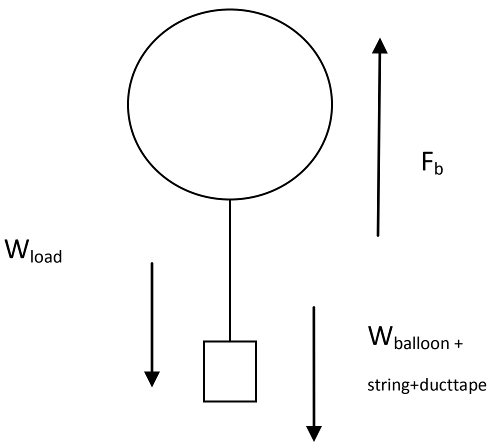
Name (s): ____ Hr. ____

Balloon Activity 3: Archimedes Law and the Theoretical Load

Lately, we have been taking about the Buoyancy force of the balloon. In the first activity, we used F_{net} = ma to determine the buoyancy force for the balloon in a statics (a = 0) case.

$(F_b - W_{balloon + ducttape+string} - W_{load}) = 0$



Let's look at the situation in another way.

In ancient history, Archimedes discovered that the buoyancy force on an object is equal to the weight of the fluid (air or water, etc.) displaced or moved out of the way.

Archimedes was a famous mathematician and scientist who lived in Sicily around 250 BC. He invented many things and tested many mathematics and physics principles.

In terms of this lesson, he discovered the principle that now bears his name, 'Archimedes principle' which is a statement about buoyancy.

Here is an interesting video about this discovery: https://media.usd497.org/video/How-taking-a-bath-led-to-Archimedes%2526%2523039%253B-principle-Mark-Salata-YouTube-TED/5584813bcc7272fec1fce318efaa915f

In terms of an equation, we can state this:

$F_{buoyancy} = W_{fluid\ displaced} = m_{fluid\ displaced}\ (g)$

In the case of a balloon we would have the weight of the air displaced by the balloon. But it is difficult to get the mass of the air displaced. It's difficult to measure and mass out the mass of air.

However, we can use the idea of density to help us. As you know or might know:

Density = mass of an object / Volume of the object

Or,

mass = ρ (this is the Greek symbol rho and symbolizes density)·V

So, we can write:

$F_{buoyancy} = W_{fluid\ displaced} = m_{fluid\ displaced}(g) = \rho_{air} \cdot V \cdot g$ [rhoVeeGee]

So, you can get the Buoyant Force by taking the product of three things:

(1) ρ_{air} (density of air, look this up on the internet, make sure it is in kg/m^3)

ρ_{air} = _________________ kg/m^3

Volume (this would be the volume of the spherical balloon. The volume of a sphere is $4/3 \cdot \pi \cdot r^3$. Can you think of a way to get the radius of the balloon and thus its volume? Can you use a piece of string and work through the circumference ($C = 2\pi r$)

radius = _________________ meters (Make sure this is in meters!)
So,

(2) Volume = $4/3 \cdot \pi \cdot r^3$ = _________________________ m^3

(3) g = 9.8 m/s/s

Multiply these together (1 & 2 & 3) to get the F_b

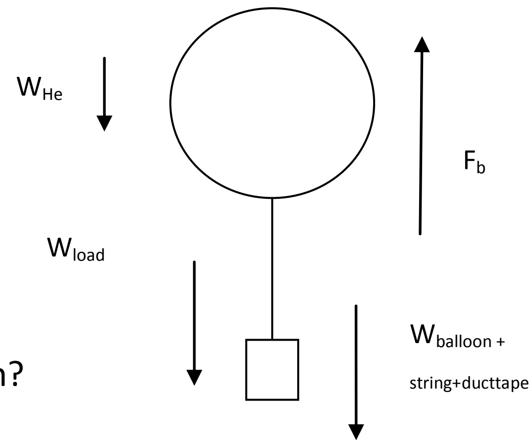
(4) $F_b = \rho_{air} \cdot V \cdot g$ = _____________ kg/m^3 · _________________ m^3 · 9.8 m/s/s

F_b = _______________ Newtons

This should compare favorably to our calculation of the buoyancy force from the first activity. It would be equal as you might have a different balloon or there may have been some loss of buoyancy over the course of the several days since we did activity 1. Check the buoyancy from the first activity and see.

PART 2: Theoretical load of the balloon.

Let's take our force diagram from page 1 but let's add another force, the Weight of the Helium in the balloon (W_{He}), we can develop a force equation when the balloon is at neutral buoyancy:



$F_b - W_{balloon + ducttape+string} - W_{load} - W_{He} = 0$

Let's solve this for the W_{load}:

$W_{load} = F_b - W_{balloon + ducttape+string} - W_{He}$

How might be easily get the weight of the helium?

We can use the density again but in this case:

$W_{He} = \rho_{He} \cdot V \cdot g$ [rhoVeeGee]

So, you can get the Buoyant Force by taking the product of three things:

(5) ρ_{He} (density of helium, look this up on the internet, make sure it is in kg/m^3)

ρ_{He} = _________________ kg/m^3

(6) Volume of the balloon, you determined this on line 2 on the previous page. Rewrite:

Volume = $4/3 \cdot \pi \cdot r^3$ = _________________________ m^3

(7) g = 9.8 m/s/s

Multiply these together (5 & 6 & 7) to get the F_b

(8) $W_{He} = \rho_{He} \cdot V \cdot g$ = _____________ kg/m^3 · _________________ m^3· 9.8 m/s/s

W_{He} = _______________ Newtons

Let's go back to our Newton's 2nd Law equation:

$W_{load} = F_b - W_{balloon + ducttape+string} - W_{He}$

We'd like to solve for the weight of the load. This would be a mathematical or theoretical number as we will use equations and numbers to solve for this. We need to get three things:

F_b = __________________ Newtons (from step 4, p. 2)

$W_{balloon + ducttape+string}$ = _________________ Newtons (this is our empty balloon with the string and duct tape). We got this number on the first activity or you can find its mass of the empty balloon again with the digital scale, put it in kilograms and multiply by 9.8 m/s/s.

W_{He} = ___________________ Newtons (from step 8, p. 3)

$W_{load} = F_b - W_{balloon + ducttape+string} - W_{He}$

W_{load} = ___________ Newtons - ______________ Newtons - _____________ Newtons
(be careful with your signs...)

(9) W_{load} = ___________________________ Newtons

Calculate the mass of this weight (W = mg)

(10) Mass = __________________ kilograms

(11) Convert to grams: ___________________ grams (1000 g per 1 kg)

This would be the theoretical mass that balloon might hold. Now try to find the experimental mass. Use paper clips or something small. Mass out one paper clip and add on more to see how close you get to the theoretical mass

(12) Actual or experimental mass in grams = _________________________ grams. This should be close to (11). Let's see how close we get!