Systems Analysis and Control

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Lecture 1: Introduction to Control Systems

What is Control?

Control is the study of how to use technology.

- How to make a airplane fly.
- How to make a robot build a car
- How to drive a car

The most common source of **Control** is **Human**.

In this class we focus on *Automatic Control*

What is a Control **System**?

It is a System.
Lets start with the simpler question:
What is a System?

Definition 1.

A **System** is anything with inputs and outputs

Let start with some examples.

Examples of Systems

Stereo

Inputs and outputs depend on what we want to do.

Examples of Systems

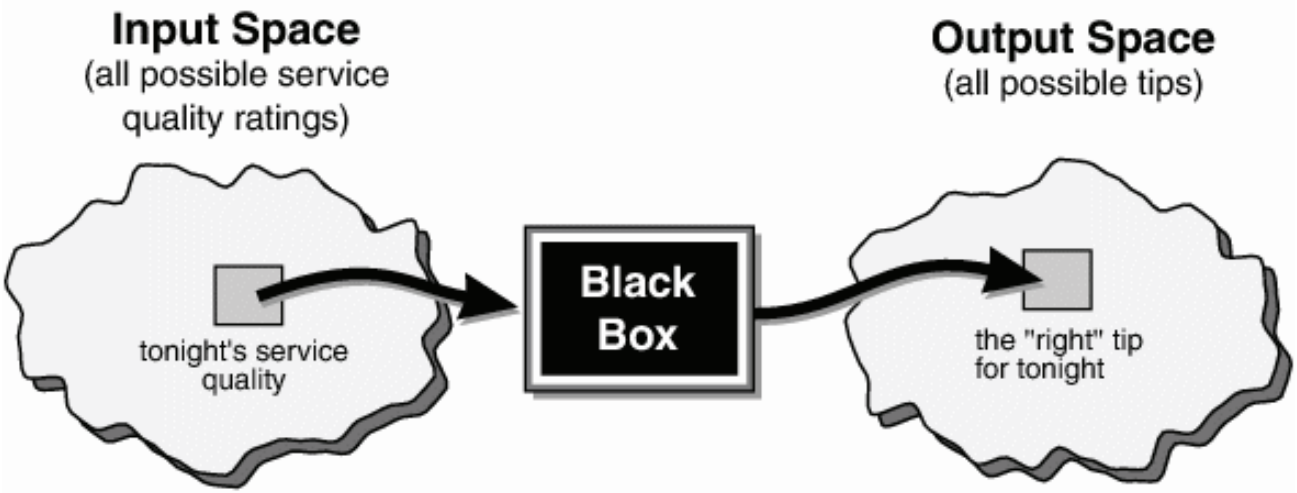
Stereo

Examples of Systems

Tipping

Examples of Systems

Tipping



An input-output map for the tipping problem:
"Given the quality of service, how much should I tip?"

- Note that the dining experience may have many possible inputs and outputs
- We must chose the inputs and outputs relevant to the waiter!!

