10-100 Accelerometer

Purpose:
To measure acceleration by viewing a liquid surface against a centimeter grid.

Required Accessories:
Dynamics Cart, Inclined Plane, Turntable, suitable tape for temporary attachment.

Preparation:
Begin by unscrewing the two screws located on the side of the plastic chamber near its top. Remove plastic chamber from base. The accelerometer can be filled by holding it under a slowly streaming faucet or by pipetting water into one of the holes. Fill the chamber half full so that the water level comes up to the zero line on the grid when held upright and at rest. Coloring the water slightly with food coloring will make the accelerometer easier to see when in motion. Screw the two screws back into place and remount the plastic chamber in the slotted wooden base.

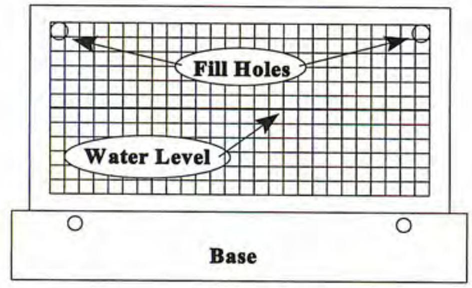


Figure 2
The Accelerometer.

Procedure:
The liquid surface accelerometer is a hollow, flat, plastic container, partially filled with colored liquid (try a little food coloring in water). One face of the accelerometer is marked with a centimeter grid to accurately record the position of the liquid surface.When the accelerometer is not being accelerated, the liquid surface is horizontal. But when it is accelerated toward the right with a constant acceleration "a" thenthe surface has a measurable slope. The liquid level rises a distance "h" at one end of the accelerometer and drops by an equal amount at the other end. The greater the acceleration, the steeper the slope of the water's surface. This allows us to measure the magnitude of the uniform acceleration.

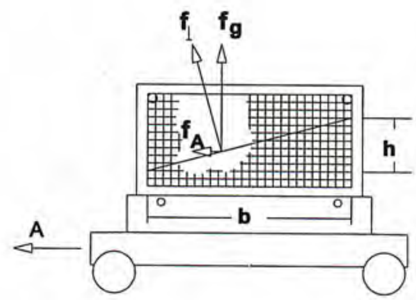


Figure 3
Force diagram for a horizontally accelerated object.

There is a simple relation that expresses the acceleration in terms of the slope of the water's surface. This is:

Slope = h/b = a/g

Where:
h is the difference in height from one end of the slope to the other.
b is the length of the accelerometer grid
g is the acceleration due to gravity

To find acceleration, multiply the slope (h/b) by g.

For this experiment the cart with the accelerometer mounted on it is accelerated along a bench, perhaps by a weight on a cord running over a pulley at the edge of a bench. The cord's pull accelerates the whole apparatus and the liquid's surface is seen to slope evenly. If the acceleration is toward the left, for example, the liquid tilts up on the right as it resists the acceleration according to the law of inertia. Again the forces on each drop are balanced, and the surface is perpendicular to the direction of the balanced forces for the same reasons as before.

The figure 3 shows the sloping liquid surface with arrow $f_\perp$ representing the external force which acts on the surface drop. The arrow f_G represents the external force necessary to balance the drop's weight, and f_A the external horizontal force which keeps the drop accelerating along with the liquid as a whole. The equation f_A/f_G = h/b comes from the similar triangles. Where b is the length inside the tank and h is the difference in depth between the ends. Finally, the equation translates to acceleration equals the h/b fraction of the acceleration of gravity.

Acceleration on an Incline:

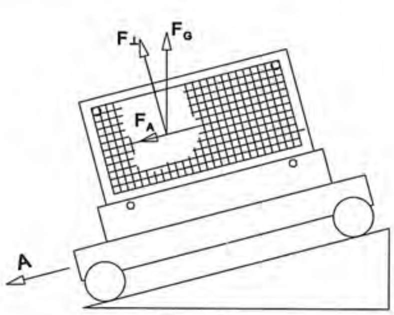


Figure 4
Force diagram for accelerometer on an incline.

