The Physics of Car Crashes

Can we use physics concepts to help design safer vehicles?

Collisions overview – Elastic

Momentum in = momentum out

$$Kinetic\ Energy\ in: \frac{1}{2}mv^2 = kinetic\ energy\ out$$

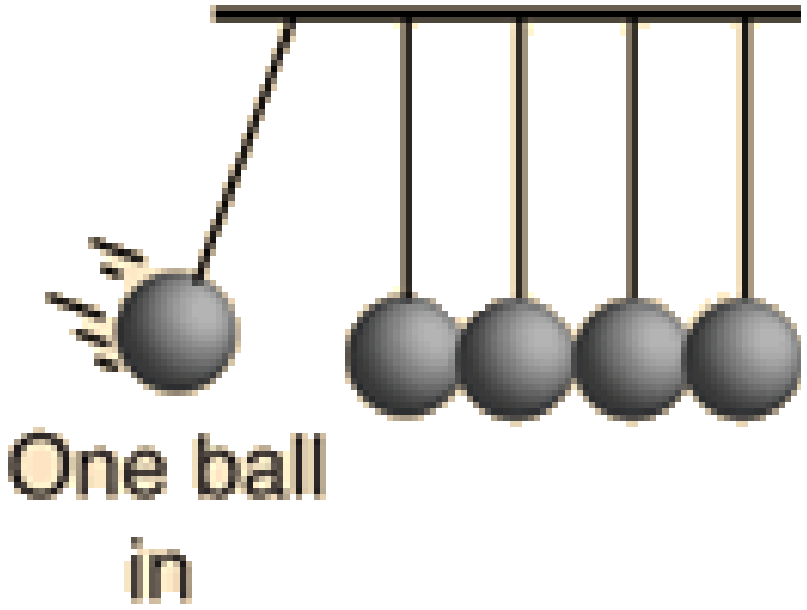

Image credit: Georgia state university

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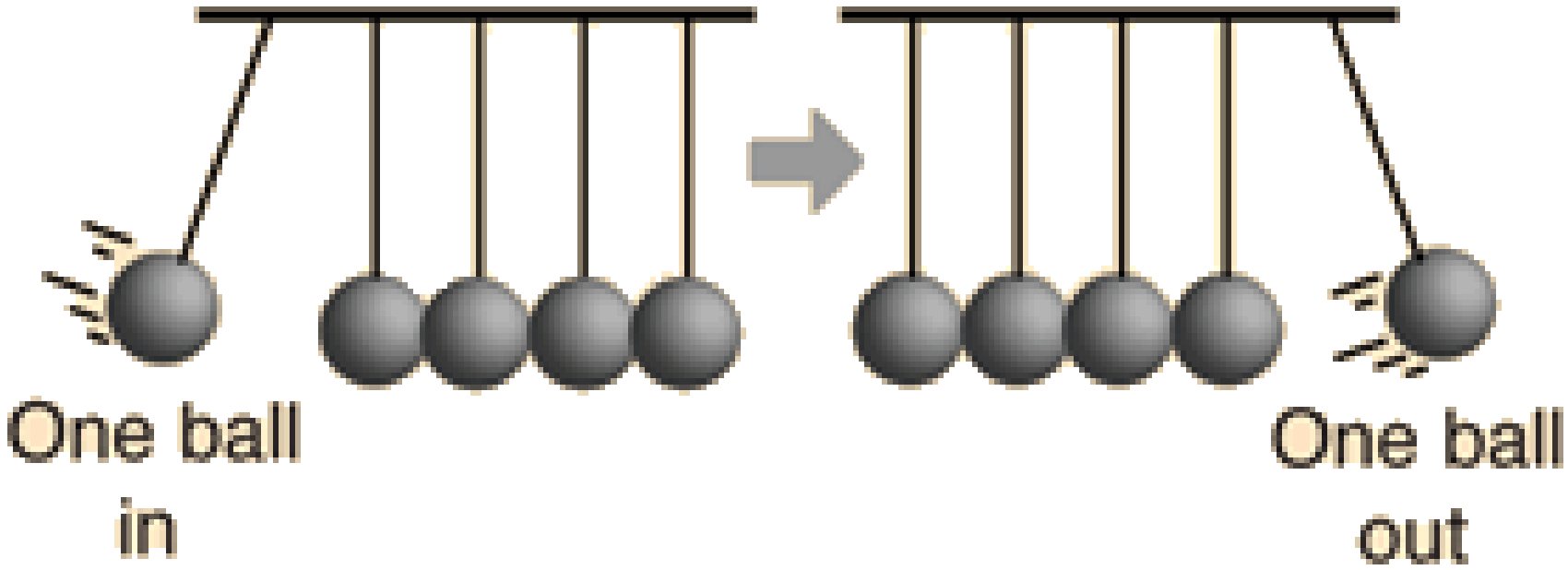
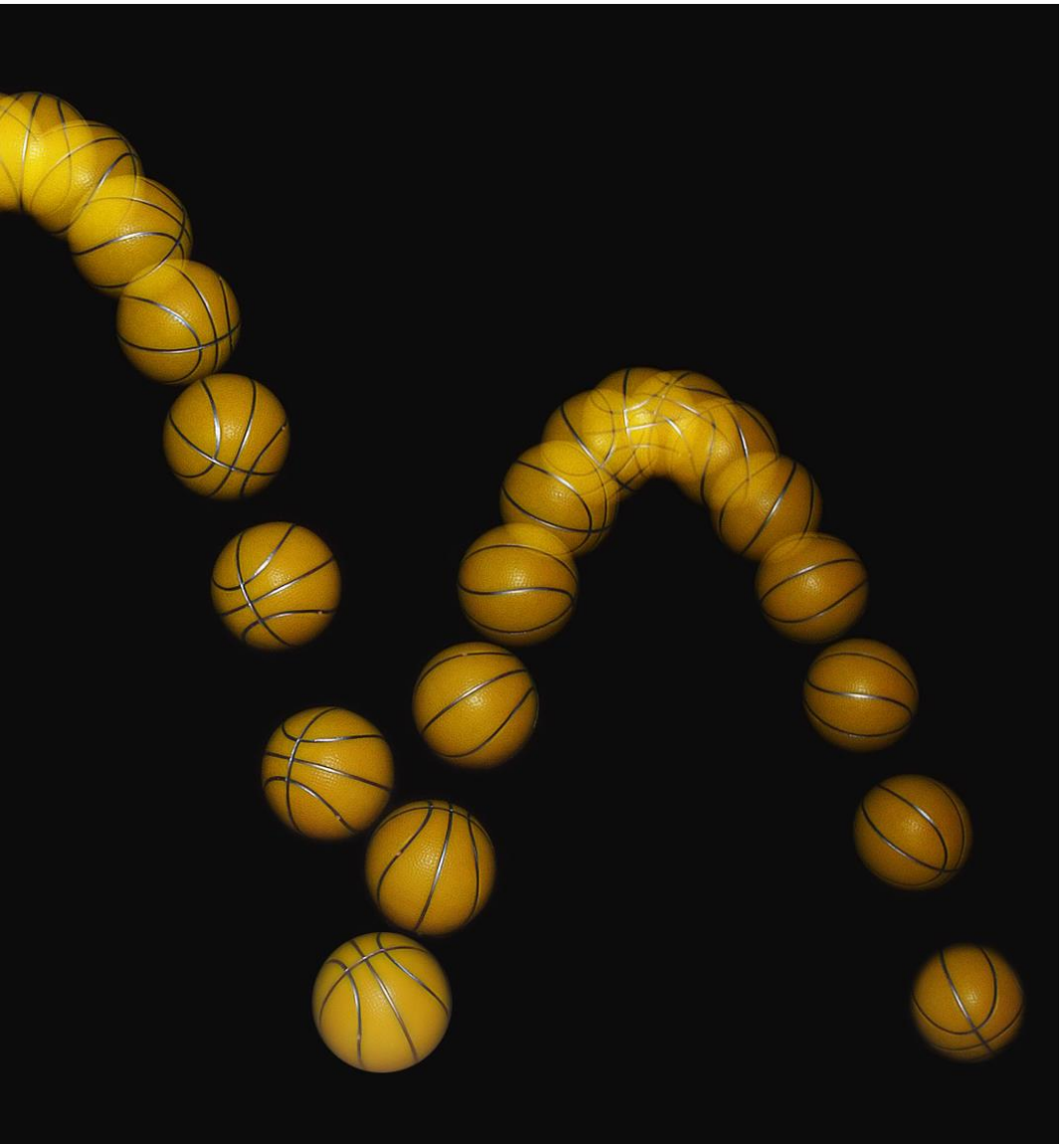


