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A PROPOSAL OF A METHOD TO ATTEMPT TO DISCOVER THE POSSIBLE EXISTENCE OF A FINITE VELOCITY OF PROPAGATION OF A GRAVITIC FIELD

by

Richard Blythe

Summary

In substance, a method is proposed by which it seems reasonable that the velocity of propagation (if such exists) of a gravitic effect may possibly be determined. The requirement is that the velocity be not orders of magnitude greater than the velocity of light, at least at the present state of the art of measurement. Basically, the method compares the phase of position of rotating masses with the phase of the motion induced on a gravitically driven mass, taking care to compensate for all system induced phases. Then, having measured a phase or equivalent time difference between driver and driven, the velocity of propagation of the gravitic effect can be found.

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General Discussion

Research on and understanding of the nature of gravity have been seriously hampered by the lack of knowledge of whether or not there exists a finite velocity of propagation of the gravitic effect. Since no known occultation of a gravitic field exists, astronomic methods of determining gravitational velocity have not been possible. In addition, it has not been possible to produce motions of gross matter of sufficiently large amplitude and high frequency, as can be done with electric charges, to produce waves whose velocity of propagation can be directly measured.

It occurred to the writer, however, that by the use of modern techniques for measuring extremely small amplitudes of motion and extremely small time increments, it should be possible to dynamically measure, within reasonably wide limits, whether there is, indeed, a velocity of gravitational propagation. Possible magnitudes of amplitude and time will be discussed later.

Proposed Experiment

The proposed experiment can best be understood by reference to Figure I.

