Revised Theory of Transient Mass Fluctuations

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Abstract

Several publications during the last 10 years by Woodward and colleagues have: (1) indicated a theory based on special relativity, that predicted transient mass fluctuations; (2) cited specific embodiments where a net average force would be present; (3) suggested a few ways that this theory might be tested in the laboratory; and (4) reported such test results incorporating these embodiments, which are interpreted to support theory (1) to (3) above. In this paper we show that: (1) the average force predicted by Woodward's theory occurred only because of a neglected term in a product derivative, and that when the neglected term is correctly returned, the average force identically vanishes; (2) this vanishment of the average force occurs for arbitrary forcing functions, not just the sinusoidal one considered by Woodward; (3) the transient mass fluctuation, predicted by Woodward, was developed in a theory which neglected local gravitational forces which are several dozen orders of magnitude greater; (4) additionally considering the dominant local gravitational forces produces a vastly smaller transient mass fluctuation; (5) several inconsistencies between Woodward's referents and the development of his wave equation lead to a formulation that does not follow from the antecedents even in the absence of the demonstrations (1) to (4) above; (6) there is an alternate interpretation of the Woodward/Mahood experiments that can entirely explain the findings in terms of force contributions due to time varying thermal expansion, without invoking any general relativistic effects; and (7) a laboratory demonstration of the alternate interpretation produced 100 times the Woodward effect without resort to non-Newtonian explanations.

1. Introduction

It would be a major advance in space travel if a rocket could be made that would require no material to be ejected as the source of the rocket's momentum. From the standpoint of classical

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mechanics, this would appear to be a violation of momentum conservation. One approach has been taken by Woodward et al. [1,6] whereby non-conservation of classical momentum is justified by the assertion that the momentum imbalance is made up by a corresponding momentum change in the rest of the universe. This assertion is made in the context of an analysis consisting of a flat-space low-velocity relativistic evaluation of the four-divergence of gravitational field using Machs' principle and a (first order) theoretical result by Sciama [7]. From this proposition, several publications during the last 10 years by Woodward and colleagues [1,6] have: (1) predicted transient mass fluctuations; (2) cited specific embodiments where a net average force would be present; (3) indicated how this might be tested in the laboratory; and (4) reported such test results incorporating these embodiments. In this paper we will comment on these findings.

2. Reconsideration of the Average Force for the Case Considered by Woodward

The average force predicted by Woodward can be shown to occur only because of a neglected term in a product derivative, and that when the neglected term is correctly returned, the average force can be shown to vanish identically. The product derivative is:

$$\mathbf{F} = \frac{d}{dt}(m\mathbf{v}) = m\frac{d\mathbf{v}}{dt} + \mathbf{v}\frac{dm}{dt} \tag{1}$$

The equation immediately preceding Eq. (A.31) in Mahood [5] neglects, without alert, the second term in the product derivative, **vdm/dt**. It turns out that, at least for the case considered by Woodward [1-5], the **vdm/dt** term is identically the same magnitude as the **mdv/dt** term, but of opposite sign causing a complete cancellation of the average force arising from transient mass fluctuations. According to this result, any transient mass effect that may exist would not be observed, at least for the sinusoidal driving forces considered.

3. Reconsideration of the Average Force for Arbitrary Forcing Functions

The conclusion of the previous section is true for the specific case that Woodward considers, namely that of a sinusoidally driving force.

$$\begin{aligned} F = \{[m_0 + \delta m_0 \cos(2\omega t)][-4\omega^2 \delta l_0 \cos(2\omega t + \gamma)] \\ + [-2\omega\delta m_0 \sin(2\omega t)][-\omega\delta l_0 \sin(2\omega t + \gamma)]\}\ . \end{aligned} \tag{2}$$

