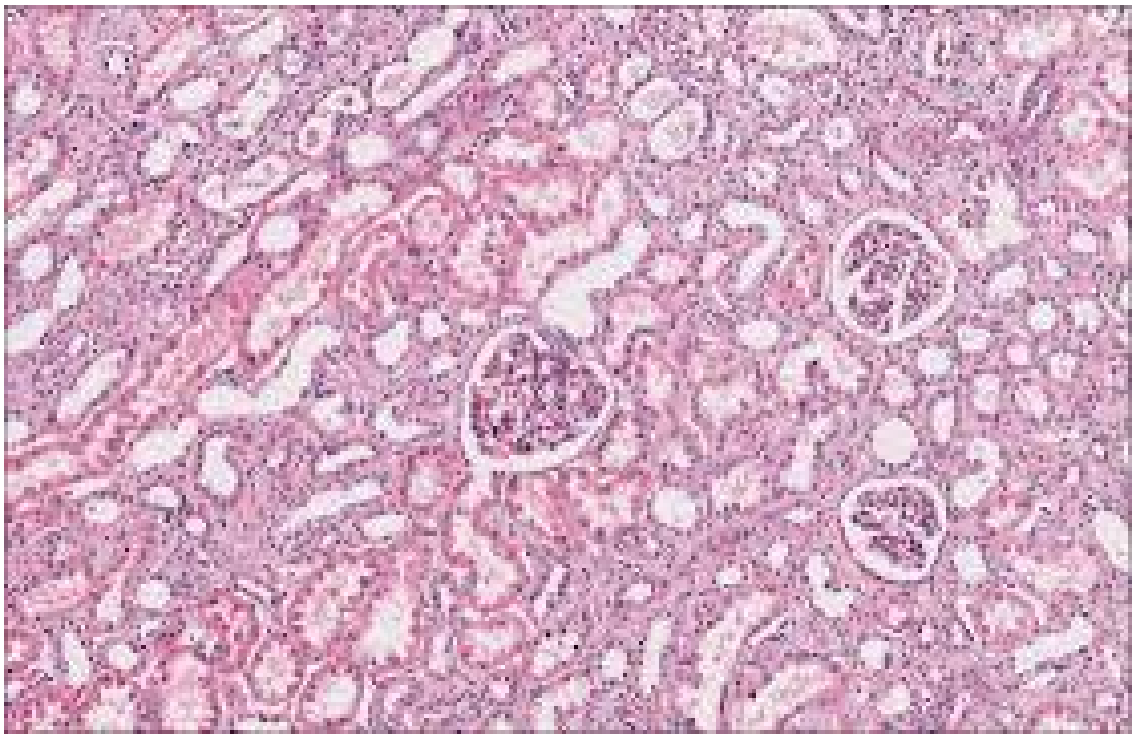
2021 Alphademic Science Bowl Qualifying Exam

Instructions: Answer all questions on the answer sheet. In order to receive credit for a question, your team must answer all parts of the question correctly. All answers that come out as non-integers must be answered as fractions in the simplest form. Fractions should be typed as “x/y” where x is the numerator and y is the denominator or you can use the fraction format through google docs “$\frac{x}{y}$” Square roots can be typed as “sqrt(2)” or can use the square root symbol through google docs “$\sqrt{2}$”

Biology

1) **1 point -** Jerry likes pie. In fact, he likes pie so much that he eats three pies every day. Due to his unhealthy habits, Jerry develops Type II diabetes, characterized by high blood sugar. The hormone, insulin, which is responsible for the removal of glucose from the blood and into the tissues becomes obsolete to the body. Which organ produces insulin?
2) **2 points -** What organ is heavily affected by diabetes, and is shown in the histological slide below?



3) **3 points** - Jerry finds that one day he is very tired, has abdominal pains, is hungry and thirsty, and is breathing excessively.
    a) What is the complication of diabetes he has developed?
    b) Which organ is responsible for the production of the molecule that is causing Jerry’s complication?
    c) Why has Jerry’s breathing changed?

