# Summary of Qualitative Physics using Dimensional Analysis

## Introduction

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## Oversimplified analogy

I would like to start this summary with over-simplified analogy story, which we can call as “Coffee Latte Analogy”. My grandma made her own pre-mix of coffee latte using coffee, sugar, and milk powder. Her recipe stated for every premix she needs 1 table spoon (tbs) of coffee, 1 (tbs) of sugar, and 1 (tbs) of milk powder.

For simplification, she calls her pre-mix recipe as coffee:sugar:milk powder, as all composition are in tbs. This comparison can be called as (oversimplified) *dimensionless* variables. Because, all the ingredients share same measurement (tbs).

When I make my coffee exactly with pre-mix recipe, it can be called as (oversimplified) *intra-regime partials*, as all the parts come from recipe (*regime*).

After we got the recipe, we started to be creative and change the water temperature to boil the coffee latte, as she didn’t put it in her notes. This can be called as (oversimplified) *inter-regime partials*, as we have the ingredients from the recipe (*dimensionless variables*), but we add some changes (*variables*) from outside the recipe.

One day, I made this recipe in my boyfriend’s place. He has a fancy coffee maker. And instead of boiling like usual, I used the pre-mix recipe with this coffee machine. This can be called as (oversimplified) *inter-ensembles partials*, as we same (*contact variables)* ingredients from the recipe (*dimensionless variables*), but we do it in different house (*ensembles*).

Now, I would extend this logic into proper physics scenarios, with one of the simplest physic scenarios, determining period of oscillation of a pendulum.

## Basic mathematical symbol

Before going deep, I would like to remind 3 basic mathematical theorem and symbols.

1. The principle of Dimensional Homogeneity

The left and right side of =, should have same value. Therefore, A value is equivalent to the sum of B and C.

1. π in this research is not the π of circle. π in here representing dimensionless number. Because π is dimensionless, 2π is Constanta (C).
2. ∝ is representing direct proportionality.

, means when A increased, the B will be decreased.

, means when A increased, the B will be increased as well.

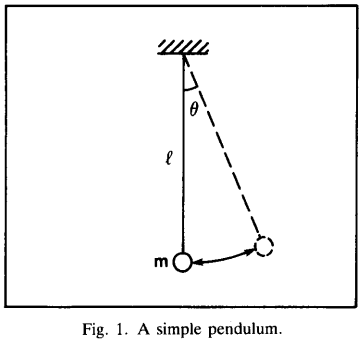
1. The Early Theorem is applying mathematical relationships between variables.

The most basic format of The Early Theorem is:

, with y is the variable we want to define, C is dimensional Constanta, x is independent variable, and a is exponent of x.

1. Buckingham π Theorem gives us the theoretical basis for why we can determine variables without knowing the original physics formula. It gives us systematic method to determine how many dimensionless combination can be acquired from a group of variables.  
   The most basic formats of Buckingham π Theorem is  
    , with Regime π comes from the number of variables (n) minus the number of basic dimensions (r).
2. Buckingham π Theorem only turn physical phenomenon in mathematical symbols. It does not tell us their physical roles nor it guarantees that each number contains only one variable that is not the basis. Hall’s Theorem takes the result and gave us the definition of physical role of the variable in each regime. Hall’s Theorem takes dimensional analysis from being a tool for modelling problems in engineering to a method for problem solving in artificial intelligence.

## Dimensionless Analysis Proof of Concept, using the formula of *Pendulum’s Period of Oscillation*



m = mass units [M] (say G-mass),   
l = length units [L] (say CM),   
g = acceleration units [] (say CM per second squared),   
θ = angle of the pendulum oscillation (no dimensions [ ]).  
t = oscillation time (the time needed for one complete swing) [T] (say seconds)

1. The variables available in the Fig.1, can be sum up as:
2. By inspection it is clear that mass only available on the right side of the equation, so we can omit the m from the right side as well:

1. is dimensionless, so it can be entered only as product, and therefore can be omitted from this equation. Which means, only time, length and gravitation are relevant in this calculations.
2. Based on Buckingham π Theorem, we can determine there are 1 π regime, from:

n = 3 [number of variables: T, L, g]

r = 2 [number of basic dimensions: T, L. Because g is (T/L2), this formula only have 2 dimensions T and L].

. Therefore, in this formula, there is only 1 regime(π).

1. From The Early Theorem, Step 3 and Step 4, we can get the formula:

, from Buckingham π Theorem in step 4, we can know the regime is 1, therefore:

1. We can get this replace the formula in step 4 and 5 with its respective symbol.

. Remember from step 4, that g is T/L*2*, so it can be changed into

, can be further simplified into:

, which means:

and .

So from T, we can get: , which means b = -1/2.

And from L, we can get: , which means , which resulting a = ½

1. If we replace a and b from (Step 5), into ½ and -1/2 (Step 6), we can get:

, which equivalent to :

From this notation, we can summarize that

1. We can proof the formula, by replace it with its symbol.  
    which means and

## The π-calculus

* Π is conceptual machine for reasoning the dimensions numbers. Machine in here is not in the sense of computer, but logical thinking framework.
* *Basis* is the set of variables that repeated in each Π. Basis plays significant role in constructions of regimes. All basis variables (r), should accomplished these criteria: (1) Every dimension that occurs in the dimensional representation of the n variables characterizing the system must occur in the dimensional representation of one or more basis variables. (2) The dimensional representations of the basis variables should be linearly independent.
* Each dimensionless number (Π), refers to a particular physical aspect of the system, which we called as *regime*. Regime is the result of dimensionless analysis.
* A collection of regimes is called *ensemble*.
* If same variables available in both Π 1 and Π 2, it is called as *contact variables* or *pivot*.
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- If zj is in the basis and occurs in H i, then use intra-regime partials. - If zj is in the basis but not in Hi, then reason using chains of inter-regime partials. - If zj is not in the basis, then use the appropriate inter-regime partial linking H i and//1..

# Flowchart of Simple Pressure Regulator Logic based on Dimensional Analysis in Python