Systems of Particles – Set 4

1. **Which would be more damaging – driving into a massive concrete wall, or driving at the same speed into a head-on collision with an identical car traveling toward you at the same speed? Explain.**

The damage will be equal because the IMPULSE will be the same.

① Brick wall; $\vec{J} = \Delta\vec{P} = \vec{P}_F - \vec{P}_I = -P_I$, $\vec{P}_F = 0$ since your car will stop

② Other car: $\vec{P}_F = 0$ still because the momentum of the system will be conserved. $\vec{P}_{TI} = 0$ if the other car is identical and has the same speed.

2. **A lunar vehicle is tested on Earth at a speed of 10 km/hr. When it travels as fast on the moon, is its momentum more, less, or the same?**

The momentum is the same since mass is independent of gravity. Weight is a force. eg: mg is your weight.

3. **It is generally much more difficult to stop a heavy truck than a skateboard when they are moving at the same speed. State a case where the moving skateboard (still moving at the same speed) could require more stopping force.**

To stop, you need a change in momentum, which is impulse. $\Delta P = \vec{J} = \int \vec{F} dt$. Impulse depends on time. So, to stop you could apply a small force for a long time or a large force for a short time. So if you want to stop the skateboard really quickly, it could require a very large force.

4. **A drain plug is opened in the bottom of a rolling car that is full of water. Consider the effects of speed, momentum, and kinetic energy of the rolling car.**

The speed of the car will
(a) increase (b) decrease [✓ (c) not change.]

The momentum of the car will
(a) increase [✓ (b) decrease] (c) not change.

The kinetic energy of the car will
(a) increase [✓ (b) decrease] (c) not change.

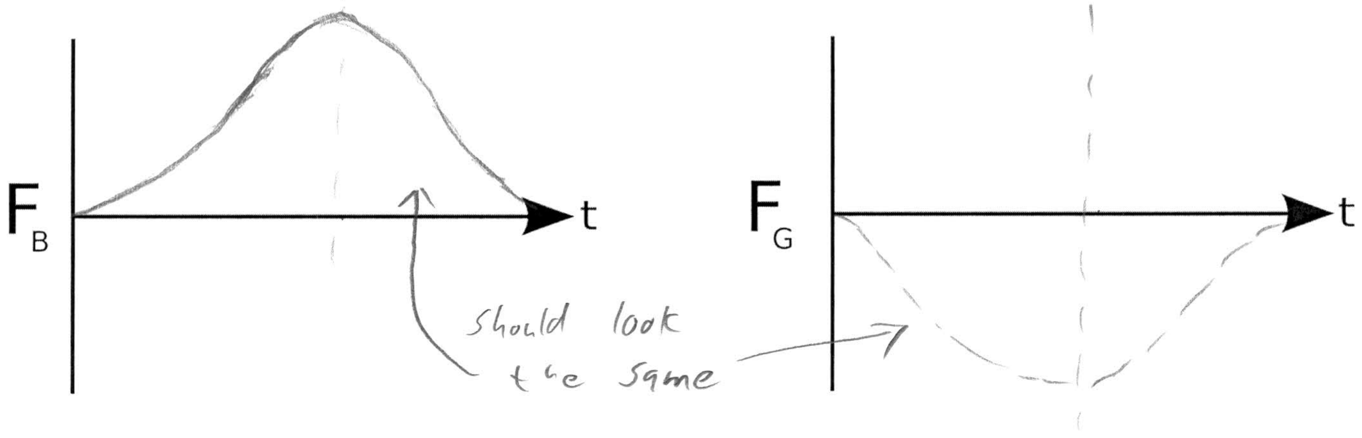
Systems of Particles – Set 4

A golf ball G and a bowling ball B, move towards each other, collide and bounce apart. Let $\mathbf{F}_G$ be the force experienced by the golf ball and let $\mathbf{F}_B$ be the force experienced by the bowling ball.

1. $\mathbf{F}_G$ is _____ $\mathbf{F}_B$.
   - a) Greater than
   - [✓ b) The same as]
   - c) Less than

2. The amount of time that $\mathbf{F}_G$ is applied is _____ the time that $\mathbf{F}_B$ is applied.
   - a) Greater than
   - [✓ b) The same as]
   - c) Less than

3. Sketch a graph showing a plausible $\mathbf{F}_G$ as a function of time and another graph showing $\mathbf{F}_B$ function of time. Be sure to consider the *sign* of each force.



