Controlling Collisions ... with F•Δt = m•Δv

Lesson Notes

Learning Outcome

- How can the variables of the impulse-momentum change equation be varied in order to increase or decrease the force on an object in a collision?

Thinking About F•Δt = m•Δv

The impulse-momentum change equation predicts the relationship between four collision variables - force, collision time, object mass, and the velocity change.

$$F \cdot \Delta t = m \cdot \Delta v \quad \Rightarrow \quad F = \frac{m \cdot \Delta v}{\Delta t}$$

How can the variables be controlled to make the force larger or smaller … as needed? That is, how can we manipulate the variables so as to exercise control over a collision?

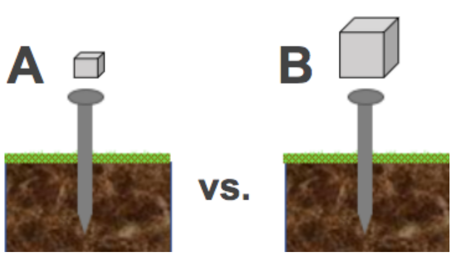
The Effect of Mass on Force

- The collision force and the object mass are directly proportional.
- Doubling mass results in a doubling of force.
- Halving mass results in a halving of force.
- By whatever factor that the mass is changed, the force is changed by the same factor.

Collision Comparison - Mass Variations

Compare the collision of Object A (small m) with the stake to the collision of Object B (large m) with the stake. Assume A and B are released from the same height and their collision time is the same.

Compare their momentum change, impulse, and force.



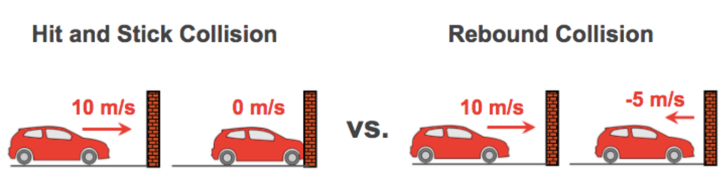
B has the greater m and thus the greater momentum change (m•Δv) …

… and therefore the greater impulse (F•Δt) …

… and thus the greater force.

Effect of ΔVelocity on Force

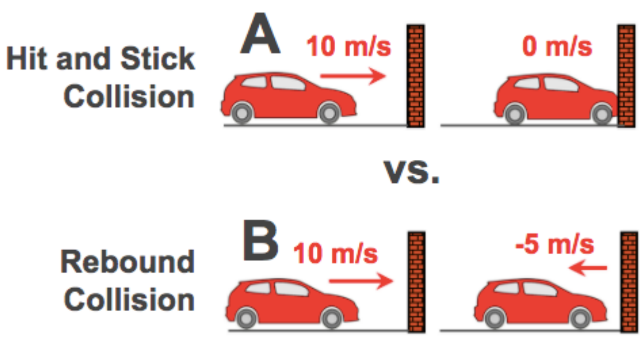
- The collision force and the velocity change (Δv) are directly proportional.
- Doubling Δv results in a doubling of force.
- Halving Δv results in a halving of force.
- By whatever factor that the Δv is changed, the force is changed by the same factor.



Collision Comparison - Δvelocity Variations

Compare the *hit and stick* collision of Car A with the *rebound* collision of car B. Assume Cars A and B have the same mass, contact the barrier at the same speed, and experience the same collision time.

Compare their momentum change, impulse, and force.



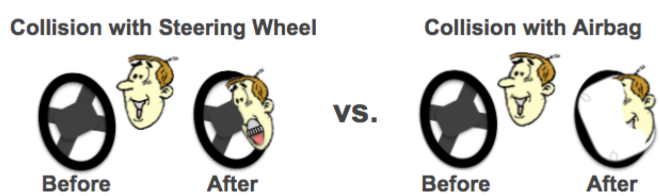
B has the greater Δv and thus the greater momentum change (m•Δv) …

… and therefore the greater impulse (F•Δt) …

… and thus the greater force.

Effect of Δtime on Force

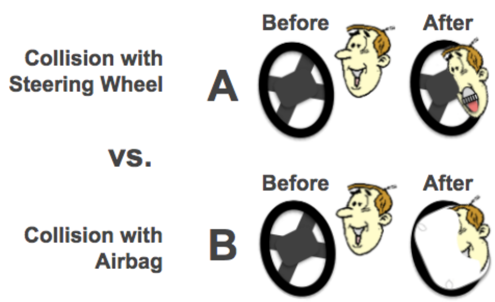
- The collision force and the collision time (Δt) are inversely proportional.
- Doubling Δt results in a halving of force.
- Halving Δt results in a doubling of force.
- By whatever factor that the Δt is changed, the force is changed by the inverse factor.



Collision Comparison - Δtime Variations

Compare the collision of Driver A with a steering wheel to the collision of Driver B with an airbag. Assume the mass and before-collision speeds are identical and that the drivers come to a stop as a result of the collisions.

Compare their momentum change, impulse, and force.



The velocity change (Δv) and the momentum change (m•Δv) are the same …

… and therefore the impulse (F•Δt) is the same …

… but the collision time (Δt) is longer for B, making the force (F) smaller for B.