Momentum Linear dan Tumbukan (*Linear Momentum and Collisions*)

Momentum and Collisions

Linear Momentum

The linear momentum of a particle of mass *m moving with a velocity v is defined* to be the product of the mass and velocity:

$$\mathbf{p} = m\mathbf{v}$$

If a particle is moving in an arbitrary direction, **p** must have three components,

$$p_x = mv_x \qquad p_y = mv_y \qquad p_z = mv_z$$

Linear Momentum

Using Newton's second law of motion, we can relate the linear momentum of a particle to the resultant force acting on the particle: ***The time rate of change of the linear momentum of a particle is equal to the net force acting on the particle:***

$$\sum \mathbf{F} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t} = \frac{\mathrm{d}(m\mathbf{v})}{\mathrm{d}t}$$

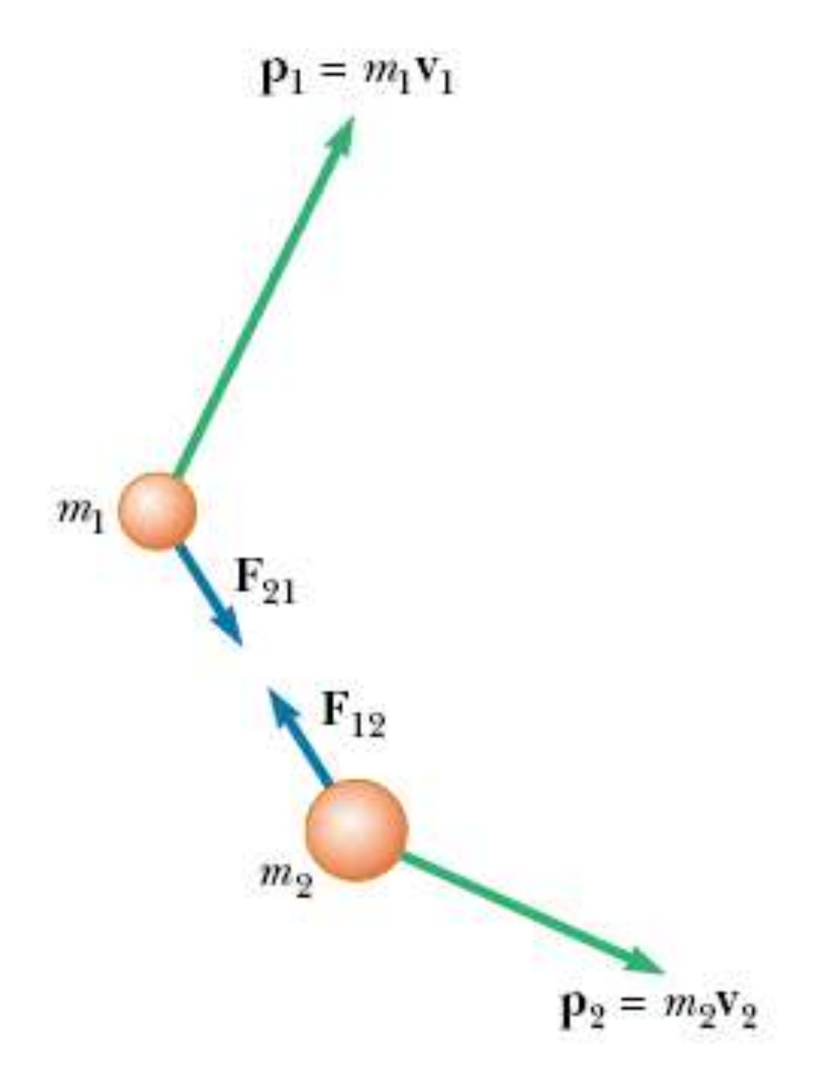
The real value of Equation as a tool for analysis, however, stems from the fact that when the net force acting on a particle is zero, the time derivative of the momentum of the particle is zero, and therefore its linear momentum is constant.

$$\sum \mathbf{F} = 0$$

$\mathbf{p}$ remains unchanged

This means that $\mathbf{p}$ is conserved

Conservation of Momentum for a Two-Particle System



$$\mathbf{F}_{21} = \frac{d\mathbf{p}_1}{dt} \quad \text{and} \quad \mathbf{F}_{12} = \frac{d\mathbf{p}_2}{dt}$$

Newton's third law tells us that :