4) **4 points** - Thankfully Jerry has survived and has stopped eating so many pies. Unfortunately, he develops an incredibly rare disease that causes lower protein levels in the blood.
    a) What will happen to Jerry's hydrostatic pressure and osmotic pressure?
    b) Jerry's doctor says that the disease's inheritance pattern is autosomal dominant. If both of Jerry's parents are heterozygous, what is the probability that Jerry is also heterozygous?
    c) Jerry and his wife want to have a daughter. They had 2 sons and 2 daughters, all of whom did not have the disease. What is the probability they have a daughter with the disease? (Jerry's wife is homozygous recessive)
5) **5 points** - In the final moments of Jerry's life, he decides that he wants to adopt flies. He notices the characteristics of the fly are associated with its genotypes for the v, w, and z genes. Each is inherited through an autosomal recessive pattern. (+++ - wildtype, vwz - recessive). Given the data Jerry collected:
    a) What gene is in the middle?
    b) What is the distance between z and w?

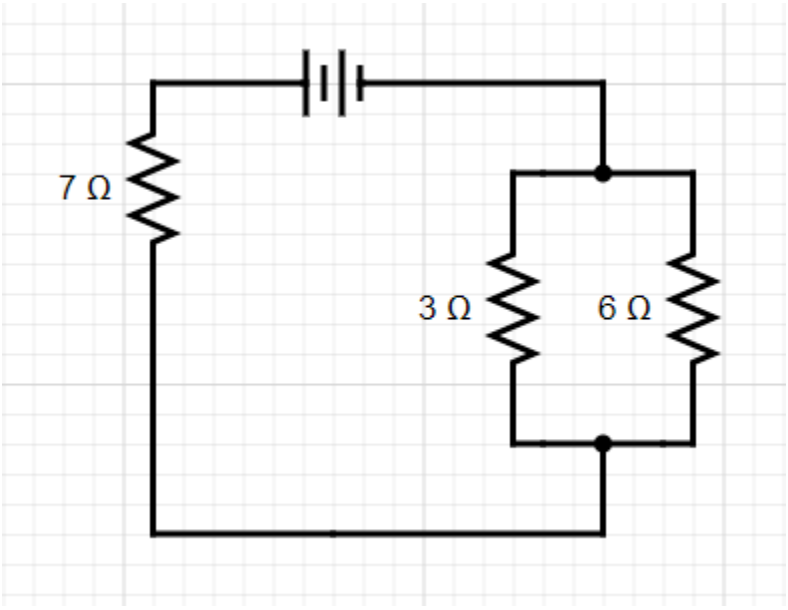
+ + z	367
v w +	338
+ w +	88
V + z	96
V + +	61
+ w z	46
v w z	1
+ + +	3

Mathematics

1) **1 point -** Andrew, Bella, Cait, Dave, and Ethan all go to see a movie. Suppose that there are only 5 available seats in the theater when they arrive. It happens that these seats are all consecutive in the same row. Andrew and Bella don't get along with each other, so they insist on sitting apart from each other. In how many ways can the group seat themselves such that everyone is happy?
2) **2 points -** To pass time, Frank and Greg are playing a game with a weighted die. This cube-shaped die has the property that the probability of rolling a number is proportional to that number. For example, it is three times more likely to roll a three than a one. Each person takes a turn rolling the die, and whichever person rolls the higher number wins the game. If they roll the same value, the person that rolled last wins. Given that Frank rolls first and wins the game, what is the probability that he rolled a prime number?
3) **3 points -** Let *f(x)* be the unique monic second-degree polynomial tangent to both of the lines y = 5x + 5 and y = -x - 7. Determine the value of *f(2)*.
4) **4 points -** In triangle ABC, AB = 52, BC = 56, and AC = 60. Let D be the foot of the altitude from A to BC. AD is extended past D until it intersects the circumcircle of triangle ABC at E. What is the inradius of triangle AEC?
5) **5 points -** Let z = $\sqrt{3} + i$, where $i = \sqrt{-1}$. Determine $\sum_{k=1}^{600} (\frac{z}{2})^k + k^2 + 1$.

