Feedback Control of Dynamic Systems 8th edition Powell Solutions Manual

SKU: 9780134685717-SOLUTIONS

Solutions Manual: Chapter 1

8th Edition

Feedback Control of Dynamic Systems

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Chapter 1

An Overview and Brief History of Feedback Control

1.1 Problems and Solutions

1. Draw a component block diagram for each of the following feedback control systems.

   (a) The manual steering system of an automobile

   (b) Drebbel's incubator

   (c) The water level controlled by a float and valve

   (d) Watt's steam engine with fly-ball governor

   In each case, indicate the location of the elements listed below and give the units associated with each signal.

   - the process
   - the process desired output signal
   - the sensor
   - the actuator
   - the actuator output signal
   - the controller
   - the controller output signal
   - the reference signal
   - the error signal

   Notice that in a number of cases the same physical device may perform more than one of these functions.

   Solution:

   (a) A manual steering system for an automobile:

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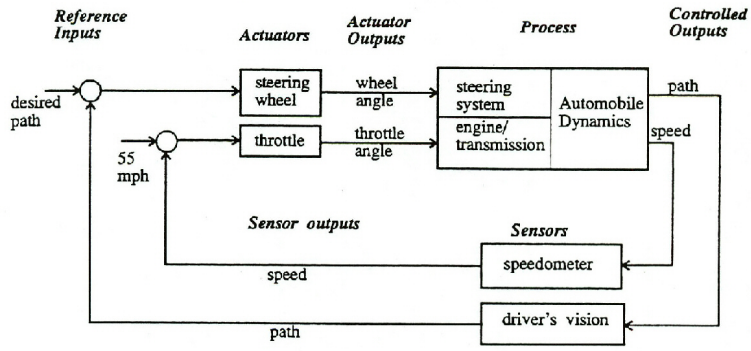
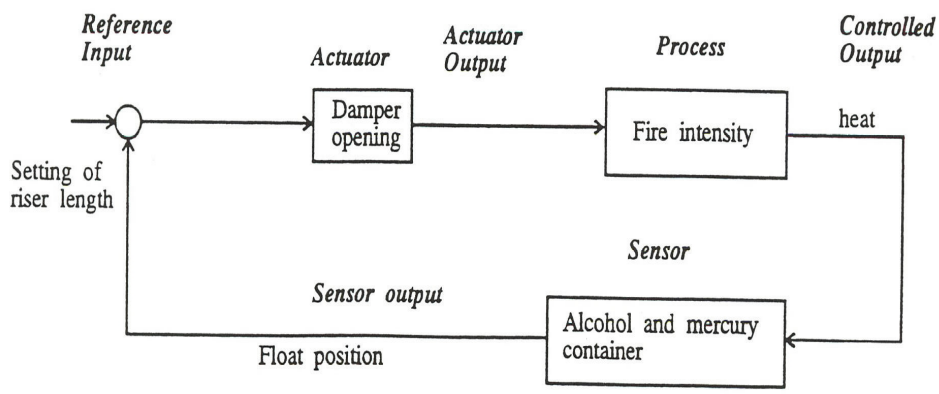
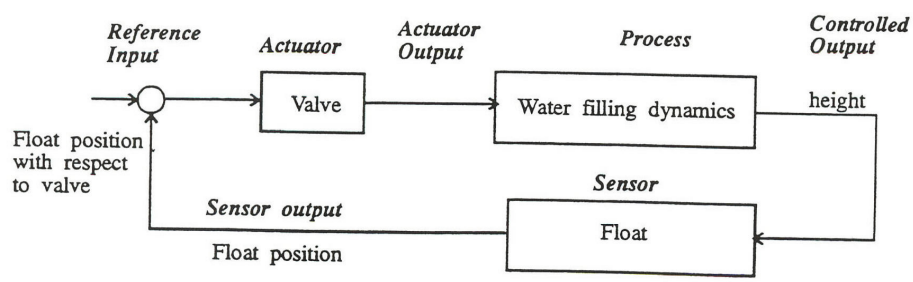


(b) Drebbel's incubator:



(c) Water level regulator:



(d) Fly-ball governor:

