

## Problem 1.42

[Difficulty: 2]

**1.42** The mass of the standard American golf ball is  $1.62 \pm 0.01$  oz and its mean diameter is  $1.68 \pm 0.01$  in. Determine the density and specific gravity of the American golf ball. Estimate the uncertainties in the calculated values.

**Given:** Standard American golf ball:  $m = 1.62 \pm 0.01 \text{ oz}$  (20 to 1)  
 $D = 1.68 \pm 0.01 \text{ in.}$  (20 to 1)

**Find:** Density and specific gravity; Estimate uncertainties in calculated values.

**Solution:** Density is mass per unit volume, so

$$\rho = \frac{m}{V} = \frac{m}{\frac{4}{3}\pi R^3} = \frac{3}{4\pi} \frac{m}{(D/2)^3} = \frac{6}{\pi} \frac{m}{D^3}$$

$$\rho = \frac{6}{\pi} \times 1.62 \text{ oz} \times \frac{1}{(1.68)^3 \text{ in.}^3} \times \frac{0.4536 \text{ kg}}{16 \text{ oz}} \times \frac{\text{in.}^3}{(0.0254)^3 \text{ m}^3} = 1130 \text{ kg/m}^3$$

and 
$$\text{SG} = \frac{\rho}{\rho_{\text{H}_2\text{O}}} = 1130 \frac{\text{kg}}{\text{m}^3} \times \frac{\text{m}^3}{1000 \text{ kg}} = 1.13$$

The uncertainty in density is given by 
$$u_\rho = \left[ \left( \frac{m}{\rho} \frac{\partial \rho}{\partial m} u_m \right)^2 + \left( \frac{D}{\rho} \frac{\partial \rho}{\partial D} u_D \right)^2 \right]^{\frac{1}{2}}$$

$$\frac{m}{\rho} \frac{\partial \rho}{\partial m} = \frac{m}{\rho} \frac{1}{V} = \frac{V}{V} = 1; \quad u_m = \frac{\pm 0.01}{1.62} = \pm 0.617\%$$

$$\frac{D}{\rho} \frac{\partial \rho}{\partial D} = \frac{D}{\rho} \cdot \left( -3 \frac{6m}{\pi D^4} \right) = -3 \frac{6}{\pi} \frac{m}{\rho D^4} = -3; \quad u_D = \frac{\pm 0.1}{1.68} = \pm 0.595\%$$

Thus

$$u_\rho = \pm \left[ u_m^2 + (-3u_D)^2 \right]^{\frac{1}{2}} = \pm \left[ 0.617\%^2 + (-3 \times 0.595\%)^2 \right]^{\frac{1}{2}} \quad u_\rho = \pm 1.89\% = \pm 21.4 \frac{\text{kg}}{\text{m}^3}$$

$$u_{\text{SG}} = u_\rho = \pm 1.89\% = \pm 0.0214$$

Finally, 
$$\rho = 1130 \pm 21.4 \text{ kg/m}^3 \quad (20 \text{ to } 1)$$

$$\text{SG} = 1.13 \pm 0.0214 \quad (20 \text{ to } 1)$$