2.4: Multiple Forces

In the examples in Section 2.3 there was only a single force acting on the particle of interest. Usually there will be multiple forces acting at the same time, not necessarily pulling in the same direction. This is where vectors come into play.

Suppose you put a book on a table. The Earth's gravity pulls it down with a force of magnitude F_g. Consequently the book exerts a normal force down on the table with the same magnitude, and the table reciprocates with an identical but oppositely directed normal force of magnitude $F_n = F_g$. Now suppose you push against the book from the side with a force of magnitude F. As we've seen in Section 2.2, there will then be a friction force between the book and the table in the opposite direction, which, as long as it doesn't exceed $\mu_s F_n$,equals the force you push with. However, once F is larger than $\mu_s F_n$, there will be a net force acting on the book. It is the net force that we substitute into Newton's second law, and from which the book will get a net acceleration.

In the situation described above, things are still simple - you get the net force by subtracting the kinetic friction $F_f = \mu_f F_n$ from the force F you exert on the book, because these are horizontal and thus perpendicular to the vertical normal and gravitational forces. But what happens if you lift the table on one end, so that it becomes slanted? To help organize our thoughts, we'll draw a free body diagram, shown in Figure $2.4.1$.

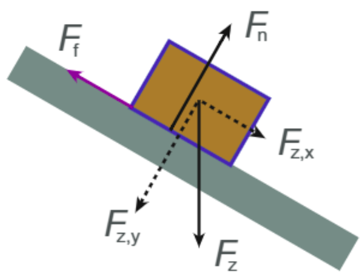

Figure $2.4.1$: Free body diagram of the forces acting on a book on a slanted table. Gravity always points down, normal forces always perpendicular to the surface, and frictional forces always parallel to the surface. The force of gravity can be decomposed in directions perpendicular and parallel to the surface as well.

Gravity still acts downward, and the mass of the book stays the same, so F_g doesn't change. However, the orientation of the contact plane between the book and table does change, so the normal force (remember,normal to the surface) changes as well. Its direction will remain perpendicular to the surface, and as long as you don't push on the book (or push along the surface only), the only other force having a component perpendicular to the surface is gravity, so the magnitude of the normal force better be equal to that (or the book would either spontaneously start to float, or fall through the table). You can find this component by decomposing the gravitational force along the directions perpendicular and parallel to the slanted surface. The remaining component of the gravitational force points downward along the surface of the table, and is comparable to the force you were exerting on the book in the flat case. Up to some point it is balanced by a static frictional force, but once it gets too large (because the slant angle of the table gets too large), friction reaches its maximum and gravity results in a net force on the book, which will start to slide down (as you no doubt guessed already).