$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

$$\mathbf{F}_{21} + \mathbf{F}_{12} = 0$$

$$\frac{d\mathbf{p}_1}{dt} + \frac{d\mathbf{p}_2}{dt} = \frac{d}{dt}(\mathbf{p}_1 + \mathbf{p}_2) = 0$$

$$\mathbf{p}_{tot} = \sum_{\text{system}} \mathbf{p} = \mathbf{p}_1 + \mathbf{p}_2 = \text{constant}$$

$$\mathbf{p}_{1i} + \mathbf{p}_{2i} = \mathbf{p}_{1f} + \mathbf{p}_{2f}$$

the law of conservation of linear momentum

$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_2\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$$

The total momentum in the *x, y, and z* directions are all independently conserved:

$$\sum_{\text{system}} p_{ix} = \sum_{\text{system}} p_{fx} \qquad \sum_{\text{system}} p_{iy} = \sum_{\text{system}} p_{fy} \qquad \sum_{\text{system}} p_{iz} = \sum_{\text{system}} p_{fz}$$

$$m_1 v_{1ix} + m_2 v_{2ix} = m_1 v_{1fx} + m_2 v_{2fx}$$

$$m_1 v_{1iy} + m_2 v_{2iy} = m_1 v_{1fy} + m_2 v_{2fy}$$

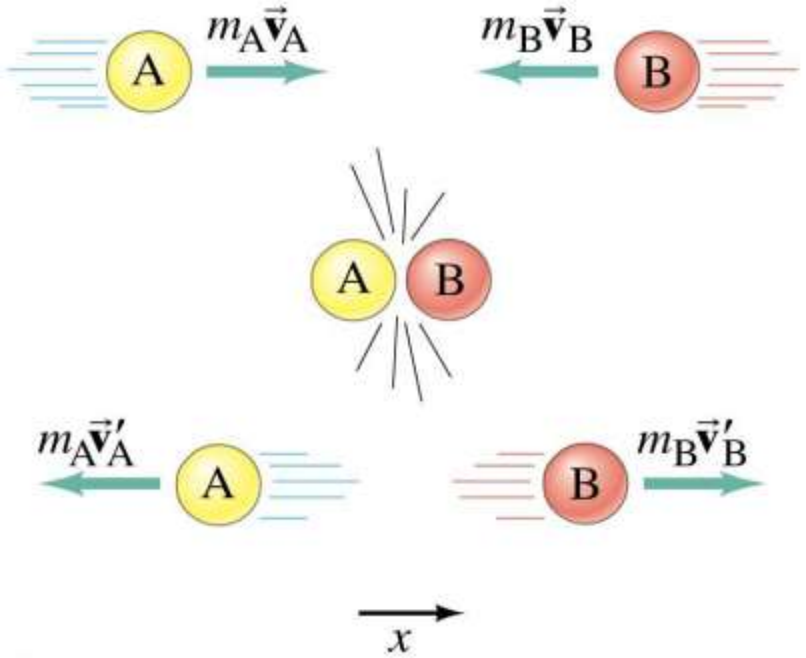
$$m_1 v_{1iz} + m_2 v_{2iz} = m_1 v_{1fz} + m_2 v_{2fz}$$

This law tells us that the total momentum of an isolated system at all times equals its initial momentum.

Hukum Kekekalan Momentum

Selama tumbukan, pengukuran menunjukkan bahwa jumlah momentum sebelum tumbukan dan setelah tumbtukan tidak berubah:

$$m_A \vec{\mathbf{v}}_A + m_B \vec{\mathbf{v}}_B = m_A \vec{\mathbf{v}}'_A + m_B \vec{\mathbf{v}}'_B$$



Momentum Conservation Principle

Consider a collision between two objects - object 1 and object 2. For such a collision, the forces acting between the two objects are equal in magnitude and opposite in direction (Newton's third law). This statement can be expressed in equation form as follows.

$$F_1 = - F_2$$

The forces are equal in magnitude and opposite in direction.

