LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Parameter Set, Mode Frequencies and Transfer Functions for the As-Built LLO OMC Suspension

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LIGO Scientific Collaboration

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1 Introduction

The purpose of this document is to serve as record of the best estimate of the parameter set and the expected mode frequencies for the ELIGO Output Modecleaner (OMC) suspension installed at LLO in January 2008.

2 General description of the OMC suspension

The OMC suspension consists of a double pendulum with two sets of maraging steel blades to give extra isolation in the vertical and roll modes. The lower mass of the pendulum takes the form of a silica bench to which the optics for the OMC are attached. A picture of the OMC installed in HAM 6 at LLO is given in figure 1.

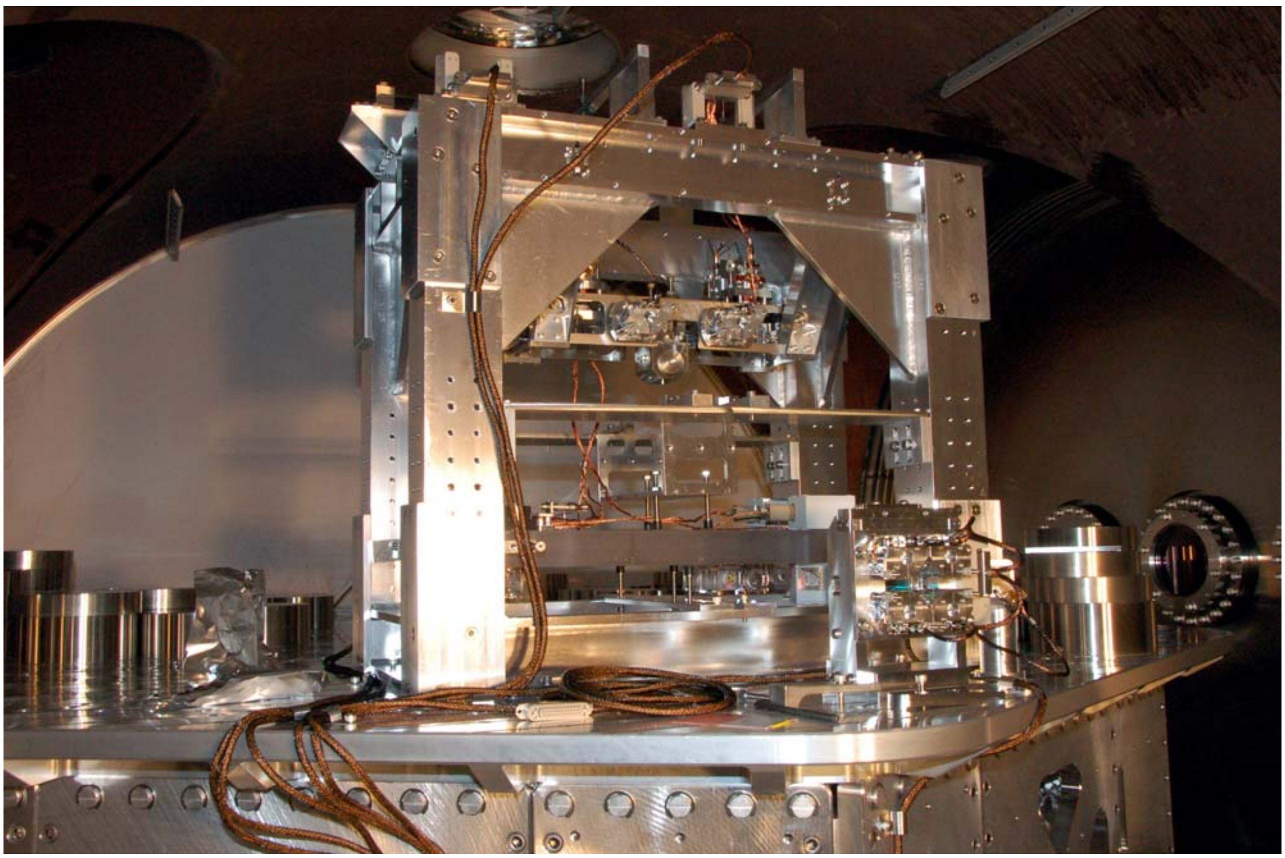

Figure 1. OMC installed on the HAM-ISI in the HAM 6 chamber at LLO

A summary of the main features of the OMC suspension can be found in the presentation G070062. Further details can be found on the OMC SUS wiki at

