DISCOVERY OF SELF-MOTION

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Self-motion was a central issue in Aristotelian physics. The subject has been generally neglected for four centuries. The author discovered that self-motion can be produced by dynamic coupling of two or more pulse trains within the moving body. Changing the frequency or the amplitude of the pulses can change the speed, direction and other characteristics of the motion. This paper describes the self-motion mechanism, delineates some of its features and gives step-by-step directions for others to reproduce and further study the effect.

Self-motion denotes the motions that are produced from within the moving body. Aristotle attributed those motions to *Soul*. Not much progress was made on the subject by the time of Sir Isaac Newton. Newton gave the phenomenon a passing mention in the very last paragraph of the *Principia*, where he wrote that such motions are due to the "vibrations" of "a certain most subtle Spirit." In the Twentieth Century, scientists and engineers have attempted to describe living motions in terms of classical or quantum rules, but the attempts have not been successful. Extensive experimental and study programs led the author to induce repeatable and controlled self-motion in bodies made of different materials and shapes. The motion mechanism and other features are described below.

The rotation of an unbalanced mass within a body produces erratic and uncontrolled motion, e.g., the rocking of a washing machine with an unbalanced load. Similar instabilities are produced in rotating motors, turbines, engines and tires. The theory of vibration deals extensively with the effects of pulses generated by inertial unbalance. In engineering, a primary goal in design is to eliminate the unbalance altogether from rotating systems. The author discovered that by purposely applying two pulse trains generated by inertial unbalance symmetrically on a body, the body could be made to move linearly within a range of pulse frequencies and amplitudes. The pulse trains can be generated by unbalanced inertia masses attached to the rotating shafts of two motors which, in turn, are firmly and symmetrically attached to the body. By varying the frequency and the amplitude of the pulses, smooth and repeatable linear motion can be obtained and analyzed.

Researchers can reproduce the motion effect by following the steps given below:

1. Mount 2 dc motors firmly symmetrically on top of a body. Initially, use standard shapes, e.g., a cube, a box, etc. (Fig. 1). The model can be made of wood, plastic, styrofoam, metals, etc.

2. Cross-wire the motors to rotate the shafts in opposite directions; clockwise (CW) and counterclockwise (CCW) as in Fig. 1.

3. Attach equal unbalanced masses (inertia elements) securely to the motors' shafts. Rotation of the inertia elements produces pulses that travel in the body and produce linear motion of the whole body. The material and shape of the inertia elements do not matter, though, one might use inertia rules to optimize effects.

4. Connect the motors to a power supply or a battery (1.5, 3, 4.5, 6, 9, 12 Volts), and watch the model move.

5. The motions can be produced with infinite combinations of pulse frequencies and pulse amplitudes. In the initial trials, the following ratios and ranges are recommended:

$$\frac{1}{20} \leq \frac{\text{Mass (motors)}}{\text{Mass (total)}} \leq \frac{1}{2}$$

$$\frac{1}{100} \leq \frac{\text{Mass (inertia element)}}{\text{Mass (total)}} \leq \frac{1}{10}$$

$$5 \text{ cps} < f < 500 \text{ cps}$$

Whatever the material and shape of the model, motion will be produced in the ranges given above. If smooth linear motion is not obtained, then corrections can be made as follows:

1. If the model jumps around erratically, then, (a) reduce the motors' RPM, (b) reduce the inertia of the drive elements, (c) both a and b, (d) apply damping material to the base of the model, or (e) try the model on a carpet or a similar soft surface.

2. If the model turns around in circles, reduce the pulse frequency or increase the pulse magnitude.

3. Dynamic coupling of the pulses tends to loosen one of the motors during operation, which can significantly reduce, or diminish, the motion. If temporary connections are used, e.g., adhesive tapes or glue, be sure the two motors remain equally firmly attached during operation.

After a few successful trials, researchers may want to expand their programs and vary parameters. Again, there are infinite ways to produce the motion. Here are some suggestions:

1. Move the motors laterally and axially to different locations on the model

and compare the motions for different locations of pulse excitations.

