Kathleen Boyce 1/9/19

Momentum

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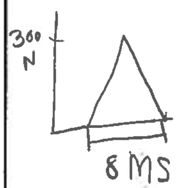
Impulse - Force exerted over a time (force can change)

$J = \text{Force} \cdot \Delta t$ Area under a Force vs. time graph is impulse

↑ abbreviation for impulse

☆ You can use the average force instead of integrating

$J = F_{Avg} \cdot \Delta t$ Units: $N \cdot s = \frac{kgm}{s}$



Impulse: $J = \frac{1}{2}(300)(0.008) = \boxed{1.2\ N \cdot s}$

Don't forget to convert ms to s !!!

Average Force $= J/\Delta t = \frac{1.2}{0.008} = \boxed{150\ N}$

How are time and force related?

$\Sigma F = ma$ $\Sigma F = m\frac{\Delta V}{\Delta t}$ $\boxed{\Sigma F \cdot \Delta t = m \Delta V}$

Very important equation

Net force vs. Impulse

$J = F \cdot \Delta t$

Roll with the punches < Lean in = Shorter time, greater force; Roll in same direction = Greater contact time

☆ Momentum is not inertia ☆ Inertia = Resistant to any change

Momentum - How hard it is to stop something

Depends on mass + velocity (greater mass = greater inertia and need to be moving fast)

$p = \text{mass} \cdot \text{velocity}$

$\boxed{p = m \cdot V}$ p = abbreviation for momentum

Momentum is a vector → same direction as velocity

$J = F \cdot \Delta t = m \Delta V$

$F \Delta t = m(V_f - V_i) = mV_f - mV_i = \vec{p_f} - \vec{p_i}$

$J = \Delta P$ ~~Impulse~~ Impulse = Change in momentum

ΔP is also area under a force vs. time graph

Momentum has same units as impulse

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$p = mv$ $V_i = 1.3 \frac{m}{s}$ $V_f = 0 \frac{m}{s}$ $m = 0.25$ kg

Initial momentum = $p = 0.325$ kg $\frac{m}{s}$

Impulse delivered by the wall $J = \Delta p = -0.325$ kg $\frac{m}{s}$

$V_i = 1.3 \frac{m}{s}$ $V_f = -1.1 \frac{m}{s}$ $m = 0.25$ kg

$p_i = (1.3)(0.25) = 0.325$ kg $\frac{m}{s}$

$p_f = (-1.1)(0.25) = -0.275$ kg $\frac{m}{s}$

$J = \Delta p = p_f - p_i = -0.275 - 0.325$ $\boxed{J = -0.6 \text{ kg} \frac{m}{s}}$

☆ Force vs. time graphs will be very important

Momentum is a conserved quantity → we can use it to make predictions

2 carts with m = 500g $V_1 = 0.75 \frac{m}{s}$ $V_2 = 0.5 \frac{m}{s}$

$\Sigma p = p_1 + p_2$ $p_1 = (0.5)(0.75) = 0.375$

$\boxed{\Sigma p = 0.625 \text{ kg} \frac{m}{s}}$ $p_2 = (0.5)(0.5) = 0.25$

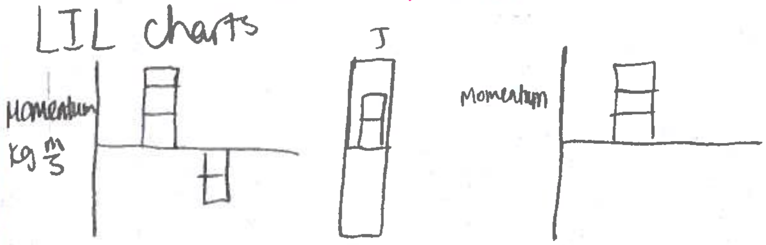
Conservation of Momentum in Isolated systems

Third Law pairs

$\boxed{\text{Isolated systems: } p_i = p_f}$ → no outside forces (we won't use this a lot)

$\boxed{p_i + J = p_f}$ → Non-isolated systems → more practical

LIL charts



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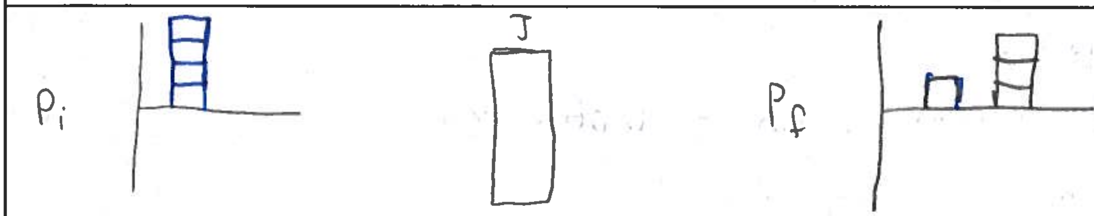
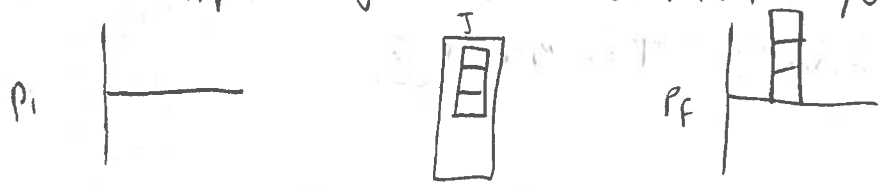


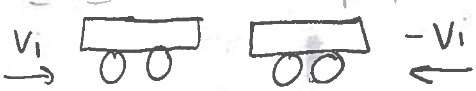
Isolated system = No impulse V_B = moving $V_R = 0\frac{m}{s}$ then moving