Acceleration on an Incline:
If an accelerometer on a frictionless cart on an incline accelerates down the incline under the force of gravity, the liquid surface is parallel to the incline. The reasoning is the same as before when the accelerometer is experiencing a horizontal acceleration except in a different order. The incline determines the direction of the cart's motion, and therefore the accelerating force FA acting on a drop, and the perpendicular force $F_\perp$. Because the

direction of $F_{\perp}$ determines the slope of the liquid this slope is the same as the slope of the incline.

Friction:
Put tape on two wheels at the same end of the cart so that they cannot turn. Tilt the incline enough to accelerate the cart and accelerometer even while the rear wheels drag. This frictional force reduces the rate of acceleration and affects the slope of the liquid. The difference between the slopes of liquid and incline can be used to calculate the amount of friction.

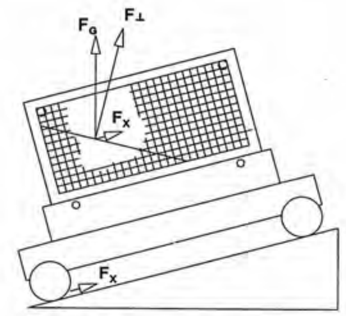


Figure 5
Force diagram for accelerometer on an incline with friction.

Acceleration on a Turntable:
The accelerometer must be carefully centered and secured on the turntable. For a constant rate of rotation the centripetal acceleration is proportional to the distance R from the center of rotation, that is

a = ω2R

where ω depends on the rate of rotation. Consider the boundary condition of R=0; this corresponds to a point directly over the center of rotation. If R=0 then the radial acceleration a will also be zero and gravitational acceleration is the only component of acceleration acting on that point. As R increases the radial component of acceleration increases, and the slope will also increase.

The curve of the liquid surface is described by a parabola with its apex directly over the center of rotation. Can you plot enough points from the accelerometer's grid to confirm the parabolic shape? How does this shape change with varying rotational velocities?
The changing slope cannot be calculated directly from the accelerometer's scale as in the case of a constant slope h/b, but the slope can be found by an indirect procedure. Carefully observe the curved surface for a particular rotational velocity. Draw several points on a sheet of graph that correspond to points observed on the accelerometer then draw a smooth curve through these points. Pick a point on your curve a distance R from the center of rotation (the bottom of the curve) then draw a straight line through that point tangent to the curve. You can now measure the slope of this line graphically to determine the acceleration at that point.

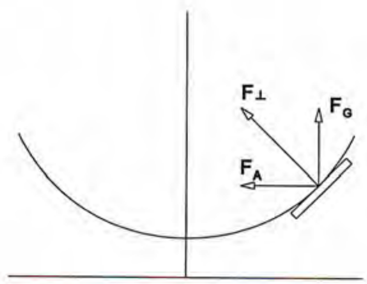


Figure 6
Force diagram for a point on the surface of the liquid spinning on a turntable.

