Flipping Physics Lecture Notes:
Impulse Introduction or
If You Don't Bend Your Knees When Stepping off a Wall

This video is an extension of “Calculating the Force of Impact when Stepping off a Wall”[♥]. The idea is to figure out how much force would be exerted on mr.p’s body if he didn’t bend his knees. I am unwilling to demonstrate this; instead I dropped a tomato. The time of impact for the tomato was 6 frames in a video filmed at 240 frames per second: $\Delta t = 6 frames \times \frac{1 \sec}{240 frames} = 0.025 \sec$

The idea is that we can approximate the time during the collision if I did *not* bend my knees to be the same as the collision for the tomato. Do I know this to be true? No. However, again, I am unwilling to demonstrate stepping off a wall and not bending my knees, so this is a good approximation.

Because I fell 73.2 cm, we determined last time my velocity right before striking the ground is 3.7897 m/s down and my velocity after striking the ground is zero because I stop. My mass is 73 kg. That means the force of impact during the collision is:

Unbent knees: $\sum \vec{F} = \frac{\Delta \vec{p}}{\Delta t} = \frac{m\vec{v}_f - m\vec{v}_i}{\Delta t} = \frac{(73)(0)-(73)(-3.7897)}{0.025} = 11065.93N \times \frac{1lb}{4.448N} = 2487.84 \approx 2500lb$

Bent knees: $\sum \vec{F} = \frac{(73)(0)-(73)(-3.7897)}{0.28} = 988.03N \times \frac{1lb}{4.448N} = 222.13 \approx 220lb$

(The time of impact when bending my knees was 0.28 seconds.)

Not bending my knees decreases the time of impact from 0.28 seconds to 0.025 seconds and:

$\frac{\sum F_{not\,bent}}{\sum F_{bent}} = \frac{11065.83}{988.03} = 11.2 \approx 11$ Makes the force of impact roughly 11 times what it is when I bend my knees.

The key here is that the only thing which is different between the two examples is the time during the collision. The mass, final velocity and initial velocity are all the same in both examples. In other words, the change in momentum during both examples is exactly the same. For this reason, the change in momentum is given a specific name, it is called Impulse. The symbol for Impulse is usually a capital J and sometimes a capital I; I will usually just write out the word Impulse. Note that we can rearrange Newton’s second law to solve for impulse.

$\sum \vec{F} = \frac{\Delta \vec{p}}{\Delta t} \Rightarrow \sum \vec{F} \Delta t = \Delta \vec{p} = Impulse$ Note: Impulse is a vector!

The dimensions for Impulse are $N \cdot s$, which is the same thing as $\frac{kg \cdot m}{s}$ because:

$$N \cdot s = \left(\frac{kg \cdot m}{s^2}\right) s = \frac{kg \cdot m}{s}$$

Point of confusion for students: Impulse is equal to the change in momentum of an object *and it is also equal to* the force of impact times the change in time.

$$Impulse = \sum \vec{F} \Delta t = (988.03)(0.28) = (11065.93)(0.025) = 276.65N \cdot s \approx 280N \cdot s$$

$$\Rightarrow Impulse = \Delta \vec{p} = m\vec{v}_f - m\vec{v}_i = (73)(0) - (73)(-3.7897) = 276.65 \approx 280\frac{kg \cdot m}{s}$$

[♥] http://www.flippingphysics.com/impact-force-problem.html