#5

Mass Experiment

Optic Pick Off and Counter

2.3

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The accuracy with which the point of zero crossing is determined is fundamental to the accuracy of the entire system. Although the ~~frequency~~ ~~fundamental~~ basic measurement is time it is dependent upon the distance resolution of the zero crossing detector and velocity of the mass at zero crossing as follows:

D=VT

$$\text{Time Resolution} = \frac{\text{Velocity at zero displacement}}{\text{Distance Resolution}}$$

D

Taking a nominal frequency

of 1 c.p.s. $\bar{c}$ a peak displacement of 1" will give a peak velocity of $\frac{dX}{dt} = X\, 2\pi \cos \theta\, \omega$

$= 1 \cdot 2 \cdot 3.14 \cdot 1$

$= 6.28 \approx 6$ "/sec.

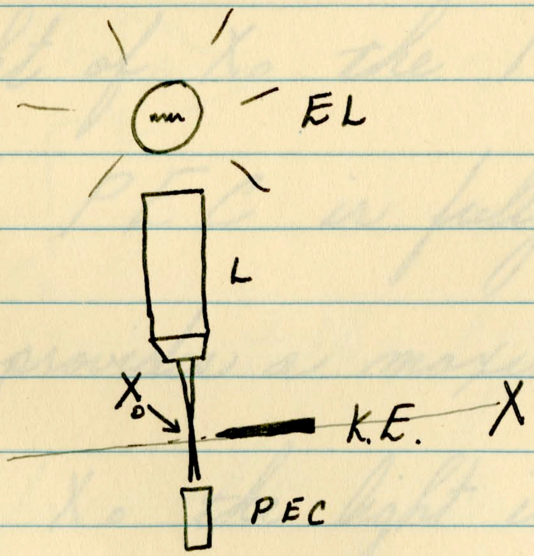
For a time resolution of 5 m Sec - the distance resolution must then be.

Dist = Vel. X Time

$= 6$ "/sec X .5 X 10^{-3} sec

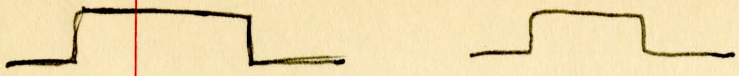
$= 3. \times 10^{-3}$ "

~~As~~ ~~fine~~ narrow beam of light interrupted by a ~~kn~~ knife edge has been ~~to~~ chosen for the ~~pick off~~ ~~o~~ zero crossing detection method. This is shown digrammatically in Fig ———



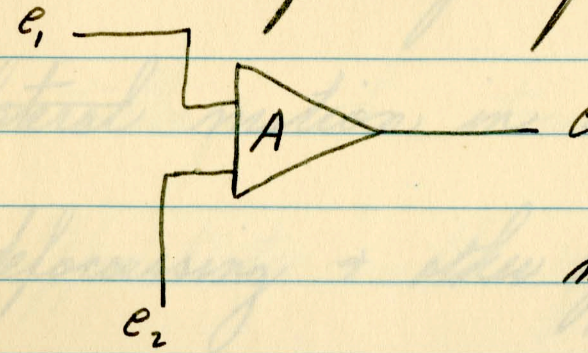
An incandescant bulb E.L. illuminates a slit in the optic tube assembly L which is then focussed as a vertical ribbon of light .001" wide at X_o.

A knife edge K.E. is attached to the oscillating mass and moves along the axis X. At all points right of X_o the photo electric cell PEC is fully illuminated and it provides a maximum light output. At X_o the light is cut off in .001" and remains off when the mass is left of this point.



The system has then an inherent accuracy of .001". This is further enhanced by the electronic circuitry as follows.

The voltage e_1 ~~sepsep~~ is the output of the photocell while ~~it~~



e_2 is fixed at 1/2 the max. voltage of e_1.

A is a stable high gain differential amplifier that will provide an output of ~20 V for a 1 mV. difference between e_1 and e_2.

The slope of the PEC output is several volts / 10^{-3} inches as the ~~light~~ ~~mass~~ knife crosses the light beam. This results in a theoretical resolution of micro-inches. ~~Since there~~ Practically there is some ~~lateral~~ motion in other planes c̄ defocussing + other effects. A measured series of curves c̄ controlled errors introduced are given in fig. and show that a resolution of 10^{-4}

inches may be reasonably expected. This is more than 6x orders of magnitude greater than the required resolution.