http://ilog.ligo-wa.caltech.edu:7285/advligo/OMC_Suspension

3 MATLAB model of the OMC suspension

3.1 Parameter Set

The parameter set used in the MATLAB model of the OMC LLO suspension as at 28th April 2008 is as follows, where all units are SI.

pendulum_model: 'double_pendulum'

m1: 2.7540

I1x: 0.0150

I1y: 0.0025

I1z: 0.0148

m2: 6.8950

I2x: 0.1390

I2y: 0.0164

I2z: 0.1500

l1: 0.2500

l2: 0.2500

nw1: 2

nw2: 4

r1: 1.7800e-004

r2: 1.0200e-004

Y1: 2.1200e+011

Y2: 2.1200e+011

ufc1: 2.3800

ufc2: 2.1300

d0: 0.0018

d1: 0.0015

d2: 0.0030

su: 0

si: 0.0300

n0: 0.0720

n1: 0.0720

n2: 0.1350

n3: 0.1350

Diagram illustrating the physical dimensions is shown in appendix A (figures 8 and 9). The values for the masses (m1 and m2) and principal moments of inertia (I1x, I1y etc) come from Solidworks models of the top mass and silica bench with its various attachments produced by Chris Echols.

Other symbols are as follows:

ufc1 = uncoupled resonant frequency of the top mass on the top blades

ufc2 = uncoupled resonant frequency of the lower mass on the lower blades

nw1, nw2 are the number of wires in the top and lower stages respectively

r1, r2, Y1 and Y2 are the radii and Young's modulus values for the upper and lower wires respectively.

The values for ufc1 and ufc2 have been estimated from measurements of the blade spring constants (see T030104-02) The blades used were spares from the input modecleaner prototype. For the upper blades we used Lobart blades 1L and 2L. For the lower blades we used Superior Jig blades 8S and 10S at one end and 7S and 13S at the other.

Regarding the d values given above, these are the effective values taking into account the stiffness of the wires.

3.2 Mode frequencies

In the MATLAB model the longitudinal and pitch modes and transverse and roll modes are coupled. The modes which are most closely associated with longitudinal and transverse motion are italicised below, although it should be noted that the first pairs of modes in each case are quite closely coupled (see transfer functions).

All values are in Hz.

longpitch: [*0.707* 0.797 *2.54* 3.93]

yaw: [0.478 3.59]

transroll: [*0.719* 0.749 *2.53* 6.85]

vertical: [1.12 4.48]

The nomenclature corresponds to the following directions. Longitudinal is into the page in figure 1, (i.e. parallel to the short axis of the silica bench). Transverse is parallel to the long axis of the silica bench. Pitch is rotation about the transverse axis, roll is rotation about the longitudinal axis and yaw is rotation about the vertical.

3.3 Transfer functions

These are shown in figures 2 to 7 inclusive for the 6 degrees of freedom. Damping has been turned down so that the modes can be clearly identified. Units are all SI.

4 Limitations of the model

Firstly it should be noted that the MATLAB model (see T080138-00-R) from which the mode frequencies and transfer functions are derived assumes symmetry in the shape of the masses. This is only an approximation to reality. The silica bench in particular is not completely symmetric when the optics and electronics are added, so that there will be some differences between the predicted and measured transfer functions. A larger effect comes from the presence of the electronics wiring which goes from the silica bench directly to the structure. This will inevitably produce cross-coupling at some level, with more effect in some degrees of freedom than others.