Therefore, a Fourier expansion of the forcing function,

$$\begin{aligned} F = {}_{k}\ {}_{j} a_k b_j \{[m_0 + \delta m_0 \cos(2\omega_j t)][-4\omega_k{}^2 \delta l_0 \cos(2\omega_k t + \gamma_k)] \\ + [2\omega_j \delta m_0 \sin(2\omega_j t)][\omega_k \delta l_0 \sin(2\omega_k t + \gamma_k)]\}\ , \end{aligned} \tag{3}$$

may be grouped in such a way that a term by term cancellation can be demonstrated analytically. Further, one may see that the term cancellation occurs for any forcing function representable by a Fourier series, not just the sinusoidal one considered by Woodward. These arguments suggest that attempts to measure an average net force associated with transient mass fluctuations under the Woodward-Mahood paradigm will fail and that any unresolved anomalies found in the experiments are not due to transient mass effects, but rather due to other causes. In a later section, we will establish a systematic effect which has gone unnoticed and which would mimic the transient force effects expected by Woodward and Mahood. However, these arguments do not in and of themselves allow any conclusion about the existence of the transient mass effect itself, just their measurability with the proposed experimental paradigm. In the next three sections we will consider the development of the theory leading to a transient mass effect itself.

4. Reconsideration of the Proposed Transient Mass Fluctuations

Examination of the Woodward theory [1-5] leading to the transient mass fluctuation indicates that only non-local gravitational forces were considered in his simplification of the relativistic time term and all other forces, which are vastly larger, were neglected. By the term "non-local gravitational force" we mean that gravitational forces due to local inhomogeneities such as the earth in the ambient mean density are neglected. This omission in the theory occurs when he substitutes $\phi = c^2$, which he attributes to Sciama's [7] estimate of the potential due to non-local matter, to eliminate two terms and obtain Eq. (A.17) of [5], whose remaining terms are replicated below,

$$-\frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \frac{\phi}{\rho_0 c^2}\frac{\partial^2\rho_0}{\partial t^2} - \nabla\bullet\mathbf{F} = 4\pi G\rho_0 - \frac{1}{c^4}\left(\frac{\partial\phi}{\partial t}\right)^2 - \left(\frac{\phi}{\rho_0 c^2}\right)^2\left(\frac{\partial\rho_0}{\partial t}\right)^2, \qquad (4)$$

$$\textbf{and}\ \ \mathbf{F} = -\nabla\phi\ , \qquad (5)$$

where the forces acting on the test body are equal to the negative gradient of the same non-local gravitational scalar potential (Eq. 5). All of the terms in Eq. (4) refer to a non-local gravitational potential. Equations (4-5) directly lead to the inhomogeneous wave equation, below for the non-local gravitational potential ϕ:

$$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2\phi}{\partial t} = 4\pi G\rho_0 + \frac{\phi}{\rho_0 c^2}\frac{\partial^2\rho_0}{\partial t^2} - \frac{1}{c^4}\left(\frac{\partial\phi}{\partial t}\right)^2 - \left(\frac{\phi}{\rho_0 c^2}\right)^2\left(\frac{\partial\rho_0}{\partial t}\right)^2, \qquad (6)$$

which is the essential result of Woodward’s transient mass theory if one assumes his relativistic simplification is correct. The second term on the RHS is the transient mass term and the last two terms on the RHS are argued to be smaller and are eventually neglected. Given that the forces are non-local gravitational forces, the only way the equations are consistent is if the density is also the homogeneous density of the universe as a whole.

Since local gravitational forces are neglected, this determination of transient mass fluctuation neglects all commonly observed and far larger forces, including even those required to test the concept in the laboratory. As an example, in spite of the enormous precision trajectory calculation required to send a probe out to the distant planets, no consideration of non-local gravitational forces need ever be made – only a very precise calculation of local gravitational forces. In summary, the theory is constructed around a nonlocal gravitational potential (Eqs. 4-5), while Eq. 2 above (or equation A.31 [5]), considers local forces.

