 5.52 rad/s
C) 8.28 rad/s
D) 8.98 rad/s
E) 12.5 rad/s



P10. You attach a mass to a string to form a simple pendulum. Your pendulum has a period of 0.750 seconds. You enter an elevator and while the elevator is accelerating upwards, the period of the pendulum changes to 0.650 seconds. What is the acceleration of the elevator?

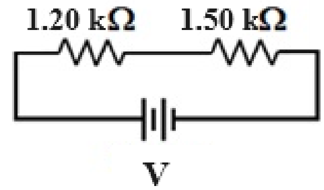
A) 0.727 m/s^2
B) 1.51 m/s^2
C) 2.44 m/s^2
D) 3.25 m/s^2
E) 7.36 m/s^2

P11. A 20.0g piece of aluminum that has a specific heat capacity of 900 J/kgK is heated until it glows. The aluminum is placed in a cup containing 100.0g of pure water with an initial temperature of 22.0°C. The specific heat capacity of water is 4186 J/kgK. After reaching thermal equilibrium, the water and aluminum have a final temperature of 55.0°C. What was the temperature of the aluminum when it was glowing?

A) 602 °C
B) 712 °C
C) 822 °C
D) 932 °C
E) 1040 °C

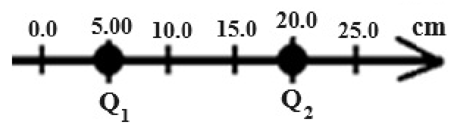
P12. For the circuit shown below, the energy dissipated in the 1.20kΩ resistor is 0.2016W. Determine the magnitude of the voltage source, V.

A) 11.0 V
B) 17.6 V
C) 24.2 V
D) 30.2 V
E) 35.0 V



P13. A $4.50\mu C$ charge (Q_1) is placed on the x-axis, at the 5.00cm mark, as shown below. Calculate the work needed to move a second charge, $Q_2 = 1.25\mu C$, from a long distance to the 20.0cm mark on the axis.

A) 0.253 J
B) 0.337 J
C) 1.26 J
D) 2.25 J
E) 5.06 J

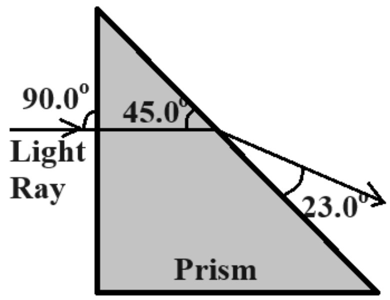


P14. Aluminum is an example of a paramagnetic material. What does that tell us about the magnetic dipoles of the atoms in aluminum?

A) The dipoles align with an external magnetic field but do not remain aligned when the external field is removed.
B) The dipoles anti-align with an external magnetic field but do not remain anti-aligned when the external field is removed.
C) The dipoles align with an external magnetic field and remain aligned when the external field is removed.
D) The dipoles anti-align with an external magnetic field and remain anti-aligned when the external field is removed.
E) The dipoles are unaffected by an external magnetic field.

P15. A light beam intersects a prism as shown below. The beam enters the prism at 90.0° to the first surface. It passes through the prism and intersects the second surface at an angle of 45.0°. The beam refracts, leaving the prism at an angle of 23.0° with respect to the second surface. Based on this information, determine the index of refraction of the prism.

A) 2.56
B) 1.81
C) 1.60
D) 1.41
E) 1.30

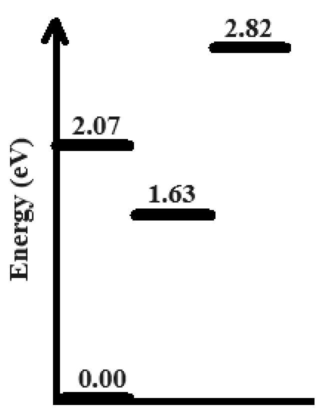


P16. You use a converging lens as a magnifier to examine a small snail. The snail is located 6.00cm in front of the lens, and its actual size is 1.22mm. The image of the snail that you see using the magnifier is upright and 3.75mm in size. What is the focal length of the lens?

