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Experimental Techniques for Low-Temperature Measurements by Jack W. Ekin, Oxford University Press, Oxford, 2006, pp. xxvii + 673. Scope: monograph. Level: postgraduate, scientists and engineers.

We are fast approaching the centenary of the historic first liquefaction of helium by Kamerlingh Onnes and his team in Leiden, on 10 July 1908. Helium was the last of what had been called the "permanent gases" to succumb to the sustained international efforts of many scientists. Their difficulty had been mainly that its liquefaction temperature would turn out to be so low. But at about 4 K it duly collapsed into a colourless liquid whose extraordinary properties would not be properly appreciated or understood for another three decades. One of its oddest features, whose explanation had to await the advent of quantum mechanics, is that helium at low pressure does not solidify at all but remains liquid right down to the absolute zero of temperature – unlike every other material.

It was the liquefaction of helium that launched low temperature physics as a distinct subdiscipline, and provided a basis for many of the technologies that followed. It enabled experiments to be carried out over a huge range of lower temperatures, in some cases far below 4 K: by pumping on a bath of the common isotope ^{4}He one can reach 1 K; pumping a bath of the rare isotope ^{3}He takes one to 0.3 K; appropriate mixing of the two isotopes (dilution refrigeration) enables the attainment of temperatures down to 2 mK, providing the launching pad for nuclear demagnetization techniques to temperatures a thousand times colder again.

It was quickly discovered that the properties of all materials undergo enormous changes as their temperatures are reduced below ambient. For example, thermal contraction occurs and continues down to about 50 K or lower for some materials. Thermal conductivity can rise, or fall, by many orders of magnitude, and often changes nonmonotonically. The same is true of electrical resistance, which can even fall to zero if the conductor enters the superconducting state. Specific heats must all approach zero at low enough temperatures according to the Third Law of Thermodynamics, but they can exhibit complex behaviour before they reach the ultra-low temperature range. Phase transformations also occur and, around 4 K not only water but also air, hydrogen – and indeed everything except helium itself – are frozen solids. It is a very different world to the one we inhabit at room temperature. Not surprisingly, enormous care is needed to design cryostats and other machinery and instrumentation to operate at low temperatures.

Jack Ekin's book has been written to help a wide range of experimentalists, including graduate students, physicists, engineers, material scientists and experienced researchers who need to make measurements or design equipment to function at low temperatures. It tells them how to do it. In his Preface, he says that "The mantra for this book is that it be *useful*". Acting on this he describes in some cases how not to do things – his own errors from the past – as well as approaches that do work. It is a big book. Its 673 pages are divided between 10 chapters, with enumerable figures and tables, covering everything that the practicioner needs to know.

Part I of the book, consisting of chapters 1–6, is devoted to cryostat design. It covers the different types of cryostat used for measurements down to about 1 K, how to choose them, how to design and run them, and how to make measurements in them. There is extensive discussion of the selection of constructional materials, how heat transfer takes place at low temperatures, soldering, welding, thermal anchoring of measurement leads, high vacuum techniques, electrical lead-throughs, temperature measurement and control, and much else. A lot of physics is included too, but it is brought in as needed to illustrate the practicalities of design. The rest of the book is more specialised. Part II consists of just two chapters, and is devoted to the practicalities of making electrical transport measurements. Again, there is detailed explanation of how to do them including the design/selection of sample holders for different purposes and how to make good contacts. The final two chapters comprising Part III cover how to measure and analyse critical currents in superconductors. There are extensive references and a select bibliography for each chapter, and 135 pages of appendices providing essential data about the materials needed for cryostat design.

All those involved in low temperature physics or cryogenics can with advantage dip into Jack Ekin's book. It is the distillation of a lifetime's experience in cryogenics, and even very experienced practicioners will find useful tips and ideas about how to do things better. Part I especially is quite generally applicable and likely to be useful to a wide range of physicists and engineers interested in measurements down to 1 K. It will also be of use to those working at the far lower tempertatures where most of the cutting edge work in the discipline is now to be found, given that even state-of-the-art nuclear demagnetization cryostats have much of their structure operating above 1 K. Every low temperature laboratory, as well as libraries, will need a copy.

Peter V. E. McClintock

Lancaster University.