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Analysis of thermal noise of newly proposed design and material for the Advanced LIGO suspensions

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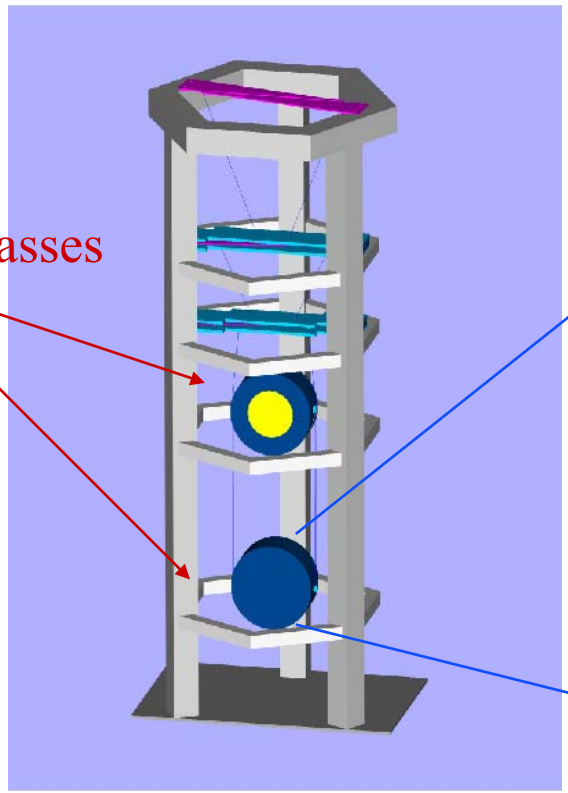
What is a LIGO suspension?

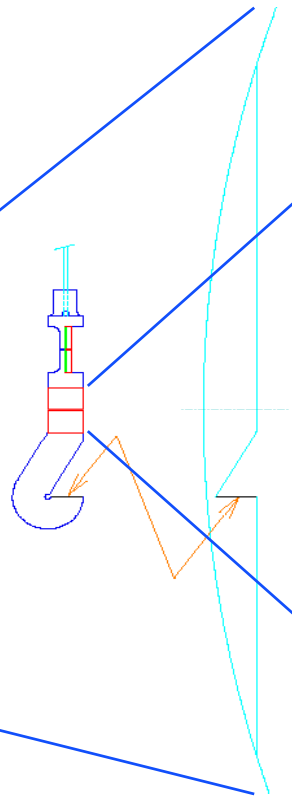
Seismic Attenuation System

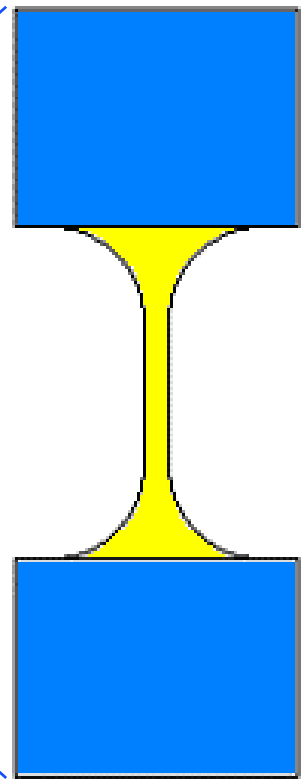
The Hook

And Finally…The Joint

Test Masses







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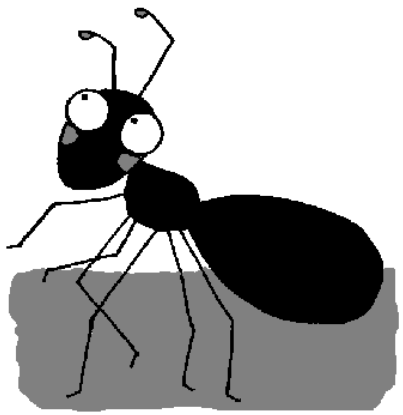
An idea of the dimension of the Joint



For the Central Beam :

h = 2 mm

L = 3 mm

t = 10 um

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Why are we interested in something so small?

