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.

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

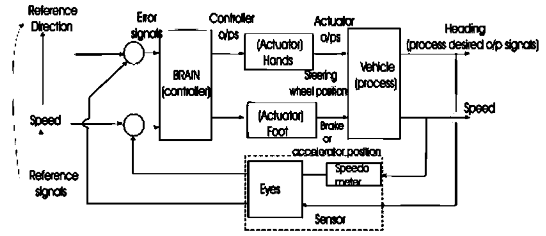
- The process
- The process desired output signal
- The sensor
- The actuator
- The actuator output signal
- The controller
- The controller output signal
- The reference signal
- The error signal

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

Step-by-step solution

Step 1 of 4

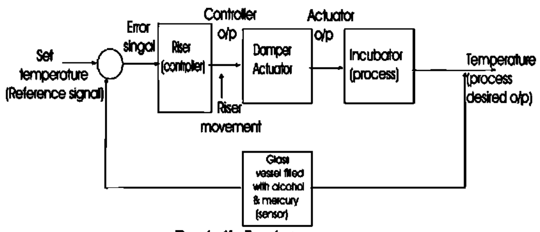
(A).



Manual Steering Systems

Step 2 of 4

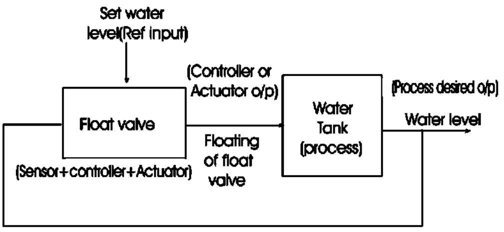
(B)



Dreabel's Incubator

Step 3 of 4

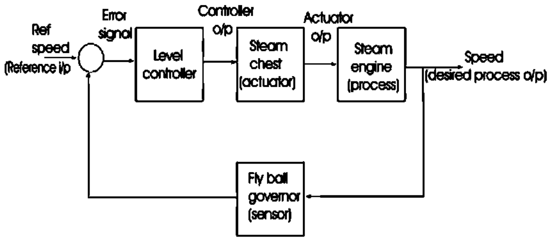
(c)



Water Level Controller

Step 4 of 4

(D)



Fly-Ball Governor

Problem 1.02PP

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

office.

Step-by-step solution

Step 1 of 1

Thermostat is used as the sensing element for controlling the room temperature. It performs the task of automatic reduction of error to zero, irrespective of the situation created by disturbance.

Working Principle: It contains a fluid which is able to expand or contract due to temperature change, which causes the snap - action of a switch that makes switching – ON or OFF of the heat source.

A machine for making paper is diagrammed in Fig. 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 block diagram and identify the nine components listed in Problem part (d) for the following:

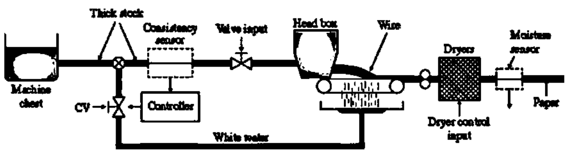
(a) Control of consistency

(b) Control of moisture

Figure A papermaking machine

(b) Control of moisture

Figure A papermaking machine



Problem part (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

Step-by-step solution

Step 1 of 13

(a)

Step 2 of 13

Figure 1 shows the general block diagram to understand the process of the system. The nine components listed below are identified in figure 1.

- Process
- Process desired output signal
- Sensor
- Actuator
- Actuator output signal
- Controller
- Controller output signal
- Reference signal
- Error signal

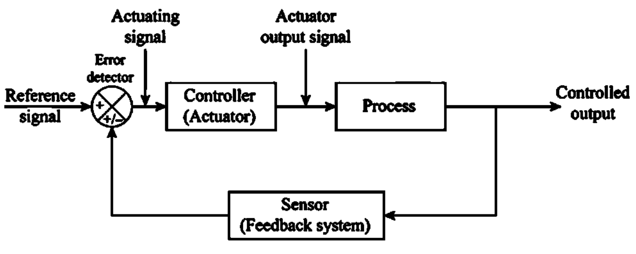


Figure 1

Step 3 of 13

Draw the block diagram for the figure 1.12 in the textbook to understand the process of control of consistency.

