My greatest personal interests are on the boundary between physics and pure mathematics. What I find most fascinating are the subtle ways in which simple ideas like counting, or theories about abstract mathematical objects like sets, numbers, and functions, reveal important and observable properties of the physical world we live in (too abstract? Make it less laundry-listy. I find most fascinating the ways in which simple ideas like counting reveal important and observable properties of the physical world, like the possible arrangements of something, like the possible states of an electron). I enjoy mathematical modelling of physical phenomenon because it is a unique opportunity to see directly how physics and mathematics interact, and to explore the fundamentally mathematical properties of nature. I am deeply interested in the theoretical and computational modelling sides of physics, and hope to contribute to the application of pure mathematics to theories of physical relevance. Nothing to grab onto in this paragraph because it’s too abstract. Go back and make sure that every sentence has one thing it’s trying to say, and that it’s different than its fellow sentences.

My fascination with the relationship between pure mathematics and physics became well-defined while I was a student in an experimental research group studying liquid crystal materials. A primary focus of our group was the study of how uniquely-shaped particles, such as figure-8s and knots (bows? Loops?), interacted with the liquid crystal medium. In a branch of geometry that studies the intrinsic properties of shapes, a coffee cup and a doughnut are mathematically the same shape because they have one hole (the hole in your coffee cup is its handle). An interesting result of our experiments was that the properties of an object in liquid crystal are determined by its number of holes (its abstract mathematical shape () rather than by its apparent physical shape. (Can you say something specific about how their number of holes affects their behavior?) Such surprising relationships have turned up with increasing frequency as I have continued my studies (The further I get into these subjects the more I see such relationships…), and they keep me always excited about my future in physics and mathematics. Focus on the cool aspects of shape, and push all of the math jargon out. Devin wants something non-abstract for the “properties of an object in liquid crystal” are an object with one hole does this, and an object with two holes does another thing.

I am currently a member of a research group that studies a newly-discovered material of great theoretical interest, quark-gluon plasma, which is created in high-energy collisions between heavy nuclei like lead and gold. Quark-gluon plasma is exceptionally difficult to study experimentally, so theory and computer modelling are of great importance to the progress of the discipline. Our group studies the material properties of quark-gluon plasmas theoretically and develops new methods in fluid dynamics that can be used to simulate them on the computer. In my current work, I am exploring a relationship between quark-gluon plasma and a similar fluid, the cold Fermi gas, ( awkard, and confusing why this would be true )which may allow us to calculate values for the viscosity of quark-gluon plasma with higher precision than has yet been experimentally determined. The viscosity of quark-gluon plasma is of great importance because it reveals information about the interactions between quarks and gluons, which are believed to be the fundamental constituents of protons, neutrons, and all macroscopic matter. In my future work with this group I hope to contribute to improving the computability and accuracy of methods in fluid dynamics that will allow us to more effectively and efficiently simulate the behavior of quark-gluon plasmas.

My academic goal is to enter a PhD program in theoretical physics after my graduation from the University of Colorado. I hope to spend my career doing fundamental high-energy physics or nuclear fusion energy research at a university or national laboratory.

Compared to ordinary fluids, quark-gluon plasmas have the added complexity of being a high-energy, relativistic fluid. Relativistic hydrodynamics describes how fluids behave near very massive objects (like stars) or when they are exceptionally high in energy. It has important applications across several branches of physics, including astrophysics and magneto-hydrodynamics, and is essential for studying the fluid dynamics of quark-gluon plasma. Current methods in relativistic fluid dynamics are much more complicated than their non-relativistic counterparts, and are often too difficult for computers to solve numerically in a practical amount of time. In my future work with this group, I hope to contribute to improving the computability and accuracy in relativistic hydrodynamics that is central to the effective simulation of quark-gluon plasmas.

I thoroughly enjoy the opportunity to study the mathematics underlying fluid mechanics and numerical methods, and to apply these to an unsolved problem in physics. I am excited to contribute to research in high-energy physics because the discipline is very young and has many important consequences in modern physics. Quark-gluon plasma for example, first observed in 2000, is the first medium in which to directly study quarks, which are believed to be the fundamental unit from which matter is composed. High-energy physics also is essential to the study of the early universe and to the development of nuclear fusion energy. I am interested in continuing research in this discipline, and hope to contribute to the fundamental mathematical background for this area of physics.

Simulating any fluid on the computer involves many approximations, including how temperature varies and how the fluid dissipates energy or relaxes to equilibrium, and the best assumptions for cold Fermi gases are also expected to be approximately correct for quark-gluon plasmas. Because cold Fermi gases have been studied with low experimental uncertainty, the fluid models we use to simulate quark-gluon plasmas can be approximately experimentally-verified via this relationship.

Although quark-gluon plasmas and unitary Fermi gases have many similarities, quark-gluon plasmas have the added complexity of being a high-energy, relativistic fluid. In my future work, I hope to contribute to the efficient computer implementation of relativistic hydrodynamics, and to use these methods to calculate theoretical bounds for the viscosity of quark-gluon plasma.