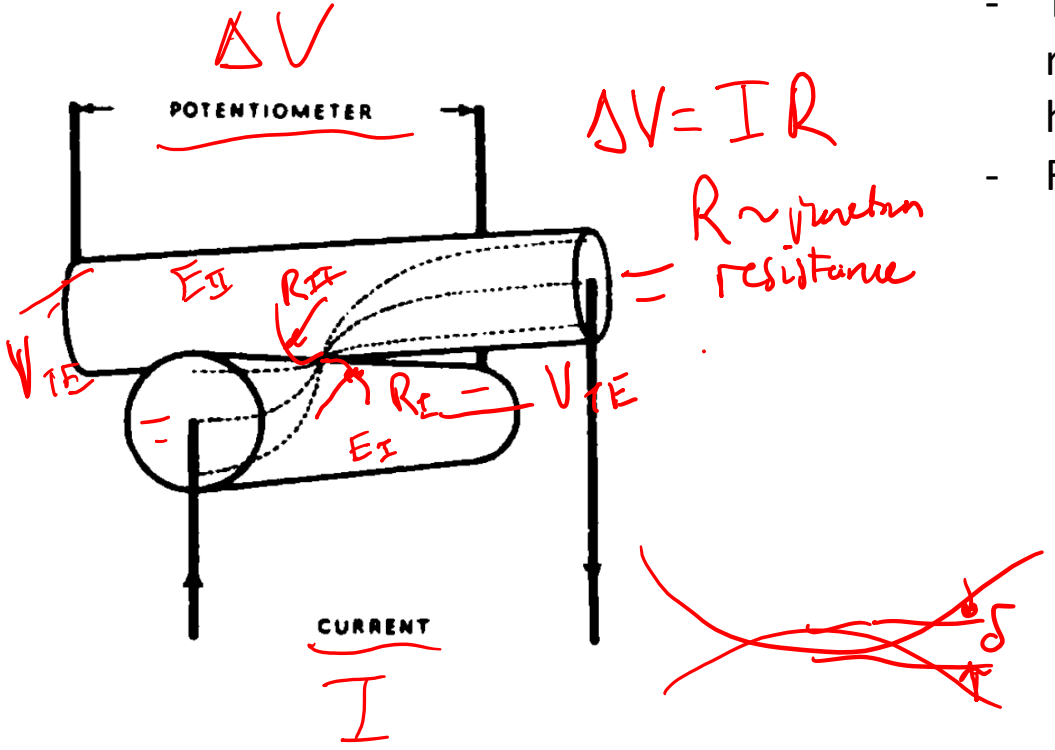
Week 10: Introducing the measurement hardware, reviewing the Hertz calculation and demonstrating low resistance measurement

Reading: Keithley model 6221 current source manual, chapter 5 (delta mode operation); review the Hertz scaling notes from day 1.

Tabor manuscript

The measurement: real area of contact using analog electronics (or sophisticated measurement apparatus!)



Recall the theory behind the measurement:

- The junction has a finite contact area. Based on the known bulk resistivity of silver, we can measure this contact area provided we have a sufficiently strong current source and sufficiently sensitive voltmeter.
- Recall from day 1:

constant close to 1

Lateral scale, a: $a \propto \left[P\frac{\left(\frac{1}{E_I}+\frac{1}{E_{II}}\right)}{\left(\frac{1}{R_I}+\frac{1}{R_{II}}\right)}\right]^{\frac{1}{3}}$, where P is the applied force;

Contact pressure, p_m: $p_m \propto \frac{P}{\pi a^2} = \left[\sqrt{P}\frac{\left(\frac{1}{R_I}+\frac{1}{R_{II}}\right)}{\left(\frac{1}{E_I}+\frac{1}{E_{II}}\right)}\right]^{\frac{2}{3}}$

Vertical displacement δ: $\delta \propto \left[P\frac{\left(\frac{1}{E_I}+\frac{1}{E_{II}}\right)}{\sqrt{\left(\frac{1}{R_I}+\frac{1}{R_{II}}\right)}}\right]^{\frac{2}{3}}$

Simplify these expressions for silver wires of diameter 6.35 mm.

