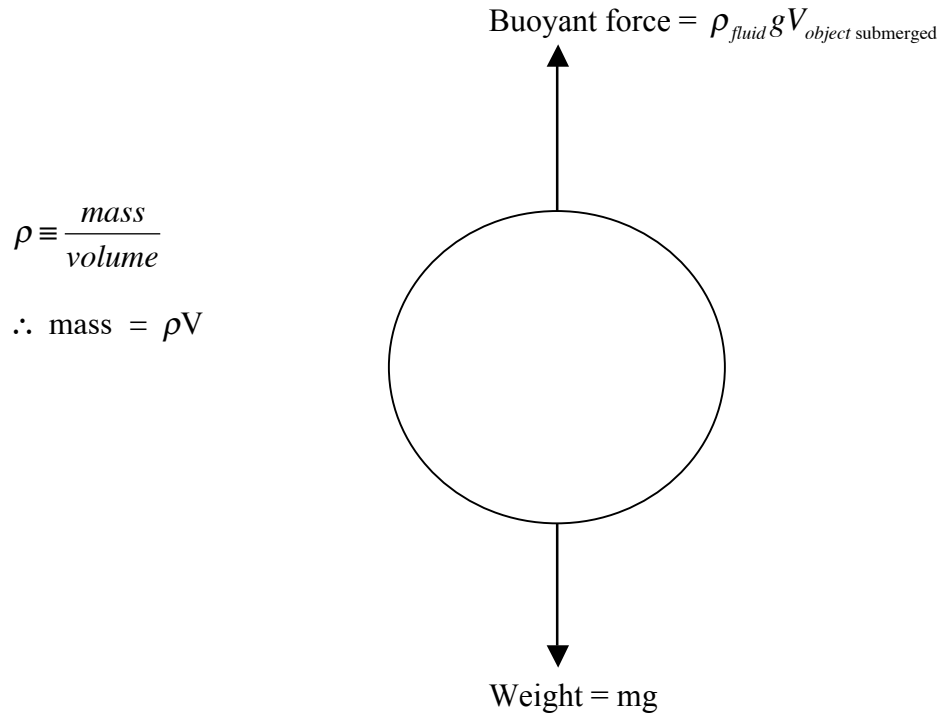


How many helium balloons are required to lift a 30 kg child off the ground?

Any object submerged in a fluid will have a buoyant force upward applied to it by the pressure difference of the surrounding fluid, between the top and the bottom of the object. The object will also have a force downward on it due to gravity, called its weight.



The net force on the balloon will be equal to the buoyant force minus the balloon's weight. To determine the balloon's weight, I am going to just get the weight of the helium in the balloon, and ignore the weight of the balloon fabric.

$$\begin{aligned} \text{Net force} &= \text{B.F.} - \text{weight} \\ &= \rho_{air} g V_{object} - m_{He} g \end{aligned}$$

Substituting for B.F. and the mass of the helium we get,

$$\text{Net force} = \rho_{air} g Vol - \rho_{He} Vol \cdot g$$

Next factor out the common terms.

$$\text{Net force} = Vol \cdot g (\rho_{air} - \rho_{He}); \text{ where } g = 9.8 \frac{m}{s^2}, \text{ and } \rho_{air} = 1.29 \frac{kg}{m^3} \quad \rho_{He} = .178 \frac{kg}{m^3} \text{ at } 0^\circ C$$

$$\text{Net force} = Vol \cdot g \left( 1.29 \frac{kg}{m^3} - .178 \frac{kg}{m^3} \right) = Vol \cdot 9.8 \frac{m}{s^2} \cdot 1.11 \frac{kg}{m^3}$$

Net force =  $10.9 \frac{N}{m^3} \cdot Volume$  We see that a helium balloon can lift 10.9 newtons per cubic meter of helium.

A 30 kg child will have a metric weight of approximately 300 newtons. In order to lift 300 newtons, we would have to have a total balloon volume of:

$$\text{Volume} = \frac{\text{Net force}}{10.9 \frac{N}{m^3}} = \frac{300 \text{ newtons}}{10.9 \frac{N}{m^3}} = 27.5 \text{ m}^3 \text{ of helium.}$$

Now how many balloons will that be? It depends on the size of the balloon. Let's arbitrarily take 15 cm radius balloon and determine its volume.

The volume of a sphere is  $\frac{4}{3}\pi r^3 = \frac{4}{3}\pi \cdot (.15m)^3 = .0141m^3$  per balloon.

Therefore, the number of balloons necessary to lift 300 newtons will be:

$$27.5m^3 \cdot \frac{\text{balloons}}{.0141m^3} = 1,950 \text{ balloons}$$

Remember, the 300 newtons is the total lift. To determine the heaviest child that could be lifted off the ground by 1,950 balloons, you have to subtract the weight of that many balloons. I will leave that part to you.

It looks like it is safe to buy your kid two or three hundred balloons at the parade.

R.E. Tremblay

Nov. 2007