Sweet spot of a tennis racket

Problem-orientated animations for education purposes.

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Even if the concepts of translational and angular momentum conservation are understood nicely, the combination of the two can be quite difficult to pupil. For example imagine what happens, if a hockey-puck will hit a wooden bar laying on ice. In order to make understanding more easy and intuitively, I created several animations to that problem.

Contents

1 Translational & angular momentum conservation

The animation to the picture seen in Fig. 1 shows a (vertical laying) wooden bar on ice which is hit by a puck (constant, linear-horizontal movement, elastic collision). I've chosen ice as ground for approximate non-friction surface. The first sequence in this animation is the case, that the puck is hitting the center of the bar; so that no rotational movements has to be considered (pupil should know this case). Then the puck changes position and moves again in the same way towards the bar.

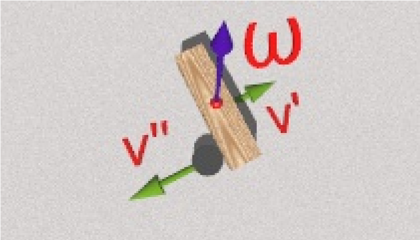

Figure 1: A puck impacts a wooden bar on ice.

The animation pauses at the beginning and the time of the impact and (labelled) vectors for velocity and angular momentum appear. Those vectors are very important for understanding quantitatively. So you can see easily, that after the impact, the puck is moving back in the exact opposite direction as it came, the center of the wooden bar is moving in the same direction as the puck before hitting the bar and the bar gets some angular momentum around the center of it. In order to recognize this movement more clear, I put a little red dot above the center mass on the surface of the bar, so pupil can follow the movement of the center more easy. The reason why the *center* of the bar is moving with constant velocity in this direction and the bar also rotates around the *center*, is because in this case the *geometric* center is also the center of *mass*. Furthermore, after the hit, I put in a trace of the moving bar. By that, you can see the center is moving linear and with constant velocity, because the distance between the "traced wooden bars" is constant; as seen in Fig. 2.

Figure 2: The "traced" wooden bar with red dot above the center of mass.

In this chronological sequence, students can see the effect of an impact like this, and in the same moment, it's possible to understand *why* the movement has this shape, because of the pause and the appearing vectors. After the hit, you can see the movements itself, and in the same moment, recognize that the bar does a combination of a linear movement with constant velocity and constant rotation. This immersion of *watching*, *recognition* and *intuitive understanding* cannot be reached that easily with just one picture or graphic.

2 Elimination of bottom velocity

The animation shown in Fig. 3 shows the impact on different points at the bar in a way, so that the bottom velocity is eliminated. This point depends on velocity and mass of puck and bar.

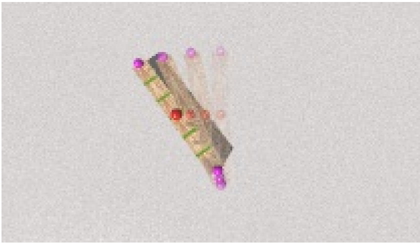

Figure 3: A special case that the bottom velocity is eliminated.

3 Bottom velocity is not changed

The animation shown in Fig. 4 shows the impact on a point of the bar in a way, so that the bottom velocity doesn't change. This point does *not* depend on velocity nor mass of puck or bar. This knowledge can be used for determining the so called "sweet spot" of a tennis racket[1]. The equations are a different, compared to the puck or a real tennis racket, but the principle is the same.

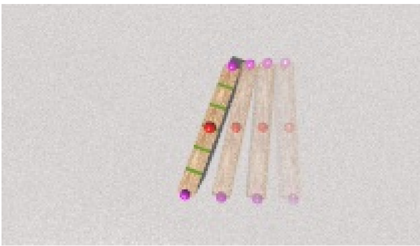

Figure 4: In this case bottom velocity doesn't change.

[1] The "sweet spot" here is the point of hit, where impact shock and vibrations are optimally subdued.

4 Sweet spot of a tennis racket

In this last figure you can see a snapshot of a animation of a tennis racket hitting a ball on the "sweet spot". In this case, the tennis racket consists of a cylinder (handle) and a ring with net; the center of mass is located at their touching point. The radius r of the ring and the length of the handle l are equal to each other. The "sweet spot" does *not* lay in the center of the net, even if it may look like it. The point is located $\frac{5}{18}r$ below the center of the net.

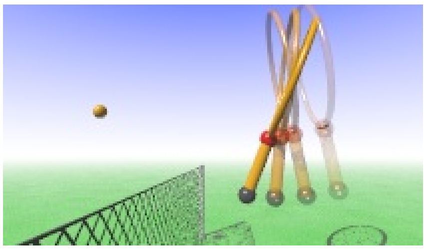

Figure 5: The sweet spot of a tennis racket.

This last animation (Fig. 5) represents one possible way of using the covered things for solving real-life-problems, and can be also shown as a motivational introduction to the topic and/or the closing of it.