The neglect of nonlocal gravitation is justified if the mass distribution in the universe is not only continuous, but also homogeneous. To everyone who has noticed that they are attracted to the center of the earth (to a good approximation) instead of the center of the universe, or who has bumped into a wall, the approximation of a homogeneous mass distribution is certainly suspect. It would be useful in this context to provide a sense of how dominant the local gravitational forces are compared to the nonlocal forces. The absolute value of the nonlocal potential is about 10^{20} (cgs) [7]. Since the Hubble Radius of the universe is 10^{23} cm, the gradient of the potential is about 10^{-3} (cgs). On the other hand, the gradient of the local gravitational potential gradient near the surface of the earth is 980 (cgs). The ratio between these shows that the nonlocal gravitational potential gradient is 10^{+6} times smaller than the experiential local gravitational potential gradient. Another way of looking at it is that the nonlocal gravitational potential gradient is about the same as the gravitational potential gradient produced by a one-half kilogram object a meter away.

5. Extension of Woodward's Theory to include Experiential Forces

Alternatively, to consider other forces during the formulation process, one needs to at least consider the simplest alternative to Woodward's equation (4) for which a potential, ψ, induced by local sources, whose spatial dependence can be significant on laboratory scales, is added to the potential, ϕ, induced by observable non-local sources. Replacement of ϕ by $\phi+\psi$ leads to

$$-\frac{1}{c^2}\frac{\partial^2(\phi+\psi)}{\partial t^2}-\frac{(\phi+\psi)}{\rho_0 c^2}\frac{\partial^2\rho_0}{\partial t^2}-\nabla\bullet\mathbf{F}=4\pi G\rho_0-\frac{1}{c^4}\left(\frac{\partial(\phi+\psi)}{\partial t}\right)^2-\left(\frac{(\phi+\psi)}{\rho_0 c^2}\right)^2\left(\frac{\partial\rho_0}{\partial t}\right)^2, \tag{7}$$

$$\textbf{and } \mathbf{F}=-\nabla(\phi+\psi). \tag{8}$$

It is important to note that while the nonlocal potentials are vastly larger than the local potentials, $\phi+\psi\sim\phi$, the gradients of the local potentials can be vastly larger than the gradients of the nonlocal potentials, $\nabla(\phi+\psi)\sim\nabla\psi$, in fact by as much as eight orders of magnitude, as described above. It is also important to note that while time derivatives of the non-local potential are very small, the time derivatives of the local potential may not be neglected. Taking the Mahood/Woodward's [5] interpretation of Sciama's theory [7] to second order so that the local potential appears, and inserting into Woodward's theory, one gets

$$\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2\psi}{\partial t^2} + \frac{1}{c^4}\left(\frac{\partial\psi}{\partial t}\right)^2 = 4\pi G\rho_0 - \nabla^2\phi + \frac{\phi}{\rho_0 c^2}\frac{\partial^2\rho_0}{\partial t^2} + \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} + O\left(\frac{1}{c^4}\right) \text{ . (9)}$$

This is a hyperbolic wave equation in terms of the local potential instead of the nonlocal potential. Also there is a term of order c^{-4} involving the local potential retained on the left hand side. All derivative terms on the right hand side involve the nonlocal potential and so are expected to be small.

6. Miscellaneous Inconsistencies Including those in the Four-Divergence Equation

Mahood and Woodward [5] derive an invariant function and manipulate its terms to define a mass fluctuation. The function he chooses is the D'Alembertian or wave equation, which he isolates from terms that arise from the four-divergence of the gravitational field (a scalar) over a small volume containing a mass, m. In his derivation the gravitational field is treated as a vector. This section explores only the self-consistency of his derivation and does not deal with the validity of its flat-space approach.

The exploration considers a parallel derivation of the wave equation that used the conventional definition of force according to Rindler [8]. Mahood and Woodward introduced a minus sign. The potential energy from gravitational sources is negative as confirmed by Sciama's [7] estimate, $\phi/c^2 = -1$, to estimate orders of magnitude. (Woodward employs a plus sign consistent with his definition of negative force.) Our definition of relativistic energy density is $\varepsilon = T/\Delta V + \rho_o c^2$ ($E = T + m_o c^2$), where $T/\Delta V = V_{max}/\Delta V - \rho\phi$ and ΔV is a volume element. T is the kinetic energy of a unit volume constrained to move between potential energies, V_{max} and V_{min}, in a region whose local potential is ϕ. The equation for relativistic energy density is now $\varepsilon = V_{max}/\Delta V - \rho\phi + \rho_o c^2$, which differs from Woodward's $\varepsilon = +\rho\phi$. We take the relation between ρ and ρ_o to be $\rho = \gamma^2\rho_o$, which corresponds to a collisionless mass density distribution [8]. It follows that

