The Novel Pathway to Determine Planck's Constant in SI Units

Cheng-Jhih, Tsai(蔡承志) and Chun-Hung, Huang(黃浚紘)

Professor : Yung-Fu, Chen(陳永富) TA : Yu-Ting, Lin(林侑鋌)

Department of Physics, Nation Central University

Background

- **Planck's constant** – a physics constant, published in 1900, which is a fundamental constant in quantum mechanics.
- **Black body radiation experiment** – first time to obtain the value of Planck's constant
- **Conventional units** – in 1990, the standard voltage and the standard resistance had been redefined though the Josephson effect and the quantum Hall effect.
- $\boldsymbol{h_{90}}$ – defined by the Josephson effect and the quantum Hall effect.

Goals

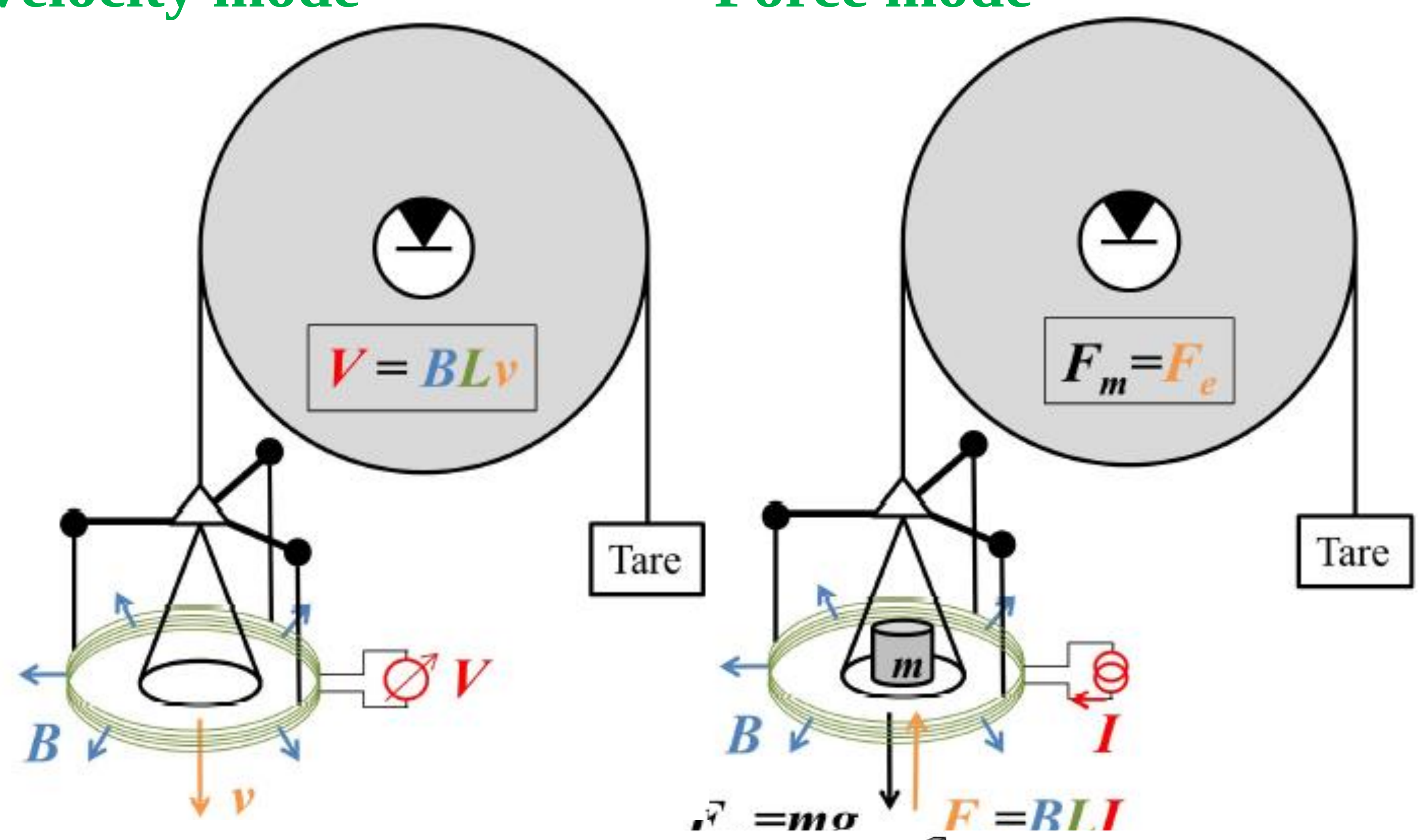
- Using LEGO bricks to setup a simple Watt balance.
- Using the Faraday's law and Lorentz force , we can get the ratio of the Planck's constant(h) and the conventional Planck's constant(h_{90}).