Examples of Systems

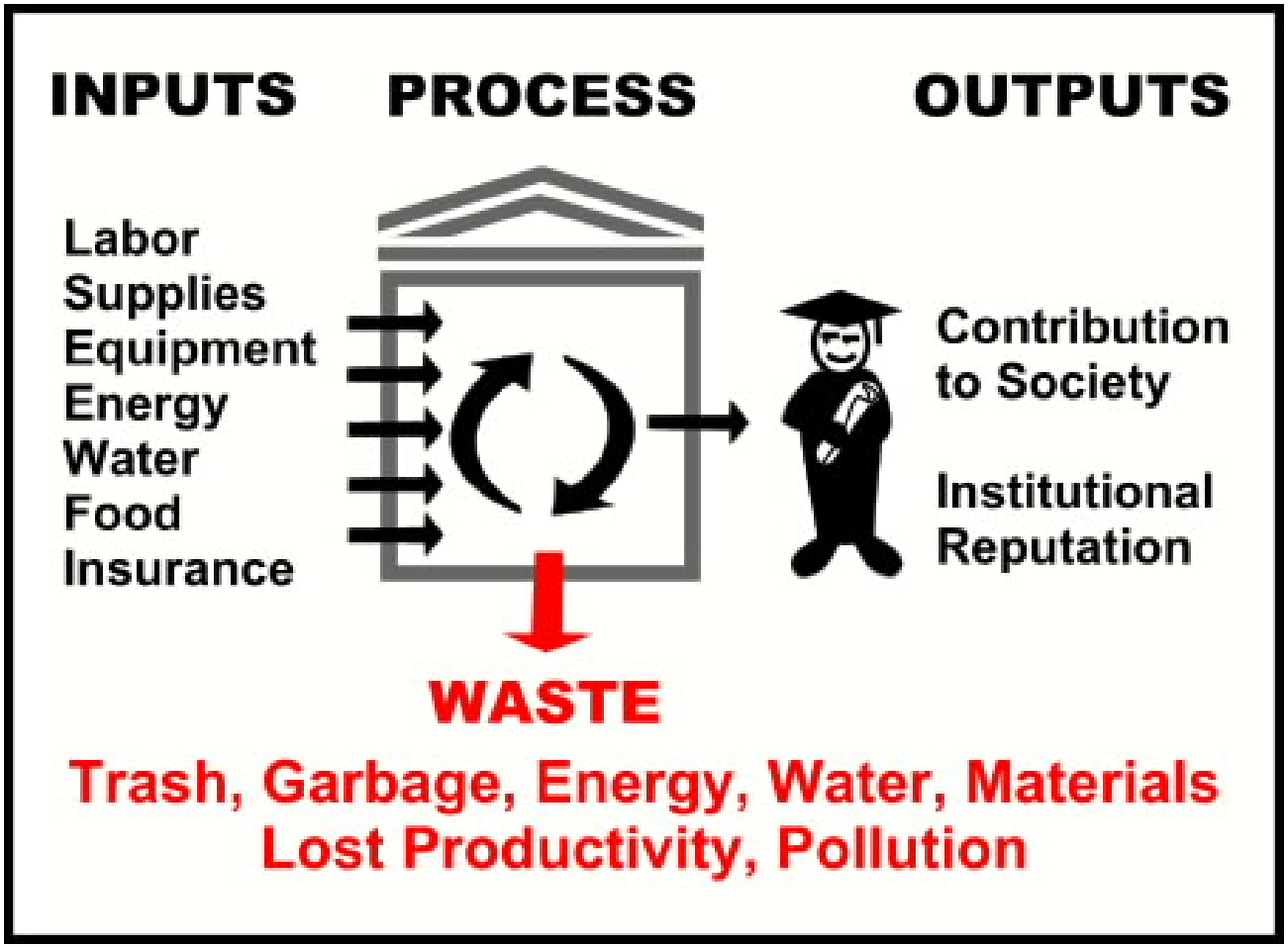
College

Definition 2.

The System to be controlled is called the **Plant**.

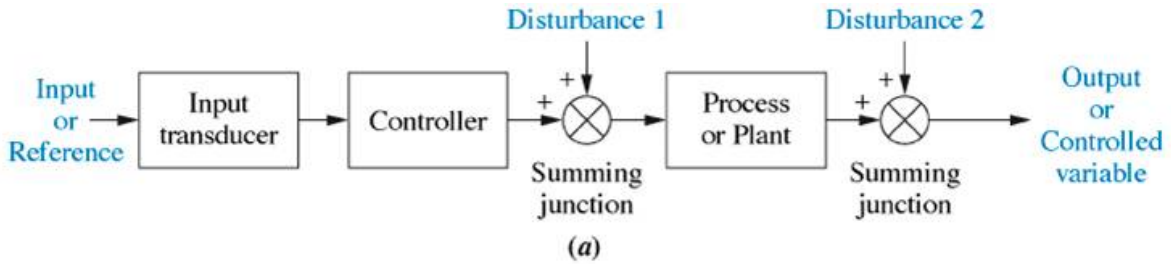
Examples of Systems

College



Definition 3.

A **Control System** is a system which modifies the inputs to the *plant* to produce a desired output.



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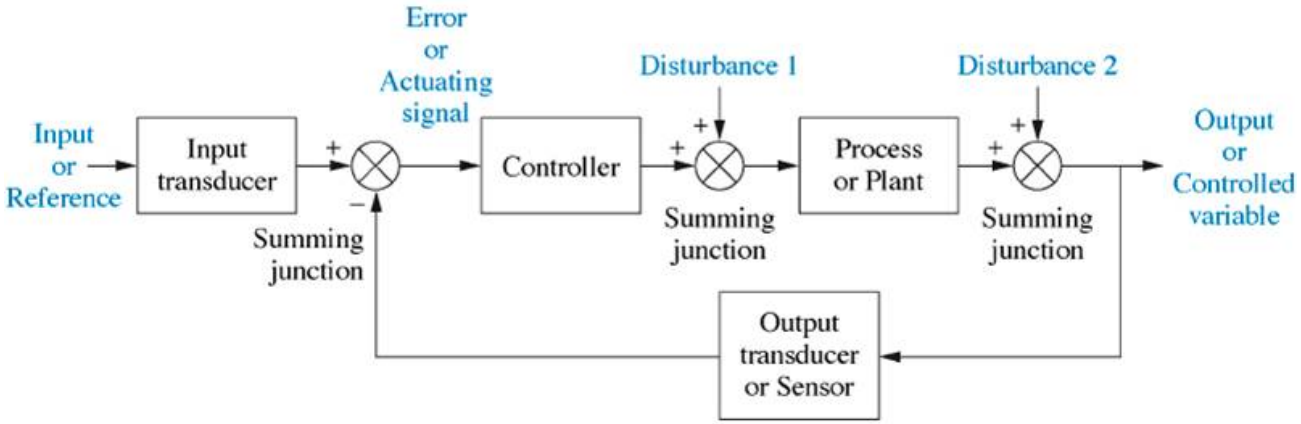