It should also be noted that the frequencies given here are for the silica bench. The metal bench which is used to first assemble the suspension is slightly different in moments of inertia and the d2 value (at the bench) and hence the frequencies with the metal bench in place would be slightly different, in particular the lowest pitch frequency.

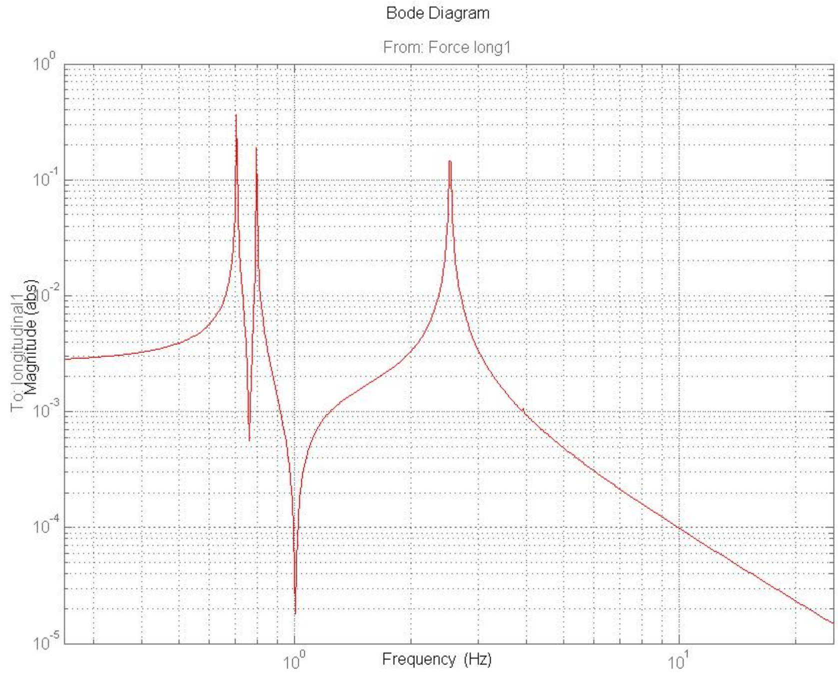

Figure 2. Transfer function for longitudinal: force at top mass to displacement of top mass

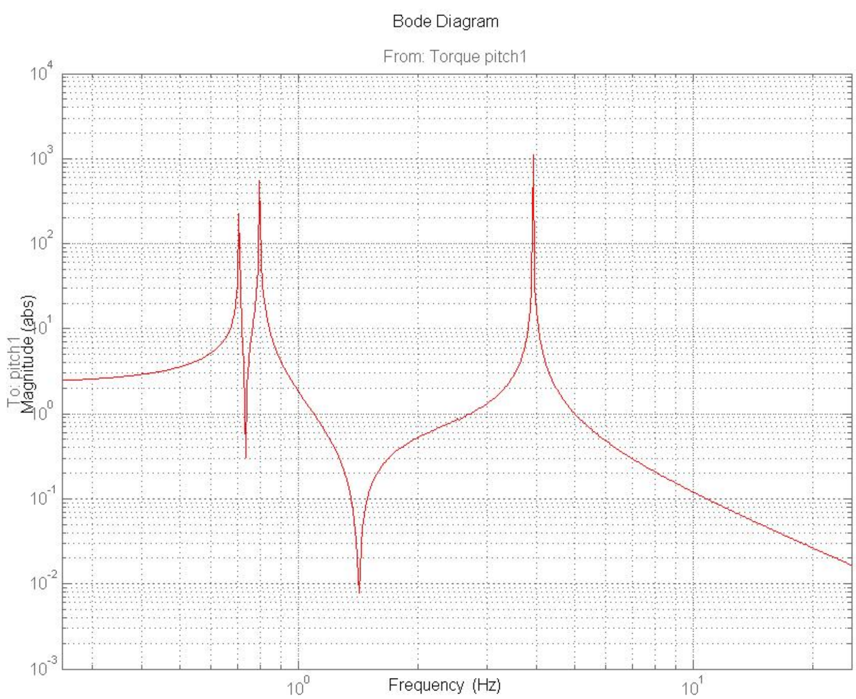

Figure 3. Transfer function for pitch: torque at top mass to pitch of top mass.