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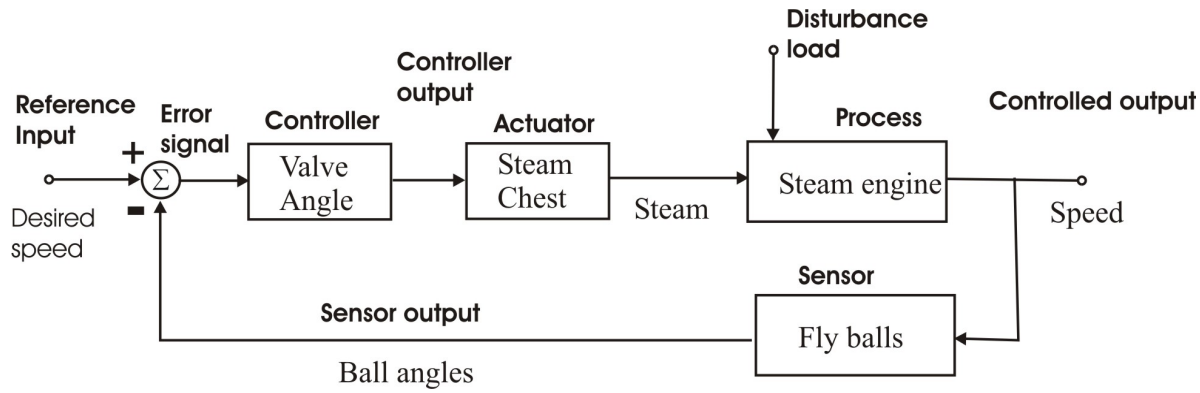

2. Identify the physical principles and describe the operation of the thermostat in your home or office.

Solution:

A thermostat is a device for maintaining a temperature constant at a desired value. It is equipped with a temperature sensor which detects deviation from the desired value, determines whether the temperature setting is exceeded or not, and transmits the information to a furnace or air conditioner so that the temperature in the room is brought back to the desired setting. Examples: Tubes filled with liquid mercury are attached to a bimetallic strip which tilt the tube and cause the mercury to slide over electrical contacts. A bimetallic strip consists of two strips of metal bonded together, each of a different expansion coefficient so that temperature changes bend the metal. In some cases, the bending of bimetallic strips simply cause electrical contacts to open or close directly. In most cases today, temperature is sensed electronically using,for example, a thermistor, a resistor whose resistance changes with temperature. Modern computer-based thermostats are programmable, sense the current from the thermistor and convert that to a digital signal.

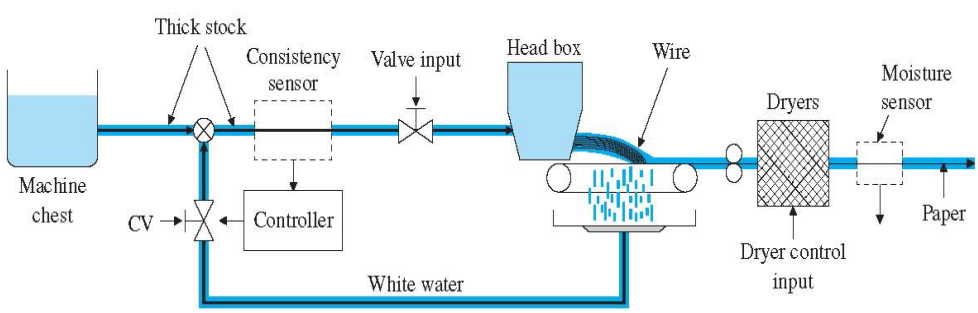

Fig 1.12 A Paper Making Machine

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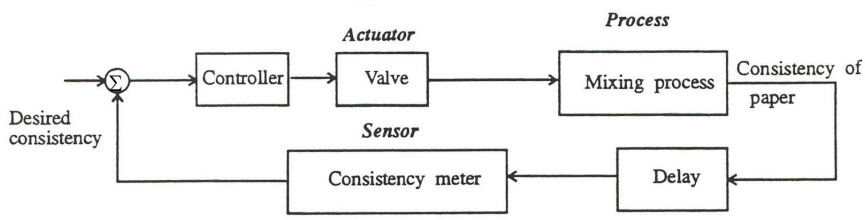
3. A machine for making paper is diagrammed in Fig. 1.12. There are two main parameters under feedback control: the density of fibers as controlled by the consistency of the thick stock that flows from the headbox onto the wire, and the moisture content of the final product that comes out of the dryers. Stock from the machine chest is diluted by white water returning from under the wire as controlled by a control valve (CV). A meter supplies a reading of the consistency. At the "dry end" of the machine, there is a moisture sensor. Draw a signal graph and identify the seven components listed in Problem 1 for

