Mon: HW by 5pm

Weds: Warm Up 11 / Group Ex

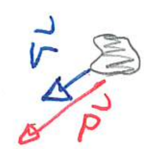
Thurs: Discussion/quiz
Ex 264, 267, 268, 269, 270, 273, 274

Momentum

We will consider situations where objects interact with each other while their surroundings have no overall affect on their motion

Demo: Skipping collision video

The crucial quantity in this analysis will be momentum. For a single object

> The momentum of an object with mass m and velocity $\vec{v}$ is
>
> $$\vec{p} = m\vec{v}$$
>
> 
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Recall that momentum:

1) is a vector
2) has the same direction as velocity.

Given a system of many objects we can combine their individual momenta.

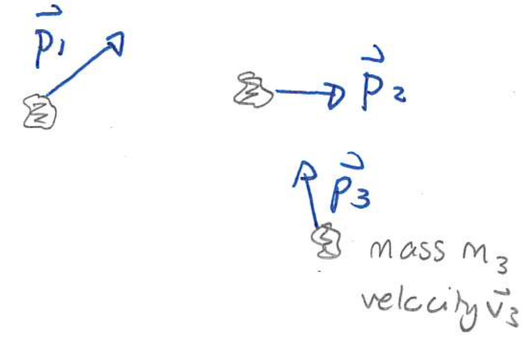
The net (total) momentum of a system is

$$\vec{p}_{tot} = \vec{p}_1 + \vec{p}_2 + \ldots$$

where

$$\vec{p}_i = m_i \vec{v}_i$$

is the momentum of particle i



ADD VECTORS

The total momentum is a vector sum. Provided that the collision is in one dimension, we can describe directions as positive or negative

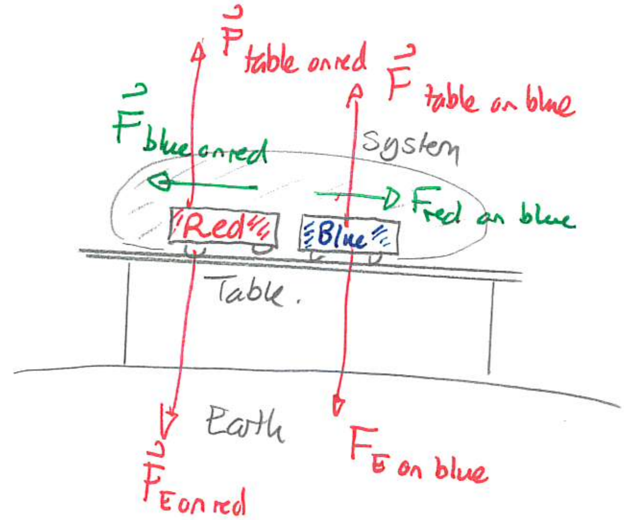
Quiz 1 80% – 95%

Conservation of momentum

Now consider a system of objects that can interact with each other and also objects in their surroundings. In the example

System = red cart + blue cart

Surroundings = Earth, table



We split the forces into two categories:

1) Internal force ~ exerted by one part of the system on another part of the system

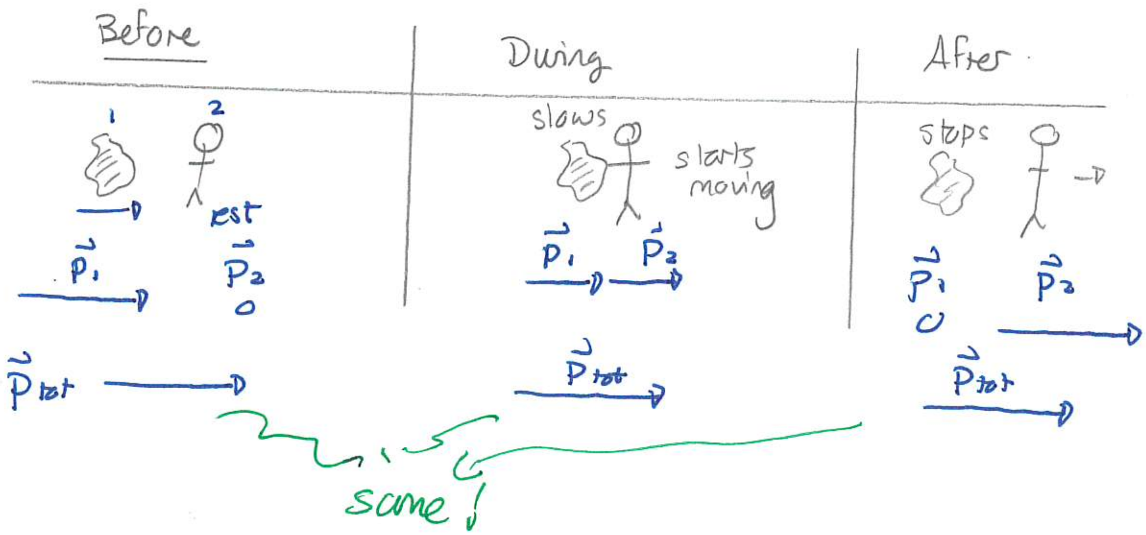
2) external force ~ exerted by surroundings on the system.

