I. Timokhin & A. Mischenko (2016). *Novel approach to Room Temperature Superconductivity problem.*

[*https://arxiv.org/abs/2003.14321*](https://arxiv.org/abs/2003.14321)

This paper is not printed in a peer-reviewed journal but is instead on the Physics arXiv (pronounced *archive*). The arXiv is an open-access repository of papers that have been moderated but haven't gone through the peer-review process of a journal. Many papers on the arXiv are first drafts of papers to show the scientific community that the work has been done whilst the manuscript goes through the (sometimes lengthy) process of peer review.

The arXiv is full of amazing papers, but we must be even more cautious about information found here as it has not been thoroughly checked and may, therefore, be wrong. This paper is on the arXiv, though, as it is a more light-hearted paper and will almost certainly not be acceptable to a scientific journal.

Last week, we discussed how the author list works, with the superscript number next to each author corresponding to the institution that they work for. This week, you'll see that the authors are working from home during the COVID-19 pandemic, and as we shall see, are clearly working in their kitchen.

ABSTRACT

Remember, the abstract is a short summary of the main findings of the paper. Scientists use them to work out whether or not they need to read the rest of the paper.

What is T_C?	The superconducting critical temperature of a material.
What novel approach have the authors taken?	Rather than actually finding a new superconducting material whose T_C value lies around typical room temperatures, they've chosen to simply lower the temperature of a 'room' to below the critical temperature of a known superconductor. Thus they have a '*room temperature'* superconductor.
Why should we be wary of papers on the arXiv that propose a 'novel approach'?	Without being peer-reviewed, there's no guarantee that the work is 'correct'. Peer-review is not a perfect process, but is the best system we currently have, and does a good job of filtering out papers that have significant errors in their experimental procedure/data analysis/conclusions. A paper purporting to give a novel solution to an old problem that has not been peer-reviewed may well be incorrect. To me, it often brings to mind people searching for perpetual motion machines (it's always fun to work out why these are not truly perpetual motion machines: https://makezine.com/2016/04/07/these-7-machines-may-just-convince-you-perpetual-motion-is-possible/)

One of the things we often have to do when reading papers is to follow a reference or look up a concept you don't already know about so that you can fully understand a piece of work. As you do this, more and more tabs open on your computer and you might start to feel a bit lost in the web of references, and ultimately forget what you're looking for in the first place.

If, after a bit of reading, if you notice that you're feeling the urge to start tracking down more than just the odd fact, then stop and write down exactly what you're hoping to find out. If you're going to start trawling through literature and the rest of the internet, then you need a bit of direction. This is where Cornell notes are so useful. This is what to do:

- Skim read the entire article and highlight or list bits that you don't know about. It's absolutely fine to not understand things – it may even be the authors fault for not being clear.
- Phrase these ideas into a few prompt questions in Cornell notes. The questions should be written to maximise the amount of the article that you'll be able to understand afterwards.
- Google or use the references in the text to find answers to your questions and write them in your own words in as succinct a form as possible.
- Your answers might not be completely perfect, but they will hopefully get you to a better understanding of the paper. The next time the same concepts appear in your reading, you'll learn a little more and a little more.

The key thing is that you can't become an expert in a field overnight. It takes prolonged exposure to ideas in multiple different circumstances. It could take a lot of time, particularly at this stage in your education, trying to gain a *complete* understanding of just one idea within this article. But you're not expected to have a complete understanding yet – we need to learn enough to get by to gain further exposure.

At this point, ***skim read the entire article***, thinking about what questions you have.