$$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} = -\frac{2}{c^2}\frac{\partial^2\phi_o}{\partial t^2} + 4\pi G\rho_o - \frac{\phi}{\rho_o c^2}\frac{\partial^2\rho_o}{\partial t^2} + -\frac{1}{c^4}\left(\frac{\partial\phi_o}{\partial t}\right)^2 \frac{2}{\rho_o c^2}\frac{\partial\phi_o}{\partial t}\frac{\partial\rho_o}{\partial t} - \frac{3}{\rho_o^2}\left(\frac{\partial\rho_0}{\partial t}\right)^2 , \qquad (10)$$

compared with the Mahood/Woodward [5] equation replicated above (Eq. 6). Three significant observations emerged from this discussion.

1. Proper evaluation of the scalar from the four-divergence in the rest frame of mass, $\rho_o\Delta V$, produced an additional two terms compared with Woodward's $4\pi G\rho_o$ term. These terms are

$$\nabla_4 \cdot E_4\big|_o = -4\pi G\rho_o - \frac{1}{\rho_o^2}\left(\frac{\partial\rho_o}{\partial t}\right)^2 + \frac{1}{\rho_o}\frac{\partial^2\rho_o}{\partial t^2} \ . \tag{11}$$

2. Woodward's use of a minus sign in the initial definition of force (anti-force) is followed by an inconsistent representation of force (anti-force) as the negative gradient of a potential. The Mahood/Woodward [5] unconventional initial force (anti-force) definition requires that force be a positive gradient of a potential, which causes the spatial- and time-dependent terms of the wave equation to have the same sign.

3. After the wave equation is isolated to delineate the function it contains terms that cannot be dismissed because they are squares and cross products of time derivatives of rest mass density and local potential energy. These time derivatives will normally be significant as discussed in section.

4. Because the time derivative of the local potential can be significant the term, $(\partial\phi_o/\partial t)^2/c^4$, cannot be ignored. Since ϕ/c^2~-1 and mass fluctuation depends upon the time rate of change of the rest mass density not being zero, Woodward's last term in Eq. 6 is of the same order as retained terms and can't be ignored.

There are four differences between Eq. 10 and the Mahood/Woodward [5] Eq. 6. These are: 1) Another term that is twice the time-dependent term in the wave equation appears on the RHS; 2) When the additional time derivative of the rest mass density in Eq. 10 is considered, Woodward's last term in Eq. 6, which can't be ignored, is multiplied by -3 instead of -1; 3) When the additional time derivative of the rest mass density in Eq. 10 is considered, another term in the product of the time derivative of the potential with the time derivative of the rest mass density appears, which cannot be ignored; and 4) the sign of the mass transient term is reversed.

Our conclusion is that Woodward's derivation is not consistent with itself.

7. An Alternate Interpretation of the Woodward and Mahood Experiments

This section is based on the experiments discussed in the Mahood Thesis [5] which purport to show a transient mass effect quantitatively consistent with Woodward's thesis [1-5]. We here show that a systematic effect was neglected in the interpretation of these experiments, which, when accounted for, suggests that the anomalous transient mass observations are explainable by simple classical Newtonian thermodynamic considerations. As an aside the Mahood experiments originally appeared to exhibit one millionth of the effect predicted by the original theory [1-5] and so cannot be said to be in agreement with the Woodward/Mahood theory anyway. Now that the original theoretical development has been shown above to produce no average force due to transient mass fluctuations (Sect. 2, 3), and any transient mass effects if they exist at all are several orders of magnitude smaller, it is no surprise that there was a disagreement. But there is still a small anomalous force in the Woodward/Mahood interpretation of the experiment and so it is useful to reconsider the analysis of the experiment to see if a simple classical explanation can be found. In the Woodward experiment, a mass is excited by a piezoelectric device providing oscillatory motion and, incidentally, becoming hot in the mode of operation chosen to produce the greatest anomalies.

