My Journey to The Idea of Fields

An interest in physics, seeded by a fascination for exploring the inner workings of nature, led me to opt for a Physics major at IIT Kanpur. When I was first introduced to the concept of fields and potentials during high school, it was really a transformative experience for me, that things can talk to each other without even touching with the help of force fields. My high school physics teacher used to praise a book by the name of "Introduction to Electrodynamics". In an avalanche of curiosity, I bought that book, which turned out to be one of the best things in my life, and started to read the first chapter which was all about vector fields. I was drowned into the beauty of mathematics describing those fields.

When my freshmen year started, I was reintroduced about Newton's Laws after high school. I celebrated the success of those laws, after all, they explained uncountable phenomena that occur everyday in nature. But then I looked deeper and asked myself "What is a Force? Or how does one measure a force?". This question remained inside the active corners of my mind. During that time, I was also working on vector fields. I did solve some special cases of vector integrals on loops, surfaces, and volumes. I went on to generalize those in higher dimensions. But soon I realized that there were some problems of which the major one was that **Area vector** can't be defined as a vector in 4 or more dimensions. I tried many attempts to solve that. During one of my lectures on Newtonian Mechanics, the professor introduced us with an ancient problem by the name **Brachistochrone Problem**. I tried very hard solving that. Soon a new course Electrodynamics started and I found the description of the magnetic field a little unsatisfactory. Magnetic fields are described as **pseudo-vectors**, not as some real objects. Pseudo-vectors break some symmetries. So I added one more task which was to construct a real mathematical object which can describe magnetism without any loss of symmetry. New problems were being added to my list and only a few of them were solved.

After struggling through months in the quest of those problems, I realized that the problem of area vector and magnetic field are exactly the same and soon found their solution. That real object to describe a magnetic field is a tensor and to describe areas in higher dimensions we require a tensor. Generalizing **area tensor** led to new problems of generalizing volume in higher dimensions. Luckily, its answer came when I was introduced to the idea of mathematical exchange asymmetry in Fermions in a Quantum Mechanics course and generalized those ideas not only for area or volume but for any dimensional element. I also developed some kinematics of continuum bodies and developed independently a theorem in fluid mechanics called as **Reynold's Transport Theorem**, which I used later to prove Ampere's Circuital Law for this newly developed Magnetic Tensor. While thinking about higher dimensions, I started to think about vectors of infinite dimensions and suddenly got a new insight that a vector of infinite dimensions is nothing but a function and then I realised that I can finally solve Brachistochrone problem and in around a week I did it. With the same idea of thinking that functions as vectors and vice versa, I also understood how tensor products work. I soon generalized the solution of Brachistochrone problem and developed independently calculus of variations up to a basic level.

All these ideas led me to think that "Everything is connected if you look close enough." I did a satisfactory amount of mathematical research in many other but related ideas and generalized many theorems of vector calculus into tensor calculus and before all this I didn't know much about tensors. But because I needed some mathematical objects to solve my problems and tensors came up to the rescue, I appreciate tensors quite a lot. Discovering things by myself led me to highly appreciate each and everything that was included in my coursework or otherwise.

In the summer of 2017, I worked with Prof. AK Jha in Quantum Optics and where I was introduced to the idea of Quantum Fields, which was again a new paradigm shift in my thinking of Electrodynamics. In a course on Statistical Mechanics, I was taught about indistinguishable particles like Fermions and Bosons, but I wondered how could these be indistinguishable if these are particles, i.e. I was not able to imagine them, like I could imagine a lump of classical gas particles in a box. Then I read about Gibb's Paradox. All these made me to ask a question to myself about "What does it mean to be indistinguishable or by what mechanism these could be indistinguishable?" Then, suddenly I reminded myself of the Quantum Fields. What if there is an intrinsic field that excites at different places and the excitation themselves travel like a wave and that's what we feel as a particle, just like QFT. The prevailing method, for making symmetric and anti-symmetric wave-functions for Bosons and Fermions, also inspired me a lot.

Considering all this, I request you for a chance to work with you on a problem on Fermionic Field Theory, to be solved or understood, in summer 2018. This assignment would give me a chance to obtain a diversity in my approach towards research and also instil in me a structured and dedicated learning paradigm and help me transcend into a better researcher. To attain a prerequisite first level of apprehension, I have about two months before summer of 2018, in which I shall be studying about Quantum Statistical Mechanics with as much effort as I can. I am ready to stay in constant touch with you till summer, updating myself regularly of the advancements in the field and come prepared.

Hoping for a wonderful chance
Yaman Sanghavi