Flipping Physics Lecture Notes:

Impulse Comparison of Three Different Demonstrations

Example Problem: A racquetball is dropped on to three different substances from the same height above each: water, soil, and wood. Rank the _____ during the collision with each substance in order from least to most. (a) Impulse. (b) Average Force of Impact.
(Assume the racquetball stops during the collision with the water and soil.)

Let's split the demonstrations up in to parts:

Part 1 is the free fall portion. Because the racquetball is dropped from the same height in all three examples, the velocity at the end of part 1 is the same for all three substances.

Part 2 is the collision. The initial velocity for part 2 is the final velocity for part 1 so all three substances have the same initial velocity for part 2. We are assuming the racquetball stops after colliding with the water and soil, therefore the velocity for part 2 final for each is zero. However, after colliding with the wood, the ball rebounds to about 2/3rds its original height, therefore the racquetball has a positive final velocity for part 2.

	Water	Soil	Wood
$\vec{v}_{1f} = \vec{v}_{2i}$	Same	Same	Same
$\vec{v}_{2f}$	0	0	Positive
$m_{racquetball}$	Same	Same	Same

The mass of the racquetball is the same for all three substances.

Part (a) for the water and the soil: $Impulse_2 = \Delta\vec{p}_2 = m\vec{v}_{2f} - m\vec{v}_{2i} = m(0) - m\vec{v}_{2i} = -m\vec{v}_{2i}$

So the impulse for the water and the soil is the same.
Note: This impulse is actually positive because the velocity for part 2 initial is down and therefore negative, which makes the impulse for the collisions with both the water and the soil, positive.

For the wood $Impulse_2 = m\vec{v}_{2f} - m\vec{v}_{2i}$ and we know velocity for part 2 final is positive, so the impulse for the wood is greater than the impulse for the water and the soil.

Answer: $Impulse_{water} = Impulse_{soil} < Impulse_{wood}$

Part (b) because they both have the same impulse, comparing force of impact for water and soil is rather straightforward. We know impulse equals the average force of impact multiplied by the change in time during the collision. From the video, you can see the time of impact during the collision with the water is much greater than the time of impact with the soil, therefore the average force of impact during the collision with the water must be less than the average force of impact with the soil.

$Impulse = \vec{F}_{avg}\Delta t$: Impulse is the same, $\Delta t_{water} > \Delta t_{soil} \Rightarrow \vec{F}_{water} < \vec{F}_{soil}$

We already know $Impulse_{soil} < Impulse_{wood}$, however, in order to compare the average force of impact between the soil and the wood, we need to be able to compare the change in time during each collision. Both of those collisions appear to last for roughly 1 frame. Therefore we can *estimate* that the time during the collision is the same. Because the impulse for the soil is less than the impulse for the wood and the two changes in time are the same, then the force of impact for the soil must be less than the force of impact for the wood. Answer: $\vec{F}_{water} < \vec{F}_{soil} < \vec{F}_{wood}$