The excited mass and piezoelectric elements are at each end of a torsional pendulum and all classically expected motion is perpendicular to the arm of the pendulum. When the piezoelectric element and associated mass heat up and begin to expand, there is initially a momentum jerk due to the onset of thermal expansion (accelerated thermal expansion) and thus a transient force giving rise to a torque about the axis of interest, for each expanding element,

$$\Gamma = \mathbf{r} \times \mathbf{F} = \mathbf{r} \times \frac{d(m\,\mathbf{v})}{dt} \,. \tag{12}$$

A parabolic diffusion equation was solved for the temperature distribution evolving from a finite width distribution of heat flux. This was subsequently used with equations (14) and (15) to derive the transient force that results from heating and cooling the piezoelectric element and associated mass.

$$\frac{\partial^2 T(x,t)}{\partial x^2} - \frac{1}{\alpha(x)} \frac{\partial T(x,t)}{\partial t} = \frac{Q(x)}{k}, \tag{13}$$

$$dl = \alpha(x) l dT \,, \quad a = \frac{d^2 l}{dt^2} \,, \tag{14}$$

$$\text{and } F = ml \quad \alpha(x) \frac{d^2 T(x)}{dt^2} dx \,. \tag{15}$$

Figure 1 is a model for the Lagrangian development of the forces in this problem. Solving for the forces provides the following equation, which shows that there will be force components due to the time dependent heat distribution with concomitant acceleration of mass due to transient thermal expansion. This derivation also has the advantage that it is easily used to model the forces due to different materials in a line such as is present in the Woodward experiment:

$$M\ddot{X}_C - m_L \frac{h\alpha_L}{2} \frac{\partial^2 T_L}{\partial t^2} + m_{R1} \frac{h\alpha_{R1}}{2} \frac{\partial^2 T_{R1}}{\partial t^2} + m_{R2} \frac{h}{2}\left[2\alpha_{R1} \frac{\partial^2 T_{R1}}{\partial t^2} + \alpha_{R2} \frac{\partial^2 T_{R2}}{\partial t^2}\right] + m_{R3} \frac{h}{2}\left[2\alpha_{R1} \frac{\partial^2 T_{R1}}{\partial t^2} + 2\alpha_{R2} \frac{\partial^2 T_{R2}}{\partial t^2} + \alpha_{R3} \frac{\partial^2 T_{R3}}{\partial t^2}\right] + K(X_C - X_0) = 0 \,. \tag{16}$$

When an element expands with constant velocity, the force due to that thermal expansion vanishes. However, at least initially, the time dependent temperature distribution that results as the heat flows from the piezo electric unit to a block of metal at one end always results in a non-zero second order time derivative, or acceleration of portions of the expanding elements and attachments. When the piezoelectric unit is turned off, typically after five seconds, a second momentum jerk occurs in the opposite direction, resulting in a transient force in the opposite direction. If the application and removal of heat is synchronized with the movement of the pendulum, the pendulum motion may be increased in a resonant fashion. With no further operation of the piezoelectric element the temperature eventually starts to decrease and the mass compresses. A momentum in the opposite direction, although much smaller, appears and a small negative torque is generated. This is cancelled out later when the mass fully contracts, a matter of many minutes in the apparatus described in the Mahood thesis.

Figure 2 shows the force and the subsequent pendulum motion predicted by the thermal model described above for the nonsymmetric case in [5]. In the example considered here the system is initially at rest; the motion shown is entirely due to the purely classical phenomena of accelerated thermal expansion.

