Today: 8.3 & 8.4

$\boxed{L25}$

ASU

Today: 8.3 & 8.4

L25

Momentum conservation & collisions

Today: 8.3 & 8.4 L25

Momentum conservation & collisions

Elastic collisions

$\boxed{L25}$

Today: 8.3 & 8.4

Monday: 8.5 & 8.6

ASU

L25

Today: 8.3 & 8.4

Monday: 8.5 & 8.6

Center of mass

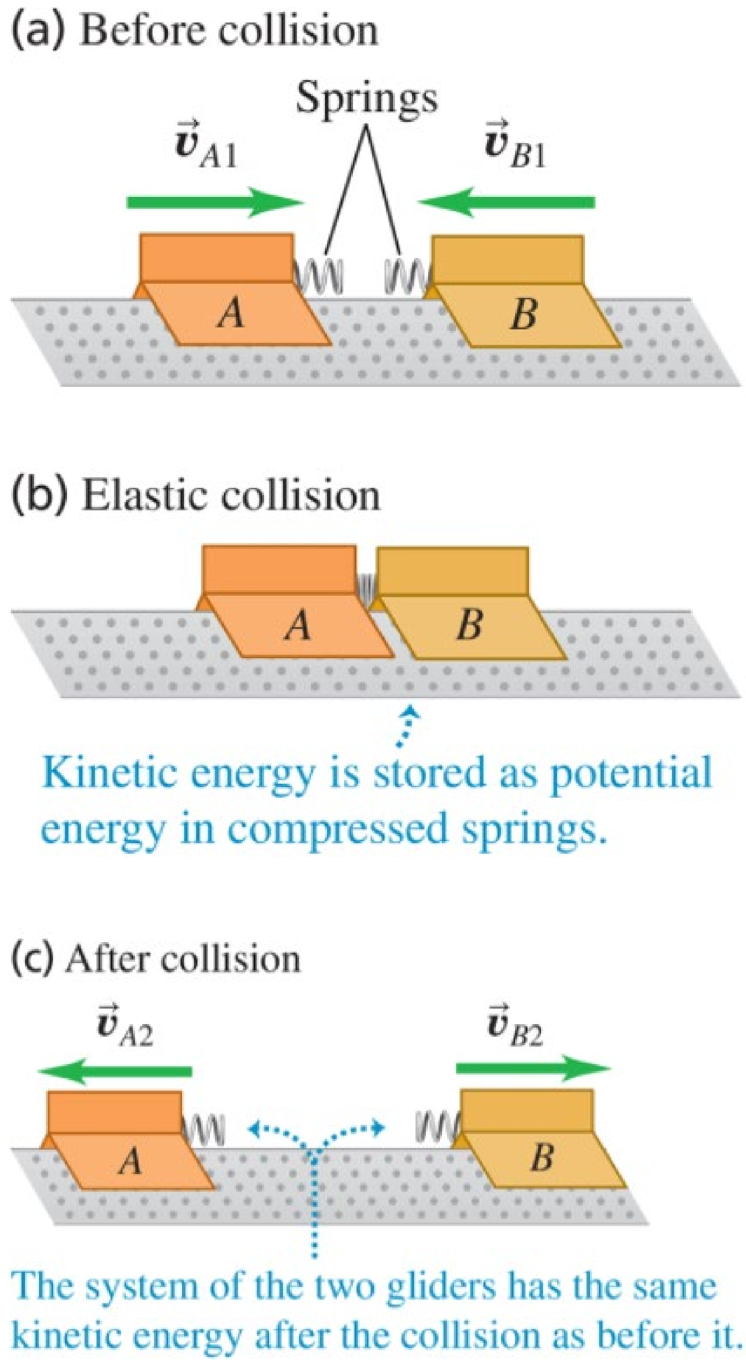
Today: 8.3 & 8.4

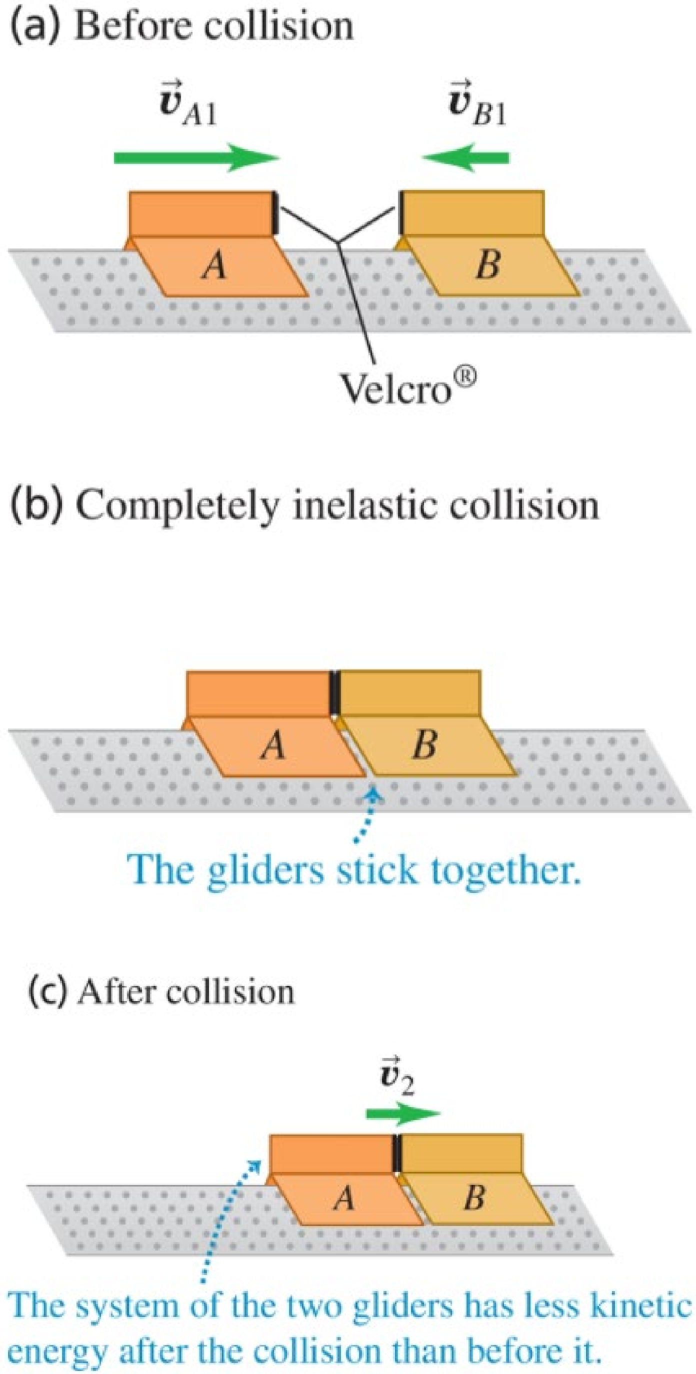
L25

Monday: $\underbrace{8.5}_{\text{Center of mass}}$ & $\underbrace{8.6}_{\text{Rocket propulsion}}$

Center of mass

Rocket propulsion

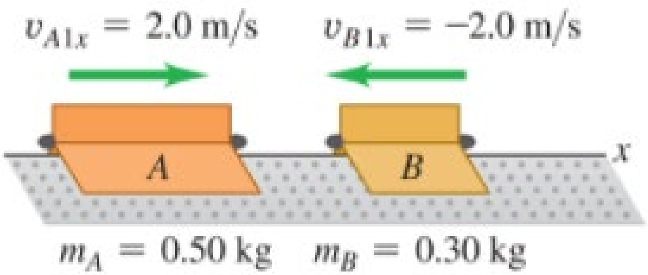

(a) Before collision
Springs
$\vec{v}_{A1}$
$\vec{v}_{B1}$
A
B
(b) Elastic collision
A
B
Kinetic energy is stored as potential energy in compressed springs.
(c) After collision
$\vec{v}_{A2}$
$\vec{v}_{B2}$
A
B
The system of the two gliders has the same kinetic energy after the collision as before it.


(a) Before collision
$\vec{v}_{A1}$
$\vec{v}_{B1}$
A
B
Velcro®
(b) Completely inelastic collision
A
B
The gliders stick together.
(c) After collision
$\vec{v}_2$
A
B
The system of the two gliders has less kinetic energy after the collision than before it.

Cars are designed so that collisions are inelastic—the structure of the car absorbs as much of the energy of the collision as possible. This absorbed energy cannot be recovered, since it goes into a permanent deformation of the car.

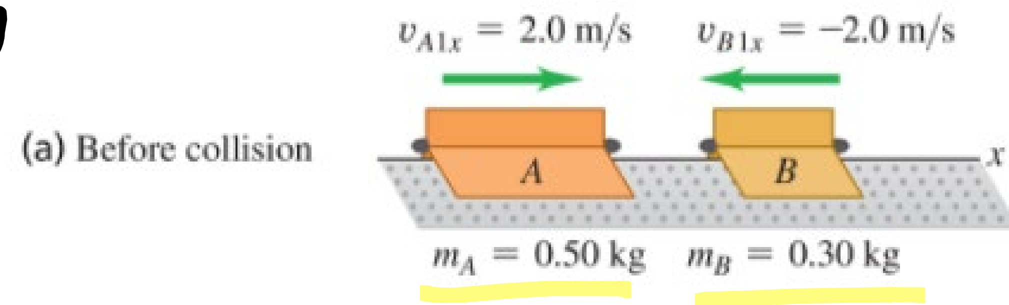
We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

(a) Before collision



We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

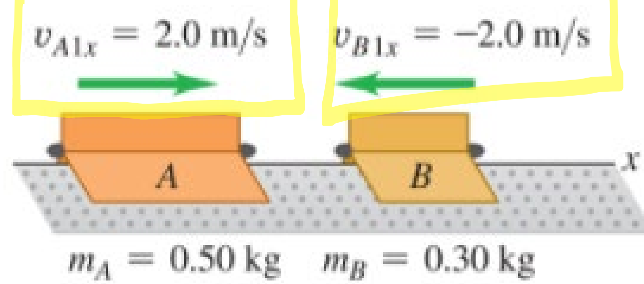
$m_A = 0.5\,kg$, $m_B = 0.3\,kg$



We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\,kg$, $m_B = 0.3\,kg$

$V_{A1} = 2\frac{m}{s}\hat{i}$, $V_{B1} = -2\frac{m}{s}\hat{i}$,



(a) Before collision

![ASU logo]

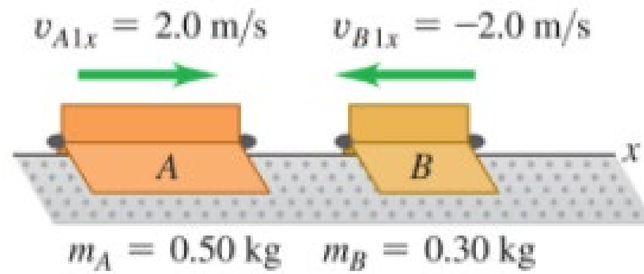
We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\,kg$, $m_B = 0.3\,kg$

$V_{A1} = 2\frac{m}{s}\hat{i}$, $V_{B1} = -2\frac{m}{s}\hat{i}$

Find $V_2 = V_{A2} = V_{B2}$

(a) Before collision



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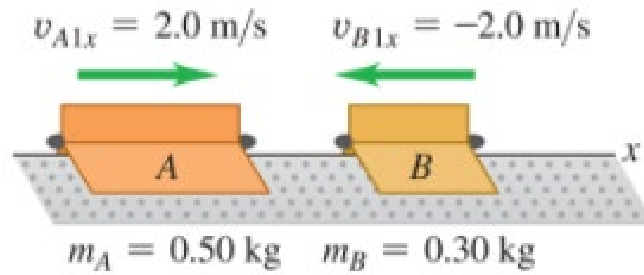
Find $V_2 = V_{A2} = V_{B2}$:

$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2}$

(a) Before collision



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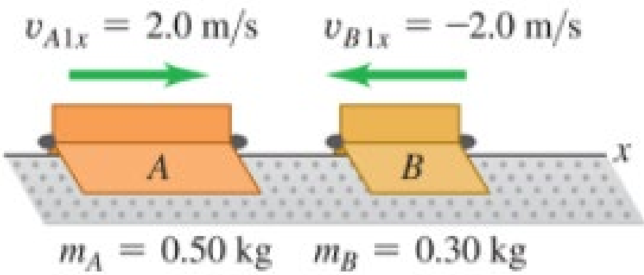

(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2}$

Note

$\vec{P}_{A2} + \vec{P}_{B2} = (m_A + m_B)\vec{V}_2$

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

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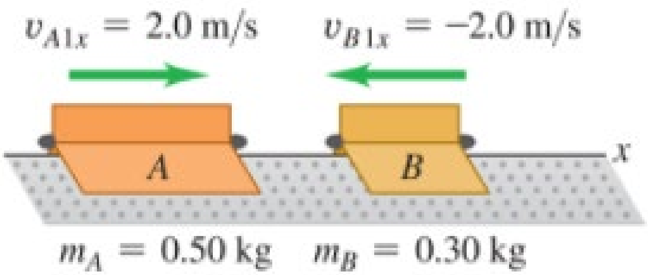