4. Compare the impulse delivered to the golf ball to the impulse delivered to bowling ball. What's the same? What's different?

The impulses will have the same magnitude but opposite direction.

The forces in question is a Newton's 2nd law reaction pair, They are always equal and opposite

5. The *magnitude* of the change in momentum of the golf ball is ___ the *magnitude* of the change in momentum of the bowling ball
   - a) Greater than
   - [✓ b) The same as]
   - c) Less than

6. After the collision, the kinetic energy of the golf ball is ____ the kinetic energy of the bowling ball.
   - [✓ a) Greater than]
   - b) The same as
   - c) Less than

why? The golf ball loses very little kinetic energy in the collision.

$$V_{GF} = \frac{m_G - m_B}{m_G + m_B} V_{GI}$$

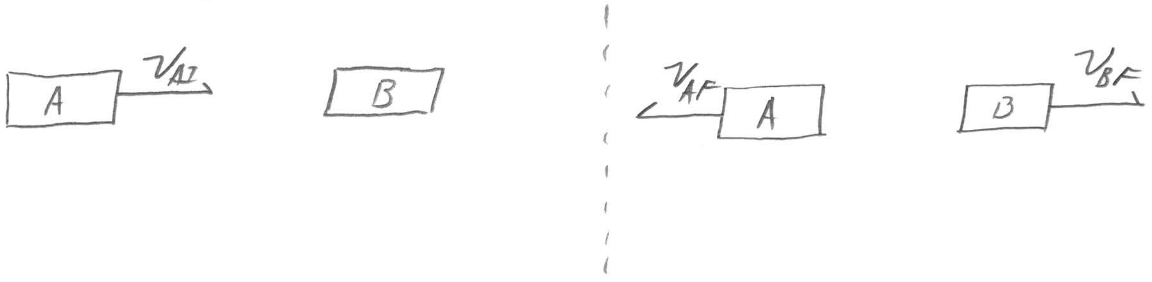
As $m_B >> m_G$, $\frac{m_G - m_B}{m_G + m_B} \Rightarrow \underline{-1}$

Because energy is conserved, and the golf ball retains most of the initial energy, the bowling ball gets very little.

Systems of Particles – Set 4

Train Car A has a mass of 2600 kg and a velocity of 16 m/s to the right. It collides with a stationary Train Car B whose mass is 5900 kg. The cars undergo a *partially* elastic collision bounce off of each other, and Car B moves to the right at 8 m/s. The two cars are in contact with each other for 1.8 seconds during impact.

a) What is the velocity of Train Car A just after the collision?
b) What average force (magnitude and direction) does Car A exert on Car B during the collision?
c) What impulse (magnitude and direction) does Car B exert on Car A during the collision?
e) Calculate the change in momentum of both cars.
d) How much energy was lost in the collision?



a) $\vec{P}_I = \vec{P}_F$

$$m_A v_{AI} = m_A v_{AF} + m_B v_{BF}$$

$$\Rightarrow \boxed{v_{AF} = v_{AI} - \frac{m_B}{m_A} v_{BF}}$$

$$v_{AF} = 16\ \text{m/s} - \frac{5900\ \text{kg}}{2600\ \text{kg}}\, 8\ \text{m/s} = \boxed{-2.15\ \text{m/s}}$$

b) $\vec{F}_{AVG} = \frac{\vec{J}}{\Delta t} = \frac{\Delta \vec{P}}{\Delta t} = \frac{\vec{P}_{BF} - \vec{P}_{BI}}{\Delta t} = \frac{m_B v_{BF} - 0}{\Delta t}$

$$\vec{F}_{AVG} = \frac{(5900\ \text{kg})(8\ \text{m/s})}{1.8\ \text{s}} = \boxed{2.62 \times 10^4\ \text{N}}$$

(c and d) $\vec{J}$ and ΔP are the same for both cars so:

$$\Delta P_A = \Delta P_B = m_B v_{BF} - 0 = (5900\ \text{kg})(8\ \text{m/s}) = \boxed{4.72 \times 10^4\ \text{Ns}}$$

Systems of Particles Set 4, P4 - continued.

e) $K_I = \frac{1}{2} m_A V_{AI}^2 = \frac{1}{2}(2600)(16)^2 = \underline{3.33 \times 10^5 \text{ J}}$

$K_F = \frac{1}{2} m_A V_{AF}^2 + \frac{1}{2} m_B V_{BF}^2 = \frac{1}{2}(2600)(2.15)^2 + \frac{1}{2}(5900)(8)^2$