   (a) control of consistency

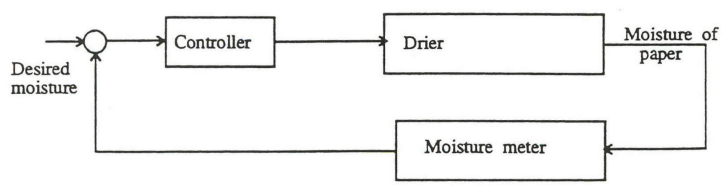
   (b) control of moisture

   Solution:

   (a) Control of paper machine consistency:



   (b) Control of paper machine moisture:



4. Many variables in the human body are under feedback control. For each of the following controlled variables, draw a graph showing the process being controlled, the sensor that measures the variable, the actuator that causes it to increase and/or decrease, the information path that completes the feedback path, and the disturbances that upset the variable. You may need to consult an encyclopedia or textbook on human physiology for information on this problem.

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(a) blood pressure

(b) blood sugar concentration

(c) heart rate

(d) eye-pointing angle

(e) eye-pupil diameter

Solution:

Feedback control in human body:

Variable	Sensor	Actuator	Information path	Disturbances
a) Blood pressure	-Arterial baroreceptors	-Cardiac output -Arteriolar/venous dilation	-Afferent nerve fibers	-Bleeding -Drugs -Stress,Pain
b) Blood sugar concentration (Glucose)	-Pancreas	-Pancreas secreting insulin	-Blood flow to pancreas	-Diet -Exercise
c) Heart rate	-Diastolic volume sensors -Cardiac sympathetic nerves	-Electrical stimulation of sino-atrial node and cardiac muscle	-Mechanical draw of blood from heart -Circulating epinephrine	-Hormone release -Exercise
d) Eye pointing angle	-Optic nerve -Image detection	-Extraocular muscles	-Cranial innervation	-Head movement -Muscle twitch
e) Pupil diameter	-Rods	-Pupillary sphincter muscles	-Autonomous system	-Ambient light -Drugs
f) Blood calcium level	-Parathyroid gland detectors	-Ca from bones to blood -Gastrointestinal absorption	- Parathormone hormone affecting effector sites	-Ca need in bones -Drugs

5. Draw a graph of the components for an elevator-position control. Indicate how you would measure the position of the elevator car. Consider a combined coarse and fine measurement system. What accuracies do you suggest for each sensor? Your system should be able to correct for the fact that in elevators for tall buildings there is significant cable stretch as a function of cab load.

Solution:

A coarse measurement can be obtained by an electroswitch located before the desired floor level. When touched, the controller reduces the motor speed. A "fine" sensor can then be used to bring the elevator precisely to the floor level. With a sensor such as the one depicted in the figure, a linear control loop can be created (as opposed to the on-off type of the coarse control).Accuracy required for the course switch is around 5 cm; for the fine floor alignment, an accuracy of about 2 mm is desirable to eliminate any noticeable step for those entering or exiting the elevator.

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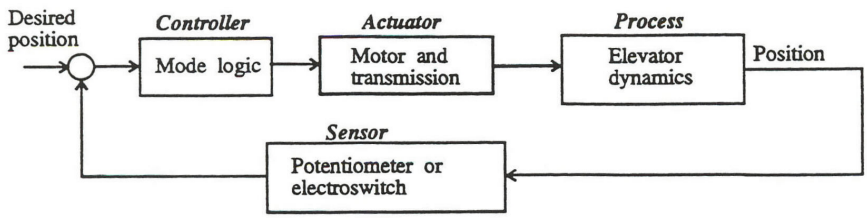


