# Problems

**P1.1**. For each block-diagram in Fig. 1.11 identify *inputs*, *outputs*, and other relevant *signals*, as well as describe what physical quantities the signals could represent. Tell whether the system is in *closed-loop* or *open-loop* based on the presence or absence of *feedback*. Is the relationship between the inputs and outputs dynamic or static? Write a simple equation for each block if possible. Which signals are *disturbances*?

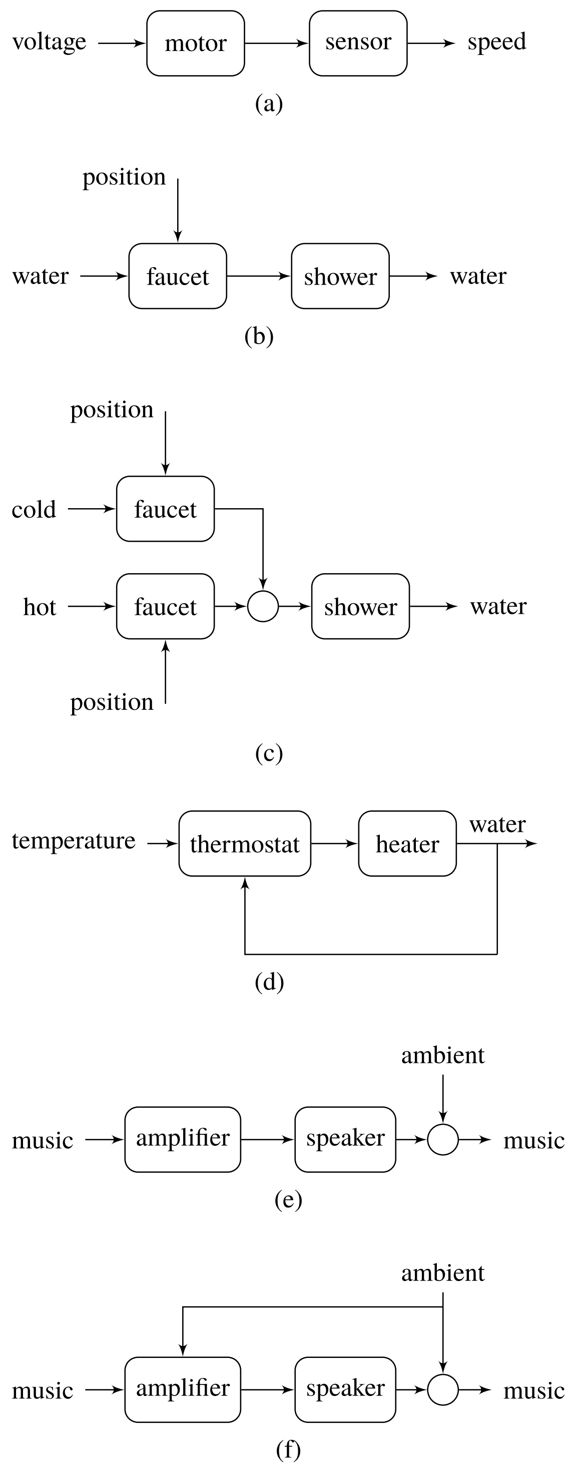


Fig. 1.11: Block diagrams for **P1.1**

**P1.2**. Sketch block-diagrams that can represent the following phenomena as *systems*:

a) skin protection from sunscreen;
b) money on a savings account;
c) a chemical reaction;
d) bitterness of your morning coffee;

Identify potential *input* and *output* signals that can be used to identify a cause-effect relationship. Discuss the assumptions and limitations you used in the construction of your *model*. Is the relationship between the inputs and outputs dynamic or static? Write simple equations for each block if possible.

**P1.3**. Mammals are able to regulate their body temperature near $36.5°$ C ($\sim$ 98 F) despite large fluctuations in the ambient temperature. Sketch a block-diagram that could represent a possible temperature control system in mammals. Identify disturbances, signals and possible principles of sensing and actuation that could be used by mammals to lower or increase the body temperature. Compare possible *open-loop* and *closed-loop* solutions. Discuss the difficulties that need to be overcome in each case.

**P1.4**. Most cars nowadays are equipped with an *anti-lock breaking system* (ABS), which are designed to prevent the wheels from *locking up* when the driver actuates the break pedal. It helps with emergency breaking and breaking under adverse road conditions by ensuring that traction is maintained on all wheels throughout breaking. An ABS system detects potential locking of a wheel by comparing the rotational speeds among wheels and increases or reduces the pressure on the hydraulic break mechanism as needed. Sketch a block-diagram that could represent the signals and systems involved in ABS.

**P1.5**. Humans learn to walk early in life. Sketch a block-diagram that could represent signals and systems required for navigate accros an unknown environment. What sensors are used? Is there feedback involved?