Image credit: Georgia state university

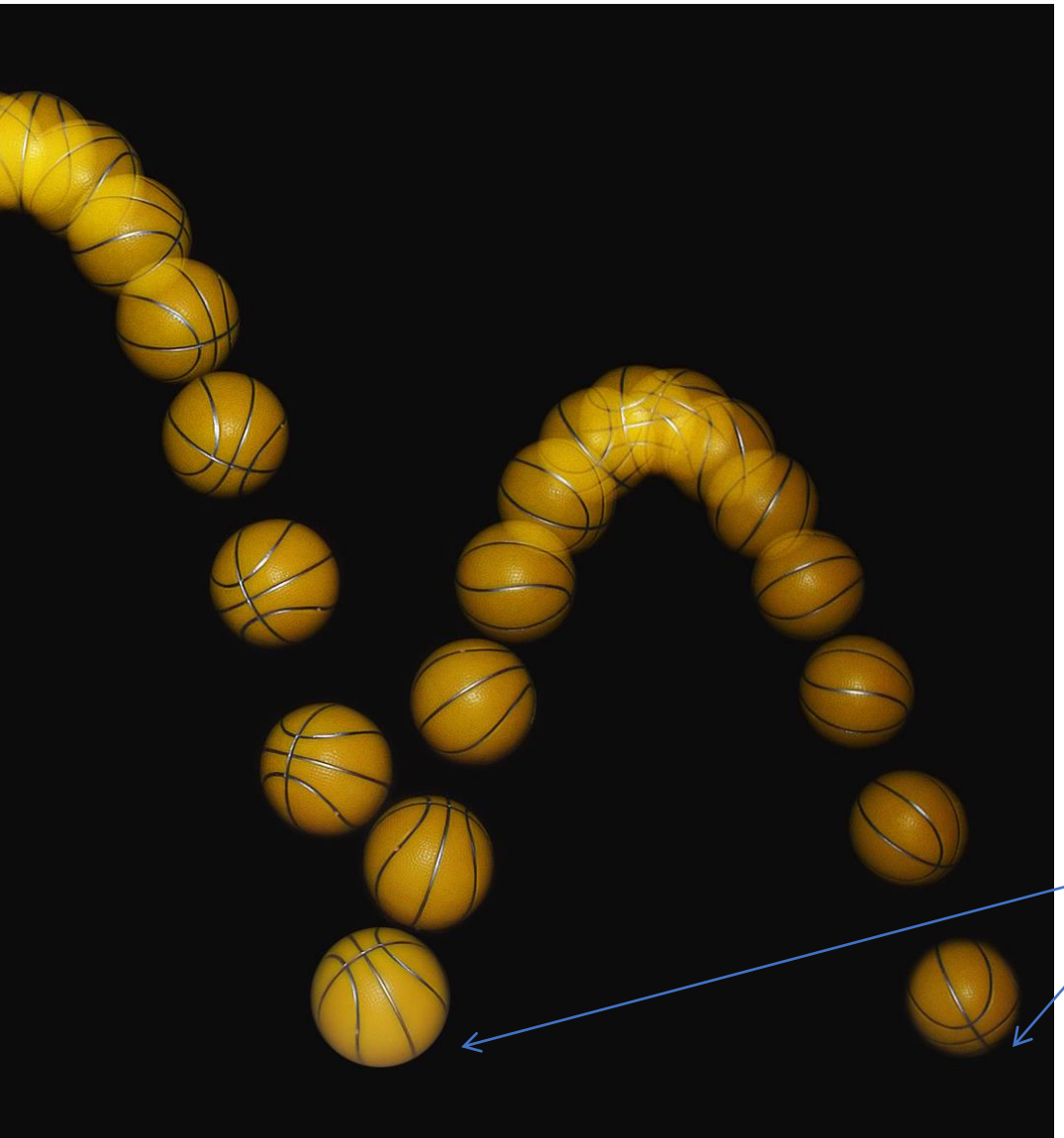
Collisions overview – Inelastic



- Momentum in (mv) = momentum out (for the whole system)
- Kinetic energy in = $\frac{1}{2}mv^2 \neq$ kinetic energy out

Image credit: wikipedia

Collisions overview – Inelastic



Momentum in (mv) = momentum out (for the whole system)