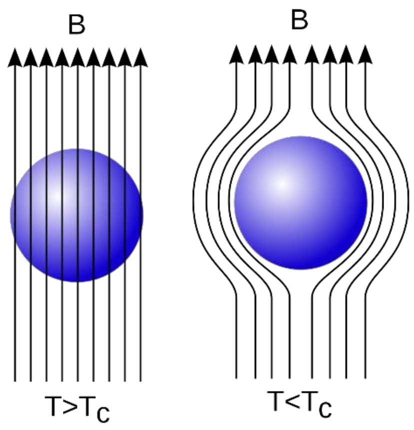
Our suggested questions would look something like this

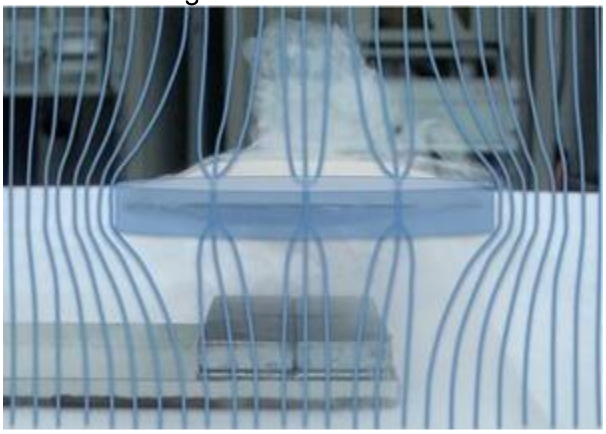
1. Why do superconductors have a superconducting transition temperature?
2. What are the behaviours that indicate an object is in a superconducting state?
3. What is the Meissner effect?
4. What is flux locking (also known as quantum locking)?

Here, we've done the next bit for you which is to proceed to answer the questions you've written by doing a bit of research. Below is just an example of what you might write. Added in brackets after each answer are the places we found the information – note that we didn't just use Wikipedia, we always verified any information we found there by checking a non-editable source of information. *But* Wikipedia is an excellent resource if used carefully, just like the arXiv.

Under each example answer that's been written for you, write down an answer *in your own words* to the same question, using the references that we've found. Here we're trying to break the process down for you so you don't waste time doing your own Googling right now – we just want you to concentrate on reading the information and synthesising a simple answer.

1. Why do superconductors have a superconducting transition temperature?	Much like cooling water so that it forms ice (a transition that occurs at a specific temperature, the melting point: 0^{o}C), superconductivity is a phase of matter that occurs below a specific temperature (the superconducting transition temperature). In water and ice, the transition alters the intermolecular bonds between water molecules. In the superconducting transition, it's a transition in the way that the electronic structure (the electrons) behave. Once cooled, the electrons behave as if there's no electrical resistance within the material (from the lattice). For conventional superconductors, the reasons for this are understood (the electrons form Cooper pairs), but there are a group of superconductors – the high temperature superconductors – where the mechanism for the electrons' pairing remains unknown.

	To form this answer we read the first couple of paragraphs of this: https://en.wikipedia.org/wiki/Superconductivity#Phase_transition And we read about half of the superconductivity section (Section 21-5) of this https://www.feynmanlectures.caltech.edu/III_21.html (The online Feynman lectures are a great resource by the way). **Your own answer:**
2. What are the behaviours that indicate an object is in a superconducting state?	The superconducting transition is highlighted by abrupt changes in the materials resistivity and its specific heat capacity (a so-called phase transition). In its superconducting state, a superconductor has zero electrical resistance (which makes it useful for lossless transmission of electrical currents). A 'perfect conductor' would also display zero resistance but what sets a superconductor apart from a perfect conductor (as well as the abrupt phase transition) is the Meissner effect. We read this http://www.chm.bris.ac.uk/webprojects2006/Truscott/paged_r.html And this https://en.wikipedia.org/wiki/Superconductivity#Elementary_properties_of_superconductors **Your own answer:**
3. What is the Meissner effect?	The sudden expulsion of a magnetic field from within the bulk of a superconductor when cooled below its superconducting transition temperature. As soon as the temperature is below T_C, a superconductor instantly ejects a magnetic field from within its bulk (the magnetic field does penetrate a small distance into the material – the London penetration depth).  Taken from https://en.wikipedia.org/wiki/Superconductivity#Meissner_effect And https://www.open.edu/openlearn/science-maths-technology/engineering-technology/superconductivity/content-section-2.3 **Your own answer:**