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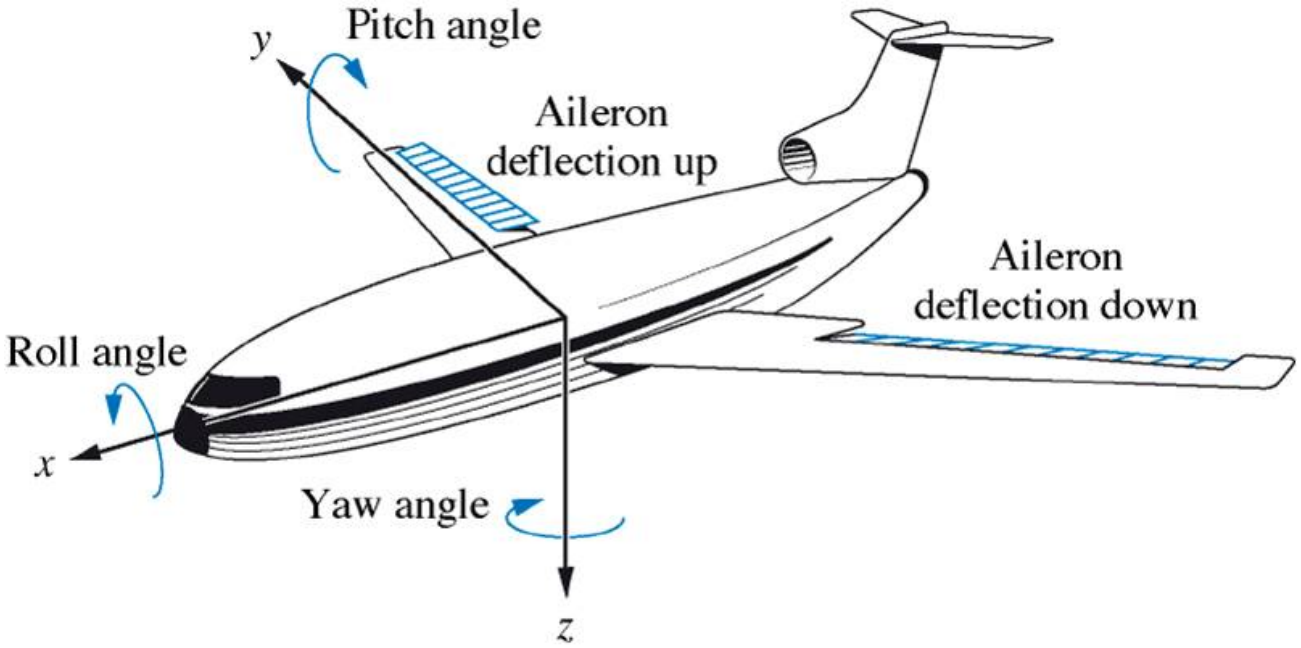
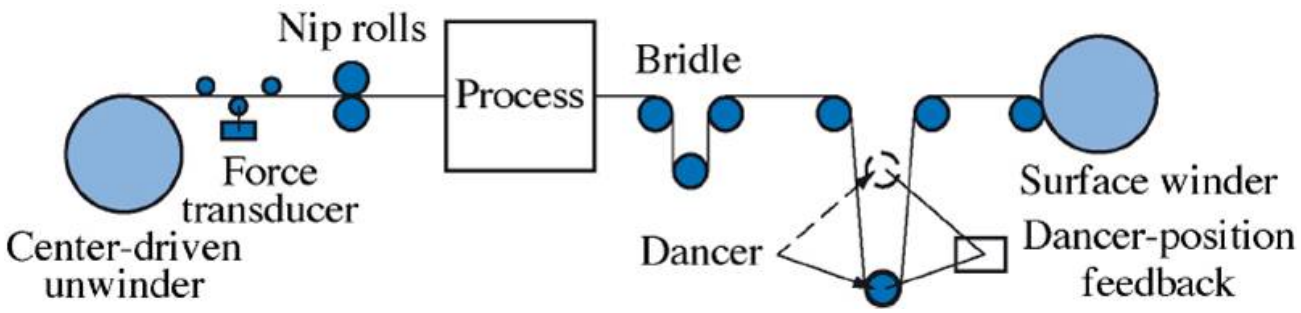
Examples of Systems