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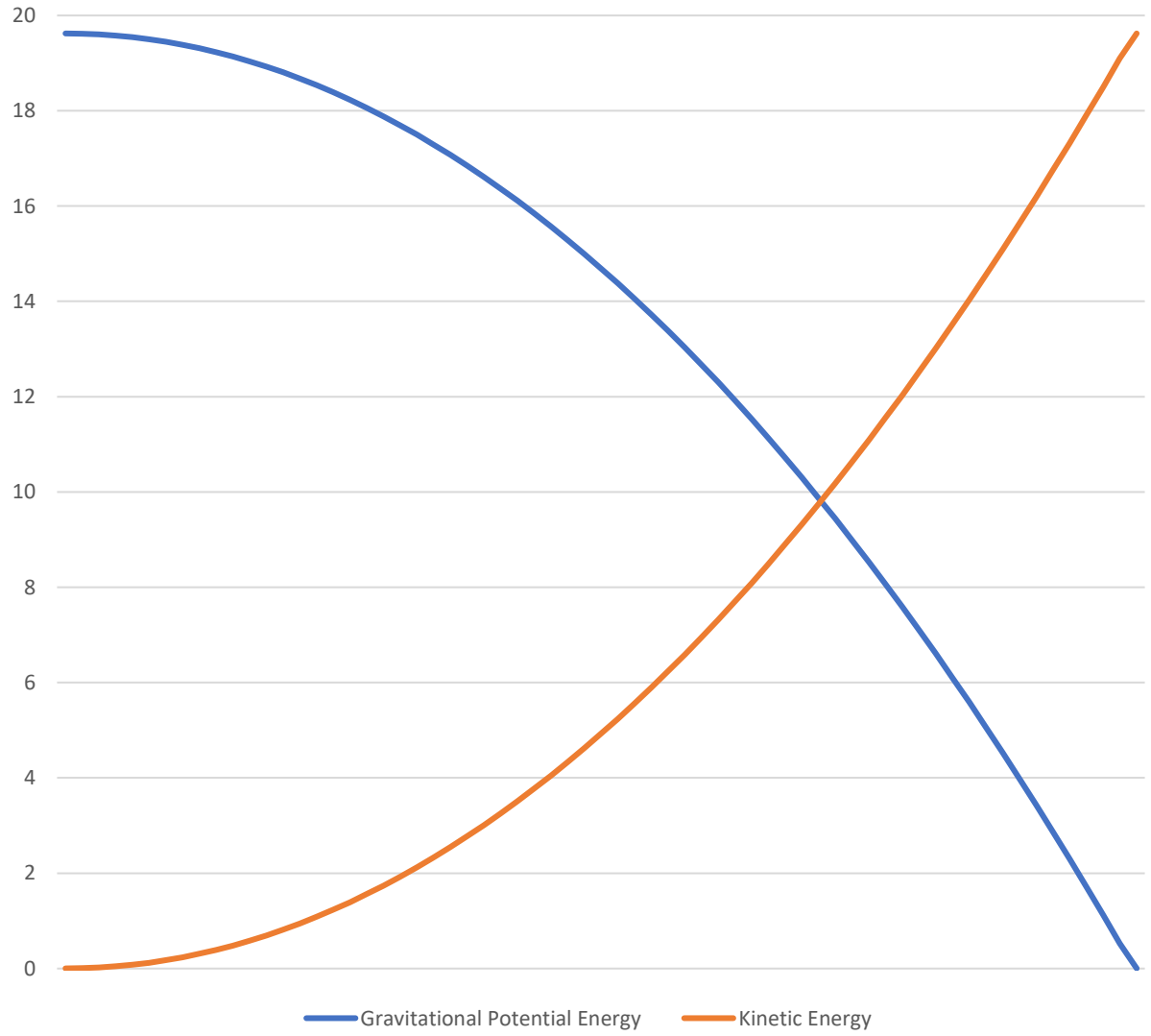
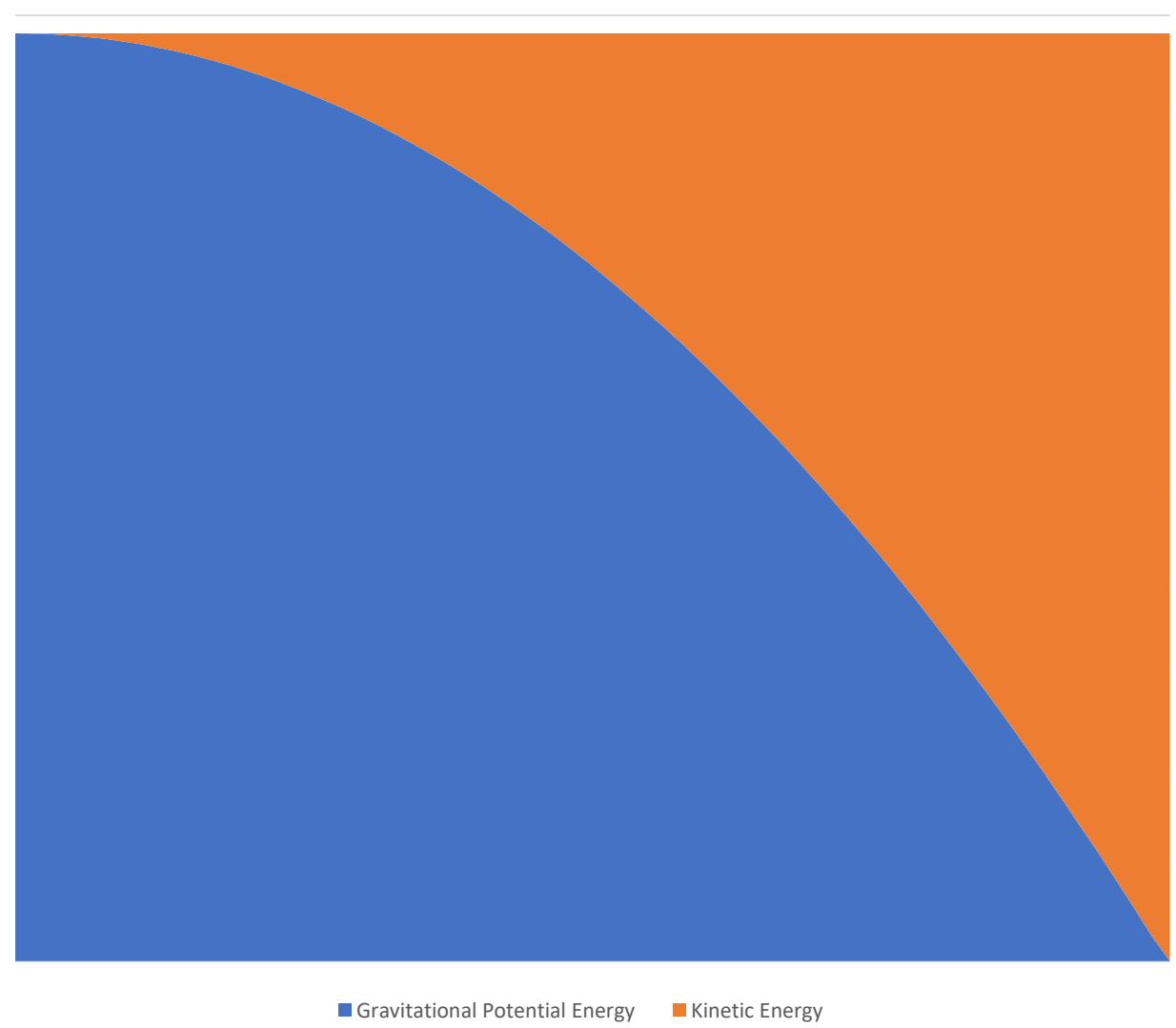
Some KE into-> Sound and heat here

