ECEN315 Lab Project

Control of a motorised rigid pendulum*.

* Based on an experiment designed by Prof Paul Oh of Drexel University, PA, USA.

1. Introduction.

The purpose of this lab is to serve as a design project for the course. It presents you with a relatively complex system; a motorised, propeller driven rigid pendulum and then allows you to explore various aspects of this system. It is meant to be relatively open-ended in solving the various problems. In the first few labs we will look at the system characteristics, derive a mathematical model of the system and measure the open loop response. However, the ultimate goal of the lab is for you to design a closed loop control system that will improve the system response and this will be the aim of the later laboratories.

2. The system.

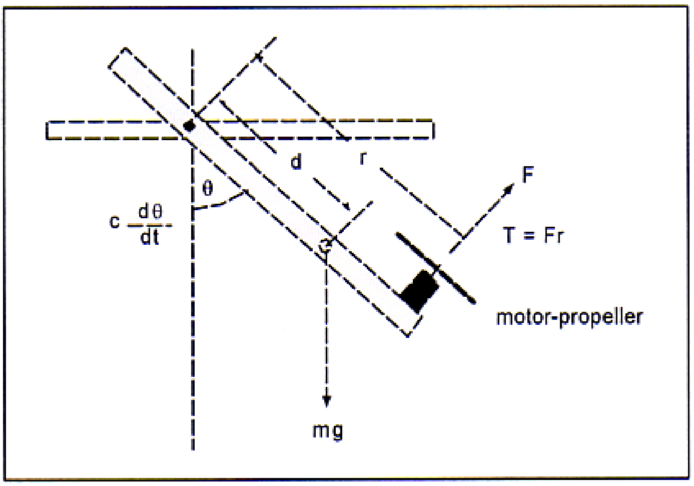

Figure 1: The basic propeller driven pendulum.

You will be provided with the components to construct the motorised pendulum shown above. A torque to the system is provided by a propeller driven by a small electric motor. A step in the voltage input will cause the pendulum to swing through some angle, oscillate for some time and then settle down at a steady state angle. The angular displacement of the system can be monitored by a rotary potentiometer so that a record of angular position with time can be obtained. The system is underdamped and in the open loop configuration the system response will look somewhat like below:

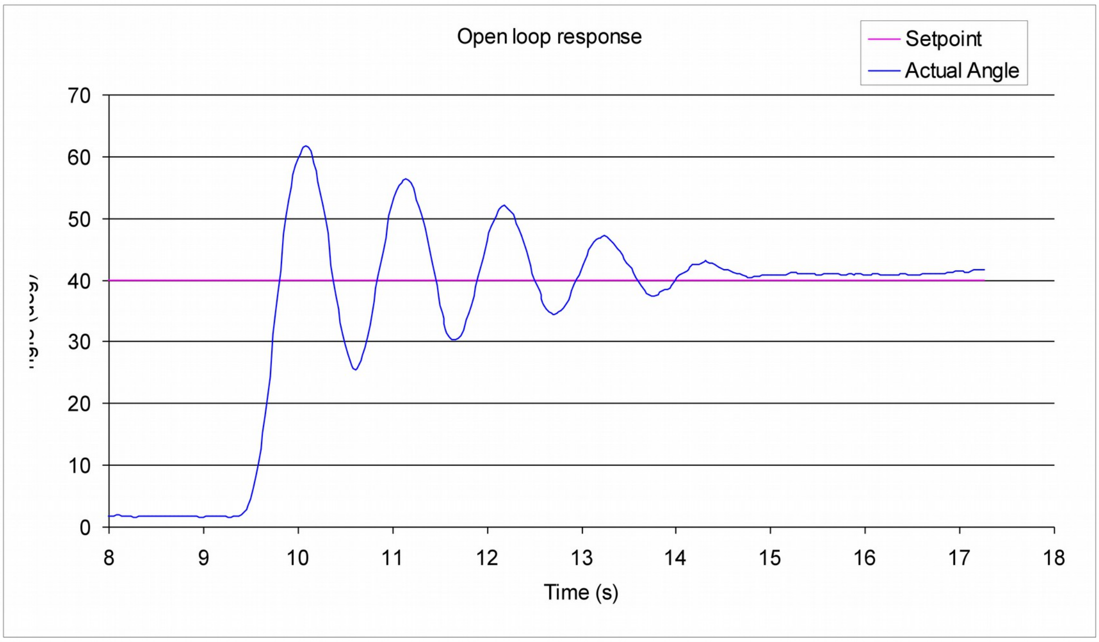

Figure 2: Open loop response of the system.

