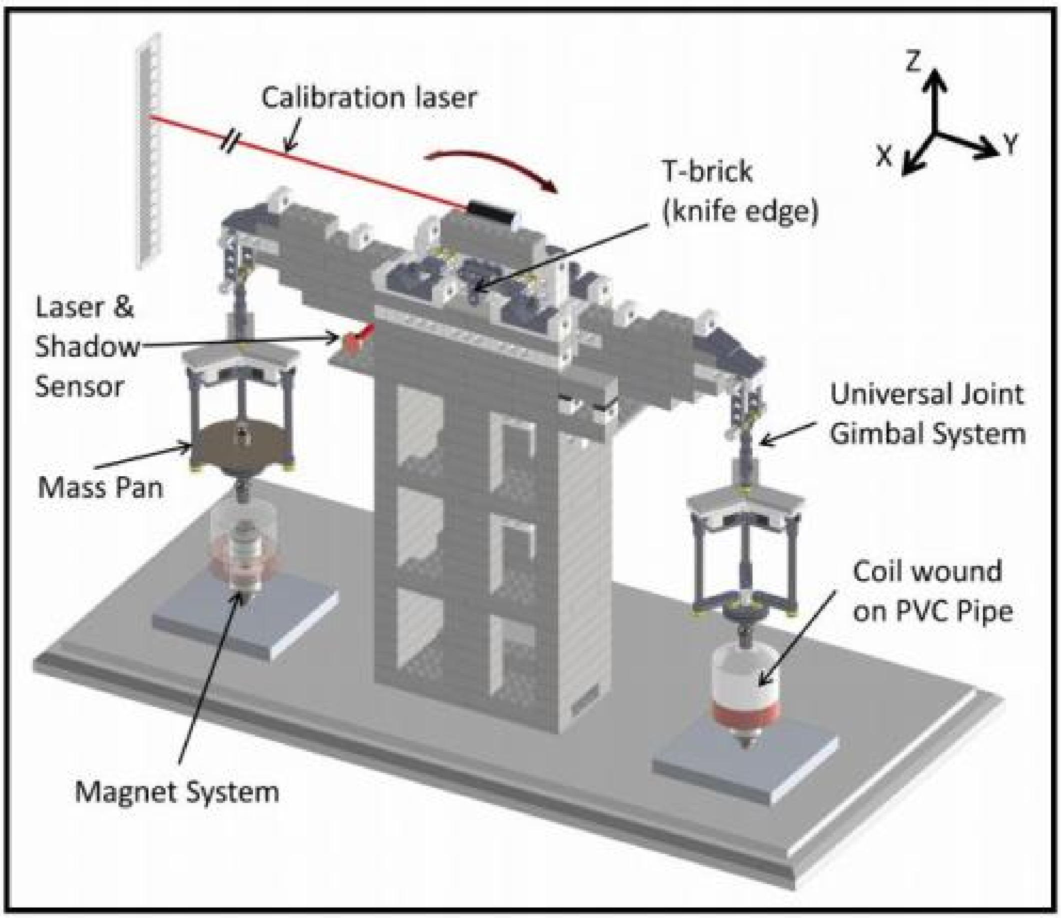
NIST physicists build a watt balance using LEGO blocks to measure Planck's constant

December 16 2014, by Bob Yirka



CAD model of the LEGO watt balance. The balance pivots about the T-block at the center. Two PVC endcaps with copper windings hang from universal joints off either side of the balance beam. Coil A is on the left and Coil B is on the right. A 10 gram mass sits on the Coil A mass pan and each coil is concentric to its own magnet system. Two lasers are used to calibrate and measure the linear velocity of each coil. Credit: arXiv:1412.1699 [physics.ins-det]

(Phys.org)—A team of physicists at the National Institute of Standards and Technology (NIST) outside of Washington D.C. has found a way to bring physics to the masses—they've designed and built a watt balance based on LEGO blocks. They've also written a paper and uploaded it to the preprint server *arXiv* in which they describe their device and how it was built it, should readers wish to construct one of their own.