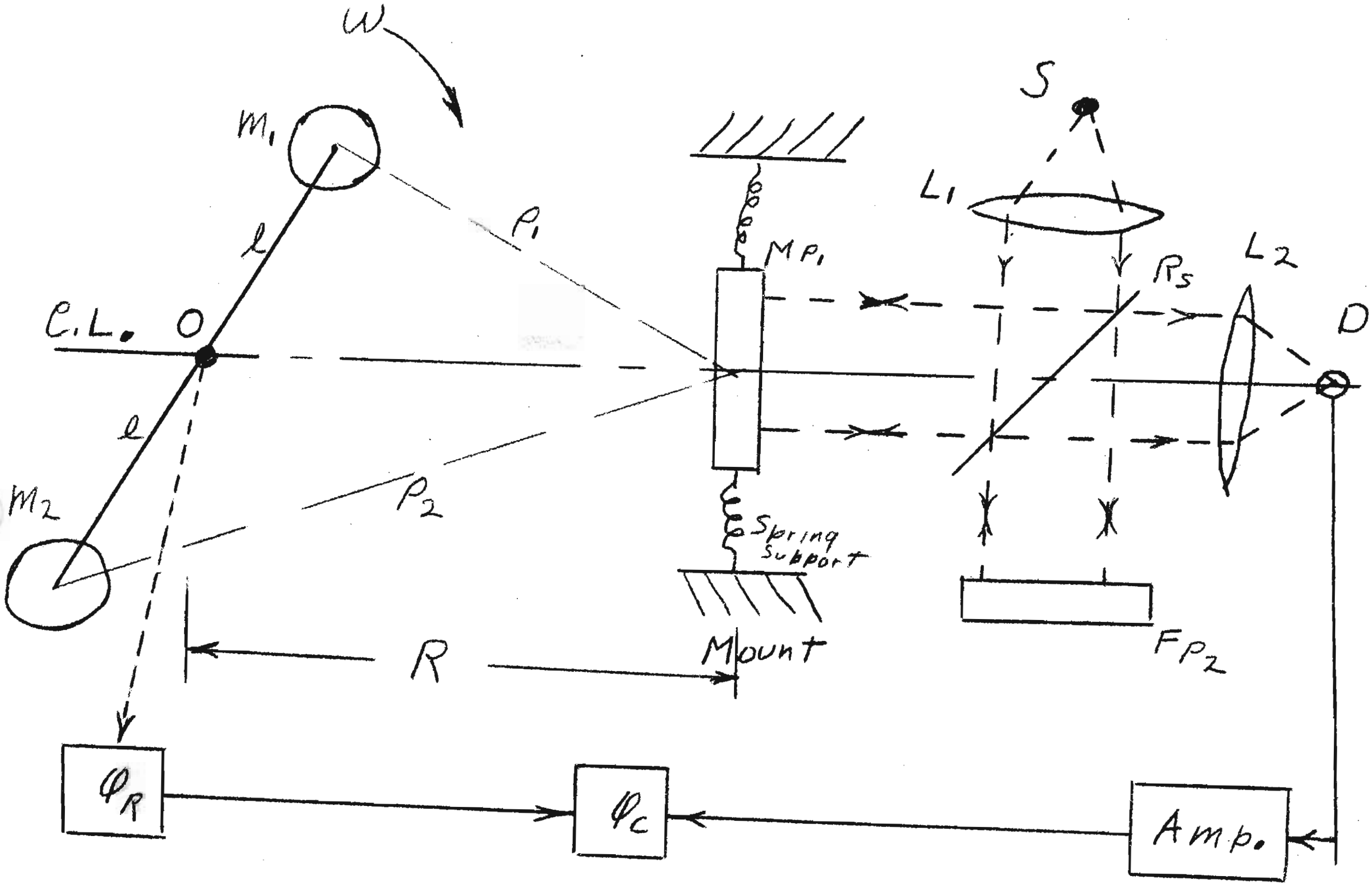

Figure I. Schematic of Proposed Experimental Setup.

Notation:

m_1 , m_2 = masses rotating at angular frequency ω at a radius ℓ from center of rotation O .

R = distance between origin O and movable interferometer plate Mp_1 .

ℓ = distance of center of gravity of masses m from rotational center O .

$\rho_{1,2}$ = instantaneous distance of masses $m_{1,2}$ from intersection of centerline with movable interferometer plate Mp_1 .

S = source of extremely monochromatic optical radiation, such as a mercury 198 lamp.

R_s = 45° plane half silvered mirror.

Fp_2 = fixed plate of interferometer, which consists of Mp_1, R_s, and Fp_2. Here a Michelson type interferometer is considered, but a multiple reflection type may be substituted to get higher resolution and thus greater sensitivity.

L_1 , L_2 = collimating lenses. For additional refinement in measurement, L_2 may be replaced by a dispersing device of high resolution with detector D behind a narrow distant slit.

D = detector of the optical energy passed by the interferometer. For example, a 931 A photomultiplier, calibrated for phase lag, could be used to drive the amplifier.

φ_R = mechanism for detecting the angular position of the rotating masses at any time. This may be any of a number of electrical devices, but probably most accuracy would result from interruption of a number of fiducial light beams by the rotating masses themselves.

Amp. = highly stable amplifier with calibrated delay and phase characteristics to amplify the electrical signals from detector D.

φ_c = phase comparison mechanism to compare the phases of the equal frequency signals from the rotating masses with those from the vibrating interferometer. This may be the sweep on a very high speed oscilloscope. For example, special oscilloscopes have resolved 10 centimeter waves. The time per cycle is then

$$T = \frac{1}{f} = \frac{1}{3 \times 10^{9}/\text{sec}} = 3.3 \times 10^{-10} \text{ sec.}$$

If 1/30 of a wave can be resolved, this would give a least time measurement of about 10^{-11} seconds, or the time for light to travel about 3 m.m.

The operation of the proposed measurement would be somewhat as follows, subject, of course, to the changes that inevitably occur during the process of any precision experiment. The masses m_1 and m_2 are rotated as rapidly as possible about a center O . The masses produce a gravitational attraction upon a movable interferometer plate Mp_1 . This plate should be so mounted that it acts as a very high Q oscillator tuned to the driving frequency of the masses. A later calculation will show that there is a difference in gravitational attraction, and thus a difference in force applied to the plate Mp_1, when the masses lie on the center line C.L., and when the radius ℓ to the masses is perpendicular to C.L.