2. Mount the motors inside the model, e.g., inside of a box.
3. Try the motion mechanism with models made of different materials and of different shapes.
4. Build a separate drive module. Mount the motors and battery on a separate strip of metal, plastic or wood and attach the drive module to different bodies at different locations and observe the motions.
5. Control the direction of motion by changing frequency, phase, polarity, cg (center of gravity) location, etc.
6. Connect a potentiometer to the power supply so as to vary the pulse frequency. Observe the motion at different frequencies.
7. Move the same model on surfaces with different coefficients of friction, and observe the results.
8. Try specialized motions with the mechanism, e.g., pendulum, rocking, orbital, uphill and joints motions.
9. Add remote control elements (infrared, radio control, etc.) to the motion model, and operate remotely.

Careful observations during operation will reveal many features of the motion mechanism. A few observations made by the author are given next:

1. Speed is constant for a given input pulse frequency, hence the kinetic energy, E, of the model is constant at the driving frequency.
2. Terminal speed is reached nearly instantaneously.
3. Models can be accelerated by gradually increasing the pulse frequency (in the operational range), i.e., acceleration is proportional to frequency.
4. There is a cutoff frequency f_o below which motion does not occur.
5. There is a frequency range ($f_{min} < f < f_{max}$) within which the speed and kinetic energy of the model increase as the frequency is increased.
6. Observations 4 and 5 are shown in Fig. 2. Compare this behavior to the photoelectric effect.
7. Beyond the maximum frequency (f_{max}), the speed diminishes rapidly and the models stop moving.
8. Observations 4, 5, and 7 add up to Fig. 3. Compare to Wien's Law and Planck's Radiation Formula.
9. At certain pulse frequencies (generally low frequency) and for highly

symmetric locations of the motors, stepped motion at a distinct frequency and a distinct wavelength occurs. Compare this feature to the Compton's Effect. Here, one input frequency (the driving frequency with its distinct wavelength) produces two distinct frequencies and their associated wavelengths; i.e., the input driving frequency and the model's output distinct stepped motion frequency.

The author has established the following general mathematical relationships for the motion through many and repeated tests of the phenomenon; and other researchers can verify our results:

$$s \propto F(f)$$

$$s \propto \frac{1}{F(m)}$$

$$E \propto f$$

$$a = \frac{dv}{dt} \propto \frac{df}{dt}$$

Where, *f* is the pulse frequency within the range described above, s the speed of the motion model, m the total mass of the model, E the kinetic energy of the model, and a is acceleration.

Generally, the motions produced by dynamic coupling of pulses do not obey Newton's Laws of Motion. In particular, Newton's Laws do not involve frequency or wavelength terms. The author attempted to fit the above and related observations into classical, electromagnetic or quantum rules. The best explanation for the motion phenomenon appears to be that of the *beat* effect, which is known to occur when two equal waves are superposed or modulated. It is generally known that two harmonic frequencies can couple to produce a third distinct oscillation, known as the beat. Examples include the beats produced when striking two tuning forks, two similar piano notes, or the modulation of electromagnetic frequencies. The beat represents the superposition of two identical, or nearly identical, notes, f_1 and f_2. The beat itself has its own distinct frequency, f_b, which varies harmonically with its own amplitude, A_b, or beat amplitude. The beats usually propagate as traveling waves. The wave groups, which travel with a given speed, the group velocity, carry energy as they travel. Apparently, by introducing two mechanical pulse trains into a physical body, the pulse trains couple, or modulate, and produce a beat with its own distinct frequency and distinct wavelength within the body itself. The energy of the beat transfers to the motion model causing the model to move as observed in the experiments outlined above. This explanation is supported by other observations. For example, when the beat amplitude A_b goes through one complete cycle of oscillation, dynamic analysis indicates that the amplitude goes through a maximum (+1) and a minimum (-1) value. Yet, careful observation of the stepped motion that is produced with the motion mechanism shows only motion steps in the same direction; i.e., only maximum (+1) amplitudes and zero amplitudes are observed. This is typical of the behavior of *square-law detectors*, which is noted in the beats produced by the modulation of two harmonic oscillations or electromagnetic signals.