Theory

- **Watt balance** – a balance with two coils that has two operation modes, force mode and velocity mode.
- **Force mode** – base on Lorentz force $F = BLI$ and we can get the BL in force mode $(BL)_F = \frac{F}{I}$.
- **Velocity mode** – base on Faraday's law $V = BLv$ and we can get the BL in velocity mode $(BL)_V = \frac{V}{v}$.
- The ratio between SI units and conventional units –

$$\frac{h}{h_{90}} = \frac{(BL)_F}{(BL)_v} = \frac{\{mgv\}_{SI}}{\{VI\}_{90}}$$

Velocity mode   Force mode

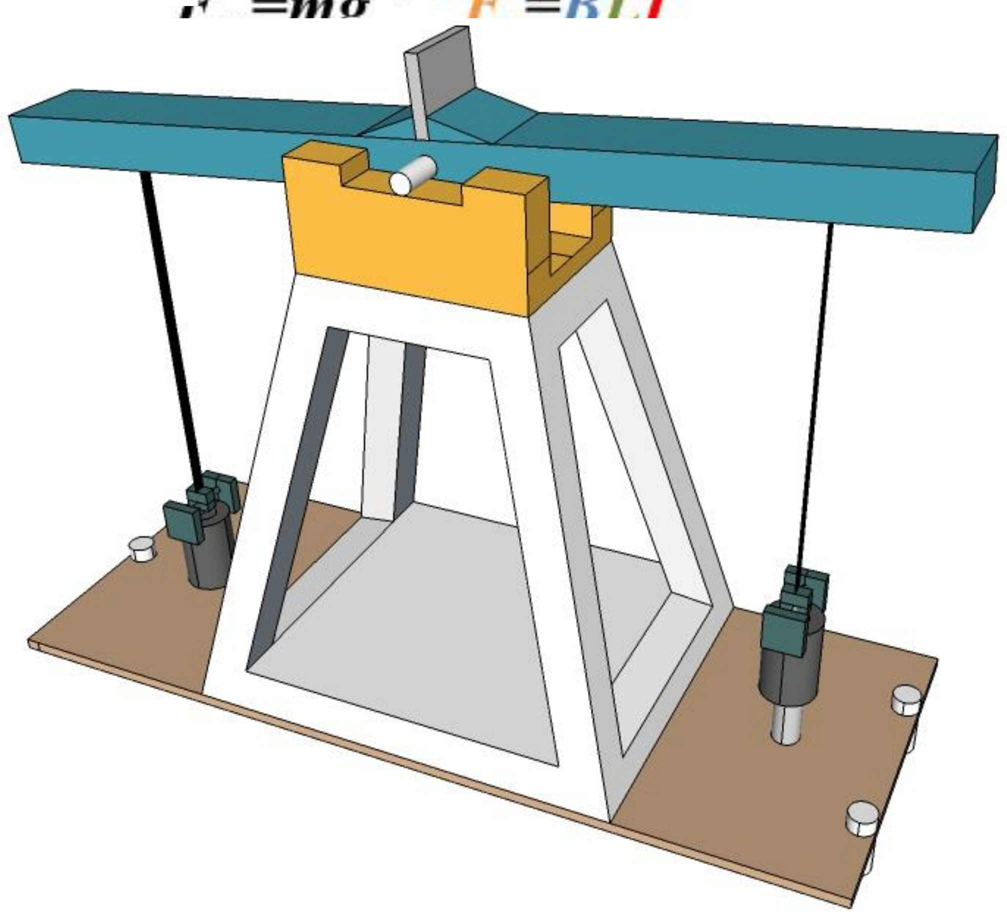


Experiment setup

- **Watt balance**(fig.3)