Thus, the rotation of the masses m_1, m_2 provides a generally sinusoidal type driving force to the tuned mechanical oscillator Mp_1 in its mounting springs. Since the decrement of the oscillating system comprising Mp_1 and its mountings can be found, the phase lag of its response to a driving force can be found. Thus the phase of the driving force at Mp_1 can be found. Any difference between this phase and the phase detected at the rotating masses can be measured, and this measurement then will give a measure of the velocity of propagation of the gravitic force from mass m to the mass of the interferometer plate Mp_1.

The purpose of interferometric detection of the motion of plate Mp_1 is to enable exceedingly small displacements to be measured (Refs. 1, 2). (The author has measured distance variations of the order of 2 Å as a least scale reading on a milliameter). In the calculations, it will be shown that exceedingly small forces will be available, thus requiring very sensitive measure of length variation.

It would, of course, be necessary to isolate the optical system and vibrating parts very completely from the mechanical rotation, yet both must be as near to each other as possible to make the variations in field as large as possible compared to the steady field component. Other geometries may help here.

In addition, many problems of accurate calibration, machining, mounting, etc. would occur in the process of "debugging" any such equipment. As a possibility, air transmitted vibrations could be reduced by placing the optical section of the equipment in a vacuum chamber. Also any mounting resonances of any parts of the optical equipment, except of movable plate Mp_1 itself, must be far from the rotation frequency of the masses.

Calculations

Available Force

For a first approximation, we shall take the forces with the line connecting the masses m_1, m_2 along and perpendicular to the center line. Then the difference force, i.e., the force available to cause vibration of the interferometer, is

$$\delta F = F_{\parallel}^{\parallel} - F_{\perp}^{\perp}$$

$$F_{\perp}^{\perp} = 2\,\frac{Gm_1M_p}{\rho^2} = \frac{2Gm_1M_p}{R^2 + \ell^2}$$

where $m_1 = m_1 = m_2$

$$F_{\parallel}^{\parallel} = \frac{Gm_1M_p}{(R-\ell)^2} + \frac{Gm_1M_p}{(R+\ell)^2}$$

$$\therefore \delta F = Gm_1M_p \cdot \frac{4\ell^2}{(R+\ell)^2(R-\ell)^2}$$

Putting in numbers,

$$G = 6.66 \times 10^{-8}\ \frac{cm^3}{gm\ sec^2}$$

Let $M_1 = 10$ gm. , M_p 10 gm.

$= 10$ cm.

$R = 20$ cm.

Then

$$F = 6.66 \times 10^{-8} \frac{\text{cm}^3}{\text{gm sec}^2} \times 100 \text{ gm}^2 \cdot \frac{4 \times 100 \text{ cm}^2}{(30 \text{ cm})^2 (10 \text{ cm})^2}$$

$$\underline{F = 2.96 \times 10^{-8} \text{ dynes}}$$

Time

$$t = \frac{s}{v} = \frac{10 \text{ cm}}{3 \times 10^{10} \text{cm/sec}}$$ (if a velocity = that of light be assumed)

$$\underline{t = 3.33 \times 10^{-10} \text{ sec}}$$

Conclusions

Thus it can be seen that although such an experiment would require great care, it does not appear to be too close to marginal in the time measurement portion. And as for measuring the force, this was done by Cavendish with large fixed masses. It seems reasonable that sensitive motion detectors and high Q mechanical resonance can permit an even greater reasonableness in the determination of the gravitic effect now than was possible at the time Cavendish did his work.

It would, of course, be necessary to integrate the force over a full cycle to get the true force, in its proper phase on the moving interference plate.

The writer, then, submits the foregoing as the basic method for the possibility of determining the velocity of gravitic propagation. It is to be noted that it is generally possible, during the actual course of a precision experiment, to come upon methods of improving the sensitivity or accuracy of the experiment over that originally proposed.

References

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2. "Multiple Beam Interferometry of Surfaces and Films", S. Tolansky, Oxford at the Clarendon Press, 1949.