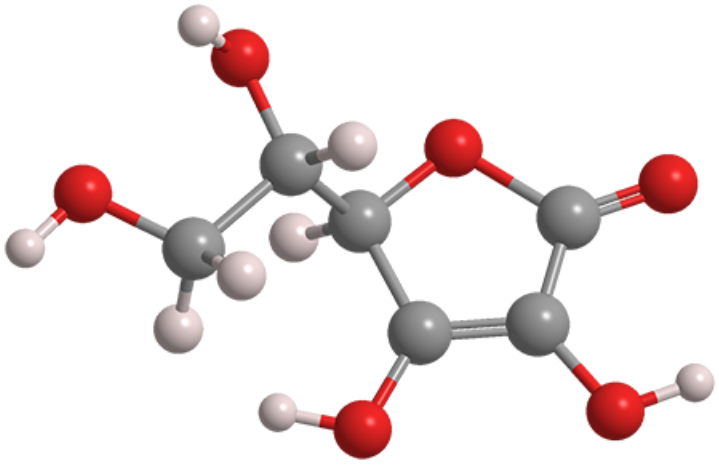
Physics

1) **1 point -** A 5 kg object is at rest on a flat, frictionless plane. A person exerts a 20 N force on the object, causing it to accelerate. After 10 seconds, how far will the object have travelled?
2) **2 points -** A pail of water is rotated in a vertical circle of radius 0.5 meters. What is the minimum speed of the pail at the top of the circle if no water spills out? Let g = 10 m/s^2.
3) **3 points -** An object of mass 2 kg is initially moving parallel to the x axis at 5 m/s. It collides with another object of mass 3 kg initially moving parallel to the y axis at 10 m/s. Upon collision, the two objects stick together. What is the final speed of the composite object?
4) **4 points -** A person kicks a rock horizontally off of an 80 meter high cliff into a pool of water. If he hears the sound of the splash $4\frac{2}{7}$ seconds later, what was the initial speed given to the rock? Assume g = 10 m/s^2, speed of sound = 343 m/s.
5) **5 points -** Consider the following circuit diagram. What is the equivalent resistance of the circuit?



Chemistry

1) **1 point -** Ascorbic acid, also known as Vitamin C, is an essential vitamin found in many foods and often taken as a dietary supplement. Its structure is shown below. The gray atoms are carbon, the red atoms are oxygen, and the white atoms are hydrogen.

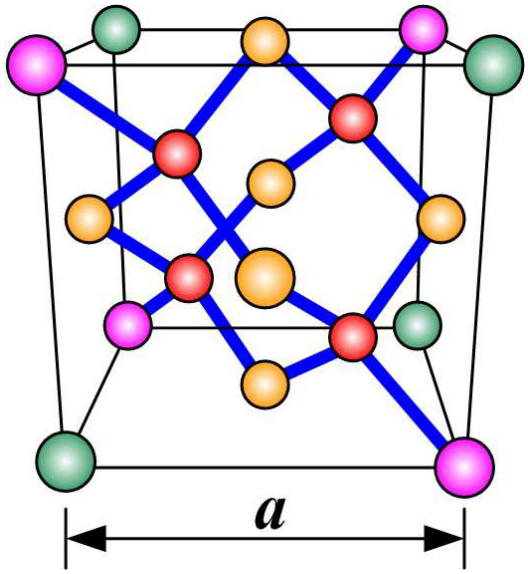


   a) What are the molecular and empirical formulas of ascorbic acid?
   b) What is the molar mass of ascorbic acid? *M*(C)=12.01 g/mol, *M*(H)=1.008 g/mol, and *M*(O)=16.00 g/mol.