(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

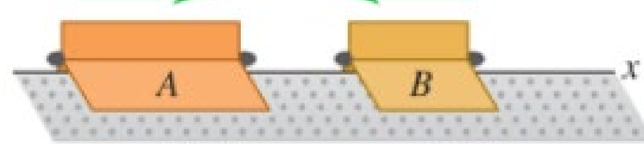
$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$

$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2$

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\,kg$, $m_B = 0.3\,kg$

$V_{A1} = 2\frac{m}{s}\hat{i}$, $V_{B1} = -2\frac{m}{s}\hat{i}$



(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B}$$

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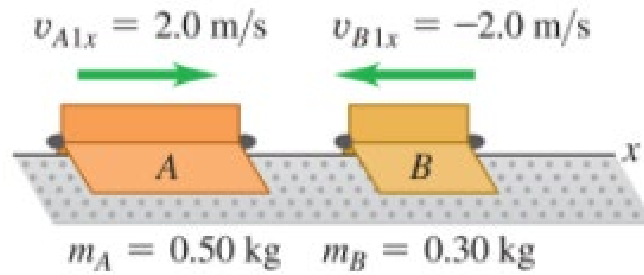
(a) Before collision



Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

$$V_2 = \left[\frac{1 - 0.6}{0.8}\right] \frac{m}{s}$$

ASU

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

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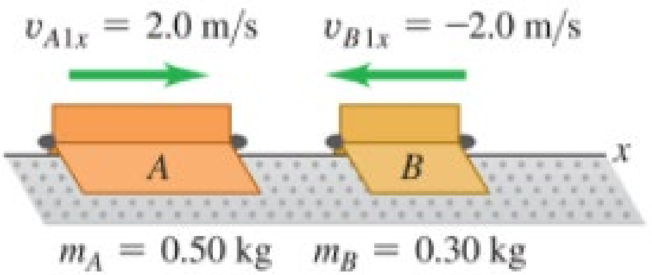

(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s}$$

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

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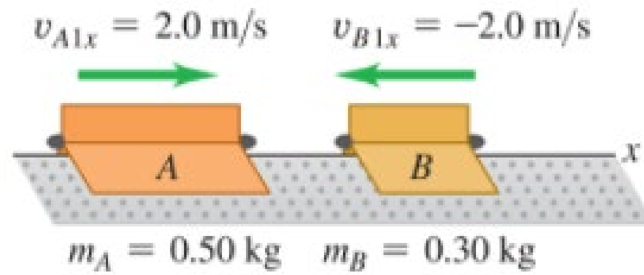


(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

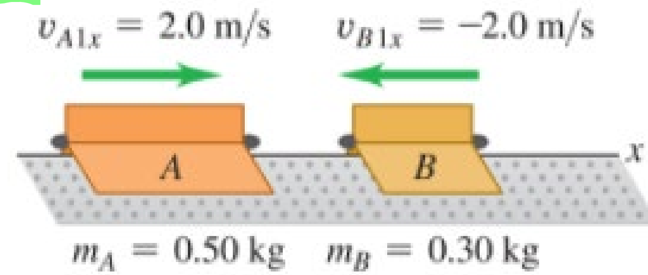
$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\, m/s}$$

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\,\text{kg}$, $m_B = 0.3\,\text{kg}$

$\vec{V}_{A1} = 2\frac{m}{s}\hat{i}$, $\vec{V}_{B1} = -2\frac{m}{s}\hat{i}$

(a) Before collision



Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\,\text{m/s}}$$

Find $K_2/(K_{A1} + K_{B1})$

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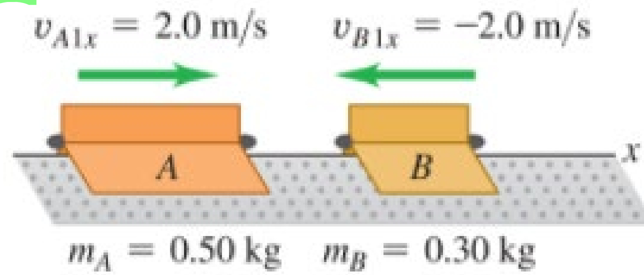
$V_{A1} = 2\frac{m}{s}\hat{i}, \; V_{B1} = -2\frac{m}{s}\hat{i},$



(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\, m/s}$$

Find $K_2/(K_{A1} + K_{B1}) = \dfrac{\frac{1}{2}(m_A + m_B)V_2^2}{\frac{1}{2}m_A V_{A1}^2 + \frac{1}{2}m_B V_{B1}^2}$

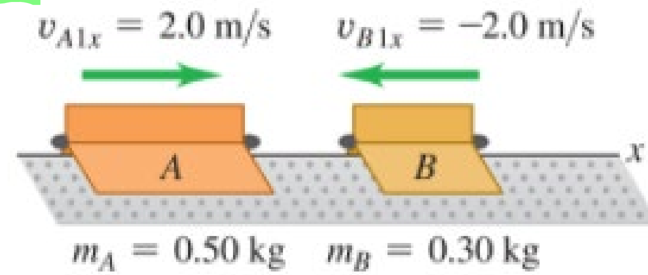
ASU

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\,\text{kg}$, $m_B = 0.3\,\text{kg}$

$V_{A1} = 2\frac{m}{s}\hat{i}$, $V_{B1} = -2\frac{m}{s}\hat{i}$

(a) Before collision



Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\,\text{m/s}}$$

Find $K_2/(K_{A1} + K_{B1}) = \dfrac{\frac{1}{2}(m_A + m_B)V_2^2}{\frac{1}{2}m_A V_{A1}^2 + \frac{1}{2}m_B V_{B1}^2}$

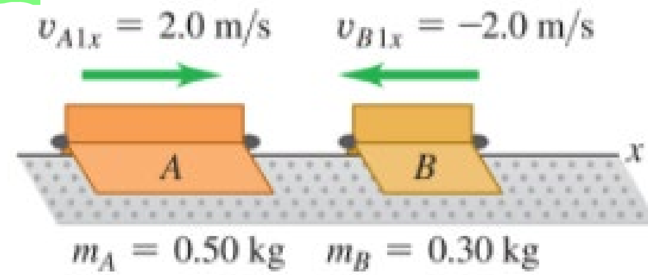
$$= \frac{(m_A + m_B)V_2^2}{m_A V_{A1}^2 + m_B V_{B1}^2}$$

ASU

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\ \text{kg}$, $m_B = 0.3\ \text{kg}$

$\vec{V}_{A1} = 2\frac{m}{s}\hat{i}$, $\vec{V}_{B1} = -2\frac{m}{s}\hat{i}$



(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B)V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\ m/s}$$

Find $K_2/(K_{A1} + K_{B1})$

$$= \frac{\frac{1}{2}(m_A + m_B)V_2^2}{\frac{1}{2}m_A V_{A1}^2 + \frac{1}{2}m_B V_{B1}^2}$$

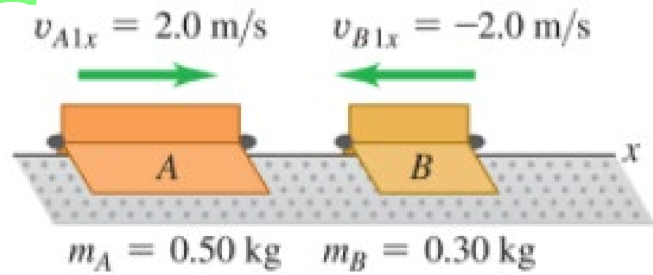
$$= \frac{(m_A + m_B)V_2^2}{m_A V_{A1}^2 + m_B V_{B1}^2} = \frac{(0.8)(0.25)}{2 + 1.2}$$

ASU

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\ \text{kg},\ m_B = 0.3\ \text{kg}$

$V_{A1} = 2\frac{m}{s}\hat{i},\ V_{B1} = -2\frac{m}{s}\hat{i}$



(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$

$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$

$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\ m/s}$

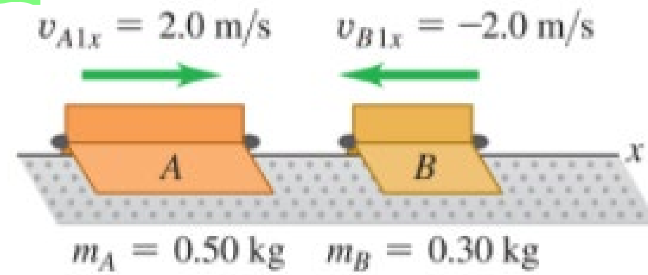
Find $K_2/(K_{A1} + K_{B1}) = \frac{\frac{1}{2}(m_A + m_B)V_2^2}{\frac{1}{2}m_A V_{A1}^2 + \frac{1}{2}m_B V_{B1}^2}$

$= \frac{(m_A + m_B)V_2^2}{m_A V_{A1}^2 + m_B V_{B1}^2} = \frac{(0.8)(0.25)}{2 + 1.2} = \frac{0.2}{3.2}$

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\text{ kg}, \; m_B = 0.3\text{ kg}$

$V_{A1} = 2\frac{m}{s}\hat{i}, \; V_{B1} = -2\frac{m}{s}\hat{i},$



(a) Before collision

Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\,m/s}$$

Find $K_2/(K_{A1} + K_{B1})$ $= \dfrac{\frac{1}{2}(m_A + m_B)V_2^2}{\frac{1}{2}m_A V_{A1}^2 + \frac{1}{2}m_B V_{B1}^2}$

$$= \frac{(m_A + m_B)V_2^2}{m_A V_{A1}^2 + m_B V_{B1}^2} = \frac{(0.8)(0.25)}{2 + 1.2} = \frac{0.2}{3.2} = \frac{2}{32}$$

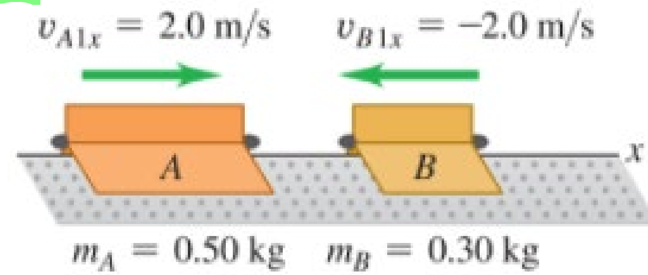
ASU

We repeat the collision described in Example 8.5 (Section 8.2), but this time equip the gliders so that they stick together when they collide. Find the common final x-velocity, and compare the initial and final kinetic energies of the system.

$m_A = 0.5\text{ kg}, \; m_B = 0.3\text{ kg}$

$\vec{V}_{A1} = 2\frac{m}{s}\hat{i}, \; \vec{V}_{B1} = -2\frac{m}{s}\hat{i}$

(a) Before collision



Find $V_2 = V_{A2} = V_{B2}$:

$$\vec{P}_1 = \vec{P}_2 \Rightarrow \vec{P}_{A1} + \vec{P}_{B1} = \vec{P}_{A2} + \vec{P}_{B2} \Rightarrow$$

$$m_A V_{A1} + m_B V_{B1} = (m_A + m_B) V_2 \Rightarrow V_2 = \frac{m_A V_{A1} + m_B V_{B1}}{m_A + m_B} \Rightarrow$$