A) 1.95 cm
B) 3.07 cm
C) 4.53 cm
D) 6.00 cm
E) 8.89 cm

P17. You have discovered a new element which has the energy levels illustrated in the diagram below. Which of the following wavelengths of light would not be produced by an atom of this element?

A) 335 nm
B) 440 nm
C) 599 nm
D) 761 nm
E) 1042 nm

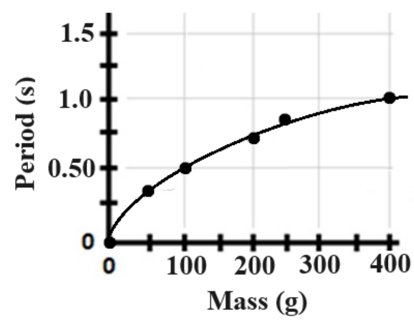


P18. The half-life of Carbon-14 is 5730 years. You discover a bone fragment in which the Carbon-14 content has decreased to 12.5% of its original amount. Approximately how old is the bone fragment?

A) 11500 years
B) 17000 years
C) 23000 years
D) 32500 years
E) 46000 years

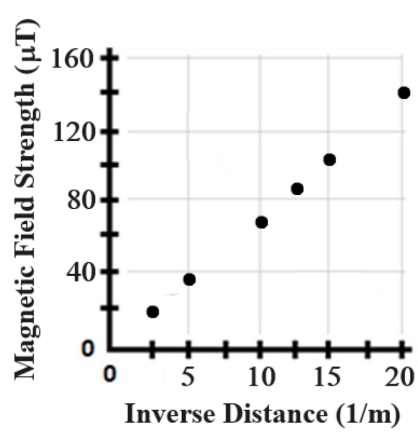
P19. You attach different masses to a spring, and each time set the system into harmonic motion. For each mass, you measure the period of the harmonic motion. A plot of the period, T, versus the mass, m, is shown below. From these data, determine the spring constant of the spring.

A) 40 N/m
B) 25 N/m
C) 16 N/m
D) 7.1 N/m
E) 2.5 N/m



P20. A long straight wire carries an unknown current, I. You measure the strength of the magnetic field produced by the current at different distances from the wire. Then you plot the magnetic field strength, $|B|$, versus the inverse of the distance $1/r$. The plot is shown below. From these data, determine the magnitude of the current flowing in the long straight wire.

A) 5.6 A
B) 18 A
C) 25 A
D) 35 A
E) 49 A



Chemistry

1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.9	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (293)	118 Og (294)

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Water Data

T_{mp} = 0°C
T_{bp} = 100°C
c_{ice} = 2.09 J/g·K
c_{water} = 4.184 J/g·K
c_{steam} = 2.03 J/g·K
ΔH_{fus} = 334 J/g
ΔH_{vap} = 2260 J/g
K_f = 1.86 °C/m
K_b = 0.512 °C/m

Constants

R = 0.08206 L·atm/mol·K
R = 8.314 J/mol·K
R = 62.36 L·torr/mol·K
$e = 1.602 \times 10^{-19}$ C
$N_A = 6.022 \times 10^{23}$ mol^{-1}
$k = 1.38 \times 10^{-23}$ J/K
$h = 6.626 \times 10^{-34}$ J·s
$c = 3.00 \times 10^{8}$ m/s
$R_H = 2.178 \times 10^{-18}$ J
$m_e = 9.11 \times 10^{-31}$ kg
$\mathcal{F}$ = 96,485 C/mol e^-
1 amp = 1 C/sec
1 mol e^- = 96,485 C

Specific heats of some metals (J/g°C)

Chromium	0.449
Tin	0.227
Titanium	0.523
Tungsten	0.134
Zinc	0.387

K_{sp} for $PbCl_2$

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

Physics

Useful Constants

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

DO NOT DISTRIBUTE TO STUDENTS BEFORE OR DURING THE CONTEST!

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY
2025 INVITATIONAL B

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

CHEMISTRY SOLUTIONS – UIL INVITATIONAL B 2025

C01. (B) Aluminum nitrate is $Al(NO_3)_3$. The molar mass is 26.98 + 3×14.01 + 9×16.00 = 213.01 g/mol

C02. (E) 2 CH_3OH (ℓ) + 3 $O_2(g)$ → 2 $CO_2(g)$ + 4 $H_2O(g)$

C03. (C) The electron has moved to a higher energy level so the atom must have absorbed some energy from its surroundings.