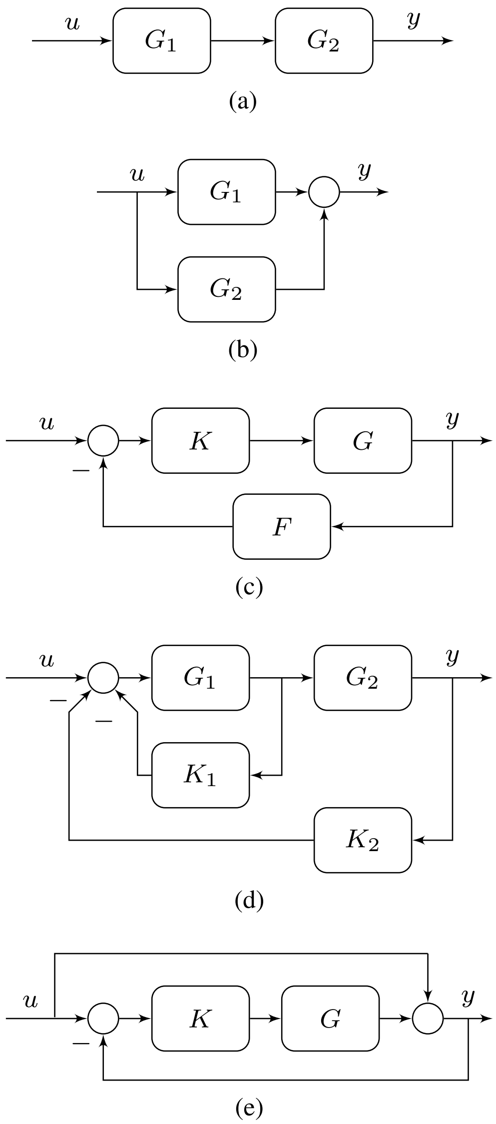


Fig. 1.12: Block diagrams for **P1.7**

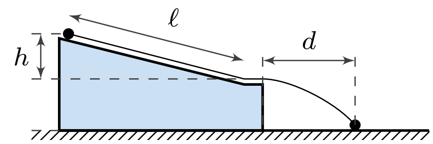


Fig. 1.13: Galileo's inclined plan

| # | Ramp distance @ 13.4° | | | |
|---|---|---|---|---|
| | 1 ft | 2 ft | 4 ft | 6 ft |
| 1 | $13\frac{15}{16}$ | $19\frac{13}{16}$ | $27\frac{11}{16}$ | $33\frac{3}{8}$ |
| 2 | $13\frac{7}{8}$ | $19\frac{13}{16}$ | $27\frac{3}{4}$ | $33\frac{5}{16}$ |
| 3 | $14\frac{1}{16}$ | $19\frac{13}{16}$ | $27\frac{3}{4}$ | $33\frac{3}{16}$ |
| 4 | 14 | $19\frac{3}{4}$ | $27\frac{9}{16}$ | $33\frac{7}{16}$ |
| 5 | $13\frac{15}{16}$ | $19\frac{3}{4}$ | $27\frac{9}{16}$ | $33\frac{5}{8}$ |

| # | Ramp distance @ 6.7° | | | | |
|---|---|---|---|---|---|
| | 1 ft | 2 ft | 4 ft | 6 ft | 8 ft |
| 1 | $10\frac{11}{6}$ | $14\frac{1}{2}$ | $20\frac{3}{4}$ | $25\frac{7}{16}$ | $29\frac{5}{8}$ |
| 2 | $10\frac{11}{6}$ | $14\frac{9}{16}$ | $20\frac{3}{4}$ | $25\frac{1}{2}$ | $29\frac{1}{2}$ |
| 3 | $10\frac{11}{6}$ | $14\frac{1}{2}$ | $20\frac{3}{4}$ | $25\frac{3}{4}$ | $29\frac{1}{2}$ |
| 4 | $10\frac{11}{6}$ | $14\frac{1}{2}$ | $20\frac{3}{4}$ | $25\frac{1}{2}$ | $29\frac{5}{16}$ |
| 5 | $10\frac{11}{6}$ | $14\frac{9}{16}$ | $20\frac{3}{16}$ | $25\frac{5}{8}$ | $29\frac{1}{2}$ |

Tab. 1.2: Data for **P1.8**

**P1.6**. Repeat **P1.5** this time from the perspective of a blind person.

**P1.7**. For each block-diagram in Fig. 1.12 compute the transfer function from the input $u$ to the output $y$ assuming that the blocks are linear.

**P1.8**. Students taking part in the Galileo Project at Rice University set out to carefully reproduce some of Galileo's classic experiments [Jen14]. One was the study of projectile motion using an inclined plane, in which a ball accelerates down a plane inclined at a certain angle then rolls in the horizontal direction with uniform motion for a short while until falling off the edge of a table, as shown in Fig. 1.13. The distance the ball rolled along the inclined plane, $\ell$ in feet, and the distance from the end of the table to the landing site of the ball, $d$ in inches, were recorded. Some of their data, 5 trials at two different angles, is reproduced in Tab. 1.2. Use `matlab` to plot and visualize the data. Fit simple equations, e.g. linear, quadratic, etc, to the data to relate the fall height, $h$, to the horizontal travel distance, $d$, given in Tab. 1.2. Justify yours choices of equations and comment on the quality of the fit obtained in each case. What other information can you obtain from this experiment knowing that the free fall was always initiated 40 inches above the ground?