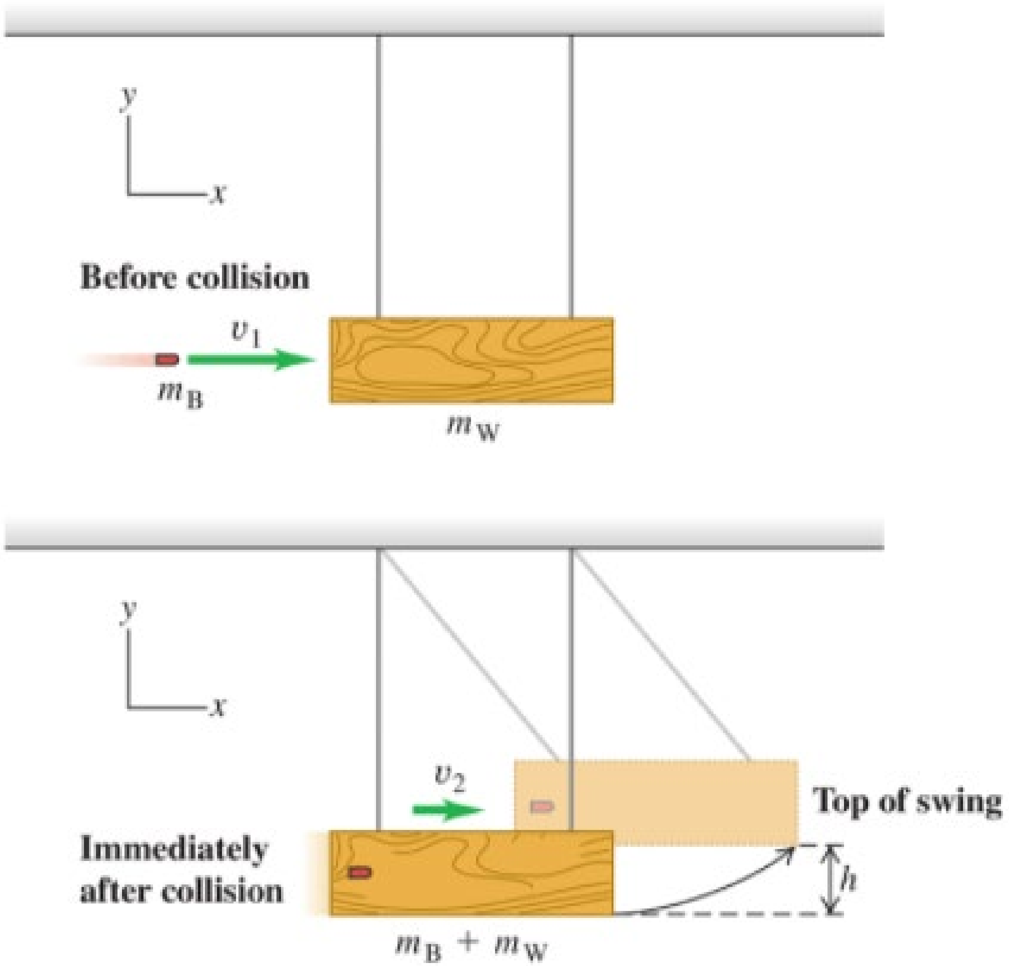
$$V_2 = \left[\frac{1 - 0.6}{0.8}\right]\frac{m}{s} = \left(\frac{0.4}{0.8}\right)\frac{m}{s} \Rightarrow \boxed{V_2 = 0.5\text{ m/s}}$$

Find $K_2/(K_{A1} + K_{B1})$ $= \dfrac{\frac{1}{2}(m_A + m_B)V_2^2}{\frac{1}{2}m_A V_{A1}^2 + \frac{1}{2}m_B V_{B1}^2}$

$$= \frac{(m_A + m_B)V_2^2}{m_A V_{A1}^2 + m_B V_{B1}^2} = \frac{(0.8)(0.25)}{2 + 1.2} = \frac{0.2}{3.2} = \frac{2}{32} = \boxed{\frac{1}{16}}$$

ASU

Figure 8.19 shows a ballistic pendulum, a simple system for measuring the speed of a bullet. A bullet of mass m_B makes a completely inelastic collision with a block of wood of mass m_W, which is suspended like a pendulum. After the impact, the block swings up to a maximum height h. In terms of h, m_B, and m_W, what is the initial speed v_1 of the bullet?



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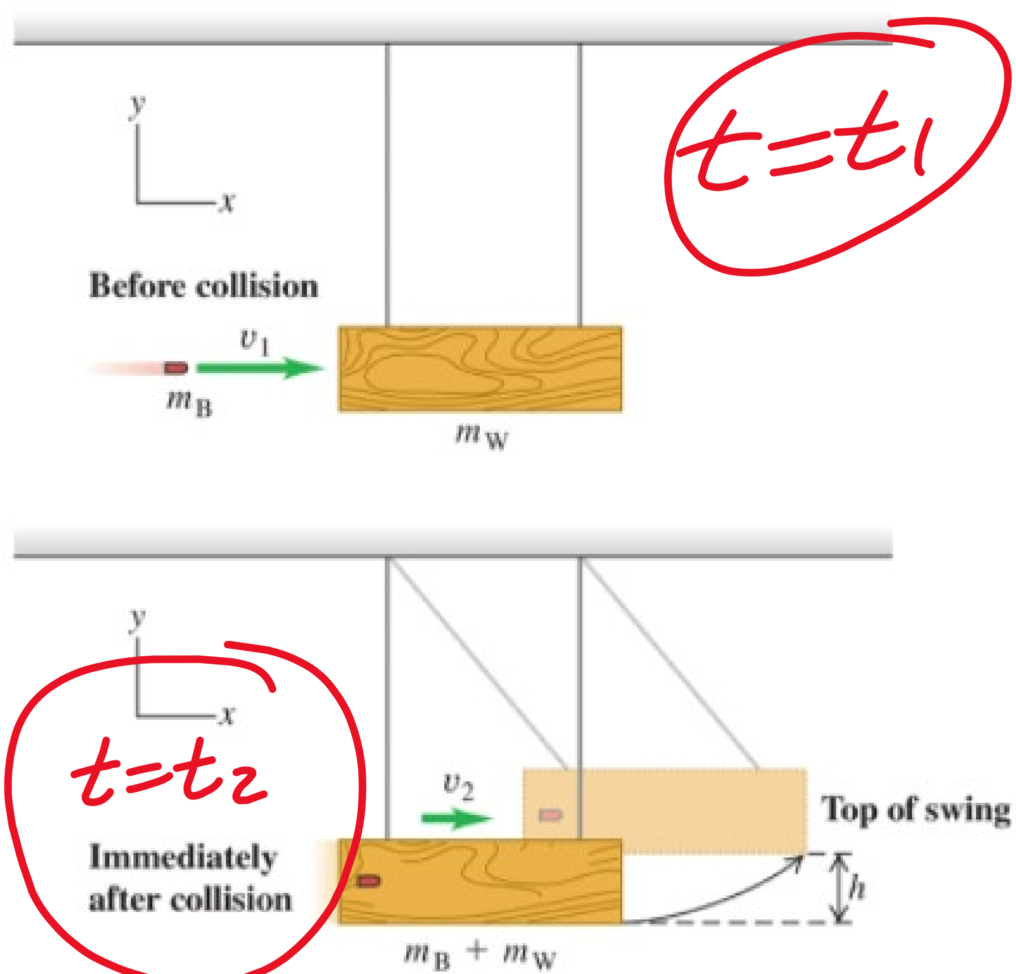

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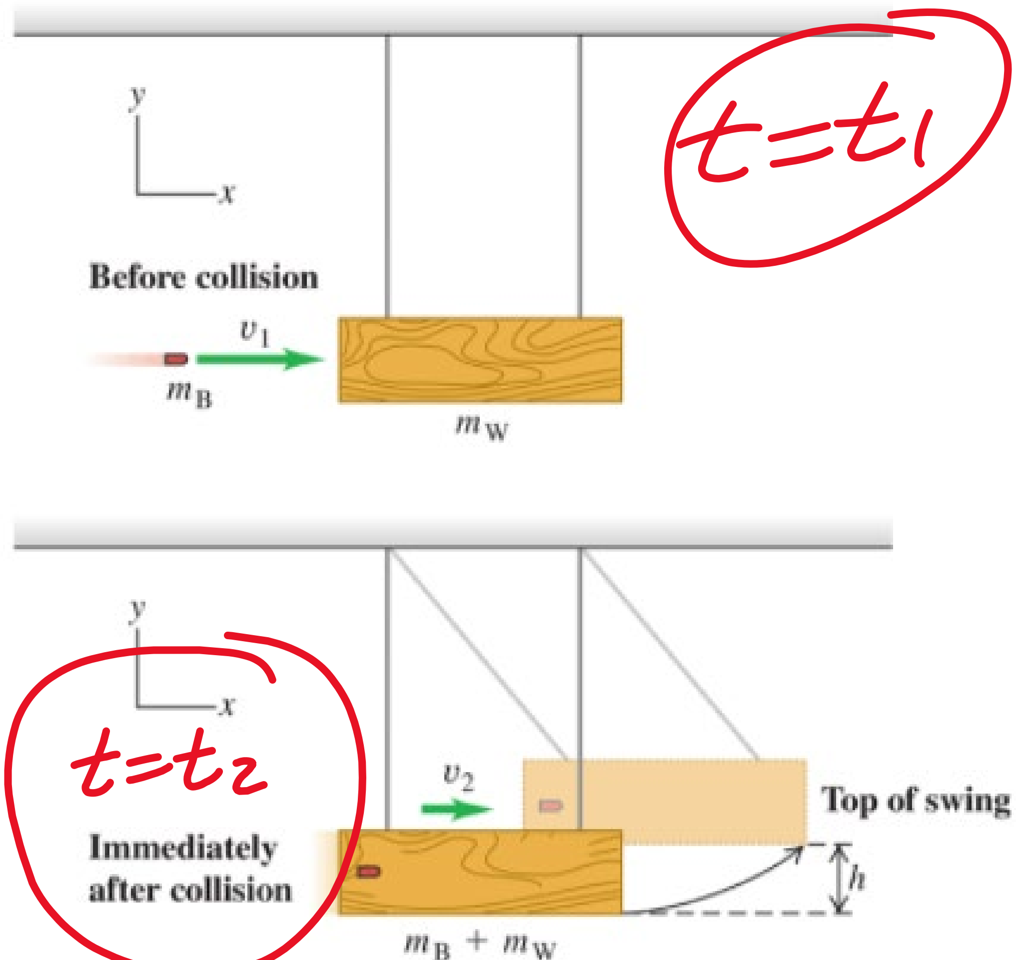

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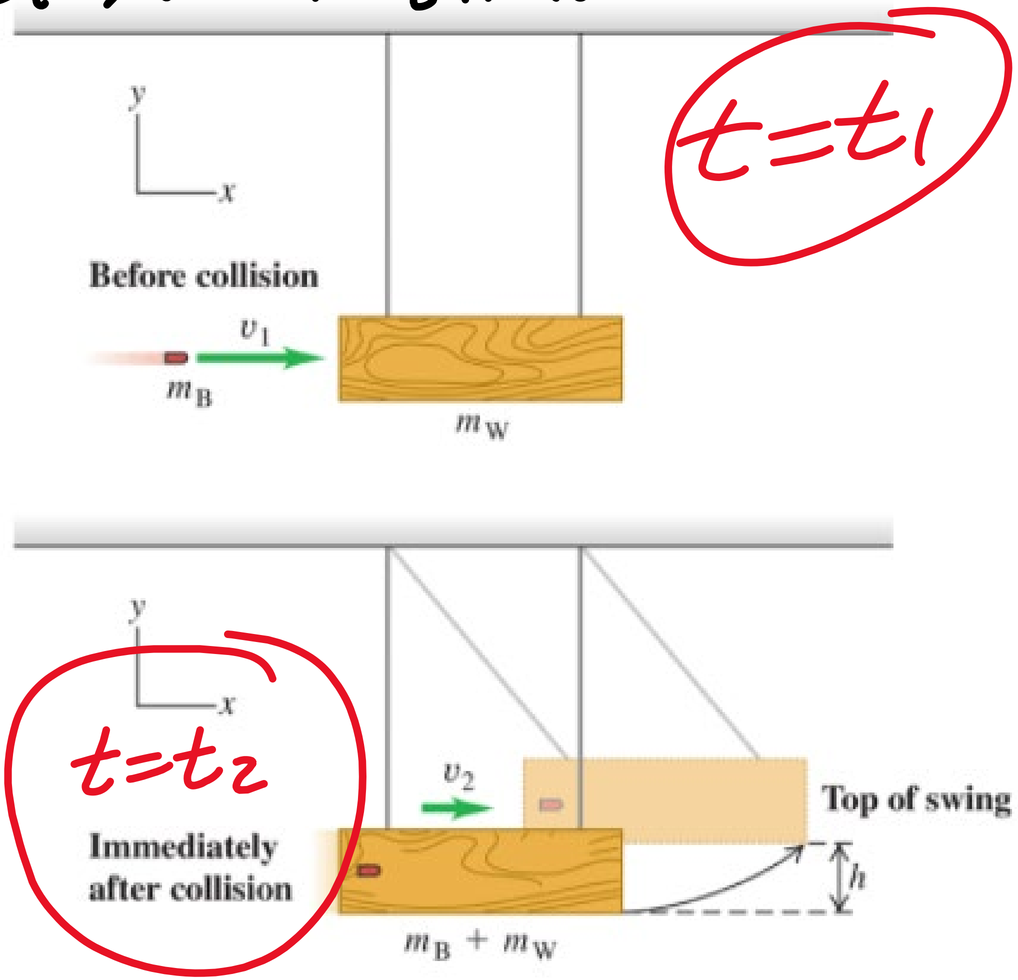