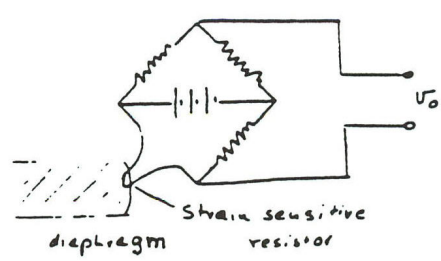
6. Feedback control requires being able to sense the variable being controlled. Because electrical signals can be transmitted, amplified, and processed easily, often we want to have a sensor whose output is a voltage or current proportional to the variable being measured. Describe a sensor that would give an electrical output proportional to:

   (a) temperature
   (b) pressure
   (c) liquid level
   (d) flow of liquid along a pipe (or blood along an artery) force
   (e) linear position
   (f) rotational position
   (g) linear velocity
   (h) rotational speed
   (i) translational acceleration
   (j) torque

   Solution:

   Sensors for feedback control systems with electrical output. Examples

   (a) Temperature: Thermistor- temperature sensitive resistor with resistance change proportional to temperature; Thermocouple; Thyristor. Modern thermostats are computer controlled and programmable.
   (b) Pressure: Strain sensitive resistor mounted on a diaphragm which bends due to changing pressure



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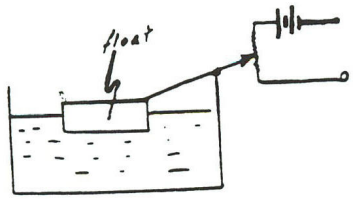
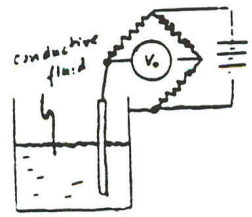
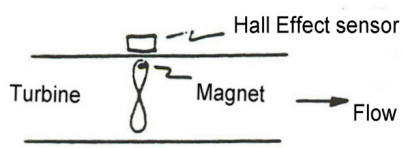
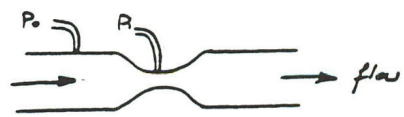
(c) Liquid level: Float connected to potentiometer. If liquid is conductive the impedance change of a rod immersed in the liquid may indicate the liquid level.





(d) Flow of liquid along a pipe: A turbine actuated by the flow with a magnet to trigger an external counting circuit. Hall effect produces an electronic output in response to magnetic field changes. Another way: Measure pressure difference from venturi into pressure sensor as in figure; Flowmeter. For blood flow, an ultrasound device like a SONAR can be used.





(e) Position.
When direct mechanical interaction is possible and for "small" displacements, the same ideas may be used. For example a potentiometer may be used to measure position of a mass in an accelerator (h). However in many cases such as the position of an aircraft, the task is much more complicated and measurement cannot be made directly. Calculation must be carried out based on other measurements, for example optical or electromagnetic direction measurements to several known references (stars,transmitting antennas ...); LVDT for linear, RVDT for rotational.

(f) Rotational position. The most common traditional device is a potentiometer. Also common are magnetic machines in which a rotating magnet produces a variable output based on its angle.

(g) Linear velocity. For a vehicle, a RADAR can measure linear velocity. In other cases, a rack-and-pinion can be used to translate linear to rotational motion and an electric motor(tachometer) used to measure the speed.

(h) Speed: Any toothed wheel or gear on a rotating part may be used to trigger a magnetic field change which can be used to trigger an electrical counting circuit by use of a Hall effect (magnetic to electrical) sensor. The pulses can then be counted over a set time interval to produce angular velocity: Rate gyro; Tachometer

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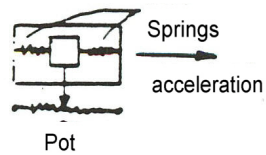
(i) Acceleration: A mass movement restrained by a spring measured by a potentiometer. A piezoelectric material may be used instead (a material that produces electrical current with intensity proportional to acceleration). In modern airbags, an integrated circuit chip contains a tiny lever and 'proof mass' whose motion is measured generating a voltage proportional to acceleration.



(j) Force, torque: A dynamometer based on spring or beam deflections, which may be measured by a potentiometer or a strain-gauge.

7. Each of the variables listed in Problem 6 can be brought under feedback control. Describe an actuator that could accept an electrical input and be used to control the variables listed. Give the units of the actuator output signal.

Solution:

(a) Resistor with voltage applied to it or mercury arc lamp to generate heat for small devices. a furnace for a building..

