Wednesday warm-up: Forces II and Forces III

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1 Memory Bank

- Force of drag, in air or other gas: $F_D = \frac{1}{2} C \rho A v^2$.
- In the above formula, C is an empirical constant, ρ is the density of the air or gas, A is the area of the object, and v is the object's velocity.
- Spring force: $\vec{s} = -k \Delta \vec{x}$, where k is the spring constant and $\Delta \vec{x}$ is the displacement.
- The horizontal force of friction: $\vec{f} = -\mu N \hat{i}$, where μ can be either the *static* or *kinetic* coefficient of friction.

2 Drag Forces, Springs, and Friction

1. Suppose a cyclist with $A = 0.5$ m^2, $C = 1.0$, and total mass $m = 70$ kg is pedalling at 20 m/s. Assume the density of air is $\rho = 1.2$ kg m^{-3}. (a) What is the drag force on the system? (b) What is the drag force if the speed drops to 10 m/s? (c) Suppose the speed is now 20 m/s again, but the cyclist ducks down to lower the area to $A = 0.25$ m^2. What is the new drag force?

2. Show that the acceleration of any object down a frictionless incline that makes an angle θ with the horizontal is $a = g \sin \theta$. (Note that this acceleration is independent of mass.)

3. (a) Show that the acceleration of any object down an incline where friction behaves simply (that is, where $f_k = \mu_k N$) is $a = g(\sin \theta - \mu_k \cos \theta)$. Show that the acceleration reduces to the expression found in the previous problem when friction becomes negligibly small.

4. Calculate the deceleration of a snow boarder going up a slope of 10 degrees, assuming the coefficient of friction for waxed wood on wet snow (0.1).

5. Suppose a spring with spring constant k supports a mass m on an incline with angle θ. (a) Derive an expression for the displacement of the spring from the unstretched position. (b) Design a situation in which the spring force is balanced by *both* the force down the incline, *and* friction. Choose reasonable numbers to test your equation.