Mass -

Exp -
#2

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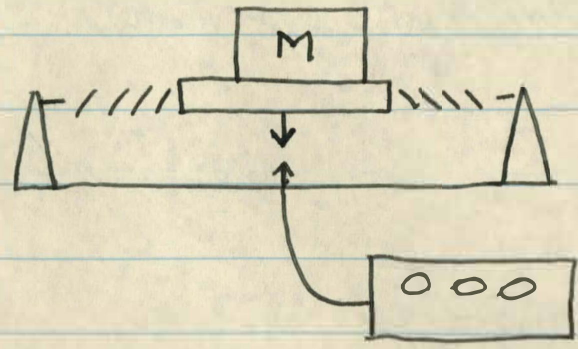
Under conditions of space the physical requirements ~~for the experiment are met by this system.~~

The practical arrangement of the measuring device under conditions of weightlessness is relatively simple.

The essentials components are a structure ~~for~~ to hold the mass to be weighed, ~~a the mechanism for restoring forces~~ spring assembly ~~(springs)~~, a device to determine precisely when the oscillating mass crosses zero point of


M

zero displacement, ~~and possibly~~

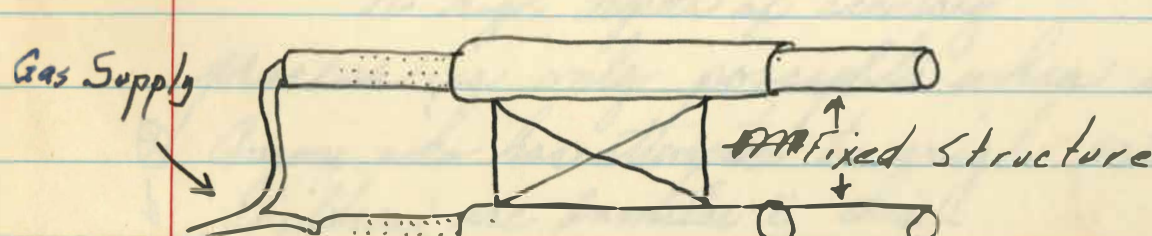
a counter for determining time periods calibrated in terms of mass and some means of ~~xx~~ providing a displacement along a given axis. Fig.- The demonstration device on earth is complicated by the need for a frictionless support.

Considerations in detemining mass of the human body:

The body is composed of a number of ~~gr~~ flexibly connected segments

~~that~~ such that determination of the center of mass is only of academic interest and could be expected to remain constant for only brief periods. ~~Any arrangement which The first~~. Almost as a corollary of this it becomes necessary to restrict the motion to the minimum degrees of freedom, which is rectilinear motion in one ~~pl~~ axis. Once this is done it is immaterial where forces and measurements are made so long as they are ~~in the~~ parallel to the plane of motion. The practical details of this will be discussed further under the proposed demonstration.

One of the simpler ways of restraining motion to a single axis c̄ minimum friction is the use of air bearings. In this case the minimum required would probably be two cylindrical units as shown in—



The only ~~shifts~~ movements that would cause ~~in~~ an error in measurement would then be the components along the axis of oscillation and the error would be present only during the period of movement. ~~[illegible]~~

~~[illegible] The same case exists in~~

~~[illegible]~~ This case is then the same as exists with an ordinary weighing scale on earth. The weighing process to high degrees of accuracy is only possible when one is

(*) Anyone who has attempted to weigh active children are familiar c̄ this.