C04. (D) In valence bond theory the *s* and *p* orbitals that hybridize must be in the same energy level (and any *d* orbitals that are involved are in $n - 1$). Since there is only one *s* orbital in each energy level you can never have two *s* orbitals hybridize together.

C05. (E) The prefixes *mono-*, *di-*, and so on are not used when naming ionic compounds, so B and C are wrong. When a metal only has one ionic valence state, such as Zn^{2+} or Ag^{+}, the oxidation state is not included in the name, so A and D are simply zinc nitrate and silver bromide respectively. Lead has two ionic oxidation states so the oxidation state must be specified in the compound name, and the iodate ion is IO_3^-.

C06. (C) $P_1V_1 = P_2V_2$, so $V_2 = P_1V_1/P_2$ $P_1 = 9.0$ atm, $V_1 = 5.0$ L, $P_2 = 3.0$ atm $V_2 = (9.0)(5.0)/(3.0) =$ 15 L. V_2 is the volume at the end which is the volume of both bulbs combined, so the volume of the bulb on the right is 15 L – 5.0 L = 10 L

C07. (C) Only ethanol and methanol have hydrogen bonding, and ethanol has a higher molar mass than methanol (which means it is more polarizable and has more dispersion forces), so the intermolecular forces will be strongest in ethanol, giving it the highest boiling point among these compounds.

C08. (A) 3000J/4200 J/mol = 0.7143 moles. 0.7143 moles × 140.22 g/mol = 100.157 grams

C09. (A) $-m_M c_M \Delta T_M = m_{water} c_{water} \Delta T_{water}$

c_M = ? J/g°C

$\Delta T_M = (27.6 - 88.0) = -60.4$ °C

m_{water} = 125 g

c_{water} = 4.184 J/g°C

$\Delta T_{water} = (27.6 - 25.0) = 2.6$ °C

$$c_M = \frac{-m_w c_w \Delta T_w}{m_M \Delta T_M} = \frac{-(125)(4.184)(2.6)}{(50.14)(-60.4)} = 0.449 \text{ J/g°C}$$

On the data sheet the metal with a specific heat of 0.449 J/g°C is chromium.

C10. (B) Z is a solid and is not part of the K_{eq} calculation.

$$K_{eq} = \frac{P_Y}{{P_W}^2 P_X} = \frac{(1.8)}{(0.75)^2(0.85)} = 3.76$$

C11. (D) moles of $Ba(OH)_2$ = 0.100 L × 0.10 M = 0.010 moles $Ba(OH)_2$ moles of OH^- = 2 × moles of $Ba(OH)_2$ = 0.020 moles. $[OH^-]$ = 0.020 mol / 0.300 L = 0.0667 M. pOH = 1.176. pH = 14 – pOH = 12.82

C12. (A) The precipitate is lead(II) chloride, $PbCl_2$, so precipitation will begin when $[Pb^{2+}][Cl^-]^2 = 1.7 \times 10^{-5}$. $[Cl^-]^2 = K_{sp}/[Pb^{2+}] = 1.7 \times 10^{-5}/ 0.0010 = 0.0170$, so $[Cl^-] = (0.0170)^{½} = 0.13$ M

C13. (A) The oxidation state of oxygen in a compound is almost always –2 (except in peroxides or OF_2), and since CO is neutral the oxidation number on the carbon atom must be +2.

C14. (B) (I hope you knew there would be a catalyst question on Invitational B after the hint in the answer to question 20 on Invitational A.)

C15. (D) The vaporization temperature and pressure are irrelevant to solving this problem. The problem gives you a volume of liquid methanol and wants to know how many molecules there are in it. Use the density to convert the volume to mass, then divide by molar mass to get moles.
325 mL × 0.792 g/mL = 257.4 grams. 257.4 g / 32.05 g/mol = 8.03 moles of CH_3OH.
8.03 moles × 6.02×10^{23} molecules/mol = 4.83×10^{24} molecules.