Airplane



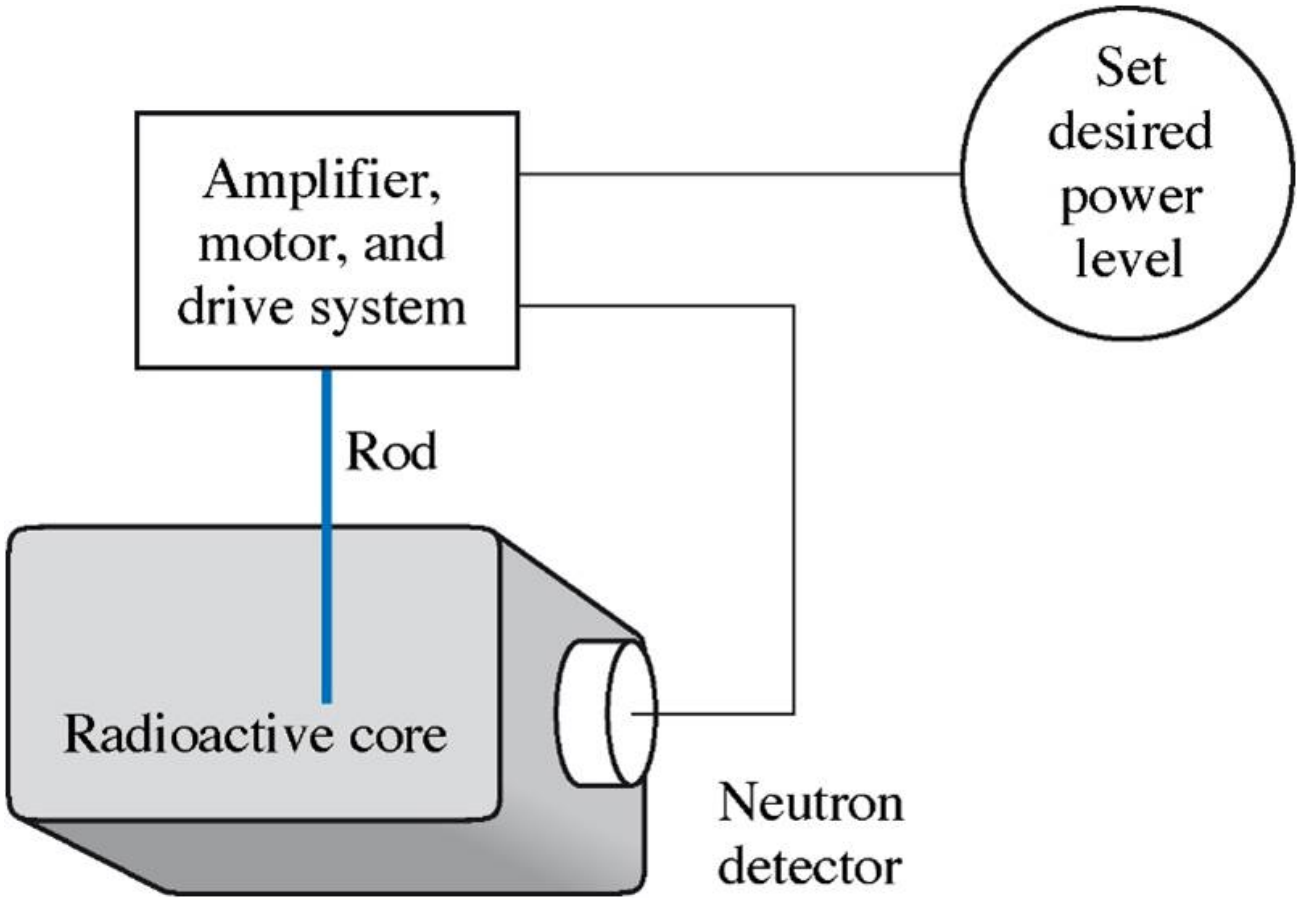
Examples of Systems

Paper Milling



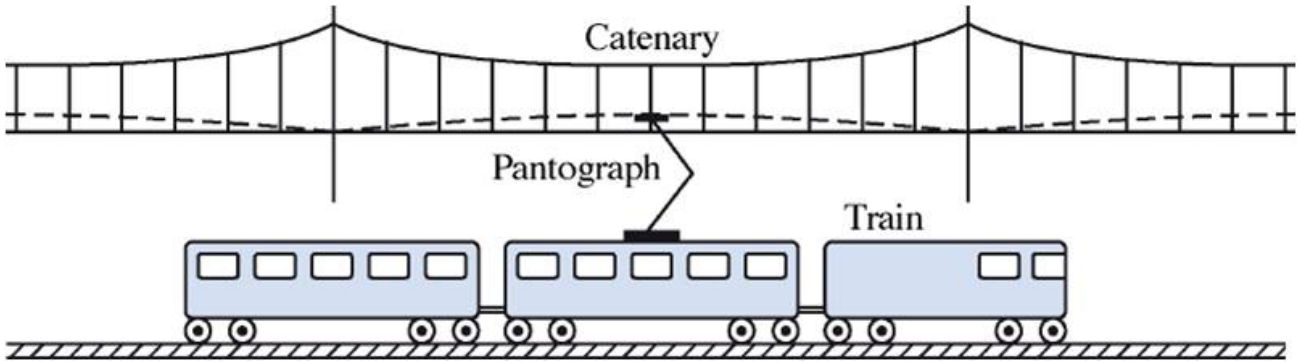
Examples of Systems

Nuclear Reactor



Examples of Systems

Pantograph



Fundamentals of Control

Any controller must have one fundamental part: The Actuator

Definition 4.

The **Actuator** is the mechanism by which the controller affects the input to the plant.

Examples:

