Ethics of a Self Driving Car - Study Guide

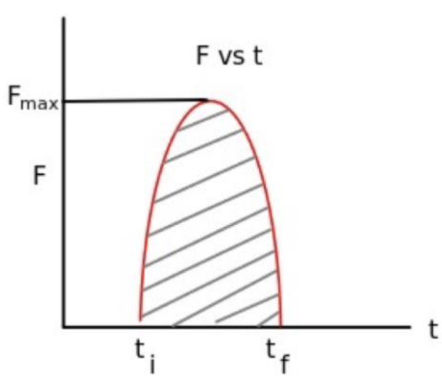
Newton's 3 Laws of Motion

1. An object at rest will stay at rest, and an object in motion will stay in motion at constant velocity (speed) unless an unbalanced force acts on the object.
2. **F = ma;** more force = more acceleration and therefore **directly proportional.** More mass = less acceleration and therefore **indirectly proportional**
3. Forces occur in pairs. For every action, there is an equal and opposite reaction

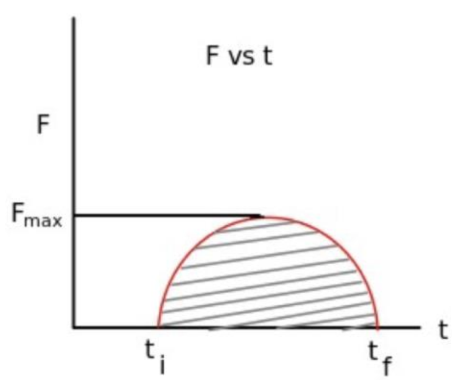
- **Motion** is a change in position measured by **distance** and **time.**
- **Speed** tells us the rate at which an object **moves.**
- **Velocity** tells us **speed,** and in what **direction.**
- **Acceleration** tells us the change in **velocity** over **time.**
- **Impulse** changes the **momentum** of an object
- **Force** is a **push** or **pull**
- **Inertia** is **Newton's First Law of Motion**, an object resisting change in speed or direction
- **Impulse** is the overall effect of a force acting over time. The unit is **N·s.**
- **Momentum** is a measurement of mass in motion. **p** = **mv.** Momentum is a vector quantity so it has size and direction. The unit is **kg·m/s.**

A **force-time graph** tells us the **force** applied to an object over **time**, or in a collision. **Area** is important!

- **Force** and **collision** time are **inversely** related. Therefore, big **F** = little **t** and big **t** = little **F**
- A **hard** collision will have a **large force** over a **short collision time**
- A **soft** collision will have a **small force** over a **long collision time**



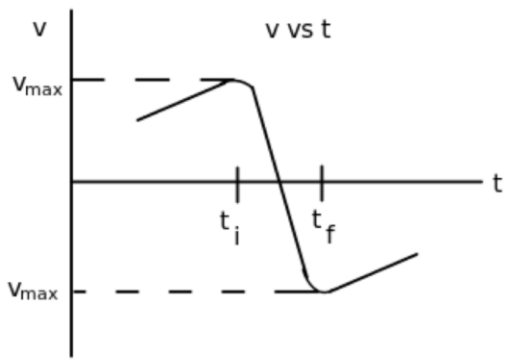
Hard Collision



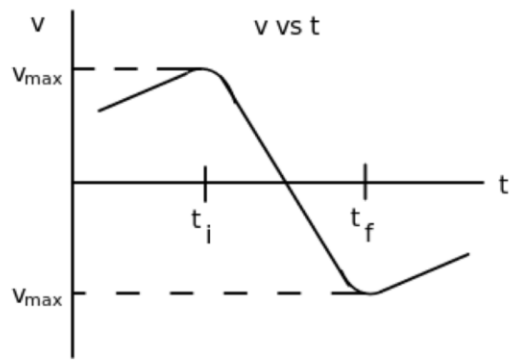
Soft Collision

A **velocity-time** graph tells us the acceleration of an object.

- **I** = **Ft**. Impulse **(Ft)** is really the change in momentum **(mv)**.
- **Impulse** is the change in momentum so, **Ft** = $\mathbf{mv_f}$ - $\mathbf{mv_i}$
- **Initial velocity** - **m/s**, starting from rest, initially/beginning, how fast
- **Final velocity** - **m/s**, comes to a stop/rest, finally/end, how fast
- **Mass** - **kg**, how much stuff
- **Time** - **s**, how long
- **Force** - **N**, a push or pull



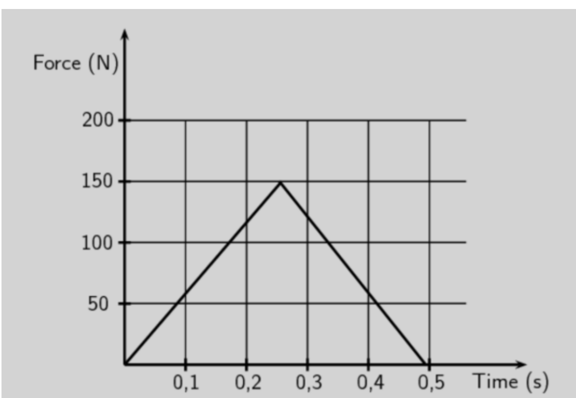
Hard Collision



Soft Collision

- Things that absorb force (lessen force) by increasing the time of the collision.
- Impulse (change in momentum) is set.