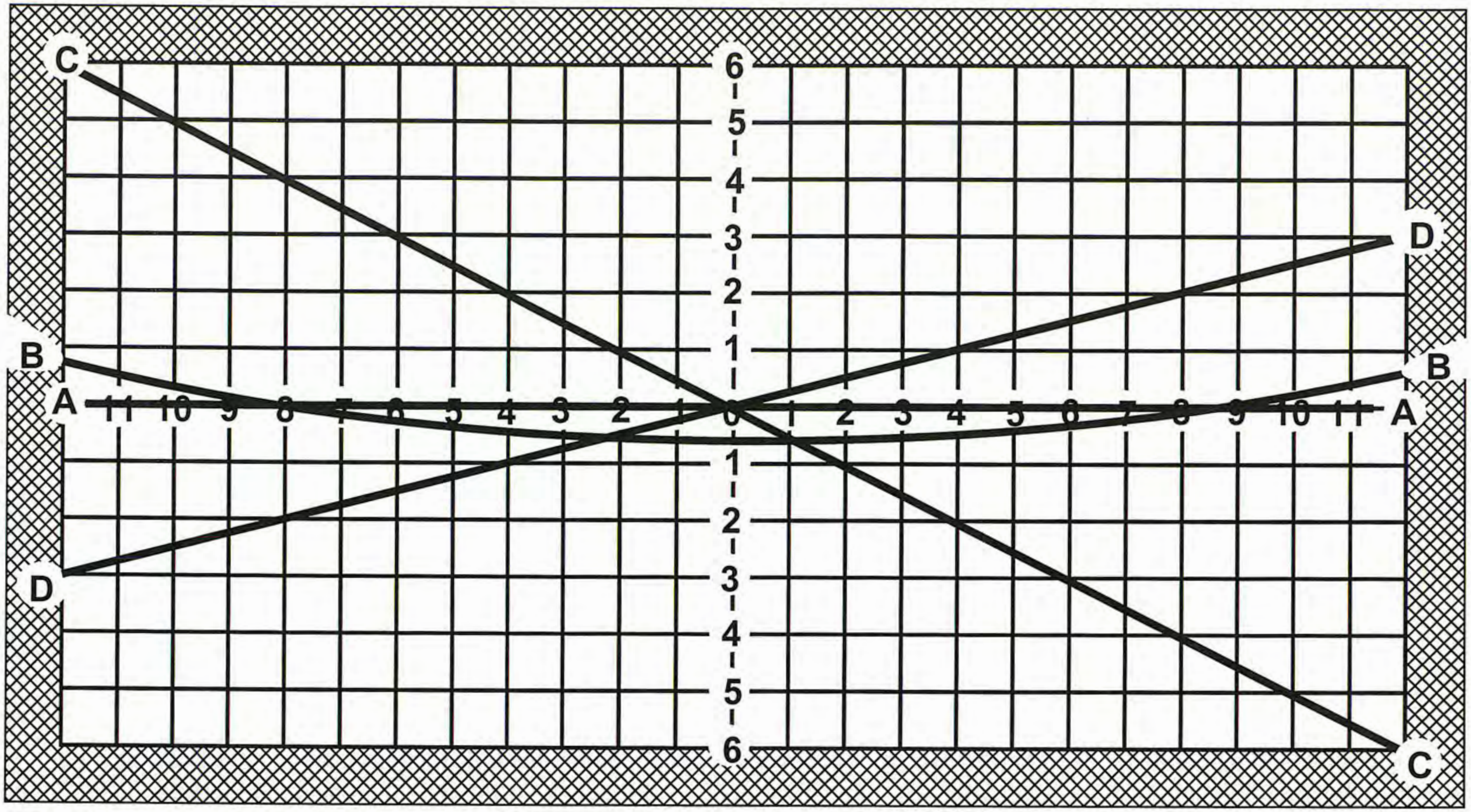
Theory:
Even when there is no acceleration, there still are two forces in balance on each drop of liquid. Acting internally, there is the drop's weight, and acting externally there is the balancing lift on the drop provided by the surrounding liquid. A still surface is always perpendicular to the direction of the balanced forces because if the liquid were too high on one side, the extra weight on that side would cause liquid to flow toward the low side.

Extension Activities:
Having established the parabolic surface for rotary motion, it is instructive to change the position of the accelerometer with respect to the center of rotation. This can be done by securely fastening the accelerometer to a motorized turntable, but with the center of rotation at one end of the accelerometer. Alternatively, the accelerometer can be held with arms outstretched by a student who is spinning in a circle or who is seated on a turntable.

Assessment:
There is included, a student worksheet that poses four situations for the student and also an answer sheet for the teacher's use. The student is asked to draw a plausible curve or line to fit each situation. The information in these instructions is sufficient for the student to calculate and draw the slope. The apparatus displays a response to acceleration only. Any reasonable parabolic curve would fit situation (B). The teacher is free to add other questions. The basic diagram is a full scale copy of the accelerometer grid.

Time Allocation:
To prepare this product for an experimental trial should take less than ten minutes. Actual experiments will vary with needs of students and the method of instruction, but are easily concluded within one class period. Masking tape is often used to temporarily mount the device on a dynamics cart. Current and future production shows an additional dado cut on the bottom of the base to accommodate either set of Dynamics Apparatus of the new style from The Science Source (#10-4300 or #14300).