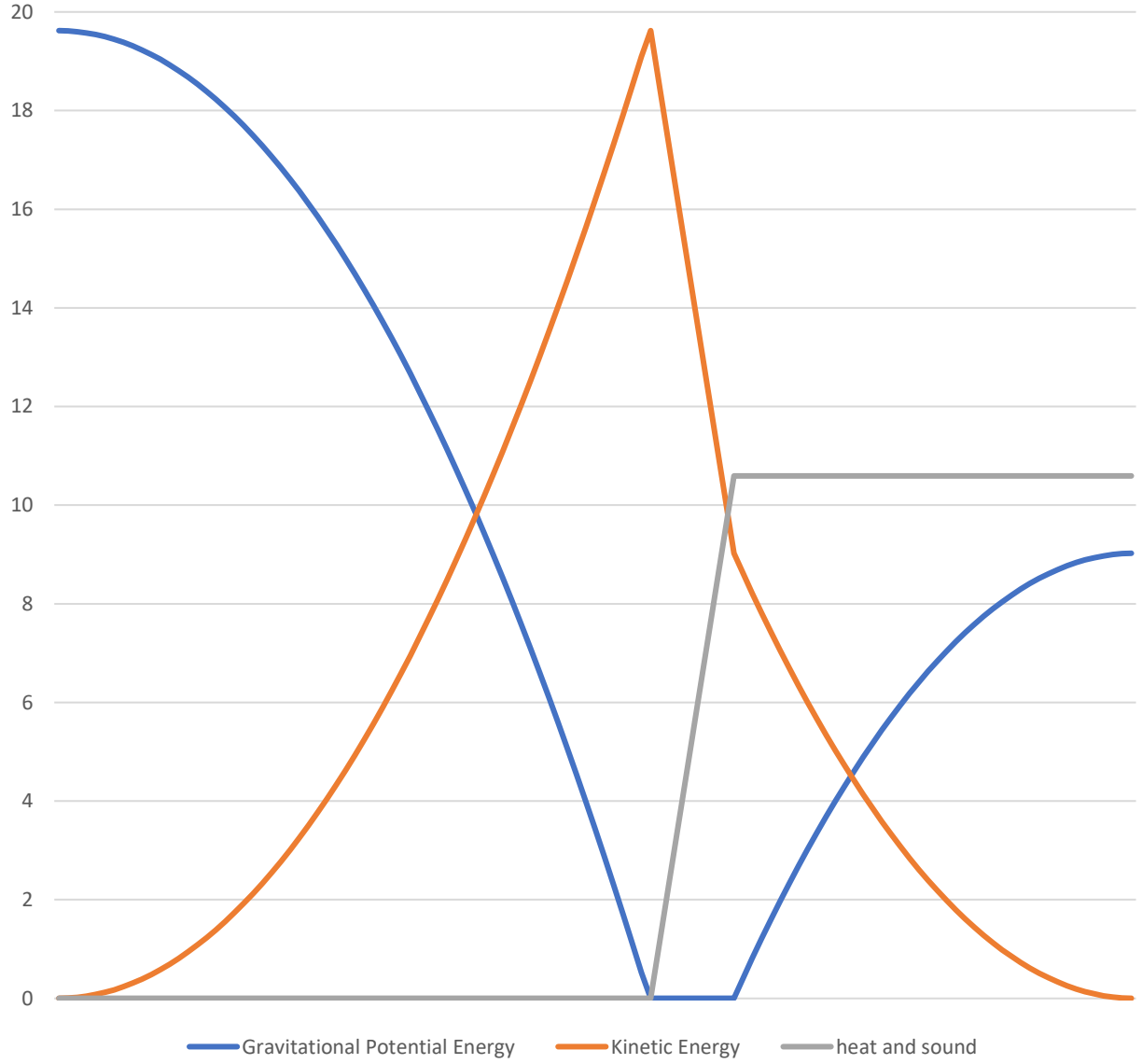
Image credit: wikipedia

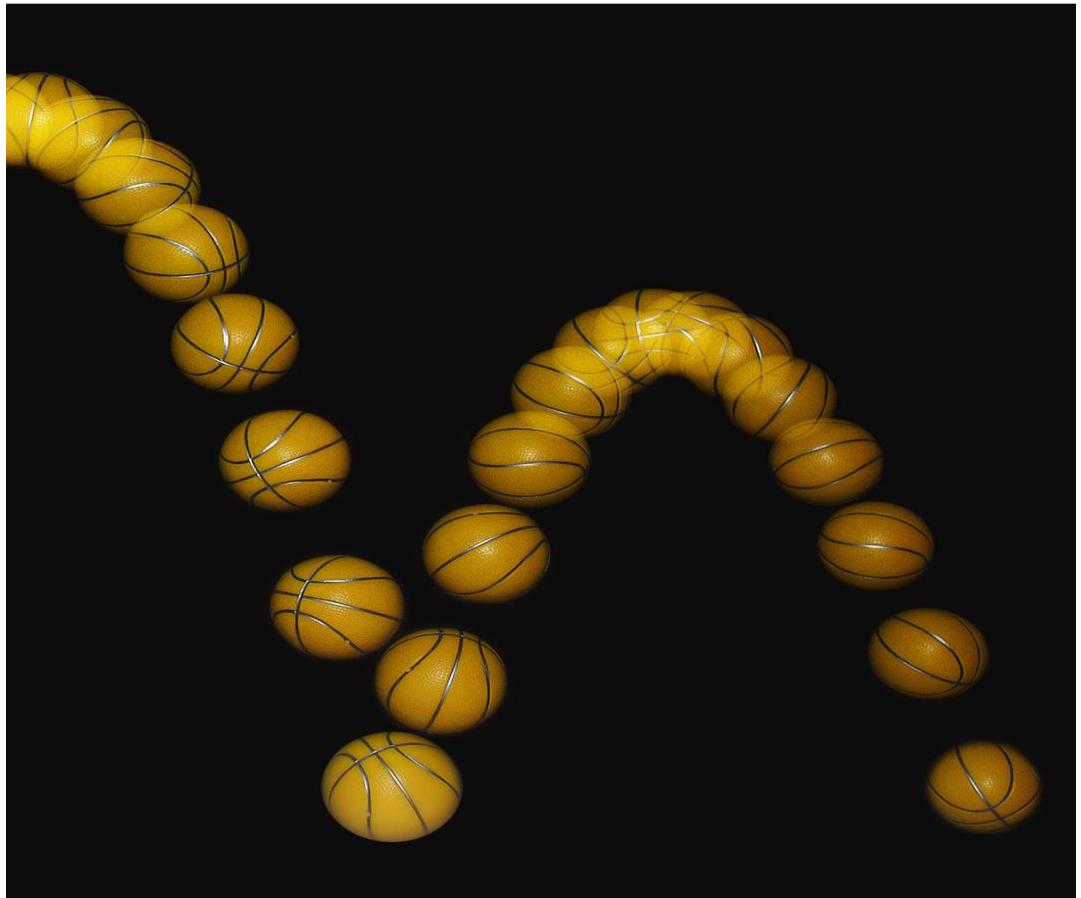
Energy of a Falling Object





Energy of a Bouncing Object





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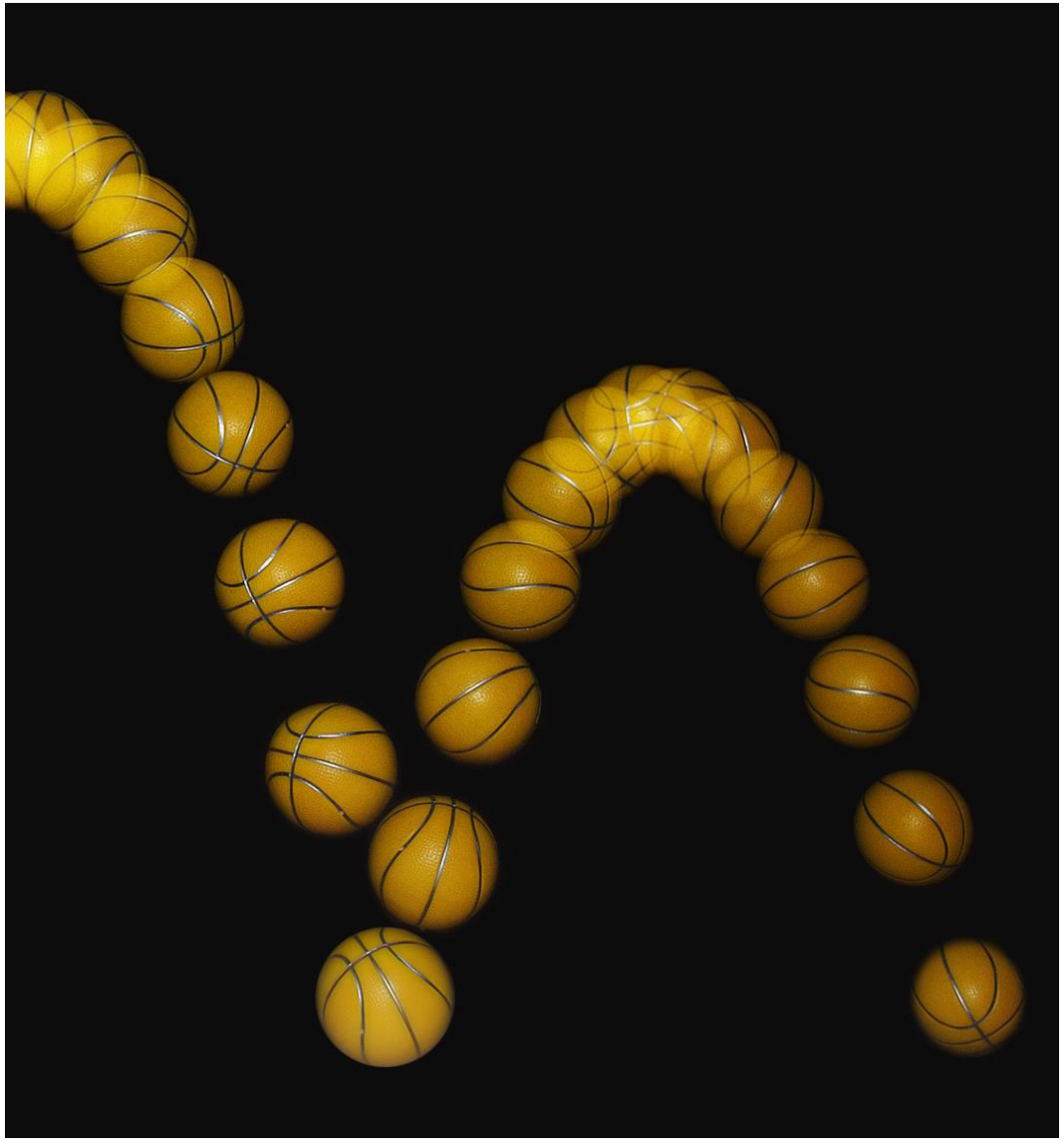
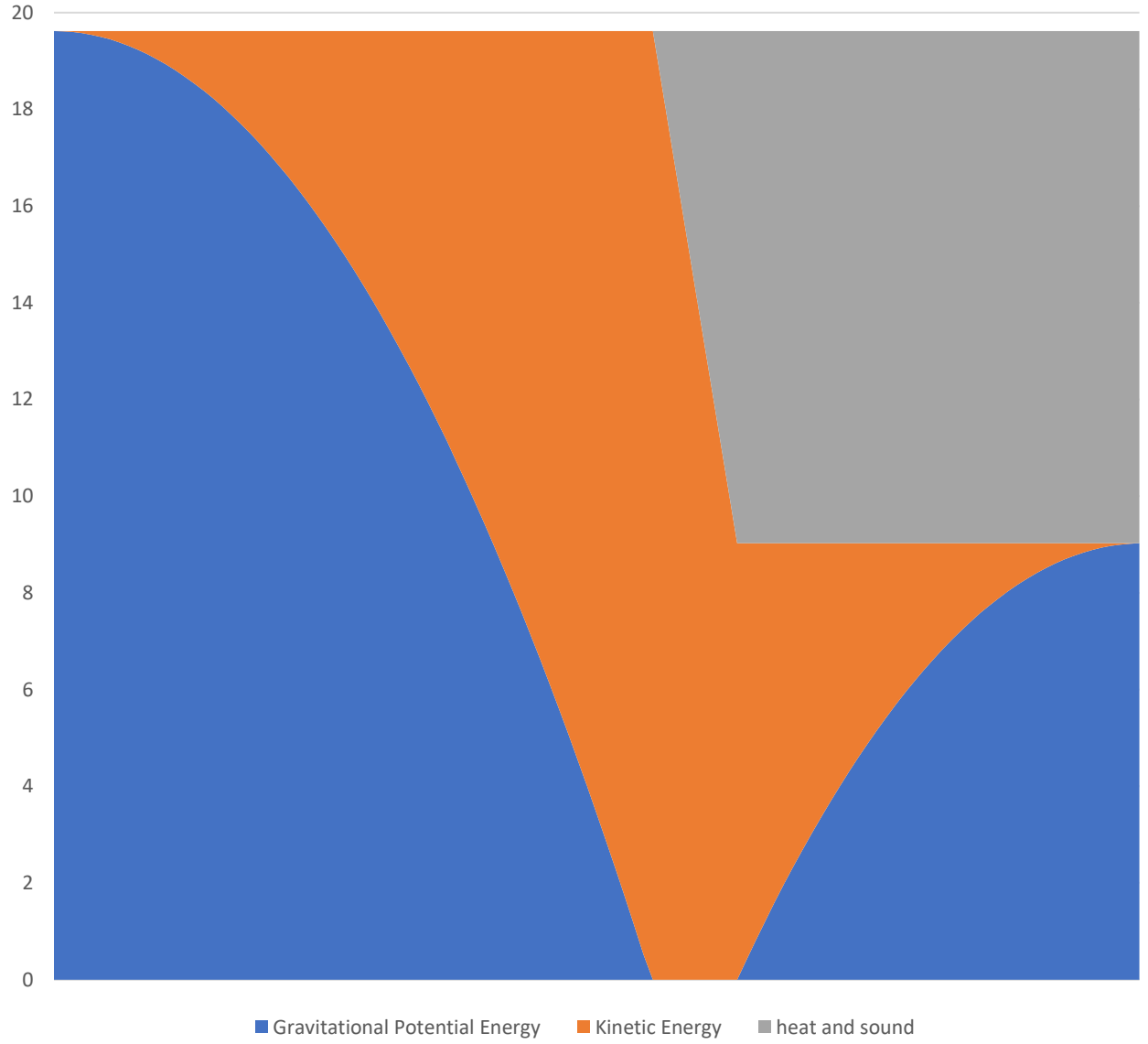




Acceleration during collision

- (Whiteboard)
- $5\frac{m}{s} \rightarrow -1.25\frac{m}{s}$, and lets say that takes 0.1 s to completely bounce
- $v_f = v_i + at$
- Rearranging
- $a = \frac{v_f - v_i}{t}$
- $a = \frac{6.25\frac{m}{s}}{.1s} = 62.5\,\frac{\mathrm{m}}{\mathrm{s}^2} \approx\ 6\mathrm{g}$