Same example but just the red cart is the system

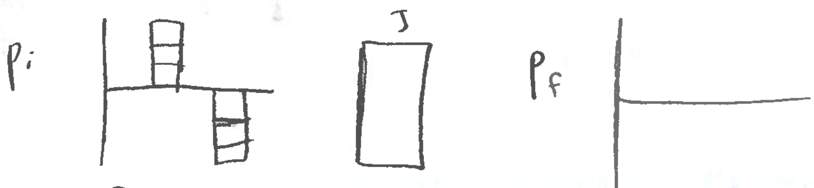


$F\Delta t = m_R V_R$

We won't use J that much (use $F \cdot \Delta t$)

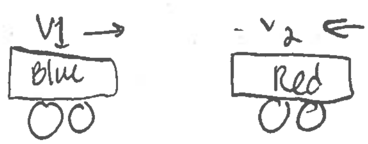


$V_B = 0$ $V_R = 0$



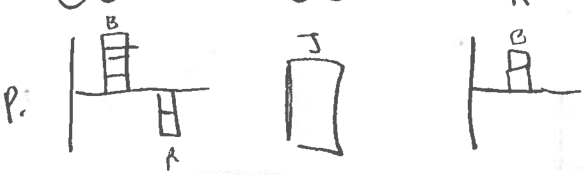
Isolated system (no impulse)

$P_B + P_R = 0$



$V_B = 1\frac{m}{s}$ $m_B = 0.4$ kg

$V_R = -1\frac{m}{s}$ $m_R = 0.2$ kg



$P_B + P_R = P_{Total}$

$m_B V_B + m_R V_R = m_{Total} V$

$\boxed{V = 0.33\frac{m}{s}}$ $\leftarrow$ $(0.4)(1) + (0.2)(-1) = 0.6V$

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Collisions

Elastic collisions - Hard collisions = no deformation occurs
no kinetic energy lost

Inelastic collisions - Deformation occurs, kinetic energy is lost ← Most collisions are inelastic (bounce off + energy is lost)

Perfectly inelastic (stick together) - Objects stick together and become on object, deformation occurs, kinetic energy is lost

Totally Inelastic Collisions = perfectly inelastic = Bullet + wood block

- Simplest type of collisions
- After the collision there is 1 velocity (1 object)
- Kinetic energy is lost
- Momentum is conserved
- Explosions are the reverse of perfectly inelastic collisions because energy is gained

Fish moving at $2\frac{m}{s}$ swallows a stationary fish which is 1/3 of its mass. What is the velocity of the big fish?

$$P_B + 0 = P_B + P_{fish}$$
$$3m(2\tfrac{m}{s}) = (m_B + m_f)V_f$$
$$6m = (3m + m)V_f$$
$$6 = 4V_f \quad \boxed{V_f = 1.5\tfrac{m}{s}}$$

Inelastic Collision

- Kinetic energy is lost
- Momentum is conserved
- Both objects move with different final velocities (don't stick together)

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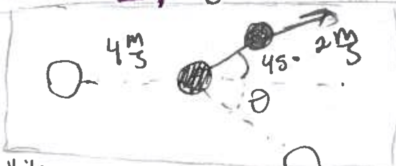
Elastic Collision = Billiards

- No deformation and no change in kinetic energy

$P_i = P_f$ (conservation of momentum)

$E_i = E_f$ (conservation of energy)



$P_x = P_{fx}$ $P_y = P_{fy}$ $E_i = E_f$

$P_W = P_{Wf} + P_{Bf}$

$0 = P_{Wy} + P_{By}$

$E_{kW} = E_{kW} + E_{kB}$

$\cos\theta = \frac{A}{H} = 2\frac{\sqrt{2}}{2} = \sqrt{2}$

w = white
b = black

Pool and hitting a shot at an angle

Finding the angle with which the cue ball is deflected

$(4\frac{m}{s})(0.5\ kg) = (0.5\ kg)(V_x) + (0.5)(\sqrt{2})$

$2 = 0.5V_x + 0.5(1.414)$ $\boxed{V_x = 2.6\ \frac{m}{s}}$

$0 = \cancel{m}V_y + \cancel{m}V_{By}$ $0 = V_y + 1.414$ $\boxed{V_y = -1.414\ \frac{m}{s}}$

Using energy now

$\frac{1}{2}\cancel{m}(4)^2 = \frac{1}{2}\cancel{m}V_w^2 + \frac{1}{2}\cancel{m}(2)^2$ $16 = V_w^2 + 4$ $\boxed{V_w = \sqrt{12}\ \frac{m}{s}}$

$\tan\theta = \frac{1.414}{2.6}$ $\boxed{\theta = 28°}$

Explosions at the Center of Mass

- Reverse of perfectly inelastic collisions → Kinetic energy is gained
- Momentum of the center of mass remains unchanged

1.5 kg cannon on a 2.0 kg cart loaded with a 52.7 g ball. All moving at $1.27\frac{m}{s}$ and ball is launched at $75\frac{m}{s}$. Find post explosion velocity of cannon + cart

$P_{total} = P_{cart/cannon} + P_{Ball}$

$(m_{cart} + m_{cannon} + m_{ball})V_i = (m_{cart} + m_{cannon})V_f + (m_{Ball})(V_{Bf})$

$(3.5527)(1.27\frac{m}{s}) = (3.5\ kg)V_f + (0.0527\ kg)(75\frac{m}{s})$

$4.511929 = 3.9525 + 3.5V_f$ $\boxed{V_f = 0.16\ \frac{m}{s}}$

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Center of mass of the system will always maintain the same momentum → center of mass = balancing point

Collisions in Two Dimenions

- Momentum is conserved in x and y directions
  - Treat directions independently

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