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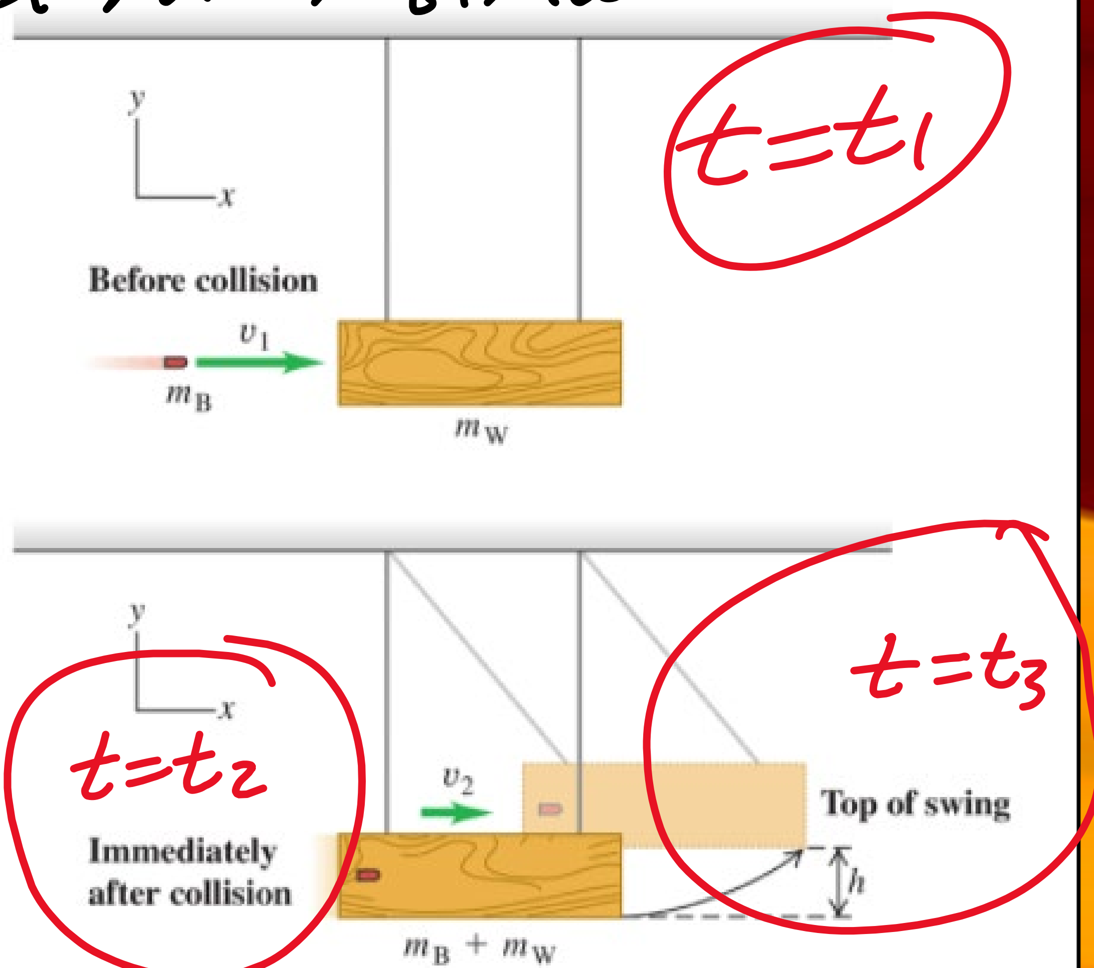

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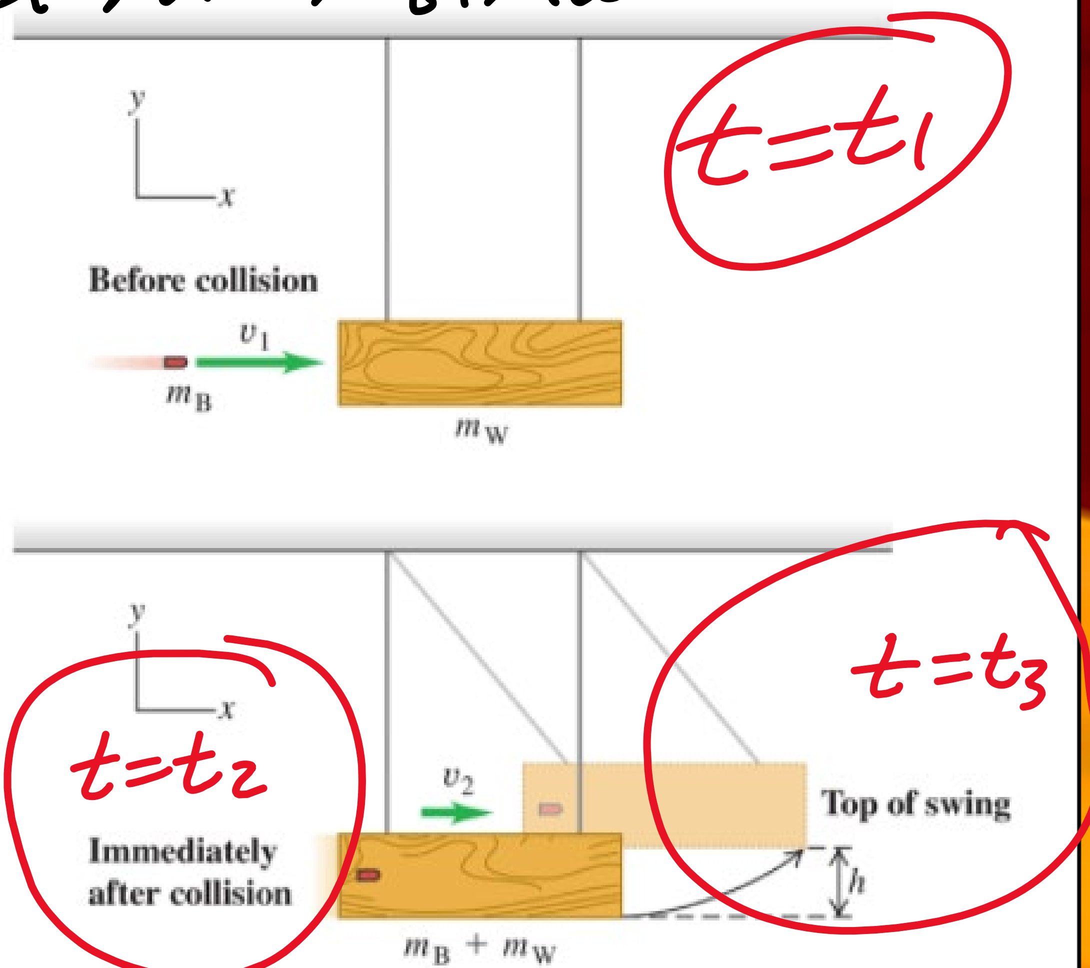

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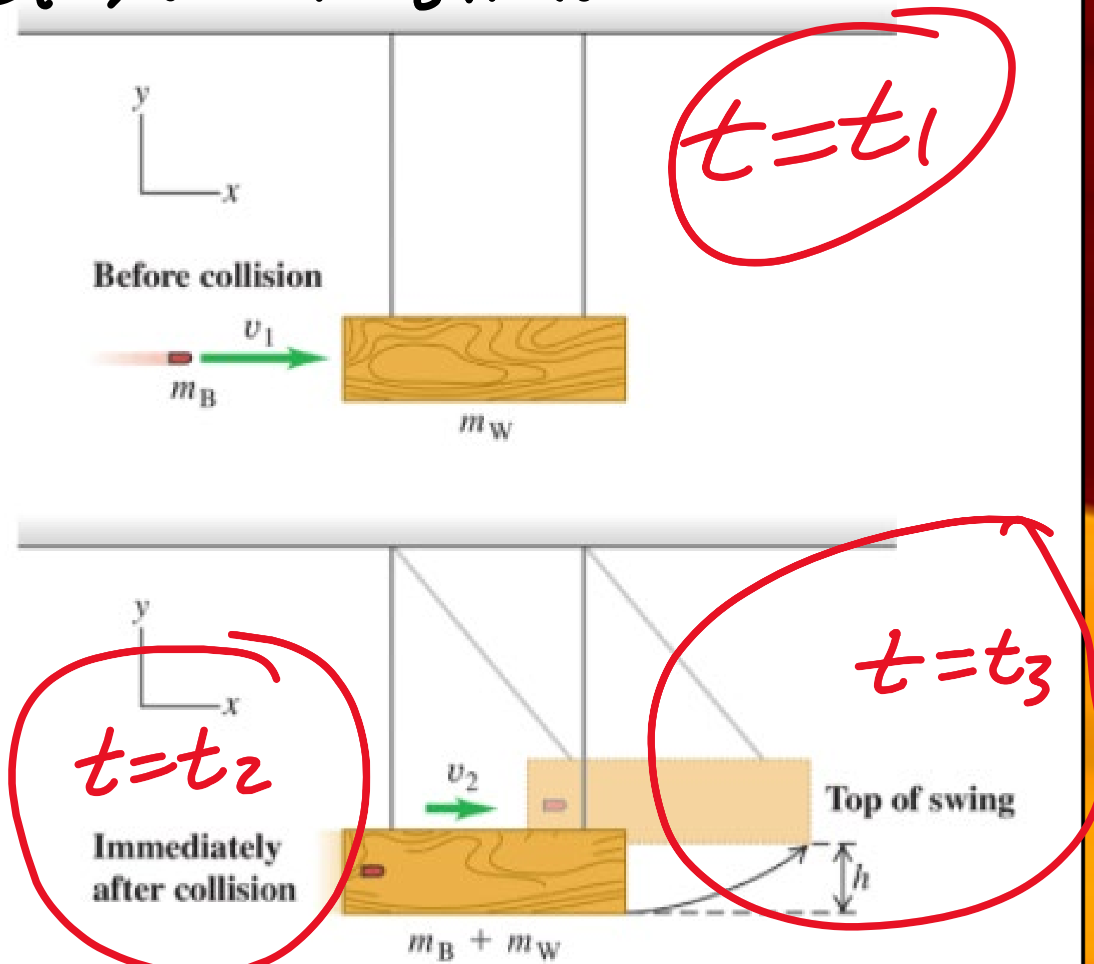

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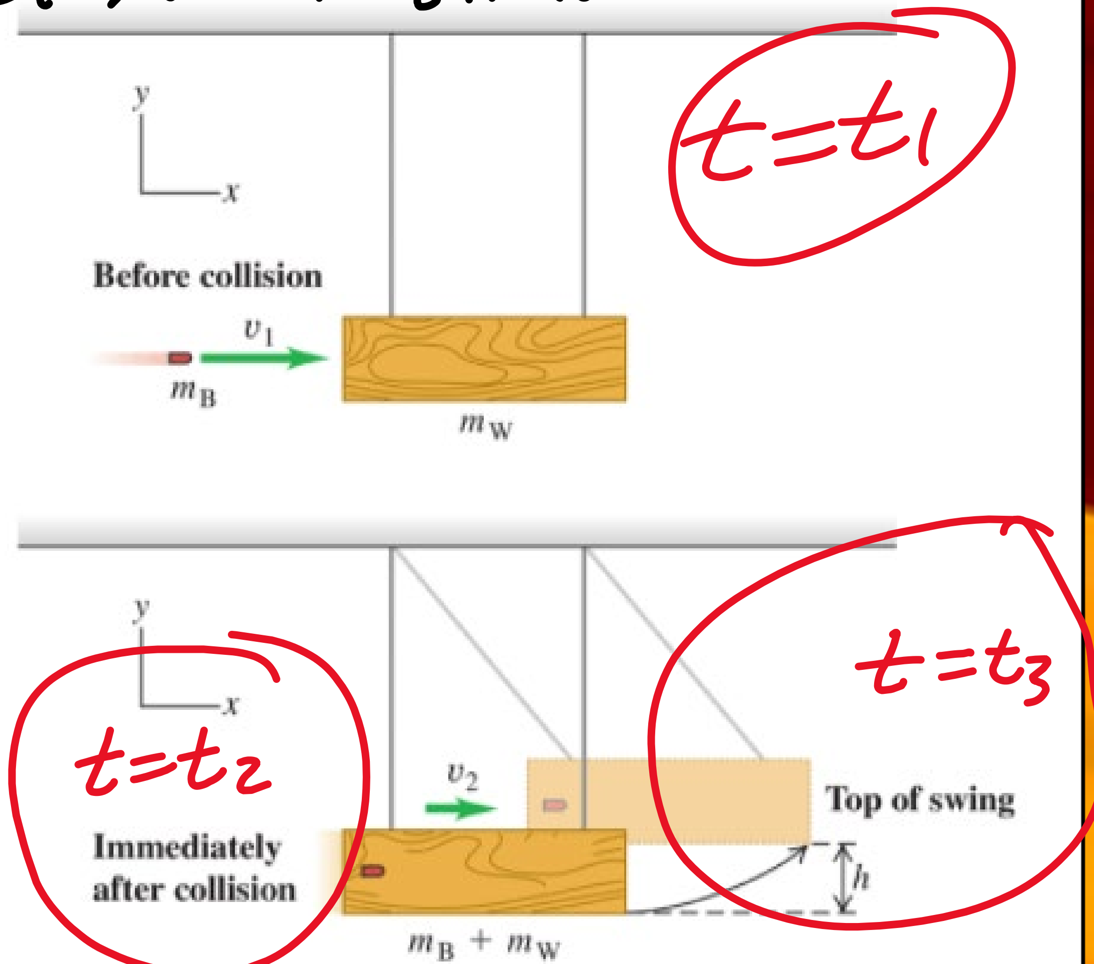
so $P_2^2/(2M) = mgh$



