PROBLEM 5.23

A balloon 20.0 m in diameter is filled with helium at a gauge pressure of 2.0 atm. A man is standing in a basket suspended from the bottom of the balloon. A restraining cable attached to the bucket keeps the balloon from rising. The balloon (not including the gas it contains), the basket, and the man have a combined mass of 150 kg. The temperature is 24°C that day, and the barometer reads 760 mm Hg.

(a) Calculate the mass (kg) and weight (N) of the helium in the balloon.

Strategy

Often, it helps to start with the result you want and work your way backward through the problem. Let's try that technique here. To determine the weight (force) of helium, we need the mass of helium. Pure helium is in the balloon so the mass of helium is easily found if we determine first how many moles of helium are in the balloon. To find the moles of helium, we need the pressure, temperature, and volume of the gas. We know the pressure and temperature and, assuming the balloon is spherical, we can determine the volume geometrically.

Solution

The procedure (in the forward direction) is below. You do the calculations.

(1) Calculate the volume, V_b, of a spherical balloon 20.0 m in diameter.
(2) Calculate the moles of helium, n_{He}, from the volume, temperature, and pressure.
(3) Calculate the mass of helium, m_{He}, from the moles of helium.
(4) Calculate the weight of helium, w_{He}, from the mass of helium (see Section 2.4).

(5.23-1)

Volume of balloon: V_b =	= _____ m^3
Moles He in balloon: n_{He} =	= _____ kmol He
Mass of He in balloon: m_{He} =	= 2065 kg He
Weight of He in balloon: W_{He} =	= _____ N

(b) How much force is exerted on the balloon by the restraining cable? (*Recall*: The buoyant force on a submerged object equals the weight of the fluid—in this case, the air—displaced by the object. Neglect the volume of the basket and its contents.)

Strategy

Whenever an object is motionless, there can be no net force acting on it. (If there were one, what would happen according to Newton?) The key to problems like this one is to draw a free body diagram, showing all the forces acting on the object, and then use a force balance to find the unknown force (in this case, the force exerted by the restraining cable).