If we want the system to have a specific angular position, we will first have to calibrate the steady state angle achieved versus the input voltage. From this calibration we should then know what voltage to apply in order to achieve the desired angle. The problem with such an open loop control system is the system may take a long time to settle down at the steady state position and that it will always be susceptible to external disturbances.

The ultimate aim is to improve this open loop control system by adding a closed loop controller so that we can improve the transient response and at the same time also counter the effect of disturbances on the system.

In order to perform this, you should complete the following tasks:

1. System Identification
2. Transfer function of a DC motor
3. System transfer function and open loop step response

Mid Trimester Break

4. Feedback, Proportional control
5. PID Control
6. Minor loop feedback

Laboratory 1: System identification and modelling.

Part One: Safety

As part of your general induction to the lab you should read the yellow safety folder available at the front of the laboratory.

The experimental apparatus used in the ECEN315 project poses a number of particular hazards. Write down as many risks as you can. For each one indicate the potential severity of the problem, its probability of occurrence. Finally, for each hazard you should indicate appropriate procedures to minimise the risk.

In particular, you should think about
1. How the pendulum should be mounted to the desk,
2. What will happen if various components of the apparatus fail

You should present your findings in a table as shown below, which should be included as an appendix in your first project report. Each row of the table can be considered as describing an independent risk.

Hazard	Cause	Probability	Severity	Mitigation

Hazard: What is something that can go wrong? The identified hazard should be the consequence of the incident.

Cause: What can go wrong with the apparatus, or operator, or environment to cause the hazard to come about? Note that there may well be more than one possible cause that can bring about the hazard.

Probability: How likely is it that a particular risk will eventuate? You don't need to be quantitative here, simple consider whether something is likely (ie you expect it to happen to you some time during the project), unlikely (it might happen to one group some time during the project) or rare (you would be surprised if it ever happened).

Severity: How damaging would the consequences of the event be? Would the result be an injury (high severity), damage to equipment (probably medium severity, depending on what is damaged), or merely inconvenient (low severity)?

Mitigation: What (if anything) will you do to address the risk. You should pay particular attention to probable and high severity incidents in devising your mitigation strategy. Again, you may have more than one mitigation measure to deal with some risks.

You will likely decide that some of the risks are not particularly important. That is fine, but you should leave these in your table to demonstrate that you have considered them.

Part Two: The system identification of the motorised pendulum.
You first need to derive a (mathematical) model of the system. In order to do this we need to consider the various subsystems present in the system.

(a) Sketch a block diagram of the various subsystems that you can identify and show how each of these subsystems are related. Identify the input and output for each sub-system. (Hint: The input into our system is voltage and the output is the angular displacement). Try to keep the operation of each block simple. Construct block diagrams for both the open loop system and the closed loop system.

(b) Write down the units of the inputs and outputs of each block. You should find that the units of any connected blocks are consistent.

(c) Derive the transfer function for each of the blocks you have identified. You do not have to assign any numeric values to the system variables yet. At this stage you simply want to think about the form of the transfer functions that you might expect, as this will help guide you towards appropriate methods for finding the parameters necessary to descibe the system.

(d) In order to model the system response, the numeric values of the system variables needs to be determined. Identify these system parameters for each of the different blocks. Try to identify ways to obtain a relatively accurate measurement for each of the parameters in (c) so that a system model can be obtained. In the next labs you will now have to measure these system variables as accurately as possible.