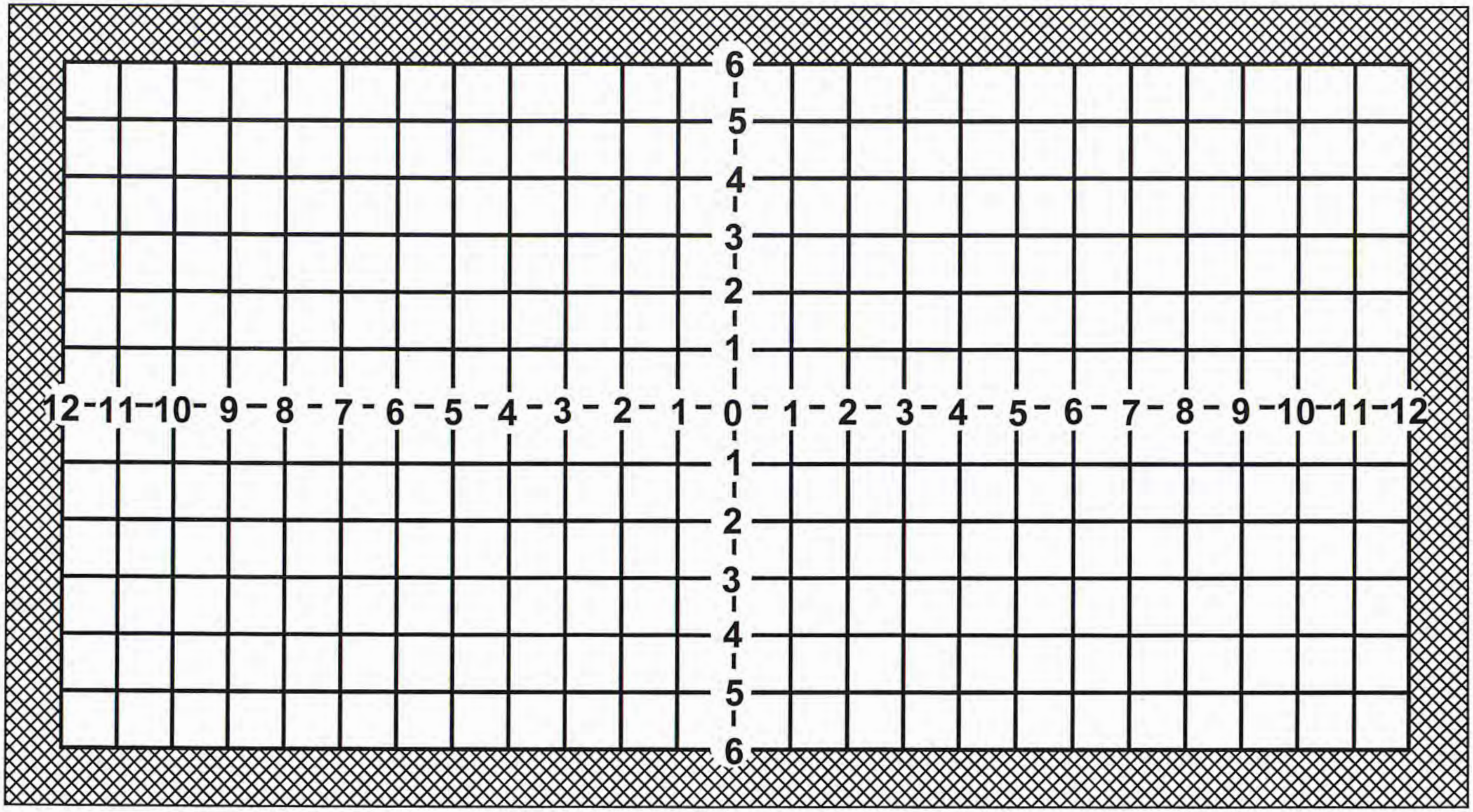
Feedback:
If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.



Student Assessment Worksheet **(with answers)** Name ____________

Draw and label a plausible line or curve to represent each of the following situations:
A. Uniform motion to the left. B. Moderate clockwise rotation about the center axis.
C. Uniform acceleration of 5m/s/s to the right. D. While moving toward the right, the accelerometer experiences a uniform acceleration of 2.5m/s/s to the left.

Presume "g" = 10m/s/s, acclerometer is half-full and upright, motion is parallel to base.



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