• Coils – 25m in 400 rings

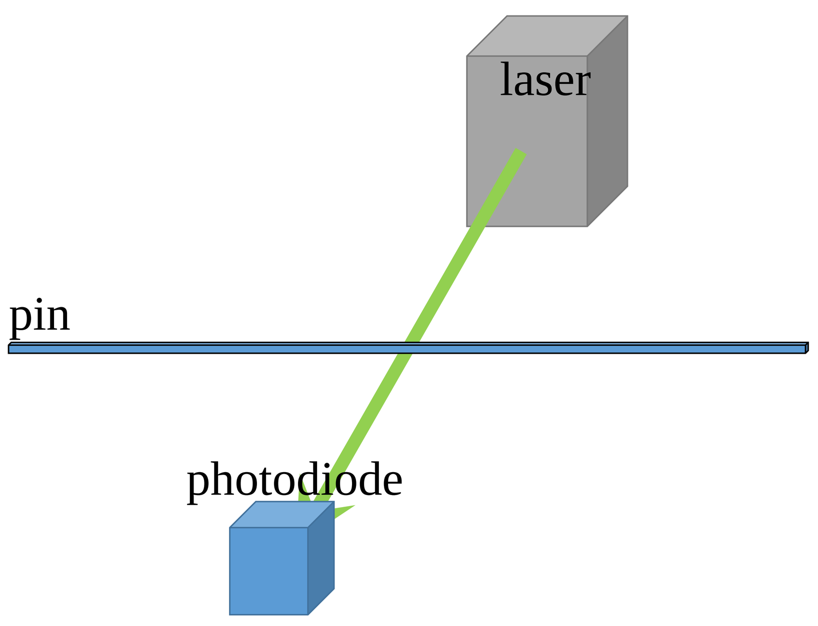
• Magnets – 6mT in the horizontal direction



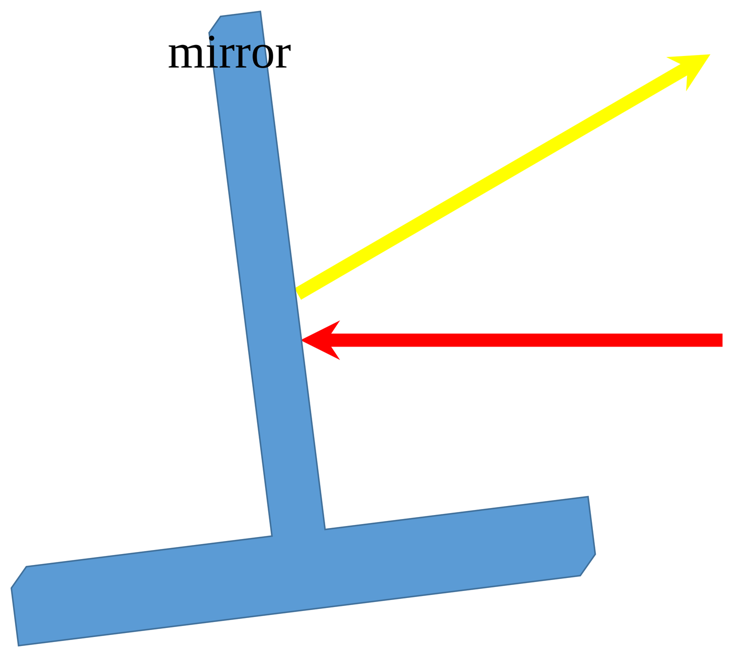
- **Force mode** – we want to find the ratio of the gravity force and the Lorentz force, so we set a very thin pin at the end of the balance and a photodiode system. When the balance deviate from the balance position, the voltage of the photodiode will change and we can adjust the input current until the voltage return to the initial value.

- **Velocity mode** – in velocity mode, we want to find the ratio of the coil's velocity and the voltage of the coil. We build a optical lever on the top of the balance to amplify its displacement. Then using the tracker to analysis the displacement of the light point.