To understand why the team at NIST would do such a thing requires a bit of background. Over the last century or so, scientists have been slowly replacing physical artifacts used for measurement, with devices that are based on more standard phenomenon—the meter, for example, is now based on time, rather than a rod sitting in a building. The lone holdout has been the kilogram, which is still defined by a chunk of metal sitting in a vault in France. But that's going to change soon, as the International System of Units is reviewing possibilities—one of which are devices based on measuring the value of Planck's constant to a certain degree of accuracy. Planck's constant describes the relationship between the energy and frequency of an electromagnetic wave. One kind of device that can be used to measure mass based on Planck's constant or taken the other way, to find a value for Planck's constant based on a known mass, is called a watt balance. It does its work by balancing the force exerted by gravity with the force of current in a coil—the mass of an object can be calculated by comparing the mechanical power to the electrical power in the device.

Scientists at NIST and other places have built elaborate and expensive watt balances, but in this new effort, they wanted to find a way to create one that anyone could build, and they found a way to do so by basing it on LEGO blocks—they actually built three, one of which they chose to outline in detail, describing not only how it works, but the parts used so that other's could build one too. Their design, they say would require a would-be constructor to lay down just $634 for all the parts, which include 2 sub- milliwatt lasers, photodiode, controllers, etc. They note that some industrious sorts would likely be able to reduce costs using other less expensive parts they source themselves.

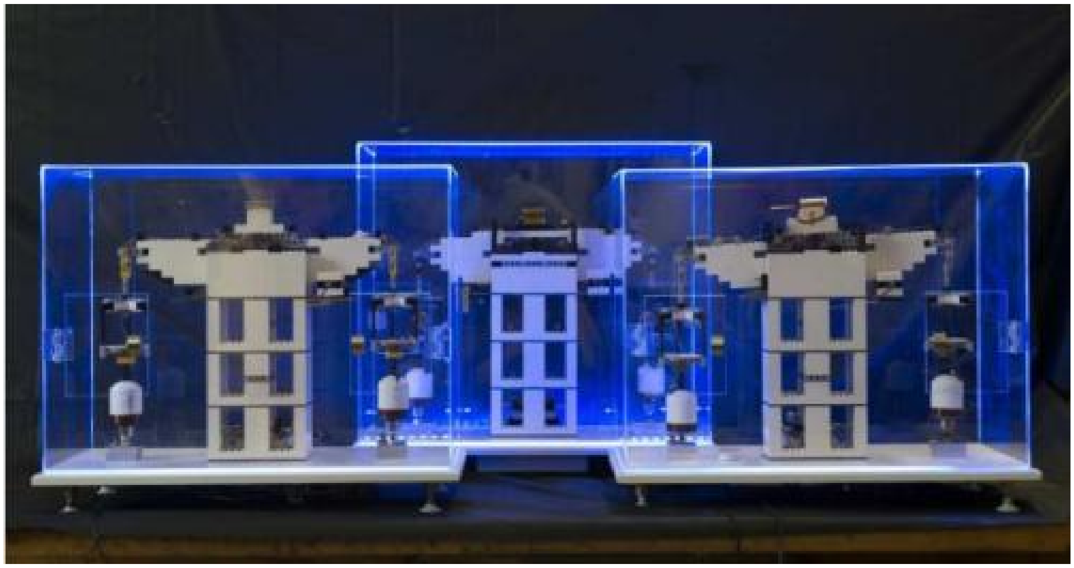


Image of three similar versions of the LEGO watt balance. The acrylic cases are backlit with blue LEDs and serve the purpose of blocking out disturbances from air currents. Two hinged doors on the front panel allow for small masses to be placed and removed from the mass pans. All the electronics are mounted below the wooden base board. Four adjustable feet are used for leveling the balance. Credit: arXiv:1412.1699 [physics.ins-det]

Video: vimeo.com/128598681

More information: A LEGO Watt Balance: An apparatus to demonstrate the definition of mass based on the new SI, *arXiv* :1412.1699 [physics.ins-det] arxiv.org/abs/1412.1699

Abstract
A global effort to redefine our International System of Units (SI) is

underway and the change to the new system is expected to occur in 2018. Within the newly redefined SI, the present base units will still exist but be derived from fixed numerical values of seven reference constants. More specifically, the unit of mass, the kilogram, will be realized through a fixed value of the Planck constant h. For instance, a watt balance can be used to realize the kilogram unit of mass within a few parts in 108. Such a balance has been designed and constructed at the National Institute of Standards and Technology. For educational outreach and to demonstrate the principle, we have constructed a LEGO tabletop watt balance capable of measuring a gram size mass to 1 % relative uncertainty. This article presents the design, construction, and performance of the LEGO watt balance and its ability to determine h.

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