$= \underline{1.95 \times 10^5 \text{ J}}$

$\Delta K = K_I - K_F = 3.33 \times 10^5 - 1.95 \times 10^5 \text{ J} = \boxed{1.38 \times 10^5 \text{ J}}$

A truck moving at 30.0 m/s undergoes a perfectly inelastic head-on collision with a car moving at 22.0 m/s. The total mass of the truck, including the driver is 9000 kg and the total mass of the car, including the driver and passenger, is 1500 kg. Each driver has a mass of 60.0 kg and the collision time for the drivers is 0.200 s. The car passenger has a mass of 60.0 kg and is not wearing a seatbelt. The passenger's collision time is 0.010 s. What is the average force on the truck driver, the car driver, and the passenger?

First, we'll find V_F so that we can calculate ΔP for the drivers and the passengers.

$$\vec{P}_I = \vec{P}_F$$

$$m_T V_{TI} - m_C V_{CI} = (m_T + m_C) V_F$$

$$\boxed{V_F = \frac{m_T V_{TI} - m_C V_{CI}}{m_T + m_C}} = \frac{(9000)(30.0) - (1500)(22)}{9000 + 1500} = 22.6 \text{ m/s}$$

All drivers and passengers have a mass of 60.0 kg

* Truck driver

$$\Delta P = m \cdot V_F - m V_I = m(V_F - V_I) = 60.0\text{kg}(22.6 \text{ m/s} - 30 \text{ m/s})$$

$$= -444 \text{ N}\cdot\text{s}$$

$$\vec{F}_{AVG} = \frac{-444 \text{ N}\cdot\text{s}}{0.2 \text{ s}} = \boxed{-2.2 \times 10^3 \text{ N}}$$

Continued ↓

Systems of particles Set 4, P 5 continued.

*Car Driver

$\Delta P = m(V_F - V_I) = 60.0\text{kg}(22.6 - {-22}) = 60.0(22.6 + 22) = \underline{2676 N_s}$

$F_{AVG} = \frac{2676 \text{ N.s}}{0.2} = \boxed{1.34 \times 10^4 N}$

Car Passenger

$\Delta P = 2676 \text{ N.s}$

$\vec{F}_{AVG} = \frac{2676 \text{ N.s}}{0.01 \text{ s}} = \boxed{2.68 \times 10^5 N}$

So, the belted driver of the car feels 10 times the force of the belted driver of the truck.

And the unbelted passenger (who is stopped by the windshield) feels 100 times the force.

For comparison, each person weighs $60.0\text{kg} \cdot 9.8 \text{ m/s} = \underline{588 N}$

So even a belted driver of a small car feels the weight of $\frac{1.34 \times 10^4}{588} = ⓶⓶$ people standing on their chest.

Systems of Particles – Set 4

6

Rain is falling straight down with a speed of 15 m/s, and it hits the roof of a car perpendicularly. The mass of rain per second hitting the roof is 0.060 kg/s. If we assume the rain comes to rest after hitting the roof, what is the average force exerted *by the roof* on the rain? How much force is exerted *by the rain* on the roof?

Compare raindrops to hailstones. If the mass of hail per second hitting the roof is also 0.060 kg/s, and the hail also falls at a speed of 15 m/s, how much average force does the hail exert on the roof if the hail bounces as soon as it hits? (Assume an elastic collision.)

Rain

$$\vec{F}_{AVG} = \frac{\vec{J}}{\Delta t} = \frac{\Delta \vec{P}}{\Delta t} = \frac{0 - {}^{-}m \cdot V_I}{\Delta t}$$

$$= \frac{\Delta m}{\Delta t} \cdot V_I$$

↑ Rate of rain drops.

$$F_{AVG} = 0.060\,\text{kg/s} \cdot 15\,\text{m/s} = \boxed{0.9\,N}$$

The average force exerted by the roof is the same as the average force exerted by the drops.

Hail

$$\vec{F}_{AVG} = \frac{\vec{J}}{\Delta t} = \frac{\Delta \vec{P}}{\Delta t} = \frac{mV_F - mV_I}{\Delta t} = \frac{\Delta m}{\Delta t}(V_F - V_I)$$

Rate of hail stones

$V_F = -V_I$ in an elastic collision. ⇒ $F_{AVG} = \frac{\Delta m}{\Delta t} \cdot 2V_I = 0.06 \cdot 30 = \boxed{1.8\,N}$

where $m_1 >> m_2$.

let m_1 = Car (or Earth)