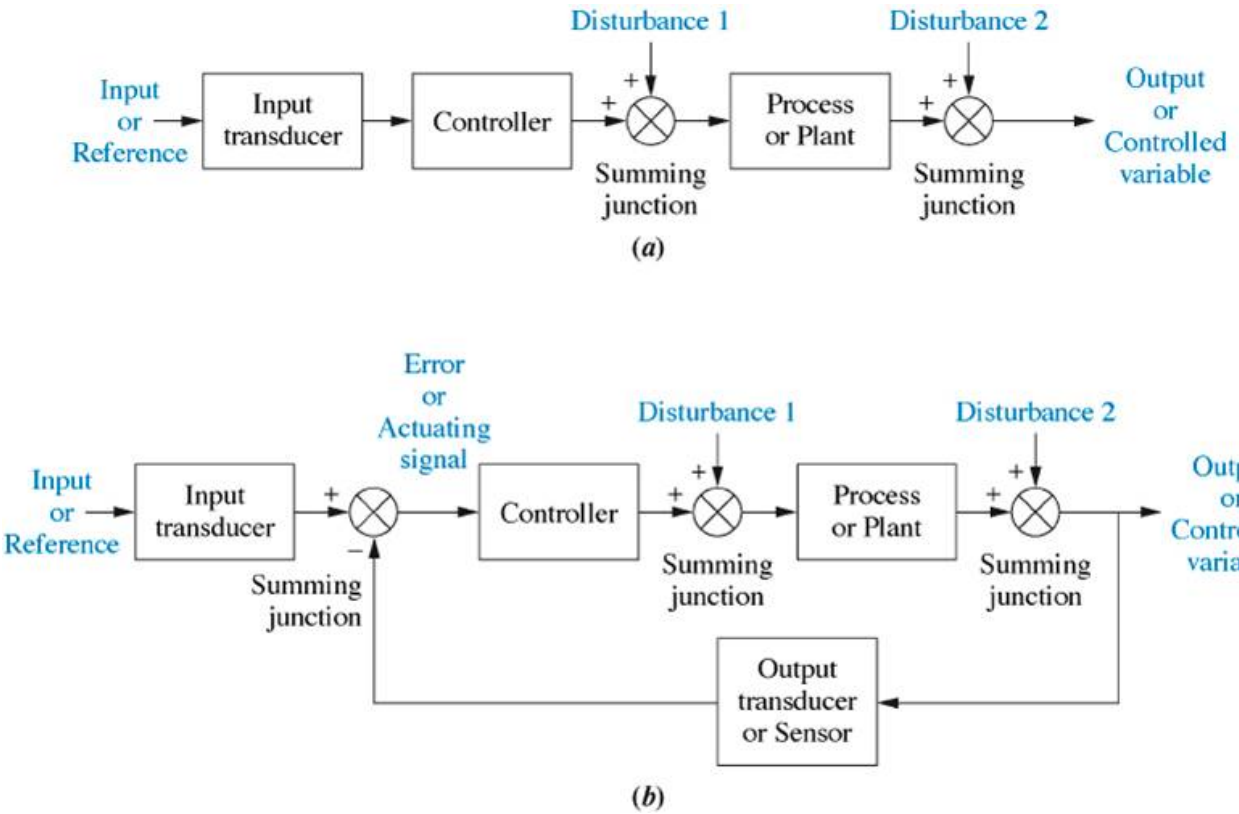
- Ailerons, Rudder
- Force Transducers: Servos/Motors
  - Servos
  - Motors
- Furnace/Boiler

The Basic Types of Control

The first basic type of control is **Open Loop**.

Definition 5.

An **Open Loop Controller** has actuation, but no measurement.



Examples of open Loop Control

- Choosing a Class
- A Pop-up Toaster
  - Actuators, Inputs, Outputs?
- Irrigation Systems
- Conveyer belts

Problems?

The Two Basic types of Control

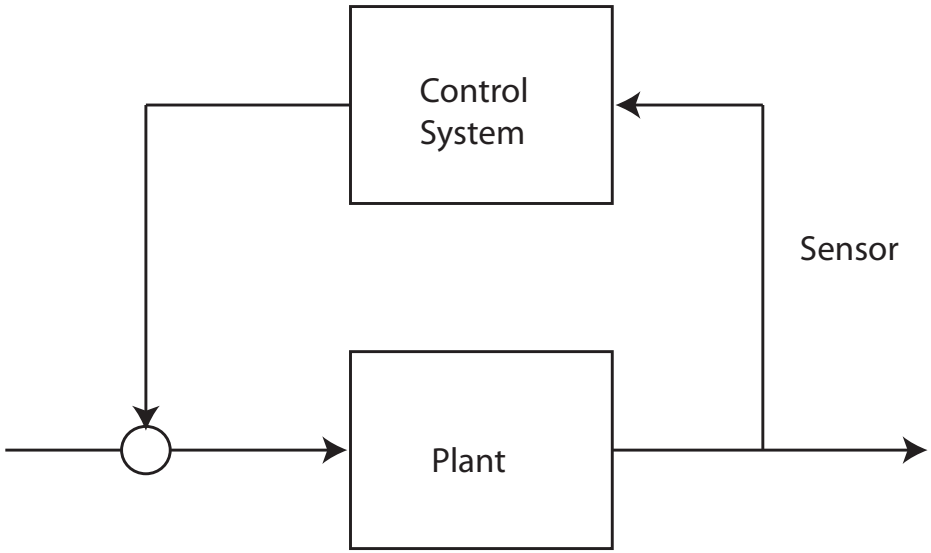
The second basic type of control is **Closed Loop**.

Definition 6.

The **Sensor** is the mechanism by which the controller detects the outputs of the plant.

Definition 7.

A **Closed Loop Controller** uses *Sensors* in addition to Actuators.



Lets go through some detailed examples.

History of Feedback Control Systems

Egyptian Water Clocks 1200BC

Time left is given by the amount of water left in the pot.
Problem: Measurement is limited to time left and by amount of water in pot.
Solution: Measure the amount of water that comes out of the pot.

History of Water Clocks

Time passed is amount of water in pot.

Problem: Water flow varies by amount of water in the top pot.

Solution: Maintain a constant water level in top pot.