- The small Joint has to carry the weight of the Test Mass
- We want to minimize Thermal Noise

These two purposes lead to different designs…… we have to find a compromise

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What is Thermal Noise ?

- Thermal Noise is generated by the Anelasticity of the material the Joint is made of
- The Joint behaves like a pendulum whose Hooke's law is modified by anelasticity

$$F = -Kdx \quad \Rightarrow \quad F = -K(1+i\Phi)dX$$

Anelasticity causes an Energy Dissipation that generates noisy fluctuations

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The big Q

- Φ is the Loss Factor……. and is our enemy
- If Φ is bad, its inverse Q = 1/ Φ is our best friend
- We need to maximize the Q fator and a pendulum is the best configuration for this purpose

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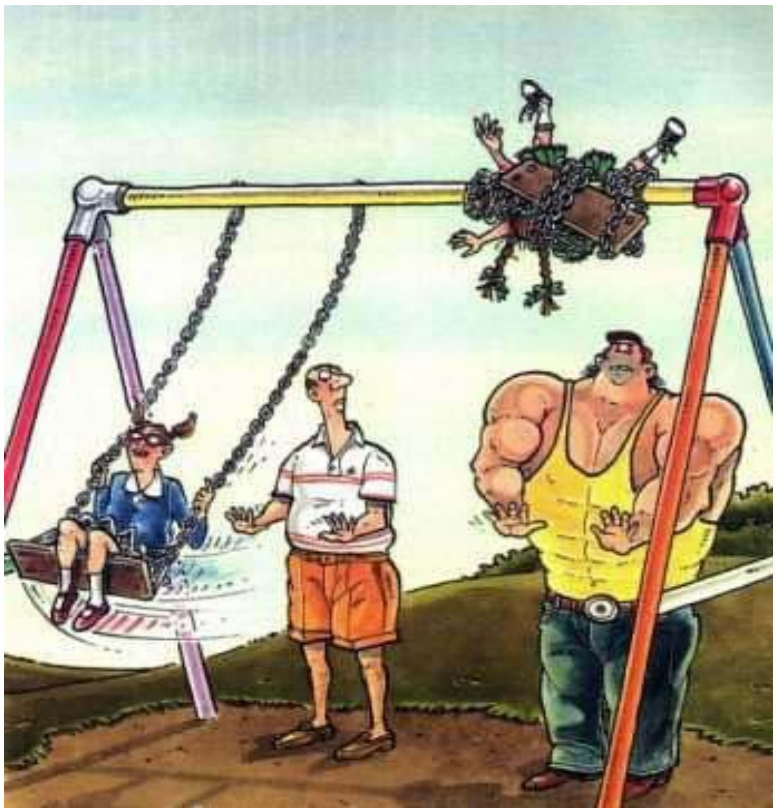
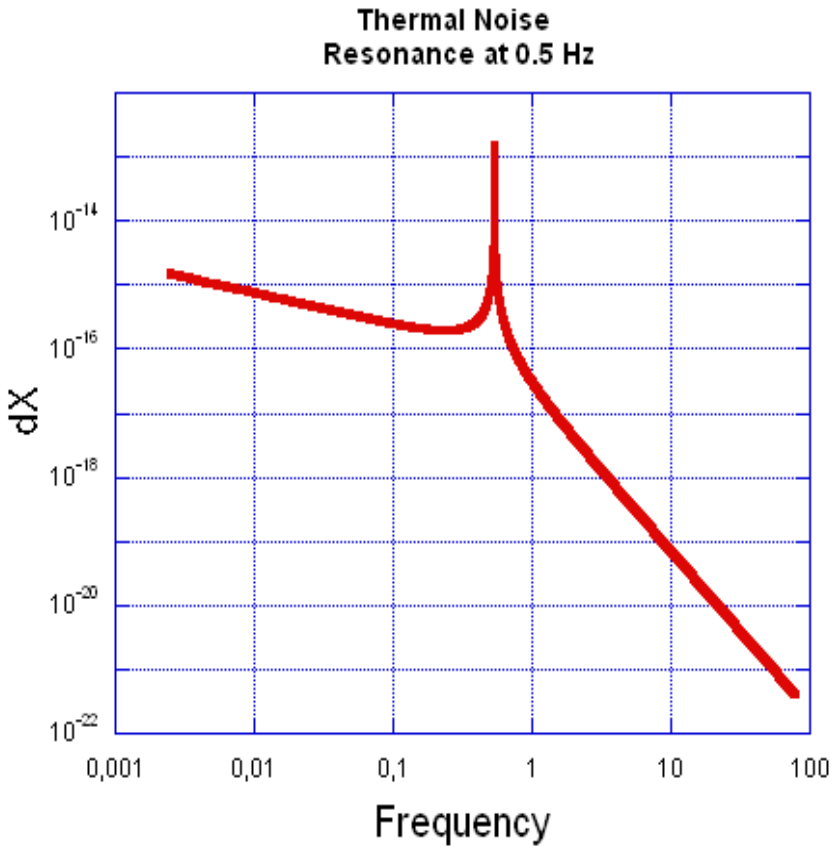
Frequency Response

