MEC516/BME516: Fluid Mechanics I

Chapter 2: Fluid Statics
Solved Buoyancy Problem

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Toronto Metropolitan University

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Solved Buoyancy Problem: Weighing Low Density Materials

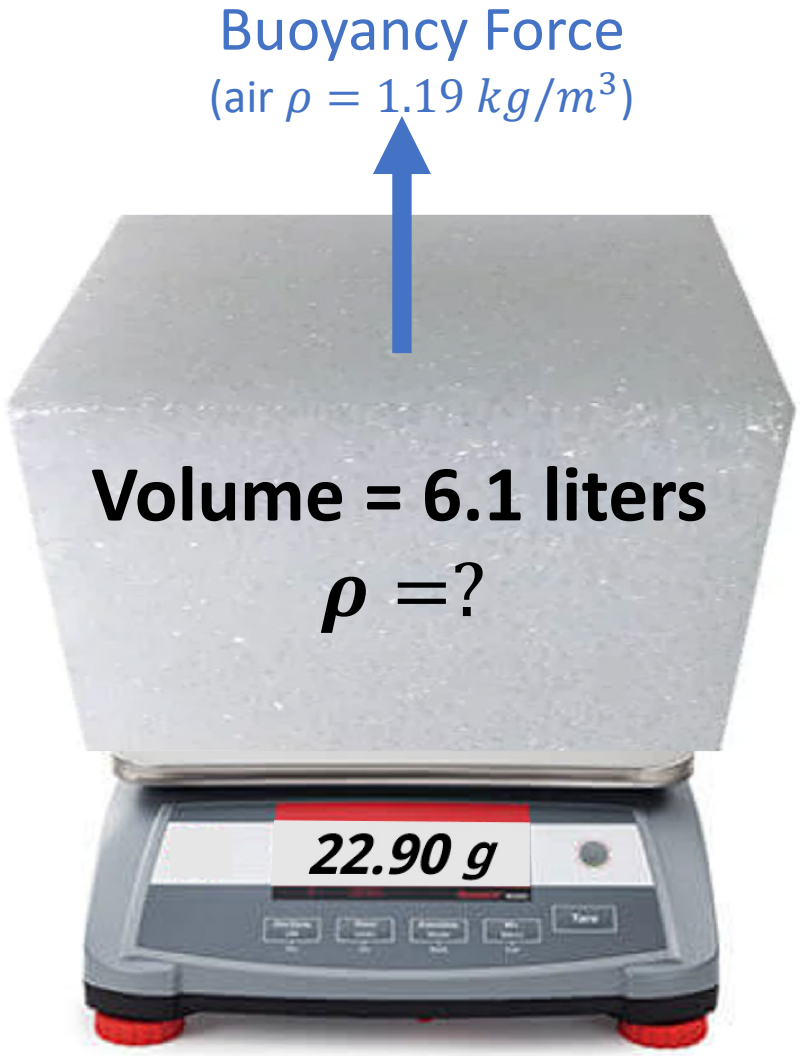
A piece of low-density foam is weighed in air at 20°C and 100 kPa. The scale indicates 22.9 grams. The volume of the foam block is 6.1 liters ($6.1x10^{-3}$ m^3).

Correcting for buoyancy, what is the density (ρ) of the foam?

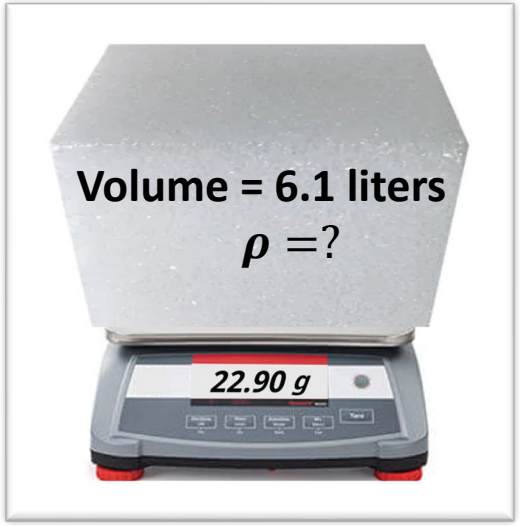
The density is **NOT**:

$$\rho_{foam} = \frac{0.0229\ kg}{6.1x10^{-3}m^3} = 3.75\ kg/m^3$$ X Wrong!

Why not?



Buoyancy Problem: Weighing Low Density Materials



- The scale does not indicate the true mass because of buoyancy
- Force balance on the foam :

