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8.01 Physics I: Classical Mechanics, Fall 1999  
Transcript – Lecture 12

We're going to discuss today resistive forces and drag forces.

When you move an object through a medium, whether it's a gas or whether it's a liquid, it experiences a drag force.

This drag force depends on the shape of the object, the size of the object, the medium through which you move it and the speed of the object.

The medium is immediately obvious.

If it's air and you move through air, you feel the wind through your hair--  
that's a drag force.

If you swim in water, you feel this drag force.

In oil, the drag force would be even larger.

This drag force, this resistive force is very, very different from the friction that we have discussed earlier when two surfaces move relative to each other.

There, the kinetic friction coefficient remains constant independent of the speed.

With the drag forces and the resistive forces, they are not at all independent of the speed.

In very general terms, the resistive force can be written as  $k_1$  times the velocity plus  $k_2$  times the velocity squared and always in the opposite direction of the velocity vector.

This  $v$  here is the speed, so all these signs--

$k_1$ ,  $v$  and  $k_2$ , and obviously  $v$  squared--

they all are positive values.

And the  $k$  values depend on the shape and the size of the object and on the kind of medium that I have.

Today I will restrict myself exclusively to spheres.

And when we deal with spheres, we're going to get that the force, the magnitude of the force--

so that's this part--

equals  $C_1$  times  $r$  times the speed plus  $C_2$  times  $r$  squared times  $v$  squared.

And again, it's always opposing the velocity vector.

$C_1$  in our unit is kilograms per meters per second and  $C_2$  has the dimension of density kilogram per cubic meters.

We call this the viscous term, and we call this the pressure term.

The viscous term has to do with the stickiness of the medium.

If you take, for instance, liquids--

water and oil and tar--

there is a huge difference in stickiness.

Physicists also refer to that as viscosity.

If you have a high viscosity, it's very sticky, then this number,  $C_1$ , will be very high.

So this we call the viscous term, and this we call the pressure term.

The  $C_1$  is a strong function of temperature.

We all know that if you take tar and you heat it that the viscosity goes down.

It is way more sticky when it is cold.

$C_2$  is not very dependent on the temperature.

It's not so easy to see why this pressure term here has a  $v$  square.

Later in the course when we deal with transfer of momentum, we will understand why there is a  $v$ -square term there.

But the  $r$  square is very easy to see, because if you have a sphere and there is some fluid--

gas or liquid--

streaming onto it, then this has a cross-sectional area which is proportional to  $r$  squared, and so it's easy to see that the force that this object experiences--

we call it the pressure term--

is proportional to  $r$  square, so that's easy to see.

Two liquids with the very same density would have...

they could have very different values for  $C_1$ .