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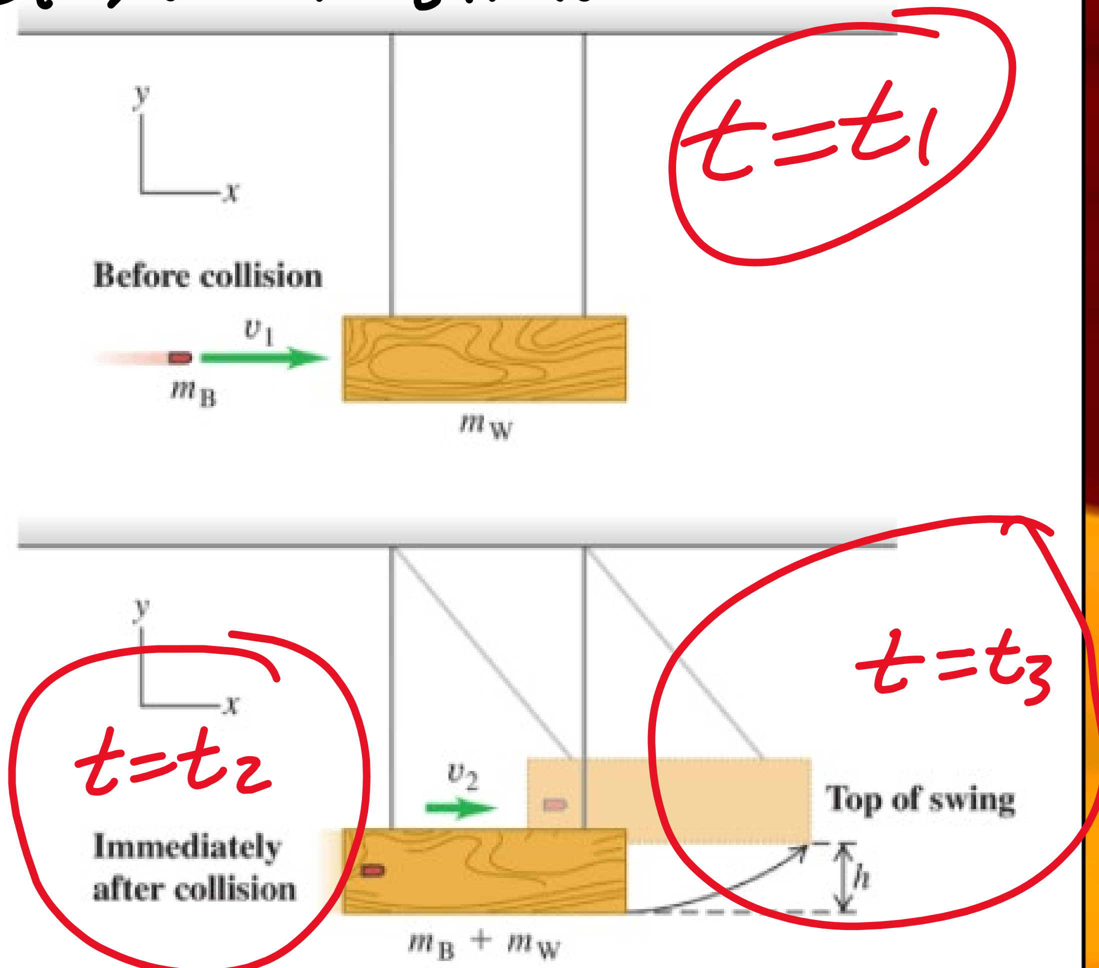

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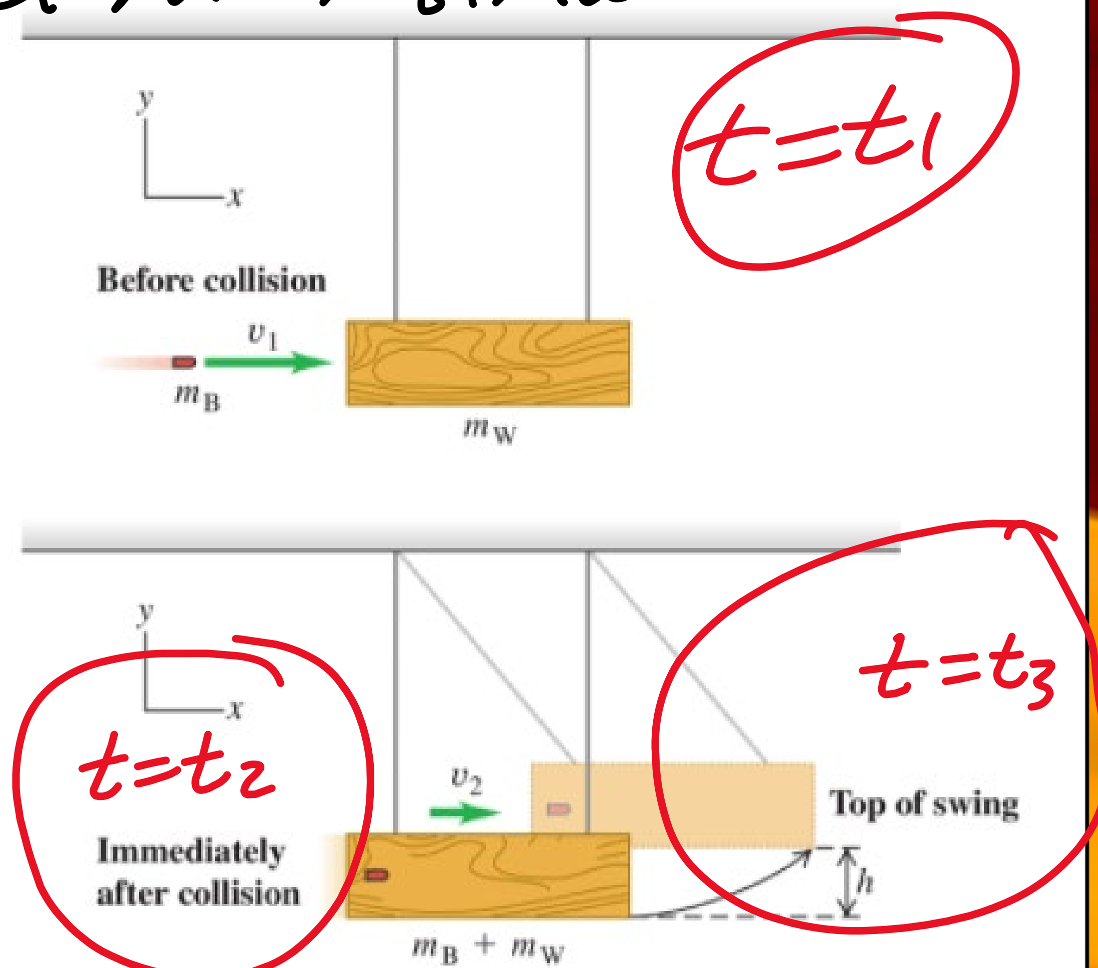

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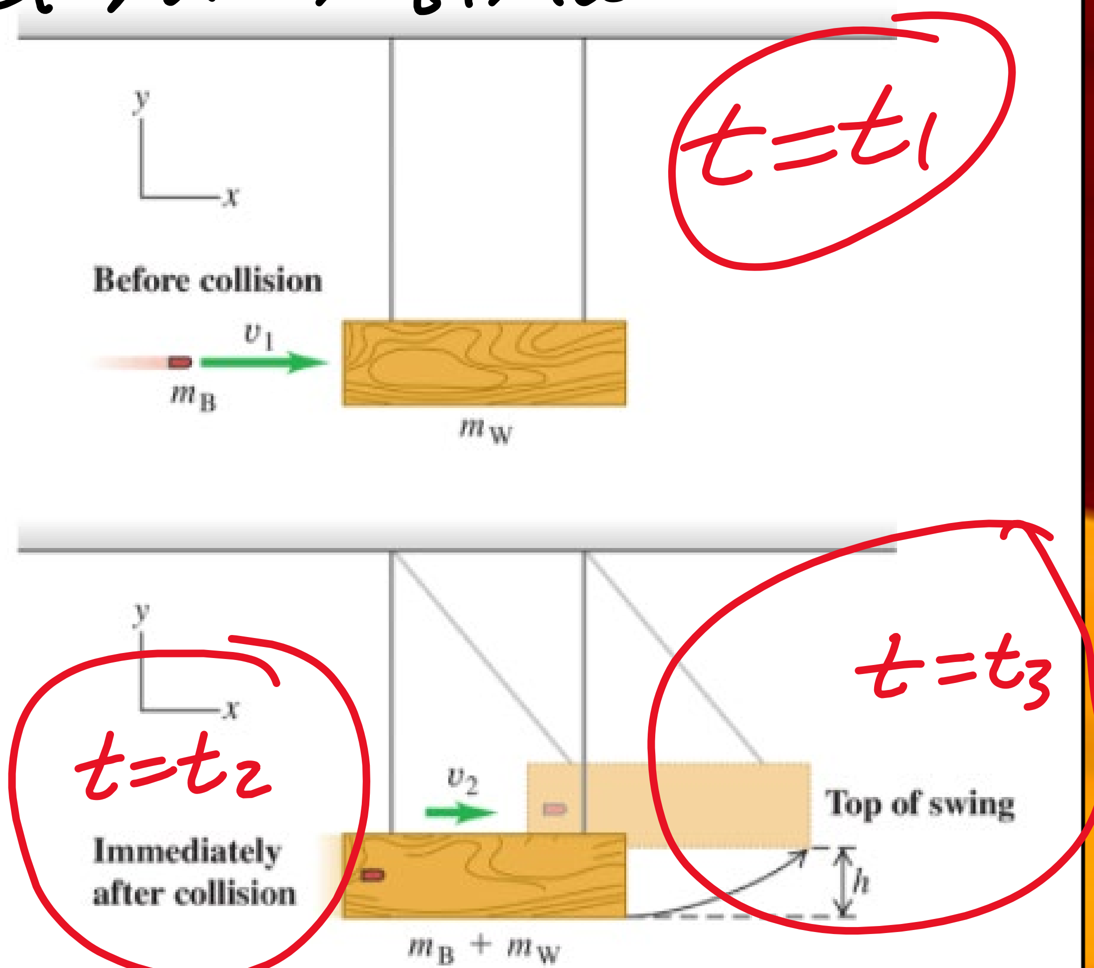

A 1000 kg car traveling north at 15 m/s collides with a 2000 kg truck traveling east at 10 m/s. The occupants, wearing seat belts, are uninjured, but the two vehicles move away from the impact point as one. The insurance adjustor asks you to find the velocity of the wreckage just after impact. What is your answer?

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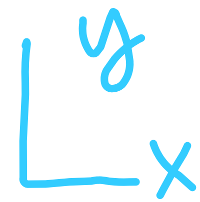

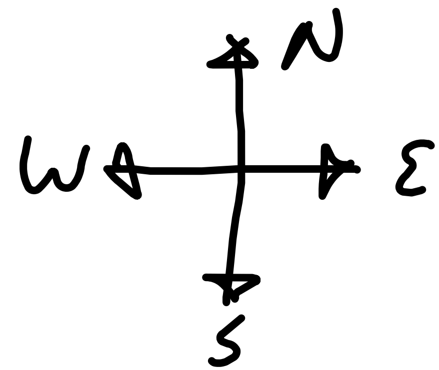

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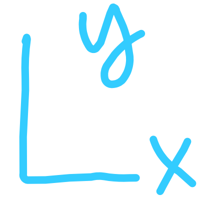

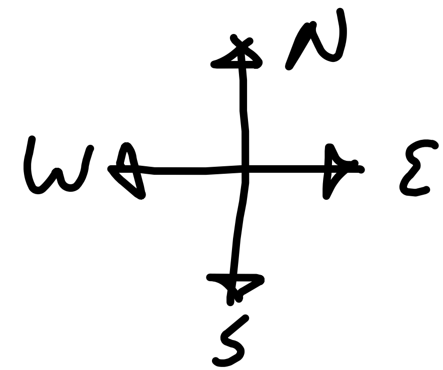

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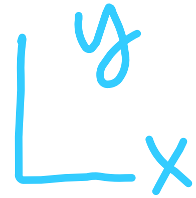

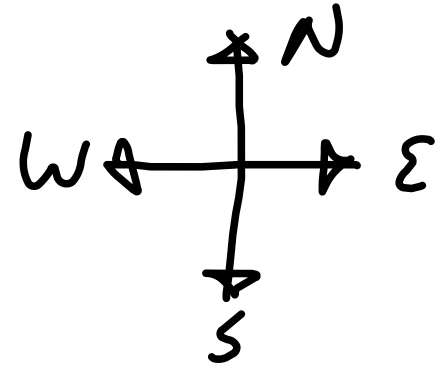

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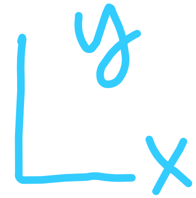