The motion mechanism described in this paper is important in *physics*. It is also important in other subjects. The author used the motion mechanism, described earlier, on his body. The pulse trains induced forward motion of the author's body without a motion command from his mind. This and related experiments demonstrate the importance of the motion mechanism in other areas, such as biology and psychology.

Note: The author is submitting Videotape, with this paper, which shows the motion features described above with some 20 Technical Models and 50 Toys. Also, for the purpose of "proof of concept," the author constructed and successfully tested, in 1999, several remotely controlled robots using the above motion mechanism for the Defense Advanced Research Projects Agency (DARPA).

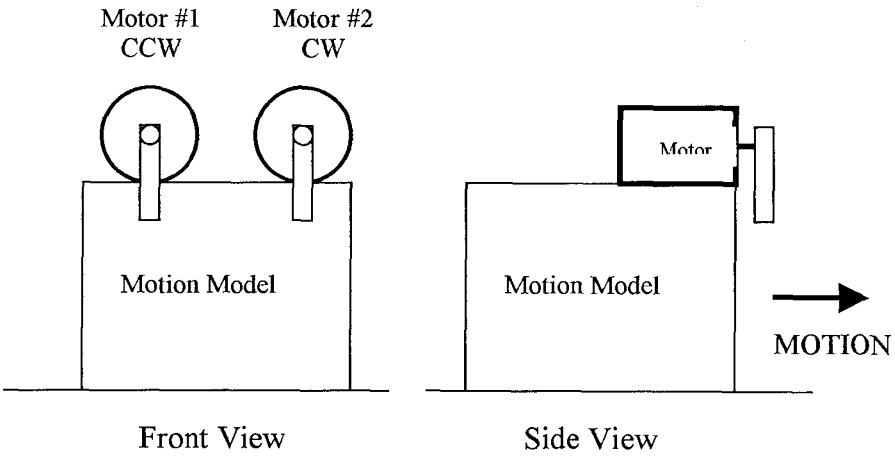

Fig. 1

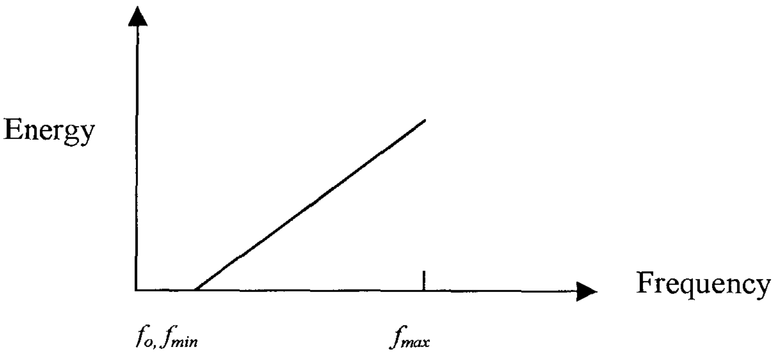

Fig. 2

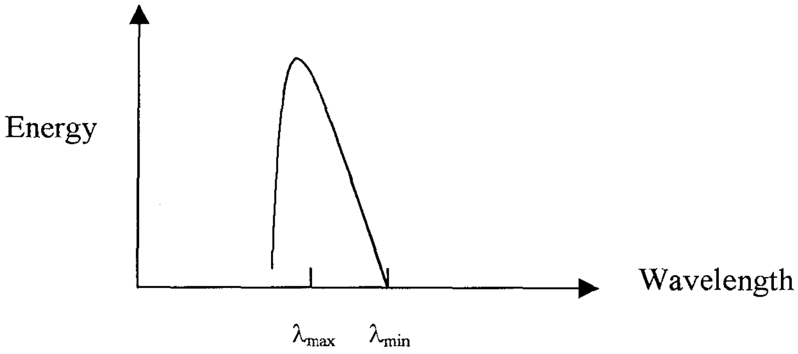

Fig. 3