History of Water Clocks

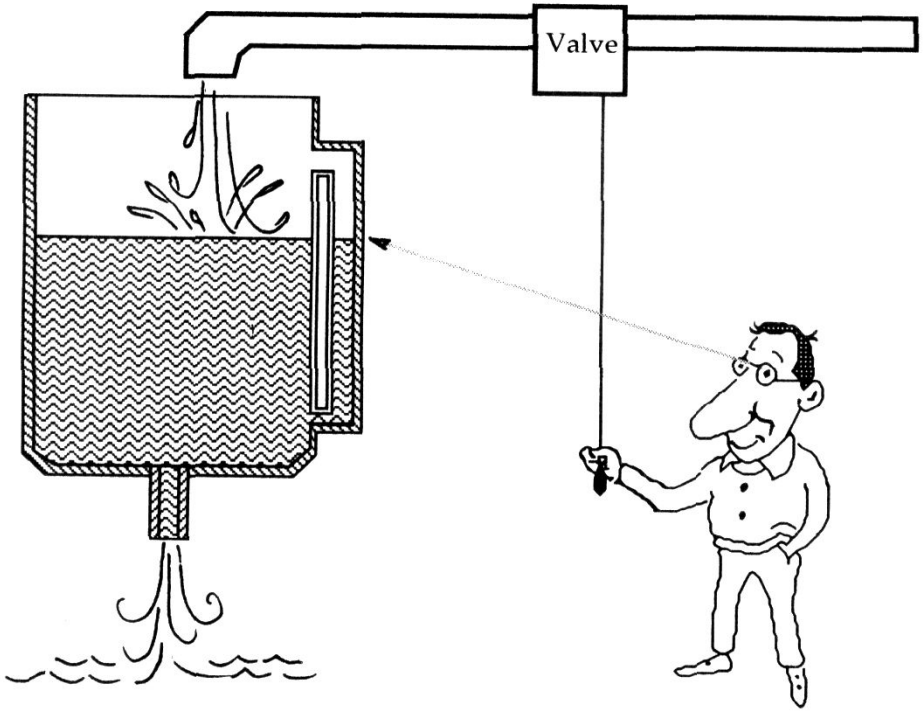


FIGURE 1.1. Level Control System. A sight tube and operator's eye form a sensor: a device which converts information into electrical signal.

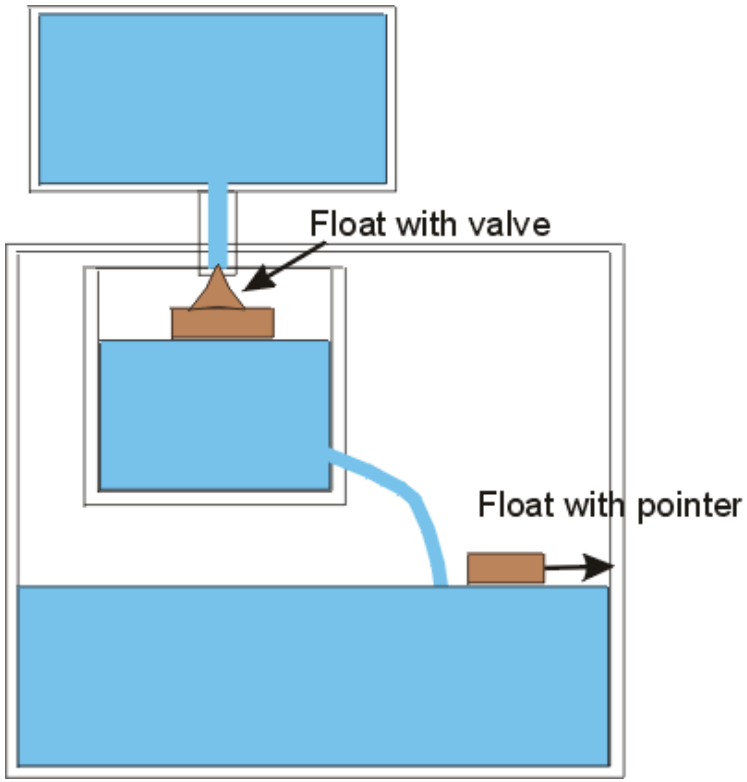
Problem: Manually refilling the top pot is labor intensive and inaccurate.
Solution: Design a control System (Inputs, Outputs?).

History of Water Clocks

Ctesibius c. 220-285 BC

Father of pneumatics

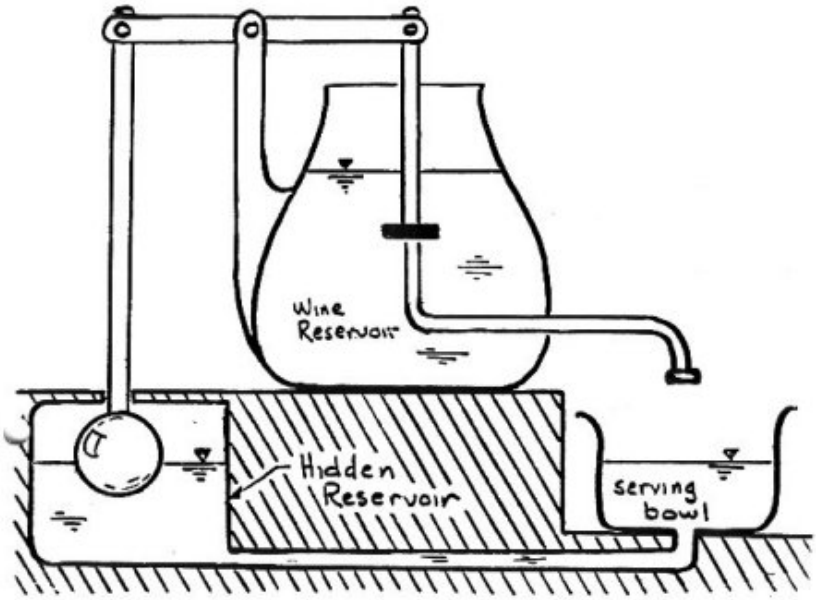
- Dirt Poor
- Created most accurate clock until Huygens (1657 AD)
- Overshadowed by better-known student Heron (Hero) of Alexandria