<table>
<tr>
<td>4. What is quantum locking (also known as flux pinning)?</td>
<td>Imagine we have a superconductor that is held below its superconducting transition temperature so that it is in its superconducting state. The superconductor is placed within a magnetic field and the strength of the magnetic field can be altered. Above a certain field strength a ‘type-I’ superconductor will stop being superconducting – it will go through a phase transition (just like it did with temperature) to a non-superconducting state. A ‘type-II superconductor’ behaves differently and above a certain field, it no longer expels all of the magnetic field, but allows the magnetic field to enter the bulk and penetrate the material in the form of ‘flux tubes’ (simply cylindrical regions of the superconductor that now allow a magnetic field to pass through). These regions are fixed in place within the superconducting material (but change in number if we alter the field). These tubes act to literally pin the superconductor where it is relative to the applied magnetic field – allowing you to turn the magnet upside down and have the superconductor stay in place now ‘hovering below’ the magnet.

We got this from
https://en.wikipedia.org/wiki/Flux_pinning
And definitely watch the following video (and ignore the manic laughing)
https://www.youtube.com/watch?v=Z52_2WGCJak

Your own answer:</td>
</tr>
</table>

Now that we've researched the few concepts that underpin the majority of this paper, you should now be in a much better position to understand *most* of the article. You might still not appreciate the entirety of the experimental setup, but you should understand the general idea of what they’re doing (and begin to understand the joke behind the paper).

We now want you to read the article in more detail now, and just as we've done in previous weeks, answer the comprehension questions for each section as we go along.

INTRODUCTION

You'll see scientists use their own abbreviations quite frequently, and let you know what they are by including them in brackets after the first use of the term. What does RTS stand for here?	Room Temperature Superconductivity
What is the Kelvin scale of temperature? If room temperature is generally considered to be 295K, what is this in degrees Celsius?	The Kelvin scale of temperature puts 0K at the lowest limit of the thermodynamic temperature scale. Thus, 0K is at absolute zero, where the motion of particles is at its minimum (with only quantum mechanical vibrations remaining). 295K = (295 – 273) ^{o}C = 22 ^{o}C
Looking at the chemical compostion of the rare-earth superhydride LaH_{10}, why are they called rare-earth superhydrides?	The rare-earth part of the name comes from them containing a rare-earth element – in this case Lanthanum (La). The superhydride part of the name comes from them containing many (super) Hydrogen (hydride) atoms.
Superhydrides have some of the highest T_C values found so far. What is their disadvantage?	They require extreme pressures to induce their superconducting state at close to room-temperature.
The formula for pressure is P=F/A where F is the applied force and A is the surface area over which it's applied. To achieve high pressures, what are the two things we could do?	Increase the force (since the pressure is directly proportional to the applied force). Decrease the area over which the force is applied (since the pressure is inversely proportional to the area).
What is one of the reasons LaH_{10} needs to be under high pressure?	So that it remains stable. The rare-earth superhydrides can only *exist* under extreme pressure.
Why might it be difficult to measure the Meissner effect within a diamond anvil?	When a sample is being squashed in between two pieces of diamond, it leaves very little space for the kinds of equipment that would be needed to monitor magnetism within a sample (such as attaching a coil of wire around it).

What does the abbreviation YBCO stand for?	Yttrium barium copper oxide.
Convert the superconducting transition temperature of YBCO (92 K) to ^oC.	92K = 92 - 273 ^oC = -181 ^oC
Liquid nitrogen has a boiling point of –196 ^oC (77 K), why is this a useful fact for their experiment?	As liquid nitrogen must be cooler than the T_C of YBCO, then we can liquid nitrogen as the cryogen in the Cryocooler to get YBCO into its superconducting state.