2) **2 points -** A sample of methane, the simplest alkane, is initially at a pressure of 1.00 atm at a temperature of 298 K and a volume of 1.00 L. If the conditions are changed so that the temperature is 323 K and the volume is 2.00 L, what will the pressure of the sample be (in atm)?

3) **3 points -** Chemists often determine the concentration of silver ions by precipitating $AgCrO_4$, which is red-brown. What mass of Na_2CrO_4 is required to precipitate all of the silver ions from 12.0 mL of a 0.150 M solution of $AgNO_3$? *M*(Na)=22.99 g/mol, *M*(Cr)=52.00 g/mol, and *M*(O)=16.00 g/mol.

4) **4 points -** In diamond, carbon forms a crystal with tetrahedral geometry at each atom. This is the unit cell for diamond. The different colors only represent different positions; the orange carbon atoms are on the edges of the unit cell.

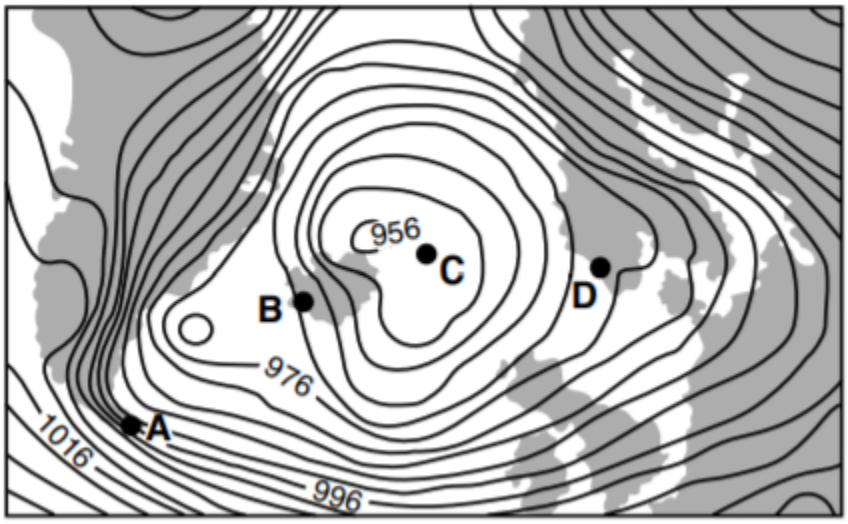


a) How many atoms of carbon are in this unit cell?
b) If a=0.357 nm, what is the density of diamond (in g/cm^3)? *M*(C)=12.01 g/mol

5) **5 points -** A buffer is a solution of a weak acid and its conjugate base (or vice versa) that can resist drastic changes in pH when small amounts of strong base or acid are added. A buffer is made using 45.0 mL of 0.100 M HNO_2 (K_a = 4.0 x 10^{-4}) and 55.0 mL of 0.100 M $NaNO_2$.
   a) What is the pH of the buffer system?
   b) What volume of 0.150 M NaOH (in mL) must be added to increase the pH by 5.0%?

Earth and Space

1. **1 point** - The image below is a weather map of Iceland. Points A, B, C, and D, are points on Earth's surface and the isobars are labelled in millibars. Which point represents the location that is probably experiencing the highest wind speed?



2. **2 points** - The Rio Tinto river in Spain is so named because of its red hue, which is derived from what abundant dissolved ion?
3. **3 points** - Cape Town, South Africa has a Mediterranean climate. Compare the winter and summer climates of Cape Town on average with regards to temperature and precipitation.
4. **4 points** - Spectroscopic binary stars can only be differentiated by oscillations in their spectra caused by their rotation around their center of mass. What is the name of the effect that causes this oscillation in their observed spectra?
5. **5 points** - Carbonaceous chondrites are a rare type of meteorite that are notable for containing water and organic compounds such as carboxylic acids and glycine. Given this information, what can one assume about the location of these meteorites compared to the sun?