"Control Theory" - Exercise #1

E1.1, E1.2, P1.3, P1.8

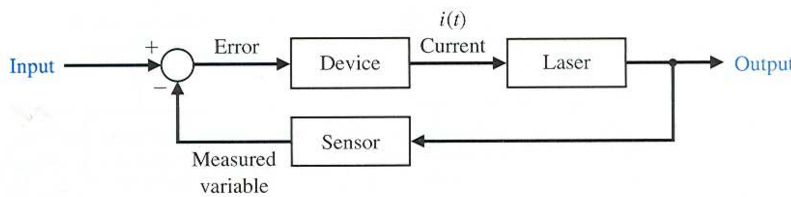

FIGURE E1.1 Partial block diagram of an optical source.

E1.1 A precise optical signal source can control the output power level to within 1% [32]. A laser is controlled by an input current to yield the power output. A microprocessor controls the input current to the laser. The microprocessor compares the desired power level with a measured signal proportional to the laser power output obtained from a sensor. Complete the block diagram representing this closed-loop control system shown in Fig. E1.1, identifying the output, input, and measured variables and the control device.

E1.2 An automobile driver uses a control system to maintain the speed of the car at a prescribed level. Sketch a block diagram to illustrate this feedback system.

E1.3 Fly-fishing is a sport that challenges the person to cast a small feathery fly using a light rod and line. The goal is to place the fly accurately and lightly on the distant surface of the stream [65]. Describe the fly-casting process and a model of this process.

E1.4 An autofocus camera will adjust the distance of the lens from the film by using a beam of infrared or ultrasound to determine the distance to the subject [45]. Sketch a block diagram of this open-loop control system, and briefly explain its operation.

E1.5 Because a sailboat can't sail directly into the wind, and traveling straight downwind is usually slow, the shortest sailing distance is rarely a straight line. Thus sailboats tack upwind—the familiar zigzag course—and jibe downwind. A tactician's decision of when to tack and where to go can determine the outcome of a race.

Describe the process of tacking a sailboat as the wind shifts direction. Sketch a block diagram depicting this process.

E1.6 Automated highways may be prevalent in the next decade. Consider two automated highway lanes merging into a single lane, and describe a control system that ensures that the vehicles merge with a prescribed gap between two vehicles.

E1.7 Describe the block diagram of the speed control system of a motorcycle with a human driver.

E1.8 Describe the process of human biofeedback used to regulate factors such as pain or body temperature. Biofeedback is a technique whereby a human can, with some success, consciously regulate pulse, reaction to pain, and body temperature.

PROBLEMS

(Problems require extending the concepts of this chapter to new situations.)

The following systems may be described by a block diagram showing the cause–effect relationship and the feedback (if present). Each block should describe its function. Use Fig. 1.9 as a model where appropriate.

P1.1 Many luxury automobiles have thermostatically controlled air-conditioning systems for the comfort of the passengers. Sketch a block diagram of an air-conditioning system where the driver sets the desired interior temperature on a dashboard panel. Identify the function of each element of the thermostatically controlled cooling system.

P1.2 In the past, control systems used a human operator as part of a closed-loop control system. Sketch the block diagram of the valve control system shown in Fig. P1.2.

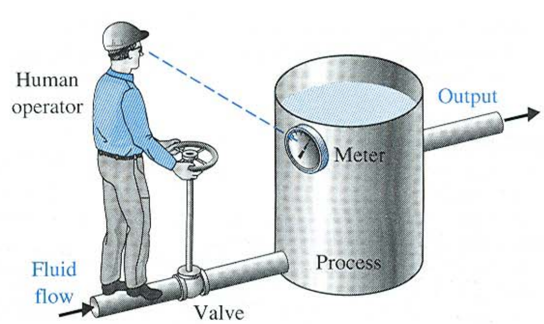

FIGURE P1.2 Fluid-flow control.

