

## Can condensed matter physics inform the metaphysics of substance?

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### Abstract

*Substance theory states that any object-like thing is constituted by a metaphysically independent substance and the properties borne of that substance (Robinson, 2020). There are some counterexamples to substance theory that physics might provide; for example, condensed matter physics offers the quasiparticle (QP). QPs like electron holes and phonons cannot exist independently of other objects, which might imply that, according to substance theory, they are un-object-like; however, they are often imagined as objects by condensed matter physicists. To investigate how physicists, philosophers, and laymen understand problems at the physics-substance theory intersection, a survey posing several open-ended problems was distributed. Participants were surveyed on the metaphysical necessity of extrinsic properties, the metaphysical distinction between colour and light, and the substancehood of QPs. The responses of 141 participants to five questions were analysed both qualitatively and quantitatively. The majority (64%) of participants responded that extrinsic properties necessarily contribute to an object's identity, indicating the idea of metaphysical independence may need refining. A significant number of participants (19%) suggested QPs are 'metaphysically between' object and property, which might indicate QPs require their own metaphysical status, perhaps as 'quasiobjects' or 'quasisubstances'. It was concluded that, to investigate 'quasiobjects' further, modal logic should be utilised to represent what they might be and how they might fit within the framework of substance theory.*

*Keywords: Condensed matter physics, substance theory, metaphysics, quasiparticle*

### Introduction

This report was financed and supported by UROS, a competitive bursary scheme that promotes collaborative research between students and academics through the creation of a summer research project. This scheme embodies the Student as Producer model and encourages undergraduates to take on researcher and author roles before graduating (Strudwick, 2021). Having learned about UROS, I was enthusiastic to participate, as this project is both contemporary and an amalgamation of the course I am currently on: Physics with Philosophy.

## Project Background

Substance theory argues that any object-like thing is constituted by a substance and the properties borne of that substance; a substance is defined as that which is metaphysically independent (Weir, 2021). Physics provides many interesting concepts in relation to substance theory. For example, light and colour are constituted of photons; however, not only are photons massless, but they behave as both particles and waves. This leads to questions about whether waves and massless particles should be classified as substances and, further, whether light and colour are metaphysically distinct. Quasiparticles (QP), like electron holes and phonons, also pose problems. QPs are often treated as objects and as metaphysically indistinct from any other particle by condensed matter physicists; however, they cannot exist independently of their respective substrates. An interesting area of research would be on whether physicists generally see QPs as objects and how correct they might be in doing so. Accordingly, this would usher in questions about whether some entities can be 'metaphysically between' substance and property.

This project aims to investigate how constructs from condensed matter physics fit into substance theory. This will be addressed by surveying physicists, philosophers, and laymen on their intuitive solutions to problems that relate to the intersection of physics and substance theory.

## Literature Review

The nature of objecthood has been at issue since Aristotle first attempted to define object-like things as substances (Weir, 2021). Aristotle proposed that a substance is something that exists in its own right. This is in opposition to things like colour, which exists relationally "in a subject," like how green exists "in," for example, a blade of grass, or things that exist "of" a subject, such as the way "blossoms" is said "of" a flower (Weir, 2024). Descartes refined the concept of substancehood, describing substances as those in which properties, qualities, and attributes reside. In other words, substances are those on which everything else is metaphysically dependent for their existence; hence, substances are metaphysically independent. (Robinson, 2024)

Descartes' rendition of substance was later objected to and critiqued as incoherent, first by Leibniz and then by many others in suit (Leibniz, 1989). Leibniz's objection is as follows: for an entity to be metaphysically independent, it must be able to exist without anything it is nonidentical to; however, so-called substances depend for their existence on the existence of their own parts and properties; thus, they cannot truly be metaphysically independent (Weir, 2021). Weir rejected this objection on the basis that it was founded on an unnatural definition of metaphysical independence. Weir proposed that metaphysical independence is not when something can exist independently of anything nonidentical to it, but rather when something can exist

independently of anything that is over and above (or unsubsumed by) it (Weir, 2021). By this definition, it is plausible that something like a table can be metaphysically independent since a table's parts and properties are neither over and above nor an addition to our conceptualisation of the table, but rather they are subsumed by the table itself.