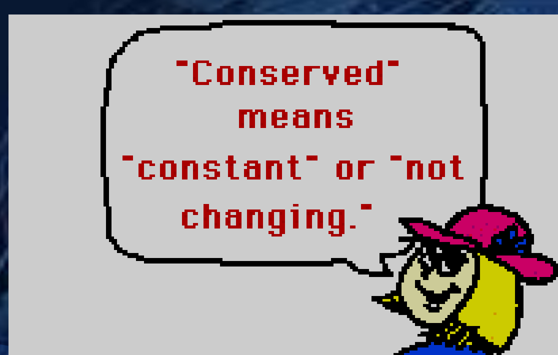
$$t_1 = t_2$$

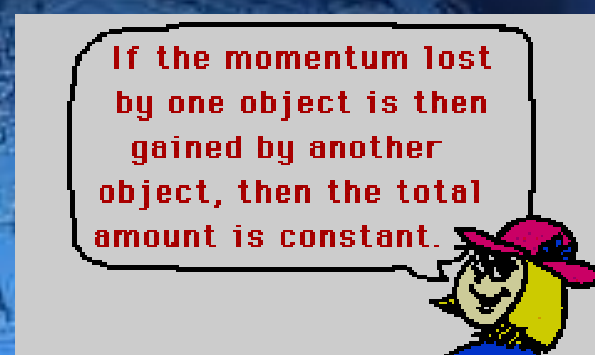
$$F_1 * t_1 = - F_2 * t_2$$

The impulses are equal in magnitude and opposite in direction.

$$m_1 * \Delta v_1 = - m_2 * \Delta v_2$$

The momentum changes are equal in magnitude and opposite in direction.



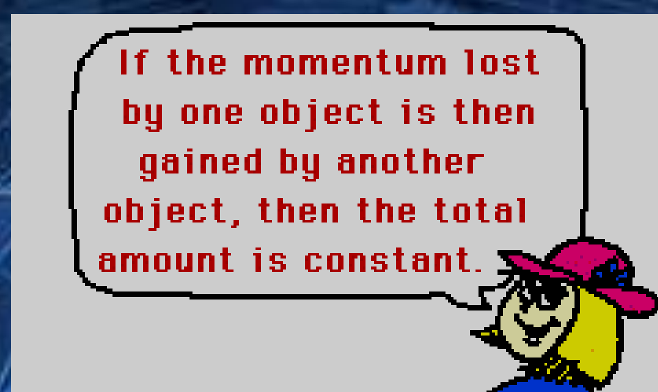


Momentum Conservation Principle (Sistem Terisolasi)

Analogi konservasi dalam interaksi finansial

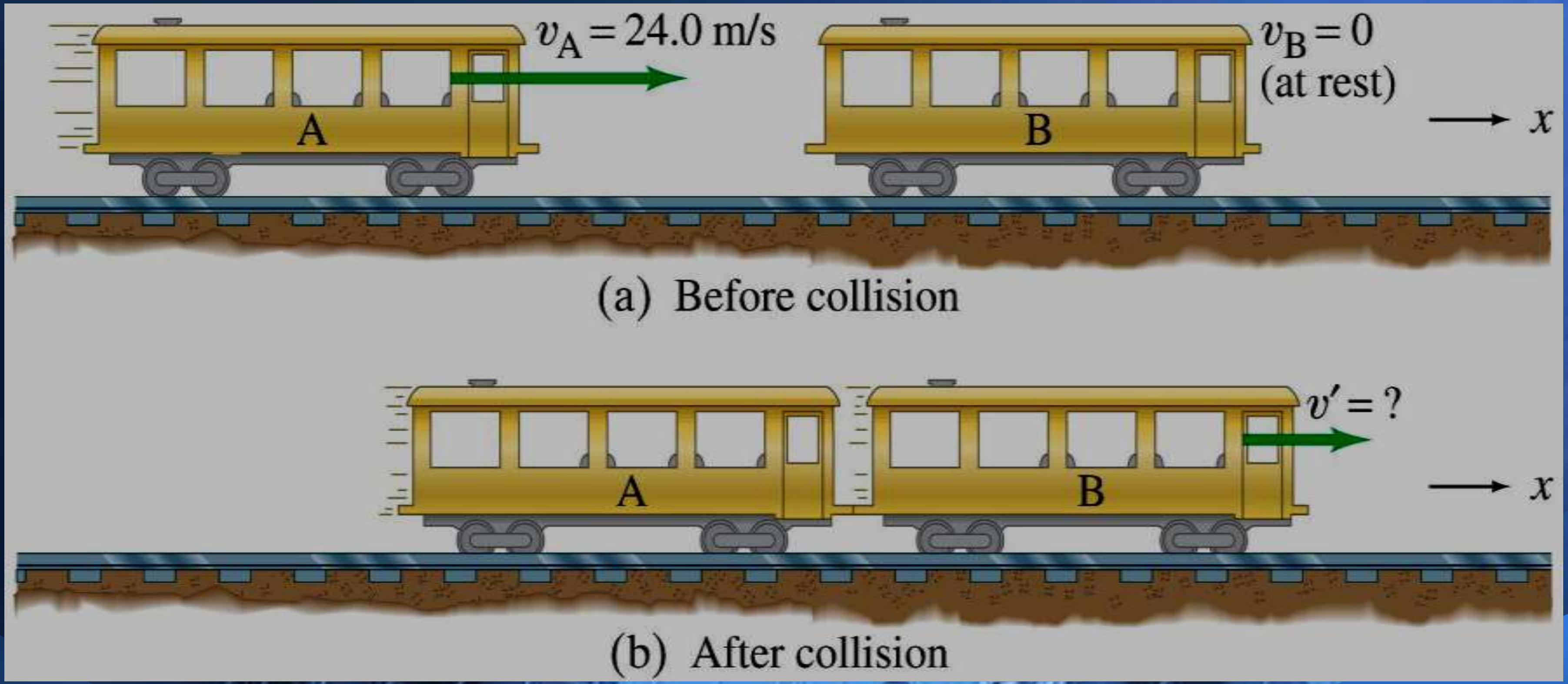
Money Conservation in a Financial Interaction