C16. (B). Only statement II is correct. Heat is a form of energy, but temperature is a measure of the average kinetic energy of the particles. During a phase change (melting or vaporization) it is possible to add heat without changing the temperature of the substance because the heat energy that is added is used to overcome intermolecular attractions between the particles. Heat is transferred to the ice and the water gets colder because it loses heat. There is no such thing as "cold" that can be transferred from one thing to another. Heat does not have mass. *Heat* does not rise, less dense objects rise. Heat causes materials to expand and become less dense.

C17. (E) $1\ C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$ I didn't give you the products of this reaction because I assume you learned them from the question on Invitational A if you didn't know them already. Question 2 on this test also provided a reminder.

C18. (B) You don't have to actually solve this problem to get the answer because you know the mixture concentration has to be between 0.95 M and 1.15 M. That leaves only answers B, C, and D. Since you have more of the 0.95 M solution than you have of the 1.15 M solution, the mixture concentration has to be closer to 0.95 M than it is to 1.15 M. That means it has to be answer B. But you should solve the problem anyway just in case this same lab partner makes a more complicated mistake on a later test using different solutions where the answer can't be reasoned out quite this easily...
Moles of chloride in the NaCl = (0.310 L)(1.15 M) = 0.3565 mol.
Moles of chloride in the KCl = (0.925 L)(0.95 M) = 0.8788 mol. Total moles = 1.235 moles Cl^-.
Total volume = 0.310 L + 0.925 L = 1.235 L. 1.235 mol/1.235 L = 1.00 M

C19. (C)

C20. (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 you need three moles of HF for every mole of Al.
165 g Al / 26.98 g/mol = 6.1156 mol Al, so you need 3× that many moles of HF = 18.3469 moles HF. $V = nRT/P$ so at STP $V = (18.3469)(0.08216)(273)/1 = 411.0$ L of HF gas

PHYSICS SOLUTIONS – UIL INVITATIONAL B 2025

P01. (E) page 52: "The crisis in physics precipitated by Maxwell's Equations and the Michaelson-Morley experiment forced physicists to reconsider some deeply held notions. The most fundamental of these notions was the idea of universal time."

P02. (A) page 69: "The most dramatic example of the clock-slowing effects of relativity involves exotic particles known as muons."

P03. (D) page 81: "The problem of length measurement is really a problem of synchronization…."

P04. (A) The ice giants, Uranus and Neptune, formed from the accretion of solid icy material in the outer solar system. The icy bodies that now form the mantles of the ice giants are primarily composed of water, ammonia, and methane.

P05. (B) The total magnitude of the electric field is the length of the hypotenuse of a triangle where the horizontal leg is 140.0N/C in length and the angle of the hypotenuse with respect to horizontal is 35.0°. Based on the triangle, we surmise $\cos\theta = \frac{x}{h} \rightarrow \cos(35.0°) = \frac{140.0}{h} \rightarrow$ $h = \frac{140.0}{\cos(35.0°)} = 171$N/C. This is the total magnitude of the electric field.

P06. (C) This problem has two parts: in the first part, the truck is accelerating, and in the second part, the truck is moving at constant speed. During the first part, we know that the truck starts from rest, ends with a speed of 30.0m/s, and accelerates at 2.25m/s^2. We do not know for how long the truck accelerated, so we'll use the equation $v_f^2 = v_i^2 + 2a\Delta x_1 \rightarrow (30.0)^2 = (0)^2 + 2(2.25)\Delta x_1$. This gives $900 = 4.50\Delta x_1 \rightarrow \Delta x_1 = 200.0$m. This is the distance traveled during the first part. For the second part, the truck travels at a constant speed of 30.0m/s for 5.00seconds. For this part, we know the acceleration is zero. We will use $\Delta x_2 = vt + \frac{1}{2}at^2 = (30.0)(5.00) + (0.5)(0)(5)^2 = 150.0$m. Therefore, the total distance traveled by the truck is $d = \Delta x_1 + \Delta x_2 = 200.0 + 150.0 = 350.0$m

