Two other temperature scales are in use. The familiar Fahrenheit scale is related to the Celsius scale by the equation

$$T(°\text{F}) = \frac{9}{5}T(°\text{C}) + 32. \tag{1.19}$$

On this scale the ice point is 32°F and the steam point is 212°F. The Rankine scale is derived from the Fahrenheit scale:

$$T(\text{R}) = T(°\text{F}) + 459.67. \tag{1.20}$$

The Rankine scale is widely used in engineering; it does not use the "degree" symbol.

We shall see later that it is possible to define the absolute scale of temperature independently of the thermometric properties of gases.

PROBLEMS

1-1 Classify the following systems as open, closed, or isolated:
- **(a)** A mass of gas in a container with rigid, impermeable, diathermal walls.
- **(b)** A mass of gas in a container with rigid, impermeable, adiabatic walls.
- **(c)** A sugar solution enclosed by a membrane permeable only to water that is immersed in a large container of water.

1-2 Using the terms defined in the chapter, characterize the following processes as completely as possible:
- **(a)** The temperature of a gas, enclosed in a cylinder provided with a frictionless piston, is slowly increased. The pressure remains constant.
- **(b)** A gas, enclosed in a cylinder provided with a piston, is slowly expanded. The temperature remains constant. There is a force of friction between the cylinder wall and the piston.
- **(c)** A gas enclosed in a cylinder provided with a frictionless piston is quickly compressed.
- **(d)** A piece of hot metal is thrown into cold water. (Assume that the system is the metal, which neither contracts nor expands.)
- **(e)** A pendulum with a frictionless support swings back and forth.
- **(f)** A bullet is stopped by a target.

1-3 On a plot of volume versus temperature, draw and label lines indicating the following processes, each proceeding from the same initial state V_0, T_0.
- **(a)** An isothermal expansion.
- **(b)** An isothermal compression.
- **(c)** An isochoric increase in temperature.

1-4 Estimate the pressure you exert when standing on the floor. Express your answer in atmospheres, in pascals, and in torr. Repeat the calculation for spiked heels.

1-5 Let the resistance R of a piece of wire be a thermometric property for measuring the temperature T. Assume that

$$R = aT + b,$$

where a and b are constants. The resistance of the wire is found to be 5 ohms when it is at the temperature of melting ice and 6 ohms when it is at the temperature at which water boils at atmospheric pressure. If the ice point is taken as 100° and the boiling point as 500° on a particular scale, what is the temperature on this scale when $R = 5.4$ ohms?

1-6 The following table gives the observed values of the pressure P of a gas in a constant-volume gas thermometer at an unknown temperature T and at the triple point of water as the mass of the gas used is reduced.

P_{TP} *(torr)*	100	200	300	400
P *(torr)*	127.9	256.5	385.8	516

Determine T in kelvins to two decimal places by considering the limit $P_{TP\to 0}(P/P_{TP})$. What is this temperature in °C?

1-7 The resistance R of a doped germanium crystal is related to the temperature T through the equation

$$\log R = 4.70 - 3.92 \log T,$$

when R is in ohms, T is in kelvins, and the logarithm is taken to the base 10. In a liquid helium cryostat, the resistance is measured to be 218 ohms. What is the temperature?

1-8 A thermocouple consists of two wires made of dissimilar metals that are joined together to form an electrical circuit. A thermal electromotive force (emf) $\mathcal{E}$ is generated when the two junctions are at different temperatures. When one junction is held at the ice point and the other is at a Celsius temperature of T, the thermometric function is given by

$$\mathcal{E} = aT + bT^2,$$

where $\mathcal{E}$ is in millivolts. Calculate the constants a and b for a thermocouple reading 60 mV at 200°C and 40 mV at 400°C. What temperature corresponds to a reading of 30 mV?

1-9 **(a)** Consider the linear relationship between the thermometric property X and the temperature T given by

$$X = aT + b.$$

Suppose that the ice and steam points are used as fixed points with temperatures of 0° and 100° respectively. Show that

$$T = 100\left[\frac{X - X_i}{X_s - X_i}\right].$$