Restitution

- Simple Basketball Experiment

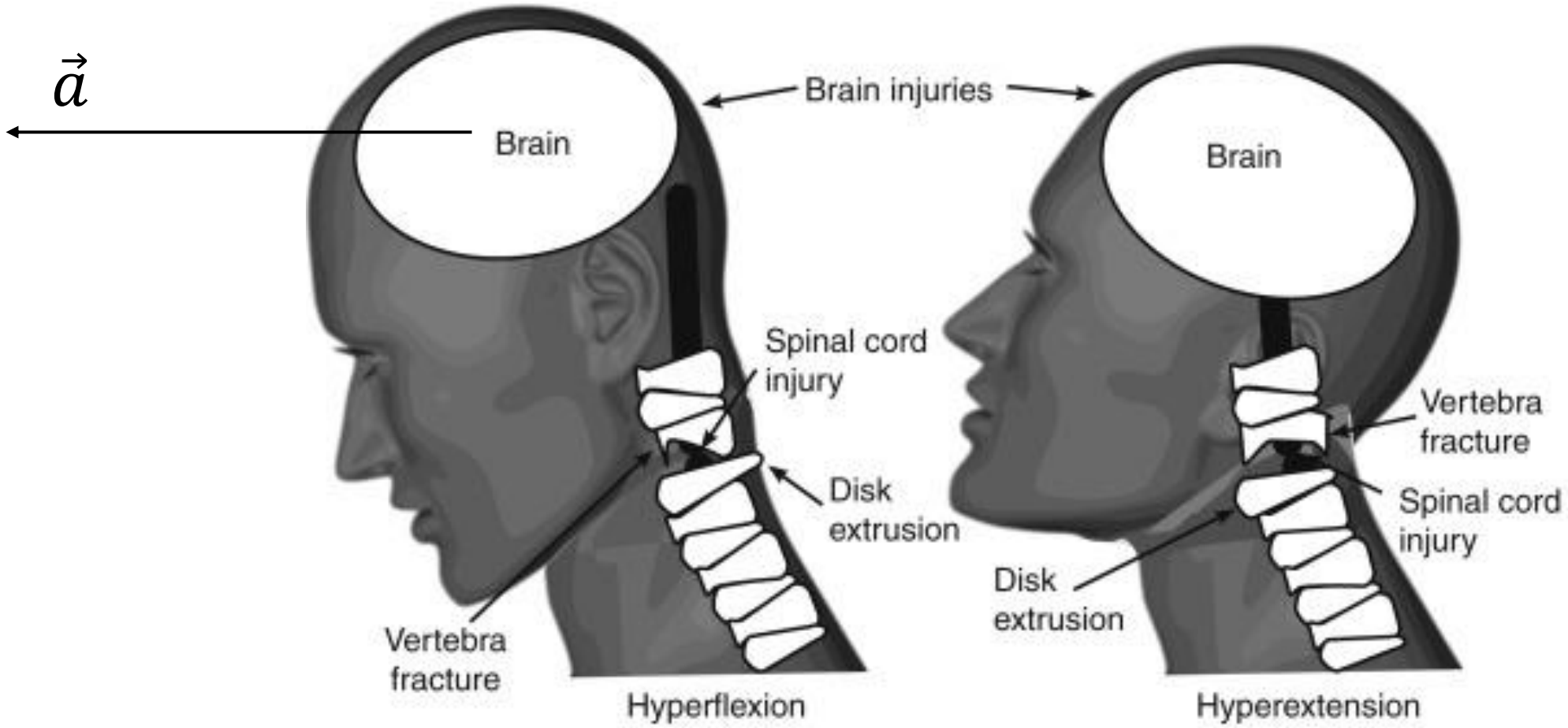
Restitution

- **Newton's law of restitution** says that when two objects collide, their speeds after the collision depend on the material from which they are made

Restitution properties

- Depends on
  - Shape of materials
  - geometry of collision
- When the material can be deformed or broken (its yield strength defeated) the coefficient of restitution will be lower

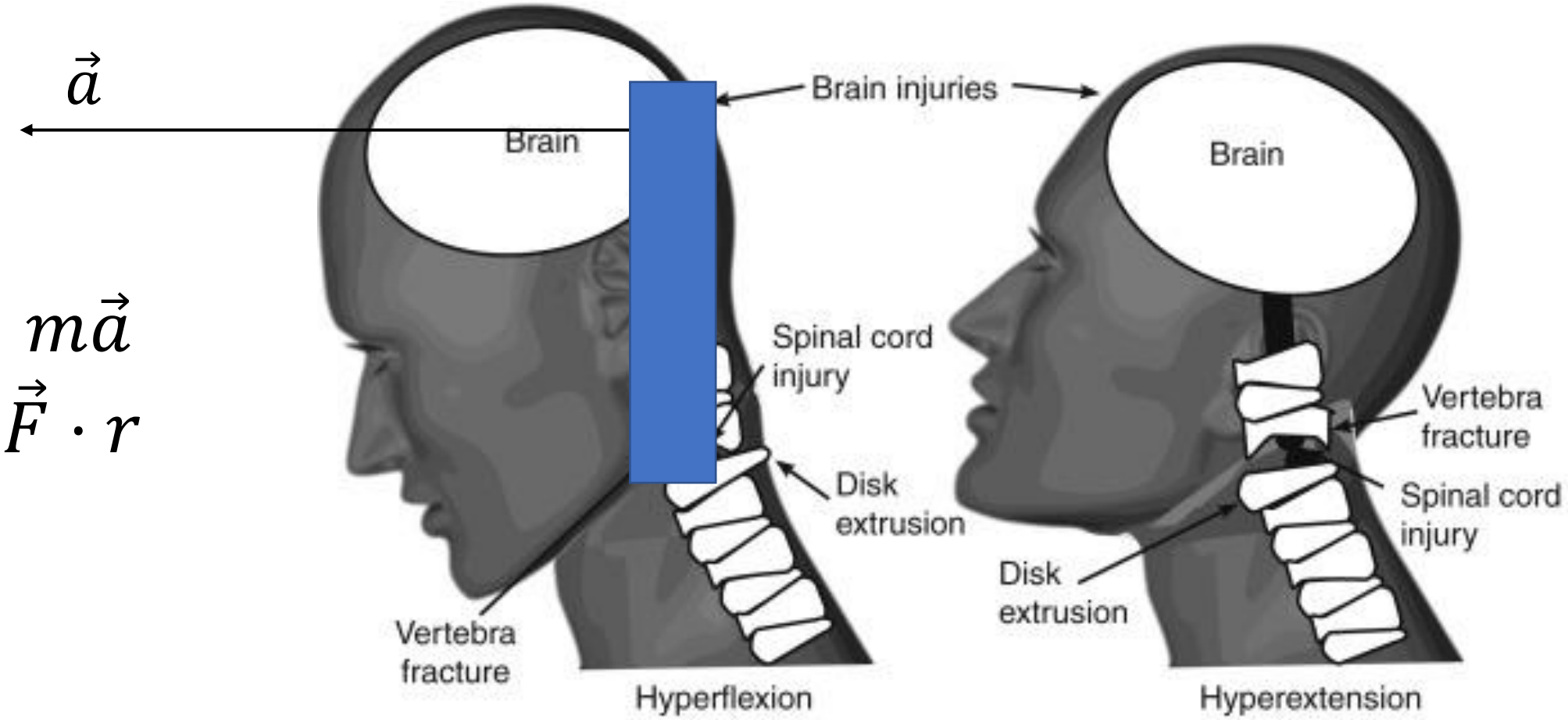
Acceleration can hurt humans!