	Before	After	Change
Jack	\$100	\$50	−\$50
Jill	\$100	\$150	+\$50
Total	\$200	\$200	



Hukum Kekekalan Momentum

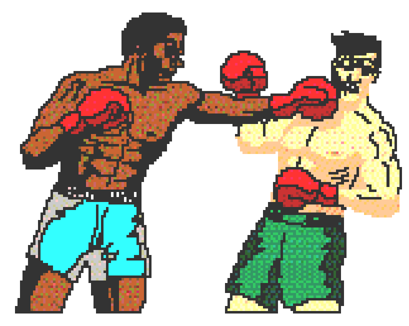
Total momentum sistem terisolasi dari benda/objek tetap konstan.

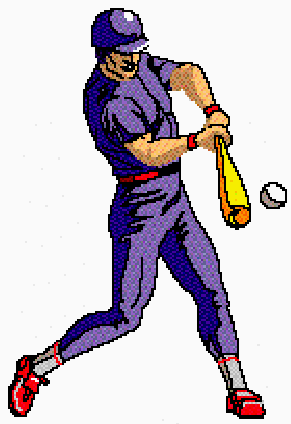


Impulse and Momentum

$$\mathbf{F} = \frac{d\mathbf{p}}{dt}$$

$$d\mathbf{p} = \mathbf{F}\,dt$$



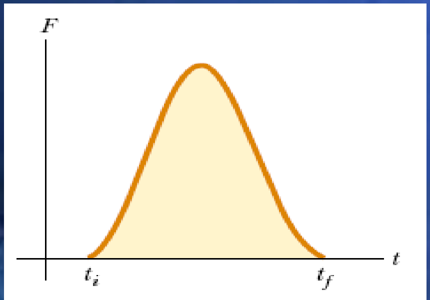


If the momentum of the particle

changes from $\mathbf{p}_i$ at time t_i to $\mathbf{p}_f$ at time t_f, integrating Equation

$$\Delta\mathbf{p} = \mathbf{p}_f - \mathbf{p}_i = \int_{t_i}^{t_f} \mathbf{F}\,dt$$