Swing



Joint



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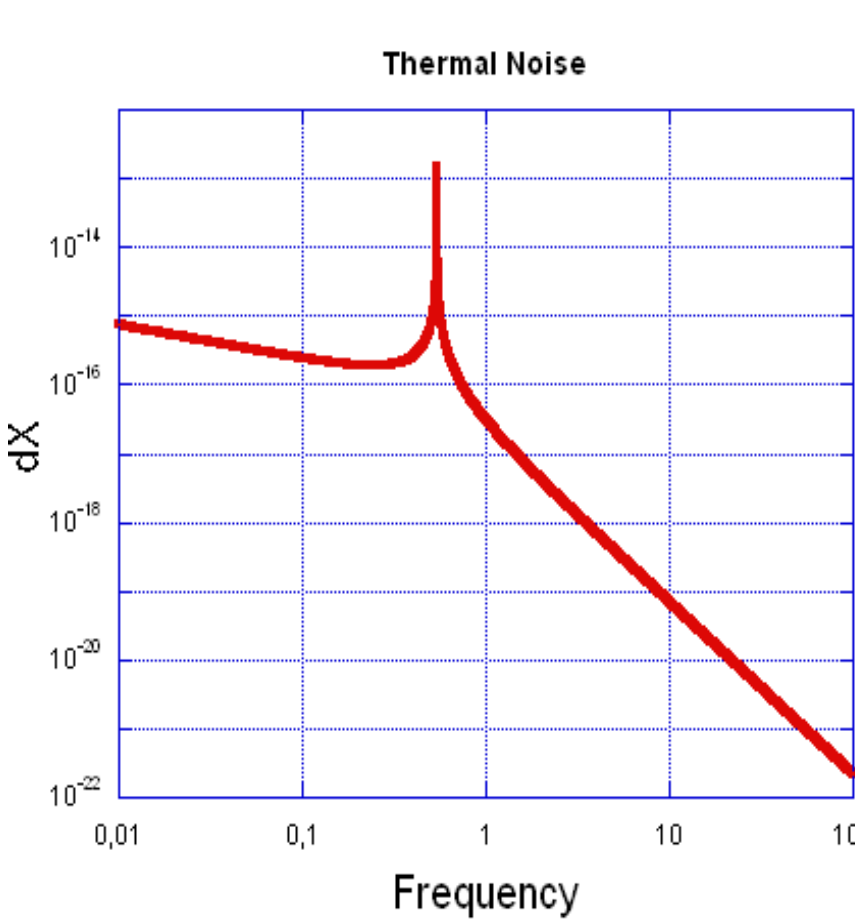
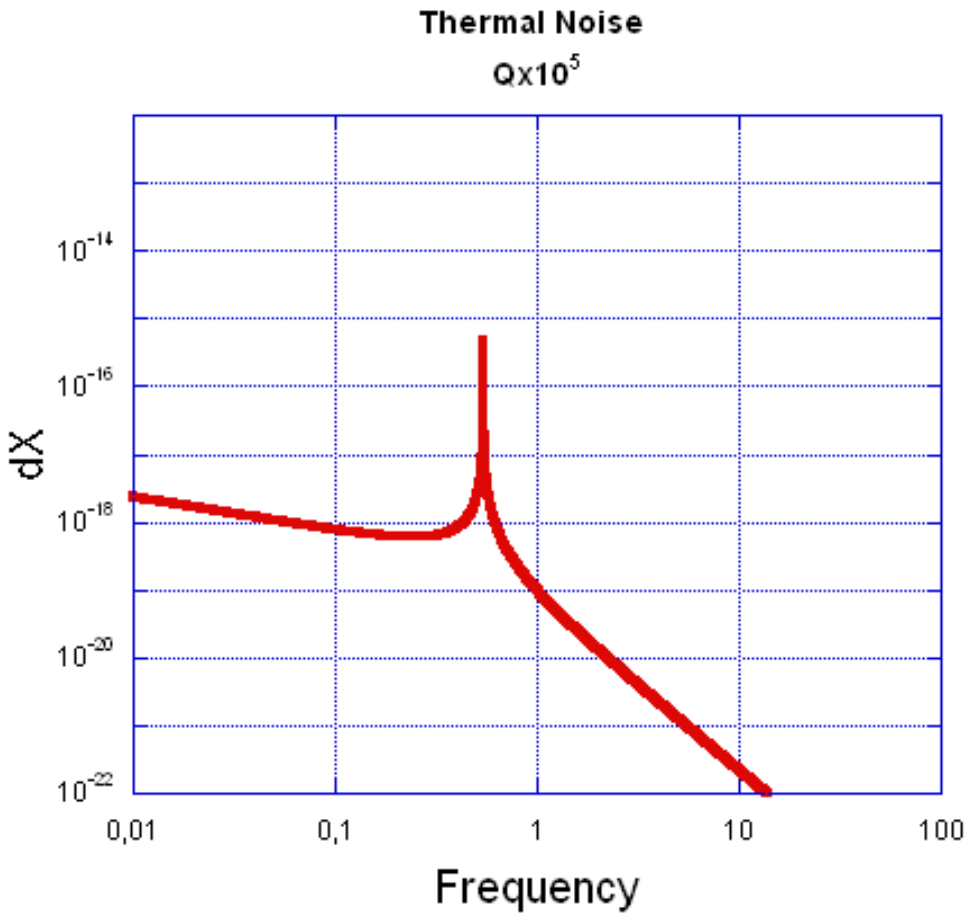
Effect of Q Changing