Acceleration can hurt humans!

$$\vec{F} = m\vec{a}$$

$$\tau = \vec{F} \cdot r$$

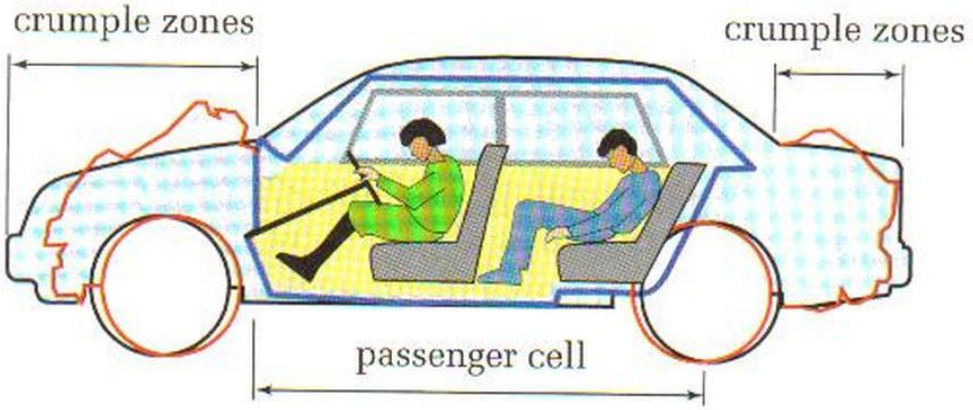


How do we cause less harm in collisions?

- How can we reduce acceleration?
- (live demo)

Brainstorming Solutions

- How might we try to make the passengers in the vehicle safer
  - crumple zone to absorb energy and a passenger zone, which can't be crushed



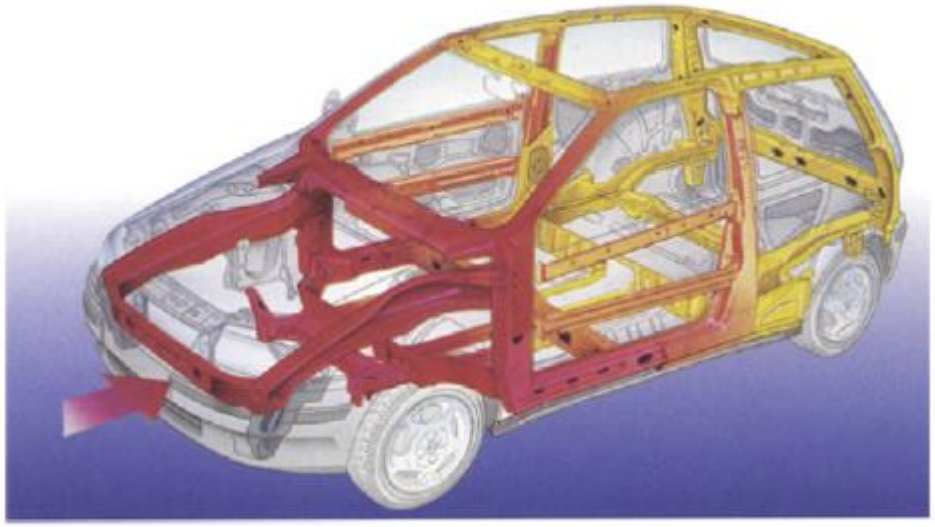


Image Source:
left cartrade.com
right: Vehicle Collision Dynamics by Dario Vangi

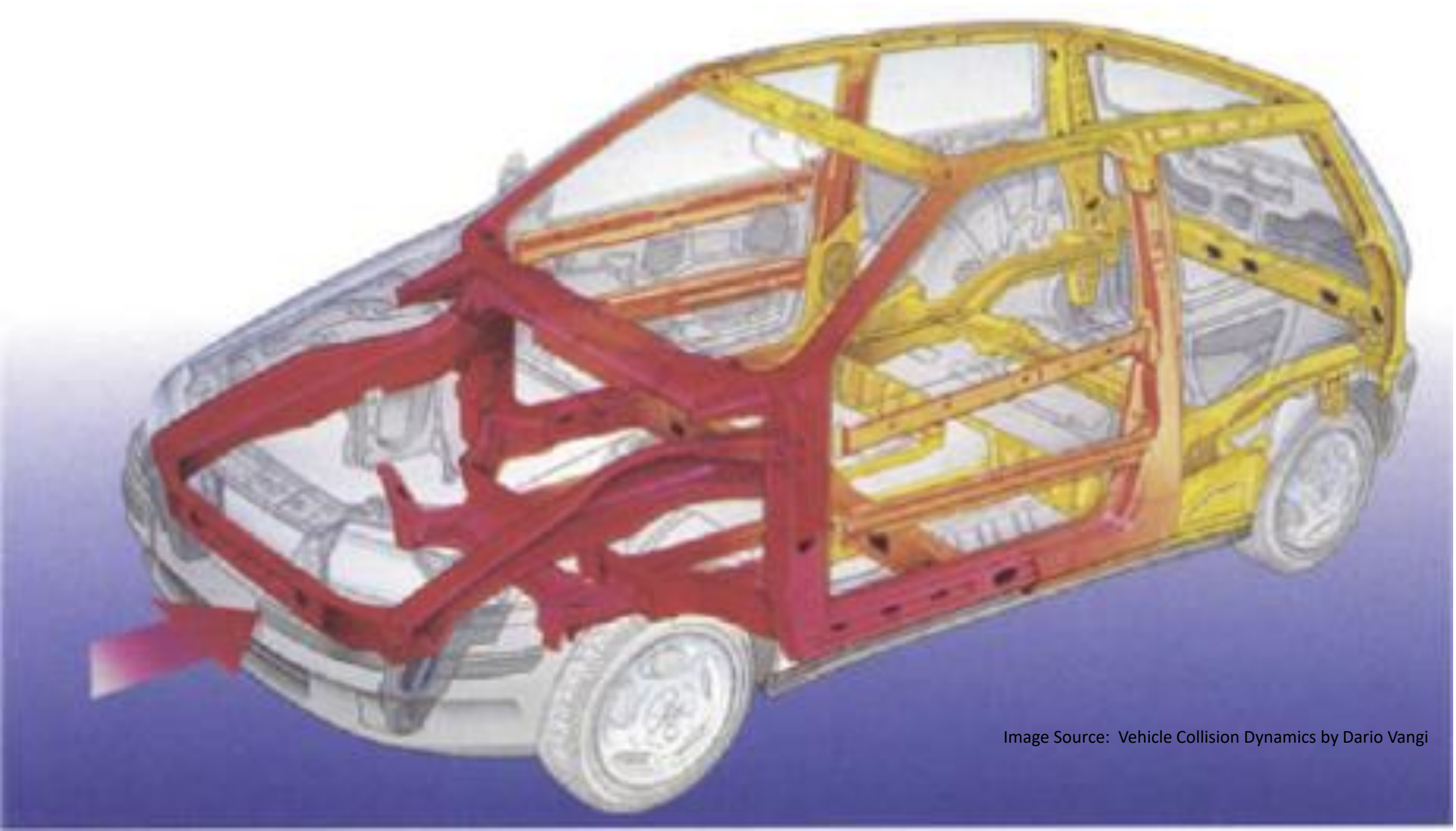


Image Source: Vehicle Collision Dynamics by Dario Vangi

Material	Collision Duration (end – start) (s)	Peak acceleration (m/s^2)	Comments
Baseline (no bumper)			
Big bubble			
cardboard foil cone			
Tin foil cone single layer			
Tin foil cone 4x layer			
Bubble Wrap			
Cardboard tube			
Styrofoam 1			
Styrofoam 2			

Crumple zone technology has improved over the years

Figure 4 Comparison of three Saab models: 1995, 1999, and 2003.