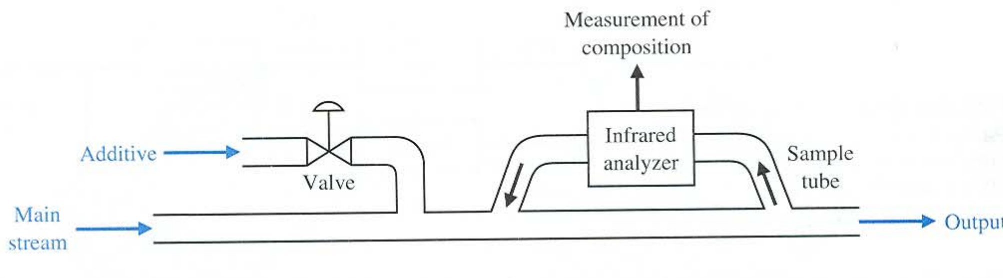

FIGURE P1.3 Chemical composition control.

P1.3 In a chemical process control system, it is valuable to control the chemical composition of the product. To do so, a measurement of the composition can be obtained by using an infrared stream analyzer, as shown in Fig. P1.3. The valve on the additive stream may be controlled. Complete the control feedback loop, and sketch a block diagram describing the operation of the control loop.

P1.4 The accurate control of a nuclear reactor is important for power system generators. Assuming the number of neutrons present is proportional to the power level, an ionization chamber is used to measure the power level. The current, i_o, is proportional to the power level. The position of the graphite control rods moderates the power level. Complete the control system of the nuclear reactor shown in Fig. P1.4 and sketch the block diagram describing the operation of the feedback control loop.

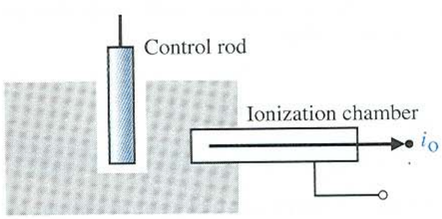

FIGURE P1.4 Nuclear reactor control.

P1.5 A light-seeking control system, used to track the sun, is shown in Fig. P1.5. The output shaft, driven by the motor through a worm reduction gear, has a bracket attached on which are mounted two photocells. Complete the closed-loop system so that the system follows the light source.

P1.6 Feedback systems do not always involve negative feedback. Economic inflation, which is evidenced by continually rising prices, is a **positive feedback** system. A positive feedback control system, as shown in Fig. P1.6, adds the feedback signal to the input signal, and the resulting signal is used as the input to the process. A simple model of the price–wage inflationary spiral is shown in Fig. P1.6. Add additional feedback loops, such as legislative control or control of the tax rate, to stabilize the system. It is assumed that an increase in workers' salaries, after some time delay, results in an increase in prices. Under what conditions could prices be stabilized by falsifying or delaying the availability

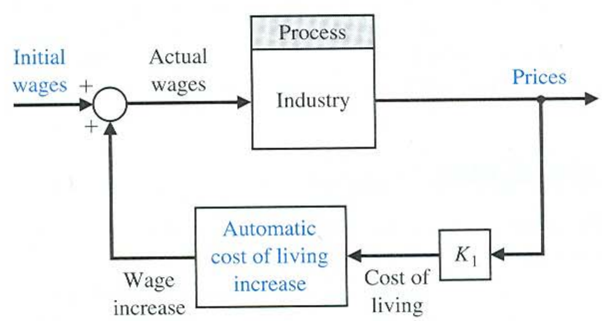

FIGURE P1.6 Positive feedback.

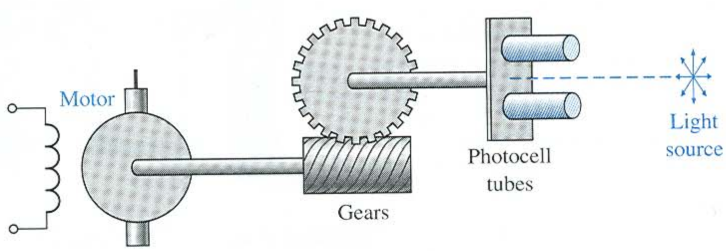

FIGURE P1.5 A photocell is mounted in each tube. The light reaching each cell is the same in both only when the light source is exactly in the middle as shown.

of cost-of-living data? How would a national wage and price economic guideline program affect the feedback system?

P1.7 The story is told about the sergeant who stopped at the jewelry store every morning at nine o'clock and compared and reset his watch with the chronometer in the window. Finally, one day the sergeant went into the store and complimented the owner on the accuracy of the chronometer.