Step 4 of 13

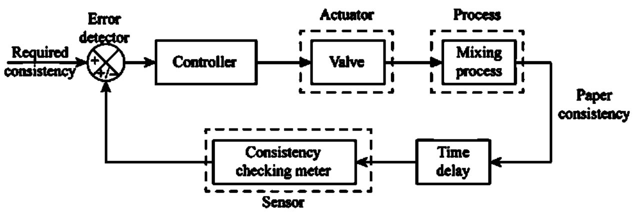


Figure 2

Step 5 of 13

Compare figure 1 and figure 2. The comparison shows the working of the paper making machine with the major components in the process of control of consistency.

Step 6 of 13

The input reference signal is given to the controller and here the valve acts as an actuator for the system. The valve initiates the mixing process and the consistency of the paper is monitored according to time delay. The consistency checking meter checks the output of the process and sends the signal to error detector. Here, the original required consistency is checked with the output received and checks for any variation in the output. The corresponding required adjustments may be done in the controller to reduce the error rate, to improve the total output of the process.

Step 7 of 13

Thus, the control of consistency is explained and the major components are identified.

Step 8 of 13

(b)

Step 9 of 13

Draw the block diagram for the figure 1.12 in the textbook to understand the process of control of moisture.

Step 10 of 13

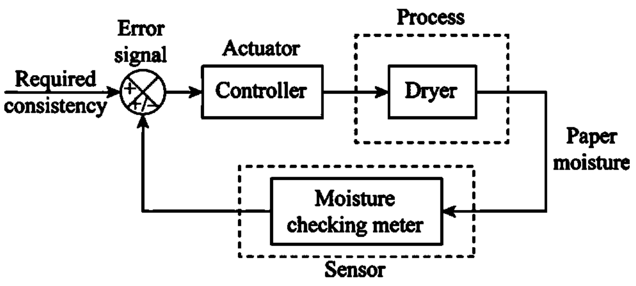


Figure 3

Step 11 of 13

Compare figure 1 and figure 3. The comparison shows the working of the paper making machine with the major components in the process of control of moisture.

Step 12 of 13

Here, Dryer remains as a main process and the moisture is checked in the moisture checking meter (sensor). The total output is compared in the error detector and required adjustments are done by the controller to improve the accuracy.

Step 13 of 13

Thus, the control of moisture is explained and the major components are identified.

Problem 1.04PP

Many variables in the human body are under feedback control. For each of the following controlled variables, draw a block diagram 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.

(a) Blood pressure

(b) Blood sugar concentration

(c) Heart rate

(c) Heart rate

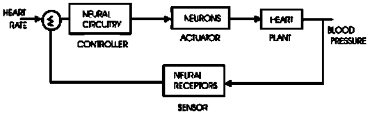
(d) Eye-pointing angle

(e) Eye-pupil diameter

Step-by-step solution

Step 1 of 2

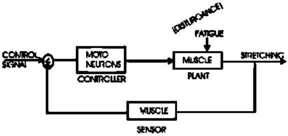
(A).
(B).
(C).



Block Diagram for Blood Pressure, Blood Sugar Concentration and Heart Rate Control

Step 2 of 2

(D).



Block Diagram of Eye-Pointing Angle and Eye – Pupil Diameter

Draw a block diagram of the components for temperature control in a refrigerator or automobile air-conditioning system.

Step-by-step solution

Step 1 of 2

Figure 1 shows the general block diagram to understand the temperature control of refrigerator and in the automobile air-conditioning system.

Actuator Process

and in the automobile air-conditioning system.

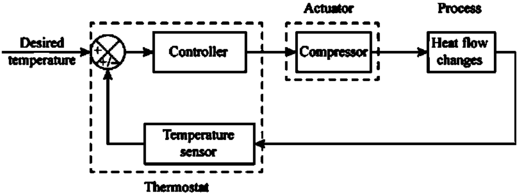


Figure 1

Step 2 of 2

The required temperature signal is set in the thermostat, and then the controller actuates the compressor for cooling process. The temperature sensor measures the temperature and compares the required reference temperature with the measured temperature in the comparator. When the required temperature is achieved, the controller stops the compressor and maintains the temperature.

The temperature sensor checks the temperature of the system periodically and actuates the controller if there is difference in the required reference temperature. This process is continued to maintain the required temperature of the system thereby controlling the ON/OFF input to the compressor.

Thus, the temperature control of refrigerator and in the automobile air-conditioning system is explained.