P07. (D) First, we need to construct a free-body force diagram. Because there is no friction, we only have three forces acting on the crate: gravity (mg, downward), the normal force (F_N, upward), and the pulling force (F, up and right). The pulling force is at an angle, so we will break it into its components. In the horizontal, we have $F_h = F\cos\theta = (120.0)\cos(31.0°) = 102.9$N. In the vertical, we have $F_v = F\sin\theta = (120.0)\sin(31.0°) = 61.8$N. Now we sum our forces. The motion is entirely horizontal, so the vertical forces must sum to zero. For the vertical, $\sum F_y = F_N + F_v - mg = 0$. This gives $F_N + 61.8 - (65)(9.8) = 0 \rightarrow F_N = 575$N. This is nice to know, but useless for solving the problem. The acceleration is horizontal, so summing the horizontal forces gives $\sum F_x = F_h = ma$. This gives $102.9 = (65)a \rightarrow a = 1.58$m/s^2, which is the answer.

P08. (C) Again, we start with a free body force diagram. There is no friction, so we only have three forces: gravity (mg, downward), the normal force (F_N, upward), and the pulling force (F, up and right). As in problem P07, we break the pulling force into its components. In the horizontal, we have $F_h = F\cos\theta = (40.0)\cos(31.0°) = 34.3$N. In the vertical, we have $F_v = F\sin\theta = (40.0)\sin(31.0°) = 20.6$N. The motion of the crate is entirely horizontal, so it is only the horizontal forces that are needed to calculate the work. The only horizontal force is the horizontal component of the applied force: $\sum F_x = F_h = 34.3$N. Work is defined as force multiplied by distance, so for the horizontal motion of the crate, we have $W = F_h d_h = (34.3N)(45.0m) = 1543J$.

P09. (A) We first consider the force diagram for this situation. There are two forces acting on the ball: gravity (mg, directed downward) and tension (T, directed upward along the rope). Because the tension acts at an angle, it must be broken into components. In the vertical, we have $T_y = T\cos\theta$ and in the horizontal, we have $T_x = T\sin\theta$. The trigonometric functions look reversed, but that is because we are working with an angle measured with respect to the vertical. Now, since the ball's motion is entirely horizontal, there is no acceleration in the vertical direction. Thus, the forces in the vertical must sum to zero: $\sum F_y = T\cos\theta - mg = 0 \;\rightarrow\; T\cos(38.0) = (3.40)(9.80) \;\rightarrow$ $T = 42.3$N. This gives us the tension in the rope.
In the horizontal direction we have only a single force component:
$\sum F_x = T\sin\theta = (42.3)\sin(38.0) = 26.0$N. This horizontal force provides the centripetal acceleration needed to keep the ball moving in a circle. Thus, $\sum F_x = 26.0 = mr\omega^2$. The last piece we need is the radius of the circle traced out by the ball. The radius equals the distance from the pole to the ball, which can be found using the length of the rope:
$r = L\sin\theta = (1.50)\sin(38.0) = 0.9235$m. Putting it all together, we obtain
$26.0N = (3.40kg)(0.9235m)\omega^2 \;\rightarrow\; \omega^2 = 8.28 \;\rightarrow\; \omega = 2.88$rad/s.

P10. (D) The equation relating the length of a stationary pendulum to its period is $T = 2\pi\sqrt{\frac{L}{g}}$. Using the initial period, we can find the length of your pendulum: $0.750s = 2\pi\sqrt{\frac{L}{9.80}} \;\rightarrow\; \frac{L}{9.80} = \left(\frac{0.750}{2\pi}\right)^2 \;\rightarrow$ $L = 0.1396$m. On the elevator, the length of your pendulum remains the same, but the acceleration has changed. This can be included in the equation: $T' = 2\pi\sqrt{\frac{L}{g+a}}$ where a is the acceleration of the elevator. Putting in the known and calculated values, we get: $0.650s = 2\pi\sqrt{\frac{0.1396m}{9.80+a}} \;\rightarrow\; \frac{0.1396}{9.80+a} = \left(\frac{0.650}{2\pi}\right)^2 \;\rightarrow$ $0.1396 = 0.0107(9.80 + a)$. This leads to $0.1396 = 0.1049 + 0.0107a \;\rightarrow\; 0.0107a = 0.0347 \;\rightarrow$ $a = 3.25$m/s^2.