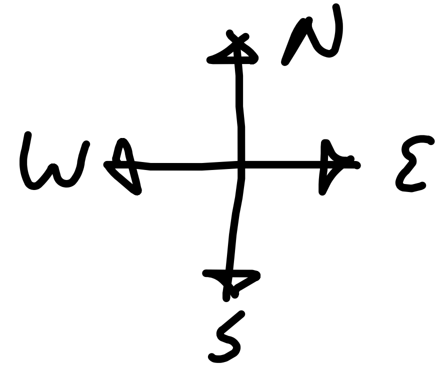

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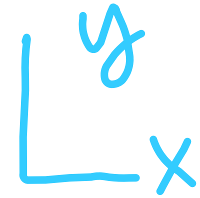

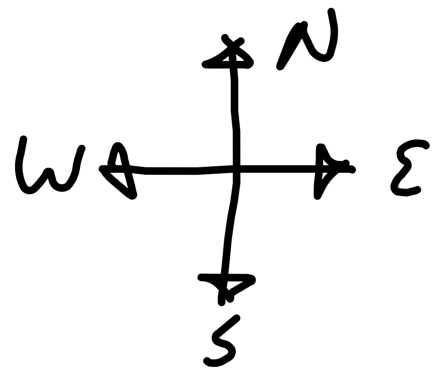

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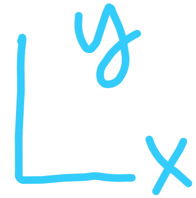

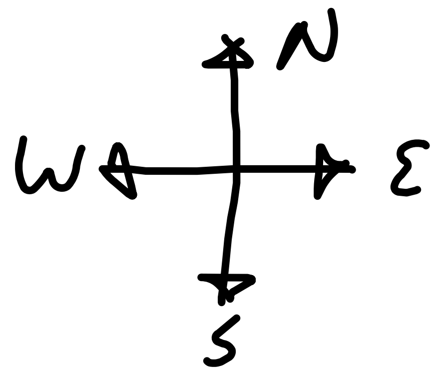

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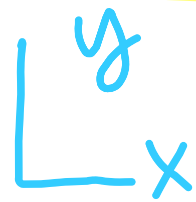

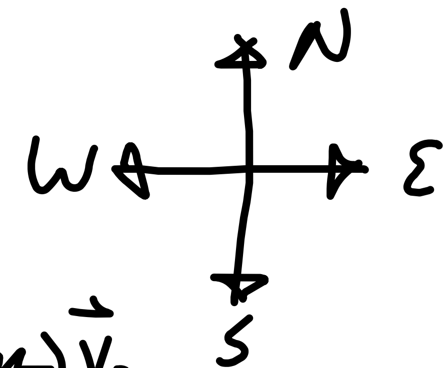

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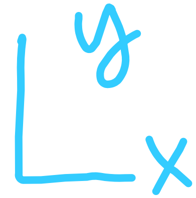

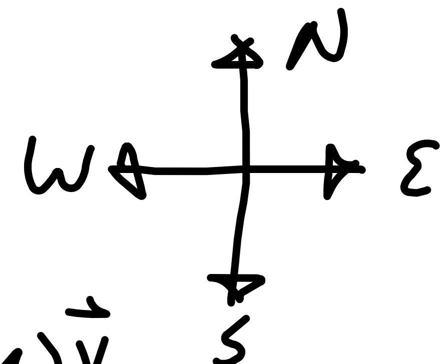

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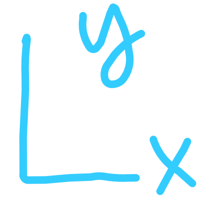

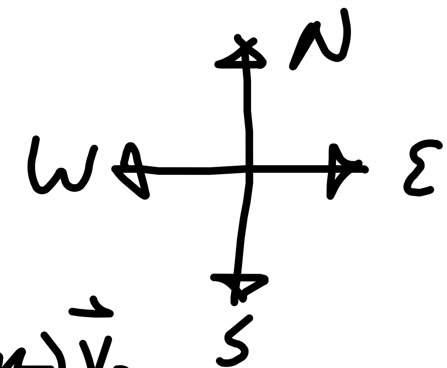

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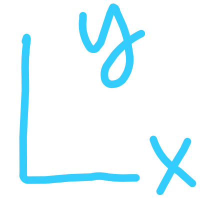

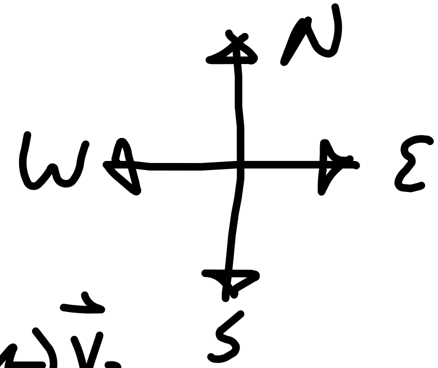

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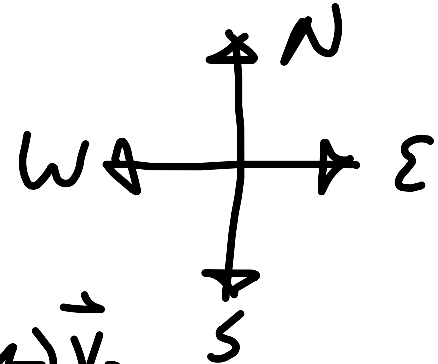

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$$V_2 = \sqrt{25 + \frac{400}{9}}\,\frac{m}{s}$$

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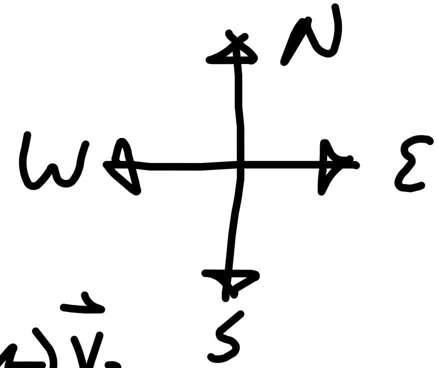


$\vec{P}_{c1} + \vec{P}_{T1} = \vec{P}_2 \Rightarrow M_c\vec{V}_{c1} + M_T\vec{V}_{T1} = (M_c + M_T)\vec{V}_2$

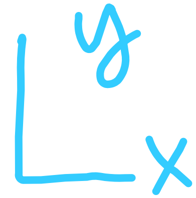
$$\Rightarrow \vec{V}_2 = \frac{M_c\vec{V}_{c1} + M_T\vec{V}_{T1}}{M_c + M_T} = \left[\frac{15000\hat{j} + 20000\hat{i}}{3000}\right]\frac{m}{s}$$

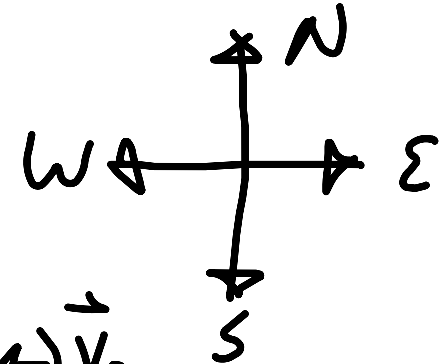
$$\Rightarrow \vec{V}_2 = 5\,m/s\;\hat{j} + \frac{20}{3}\hat{i}\;\frac{m}{s} \Rightarrow$$

$$V_2 = \sqrt{25 + \frac{400}{9}}\;\frac{m}{s} = 8{,}33\,m/s$$

$$\tan\theta = \frac{5}{20/3}$$

A 1000 kg car traveling north at 15 m/s collides with a 2000 kg truck traveling east at 10 m/s. The occupants, wearing seat belts, are uninjured, but the two vehicles move away from the impact point as one. The insurance adjustor asks you to find the velocity of the wreckage just after impact. What is your answer?





$m_c = 1000\,kg$, $\vec{V}_{c1} = 15\,m/s\ \hat{j}$

$m_T = 2000\,kg$, $\vec{V}_{T1} = 10\,m/s\ \hat{i}$

$\vec{V}_{c2} = \vec{V}_{T2} = \vec{V}_2$, $M = m_c + m_T$

$\vec{P}_{c1} + \vec{P}_{T1} = \vec{P}_2 \Rightarrow m_c\vec{V}_{c1} + m_T\vec{V}_{T1} = (m_c + m_T)\vec{V}_2$

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$$V_2 = \sqrt{25 + \frac{400}{9}}\ \frac{m}{s} = 8{,}33\ m/s$$

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A 1000 kg car traveling north at 15 m/s collides with a 2000 kg truck traveling east at 10 m/s. The occupants, wearing seat belts, are uninjured, but the two vehicles move away from the impact point as one. The insurance adjustor asks you to find the velocity of the wreckage just after impact. What is your answer?

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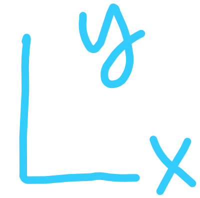

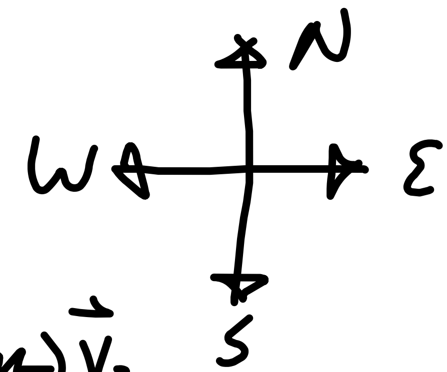

$\vec{V}_{c2} = \vec{V}_{T2} = \vec{V}_2$, $M = M_c + M_T$

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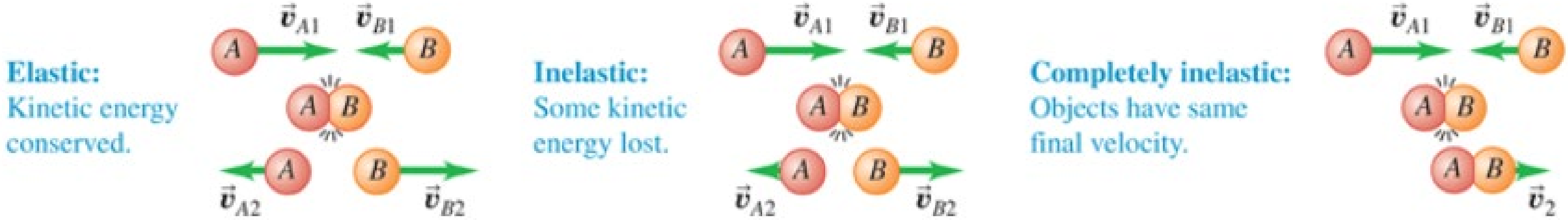
$$\Rightarrow \vec{V}_2 = 5\,m/s\ \hat{j} + \frac{20}{3}\hat{i}\ \frac{m}{s} \Rightarrow$$

$$\boxed{V_2 = \sqrt{25 + \frac{400}{9}}\ \frac{m}{s} = 8.33\,m/s}$$

$$\tan\theta = \frac{5}{20/3} \Rightarrow \theta = \tan^{-1}\left(\frac{15}{20}\right) \Rightarrow \boxed{\theta = 36.9^\circ}$$



Collisions are classified according to energy considerations.

Billiard balls deform very little when they collide, and they quickly spring back from any deformation they do undergo. Hence the force of interaction between the balls is almost perfectly conservative, and the collision is almost perfectly elastic.

