305-577A Optimum Design

Project # 1: Single-Variable Optimization
The Optimum Design of a Positioning Mechanism

Assigned: September 5, 2002 Due: September 26, 2002

Shown in Fig. 1 is the iconic model of a micro-positioning mechanism used to align fiber optic in photonic devices. The mechanism, which is being designed with geometric and mechanical symmetry, consists of:

- a plate of mass m that undergoes vertical translations and rotations in the plane of the figure, and hence, can be modelled as a slender, uniform bar of length l;
- two identical springs of stiffness k, whose axes are assumed to remain vertical, anchored symmetrically with respect to the vertical of the mass centre C of the plate, a distance $a/2$ from C.

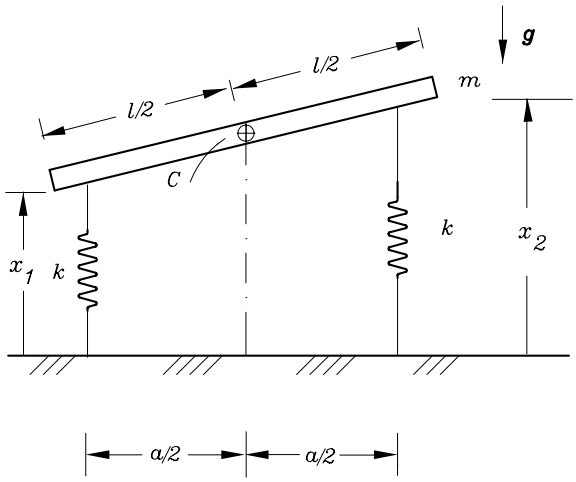

Figure 1: A micro-positioning mechanism

For maximum positioning accuracy, the two-degree-of-freedom model of the mechanism should exhibit a special behaviour: Under any perturbation from equilibrium, of a constant magnitude, i.e., under arbitrary initial conditions $x_1(0)$ and $x_2(0)$—while assuming $\dot{x}_i(0) = 0$, for $i = 1, 2$—of the displacements of the upper ends of the springs, obeying the relation

$$x_1(0)^2 + x_2(0)^2 = \text{constant}$$

the maximum energy stored in the system should be a minimum. This specification is equivalent to requiring that the ratio $r = \omega_2/\omega_1$ be a minimum, with ω_1 and ω_2 denoting the lower and the higher natural frequencies of the system.

The prescribed behaviour can be achieved by properly choosing the location of the anchor points of the springs, i.e., by properly choosing a. For practical reasons, the anchor

points shouldn't be either too close or too separate, which means that a is to be bounded, e.g., by

$$0.5l \leq a \leq l$$

Find the optimum value of a within the above bounds by means of the a) dichotomous, b) Fibonacci and c) golden-section search methods, so that the optimum lie within an interval of length 2% of the original length.

Comment on the performance of each of the above methods and on the feasibility of meeting all design specifications.

On the Marking and the Structure of the Project Report

All reports will be marked based on the results (80%) and the presentation (20%). The basic structure, on which the presentation part will be marked, comprises at least the items below:

1. An *Abstract*, describing the work reported, in about 100 words;
2. an *Introduction*, describing the problem and its connection to design and to optimum design, while providing references whenever needed;
3. the body of the project, with as many sections as needed for each case, including the mathematical modelling work in as much detail as possible, and all pertinent references;
4. *Conclusions*, stating whether the goals of the project were achieved and to what extent. What difficulties were encountered?, etc.; and
5. *References*, listing all bibliographic items referred to in the report, using a standard format. Notice that the Lecture Notes use the "(authors' names, year)" format, while listing the references in alphabetical order, with no numbers. An alternative style consists of a number, with all references listed in order of citation; not in alphabetical order! and
6. *Appendices*, with code and any ancillary material needed for a better assessment of the report.