Finding the **area** under the graph will give you the **impulse.**



Area of triangle = **½ bh**
A = ½ x 0.5 × 150
A = 37.5

I = $\mathbf{F_{average}}$ x t
(The average force is half of the maximum because it is changing at a steady rate)
I = 75 × 0.5
I = 37.5 N·s

The fronts of modern cars are deliberately designed in such a way that in case of a head-on collision, the front would crumple. Why is it desirable that the front of the car should crumple?

If the front crumples then the force of the collision is reduced. The change in momentum or the impulse of the collision would go into making the front of the car crumple and so the passengers in the car would feel less force. Longer collision time = smaller force.

<u>Momentum</u>

Momentum is mass times velocity. **p** = **mv**

Momentum is a vector quantity so it has direction.

Example: A 2250 kg pickup truck has a velocity of 25 m/s to the east. What is the momentum of the truck?

m = 2250 kg **v** = 25 m/s to the east

p = **mv**
p = (2250 kg)(25 m/s east)
p = 56,250 kg·m/s to the east

Practice Problem:
1. A deer is heading south with a mass of 146 kg is running head-on towards you with a speed of 17 m/s. Find the momentum of the deer.

2. The momentum of a student on a scooter is 84 kg·m/s. If the mass of the student is 61 kg, how fast is the student moving?

Impulse-Momentum Theorem

A change in **momentum** depends on the change in velocity. The amount the momentum changes is the impulse and will then control the force and time:

- A **fast** ball stings because it was moving faster when it hits and therefore exerts **more force** if it stops in the same amount of time
- A **slow-moving** ball was moving slower and therefore exerts **less force** if it stops in the same amount of time

$$\mathbf{F} = \frac{\Delta p}{\Delta t} \qquad \textbf{force} = \frac{\textbf{change in momentum}}{\textbf{time interval}}$$

Impulse-momentum theorem: **force × time interval** = **change in momentum**

$F\Delta t = \Delta p$ and $\Delta p = mv_f - mv_i$

$F\Delta t = mv_f - mv_i$

Example 1: A 1400 kg car moving eastward with a velocity of 15 m/s collides with a utility pole and is brought to rest in 0.30 s. Find the force exerted on the car during the collision.

m = 1400 kg $\qquad$ **Δt** = 0.30 s $\qquad$ v_i = 15 m/s $\qquad$ v_f = 0 m/s

Impulse-momentum theorem: $F\Delta t =$ $F\Delta t = mv_f - mv_i$ or $F = \frac{mv_f - mv_i}{\Delta t}$

$$F = \frac{(1400 \text{ kg})(0 \text{ m/s}) - (1400 \text{ kg})(15 \text{ m/s})}{0.30 \text{ s}}$$

$$F = \frac{-21{,}000 \text{ kg·m/s}}{0.30 \text{ s}}$$

F = -70,000 **N** or 70,000 N to the **west**

Example 2: If instead, the car in the previous problem is brought to rest in 1.1 s because it has an improved crumple zone, how much force will be exerted on the car during the collision.

m = 1400 kg $\qquad$ **Δt** = 1.1 s $\qquad$ v_i = 15 m/s $\qquad$ v_f = 0 m/s

Impulse-momentum theorem: $\mathbf{F\Delta t}$ = $\mathbf{F\Delta t}$ = $\mathbf{mv_f - mv_i}$ or $\mathbf{F} = \frac{\mathbf{mv_f - mv_i}}{\mathbf{\Delta t}}$

$$\mathbf{F} = \frac{(1400\text{ kg})(0\text{ m/s}) - (1400\text{ kg})(15\text{ m/s})}{1.1\text{ s}}$$

$$\mathbf{F} = \frac{-21{,}000\text{ kg}\cdot\text{m/s}}{1.1\text{ s}}$$

F = -19,090 **N** or 19,090 N to the **west**

Practice Problem:

1. A 0.50 kg football is thrown with a velocity of 15 m/s to the right. A stationary receiver catches the ball and brings it to rest in 0.20 s. What is the force exerted on the ball by the receiver?

Conservation of Momentum: For collisions, the total momentum of the objects before the collision is equal to the momentum of the objects after the collision.

$\mathbf{p_i} = \mathbf{p_f}$

$\mathbf{p_{1i} + p_{2i} = p_{1f} + p_{2f}}$ (**2** objects collide and separate**)**

$\mathbf{m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}}$

$$\mathbf{m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_f}$$ **(2** objects collide and stick together**)**

Practice Problems

1) Two grocery carts collide, a full one with a mass of 35 kg moving East at 2 m/s and an empty one with a mass of 10 kg moving West at 3 m/s. After the collision, the full cart is moving East at 0.75 m/s. What is the velocity of the empty cart?

2) Two football players have a head-on collision and grab onto each other's uniforms. The 80 kg Pennridge Ram was moving at 3 m/s, while the 70 kg Souderton player was moving in the opposite direction at 2.5 m/s. What is their final velocity after impact?

3) Two cars have a 'rear end' collision. A 1200 kg Honda moving at 20 m/s strikes a 1000 kg Ford moving at 15 m/s. Their bumpers become locked and they continue to move as one mass. What is their final velocity?