Elastic collisions 1d

Elastic collisions 1d

$A + B \rightarrow A + B$

Elastic collisions 1d

$A + B \to A + B$

$\&$

$$P_{1A} + P_{B1} = P_{A2} + P_{B2}$$

$$\frac{P_{1A}^2}{2M_A} + \frac{P_{B1}^2}{2M_B} = \frac{P_{A2}^2}{2M_A} + \frac{P_{B2}^2}{2M_B}$$

Elastic collisions 1d

$A + B \rightarrow A + B$

$\not\$$

$$P_{1A} + P_{B1} = P_{A2} + P_{B2}$$

$$\frac{P_{1A}^2}{2m_A} + \frac{P_{B1}^2}{2m_B} = \frac{P_{A2}^2}{2m_A} + \frac{P_{B2}^2}{2m_B}$$

Note: $K = \frac{1}{2}mv^2$

Elastic collisions 1d

$A + B \rightarrow A + B$

$\$$

$$p_{1A} + p_{B1} = p_{A2} + p_{B2}$$

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Note: $K = \frac{1}{2}mv^2 = \frac{m^2v^2}{2m}$

Elastic collisions 1d

$A + B \rightarrow A + B$

$\$$

$$p_{1A} + p_{B1} = p_{A2} + p_{B2}$$

$$\frac{p_{1A}^2}{2m_A} + \frac{p_{B1}^2}{2m_B} = \frac{p_{A2}^2}{2m_A} + \frac{p_{B2}^2}{2m_B}$$

Note: $K = \frac{1}{2}mv^2 = \frac{m^2v^2}{2m}$

$$= \frac{p^2}{2m}$$

Elastic collisions 1d

$A + B \to A + B$ &

$$\left.\begin{aligned} P_{1A} + P_{B1} &= P_{A2} + P_{B2} \\ \frac{P_{1A}^2}{2m_A} + \frac{P_{B1}^2}{2m_B} &= \frac{P_{A2}^2}{2m_A} + \frac{P_{B2}^2}{2m_B} \end{aligned}\right\}$$

$$\Rightarrow \quad P_{1A} - P_{A2} = P_{B2} - P_{B1}$$

$$\& \quad \left(\frac{1}{m_A}\right)\left(P_{A1}^2 - P_{A2}^2\right) = \left(\frac{1}{m_B}\right)\left(P_{B2}^2 - P_{B1}^2\right)$$

Elastic collisions 1d

$A + B \to A + B$

&

$$\left.\begin{aligned} P_{1A} + P_{B1} &= P_{A2} + P_{B2} \\ \frac{P_{1A}^2}{2m_A} + \frac{P_{B1}^2}{2m_B} &= \frac{P_{A2}^2}{2m_A} + \frac{P_{B2}^2}{2m_B} \end{aligned}\right\}$$

$$\Rightarrow \quad P_{1A} - P_{A2} = P_{B2} - P_{B1} \qquad (1)$$

$$\& \quad \left(\frac{1}{m_A}\right)\left(P_{A1}^2 - P_{A2}^2\right) = \left(\frac{1}{m_B}\right)\left(P_{B2}^2 - P_{B1}^2\right)$$

Elastic collisions 1d

$A + B \to A + B$

&

$$\left.\begin{aligned} P_{1A} + P_{B1} &= P_{A2} + P_{B2} \\ \frac{P_{1A}^2}{2M_A} + \frac{P_{B1}^2}{2M_B} &= \frac{P_{A2}^2}{2M_A} + \frac{P_{B2}^2}{2M_B} \end{aligned}\right\}$$

(1)

$$\Rightarrow \quad P_{1A} - P_{A2} = P_{B2} - P_{B1}$$

$$\& \quad \left(\frac{1}{M_A}\right)(P_{A1}^2 - P_{A2}^2) = \left(\frac{1}{M_B}\right)(P_{B2}^2 - P_{B1}^2) \Rightarrow$$

$$\left(\frac{1}{M_A}\right)(P_{A1} - P_{A2})(P_{A1} + P_{A2}) = \left(\frac{1}{M_B}\right)(P_{B2} - P_{B1})(P_{B2} + P_{B1})$$

Elastic collisions 1d

$$A + B \rightarrow A + B$$

&

$$\left.\begin{aligned} P_{1A} + P_{B1} &= P_{A2} + P_{B2} \\ \frac{P_{1A}^2}{2m_A} + \frac{P_{B1}^2}{2m_B} &= \frac{P_{A2}^2}{2m_A} + \frac{P_{B2}^2}{2m_B} \end{aligned}\right\}$$

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$$\left(\frac{1}{m_A}\right)\left(P_{A1} - P_{A2}\right)\left(P_{A1} + P_{A2}\right) = \left(\frac{1}{m_B}\right)\left(P_{B2} - P_{B1}\right)\left(P_{B2} + P_{B1}\right) \quad (2)$$

Elastic collisions 1d

$A + B \rightarrow A + B$

&

$$\left.\begin{aligned} P_{1A} + P_{B1} &= P_{A2} + P_{B2} \\ \frac{P_{1A}^2}{2m_A} + \frac{P_{B1}^2}{2m_B} &= \frac{P_{A2}^2}{2m_A} + \frac{P_{B2}^2}{2m_B} \end{aligned}\right\}$$

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$$\left(\frac{1}{m_A}\right)(P_{A1} - P_{A2})(P_{A1} + P_{A2}) = \left(\frac{1}{m_B}\right)(P_{B2} - P_{B1})(P_{B2} + P_{B1}) \quad (2)$$

Divide (2) by (1)

Elastic collisions 1d

$A + B \to A + B$

$\&$

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$$\& \quad \left(\frac{1}{m_A}\right)(P_{A1}^2 - P_{A2}^2) = \left(\frac{1}{m_B}\right)(P_{B2}^2 - P_{B1}^2) \Rightarrow$$

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Divide (2) by (1) to get

Elastic collisions 1d

$A + B \to A + B$

&

$$\left.\begin{aligned} P_{1A} + P_{B1} &= P_{A2} + P_{B2} \\ \frac{P_{1A}^2}{2m_A} + \frac{P_{B1}^2}{2m_B} &= \frac{P_{A2}^2}{2m_A} + \frac{P_{B2}^2}{2m_B} \end{aligned}\right\}$$

$\Rightarrow \quad P_{1A} - P_{A2} = P_{B2} - P_{B1} \quad (1)$

& $\quad \left(\frac{1}{m_A}\right)(P_{A1}^2 - P_{A2}^2) = \left(\frac{1}{m_B}\right)(P_{B2}^2 - P_{B1}^2) \Rightarrow$

$$\left(\frac{1}{m_A}\right)(P_{A1} - P_{A2})(P_{A1} + P_{A2}) = \left(\frac{1}{m_B}\right)(P_{B2} - P_{B1})(P_{B2} + P_{B1}) \quad (2)$$

Divide (2) by (1) to get

$$\left(\frac{1}{m_A}\right)(P_{A1} + P_{A2}) = \left(\frac{1}{m_B}\right)(P_{B2} + P_{B1})$$

Elastic collisions 1d

$A + B \to A + B$

&

$$\left.\begin{aligned} p_{1A} + p_{B1} &= p_{A2} + p_{B2} \\ \frac{p_{1A}^2}{2m_A} + \frac{p_{B1}^2}{2m_B} &= \frac{p_{A2}^2}{2m_A} + \frac{p_{B2}^2}{2m_B} \end{aligned}\right\}$$

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$$\left(\frac{1}{m_A}\right)(p_{A1} - p_{A2})(p_{A1} + p_{A2}) = \left(\frac{1}{m_B}\right)(p_{B2} - p_{B1})(p_{B2} + p_{B1}) \quad (2)$$

Divide (2) by (1) to get

$$\left(\frac{1}{m_A}\right)(p_{A1} + p_{A2}) = \left(\frac{1}{m_B}\right)(p_{B2} + p_{B1}) \Rightarrow V_{A1} + V_{A2} = V_{B2} + V_{B1}$$

ASU

Elastic collisions 1d

$$A + B \to A + B \quad \&$$

$$\left.\begin{aligned} p_{1A} + p_{B1} &= p_{A2} + p_{B2} \\ \frac{p_{1A}^2}{2m_A} + \frac{p_{B1}^2}{2m_B} &= \frac{p_{A2}^2}{2m_A} + \frac{p_{B2}^2}{2m_B} \end{aligned}\right\}$$

$$\Rightarrow \quad p_{1A} - p_{A2} = p_{B2} - p_{B1} \qquad (1)$$

$$\& \quad \left(\frac{1}{m_A}\right)\left(p_{A1}^2 - p_{A2}^2\right) = \left(\frac{1}{m_B}\right)\left(p_{B2}^2 - p_{B1}^2\right) \Rightarrow$$

$$\left(\frac{1}{m_A}\right)(p_{A1} - p_{A2})(p_{A1} + p_{A2}) = \left(\frac{1}{m_B}\right)(p_{B2} - p_{B1})(p_{B2} + p_{B1}) \quad (2)$$

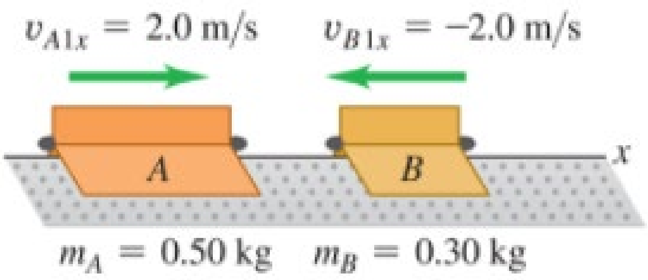
Divide (2) by (1) to get

$$\left(\frac{1}{m_A}\right)(p_{A1} + p_{A2}) = \left(\frac{1}{m_B}\right)(p_{B2} + p_{B1}) \Rightarrow v_{A1} + v_{A2} = v_{B2} + v_{B1}$$

$$\Rightarrow \quad \boxed{v_{A1} - v_{B1} = v_{B2} - v_{A1}}$$

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?

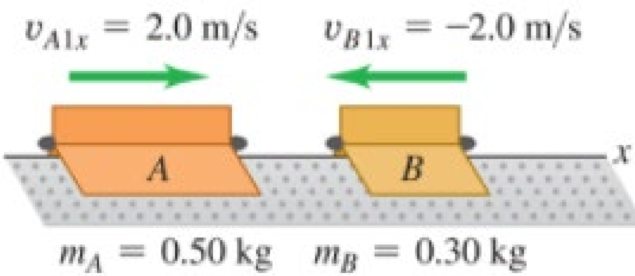
(a) Before collision



We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?

$M_A = 0.5\,kg$, $V_{A1} = 2\,\frac{m}{s}$

$M_B = 0.3\,kg$, $V_{B1} = -2\,\frac{m}{s}$



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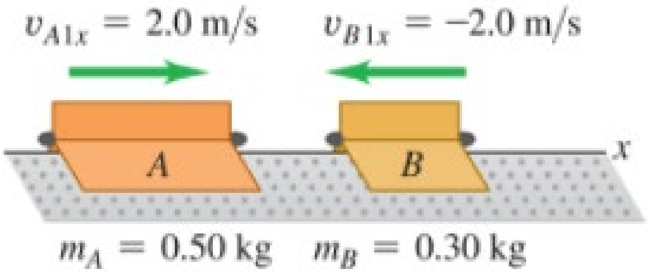

(a) Before collision

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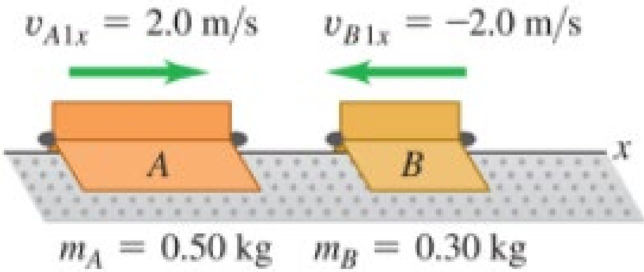
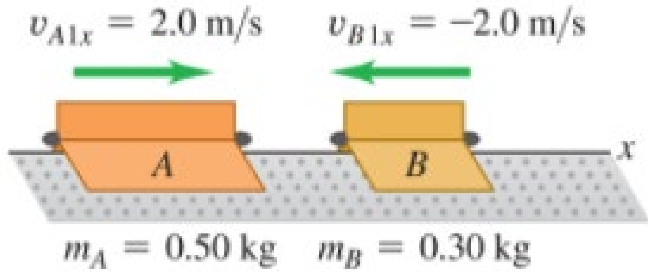
$M_B = 0.3\,kg$, $V_{B1} = -2\,\frac{m}{s}$



(a) Before collision

$$V_{B2} - V_{A2} = V_{A1} - V_{B1}$$

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?



(a) Before collision

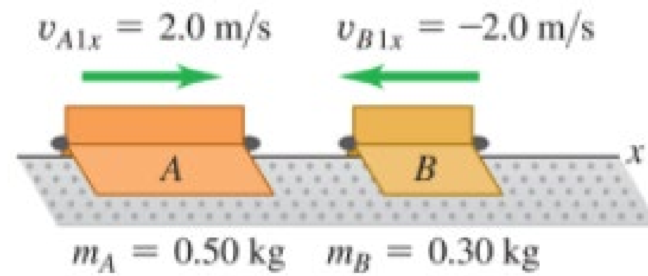
$M_A = 0.5$ kg, $V_{A1} = 2 \frac{m}{s}$

$M_B = 0.3$ kg, $V_{B1} = -2 \frac{m}{s}$

$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $M_A V_{A1} + M_B V_{B1} = M_A V_{A2} + M_B V_{B2}$

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?

(a) Before collision



$m_A = 0.5\,kg$, $V_{A1} = 2\,\frac{m}{s}$

$m_B = 0.3\,kg$, $V_{B1} = -2\,\frac{m}{s}$

$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $m_A V_{A1} + m_B V_{B1} = m_A V_{A2} + m_B V_{B2}$

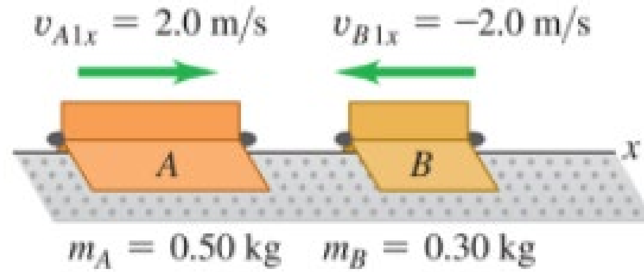
$\Rightarrow V_{B2} - V_{A2} = 4\,m/s$

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?

