LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

*LIGO Laboratory / LIGO Scientific Collaboration*

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# Triple Pendulum Parameter Descriptions and Naming Convention

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# 1 Introduction

## 1.1 Purpose and Scope

Describes the parameter names used in the Mathematica and Matlab triple pendulum dynamics models.

## 1.2 References

LIGO-T1400446: aLIGO SUS Pendulum Dynamics Modeling

LIGO-T020205: Models of the Advanced LIGO Suspensions in Mathematica™

LIGO-T080188: Models of the Advanced LIGO Suspensions in MATLAB

LIGO-T1000724: MATLAB model of Beam Splitter/ Folding Mirror Triple Suspension (BS/FM)

LIGO-T080310: MATLAB model of HAM Large Triple Suspension (HLTS)

LIGO-T080311: MATLAB model of HAM Small Triple Suspension (HSTS)

## 1.3 Version history

4/30/2004: -00

7/20/2004: -01

7/3/2014: -v1. All-new diagrams by Jeff K., all-new text by Mark B.

# 2 Parameters

The following parameters are the minimum set necessary to define a case of the Mathematica TripleLite2 model used for the aLIGO BSFM, HLTS and HSTS, or the equivalent Matlab model (ssmake3MBf.m). As near as practical, all of the parameters have the same names in both models. The parameters for blade and wire stiffness are defined per side in the Matlab but per blade in the Mathematica, and to prevent (total) confusion have been given different names. Except for the d's, n's and s's, parameters are numbered 1, 2, 3 by blade/wire/mass from the top down. The Mathematica model has a large number of additional parameters for the damping of the elastic elements which are beyond the scope of this document. The Matlab model also handles certain additional Mathematica models that were generated for R&D purposes such as TripleLite2IMDB, TripleLite2IMQB, etc, but the extra parameters which trigger this are beyond the scope of this document.

## 2.1 Parameters common to Mathematica and Matlab

| Parameter | Unit | Description |
|---|---|---|
| g | m/s^2 | local gravity |
| m1 | kg | mass of upper mass |
| I1x, I1y, I1z | kg.m^2 | diagonal components of upper mass MOI |

| | | |
|---|---|---|
| I1xy, I1yz, I1zx | kg.m^2 | off-diagonal components of upper mass MOI |
| m2 | kg | mass of intermediate mass |
| I2x, I2y, I2z | kg.m^2 | diagonal components of intermediate mass MOI |
| I2xy, I2yz, I2zx | kg.m^2 | off-diagonal components of intermediate mass MOI |
| m3 | kg | mass of lower mass |
| I3x, I3y, I3z | kg.m^2 | diagonal components of lower mass MOI |
| I3xy, I3yz, I3zx | kg.m^2 | off-diagonal components of lower mass MOI |
| dtop, d0, d1, d2, d3, d4 | m | vertical offsets of wire attachments from COM (positive outward, towards wire) - see diagrams |
| n0, n1, n2, n3, n4, n5 | m | half lateral (y-direction) wire attachment point separations, - see diagrams |
| si, sl | m | half front-back (x-direction) wire attachment point separations of intermediate and lower wires, common to top and bottom - see diagrams |
| l1, l2, l3 | m | stretched lengths of wires |
| Y1, Y2, Y3 | Pa | Young's moduli of wires |
| r1, r2, r3 | m | radii of wires |