It is from Weir's definition of substancehood that this project was placed, aiming to investigate how it holds in relation to physical entities like photons and QPs. It was hypothesised that entities like QPs might require their own metaphysical category, such as 'quasisubstance' or 'quasiobject.'

## Method

The study employed a mixed-methods approach to gather both quantitative and qualitative insights into intuitive perspectives on problems regarding the nature of substance and objecthood. Before participating in the survey, all respondents were required to complete a consent form. The survey was anonymous to preserve confidentiality and was hosted on Microsoft Forms. An information sheet was provided to explain the survey's intent, style, and data storage protocols. In total, eight questions were presented to participants, of which only five were analysed, with three being unquantifiable.

Responses were analysed qualitatively on a case-by-case basis to extract the key response themes to each question for the quantitative analysis. The open-ended survey questions encouraged participants to provide nuanced insights rather than restrict responses to predefined answer options. This approach enabled a more comprehensive exploration of perspectives while also being less costly than conducting interviews.

The second aim was to create a dataset for statistical analysis. Information regarding participants' fields of study was collected to assess potential correlations between background knowledge and survey responses. Participants were categorised into three groups: physicists, philosophers, and laymen, based on their academic backgrounds, with laymen encompassing individuals without a physics or philosophy background. In total, a sample size of 141 participants was surveyed. Students and academics were contacted to participate via University of Lincoln email channels, and the survey access link was posted on both physics and philosophy Reddit pages.

## Results

The results section provides an analysis of both the qualitative and quantitative key findings. Survey questions can be seen in Figures 1–5, with their respective quantitative analyses in Tables 2–6. It should be noted that the percentages presented do not include blank or unsure answers (non-answers) and are rounded to the nearest half decimal place. A breakdown of the participants' fields is provided in Table 1.

| Participant field | Number of participants |
|-------------------|------------------------|
| Physicists        | 67                     |
| Philosophers      | 23                     |
| Laymen            | 51                     |
| <b>Total</b>      | <b>141</b>             |

Table 1: Table displaying number of participants for each field of education, as well as a combined total in bold. Notably, the total number of participants was 141, and the average completion time was 48 minutes.

**Q1. Let us consider an electron.**

- **We can attribute three intrinsic properties to an electron: charge, mass, and spin. We call these properties intrinsic because they are innate to electrons.**
- **We can also attribute to the electron some extrinsic properties like spatial location, temporal location, and velocity. We call these properties extrinsic because they are defined by the object's relationship to the external world.**

a) Do you think an object like an electron can be fully defined by its properties, or is there something that an object 'is' that is not fully captured or described when you consider only its intrinsic and extrinsic properties?

Figure 1: Image of Question 1a taken from the Microsoft Forms survey. This question displays a prompt in red for the participant to consider.

Responses to Question 1a dichotomised between an essentialist and a nominalist position. Essentialists stated that the electron was more than the sum of its properties and had an essence, or form, that it was imperfectly embodying. Nominalists argued that electrons are the sum of their properties, although it was frequently posited that some properties were unknowable.

|                  | Essentialist position | Nominalist position | Non-answers |
|------------------|-----------------------|---------------------|-------------|
| Physicists       | 19.5%                 | 80.5%               | -           |
| Philosophers     | 41%                   | 59%                 | -           |
| Laymen           | 36%                   | 64%                 | -           |
| All participants | 31.5%                 | 68.5%               | 18.5%       |

Table 2: Table showing the essentialist/nominalist alignment percentages and percentage of non-answers for Question 1a, broken down by participant academic field and all participants.

Substance theory is arguably more in line with the nominalist position since the existence of non-spatiotemporal acausal abstracta like idealised forms or essences, often implied within the essentialist position, adds complications to the theory; hence, the physicist and layman responses can be said to support substance theory.