"Is it set according to time signals from Arlington?" asked the sergeant.

"No," said the owner, "I set it by the five o'clock (P.M.) cannon fired from the fort. Tell me, Sergeant, why do you stop every day and check your watch?"

The sergeant replied, "I'm the gunner at the fort!"

Is the feedback prevalent in this case positive or negative? The jeweler's chronometer loses two minutes each 24-hour period and the sergeant's watch loses three minutes during each eight hours. What is the net time error of the cannon at the fort after 12 days?

P1.8 The student–teacher learning process is inherently a feedback process intended to reduce the system error to a minimum. With the aid of Fig. 1.3, construct a feedback model of the learning process and identify each block of the system.

P1.9 Models of physiological control systems are valuable aids to the medical profession. A model of the heart-rate control system is shown in Fig. P1.9 [23, 24, 51]. This model includes the processing of the nerve signals by the brain. The heart-rate control system is, in fact, a multivariable system, and the variables x, y, w, v, z, and u are vector variables. In other words, the variable x represents many heart variables $x_1, x_2, \ldots, x_n$. Examine the model of the heart-rate control system and add or delete blocks, if necessary. Determine a control system model of one of the following physiological control systems:

1. Respiratory control system
2. Adrenaline control system
3. Human arm control system
4. Eye control system
5. Pancreas and the blood-sugar-level control system
6. Circulatory system

P1.10 The role of air traffic control systems is increasing as airplane traffic increases at busy airports. Engineers are developing air traffic control systems and collision avoidance systems using the Global Positioning System (GPS) navigation satellites [34, 61]. GPS allows each aircraft to know its position in the airspace landing corridor very precisely. Sketch a block diagram depicting how an air traffic controller might utilize GPS for aircraft collision avoidance.

P1.11 Automatic control of water level using a float level was used in the Middle East for a water clock [1, 11]. The water clock (Fig. P1.11) was used from sometime before Christ until the seventeenth century. Discuss the operation of the water clock, and establish how the float provides a feedback control that maintains the accuracy of the clock. Sketch a block diagram of the feedback system.

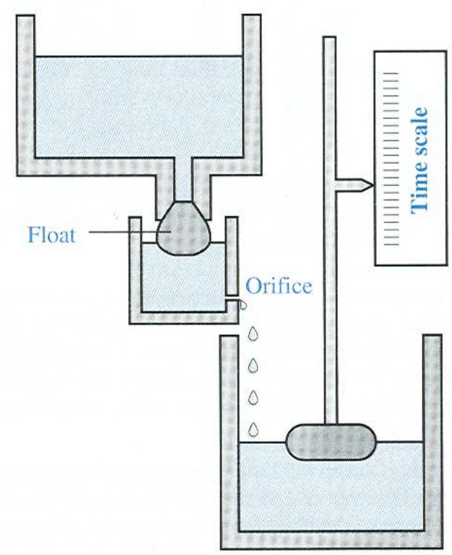

FIGURE P1.11 Water clock. (From Newton, Gould, and Kaiser, *Analytical Design of Linear Feedback Controls*. Wiley, New York, 1957, with permission.)

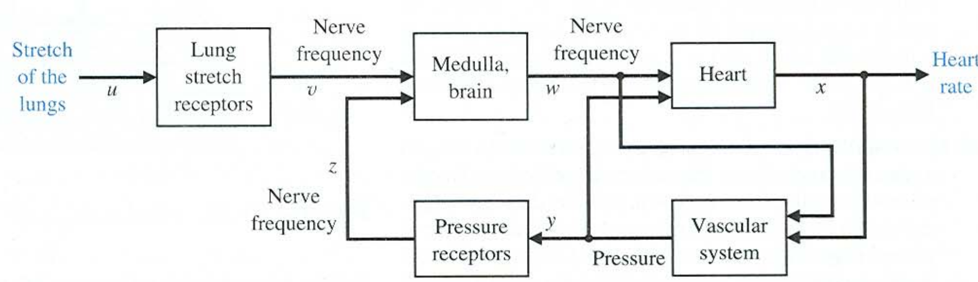

FIGURE P1.9 Heart-rate control.