P11. (C) This is a simple calorimetry problem without any phase changes. We start with: $\sum Q = 0$, which leads to $(mc\Delta T)_{water} + (mc\Delta T)_{aluminum} = 0$. Putting in the known values, and equating the changes in temperature to $\Delta T = T_{final} - T_{initial}$, we get
$(0.100kg)(4186)\left(T_{final} - T_{initial}\right)_{water} + (0.020kg)(900)\left(T_{final} - T_{initial}\right)_{aluminum} = 0$.
Recalling that differences in temperature in Celsius are the same as differences in Kelvin, and noting that the final temperature of the aluminum equals the final temperature of the water, we get:
$(418.6)(55.0℃ - 22.0℃) + (18.0)(55.0℃ - T_{initial.Al}) = 0$.
This leads to $13814 + 990 - 18T_{initial.Al} = 0 \;\rightarrow\; 18T_{initial.Al} = 14804 \;\rightarrow\; T_{initial.Al} = 822℃$.

P12. (E) We use the power dissipated to find the current flowing in the 1.20kΩ resistor: $P = I^2R \;\rightarrow$ $0.2016 = I^2(1200) \;\rightarrow\; I = 0.01296$A. Since the two resistors are connected in series, we know that this same current also flows through the 1.50kΩ resistor. Using Ohm's Law, we can now find the voltage across each resistor: $V_1 = IR_1 = (0.01296)(1200) = 15.55$V, and $V_2 = IR_2 = (0.01296)(1500) = 19.44$V. For a series circuit, the total voltage equals the sum of the individual voltages.
Thus, $V = V_1 + V_2 = 15.55 + 19.44 = 34.99 \approx 35.0$V is the voltage produced by the power supply.

P13. (B) The charge Q_2 starts a long distance away, so the initial electric potential energy associated with these two charges is zero ($U_i = 0$). Once Q_2 is brought to the 20.0cm mark, the energy associated with the two charges is found using $U_f = \frac{kQ_1Q_2}{r}$. This gives
$U_f = \frac{(8.99\times10^9)(4.50\times10^{-6})(1.25\times10^{-6})}{(20.0cm - 5.00cm)} = \frac{0.05057\,Jm}{0.15\,m} = 0.337\,J$. Thus, the total work needed to bring charge Q_2 to the 20.0cm mark is $W = U_f - U_i = 0.337 - 0 = 0.337\,J$.

P14. (A) There are three types of magnetic materials: *diamagnetic*, *paramagnetic*, and *ferromagnetic*. Dipoles in a *diamagnetic* material will anti-align with an external magnetic field but will not stay anti-aligned when the external field is removed (choice B). Dipoles in a *ferromagnetic* material will align with an external magnetic field and will remain aligned even after the external field is gone (choice C). The dipoles in a *paramagnetic* material like aluminum will align with an external magnetic field but will not remain aligned when the external field is removed (choice A, the correct answer).

P15. (E) The light ray doesn't change direction at the first surface since it intersects the surface along the normal line (that is perpendicular to the surface). Thus, we can ignore the first surface. At the second surface, the ray intersects at 45° to the surface. This means that the angle with respect to the normal line is also 45°. Thus, the incident angle is $\theta_i = 45°$. The angle at which the light ray exits the prism is 23° with respect to the surface. This gives an angle with respect to the normal line of $\theta_r = 90 - 23 = 67°$, which is the refracted angle. With the angles determined, and noting that the index of refraction of air is 1.00, we can use Snell's Law to find the index of refraction of the prism: $n_1 \sin\theta_i = n_2 \sin\theta_r \;\; \rightarrow \;\; n\sin(45.0) = (1.00)\sin(67.0) \;\; \rightarrow \;\; 0.7071n = 0.9205 \;\; \rightarrow \;\; n = 1.30.$

P16. (E) Since we are given the size of the snail and the size of the image of the snail, we can calculate the magnification: $M = \frac{h'}{h} = \frac{3.75mm}{1{,}22mm} = 3.07$. The image is upright, which confirms that the magnification is positive. We also know the object location, $p = 6.00cm$. We can go to the magnification formula to find the image location: $M = -\frac{q}{p} \;\; \rightarrow \;\; 3.07 = -\frac{q}{6.00} \;\; \rightarrow \;\; q = -18.44cm.$ The image location is negative, which means that this image is virtual. Finally, we can determine the focal length of the lens by using $\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \;\; \rightarrow \;\; \frac{1}{6.00} + \frac{1}{-18.44} = \frac{1}{f} \;\; \rightarrow \;\; f = 8.89cm.$