$$W = F_{scale} + F_B$$

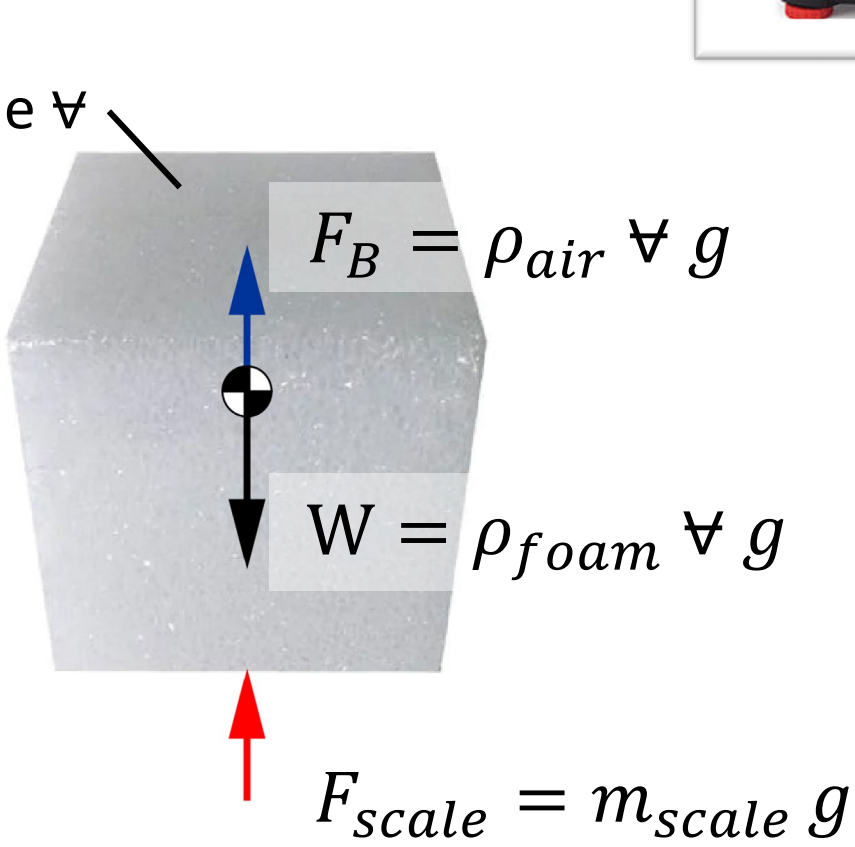
$$\rho_{foam} \forall\, g = m_{scale}\, g + \rho_{air} \forall\, g$$

- Solving for density of the foam:

$$\rho_{foam} = \frac{m_{scale}}{\forall} + \rho_{air} \qquad (*)$$

Ideal gas equation (or air properties table):

$$\rho_{air} = \frac{p}{RT} = \frac{100\ kPa}{0.287\frac{kJ}{kgK}(20+273)K} = 1.19\frac{kg}{m^3}$$



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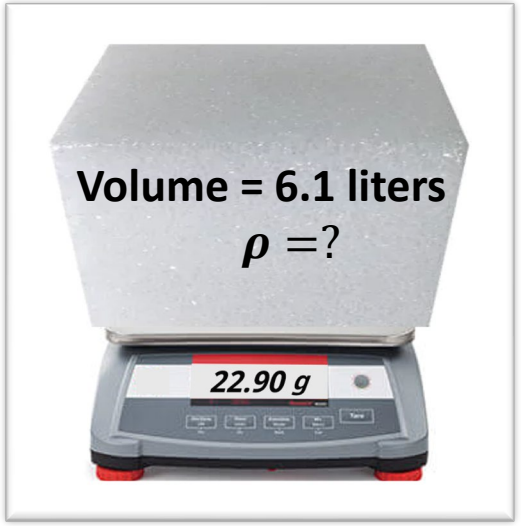


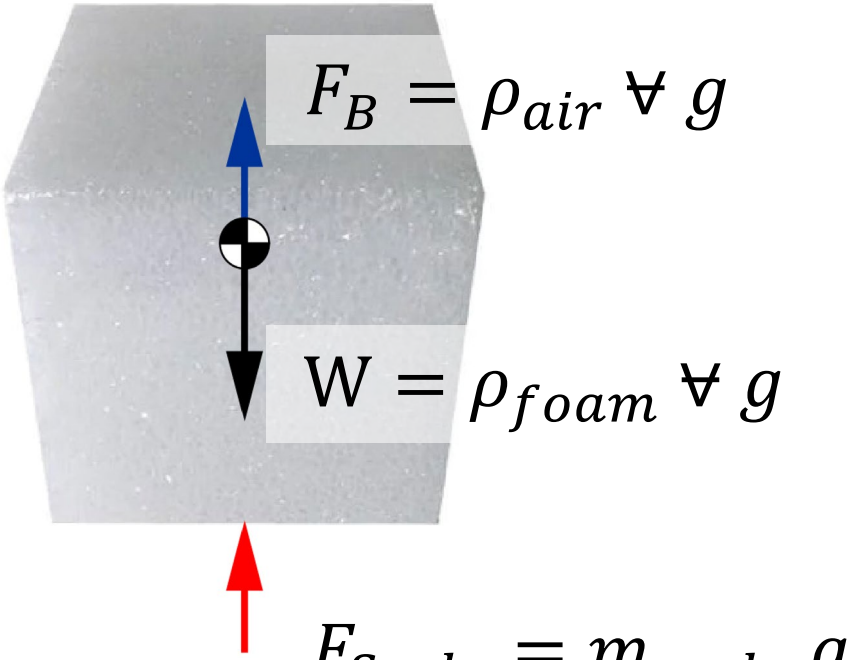
$$\rho_{foam} = \frac{m_{scale}}{\forall} + \rho_{air} \quad (*) \qquad \rho_{air} = 1.19\,\frac{kg}{m^3}$$

$$\rho_{foam} = \frac{0.0229\,kg}{6.1x10^{-3}m^3} + 1.19\,\frac{kg}{m^3} = 4.94\,\frac{kg}{m^3}$$ Answer

- If you neglect buoyancy effects:

$$Percent\ Error = \frac{3.75-4.94}{4.94}x100\% = -24\%$$

- A significant error for low density materials



Does buoyancy affect the reading on your bathroom scale?

Answer: Yes. ρ_{human}≈1000 kg/m^3. Scale reads 0.12% lighter (~0.2 lb) than your actual weight

Actual weight requires weighting yourself in a vacuum…

END NOTES

- All the videos (and pdf downloads) for this course available at: www.drdavidnaylor.net
- Presentation prepared and delivered by Professor David Naylor

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