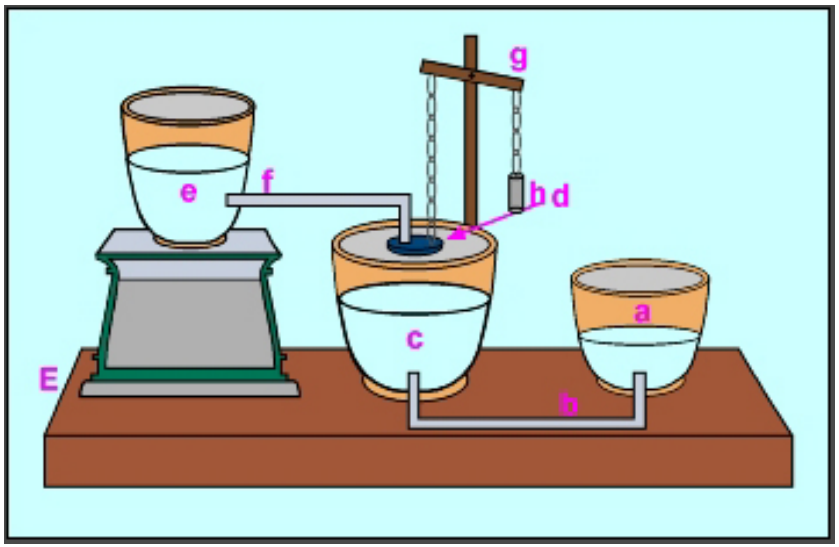
History of Water Clocks

Heron (Hero) of Alexandria c. 10 AD

As any good student, Hero used Ctesibius' water clock to perform party tricks.



HERO'S SELF-LEVELING BOWL
ca. 30 B.C.

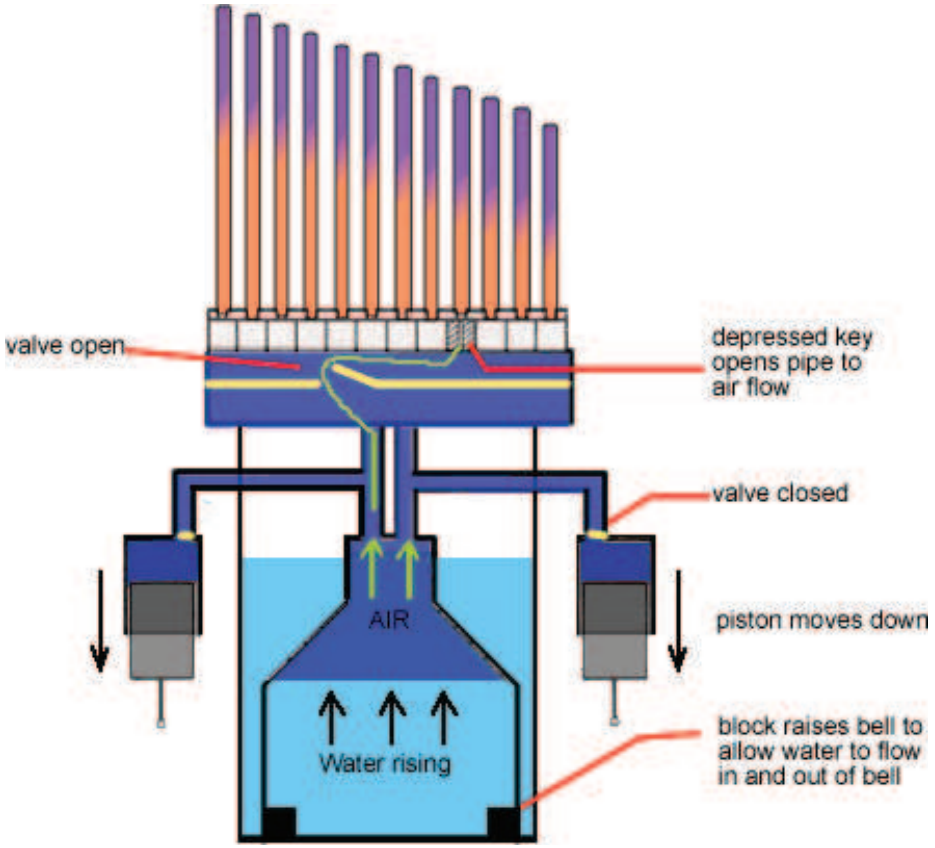


The self-replenishing wine bowl. (Inputs, Outputs?)

History of Water Clocks

The Pipe Organ

Ctesibius himself applied the principle of pneumatic control to create a pipe organ.



The Industrial Revolution

More Serious Applications

In addition to Wine bowls, Heron also developed the steam engine.

Unfortunately, the result was not applied and was unregulated.