MATERIALS AND METHODS

What are the scientists actually cooling? (Figure 1C)	The walls of the room. The cold tip of the cooling equipment is contacting the floor of the room.
Why do they use thermal grease to attach the YBCO to the room initially?	To ensure there's good thermal contact so that the YBCO can be cooled.
What is a 'field cooling'?	Cooling the sample of YBCO whilst within an external magnetic field.
Why might the base temperature (80 K) be higher than the boiling point of liquid nitrogen (77 K)?	As the cryocooler equipment utilises the liquid nitrogen for cooling, the nitrogen warms up and boils off. Thermal equilibrium is reached at a temperature that is higher than the boiling point of nitrogen, highlighting the lack of perfect efficiency in cryocooling equipment.
Why do they evacuate the room down to a pressure of 10^{-3} mbar?	To prevent things in the air from condensing onto the sample. It will also make cooling a little easier as the air would act like insulation.

RESULTS AND DISCUSSION

In Figure 2 A and B we see an abrupt change in behaviour (when the temperature changes from below to above T_C) - why is this important?	It shows that a phase transition has taken place – YBCO becomes superconducting (and stops becoming superconducting) abruptly when the temperature transitions through the superconducting critical temperature. The abruptness indicates that this is truly the superconducting transition.
Why is the term equilibrium important to this scenario of an object freely ‘floating’?	It’s in equilibrium as it’s experiencing balanced forces so that it remains stationary.
What are differences in the forces that the superconductor experiences in Figure 2A and the magnet experiences in Figure 2C that allow them to ‘float’?	In Figure 2 A the floating superconductor is positioned at a point in the magnetic field where the repulsion from the magnet balances its weight (and is aided by the quantum locking effect). In Figure 2C, the weight of the magnet and the repulsion it feels from the superconductor both act downwards. The balancing force comes from the quantum locking effect, essentially holding the magnetic field in place so that the magnet cannot move.
Why do they also need to perform the experiment upside down (note that the magnet is now suspended in Figure 2 C-F)?	To truly show the effect of quantum locking in a type-II superconductor. The magnetic field has been locked through the superconductor so that the magnet cannot fall – it is being suspended, in essence, by the trapped magnetic field lines that have penetrated the pellet of YBCO.
In Figure 2 D and E, why has the magnet moved slightly?	Because an external magnetic field has been applied – this alters the magnetic field in the vicinity of the magnet, causing a small shift in the magnet’s orientation to find the new equilibrium point.
Why does the magnet move back to its original position in Figure 2 F?	When the external magnetic field is removed, the magnetic field experienced by the magnet reverts to what it was previously, and therefore the magnet’s position of equilibrium returns to the same as in Figure 2 C.

SUMMARY (send your answers to thomas.millichamp@warwick.ac.uk)

This week, rather than summarising the paper (as hopefully you can see that the paper is really only humorous), you're going to follow the approach that we took during this paper of finding and answering the key questions needed to understand the majority of a scientific work.

For this paper, we skim read the whole piece and decided that we needed to know answers to the following questions to get a good comprehension of the article:

1. Why do superconductors have a superconducting transition temperature?
2. What are the behaviours that indicate an object is in a superconducting state?
3. What is the Meissner effect?
4. What is flux locking (also known as quantum locking)?

We then researched answers to these questions and wrote them in our own words.

You're going to do the exact same thing for a different article this week to show that you can find the key relevant background knowledge. We want you to do the following:

1. Skim read this article (J. M. A. Chawner *et al.* (2019), *LEGO® Block Structures as a Sub-Kelvin Thermal Insulator,* Scientific Reports, **9**, 19642)
2. List between three and five key questions on the background information that the reader (you) needs to know to attempt to understand the piece.
3. Find answers to these questions, writing them in your own words but also giving your sources (simply as links, not using full referencing technique for now)

Submit these to thomas.millichamp@warwick.ac.uk and the best questions and answers will be published on the website next week (along with the answers to all of the comprehension questions above).

Further reading

This article outlines some of the current research towards finding a truly 'room temperature' superconductor (that is one where the superconducting state occurs at a normal room temperature, not where we cheat and cool the entire room instead!)

https://www.nature.com/articles/d41586-019-01583-y