We can combine Newton's 2nd and 3rd Laws to show:

> If the net external force on a system is zero then the total momentum of the system stays constant.

This is the <u>conservation of momentum</u>.

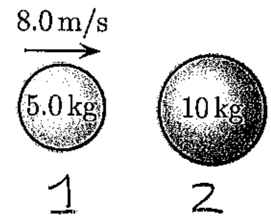
This is useful for collisions. For example:



Quiz 2 80% - 95%

263 Colliding balls, 1

Two balls, isolated from all other objects, are initially as illustrated. The 5.0 kg ball moves directly toward the 10 kg ball. They collide and subsequently the 10 kg ball moves right with speed 3.0 m/s. The aim of this exercise will be to determine the speed and direction of motion of the smaller ball after the collision. *(111F2023)*



a) Determine the momentum of the smaller ball before the collision.

b) Determine the momentum of the larger ball before the collision.

c) Determine the momentum of the system before the collision.

d) Determine the momentum of the larger ball after the collision.

e) Determine the momentum of the smaller ball after the collision.

f) Determine the velocity of the smaller ball after the collision.

g) Suppose that the construction of the balls was different and that after the collision the larger ball moves right with speed 5.0 m/s. Determine the velocity of the smaller ball after the collision.

Answer: In the following, right is positive, left negative.

a) $p_{1i} = m_1 v_{1i} = 5.0\,\text{kg} \times 8.0\,\text{m/s} = 40\,\text{kg m/s}$

b) $p_{2i} = m_2 v_{2i} = 10\,\text{kg} \times 0\,\text{m/s} = 0\,\text{kg m/s}$

c) $p_{tot\,i} = p_{1i} + p_{2i} = 40\,\text{kg m/s}.$

d) $p_{2f} = m_2 v_{2f} = 10\,\text{kg} \times 3.0\,\text{m/s} = 30\,\text{kg m/s}$

e) $p_{tot\,f} = p_{1f} + p_{2f}$

$\parallel$

$p_{tot\,i}$

$\Rightarrow 40\,\text{kg m/s} = p_{1f} + 30\,\text{kg m/s}$

$\Rightarrow p_{1f} = 10\,\text{kg m/s}.$

f) $p_{1f} = m_1 v_{1f} \Rightarrow 10\,\text{kg m/s} = 5.0\,\text{kg}\, v_{1f}$

$\Rightarrow v_{1f} = 2.0\,\text{m/s}.$

g)

$$p_{tot\,f} = p_{tot\,i}$$

$$p_{1f} + p_{2f} = p_{1i} + p_{2i}$$

$$m_1 V_{1f} + m_2 V_{2f} = m_1 V_{1i} + m_2 V_{2i}$$

$$5.0kg\ V_{1f} + 10kg \times 5.0m/s = 5.0kg \times 8.0m/s + \cancel{10kg \times 0m/s}$$

$$\Rightarrow 5.0kg\ V_{1f} + 50kgm/s = 40kgm/s$$

$$\Rightarrow 5.0kg\ V_{1f} = -10kgm/s$$

$$\Rightarrow V_{1f} = -2.0m/s!! \quad \text{(moves left!)}$$

Explosions

In an explosion two objects initially move together and subsequently separate. In a typical example the objects are initially at rest and their total momentum is zero. This allows us to determine the ratio of their speeds after the explosion.

272 Jumping crowd

A crowd of 100000 people, each with mass 80 kg are at rest on Earth's surface. They all jump up simultaneously, leaving Earth's surface with speed 3.0 m/s (relative to the background). Determine Earth's recoil speed. *(111F2023)*

Answer:

$m_{people} = 80\,kg \times 10^5 = 8.0 \times 10^6\,kg$

$m_{Earth} = 6.0 \times 10^{24}\,kg$

$V_{Ei} = 0\,m/s \qquad V_{Ef} = ?$

$V_{Pi} = 0\,m/s \qquad V_{Pf} = 3.0\,m/s.$

$p_{tot\,f} = p_{tot\,i}$

$M_p V_{pf} + M_E V_{Ef} = 0 \quad \Rightarrow \quad M_E V_{Ef} = -M_p V_{pf}$

$\Rightarrow 6.0 \times 10^{24}\,kg\ V_{Ef} = -8.0 \times 10^6\,kg \times 3.0\,m/s$

$\Rightarrow V_{Ef} = -\dfrac{24 \times 10^6\,kg\,m/s}{6.0 \times 10^{24}\,kg}$

$= -4.0 \times 10^{-18}\,m/s$ ☒