Problem 1.06PP

Draw a block diagram 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.

Step-by-step solution

Step 1 of 2

The components of elevator position control are shown in figure1.

Step 1 of 2

The components of elevator position control are shown in figure1.

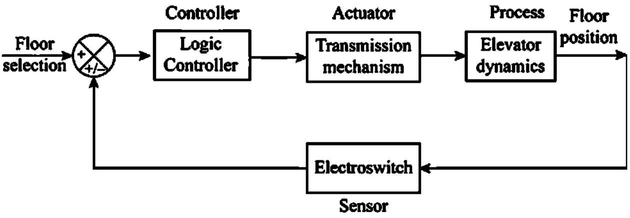


Figure 1

Step 2 of 2

The input is given to the logic controller through comparator. The logic controller drives the transmission mechanism of the elevator (Motor or hydraulic). The elevator moves up and down and reaches the required floor position.

When the corresponding floor button is pressed, the controller reduces the speed of the motor to stop the elevator in the respective floor. The electro switch acts as a sensor for coarse measurement to measure the floor level. Accuracy level can be fixed in the sensor considering the cable stretch due to cab load. This sensor enables to locate the elevator in the respective floor accurately without any deviation in the measurements.

This complete mechanism forms a closed loop as in figure 1. The error detector compares the reference input to the output of the closed loop to ensure the exact location of the elevator.

Hence, the block diagram of the elevator mechanism considering negligence is explained.

1.07PP **Problem 1.07PP**

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 the following:

(a) Temperature

(b) Pressure

(c) Liquid level

(d) Flow of liquid along a pipe (or blood along an artery)

(d) Flow of liquid along a pipe (or blood along an artery)

(e) Linear position (t) Rotational position

(g) Linear velocity

(h) Rotational speed

(i) Translational acceleration

(j) Torque

Step-by-step solution

Step 1 of 2

(A). <u>TEMPERATURE</u> : Thermocouple.

(B). <u>PRESSURE</u> : Pressure gauge.

(C). <u>LIQUID LEVEL</u> : Bourdon tube and LVDT's combination.

(D). <u>FLOW OF LIQUID ALONG PIPE FORCE</u> : Any pressure sensor can be used.

(E). <u>LINEAR POSITION</u> : LVDT (Linear Variable Differential Transformer).

Step 2 of 2

(F). <u>ROTATIONAL POSITION</u> : Potentiometer.

(G). <u>LINEAR VELOCITY</u> : Speedometer.

(H). <u>ROTATIONAL SPEED</u> : Tachometer.

(I). <u>TRANSLATIONAL ACCLERATION</u> : LVDT

(J). <u>TORQUE</u> : Combination of Gear and Tachometer.

Each of the variables listed in Problem 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.

Problem

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 the following:

(a) Temperature

(b) Pressure

(b) Pressure

(c) Liquid level

(d) Flow of liquid along a pipe (or blood along an artery)

(e) Linear position (t) Rotational position

(g) Linear velocity

(h) Rotational speed

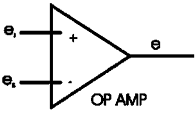
(i) Translational acceleration

(j) Torque

Step-by-step solution

Step 1 of 1

An actuator amplifies the signal taken from the sensor. Any Electronic Amplifier can be used to do such. The Operational Amplifier is the most commonly used Actuator.



OP AMP

Units of the Actuator output signal are current (Ampere) or Voltage (Volts)

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 Corticotropin Releasing Factor (CRF) which binds to a receptor in the pituitary gland stimulating it to produce Adrenocorticotropic hormone (ACTH), which in turn stimulates the adrenal cortex (outer part of the adrenal glands) to release the stress hormone Glucocorticoid (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

(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.

Step-by-step solution

Step 1 of 9

(a)

Step 2 of 9

The block diagram to show an example of closed loop negative feedback in a biological system is shown in figure 1.

Step 3 of 9

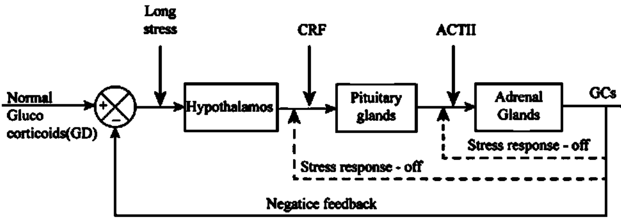


Figure 1

Step 4 of 9

Here, 'GD' is the Glucocorticiods, 'CRF' is the Corticotrophin Releasing Factor, and 'ACTH' is the Adrenocorticotropic hormone.