## 2.2 Parameters unique to Matlab

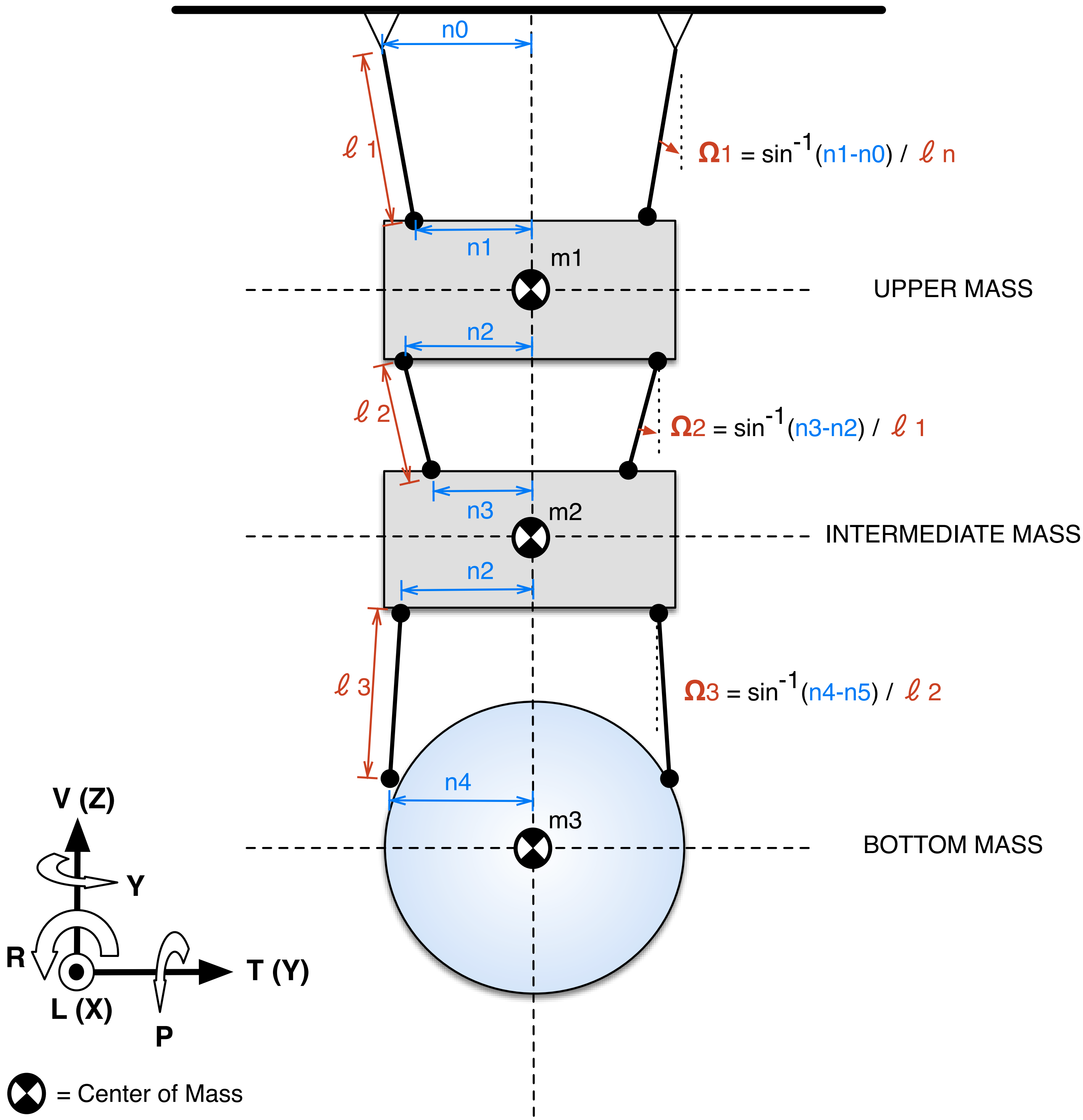
| Parameter | Unit | Description |
|---|---|---|
| kc1, kc2 | N/m | blade vertical stiffnesses ***per side***, equivalent to kbuz and ***2****kblz in Mathematica |
| stage2 | - | switch governing the interpretion of the d's: state2=1 => d's are physical, apply flexure correction; stage2=0 => d's are effective, flexure correction already included, don't reapply. |
| bd | N/(m/s), N.m/(rad/s) | a small amount of damping which is added to all DOFs to avoid unrealistically peaky TFs; defaults to 0.001. |