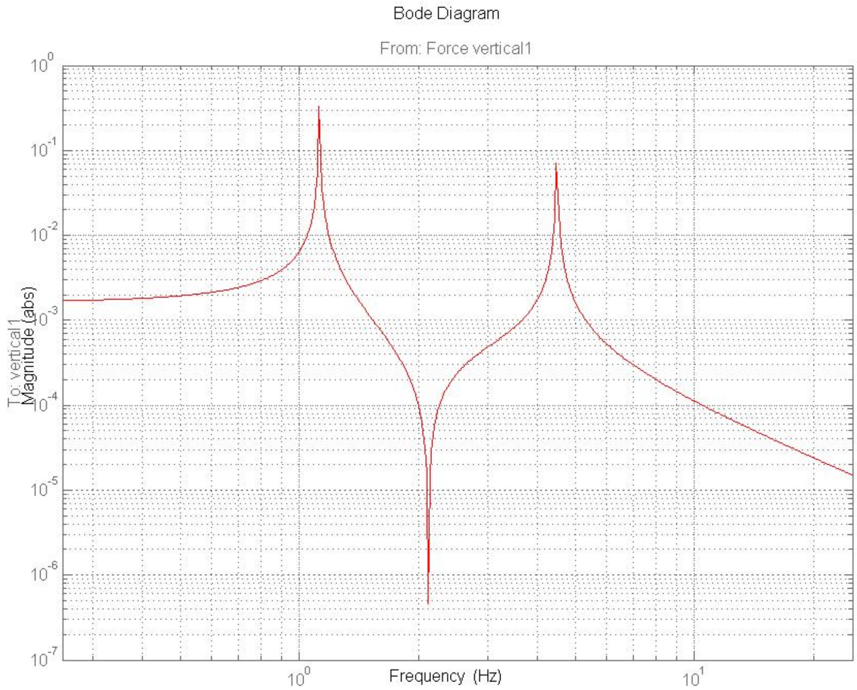

Figure 4. Transfer function for vertical: force at top mass to displacement of top mass.

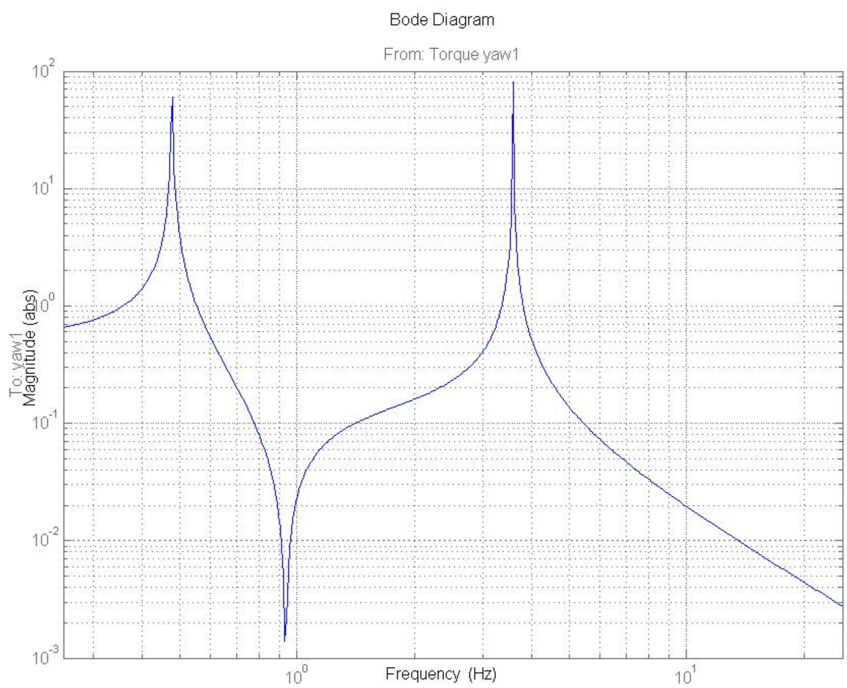

Figure 5. Transfer function for yaw: torque at top mass to yaw of top mass.