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One Formula

For a Pendulum (our Joint) the effective Q factor is given by

$$Q = Q_m \frac{TotalEnergy}{StrainEnergy} = Q_m \frac{Gravitational + Strain}{StrainEnergy}$$

- Gravitational Energy is not affected by dissipation
- The main characters are Q_m, the Quality Factor of the material, and the Strain Energy stored in the Joint

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From the Analysis

- We have to minimize Strain Energy, that goes roughly like thickness^3

A very thin Joint is needed

- The Joint has to carry safely the weight of the Test Mass

We need a very strong material, with an high Q Factor

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Our Candidates

- MoRuB amorphous alloy

- Monocrystalline Silicon

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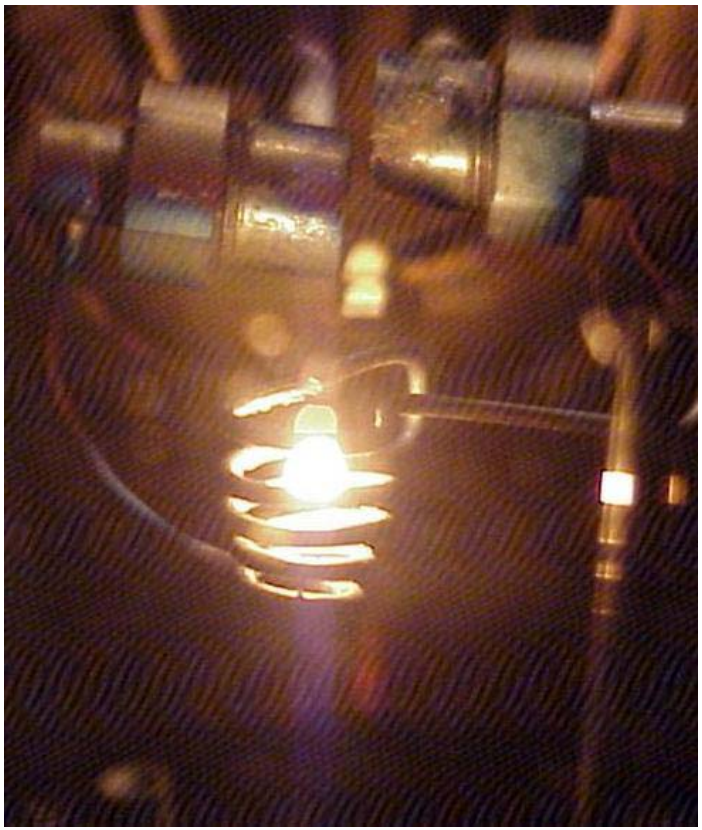
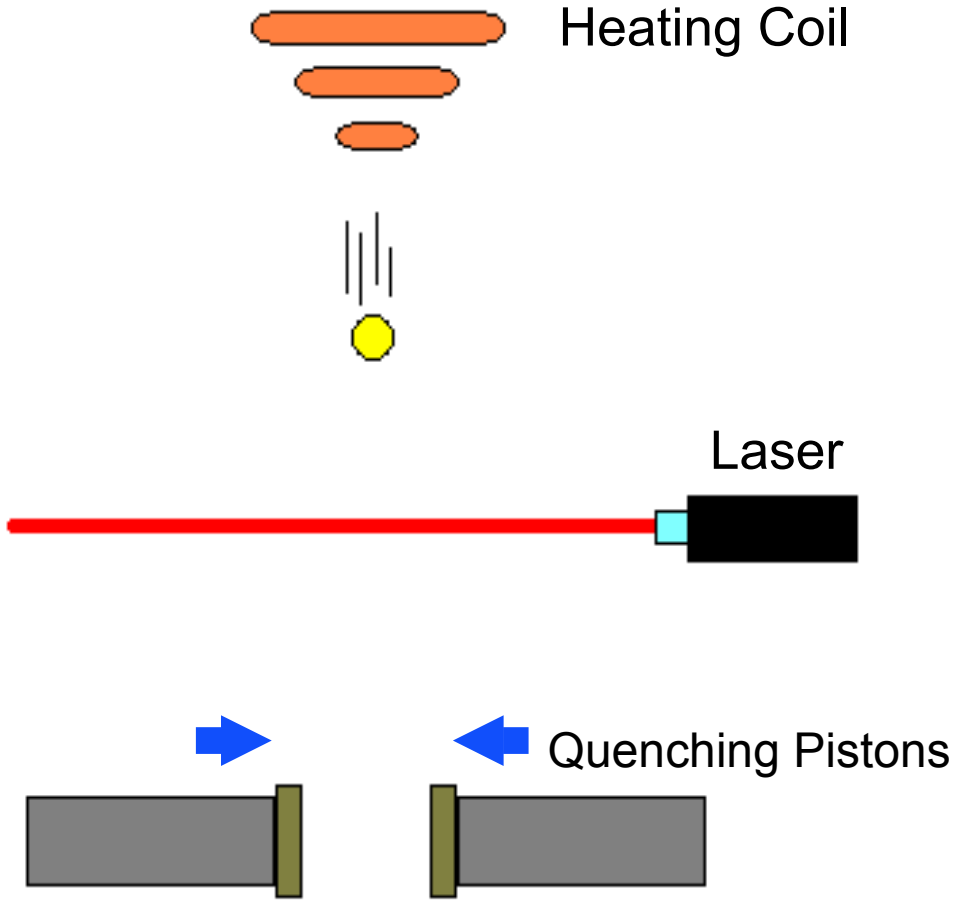
Production of MoRuB Alloy

