Cryogenics Lab

Electrical Resistance Measurement

Set up a 4 wire resistance measurement outside the cryostat.

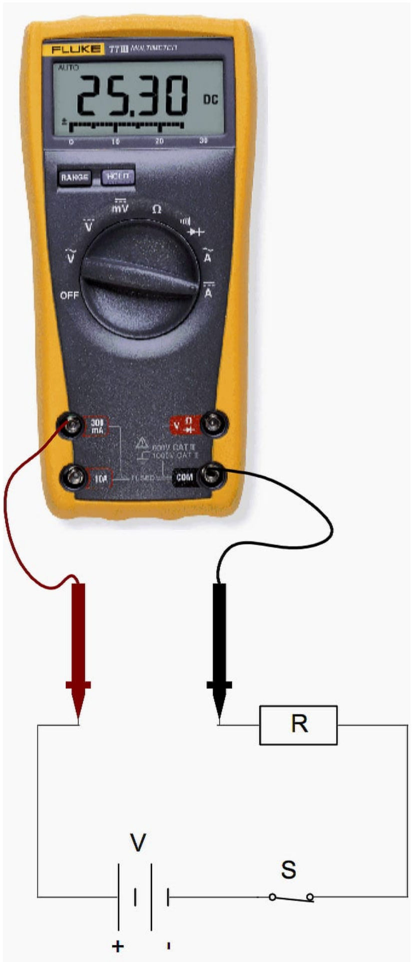
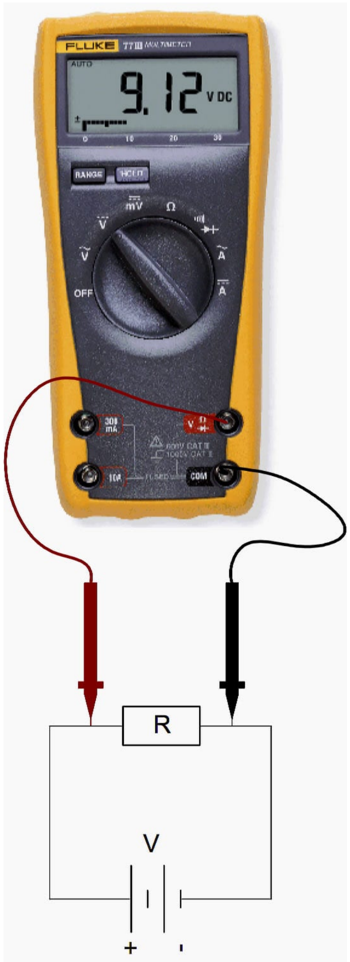
Setup: We need to know the resistances of both heaters and thermometers when they're inside cryostats. Cryogenic thermometers are devices with resistances that change significantly with temperature. Heaters are resistors we use to deposit power in known places, sometimes we want to heat stages to specific temperatures and sometimes we want to use them to calibrate our cryocoolers. In all these cases, we can't know the temperature of these devices from the start.

The wires used to connect to these thermometers and heaters also have non-trivial electrical resistances because we usually use materials with low thermal conductivity. The low thermal conductivity is necessary when wires cross stages with large temperature differences. These wires will also change electrical resistance with temperature, so we cannot know their resistance from the start either.

So, it is very important to have a method of accurately measuring resistances while a device is inside a cryostat. In our troll cryostat we have three heaters (resistors) and we want to know their resistances. Each side of the resistor is connected to two wires. All these wires go through the cryostat feedthrough so we can connect to them. You have a power supply, 2 multimeters, and however many jumper cables you need.

Draw the circuit connecting to each heater:

Measuring Current and Voltage require different multimeter setups:
BE 100% SURE YOU WILL NOT BLOW THE LOW CURRENT FUSE BEFORE CONNECTING TO THE LOW CURRENT MODE.

Current Setup	Voltage Setup
	

Draw the setup for measuring the resistance of each heater:

What is the resistance of each heater?

A:___________________

B:___________________

C:___________________

What are the wire resistances going to each heater?

A:___________________

B:___________________

C:___________________

I am working on calibrating our Pulse Tube Cryocooler. I want to put exactly 250 mW on resistor A, how do I do that?

Cable Properties	Length (mm)	Gauge (AWG)	Diameter (mm)
Cable A	610	32	0.203
Cable B	370	30	0.254
Cable C	580	30	0.254

(We know these values because we measured them before closeup!)

What are the resistivities of each wire, are they all the same material?

$R = \rho \frac{L}{A}$

A:_________________

B:_________________

C:_________________

The image below contains information about the different properties of cryogenic wires sold by Lakeshore.(https://www.lakeshore.com/products/categories/specification/temperature-products/cryogenic-accessories/cryogenic-wire)

Specifications

Material properties		Phosphor bronze	Copper	Nichrome	Manganin
Melting range		1223 K to 1323 K	1356 K	1673 K	1293 K
Coefficient of thermal expansion		1.78×10^{-5}	20×10^{-6}	—	19×10^{-6}
Chemical composition (nominal)		94.8 % copper, 5% tin, 0.2% phosphorus	—	80% nickel, 20% chromium	83% copper, 13% manganese, 4% nickel
Electrical resistivity (at 293 K)		11 µΩ•cm	1.7 µΩ•cm	120 µΩ•cm	48 µΩ•cm
Thermal conductivity *(W/(m•K))*	*0.1 K*	NA	9	NA	0.006
	0.4 K	NA	30	NA	0.02
	1 K	0.22	70	NA	0.06
	4 K	1.6	300	0.25	0.5
	10 K	4.6	700	0.7	2
	20 K	10	1100	2.6	3.3
	80 K	25	600	8	13
	150 K	34	410	9.5	16
	300 K	48	400	12	22

Based on the electrical resistivities, what do you think each wire is made of?

A:____________________________

B:____________________________

C:____________________________

If we had each of these resistors mounted on a 40K stage and those wires taking the connection out to 300K, approximately how much thermal power would be transferred to the 40K stage from 300K?

$$q = \frac{\kappa A}{L}(T_H - T_C)$$

What about if the wires were going between 4K and 100 mK?

We are planning the wiring for a new cryostat, we have determined that we can have up to 5uW of parasitic loading from the cabling down to 100 mK. [Parasitic loading means the loading just due to mechanical connections between stages]. **How many 250mm long, 30 AWG Manganin wires can we install between 4K and 100mK and still remain within this limit?**

How does that number change if the wires are very well heat sunk at 1K?

Thermal Conductivity Measurement

If the metal plate was completely black, what would be the expected radiative loading?

$$F = \sigma T^4$$

$$\sigma = \frac{2\pi^5 k^4}{15\, c^2 h^3} = 5.670374... \times 10^{-8} \frac{W}{m^2 \cdot K^4}$$

What are the equilibrium temperatures of the diodes?

With 0 W of applied heat:

Top: ________________

Bottom: ________________

With 20 W of applied heat:

Top: ________________

Bottom: ________________

What is the effective thermal conductivity of the plate and the base loading when no additional heat is applied?

What does that say about the emissivity of the aluminum plate?