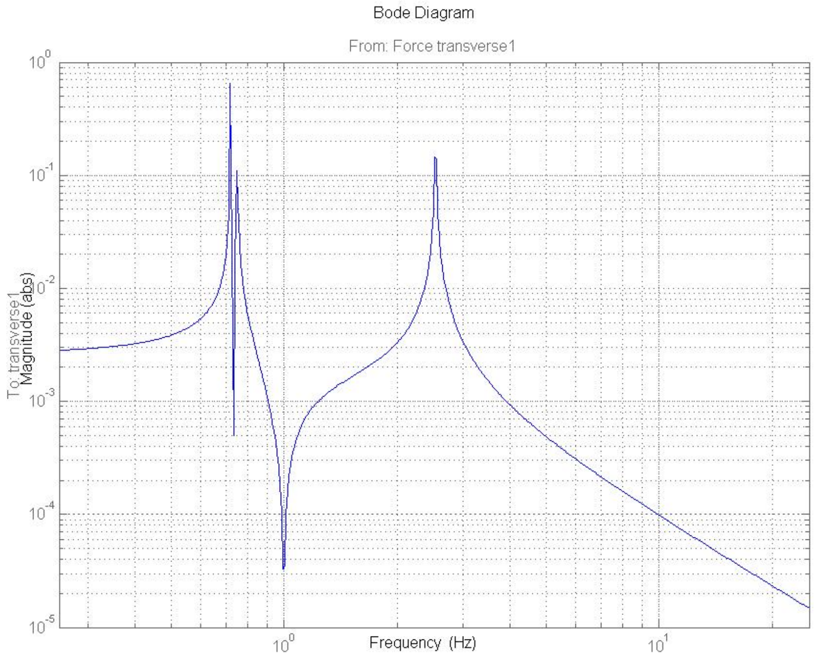

Figure 6. Transfer function for transverse: force at top mass to displacement of top mass.

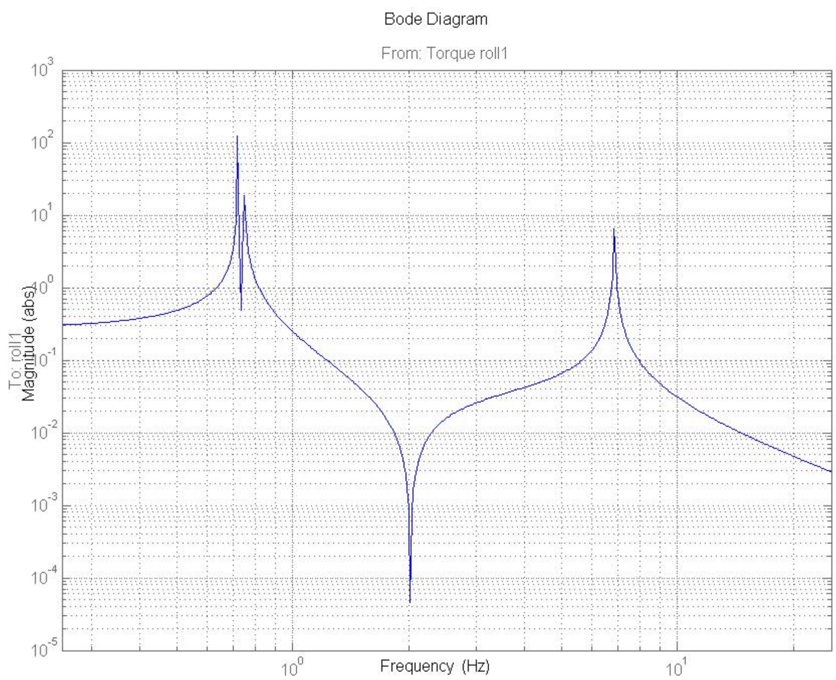

Figure 7. Transfer function for roll: torque at top mass to roll of top mass.