2.4 The output of the zero crossing detector must then be converted to signals controlling the timer. A simple differentiator will generate a pulse each time zero is ~~gross~~ crossed. Since zero is crossed 2 x each cycle + from alternatenately opposite directions, only ~~those~~ pulses of a single polarity will be passed to the counter which will then count every other complete cycle.

This arrangement will be used only in the testing phases for investigative purposes. ~~It~~ The ~~actual~~ arrangement ~~used~~ which will be used during mass measurement will consist of ~~counting a number~~ ~~of~~ timing a fixed number of cycles. Within the limits imposed the greater the number of ~~counts~~ cycles counted the greater the accuracy, assuming random errors. The time accumulated will be a direct function of the number of counts while the random errors will accumulate as the square root of the signal. The signal to ~~noise~~ error ratio ~~(or signal to error)~~ will then increase as the square root of the number of cycles taken. For example if random errors exited in the time measurement such that

the individual ~~time~~ cycle resolution

were only 1 m sec. by

counting over 4 cycles this could be

reduced to the required ½ m sec.

resolution. The timer used in

the experiment will an ordinary

H.P. $\bar{c}$ a max. time resolution of

~~1~~ 10^{-6} sec. Overall system time

resolution should be $\leq 5 \times 10^{-5}$ sec.

2.5 A system for ~~zero disp~~ initial displacement should present no great problem. The magnitude of initial displacement will be a compromise among several factors including distance resolution available, working distance of springs, space available and bearing size. A nominal distance of 1" total max. displacement has been chosen here. Since the bearing used will ~~be a~~ allow only rectilinear motion ~~only~~ some form of simple stop at ~.5" max. deflection c̄ a positive

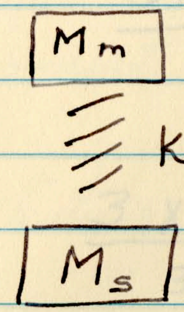
manual
release is needed. ~~A~~ ~~This will be~~

~~manual~~ -

Essentially
2.6 Frictionless support is limited to a few choices here of which the most obvious is an air bearing. A quick and dirty approximation of such a bearing is a block of dry ice supporting a smooth surface. ~~There~~ Such makeshift is not justified here and a ~~so~~ simple linear bearing c̄ lateral +

bottom surfaces will be used - Such a bearing ~~to~~ may for our purposes be considered frictionless - An air supply of a few P.S.I. & low volume will be required for operation -

Other considerations: The In flight mass of the space ship ~~is~~ ~~finite as compared to earth~~ finite cannot be neglected as may the earths mass in the ground situation - This limited ~~to~~ mass results in some ~~or~~ a small amplitude of oscillation which will shift the frequency of oscillation as follows.



M_m = Mass to be measured
M_s = Mass of Ship
K = Spring Constant

$$F = \frac{1}{2\pi}\sqrt{\frac{K(M_m + M_s)}{M_m M_s}}$$

This has the ~~practical~~ effect of an ~~equivalent~~ apparent mass, $M_E = \dfrac{M_m M_s}{M_m + M_s}$.

Using values of

$$M_m = \frac{150}{g} \text{ pounds}$$

$$M_s = \frac{30{,}000}{g} \text{ pounds}$$

$$\frac{3 \times 10^4 \times 1.5 \times 10^2}{3.0150 \times 10^4} = \frac{4.5 \times 10^6}{3.015 \times 10^4}$$

$$= 149.254 \text{ \#}$$

In absolute terms the weight would be "short" by ~.75 pounds.

This error ~~should~~ will remain essentially constant

c̄ large variations in the ships mass

and may be calculated or calibrated by

a single on-station measurement

c̄ a known mass.

The fist phase of the demonstration will consist of assembling the components and testing the validity of the derived calculations including the resolution, accuracy and stability of the proposed instrument using fixed masses. A 2° phase will consist of construction of a man~~ned~~ carrying version and development and test of the features peculiar to this application.

If successful a 3rd phase should be considered which consists of flying the two devices c̄ cylindrical bearings to determine their behavior under weightlessness and to gain operational experience c̄ this principal.

Information and guidance should be during ~~at~~ all phases to the contractor provided, as soon as valid ~~seen~~ results are obtained.