Rapid Quenching





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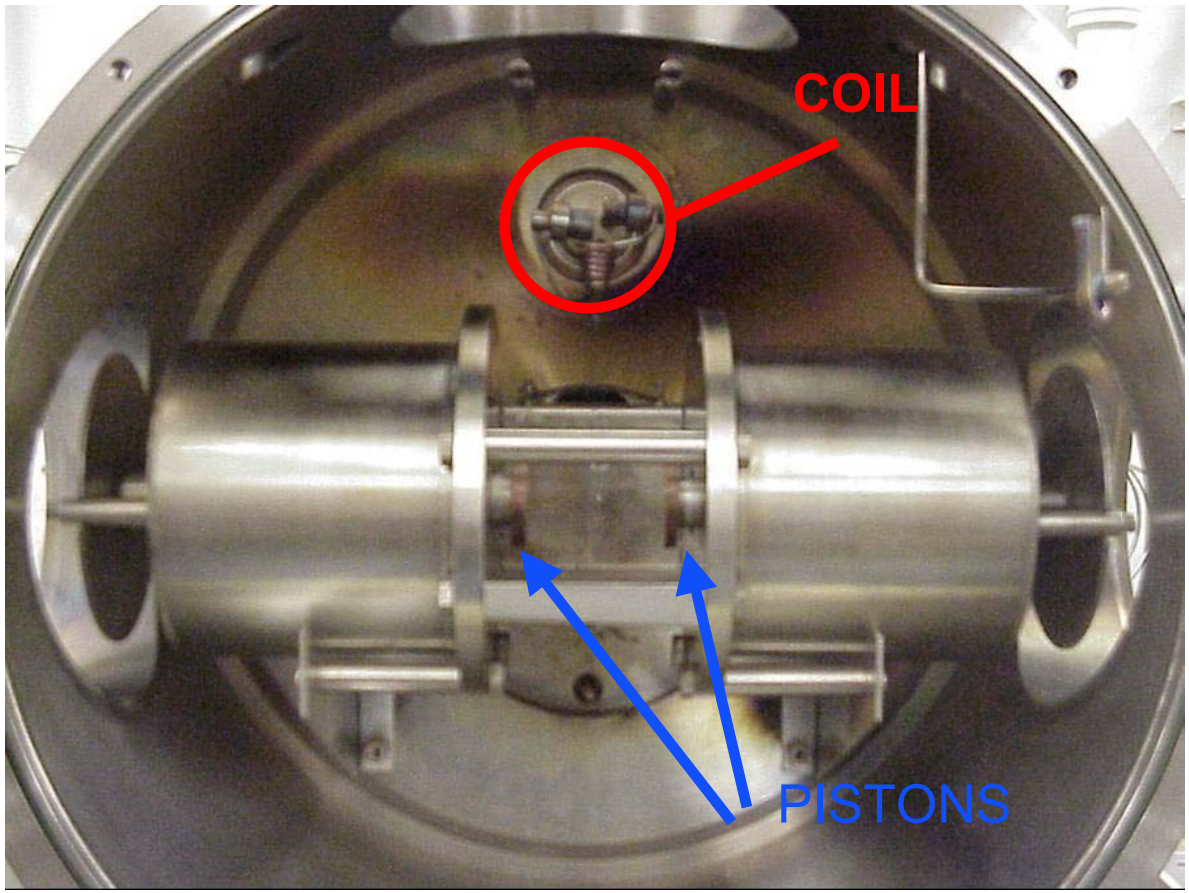
The Real Machine



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The Result

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A Good occasion to wear Fashion Sunglasses

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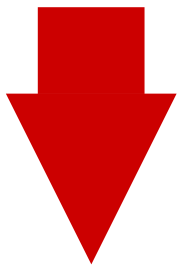
STRESS-Strain

We need realistic Values for the Young's Modulus and Yield Point of our materials



