

Physics Integration Lesson 19 – Different Forms of Inertia

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Inertia is a foundational concept of physics and it is related to mass. Newton's first law states that an object maintains its current velocity unless acted upon by unbalanced forces. If something is stationary, it remains stationary. If something is moving, it maintains constant straight-line motion. When forces are unbalanced, Newton's second law states that the net force equals the product of mass and acceleration. A mass in motion has kinetic energy and to change that kinetic energy work must be done.

Inductors are magnetic devices that store and release energy as the amount of current flowing through them changes. By Faraday's law, a change in current induces a voltage in an inductor. If the current is decreased, the induced voltage acts in such a way as to oppose this change. This is done at the expense of magnetic energy stored in the inductor. In like manner, an increase in current is opposed as the inductor stores up more magnetic energy. As a result, many refer to inductance as the electrical equivalent of inertia.

To understand the significance of this, let's compare the magnetic energy stored in an inductor to the kinetic energy of electrons flowing in the same inductor. An automobile ignition coil has an inductance of 8 millihenries. With 5 amps of current flowing through it, the magnetic energy stored in the coil is 0.1 joules. Estimating the number of electrons needed to generate 5 amps of current throughout the whole coil, results in 4×10^{24} electrons. Although the number of electrons is large, the drift velocity is slow and the mass of electrons are small. As a result, the total kinetic energy of these electrons is 2×10^{-13} J. Within the coil, the magnetic interaction of these electrons with themselves have effectively multiplied their energy of motion by 5×10^{11} times.

Although mass and inductance both resist change, one is with respect to velocity and the other is with respect to current. Is there some deeper connection between the two or is it just a coincidence of physics? Some scientists have tried to explain the mass of electrons and protons as a purely electromagnetic phenomenon. However, these models ignore quantum mechanical effects and fail to generate consistent results. The currently accepted model for explaining mass is tied to the Higgs Boson, which had its existence confirmed at the CERN particle accelerator in 2012.

1. Whether there is a deeper connection or not, mass and inductance can be treated as analogies of each other. Are there other processes or activities that act analogous to mass and inductance? In other words, are there processes or activities that try to oppose change or the status quo? Name one and explain how it is analogous to these concepts.
2. By directing electrons through a coil, their energy of motion is multiplied due to interactions of their magnetic fields. By analogy are there ways of directing your activities in order to multiply your effectiveness? Give an example and explain.