$M_A = 0.5\,kg$, $V_{A1} = 2\,\frac{m}{s}$

$M_B = 0.3\,kg$, $V_{B1} = -2\,\frac{m}{s}$

(a) Before collision



$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $M_A V_{A1} + M_B V_{B1} = M_A V_{A2} + M_B V_{B2}$

$\Rightarrow$ $V_{B2} - V_{A2} = 4\,m/s$ & $(1 - 0.6)\,kg\,\frac{m}{s} = M_A V_{A2} + M_B V_{B2}$

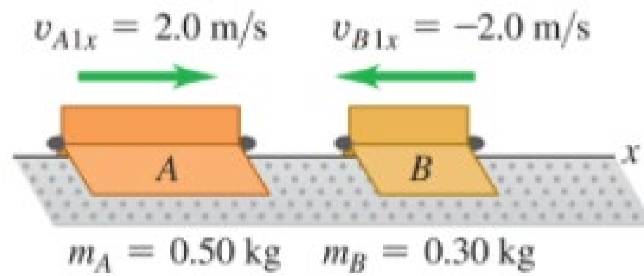
ASU

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?

$m_A = 0.5\,\text{kg}$, $V_{A1} = 2\,\frac{m}{s}$

$m_B = 0.3\,\text{kg}$, $V_{B1} = -2\,\frac{m}{s}$

(a) Before collision

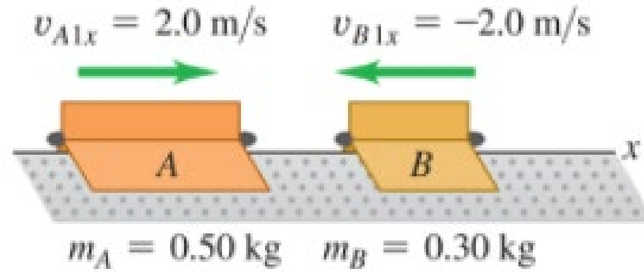


$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $m_A V_{A1} + m_B V_{B1} = m_A V_{A2} + m_B V_{B2}$

$\Rightarrow V_{B2} - V_{A2} = 4\,m/s$ & $(1 - 0.6)\,\text{kg}\,\frac{m}{s} = m_A V_{A2} + m_B V_{B2}$

$\Rightarrow V_{B2} = V_{A2} + 4\,m/s$

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?



(a) Before collision

$M_A = 0.5\,kg$, $V_{A1} = 2\,\frac{m}{s}$

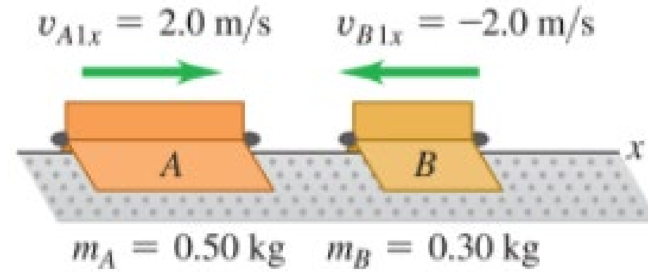
$M_B = 0.3\,kg$, $V_{B1} = -2\,\frac{m}{s}$

$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $M_A V_{A1} + M_B V_{B1} = M_A V_{A2} + M_B V_{B2}$

$\Rightarrow V_{B2} - V_{A2} = 4\,m/s$ & $(1 - 0.6)\,kg\,\frac{m}{s} = M_A V_{A2} + M_B V_{B2}$

$\Rightarrow V_{B2} = V_{A2} + 4\,m/s$ $\Rightarrow$ $0.4\,kg\,\frac{m}{s} = M_A V_{A2} + M_B(V_{A2} + 4\,\frac{m}{s})$

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?



(a) Before collision

$m_A = 0.5\,\text{kg}, \quad V_{A1} = 2\,\frac{m}{s}$

$m_B = 0.3\,\text{kg}, \quad V_{B1} = -2\,\frac{m}{s}$

$V_{B2} - V_{A2} = V_{A1} - V_{B1} \quad \& \quad m_A V_{A1} + m_B V_{B1} = m_A V_{A2} + m_B V_{B2}$

$\Rightarrow V_{B2} - V_{A2} = 4\,\text{m/s} \quad \& \quad (1 - 0.6)\,\text{kg}\,\frac{m}{s} = m_A V_{A2} + m_B V_{B2}$

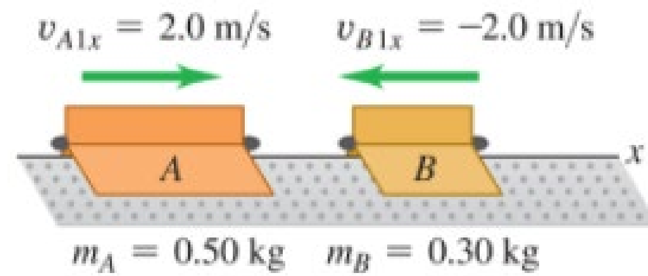
$\Rightarrow V_{B2} = V_{A2} + 4\,\text{m/s} \Rightarrow 0.4\,\text{kg}\,\frac{m}{s} = m_A V_{A2} + m_B \left(V_{A2} + 4\,\frac{m}{s}\right)$

$\Rightarrow 0.4\,\text{kg}\,\frac{m}{s} - m_B\, 4\,\frac{m}{s} = (m_A + m_B) V_{A2}$

We repeat the air-track collision of Example 8.5 (Section 8.2), but now we add ideal spring bumpers to the gliders so that the collision is elastic. What are the final velocities of the gliders?

$M_A = 0.5\,kg, \; V_{A1} = 2\,\frac{m}{s}$

$M_B = 0.3\,kg, \; V_{B1} = -2\,\frac{m}{s}$



(a) Before collision

$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $M_A V_{A1} + M_B V_{B1} = M_A V_{A2} + M_B V_{B2}$

$\Rightarrow V_{B2} - V_{A2} = 4\,m/s$ & $(1 - 0.6)\,kg\,\frac{m}{s} = M_A V_{A2} + M_B V_{B2}$

$\Rightarrow V_{B2} = V_{A2} + 4\,m/s \Rightarrow 0.4\,kg\,\frac{m}{s} = M_A V_{A2} + M_B\left(V_{A2} + 4\,\frac{m}{s}\right)$

$\Rightarrow 0.4\,kg\,\frac{m}{s} - M_B\,4\,\frac{m}{s} = (M_A + M_B) V_{A2} \Rightarrow$

$(0.4 - 1.2)\,kg\,\frac{m}{s} = 0.8\,kg\,V_{A2}$

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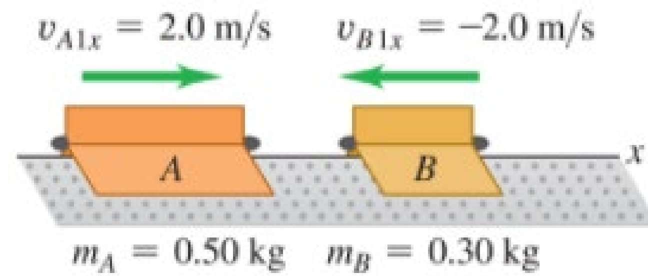

(a) Before collision

$M_A = 0.5\,kg,\ V_{A1} = 2\,\frac{m}{s}$

$M_B = 0.3\,kg,\ V_{B1} = -2\,\frac{m}{s}$

$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $M_A V_{A1} + M_B V_{B1} = M_A V_{A2} + M_B V_{B2}$

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$\Rightarrow 0.4\,kg\,\frac{m}{s} - M_B\, 4\,\frac{m}{s} = (M_A + M_B) V_{A2} \Rightarrow$

$(0.4 - 1.2)\,kg\,\frac{m}{s} = 0.8\,kg\, V_{A2} \Rightarrow \boxed{V_{A2} = -1\,\frac{m}{s}}$

ASU

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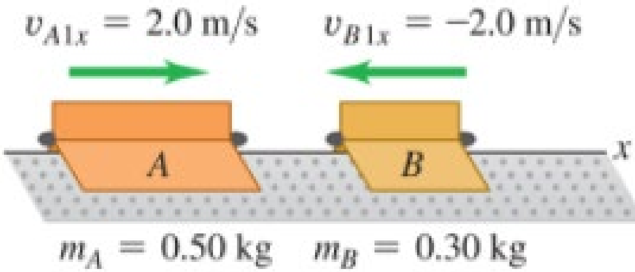

$V_{B2} - V_{A2} = V_{A1} - V_{B1}$ & $M_A V_{A1} + M_B V_{B1} = M_A V_{A2} + M_B V_{B2}$

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$(0.4 - 1.2)\,kg\,\frac{m}{s} = 0.8\,kg\, V_{A2} \Rightarrow \boxed{V_{A2} = -1\,\frac{m}{s}}$ &

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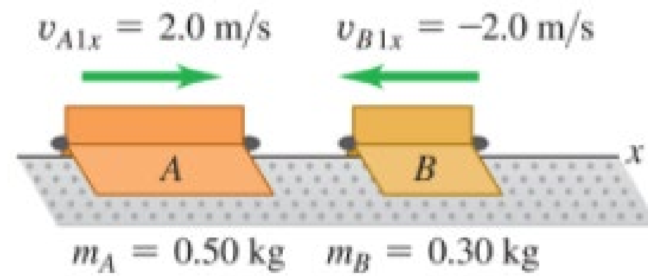

$V_{B2} - V_{A2} = V_{A1} - V_{B1} \;\; \& \;\; M_A V_{A1} + M_B V_{B1} = M_A V_{A2} + M_B V_{B2}$

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$(0.4 - 1.2)\,kg\frac{m}{s} = 0.8\,kg\, V_{A2} \Rightarrow \boxed{V_{A2} = -1\,\frac{m}{s}} \;\; \&$

$\boxed{V_{B2} = V_{A2} + 4\,m/s = 3\,m/s}$

The fission of uranium nuclei in a nuclear reactor produces high-speed neutrons. Before such neutrons can efficiently cause additional fissions, they must be slowed down by collisions with nuclei in the *moderator* of the reactor. The first nuclear reactor (built in 1942 at the University of Chicago) used carbon (graphite) as the moderator. Suppose a neutron (mass 1.0 u) traveling at $2.6 \times 10^7 \, \mathrm{m/s}$ undergoes a head-on elastic collision with a carbon nucleus (mass 12 u) initially at rest. Neglecting external forces during the collision, find the velocities after the collision. (1 u is the *atomic mass unit,* equal to 1.66×10^{-27} kg.)

$M_N = 1u$, $V_{N_1} = 2.6 * 10^7 \, m/s$

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Find V_{N2} & V_{c2}: $\quad V_{N1} - \cancel{V_{c1}}^{0} = V_{c2} - V_{N2}$ &

$M_N V_{N1} = M_N V_{N2} + M_c V_{c2}$ $\quad$ But $V_{c2} = V_{N1} + V_{N2}$

so $\quad M_N V_{N1} = M_N V_{N2} + M_c V_{N1} + M_c V_{N2} \Rightarrow$

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so $M_N V_{N1} = M_N V_{N2} + M_c V_{N1} + M_c V_{N2} \Rightarrow$

$M_N V_{N1} - M_c V_{N1} = M_N V_{N2} + M_c V_{N2} \Rightarrow V_{N1}(M_N - M_c) = V_{N2}(M_N + M_c)$

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So $M_N V_{N1} = M_N V_{N2} + M_c V_{N1} + M_c V_{N2} \Rightarrow$

$M_N V_{N1} - M_c V_{N1} = M_N V_{N2} + M_c V_{N2} \Rightarrow V_{N1}(M_N - M_c) = V_{N2}(M_N + M_c)$

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$M_N V_{N1} = M_N V_{N2} + M_c V_{c2}$ But $V_{c2} = V_{N1} + V_{N2}$

so $M_N V_{N1} = M_N V_{N2} + M_c V_{N1} + M_c V_{N2} \Rightarrow$

$M_N V_{N1} - M_c V_{N1} = M_N V_{N2} + M_c V_{N2} \Rightarrow V_{N1}(M_N - M_c) = V_{N2}(M_N + M_c)$

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ASU

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Find V_{N2} & V_{c2}: $V_{N1} - \cancel{V_{c1}}^{\,0} = V_{c2} - V_{N2}$ &

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$M_N V_{N1} - M_c V_{N1} = M_N V_{N2} + M_c V_{N2} \Rightarrow V_{N1}(M_N - M_c) = V_{N2}(M_N + M_c)$

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$V_{c2} = (2.6 - 2.2) * 10^7\ m/s$

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$M_N V_{N1} - M_c V_{N1} = M_N V_{N2} + M_c V_{N2} \Rightarrow V_{N1}(M_N - M_c) = V_{N2}(M_N + M_c)$

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$$\boxed{V_{c2} = (2.6 - 2.2)*10^7 \, m/s = 4*10^6 \, m/s}$$