Appendix A.

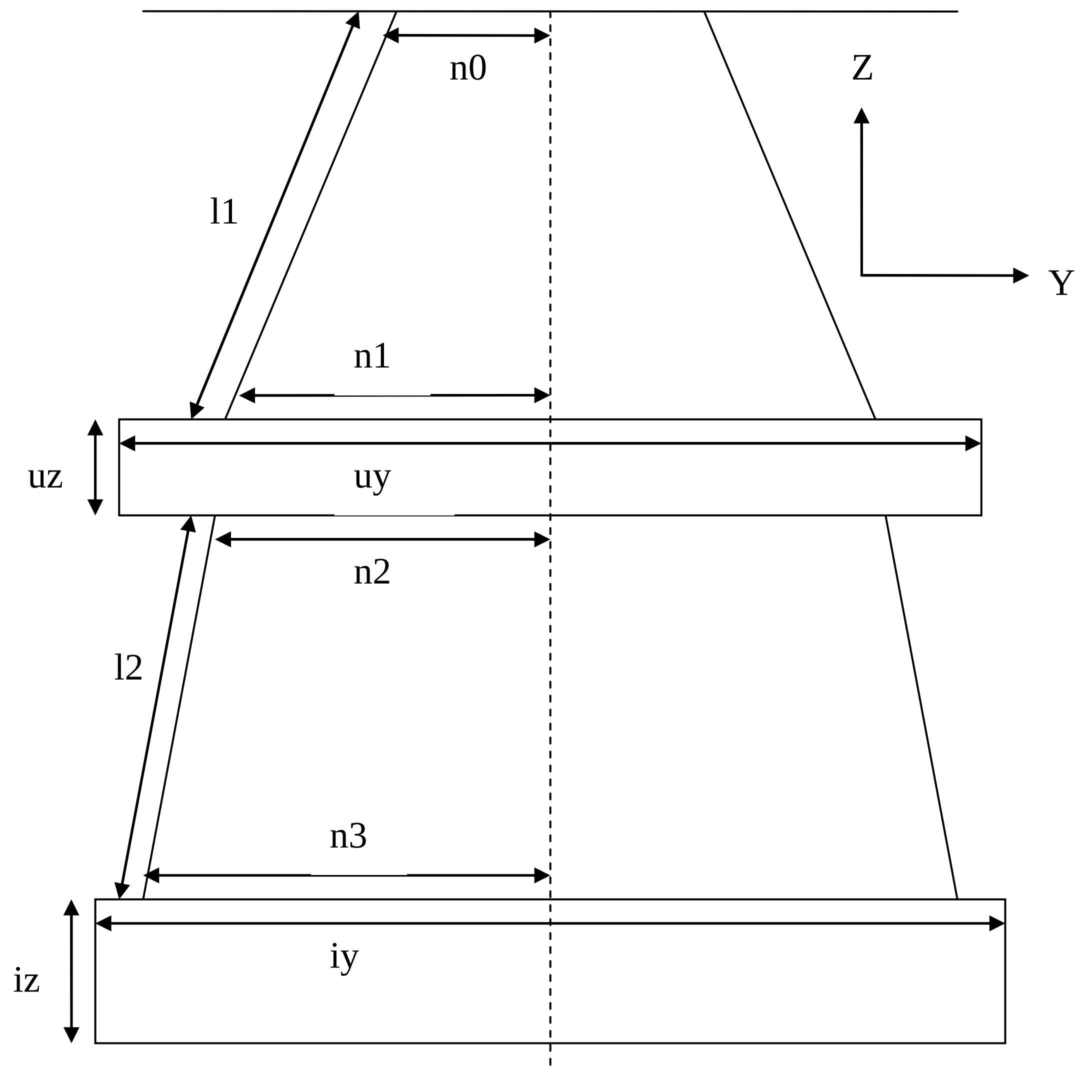

Figure 8. Parameters for a double pendulum (face on view) Coordinate x is into the page.