A torsional pendulum was constructed with a self-contained, battery-powered resistance heater coupled to a mass at one end to demonstrate the force due to heat transfer without the complication of piezoelectric elements and alternating current power supplies. The heater, shown in Fig. 3, could be switched on or off using light from an external lamp. The entire apparatus, shown in Fig. 4, was hung from a massive table and completely encased to eliminate air currents. As in the Woodward experiment, the motion could be monitored using a laser reflecting off a mirror to a meter stick. By turning the lamp on and off the pendulum could be made to oscillate with no other external influence. A typical plot showing the motion indicated on the meter stick is shown in Fig. 5.

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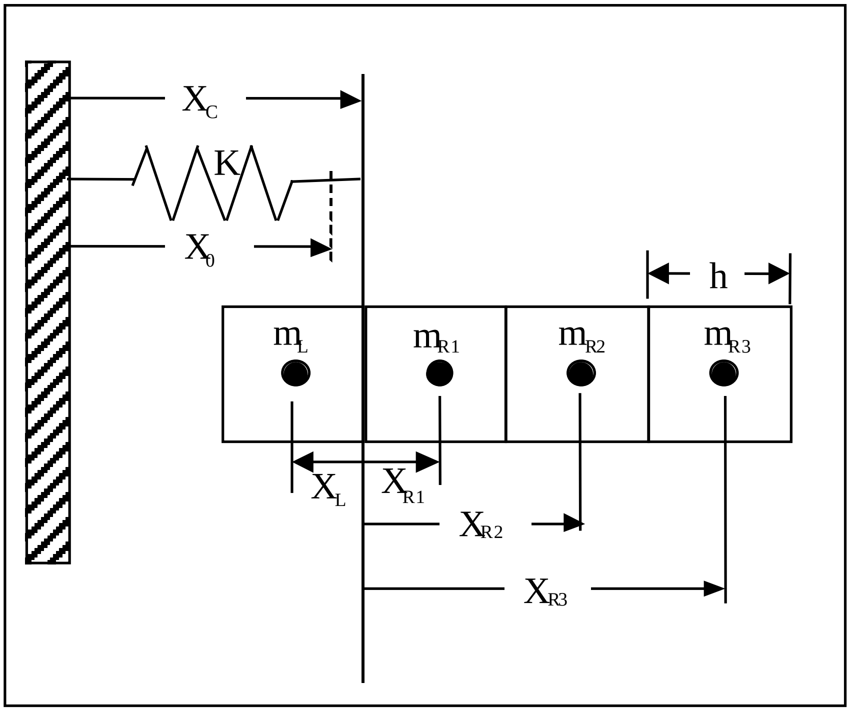

Fig. 1. Lagrangian model used to derive force equation for a series of elements. A support is included explicitly so that Woodward's symmetric and non-symmetric cases may be evaluated.