If you answered in the previous question that an object *can* be fully defined by its properties, then consider the following question; otherwise, skip.

b) If an object can be said to be the sum of its properties, do you feel this includes its extrinsic properties? Or can an object be fully defined by solely its intrinsic properties and without taking into consideration its relationship with the external world (e.g., where it is located)?



Figure 2: Image of Question 1b taken from the Microsoft Forms survey. This question displays instructions in red telling the participant to skip depending on their answer to Question 1a.

Question 1b responses dichotomised into a holistic and a reductionist position. The holistic position was that an electron's external relations are necessary for a full definition, with one response stating, "*Externalities are important in quantum physics and field interactions.*" The reductionist position often referenced identity; one participant stated, "*You can identify an electron from its intrinsic properties alone.*" Participants who took on an essentialist position in Question 1a were instructed to skip this question, as it was incorrectly thought that the holistic position was already implied by the essentialist position. In retrospect, this was a mistake.

|                  | Holist position | Reductionist position | Non-answers |
|------------------|-----------------|-----------------------|-------------|
| Physicists       | 64.5%           | 35.5%                 | -           |
| Philosophers     | 43%             | 57%                   | -           |
| Laymen           | 69%             | 31%                   | -           |
| All participants | 64%             | 36%                   | 42.5%       |

Table 3: Table showing the holist/reductionist alignment percentages and percentage of non-answers for Question 1b, broken down by participant academic field and all participants.

Substance theory is plausibly more aligned with the reductionist position since it states object-like things are metaphysically independent, which arguably discounts extrinsic properties; thus, the physicist and layman responses to Question 1b do not support substance theory.

**Q2. Contemporary physics describes light as comprising of particles called photons. However, light is also sometimes considered to be a wave.**

Do you consider light an object or not, and why?



Figure 3: Image of Question 2 taken from the Microsoft Forms survey. This question displays a prompt in red for the participant to consider.

Question 2 responses split between arguing that light either is or is not an object. Some participants argued light is an object because it is causally active, while others argued light's wave nature makes it a non-object.

|                  | Light is an object | Light is not an object | Non-answers |
|------------------|--------------------|------------------------|-------------|
| Physicists       | 70%                | 30%                    | -           |
| Philosophers     | 82%                | 18%                    | -           |
| Laymen           | 50%                | 50%                    | -           |
| All participants | 64.5%              | 35.5%                  | 24%         |

Table 4: Table showing the light is an object/light is not an object alignment percentages and percentage of non-answers for Question 2, broken down by participant academic field and all participants.

It was predicted that some participants would argue that light is something close to an object, such as a 'quasiobject'; however, the results did not support such predictions. Table 5 shows physicists and philosophers tend to see light as an object, while laymen overall are undecided.

**Q3. When we observe a blade of grass we may experience the colour green. One might say then that the blade of grass has the property of being green. However, consider the following argument:**

**Premiss 1: A photon is an object.**

**Premiss 2: The colour green is associated with photons of a specific range of wavelengths.**

**Conclusion: Therefore the colour green is itself an object.**

Do you agree with this argument or not, and why?



Figure 4: Image of Question 3 taken from the Microsoft Forms survey. This question features a counter-intuitive argument in favour of colour being an object in red for the participant to consider.

Question 3 responses were split between arguing that colour is either an object or is not. While the overwhelming majority argued for the latter, there was variability in how this was done. Many argued that colour is a property of photons, not an object. One participant said, “*Since colour is mind-dependent, it cannot be an object. It is qualia.*” On the contrary, one participant adopted a pragmatist position, stating, “*They can be objects when we need them to be.*”

|                  | Colour is an object | Colour is not an object | Non-answers |
|------------------|---------------------|-------------------------|-------------|
| Physicists       | 6%                  | 94%                     | -           |
| Philosophers     | 0%                  | 100%                    | -           |
| Laymen           | 16%                 | 84%                     | -           |
| All participants | 8.5%                | 91.5%                   | 10%         |

Table 5: Table showing the colour is an object/colour is not an object alignment percentages and percentage of non-answers for Question 3, broken down by participant academic field and all participants.