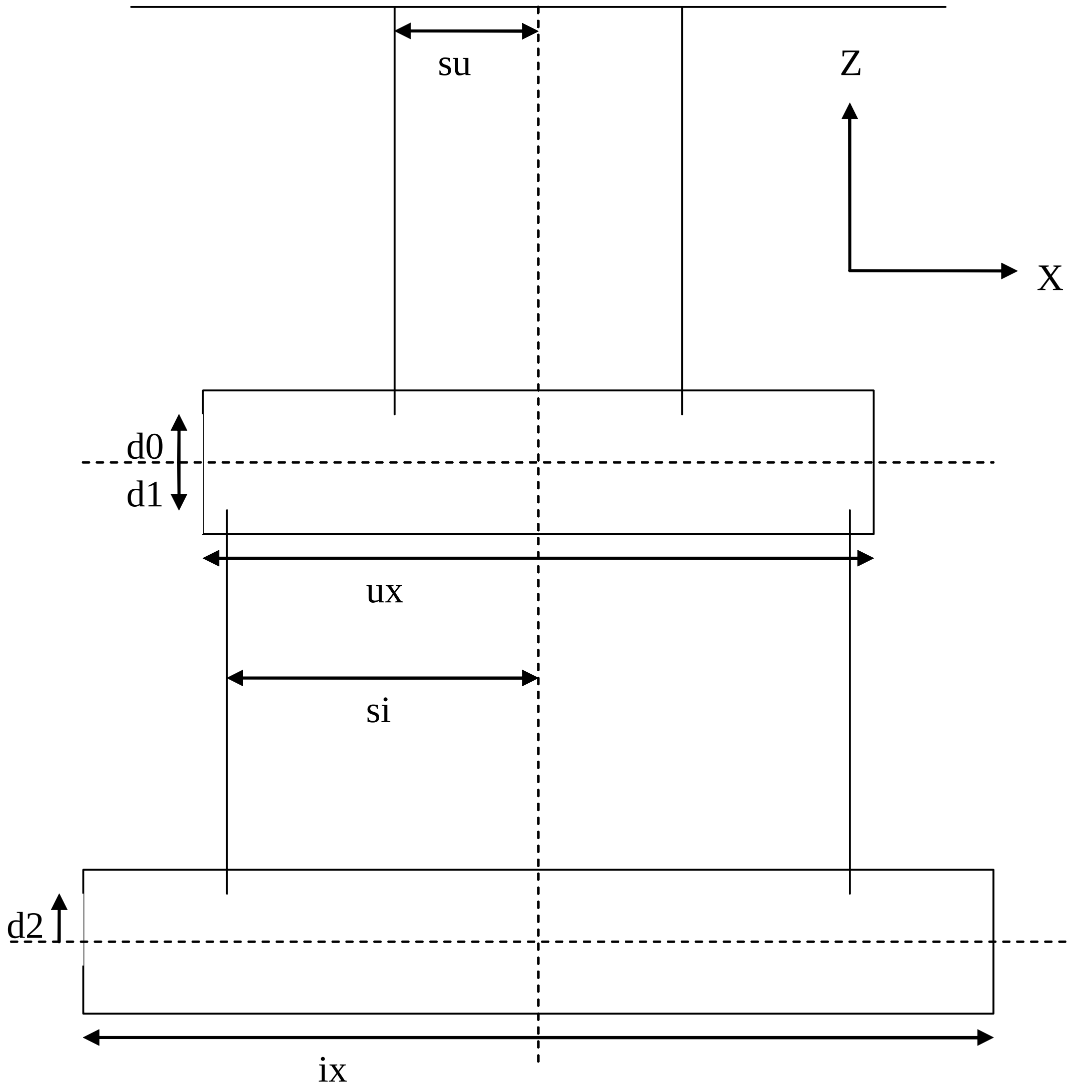

Figure 9. Parameters for a double pendulum (side view)