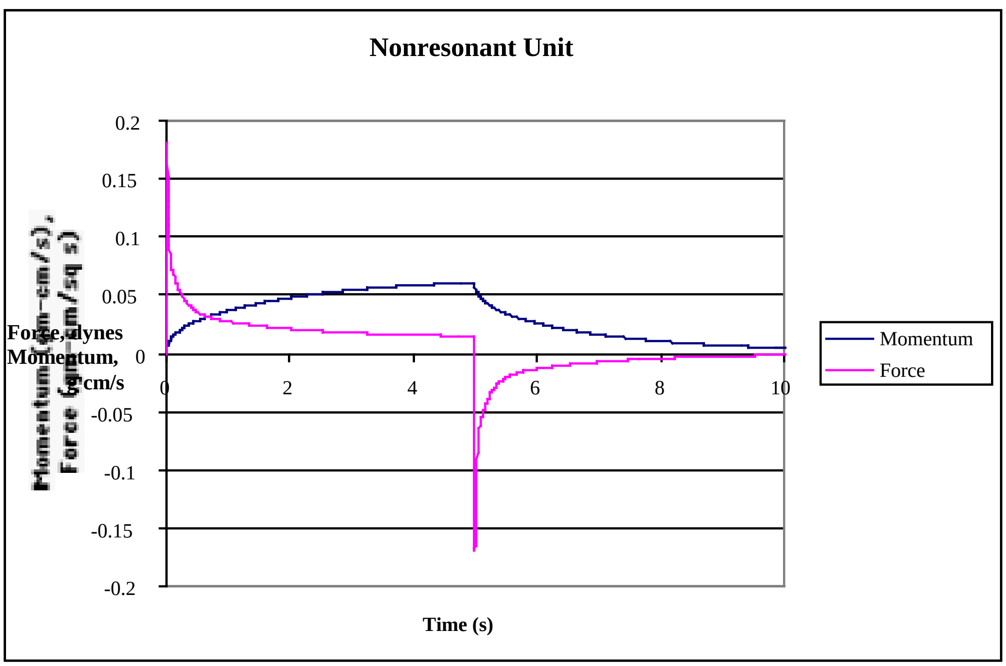

Fig. 2. Thermal model prediction for Woodward experiment.

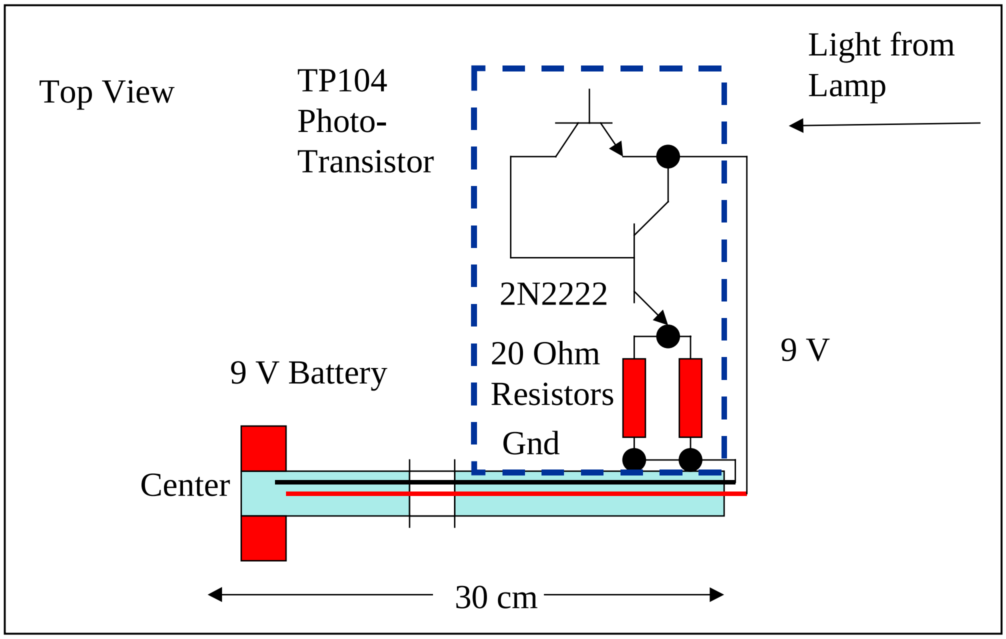

Fig. 3. Schematic of heater and photoelectric switch for demonstration of thermal expansion acceleration.

