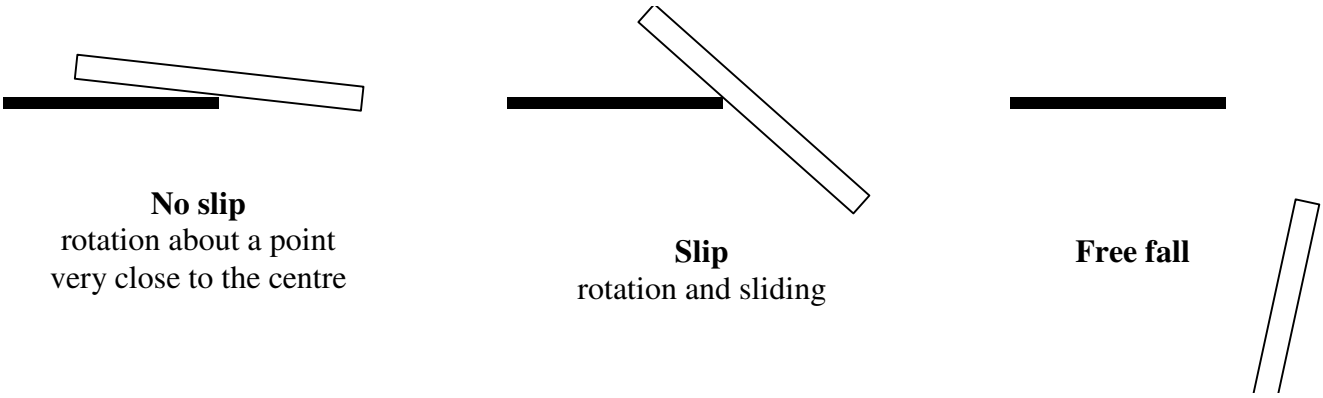
Falling Toast

Toast seems always to land buttered-side down. This is because when it falls off the edge of a table it starts to rotate. You can do good experiments with a small hard-back book (use a rubber band to hold the pages closed). The motion can be analysed using Newton's Laws of Motion. There are three phases:



**No slip**
rotation about a point
very close to the centre

**Slip**
rotation and sliding

**Free fall**

The first thing to do is to hold the book (or toast) over the edge of a table so that it will just balance. Then push it just 1mm further and it will start to fall. At first the angular velocity of the book increases gradually during the "no slip" phase until it reaches an angle of around $20^{o}$ – $30^{o}$ (depending on friction). At this point friction is insufficient to prevent slip, but the book does not lose contact. During the "slip" phase the forces acting on the book are more-widely separated so the angular acceleration is more rapid. This means that it is during this slipping phase that the book gains most of its angular velocity. Eventually the angular motion causes the book to lose contact with the table and it then enters the "free fall" stage. The angular velocity is constant but simple projectile motion requires that the book accelerate downwards at a rate of $g = 9.81 ms^{-1}$ and in the time it takes the book to turn through $180^{o}$ it has fallen a distance of about 70cm. This is the height of a typical table. What is remarkable is that this conclusion is not very sensitive to the exact starting position of the book (1mm, 2mm – doesn't matter much) or the friction coefficient (anything between $\mu = 0.1$ and 0.5 will give roughly the same answers. So it is no surprise that toast often lands upside down.