The Modern Aeolipile

Modern (Relatively) Steam Engines

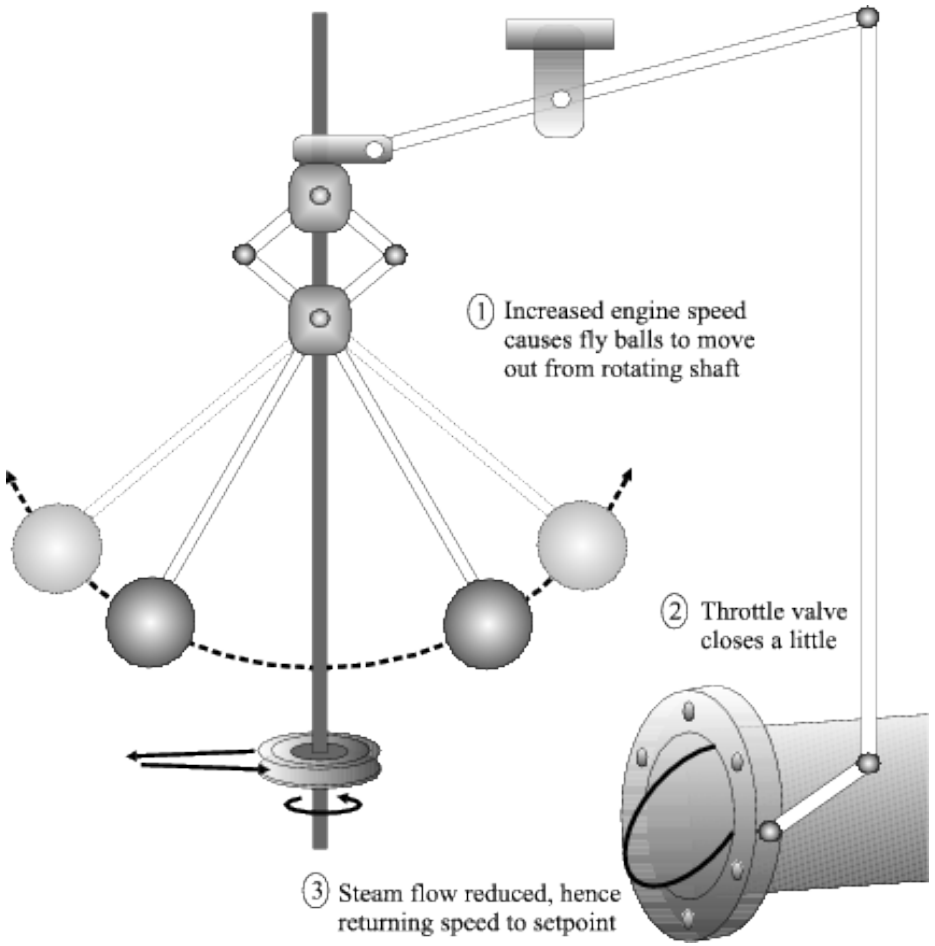
The Flyball Governor

Problem: To be useful, steam engines must rotate a piston at a *fixed speed*.

The Flyball Governor

Flyballs are attached to rotating piston

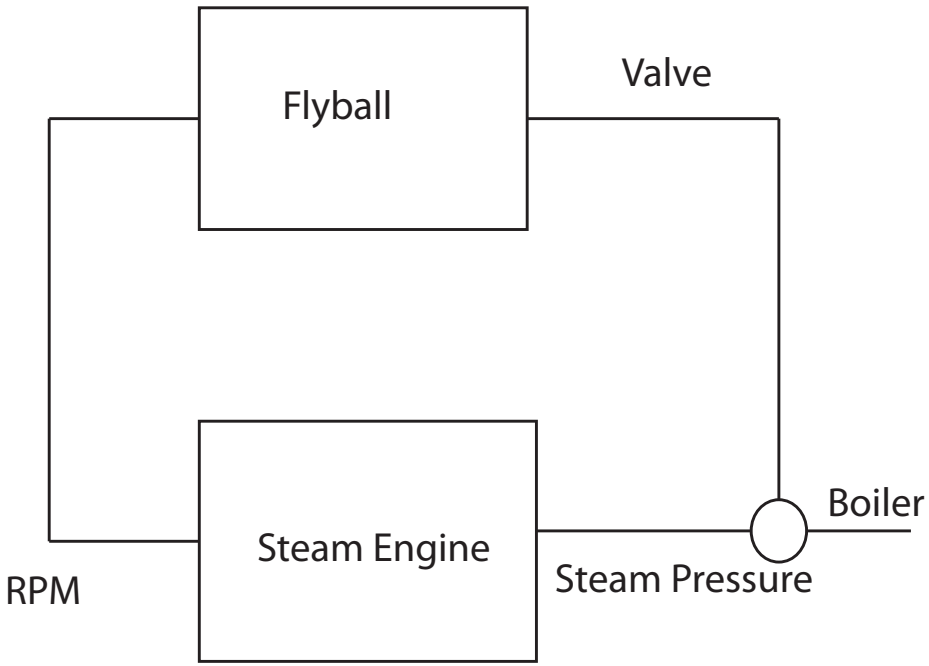
- Faster rotation = More centrifugal force.
- Centrifugal force lifts the flyballs, which move a lever which releases steam.
- Release of steam reduces pressure.
- Reduced pressure decreases engine/piston speed.



Identify the inputs and outputs

The Flyball Governor

Block Diagram Representation



The Flyball is a feedback controller for the steam engine.

The Flyball Governor

The Flyball Governor in Operation

Stuart-Turner No9 Steam Engine

True Story: When the control output was saturated, the engine was said to be going "Balls Out". This is the real etymology of the expression.

Overview of Course Objectives

Will that be on the final???

Part 1: System Analysis

- Given a system model:
  - Given an input, find the output
  - Predict the effect of Standard Inputs (Impulse, Step, Ramp, etc.)
  - Determine Stability
- Given a desired response:
  - Determine the characteristic root locations

Part 2: Controller Design

- Given a system model:
  - Plot the effect of proportional gain (Root-Locus)
  - Plot the response to sinusoidal input (Bode Plot)
- Given a desired response:
  - Propose feedback controllers (PID and lead-lag) to achieve the desired response.