Step 5 of 9

Thus the block diagram of closed loop negative feedback in a biological system is drawn and shown in figure 1.

Step 6 of 9

(b)

Step 7 of 9

The block diagram to show an example of closed loop positive feedback in a biological system is shown in figure 2.

Step 8 of 9

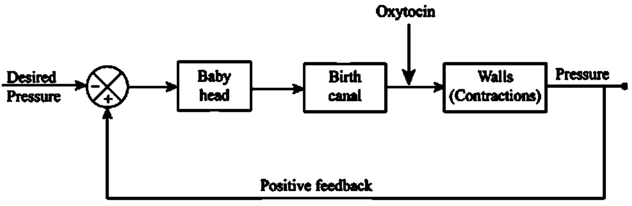


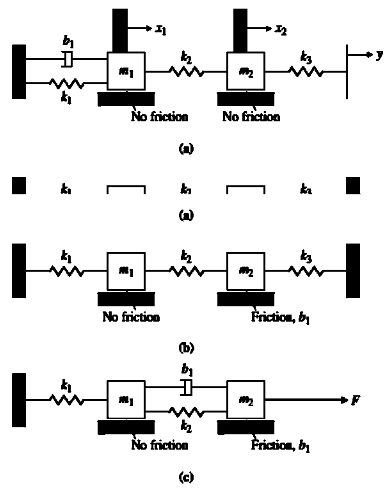
Figure 2

Step 9 of 9

Thus the block diagram is drawn to show the closed loop positive feedback in a biological system.

Write the differential equations for the mechanical systems shown in Fig.. For Fig.(a) and (b), state whether you think the system will eventually decay so that it has no motion at all, given that there are nonzero initial conditions for both masses and there is no input; give a reason for your answer.

Figure Mechanical systems



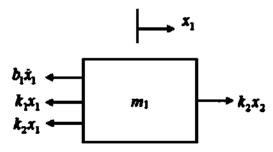
Step-by-step solution

Step 1 of 6

(a)

Refer to Figure 2.41 (a) in the text book for the block diagram of a mechanical system.

Draw the free body diagram of mass m_1.

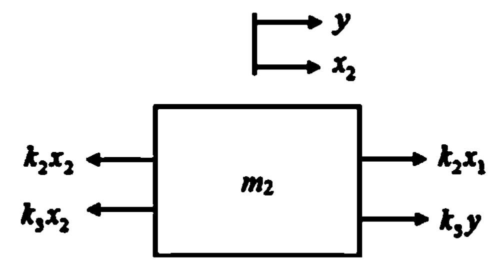


Write the differential equation describing the system.

$$m_1\ddot{x}_1 = -b_1\dot{x}_1 - k_1x_1 - k_2x_1 + k_2x_2$$
$$m_1\ddot{x}_1 + b_1\dot{x}_1 + k_1x_1 + k_2(x_1 - x_2) = 0$$

Step 2 of 6

Draw the free body diagram of mass m_2.



Write the differential equation describing the system.

$$m_2\ddot{x}_2 = -k_2x_2 - k_3x_2 + k_2x_1 + k_3y$$
$$m_2\ddot{x}_2 + k_2(x_2 - x_1) + k_3(x_2 - y) = 0$$

Thus, the differential equations describing the system are,

$$\boxed{\begin{aligned} m_1\ddot{x}_1 + b_1\dot{x}_1 + k_1x_1 + k_2(x_1 - x_2) = 0 \\ m_2\ddot{x}_2 + k_2(x_2 - x_1) + k_3(x_2 - y) = 0 \end{aligned}}.$$

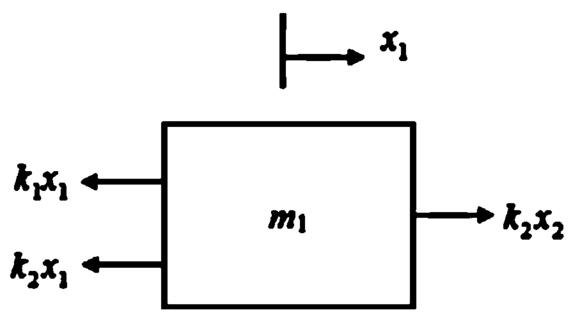
There is friction that affects the motion of both the masses. Thus, the system decays to zero motion for both the masses.