Silver wire has a bulk conductivity, which we will measure today using the nanovoltmeter and current source.

1.5.3 Young's Modulus

83.00 GPa

$E_{silver} = 8.3 \cdot 10^{10}$ Pa

Mechanical Properties of Cesium

116 (Mechanical Pr..)

1.6 Poisson Ratio

0.37

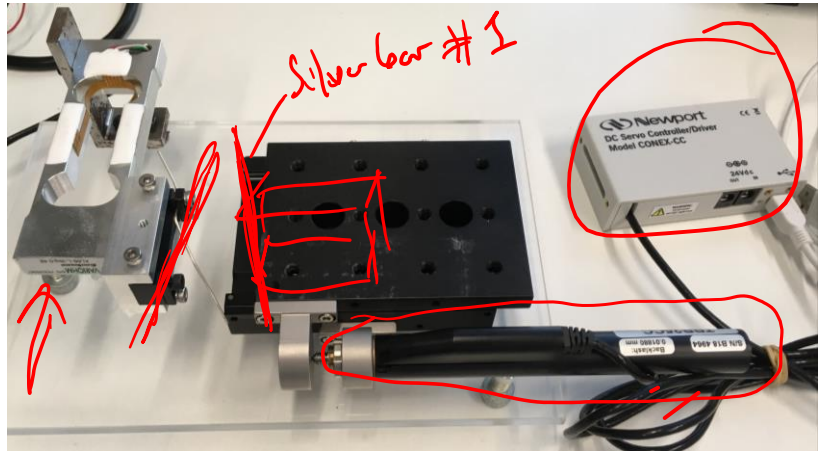
Mechanical Properties of Beryllium

0.3 (Mechanical Pr..)

The Young's modulus and the Poisson ratio will be key inputs in carrying out an accurate measurement of the junction resistivity / inverse conductivity. These values are reported on comparenature.com.

Using the value for silver's bulk conductivity (given in the Tabor paper) and the Hertz contact result, estimate the expected junction resistance at applied loads P = 10 g, 100 g and 300 g (~~the load cell's capacity~~) 3 kg.

The general layout for the physical experiment, which you will all carry out remotely:



1. 3 kg load-cell
2. Newport Conex-CC + TRB25CC
3. M433 stage

Not shown: Keysight 34470A 7.5 digit multimeter (to monitor load cell signal)
amplified

1. Keithley 2182A nanovoltmeter
2. Keithley 6221 DC/AC current source

Ch5.
1. Serial cable – synchr. communication
2. Trigger synchronizes the measurement

Next week, you'll begin to make measurements – connecting to the remote PC via Nomachine.

Ishe Team uses

Keithley control software:

