

**PROGRAM FOR INDIVIDUALIZED LEARNING
UNIVERSITY OF MINNESOTA**

NARRATIVE TRANSCRIPT FOR: Alan E. Kilian

PROJECT TITLE: Attracting Customers: Design and Construction of an Inverted Pendulum Mechanical System with a Closed-loop Control System for use at an Industry Trade Show

PROJECT DESCRIPTION: This project will produce an inverted pendulum mechanical system with a closed-loop control system. An inverted pendulum mechanical system consists of two mechanical parts: A cart which can move back and forth on a rail. This cart can be thought of as a toy train on a straight section of train track. The train can move in only one dimension. It can move forward or backwards but cannot move left, right, up or down since it must remain on the track at all times. A vertical pole mounted on the top of the cart is mounted in such a way that it can rotate about the lowest point where it is attached to the cart. The axis of rotation is perpendicular to the motion axis of the cart. This means that the pole can rotate either forward or backwards relative to the cart, but cannot rotate to the left or right.

A closed-loop control system consists of four items: an electrical device to measure the angle of the pendulum; an electrical device to measure the position of the cart along the track; an electrical device that can cause the cart to move forward and backwards; and, a computer system that uses the measurements of pendulum angle and cart position and determines the correct direction and distance to move the cart in order to cause the pendulum to reduce its tilt and become vertical and in balance. The goal of the closed-loop control system is to cause the cart to move to the left and right so that the pole remains balanced above the cart without falling over to the left or right and to attempt to keep the cart positioned in the center of its track. This project will result in a working inverted pendulum mechanical system with a closed-loop control system as documented in photographs and videos as well as a 5-7 page paper explaining the theoretical principles and practices used in the design and construction of the inverted pendulum mechanical system with a closed-loop control system.

PROJECT DURATION: March 2008 – May 2012

PROJECT EVALUATOR: *William K. Durfee, Professor, Mechanical Engineering, University of Minnesota, Minneapolis, MN.

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The purpose of this project was for Alan to learn the theory and hardware implementation of a controlled inverted pendulum. The inverted pendulum is a classic controls problem and often forms the basis of a lab exercise in college-level introductory controls courses.

Alan did a superb job on the project, meeting or exceeding the evaluation expectations described in his project proposal. Referring to the proposal:

1. Alan now understands the principles and processes of an inverted pendulum system under closed-loop control.
2. Alan did an adequate job specifying estimates for motor power and other key hardware requirements.
3. Alan selected the right mechanical and electrical components as evidenced by the chosen components being part of the functioning system.
4. The construction of the system was first rate as evidenced by Logic displaying Alan's working system at an important trade show.
5. The software met the objective of being able to control the inverted pendulum.
6. The turning process was appropriate for homing in on a set of control gains that stabilized the pendulum.

This challenging project was a useful inclusion in Alan's PIL program to earn a degree in what is essentially mechatronics. I was impressed by his skills in mechanical design, electronic design and software design, the three essential components of a mechatronic system.