DETERMINATION OF FRICTION FORCE IN LIQUID AND AIR USING A SPRING PENDULUM

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Abstract: *Where there is motion, there is obviously friction. There are many types of frictional forces, and this article examines the determination of frictional forces in liquids and air using a spring pendulum. The experiment was performed in Pocket-CASSY.*

Keywords: *friction force, liquid, air, moving,*

Friction is a force that resists the relative movement of solid surfaces, fluid layers, and material elements relative to each other. Fluid friction occurs between fluid layers moving relative to each other. This internal resistance to flow is called viscosity. In everyday terms, the viscosity of a liquid is described as its "thickness". Thus, water is "thin" and has a lower viscosity, while honey is "thick" and has a higher viscosity. The less viscous a liquid is, the more easily it can deform or move.

As a supplement to the experiment Oscillations of a spring pendulum, the oscillating body is subjected to an additional frictional force F through turbulent liquid friction or turbulent air friction (Newton friction). The magnitude of this frictional force is proportional to the square of the velocity, but its direction is always opposite to that of the motion. Thus it can be written in the form $F=-F_0\cdot(v/v_0)^2\cdot \mathrm{sgn}(v)$ (1).

F_0 is the magnitude of the frictional force acting on the system at the initial velocity $|v_0|$. The model equation then reads

$s'' = a = -D/m \cdot s - F_0/m\cdot(v/v_0)^2\cdot \mathrm{sgn}(v)$ (2).

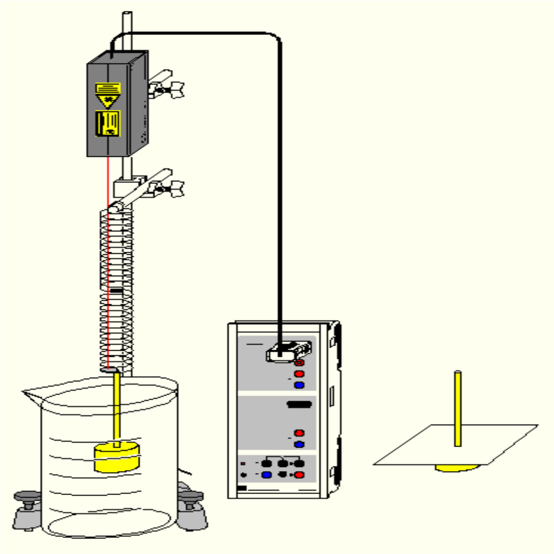
The gravitational force $-m\cdot g$ is not taken into. The constants D and m correspond to the spring constant and the oscillating mass. As water is moved and a certain portion of the spring oscillates too, the oscillating mass is greater than the mass of the pendulum bob.

From the friction constant F_0 the drag coefficient (c_w value) for the cylindrical pendulum bob can be estimated.

Set up the spring pendulum with the large spring (Æ=3.5 cm). For the path measurement, attach a piece of retroreflecting foil to the lowest turn of the spring so that the laser spot of the motion sensor hits the foil during the entire oscillation (if necessary, attach the foil outside the spring).

Due to the reversal of its helical sense in the middle, this particular spring makes possible a free stable up and down oscillation because no torsional oscillation is excited.

When the pendulum bob is in its equilibrium position, it should be near the middle of the water-filled beaker (Pic.1).



Pic 1

In the present example, the two initial conditions s(t=0)=0 and $v(t=0)=v_0$ were chosen because the triggering took place in the zero point of the path. The initial velocity v_0, the spring constant D, the mass m and the friction constant F_0 can be altered by dragging the pointer of the corresponding display instrument (or by clicking to the left or to the right of the pointer) until the model agrees with the measurement.

The dependence of the model's frictional force on the velocity can be seen in the Frictional force display.

The drag force F_L for the pendulum bob around which the liquid flows is given by

$F_L = c_w \cdot 1/2 \cdot \rho \cdot v^2 \cdot A = F_0 \cdot (v/v_0)^2$ (3)

with the drag coefficient c_w, the dynamic pressure $p=1/2 \cdot \rho \cdot v^2$ and the backwater surface $A=\pi \cdot r^2$. The drag coefficient is the ratio of the measured force and the imagined dynamic force p·A. We obtain

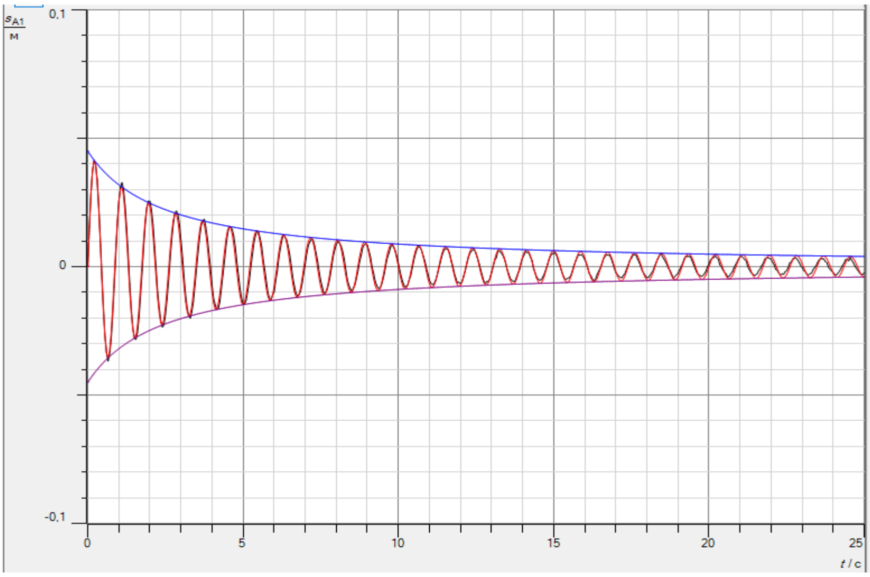
$c_w = 2F_0/v_0^2/(\rho \cdot A)$.

In the present example, we have r = 2.5 cm and ρ = 1 g/cm^3, and therefore $\rho \cdot A$ = 1.96 kg/m. The modeling process gives F_0 = 0.1828 N and v_0 = 0.325 m/s. Thus we find c_w = 1.7.

For small frictional forces proportional to the square of the velocity, the function describing the envelope is given by

$\pm f(t) = |v_0| \cdot sqr(m/D)/(1+4/3\pi \cdot F_0/m/|v_0| \cdot t) = s_0/(1+4/3\pi \cdot k \cdot t)$

with $\omega_0=sqr(D/m)$, $s_0=|v_0|/\omega_0$ and $k=F_0/m/|v_0|$ (4).



Pic 2.

During the experiment, the spring stiffness is D=30.5 N/m, the mass of the bag is m=0.584 kg, its speed is v_0=0.325 m/s, and the impact force is equal to F_0=0.1828 N.

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