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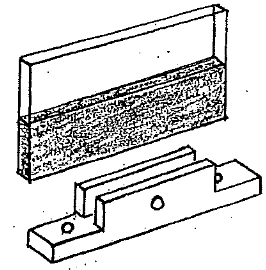
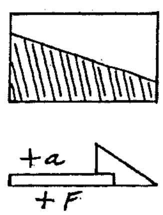


Acceleration and the HPP liquid accelerometer - Acceleration and vectors have always been difficult concepts to master for the average physics student. Combining the two concepts, i.e., that acceleration is a vector quantity with both magnitude and direction seems to add to the difficulty. To alleviate some of the difficulty, Harvard Project Physics developed the liquid accelerometer, a thin, vertical, clear plastic container, half filled with ethylene glycol containing red or blue food dye. It was a manufactured item. The glycol's inertia reflected the forces and accelerations involved in the motion being observed. A special wooden holder for the container was designed; a replica can be found, with details, in the topic "The rotating platform" part (e).

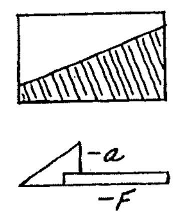
The accelerometer's usefulness continues. It "illustrates" acceleration visually very well, both its direction and relative magnitude. To further aid the visualization and understanding of acceleration and the unbalanced force causing it while using the accelerometer, I have designed special wooden "arrows" that will be explained in detail at the end of this paper. The "half-arrowhead" design closely resembles the fluid incline of the accelerometer and thus, the direction of the acceleration and corresponding unbalanced force. The steeper the fluid incline, of course, the greater the magnitude of the acceleration and the unbalanced force.

How to interpret what the accelerometer is displaying.

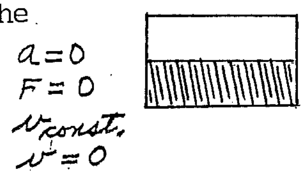
An object is speeding up while moving to the right.



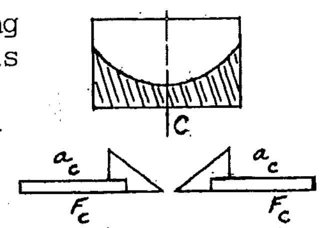
An object is slowing down while moving to the right.



An object is moving to the right at a constant velocity or the object has come to rest. (no arrow)

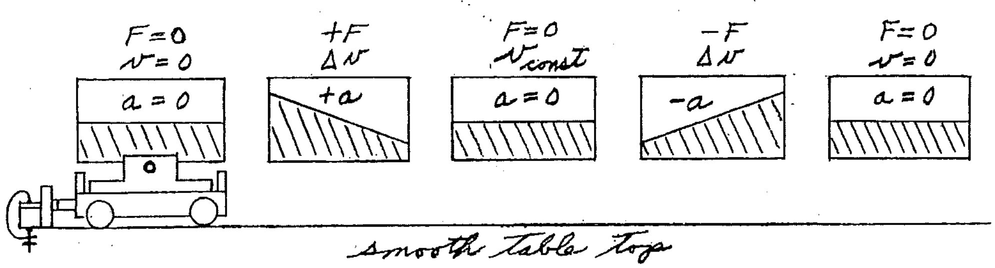


An object is rotating about a center. a_c is always toward the center. The parabola results from $a_c = v^2/r$.



What follows are some examples where the accelerometer is most useful in "showing" accelerations and unbalanced forces as vectors, especially their magnitudes and directions.

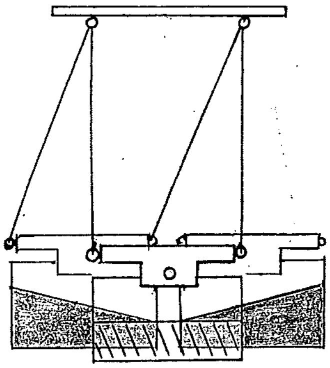
(a) Using a dynamics cart. Let it push from a "wall", coast, and stop. Very visual.



(b) Using a pendulum. To "observe" the constantly changing acceleration (forces, etc.) in a swinging, simple pendulum, the container must be kept "level" throughout the swing. Therefore, the apparatus must be set up as a "ballistic" pendulum with two threads and pivot points. Simply add screw eyes to the ends of the wooden holder and invert the container in the holder. Further, construct a simple ½" dia. dowel about 15" long with 2 screw eyes as illustrated. Tie paper clips on the ends of equal length threads (~25" or 64 cm). Bend the clips, if necessary, to get exact lengths and create "hooks" for easy manipulation.

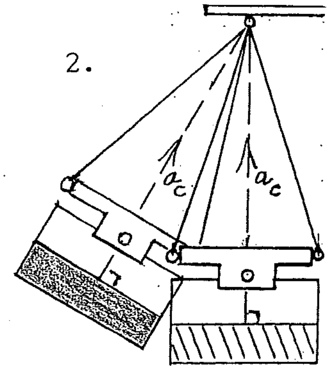
To demonstrate, pull the holder back a reasonable amount (not huge!) and let it go. The fluid will "settle" into a smooth transition pattern, actually a thing of beauty, displaying everything that is going on in the oscillation of a simple pendulum (1.).

1.

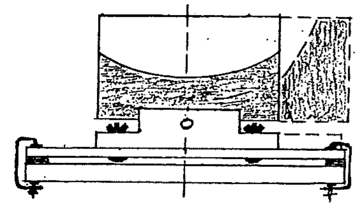


Now rearrange the two threads by putting their tops together in just one screw eye. Swing the apparatus again. A different result! This time the container and the fluid are swinging in unison, thus, no "slope" (incline) is evident. The acceleration present is centripetal acceleration or toward the center of rotation, perpendicular to the apparatus (2.).

2.



(c) On a rotating platform. See "The rotating platform" part (e) for details. Attach (clamp?) the apparatus to a smoothly rotating platform or turntable to view beautiful parabolic curves that correspond to the equation, $a_c = v^2/r$, a quadratic relationship. The display is a <u>natural</u> phenomenon. The apparatus may be fastened to a slotted piece of plywood to vary <u>r</u> and thus, produce different parabolic shapes; also, vary <u>v</u> for additional shapes. All examples are beautiful to see!



The wooden "arrows" - can be hand held, placed on a table top or any flat object, and used in combinations much as in vector diagrams. All of the "arrows" show direction; different sizes show different magnitudes. Of course, the "arrows" can also represent other vector quantities, such as velocity, force (weight), momentum, displacement, etc. They can be painted different colors (bright?) to represent different quantities.

Construction of the wooden "arrows" - All use 3/4" thick pine for the stick and 1/8" thick masonite for the "half-arrowhead". The sticks can be notched (slotted) to hold the masonite or the masonite can be attached to the side of the stick. Wood glue and four brads fasten the two pieces together; countersink the brads slightly. The dimensions for four different sizes are provided. Cardboard may be substituted for the masonite but isn't as durable.