(b) Pump: Pumping air in or out of a chamber to generate pressure. Else, a 'torque motor' produces force..

(c) Valve and pump: forcing liquid in or out of the container.

(d) A valve is normally used to control flow.

(e) Electric motor

(f) Electric motor

(g) Electric motor

(h) Electric motor

(i) Translational acceleration is usually controlled by a motor or engine to provide force on the vehicle or other object.

(j) Torque motor. In this motor the torque is directly proportional to the input (current).

8. *Feedback in Biology*

(a) *Negative Feedback in Biology*: When a person is under long term stress (say a couple of weeks before an exam!), hypothalamus (in the brain) secretes a hormone called CRF (Corticotrophin Releasing Factor) which binds to a receptor in the pituitary gland stimulating it to produce ACTH

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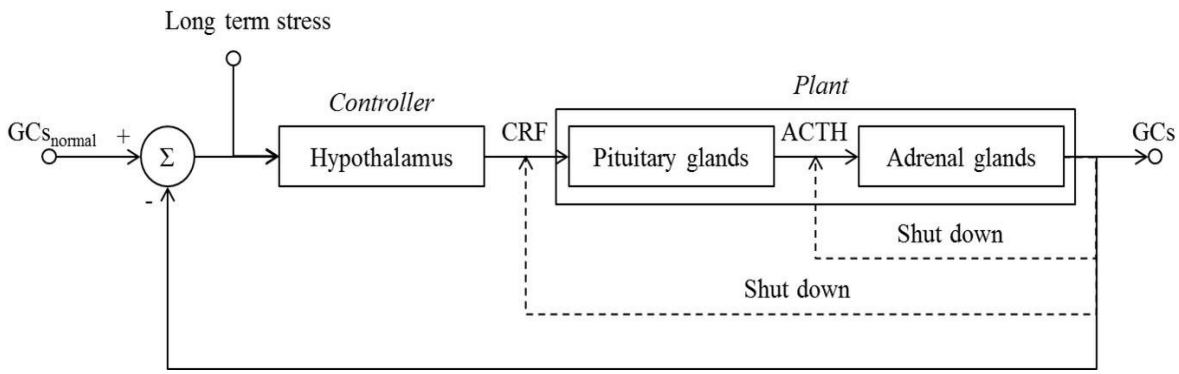
(Adrenocorticotropic hormone), which in turn stimulates the adrenal cortex (outer part of the adrenal glands) to release the stress hormone Glucocorticoids (GC). This in turn shuts down (turns off the stress response) for both CRF and ACTH production by negative feedback via the bloodstream until GC returns to its normal level. Draw a block diagram of this closed-loop system.

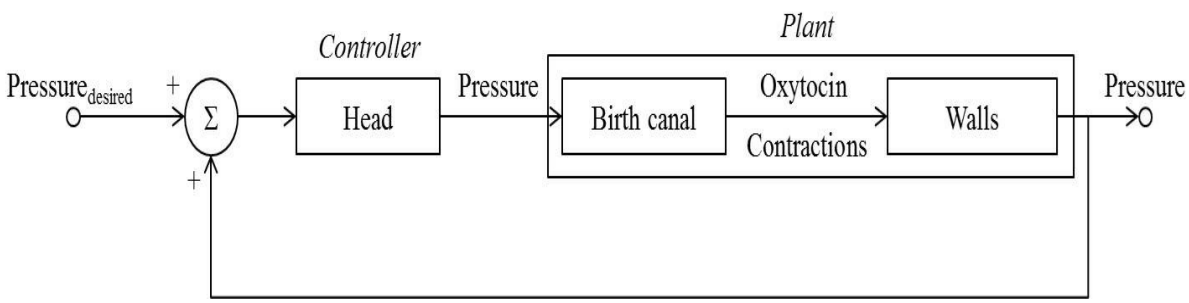
(b) *Positive Feedback in Biology*: This happens in some unique circumstances. Consider the birth process of a baby. Pressure from the head of the baby going through the birth canal causes contractions via secretion of a hormone called Oxytocin which causes more pressure which in turn intensifies contractions. Once the baby is born, the system goes back to normal (negative feedback). Draw a block diagram of this closed-loop system.

Solution:

(a) Negative Feedback in Biology - Stress



(b) Positive Feedback in Biology - Child birth



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