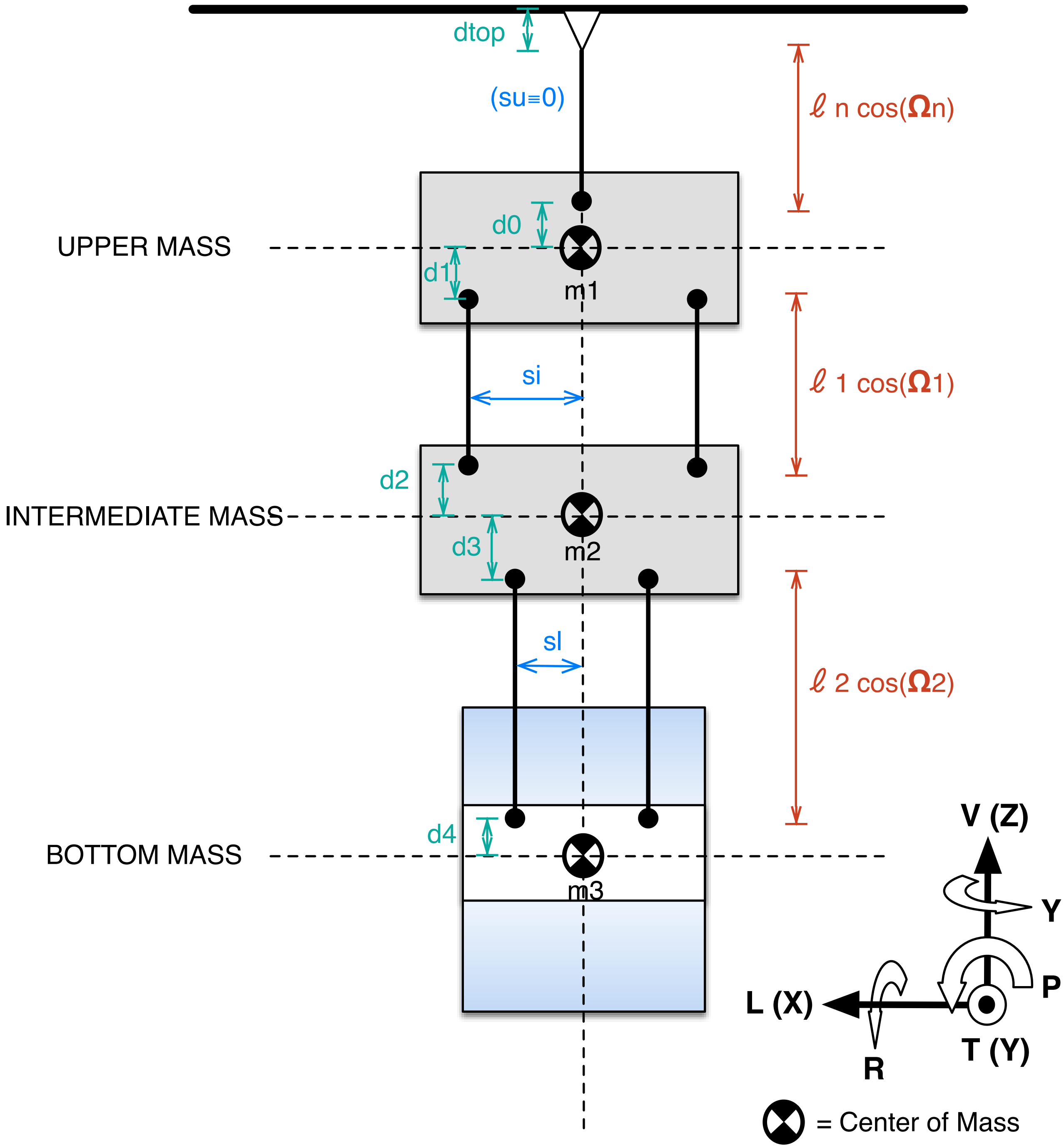
## 2.3 Parameters unique to Mathematica

| Parameter | Unit | Description |
|---|---|---|
| kbuz, kblz | N/m | blade vertical stiffnesses ***per blade***, equivalent to kc1 and kc2/2 in Matlab |
| kw1, kw2, kw3 | N/m | wire vertical stiffnesses, per wire; case definer needs to calculate these manually whereas they are calculated automatically in the Matlab |

# 3 Diagrams

In the final PDF of this document, OmniGraffle diagrams of the dimensional parameters will be appended.


n0
ℓ 1
Ω1 = sin⁻¹(n1-n0) / ℓ n
n1
m1
UPPER MASS
n2
ℓ 2
Ω2 = sin⁻¹(n3-n2) / ℓ 1
n3
m2
INTERMEDIATE MASS
n2
ℓ 3
Ω3 = sin⁻¹(n4-n5) / ℓ 2
n4
m3
BOTTOM MASS
V (Z)
Y
R
T (Y)
L (X)
P
= Center of Mass


dtop
(su≡0)
ℓ n cos(Ωn)
UPPER MASS
d0
d1
m1
si
ℓ 1 cos(Ω1)
d2
INTERMEDIATE MASS
d3
m2
sl
ℓ 2 cos(Ω2)
d4
BOTTOM MASS
m3
V (Z)
Y
P
L (X)
R
T (Y)
= Center of Mass