P17. (A) The wavelengths of emitted photons are based on the energy differences between the various levels. With four energy levels, this element can produce up to six different wavelengths. The six energy differences are $\Delta E_1 = 2.82 - 0.00 = 2.82eV$, $\Delta E_2 = 2.07 - 0.00 = 2.07eV$, $\Delta E_3 = 1.63 - 0.00 = 1.63eV$, $\Delta E_4 = 2.82 - 1.63 = 1.19eV$, $\Delta E_5 = 2.82 - 2.07 = 0.75eV$, $\Delta E_6 = 2.07 - 1.63 = 0.44eV$. This gives emitted wavelengths of $\lambda_1 = \frac{1240eVnm}{2.82eV} = 440nm$, $\lambda_2 = \frac{1240eVnm}{2.07eV} = 599nm$, $\lambda_3 = \frac{1240eVnm}{1.63eV} = 761nm$, $\lambda_4 = \frac{1240eVnm}{1.19eV} = 1042nm$, $\lambda_5 = \frac{1240eVnm}{0.75eV} = 1653nm$, $\lambda_6 = \frac{1240eVnm}{0.44eV} = 2818nm$. Thus, the wavelength that is not produced by this element is $335nm$.

P18. (B) For each half-life, the Carbon-14 content of the bone fragment decreases by a factor of two. That is, in 5730 years, the Carbon-14 content is $\frac{1}{2}$, or 50%, of its original amount. After $2 * 5730 = 11460$ years, the Carbon-14 content decreases to $\frac{1}{4}$, or 25%, of its original amount. And after $3 * 5730 = 17190$ years, the Carbon-14 content is $\frac{1}{8}$, or 12.5%, of its original amount. Thus, the bone fragment has an age of approximately three half-lives, or about 17000 years old.

P19. (C) Since this curve is not linear, our best option is to read a data point from the plot and put those values into the formula relating the mass to the period of a mass-spring system. I'm going to use the point (100g, 0.50s). The relevant equation is $T = 2\pi\sqrt{\frac{m}{k}}$. Rearranging this equation allows us to solve for the spring constant: $\left(\frac{T}{2\pi}\right)^2 = \frac{m}{k} \;\; \rightarrow \;\; k = m\left(\frac{2\pi}{T}\right)^2$. Plugging in the values from the data point selected, we get: $k = m\left(\frac{2\pi}{T}\right)^2 = (0.100kg)\left(\frac{2\pi}{0.50s}\right)^2 = 15.8 \approx 16$ N/m.

P20. (D) The equation describing the magnetic field strength produced at a distance r from a current-carrying wire is $|B| = \frac{\mu_0 I}{2\pi r}$. Emphasizing the relationship between the magnetic field strength $|B|$ and the inverse of the distance from the wire $\frac{1}{r}$, we see that $|B| = \left(\frac{\mu_0 I}{2\pi}\right)\frac{1}{r}$. This relationship is linear (as the plot also shows), and the slope of the line is $slope = \frac{\mu_0 I}{2\pi}$. So, we need to find the slope of the line traced out by the data. To do this, I will choose two points with which to estimate the slope. I'll use the points (5 m^{-1}, 37 μT) and (20.5 m^{-1}, 140 μT). This gives a slope of $slope = \frac{y_2 - y_1}{x_2 - x_1} = \frac{140 - 37}{20.5 - 5} = \frac{103}{15.5} = 6.65\ \mu Tm = 6.65 \times 10^{-6}\ Tm$. Equating this value to the slope equation we found earlier leads to: $slope = 6.65 \times 10^{-6}\ Tm = \frac{\mu_0 I}{2\pi} = \frac{4\pi \times 10^{-7}}{2\pi} I = (2 \times 10^{-7})I$. This gives a current of $I = \frac{6.65 \times 10^{-6}}{2 \times 10^{-7}} = 33 \approx 35\ A$.