standing or sitting quietly.* ~~but then~~

As an aid in simulating quiet standing ~~this~~, and

also to provide ~~aid~~ rigidity in an

oscillating system, some means should

be provided for rigid connection of the

subject to the ~~h~~ spring system as

well as for tensing the large muscles

of the body to increase rigidity.- This may be done

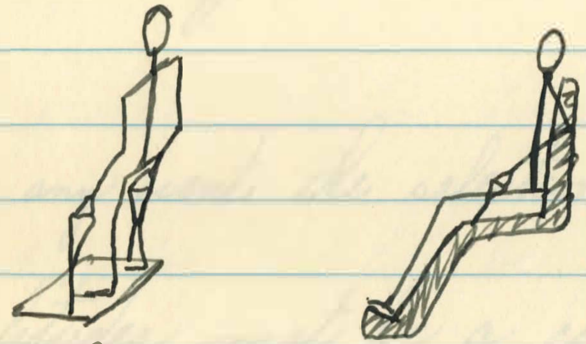
in the case of standing by simple

hand holds connecting to a foot plate.-

See F- ——

In the case of sitting both

a foot board correctly located to allow
pressure against the back and also
hand holds as in Fig ——— —



should accomplish this

The internal viscera are quite free to move but from studies done it appears that below certain critical accelerations (1) the viscosity + resistance of these organs are sufficient to cause the body to move as a whole. ~~The validity of acceleration forces not to my knowledge been established of certainty.~~

In any event the selection of frequency and amplitudes must be a compromise between

A. ~~shortest~~ short ~~possible~~ measurement time
(this may later be shown to be not so important a consideration)

B. Smallest displacement consistent c̄ accurate ~~amplitude determinations~~ position resolution

~~At amplitudes of 2+ in. peak to peak and~~

C- lowest frequency ~~consistent~~ c both possible as a function of A-

If the ~~max. G~~ min. G required to produce relative body motion were known this would be ~~possible to~~ set the limits on freq-amplitude. ~~In the~~

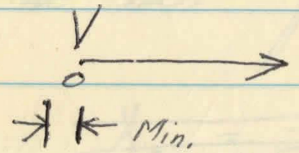
(upper)
11

Without this knowlege one must make estimates and be prepared to alter these estimates in view of experimental results-

~~A frequency of 1 C.P.S. at~~

The displacement however has a direct bearing on accuracy since it is the resolution of distance which ultimately determines the time resolution as follows. $\Delta T = \dfrac{\text{Min. dist. resolution}}{\text{Velocity at time of measurement}}$

$\frac{10^{-3}}{6}$



Thus at the point of crossing zero displacement, the only ~~logical~~ point independent of amplitude changes, the relationship is as follows.

$$\Delta T = \frac{\text{Dist. Resolution}}{X_0 \, 2\pi f \cos \omega t}$$

~~Velocity~~

& $\omega t = 0$ for $= \dfrac{\text{Dist. Resolution}}{X_0 \cdot 2\pi f}$

For a min. time resolution

of $\frac{1}{2}\,10^{-7}$ ms. (~~1/3 that required~~) and a

distance resolution of 10^{-3} " (.01")

~~the~~ product $X_0 \, 2\pi f = 1$

or ~~and~~ the frequency displacement relationship

is $\cancel{X_0 = \frac{1}{2}}$ $F = \frac{1}{2\pi X_0}$.

If an amplitude of $\frac{1}{2}$" is allowed

the min. ~~max.~~ freq. allowed is $F = \frac{1}{2\pi \frac{1}{2}} \approx \frac{1}{\pi}$ cps.

~~Acceleration (peak).~~

~~Peak acceleration occurs at 1/2~~

Acceleration is given by

$$\frac{d^2x}{dt^2} = -X_0 (2\pi f)^2 \sin \omega t$$

and peak acceleration occurs when

$\sin \omega t = \pm 1$. In terms of G units

$$\text{Acceleration}_{(max)} = -X_0 (2\pi f)^2 \cdot .0026 \cdot \pm 1$$

X_0 = initial displ. (ins)

f = (cycles / sec)

~~Acc = G or~~

For $X_0 = 1''$ and $G_{max} = 10^{-2}$

$$\sqrt{\frac{10^{-2}}{2.6 \times 10^{-3}}} = 2\pi f$$

$$\text{and } f = \frac{1}{2\pi}\sqrt{\frac{1}{2.6} \times 10}$$

$$\approx \frac{1}{2\pi}\sqrt{38.} \approx \frac{1}{6}\sqrt{}$$

$$\approx 1 \text{ cps}$$

CK

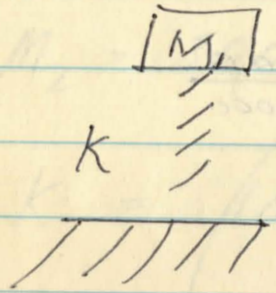
8
.308
26)1.00
78
~~300~~
220
208

$\frac{1}{6}$

From the foregoing it seems reasonable to operate $\bar{c}$ a frequency in the region of $\frac{1}{3}$-1 CPS and displacements of .5-1."

