<u>Rokos Award Report</u>

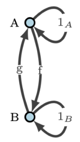
This summer I took part in a research project in Oxford with Prof James Read, one of my Pembroke tutors. James is a member of the philosophy of physics department at the University of Oxford whose research covers the philosophy of physics and the philosophy of science, but especially the philosophy of spacetime theories within the philosophy of physics. I stayed in Oxford for six weeks over the summer so that I could collaborate with James and make use of the Oxford libraries. The project took the form of responding to a research paper by Hans Halvorsen and John Manchak. This paper was one in the line of debate surrounding The Hole Argument. The Hole Argument is an argument that has been present in the philosophy of physics since it was first articulated by Einstein who came across the issue whilst developing his theory of general relativity. The topic stagnated for a few decades but was reignited in the 1980s by John Earman and has been hotly debated since.

This project gave me the opportunity to experience the process of responding to an academic paper and organising the responses into academic paper form themselves. The process involved both James and I reading a section of the paper, having a meeting in which we critically discussed it and then typing up our responses. I used Latex as the document preparation system onto which to format the response; this is a great tool for writing texts with lots of mathematical symbol and equations as well as formatting the text into a readable and presentable form, like that of an academic paper. The project also gave me an insight into the skills needed to carry out philosophy of physics research and where these differ from in tutorials, with the emphasis in discussions being on bringing original takes to the literature as opposed to analysing the literature as we do in tutorials, for example. Being in Oxford in person allowed me to do so on an in person, one-to-one basis which is invaluable experience with a philosopher of physics of such calibre.

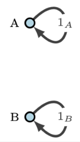
In the paper we were responding to, authors argue that the conclusion of The Hole Argument (more precisely, a common conclusion as there are several ways in which it can be interpreted given different conclusions about general relativistic spacetime) of pernicious indeterminism if one adopts substantialism towards spacetime in general relativity, is in fact a trivial problem because the different solutions mapped between in The Hole Argument in fact represent the same physical state of affairs. They give two ways in which this is the case and we criticised one mathematically and one metaphysically. The authors motivated one part of their argument using category theory; the extract below shows a part of my response to one section of their paper. I had not yet studied category theory so it was very interesting to look into this for the first time; it is always interesting to find new mathematical ways to represent reality. This project gave a great insight into what it would be like to do research into philosophy of physics and helped develop skills that will be very useful for writing my thesis this coming year. This project was a very enjoyable part of my summer and an experience I will always be grateful for.

In section 3 of the paper, Halvorsen ad Manchak introduce categories **C** and **D** related by a forgetful functor, U from **D** to **C** (i.e. $U : \mathbf{D} \to \mathbf{C}$). A given object (say A) of category **D** has 'more structure' than the corresponding object of category **C** $U(A)$ so some of the structure of the object is 'forgotten' under the action of the functor. Despite some of the structure of the objects within **D** being forgotten, the functor U is such that the invariants of **D** are preserved by the morphisms of **C**. Halvorsen and Manchak, in the fourth section of their paper, then gave an example of two such categories.

Category **C**:



Category **D**:



The category **C** consists of the set of objects $C_0 = A, B$ and the set of arrows between objects $C_1 = 1_A, 1_B, f, g$ such that $1_A : A \to A$, $1_B : B \to B$, $f : A \to B$ and $g : B \to A$. The category **D** is the same except the f and g arrows are omitted so that **C** and **D** are non-isomorphic. These categories are set up to represent two theories, which Halvorsen and Manchak call T_C and T_D (corresponding to the respective categories). According to such an example, the theory T_C represents one possibility with A and B being two different ways of representing the same possibility. They are different representations because A and B are different models (potentially different mathematical ways of representing the state of affairs) but, as T_C entails that A and B are isomorphic, under this theory, the different representations are of one and the same possibility. Under the theory T_D however, A and B represent different possibilities. This is because Halvorsen and Manchak take the standard of equivalence to be that of isomorphism. Under T_D, A and B are non-isomorphic and so represent distinct possibilities. Another way of thinking about this is that one possibility is represented by a class of objects in the category related by isomorphisms (arrows).