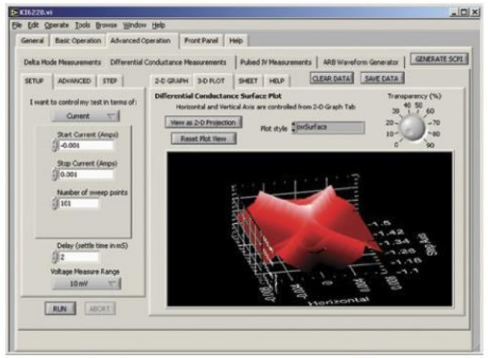


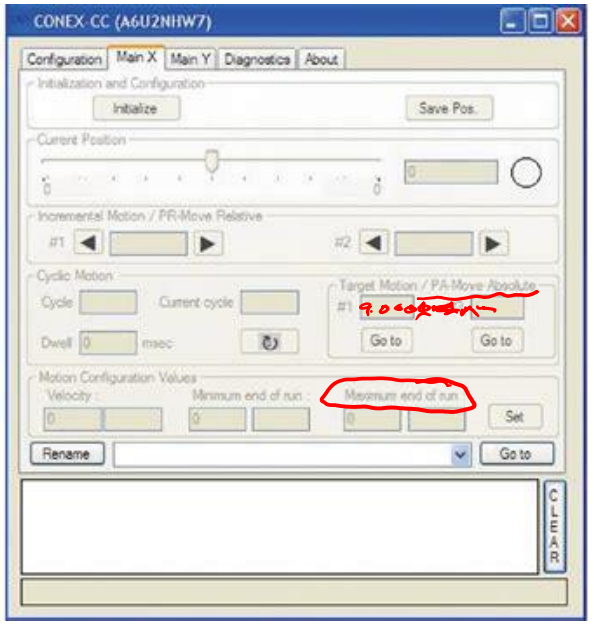
Figure 1. Perform, analyze, and display differential conductance measurements.

Delta Mode – current level is set; calc R measurement

Keithley originally developed the delta mode method for making low noise measurements of voltages and resistances for use with the Model 2182 Nanovoltmeter and a triggerable external current source. Essentially, the delta mode automatically triggers the current source to alternate the signal polarity, then triggers a nanovoltmeter reading at each polarity. This current reversal technique cancels out any constant thermoelectric offsets, ensuring the results reflect the true value of the voltage. "60"

This same basic technique has been incorporated into the Model 622X and Model 2182A delta mode, but its implementation has been dramatically enhanced and simplified. The technique can now cancel thermoelectric offsets that drift over time, produce results in half the time of the previous technique, and allow the source to control and configure the nanovoltmeter, so setting up the measurement takes just two key presses. The improved cancellation and higher reading rate reduces measurement noise to as little as 1nV.

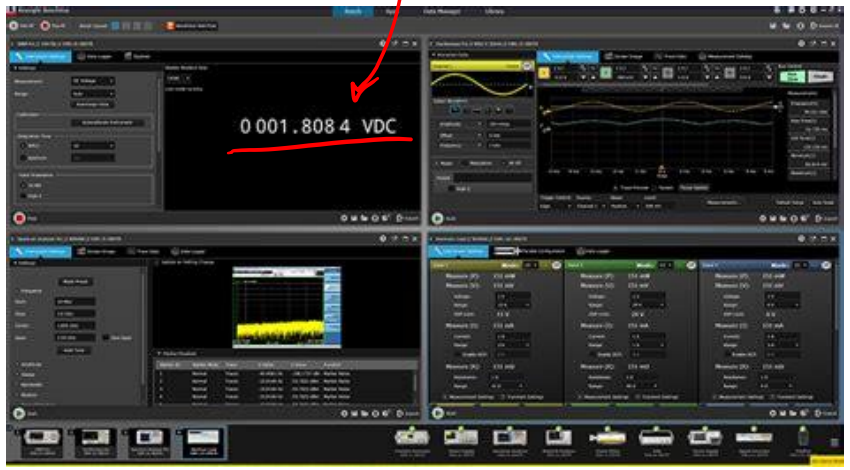
CONEX-CC GUI:



prescribing δ, overall displacement.

Keysight BenchVue:

V-meter readout
calibrate load cell + amp.



Install Nomachine on your computer, and message with on Piazza to do a trial connection once installed. Everyone needs to individually connect – each student will carry out a remote measurement.

To prepare for the measurement, write an experimental protocol of how you will carry out the measurement. No detail is too small to include here!

as short as 1 pg.

This should be a written document, and one version should be prepared for each student.

These should be included as supplementary documents for the final report. → Still a PRL formatted article.

ideally by Friday, 20th

Submit an experimental protocol to me via email. This must be prepared before you can carry out the measurements next week. Please ask any questions for clarity via Piazza.

Now a recording of some low-R measurements using the nanovoltmeter, the current source and the standard multimeter (why we need the specialty equipment will be clear)

→ measure bulk-R of Silver!

9:00 a.m: Zoom call - link on wiki.