Physica ad Dei Gloriam

Institute for Advanced Physics

# The World Just Got More Empiriological Today

## *Kilogram is Redefined*

***by Anthony Rizzi***

Today, the pound was redefined! It no longer simply refers to the mass of a piece of platinum in France.[1] You *now* need to know quantum mechanics to know what a pound is! In fact, this could be misleading for a pound is defined in terms of the kilogram and it is really the kilogram that was redefined.

Think about it. The simple thing that everyone experiences, mass (and weight)[2], needs the Schrödinger equation to be understood! What's the Schrödinger equation? That's a good question. Few know it. I'll write it if you promise not to run away.

First, a story that will, hopefully, help calm your fears. I once was on a radio show in which I was speaking with a man and woman who together host the show. When I mentioned the Schrödinger equation on the air, the woman said that she had never heard of it. The next time that I was on the show, some days later, I mentioned that a close personal friend, after hearing the last show, had said "I never heard of the Schwarzenegger [i.e., Arnold, the then famous movie star] equation either." And, the woman, instead of laughing (the man did), said "oh that makes me feel better!" The Schrödinger equation just isn't something many even know about. Think about how far removed the kilogram just became!

As I promised, here it is, the Schrödinger equation:

$$-\frac{\hbar^2}{2m}\nabla^2\psi + V\psi = i\hbar\frac{\partial\psi}{\partial t}$$

## *The Kilogram*

So, how exactly is the kilogram defined? You may add: "Is there a way to understand it that will not make ***me*** learn this equation." "Can someone that knows this equation, explain it in layman's terms?" Yes.

### The Second and the Meter

Well, you need to know other things first. You may have thought you knew how a meter was defined. You may think you know how a second is defined. A meter should be just the length of some stick. A second should be one tick of, say, a clock. Well, not empiriologically, not the way one needs to define them to mesh well with the deep knowledge modern science has encapsulated in its equations.

The *second* is defined as a certain number of cycles of the frequency of light emitted by a certain atom.[3] The *meter* is defined as a small fraction of the distance that light travels in a second.[4]

[1] The definition was officially accepted today (Nov. 16) but its use will not be "enforced" till May 20, 2019. This definition was promulgated by The International Committee for Weights and Measures (CIPM).

[2] Mass is different from weight. Mass is defined in footnote 11. Weight is the amount of force gravity exerts on a body, for example, you. When you jump up, it is gravity that pulls you back down, and the more you weight, the stronger the pull.

[3] To be more complete, it is defined as the 9,192,631,770 cycles of the hyperfine-split line in *Cs*-133 at 0 *K*.

[4] To be exact, it is 1/c the distance light travels in a second; where $c = 299\ 792\ 458$.



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### *The Definition of the Kilogram*

The new definition of a kilogram can be thought of in the following way. To explain, we need to use that funny little "$\hbar$" symbol in the Schrödinger equation above. It is pronounced "hbar" and, as far as we know, never changes. It is a constant; equationally (empiriometrically) speaking, the decision made today forces the value of hbar to be exactly a certain number.[5] How does that define the kilogram? Well, consider a photon of light, a light of a certain very well defined energy. Such light has a very well defined frequency. Pick that frequency to be a certain value related directly to hbar (in particular, take it to be $c/h$ where *c* is the speed of light and "*h*" is just a number times hbar).[6] Then, let this light hit something in your room, say your cup. When light hits things, it gives them impetus (momentum); it gives them the power to move. Ordinary light cannot do anything noticeable; indeed, its effect is very tiny. This particular light that we are discussing is extremely powerful. Its frequency is huge[7] and so is its energy. It will give a lot of impetus (1 Buridan[8] to be exact[9]). Now, here is where the answer comes. If you measure the cup to be moving at 1 meter per second speed after the light is absorbed by it, the cup has 1 kilogram of mass! [10] Now, it is very unlikely that our cup is 1 kilogram, so it will not move at 1 meter per second. But, you get the idea. There clearly is such an object and that object would have 1 kilogram mass. Again, this shows you how defining hbar defines the kilogram.

Notice how left-handed this definition is. This is the nature of the empiriometric way of thinking. In the equational world that modern physics inhabits, this makes things work much smoother. Furthermore, we do not have to worry about the changes that a "mass" (object) first made in 1889AD might be undergoing. Also, we do not have to worry about someone stealing our unit mass!

In the end, the new definition will be helpful, if we always remember that, finally, the kilogram requires a real body with mass or, at least, the potential of having such a body. After all, mass is a property of real bodies, not symbols and systems of equations! And, measurement is a relation (3rd category of property of physical things). [8] It is a comparison between two things. In this case, finally, it is a comparison between the mass[11] of one object and that of some standard, such as the one in

[5] It forces it to be exactly: $h = 6.62607015 \times 10^{-34}\ \mathrm{kg \cdot m^2 \cdot s^{-1}}$, or dropping the units: $h = 6.62607015 \times 10^{-34}$ (see footnote 6).

[6] $h = 2\pi\hbar$

[7] About $5 \times 10^{41}$ cycles in a second. Visible light is about $5 \times 10^{14}$ cycles per second. Frequency (*f*) is related to energy (*E*) (the equation is: $E = hf$). So, our chosen light has a much higher frequency which implies that it also has a much higher energy. It travels at the same speed; it just has more energy and it has more ability to cause impetus.

[8] See Rizzi, A., *Physics for Realists: Mechanics*. IAP Press, Rochester, NY (2008) (PFR-M) and Rizzi, A.: *A Kid's Introduction to Physics (and Beyond)*, IAP Press, Rochester, NY (2012) (KIP).

[9] This assumes the cup is on a frictionless surface.

[10] There are interesting points to bring out here. First, the object measured to be moving at 1 meter per second will indeed have a mass of 1 kilogram. However, such an object will not have that mass before the light hits! The light increases the mass of the object. Furthermore, (because of special relativity), the more impetus an object has, the more mass it has. A second point follows from this analysis. The mass that the body has when it is *at rest* (after it has been stopped) will only be *approximately* 1 kilogram. This is because without the impetus, it has less mass (it will still have the mass it gained from the light). However, none of this changes the central idea of the thought experiment, and these effects can be fairly easily accounted for.

[11] Mass is the resistance to the action of the impetus (see KIP and PFR-M referenced in footnote 8).


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Paris[12] or the one that can come out of an analysis like we did above using the new definition.

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[12] It is in Saint-Cloud, a suburb of Paris.


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