Step 3 of 6

(b)

Refer to Figure 2.41 (b) in the text book for the block diagram of a mechanical system.

Draw the free body diagram of mass m_1.

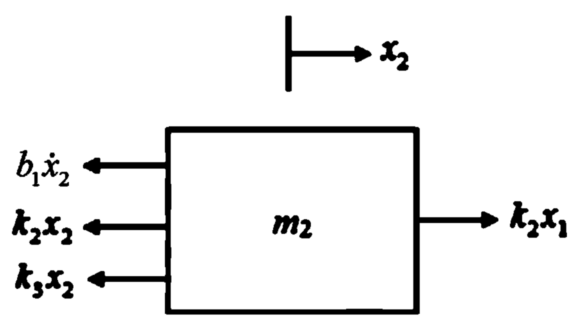


Write the differential equation describing the system.

$$m_1\ddot{x}_1 = -k_1x_1 - k_2x_1 + k_2x_2 = 0$$
$$m_1\ddot{x}_1 + k_1x_1 + k_2(x_1 - x_2) = 0$$

Step 4 of 6

Draw the free body diagram of mass m_2.



Write the differential equation describing the system.

$$m_2\ddot{x}_2 = -b_1\dot{x}_2 - k_2x_2 - k_3x_2 + k_2x_1$$
$$m_2\ddot{x}_2 + b_1\dot{x}_2 + k_2(x_2 - x_1) + k_3x_2 = 0$$

Thus, the differential equations describing the system are,

$$\boxed{\begin{aligned} m_1\ddot{x}_1 + k_1x_1 + k_2(x_1 - x_2) = 0 \\ m_2\ddot{x}_2 + b_1\dot{x}_2 + k_2(x_2 - x_1) + k_3x_2 = 0 \end{aligned}}.$$

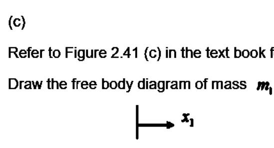
Although friction affects only the motion of the left mass directly, continuing motion of the right mass excites the left mass, and that interaction continues until all motion damps out.

Step 5 of 6

(c)

Refer to Figure 2.41 (c) in the text book for the block diagram of a mechanical system.

Draw the free body diagram of mass m_1.

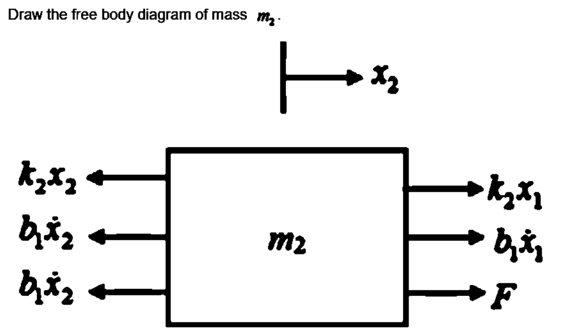


Write the differential equation describing the system.

$$m_1\ddot{x}_1 = -b_1\dot{x}_1 - k_1x_1 - k_2x_1 + k_2x_2 + b_1\dot{x}_2 = 0$$
$$m_1\ddot{x}_1 + b_1(\dot{x}_1 - \dot{x}_2) + k_1x_1 + k_2(x_1 - x_2) = 0$$

Step 6 of 6

Draw the free body diagram of mass m_2.



$$m_2\ddot{x}_2 = -k_2x_2 - b_1\dot{x}_2 - b_1\dot{x}_2 + b_1\dot{x}_1 + k_2x_1 + F$$
$$m_2\ddot{x}_2 + b_1\dot{x}_2 + b_1(\dot{x}_2 - \dot{x}_1) + k_2(x_2 - x_1) = F$$

Thus, the differential equations describing the system are,

$$\boxed{\begin{aligned} m_1\ddot{x}_1 + b_1(\dot{x}_1 - \dot{x}_2) + k_1x_1 + k_2(x_1 - x_2) = 0 \\ m_2\ddot{x}_2 + b_1\dot{x}_2 + b_1(\dot{x}_2 - \dot{x}_1) + k_2(x_2 - x_1) = F \end{aligned}}.$$