Consruction of a small machine for Stress-Strain measures

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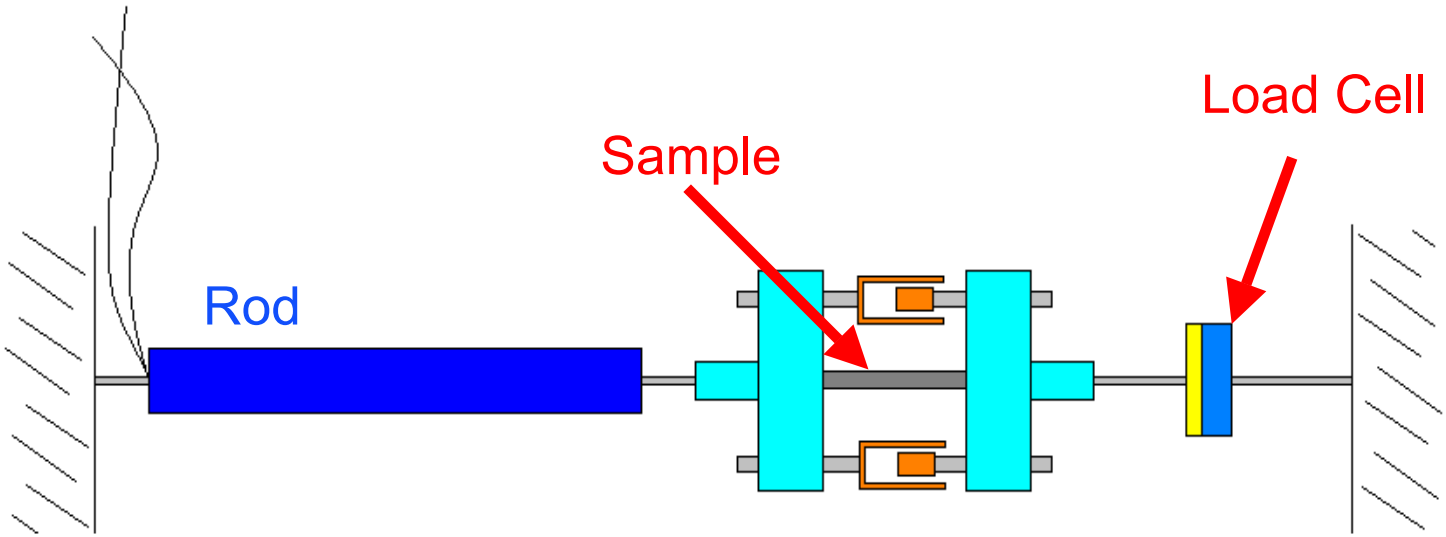
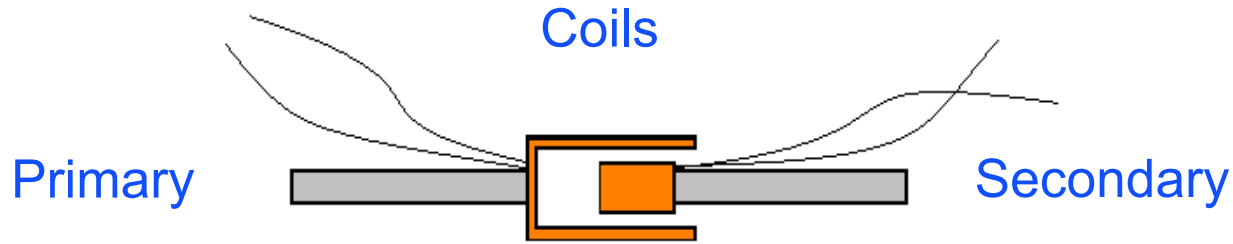
The Principle





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The Puzzle

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Future Work

- Complete the work on Thermal Noise analytical formula
- Assembly of the Stress-Strain machine and measure mechanical properties of MoRuB
- Find the best design for Monocrystalline Silicon Joint

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Aknowledgements

Thanks To:

- Xavier De Lepine, for the ANSYS simulations and RPG
- Charles Bordier, my Personal Quenching Trainer
- Stefano Tirelli, for online help on the Stress-Strain machine
- All the “De Salvo Group”, for the fun
- Dr. Riccardo De Salvo, The Chief
- Prof. Francesco Fidecaro, my prof. in Pisa University

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Aknowledgements

And of course … The Sun of California