Physics 2a, Oct 19, lecture 12

$\star$Reading: chapter 5.

• Static and kinetic friction. The contact friction force $\vec{f}$ is parallel to the surface, and opposes motion. It's perpendicular to the normal force, $\vec{f} \cdot \vec{N} = 0$, but its magnitude is proportional to the magnitude of the normal force: $f = \mu N$. Here μ is the friction coefficient, which depends on the system, and it can also depend on whether the system is static or kinetic (moving). For static situations, $f_s \leq \mu_s N$, and for kinetic situations $f_k = \mu_k N$. Examples: steel on steel, $\mu_s = 0.74$, $\mu_k = 0.57$; brass on steel, $\mu_s = 0.51$, $\mu_k = 0.36$; copper on cast iron, $\mu_s = 1.05$, $\mu_k = 0.29$ (interesting!); rubber on dry concrete, $\mu_s = 1.0$; rubber on wet concrete, $\mu_s = 0.3$; BAM (slipperiest known solid), $\mu = 0.02$.

• Fluid resistance. This is similar to friction, it opposes motion, but it is related to the velocity. For low velocities, find $f = kv$, where k depends on the system (both the fluid and the shape of the object). For higher speed, find $f = Dv^2$, where the drag coefficient D also depends on the system. Aerodynamic cars, planes, etc are designed to minimize their D.

Terminal speed: suppose that we drop an object of mass m, find its terminal speed assuming that it's low enough to use $f = kv$. Solution: at the terminal speed, $a = 0$, so the forces are in equilibrium, so $v_t = mg/k$. Now suppose instead that the speed is fast enough that we should use $f = Dv^2$. In this case, get $v_t = \sqrt{mg/D}$. Skydiver example.

Consider the case where $f = kv$. Let's solve Newton's equation to find the distance $y(t)$ of a skydiver below a plane. Newton gives $m\frac{dv_y}{dt} = mg - kv_y$, which can be solved to give $v_y = \frac{mg}{k}(1 - e^{-kt/m})$. Integrating that gives $y = \frac{mg}{k}(t - \frac{m}{k}(1 - e^{-kt/m})$.

• Circular motion. Recall that an object moving in a circle has $(x, y) = R(\cos\theta, \sin\theta)$, and thus $(v_x, v_y) = \frac{d}{dt}(x, y) = \omega R(-\sin\theta, \cos\theta)$, where $\omega = \frac{d\theta}{dt}$ is called the angular velocity. The magnitude of this velocity is $v = \omega R$. Finally, we get $(a_x, a_y) = \frac{d}{dt}(v_x, v_y) = -\omega^2(x, y) + R\alpha(-\sin\theta, \cos\theta)$, where $\alpha = \frac{d\omega}{dt}$ is called the angular acceleration. Let's consider uniform circular motion, which means that $\alpha = 0$. Then get $a = a_{rad} = \omega^2 R = v^2/R$, with the acceleration pointing inward, as seen from the minus sign in $(a_x, a_y) = \frac{d}{dt}(v_x, v_y) = -\omega^2(x, y)$. The period of revolution is given by $\omega = 2\pi/T$, so $T = 2\pi/\omega = 2\pi R/v$.

Example: spinning yo-yo overhead, cord breaks, what happens?

Example: spinning yo-yo, keep tension in rope constant, double R, what happens to the period?