This question presents an argument in favour of colour being an object to stress participants' intuition and encourage a deeper analysis of the question. Nevertheless, most participants argued that colour is not an object and supported substance theory's property-substance distinction.

**Q4. In physics, quasiparticles are special entities that can emerge in certain material structures, such as semiconductors. Among these quasiparticles, there is one called a "hole" which behaves like a positively charged particle in the material. It is customary to treat quasiparticles as if they were objects with properties just like any other particle. However, unlike other particles, they cannot exist independently of the systems they emerge in and some physicists consider them to be emergent phenomena that merely resemble particles rather than real objects.**


Would you consider quasiparticles to be objects, properties of the systems they exist within, or something else entirely, and why? 

Figure 5: Image of Question 4 taken from the Microsoft Forms survey. This question displays a short text explaining what QPs are and how they are sometimes treated by physicists in red for the participant to consider.

Question 4 responses suggested QPs were either objects, not objects, or something in between. In favour of QPs being objects, one participant reasoned, “*Organs can't*

*function without the body but are objects.*" Many (29%) argued that QPs are not objects because they cannot exist by themselves. Some (19%) argued for the concept of quasiobjects; one participant stated, "*[QPs] don't meet the criteria to be an object, but they're more than not-an-object,*" and another stating, "*Quasi-objects?*".

|                  | QPs are objects | QPs are not objects | QPs are 'quasiobjects' | Non-answers |
|------------------|-----------------|---------------------|------------------------|-------------|
| Physicists       | 25%             | 55.5%               | 19.5%                  | -           |
| Philosophers     | 20%             | 73.5%               | 6.5%                   | -           |
| Laymen           | 37.5%           | 37.5%               | 25%                    | -           |
| All participants | 29%             | 59%                 | 19%                    | 22%         |

Table 5: Table showing the QPs are objects/QPs are not objects/QPs are 'quasiobjects' alignment percentages and percentage of non-answers for Question 4, broken down by participant academic field and all participants.

Question 4 aimed to understand how QPs fit into substance theory, and like Question 2, it was predicted that an entity like a 'quasiobject' may be argued for. With 59% arguing that QPs are not objects, the results support substance theory's assertion that objects are things that can exist by themselves. Notably, 19% argued that QPs are 'quasiobjects', indicating that the 'quasiobject' concept has an intuitive basis, and provides motivation to develop the concept in future research. Substance theory is fundamentally based on intuitive identification of entities, and this leaves a lot of room for subjectivity. Substance theory should be expanded to include a category like 'quasiobject' for those entities, like QPs, that are harder to classify.

### UROS Experience

Participating in the UROS project has been an intellectually enriching experience. I learned how researcher-supervisor relationships work in real research projects, a number of research and literature analysis skills, and some technical skills in survey distribution and modal logic. The most transformative aspect was learning how to creatively solve the philosophical problems I was researching, both by myself and collaboratively. I am grateful for the support of my supervisors, who engaged in extensive daily discussions about the project, and my colleague, Phillip Coleman, whose unwavering assistance was indispensable to the project's progress.

### Conclusion

Quantitatively, there was a wide range of responses that often strongly supported substance theory. It was only the analysis of Question 1b that could be argued to be in contradiction with substance theory. The majority (64%) of participants argued that extrinsic properties necessarily contribute to an object's identity, indicating the idea of metaphysical independence may need refining. Unfortunately, Question 1b's phrasing introduced bias, making this conclusion unreliable. The conclusions drawn from the analysis of Question 4, namely that a significant number (19%) intuited the concept of quasiobjects, would support exploring this concept in greater detail. Future research should be conducted on the philosophical feasibility of quasiobjects.

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