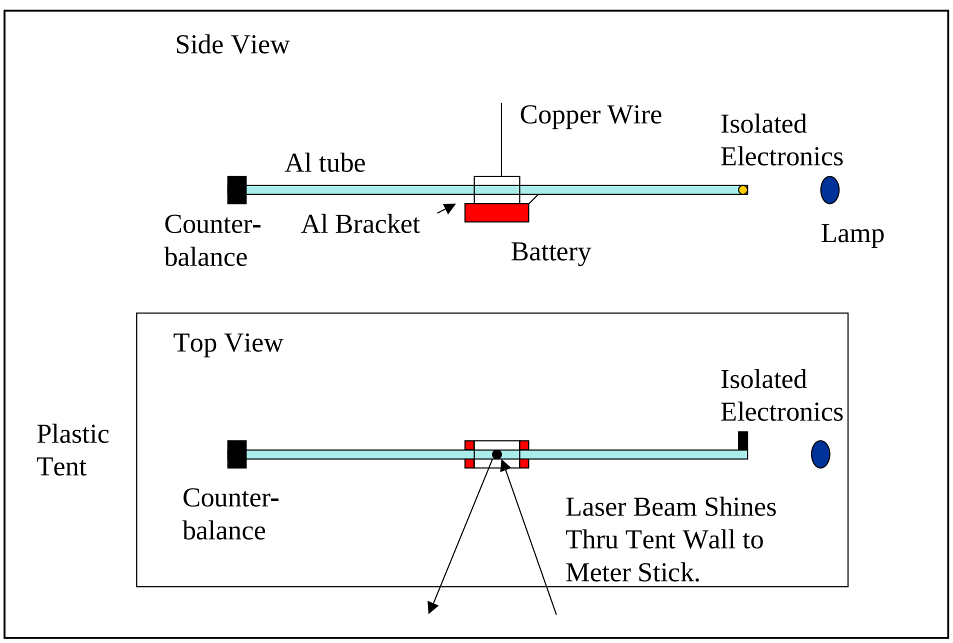

Fig. 4. Experimental layout of the torsional pendulum for demonstrating thermal expansion acceleration.

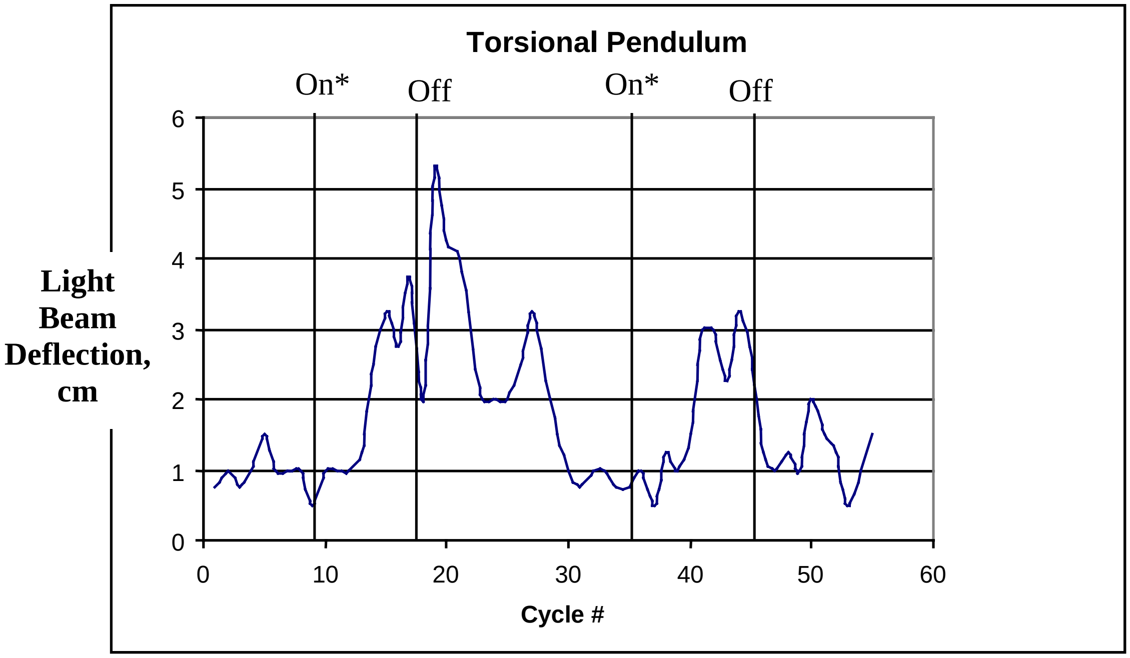

Fig. 5. Movement of torsional pendulum due to thermal expansion alone. *After the pendulum began to move, the heating was synchronized with the period in such a way as to reinforce the motion to the extent possible. Each cycle corresponds to approximately 20 seconds, the pendulum period. The maximum movement of the end of the pendulum was 0.5 cm, corresponding to 5 cm on the chart in this figure. The second peak appears lower because the second cycle starts at a higher equilibrium temperature.