Determine the position

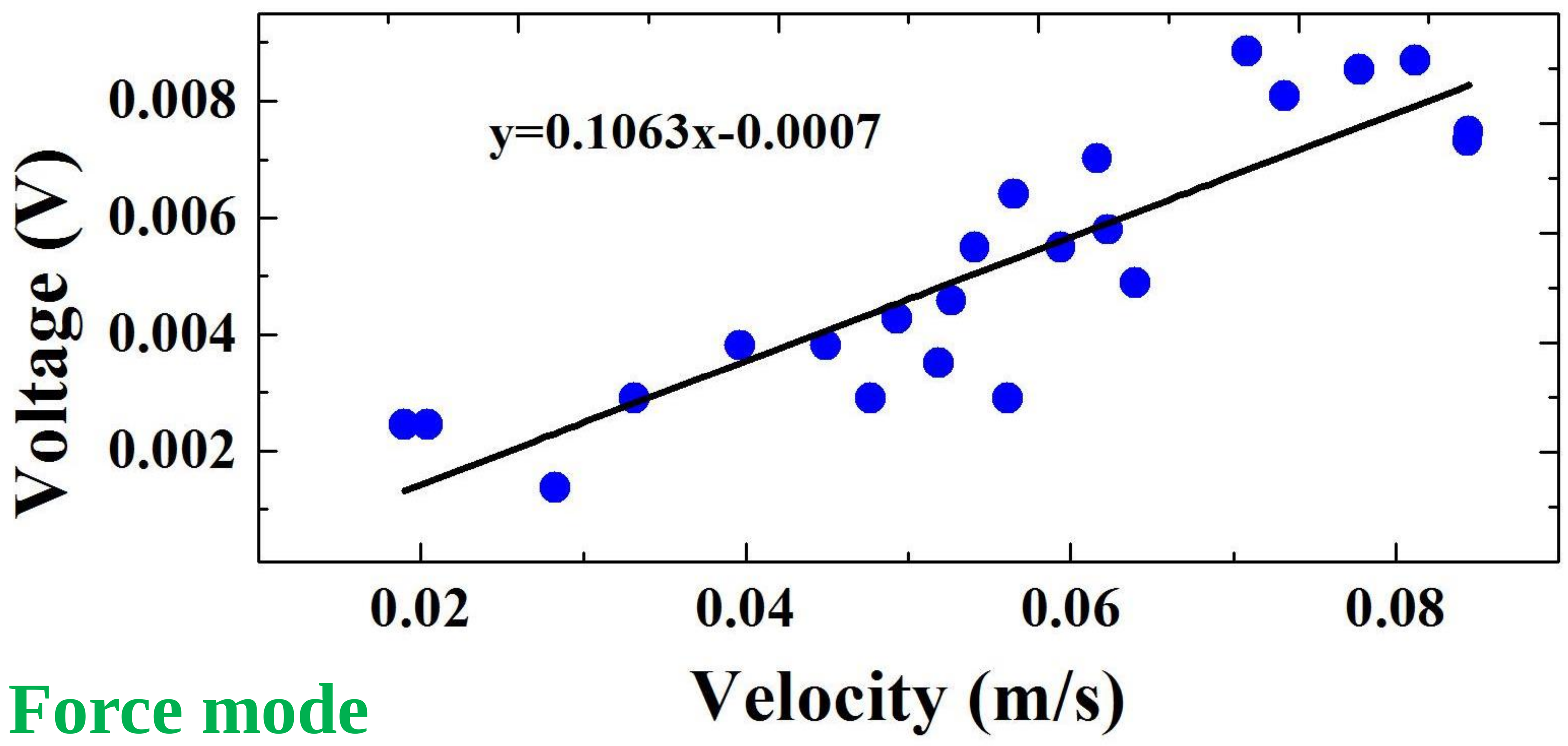


Determine the velocity

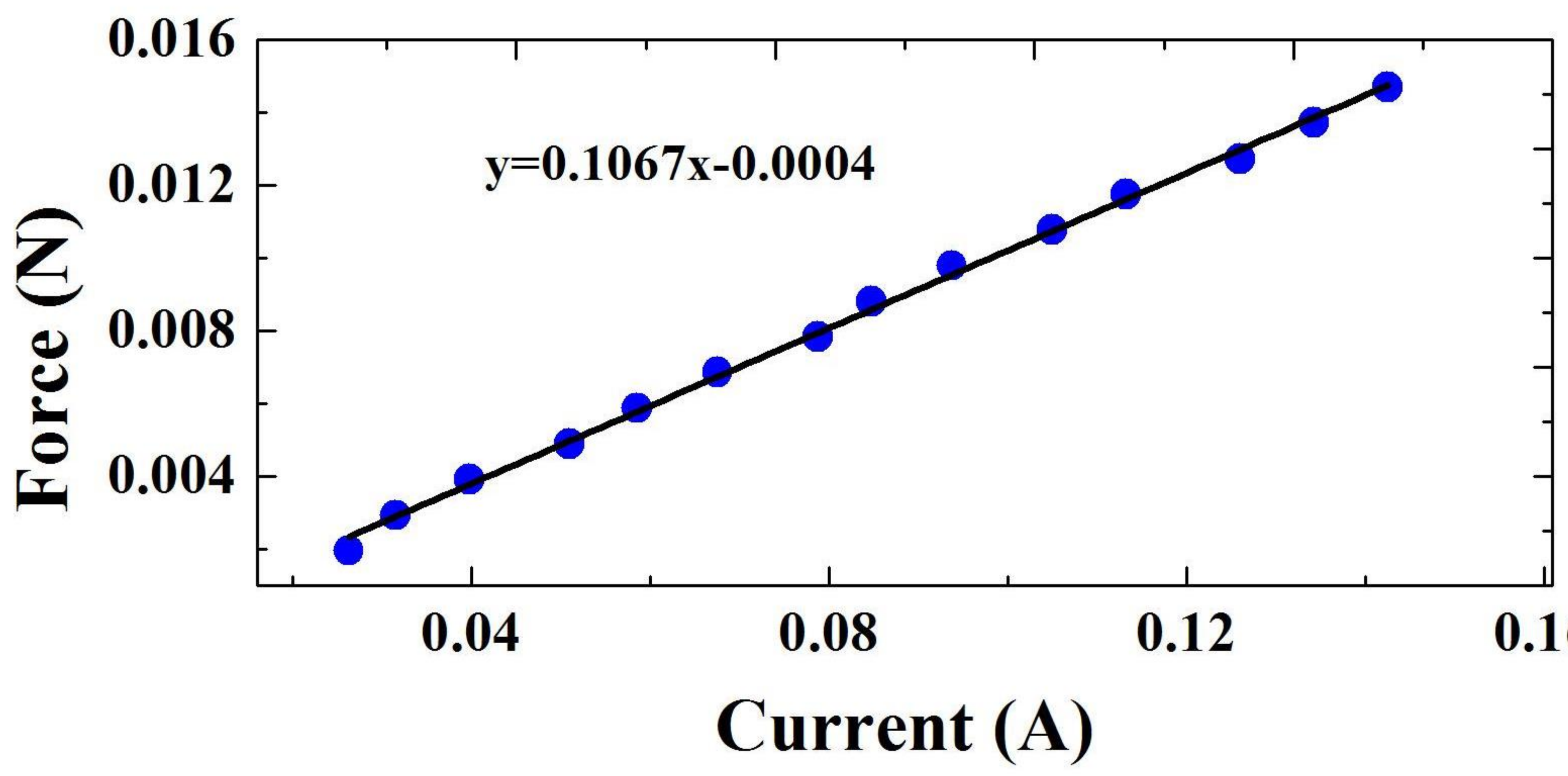


Results and Discussion

Velocity mode



Force mode



- **Force mode** - F(N)-I(A)   result:$(BL)_F$=**0.1067**(N / A)
- **Velocity mode** - V(volt)-v(m/s)   result:$(BL)_v$=**0.1063±0.0092** (V s/m)
- Our $\frac{h}{h_{90}} = \frac{(BL)_F}{(BL)_v} = \frac{0.1067}{0.1063\pm0.0092} \sim \mathbf{1.0037 \pm 0.095}$
- The Planck's constant in our experiment is about 6.650585304745
- The theoretical value is $\frac{6.62606957}{6.62606885} \times 10^{-34} \sim \mathbf{1.0000001}$ so the error is about $\mathbf{0.36 \pm 9.8\%}$.
- We think the error may come from the friction of the balance and the uneven magnetic field of the magnets.

Summery

- We have learned the relation between Planck constant(h) and the conventional Planck constant(h_{90}) and then we can measure the ratio though the experiment
- We build a watt balance to measure the product value of the B and L in the two mode
- We finally get the ratio of the SI unit and the conventional unit.

Reference

[1] L.S. Chao, S. Schlamminger, D.B. Newell, and J.R. Pratt, G. Sineriz, F. Seifert, A. Cao, and D. Haddad, X. Zhang. (2014). A LEGO Watt Balance: An Apparatus To Demonstrate The Definition Of Mass Based On The New SI

[2] Stephan Schlamminger, Darine Haddad, Frank Seifert, Leon S Chao, David B Newell, Ruimin Liu, Richard L Steiner, Jon R Pratt. (2014). Determination of the Planck constant using a watt balance with a superconducting magnet system at the National Institute of Standards and Technology