"Coming to a stop" – how does it work?

In 3.6 Giordano discusses the options a jumper has to soften the blow by bending in the knees:

The free-fall acceleration of the body with $g = 9.8 \frac{m}{s^2}$ in the downward direction not only is compensated by the normal force transmitted through the feet, but one also has to cut the velocity to zero by an upward net force

"A car hitting a wall without massive injuries to the passengers" is an engineering problem that received considerable attention in the 1970ies [as a result of political advocacy and lawsuits, cf. Ralph Nader]

"old-fashioned" approach: car is a massive, rigid cage

→ doesn't work → passengers are thrown around

→ seat belts

→ better answer: front + back of car have bumpers + fenders with crumple zones

Idea: • Car body compresses by Δx during impact

• $v_f = 0$, $v_i \neq 0$

$$v_f^2 = v_i^2 + 2a\,\Delta x$$

← assume constant deceleration ($a < 0$) acting over a short time

$v_f = 0$ $\quad\therefore\quad a\,\Delta x = -\frac{v_i^2}{2}$

$$\boxed{a = -\frac{v_i^2}{2\,\Delta x}}$$

small Δx → large $|a|$ } bad!

Powerful idea:
- avoid talking about time
- look at change in velocity (from v_0 to zero)
- assumed constant (neg.) acceleration ↔ maybe incorrect?

Model applied:
- as the front of the car makes impact
- action/reaction force pair [car hits wall; wall reacts on car]
- centre of mass of the car still moving, getting closer to the wall
- centre of mass undergoes $v_0 \rightarrow v_f = 0$

By definitions: $a = \frac{\Delta v}{\Delta t}$ would involve knowledge of Δt!

Kinematic eqn $v_f^2 = v_i^2 + 2a\,\Delta x$ allows to relate directly a and Δx.

Concrete estimates: a can be a multiple of g

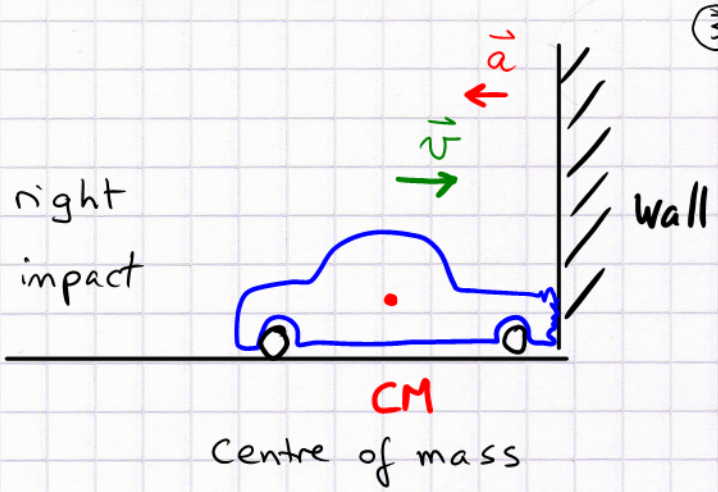
Question: can our body sustain a fall from heights such as $h = 5$ m? → paratrooper training

Answer: this requires training (allow sufficiently large Δx)

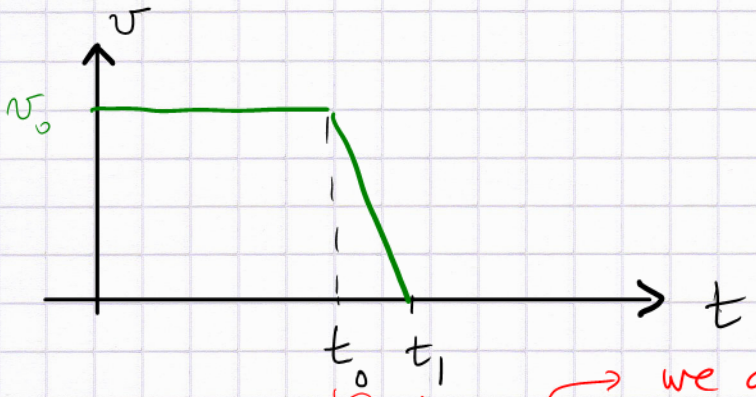
Engineering: can a car bumper sustain an impact of up to 8 km/h without damage?
↳ need large-Δx crumple zone and or "shocks"

Pictorial representation

CM continues to move to the right as the front of the car makes impact



Velocity decreases



t_0 : front of car hits wall

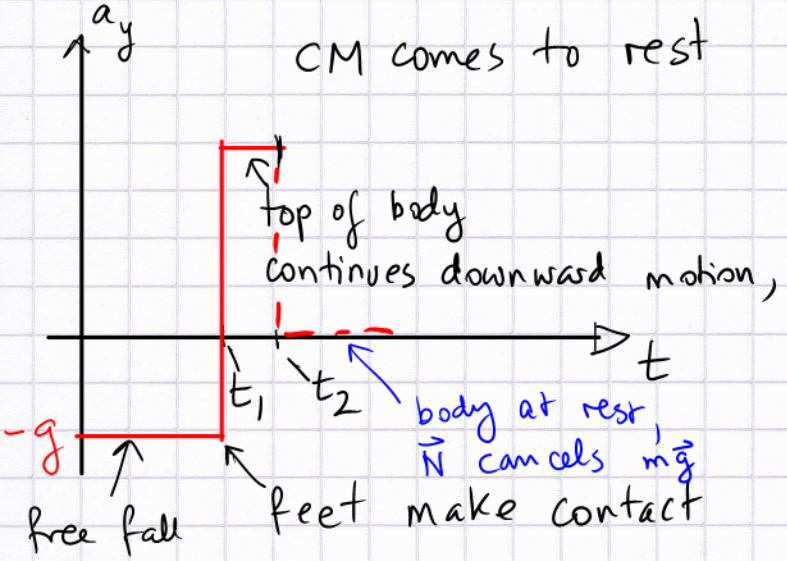
t_1 : CM comes to rest

(no rebound)

we assumed constant $a = \frac{\Delta v}{\Delta t}$

The jumping girl :

start with the acceleration, measure positive y-motion up



Knees/legs break fall; normal force exceeds gravity by large amount