Physics 2a, Oct 20, lecture 13

★Reading: chapter 5.

• 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?

• Lots of examples with incline planes, pulleys. Thinking of iphone apps.