Homework 2

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1 Buckingham's π Theorem

Buckingham's π Theorem states:

> For a physical equation involving N variables, if there are R independent dimensions, then there are $N - R$ independent dimensionless groups, denoted $\Pi_1, ..., \Pi_{N-R}$
>
> Corollary: We can write $f(\Pi_1, ..., \Pi_{N-R}) = C$ for dimensionless constant C.

Suppose we believe a relation exists among the variables F, m and a.

a.) What are the *independent* dimensions of these variables? Hint: Write each variable in terms of base units [M], [L] and [T] and look for patterns.

b.) Use Buckingham's π Theorem to determine how many independent dimensionless groups occur among the variables.

c.) Use the corollary to write the form of a physical law relating the variables up to a dimensionless constant C.

d.) If you have a scale, a $\sim$ 1kg weight, a long tape measure and camera that can take several frames per second, perform an experiment to determine the constant C. You may assume knowledge of basic physics such as the kinematic equations of motion. Feel free to experimentally determine C another way as long as you describe each step and its results.

2 Charge Separation

If all electrons in one raindrop could be removed from the Earth without removing the protons, by how much would the electric potential at the center of the Earth be increased? To estimate the size R of a raindrop, you may assume the surface tension is $\tau = 70\text{erg/cm}^2$ and use dimensional analysis to guess a relation between R, τ, g and ρ.

3 Rydberg Equivalent for Nitrogen

One Rydberg was the binding energy of an electron in a hydrogen atom: we calculated it using fundamental physical constants. Assume now that you have a partially ionized nitrogen atom, where all but one electrons were removed. What would be the energy required to fully remove the last electron, meaning to fully ionize the atom?