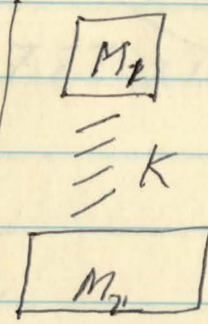
~~Many other factors will be present but most are not amenable to mathem~~

Another ~~[illegible]~~ factor is ~~the relationship of a fact~~ that the space ship is a finite mass ~~is present in the space ship - The equation for natural frequency under this~~ and ~~the space ship~~ will undergo small displacements itself which will alter the frequency as follows -



$f = \frac{1}{2\pi}\sqrt{\frac{K}{M}}$

Rigid attachment



$F = \frac{1}{2\pi}\sqrt{K\left(\frac{m_1+m_2}{m_1 \times m_2}\right)}$

Thus for a normalized freq. (any (CPS.) the change will be $\bar{c}$ $m_1 = 200^{\#}$

$m_2 = 30{,}000^{\#}$

4

10^{-1}

10

10^4

10

10^{-2}

$$\sqrt{\frac{2\times10^2+3\times10^4}{2\times10^2\times3\times10^4}} = \sqrt{\frac{3.02\times10^4}{6\times10^6}}$$

$$\approx\sqrt{\frac{1}{2}\times10^{-2}} \approx \sqrt{50}\cdot\sqrt{10^{-4}}$$

$$\approx 7\cdot10^{-2}$$

$$\approx 7\%$$

Equiv. mass –

200

30,000

$$\frac{200 \times 30,000}{200. + 30,000}$$

$$\frac{6 \times 10^6}{3.002 \times 10^4} =$$

```
          199.866
3.002 ) 6.000
        3002
        29980
        27018
        29620
        27018
        26020
        24016
        20040
        18012
        20280
```

Taking a typical case

$$M_1 = 200^{\#}/g = \frac{200}{386} \cdot \frac{\# \, sec^2}{in} = .518$$

$$M_2 = 30,000^{\#}/g = \frac{300 \times 10^2}{386} = .777 \times 10^2$$

$$K = 10^{\#}/in$$

$$F_1 = \frac{1}{2\pi}\sqrt{\frac{10}{.518}} = \frac{1}{2\pi}\sqrt{1.93} = \frac{1.39}{6.28}$$

$$F_2 = \frac{1}{2\pi}\sqrt{K \frac{77.2 + .518}{77.2 \times .518}} = \sqrt{10 \cdot \frac{77.7}{400.}}$$

$$= \sqrt{10 \cdot \cancel{.1594}\ 1.94} = 1.363$$

$$\begin{array}{r} 32.2 \\ 12 \\ \hline 644 \\ 322 \\ \hline 386.4 \end{array}$$

$$\begin{array}{r} 32.\ '/sec \\ 12 \\ \hline 64 \\ 32 \\ \hline 384\ ''/sec'' \end{array}$$

The measurement will then yield a slightly higher frequency which will be ~~related to the true~~ result in ~~an apparently a decreased~~ the mass being read short i.e. less than actual mass.