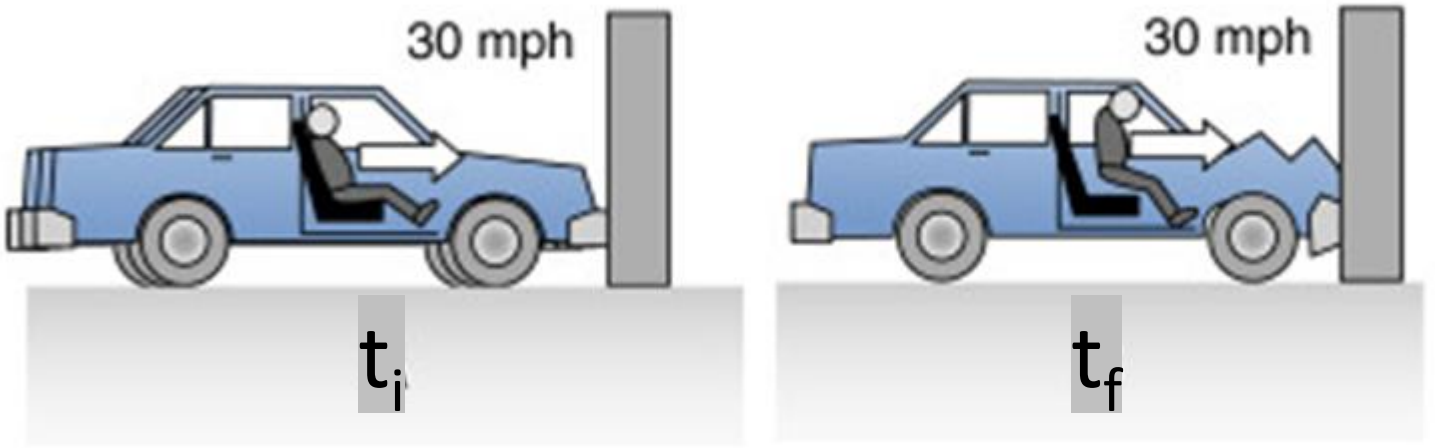
1995 Saab 900—Poor structure

1999 Saab 9-3—Improved structure

2003 Saab 9-3—Good structure

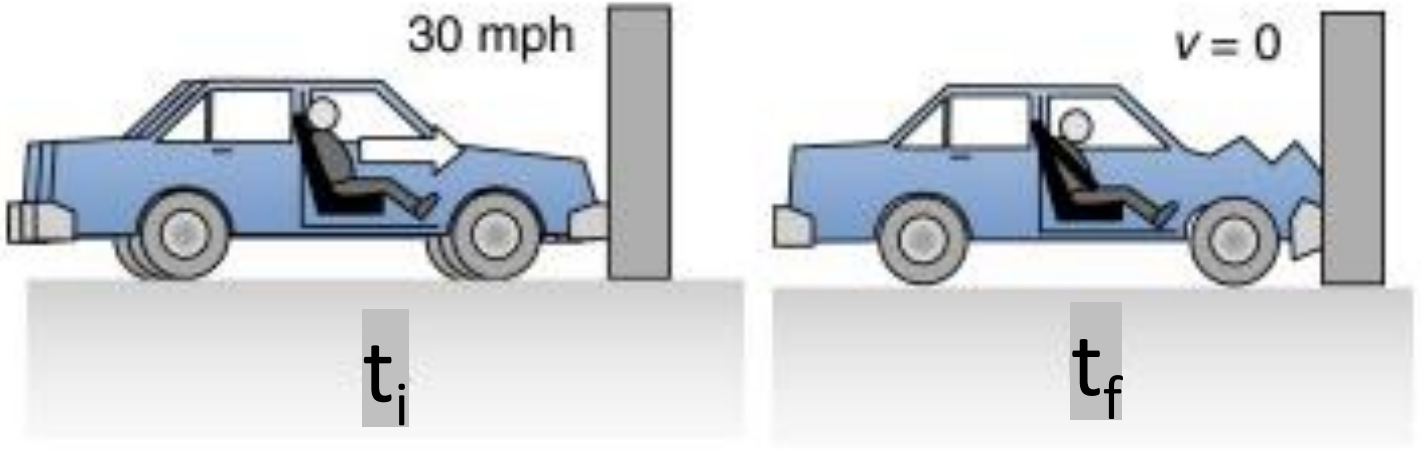
It won't work without the seatbelt & airbag

Without Seatbelt:



- Newton's first law: passenger in the top vehicle continues moving inside the vehicle has their own new collision inside the car
- All the work absorbing the crash and spreading out the impulse of the crash isn't passed to the passenger if they aren't wearing a seatbelt

With Seatbelt:

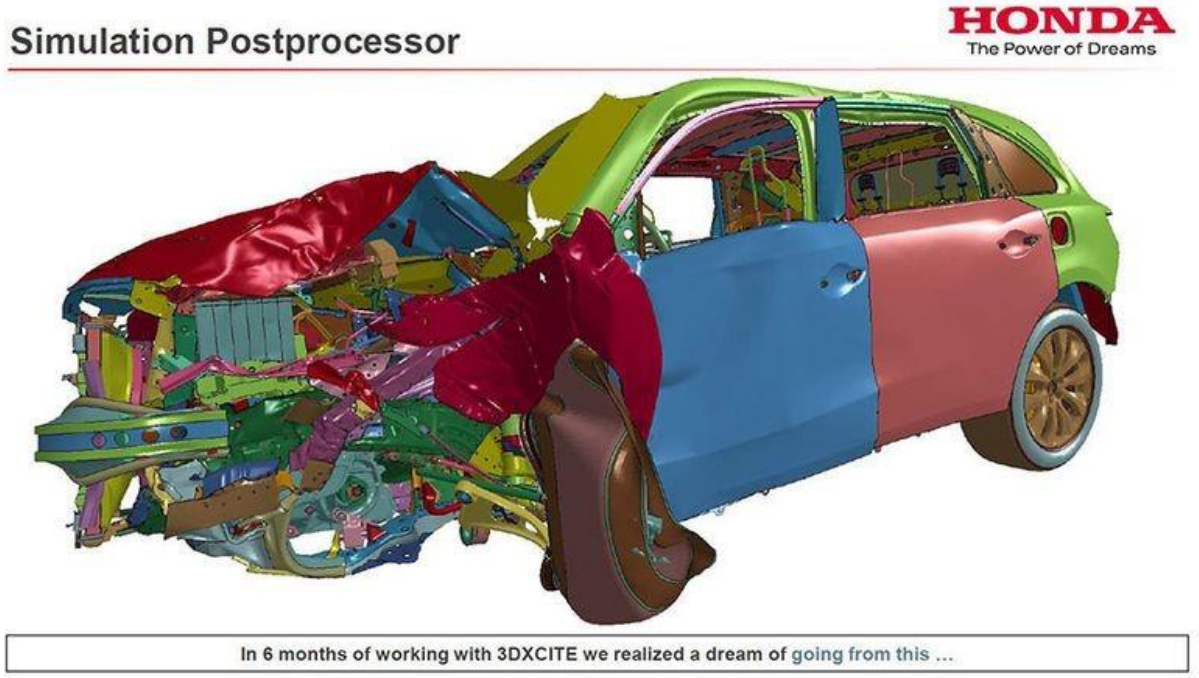


Source image: Exploring Engineering 5th edition Chapter 16 Bioengineering

Real life crash testing and simulations

- Vehicle manufacturers are still required to perform crash tests
- They also use that crash data to inform their crash simulations
- Its possible to do a really cool approximation of large scale crash test with simple stuff like your phone and some household items

Honda R&D Americas, Inc. May 2014



Questions?