Mass Measurement Demonstration

Constraints -

Negligible additional equipment.

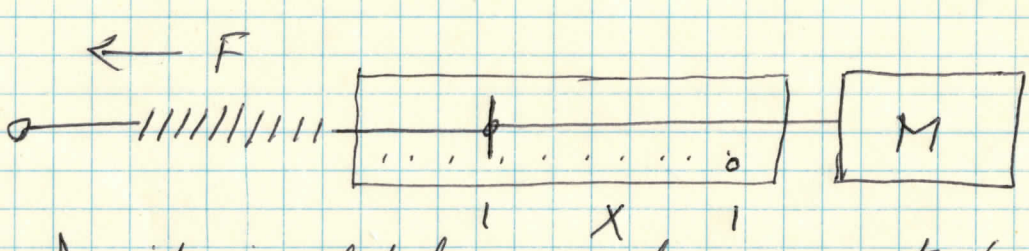
Approx 2-3 ft. of travel -

Low velocities -

Methods:

$$F_{orce} = Mass \times \frac{d^2X}{dt^2} \qquad X = V_i t + \frac{at^2}{2}$$

Only possible one is measurement of movement of mass over known distance when moved by a known or calibrated force - The most practical force would probably be a comparison in which a known mass was accelerated.



In its simplest form a force generator (spring) accelerates the mass which has attached a calibrated distance scale. Although this seems simplicity itself there are many sources of error - To be meaningful these sources of error must be realistically examined - As a beginning take the simplest case where ~~the~~ time is started when the spring is released from ~~zero pos~~ initial position & zero velocity and

$$X = \frac{aT^2}{2} \quad \text{or} \quad 2X = a\,T^2 \;\&\; \text{substituting}$$

$$a = \frac{F}{M} \qquad 2X = \frac{F}{M} T^2 \qquad T = \sqrt{\frac{2XM}{F}}$$

Chain differentiation gives $\frac{2\Delta X}{X} = \frac{2\Delta T}{T} = \frac{2\Delta F}{F} = \frac{2\Delta M}{M}$

This says that errors in measurement of either T or X will cause a double error in determination of M while errors in F will be reflected directly.

Also to be considered are practical limits on on other quantities such as maximum velocities & forces - ~~For~~ For example ~~if one limited max velocity~~ some reasonable limits might be a travel of one foot with a force of say four pounds (we for the moment will ~~ignore~~ assume a long spring and ignore variation of force over this distance) with a mass of $\frac{170}{32.2} = 5.3$ slugs

which gives a time of $\sqrt{\frac{2 \times 1 \times 5.3}{4}} = \sqrt{\frac{5.3}{2}} = \sqrt{2.65}$ 1.8 secs.

$$\begin{array}{r} 1 \\ 20\overline{)165} \end{array}$$

and an a velocity of - $V = at$

$$= \frac{4}{5.3} \times 1.8 \simeq 1.4 \text{ ft sec.}$$ If 1% max. error is allowed in ~~time~~ mass determination this means that this is the max error that can be allowed in any other determination or a cumulative total. Looking first at

timing by a photographed stop watch. This would require 1.8×10^{-2} or 18 msec. resolution or ~.02 sec. which is simply not practical. Jf