For example:

$$\text{Mass (measured)} = \frac{\text{Mass}(\text{True}) \cdot \text{Mass}(\text{ship})}{\text{Mass}(\text{True}) + \text{Mass}(\text{ship})}$$

$\text{Mass}(\text{True}) = 200^{\#}/g$

$\text{Mass}(\text{ship}) = 30{,}000^{\#}/g$

$$= \frac{200 \times 30{,}000}{200 + 30{,}000}$$

$$= \frac{6 \times 10^{6}}{3.002 \times 10^{4}}$$

$$= 199.866$$

or the measurement will be in
error by ≈ $-.13^{\#}$ in $200^{\#}$.
Since the ships mass of remains essentially
constant, this error will also remain
constant. It is to be assumed that
the mass system will be calibrated in
absolute terms when on station.
Another area of possible concern
are the characteristics of the springs.
If one purchases ~~of~~ precision
spring scale units, this should

cease to be a problem - Some
characteristics of an ~~premium~~
150 - ~~Alloy~~ Elastic ® Alloy spring are given *
Thermal coeff. of modulus - -20 to +15 $\times 10^{-6}/°F$
(this coeff. is apparently variable to account for
other temp. errors in ~~spring~~ scale mechanisms
& may theoretically be made zero)

Hysteresis error - $\leq .05\%$ of deflection
(this will be equivalent to a damping resistance)
Creep error - $\leq .02\%$ of deflection / 5 min
~~(not applicable in oscillat~~
If the mechanism is properly unloaded
when not in use the characteristics
are beyond our required accuracy & stability -
* taken from John Chatillon & Sons
bulletin 1-SD-1

A number of 2° or 3° order effects may be present but ~~do~~ do not lend themselves to computation but may be determined by measurement.

Finally there is the problem of a realistic demonstration under gravity. ~~After discov~~

The Lockheed demonstration was, as it has been misunderstood, unfortunate. ~~Mr. Riley~~ It was only intended to indicate methods & ~~som~~ feasibility ~~of~~ using very crude

techniques. The remarkable point
is that accuracies were as high as
they were. Mr. Riley (proj. engineer)
~~cont.~~ has no reservations about meeting
the ⊕ .01 pound accuracies c̄ equipment
designed for this accuracy.

However the problem is now
to make a convincing demonstration
on earth. The earth demonstration
will be more difficult than under free
fall since ~~the gravitational~~ some

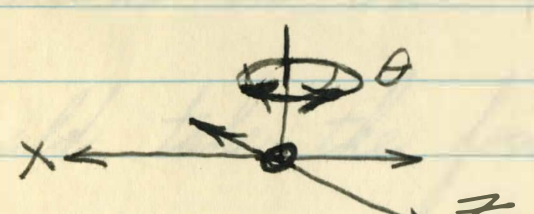
*

The bearing is a 12" circular unit constructed by Astro Physics Labs, Huntsville for a ballistocardiograph. According to its ~~designers &~~ fabricators it is capable of ~~[illegible]~~ ±.75" of motion c̄ ~~resistance~~ a resistive forces of ~~a few~~ 1-2 dynes. It has a circulary ground face on a radius of 20 ft. which will provide a restoring force toward center which will be a function of angular displacement and weight. This restoring force will be analogous to an additional spring force but will not be considered here since it should remain a system constant.

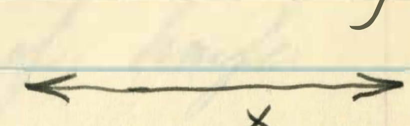
must be present
form of bearing ^ to offset gravity
ē introducing unwanted frictional effects.
Thus ~~&~~ in addition to the items listed
on page — must be added this
bearing as an essential component
of the system on earth. Of all
available bearings an air bearing
is most nearly the ideal ē ~~for~~
negligible friction coefficients. ~~You~~
Since such a bearing is
available the demonstration is built
around this unit for expediency. *

~~The air bearing itself~~

Unfortunately this bearing is a circular unit which, ~~5 additional restraints will allow~~ translatory ~~motion in an additional axis and rotatory motion~~ will allow rectilinear motion in two axes and rotatory motion about another axis. These motions have been labeled in Fig —



Allowed by air bearing



desired

labelled. Two of the degrees of freedom of motion, in the Y axis & θ rotational plane are undesired. The bearing is being used to simply support the weight and because of its availability. It may be necessary to add restraints to contain the motion in one axis. These could take the form of knife edged bearing wheels, dry ice bearing or ~~even~~ if necessary an additional