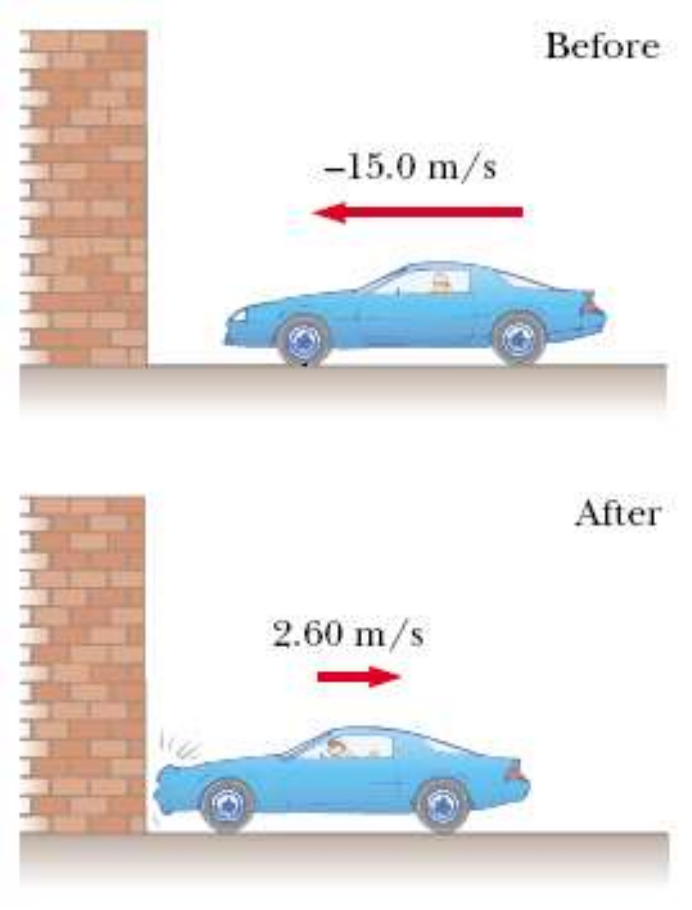
$$\mathbf{I} \equiv \int_{t_i}^{t_f} \mathbf{F}\,dt = \Delta\mathbf{p}$$



The impulse of the force **F** acting on a particle equals the change in the momentum of the particle caused by that force.

This statement, known as the **impulse–momentum theorem**,

Impulse and Momentum



$$\mathbf{p}_i = m\mathbf{v}_i = (1\,500\text{ kg})(-15.0\mathbf{i}\text{ m/s}) = -2.25 \times 10^4\mathbf{i}\text{ kg}\cdot\text{m/s}$$

$$\mathbf{p}_f = m\mathbf{v}_f = (1\,500\text{ kg})(2.60\mathbf{i}\text{ m/s}) = 0.39 \times 10^4\mathbf{i}\text{ kg}\cdot\text{m/s}$$

Hence, the impulse is

$$\mathbf{I} = \Delta\mathbf{p} = \mathbf{p}_f - \mathbf{p}_i = 0.39 \times 10^4\mathbf{i}\text{ kg}\cdot\text{m/s} - (-2.25 \times 10^4\mathbf{i}\text{ kg}\cdot\text{m/s})$$

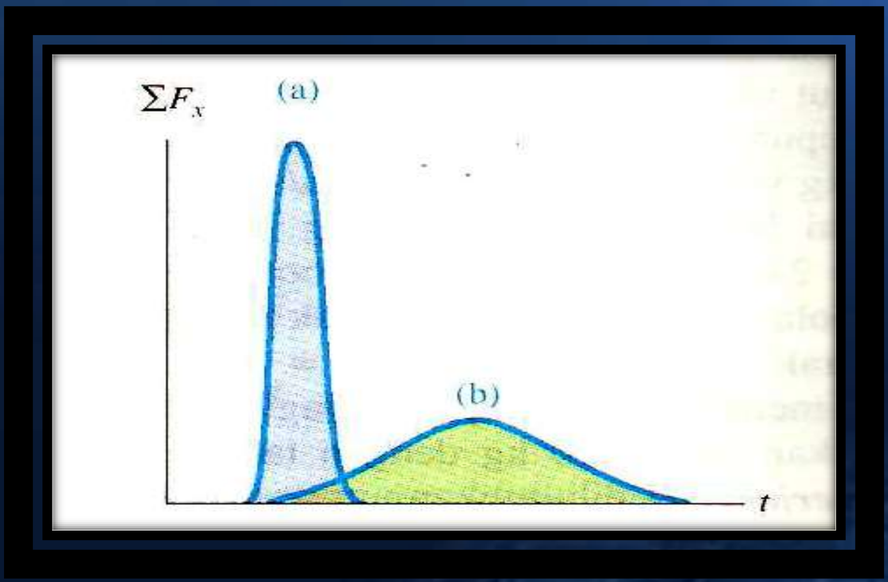
$$\mathbf{I} = 2.64 \times 10^4\mathbf{i}\text{ kg}\cdot\text{m/s}$$

The average force exerted on the automobile is

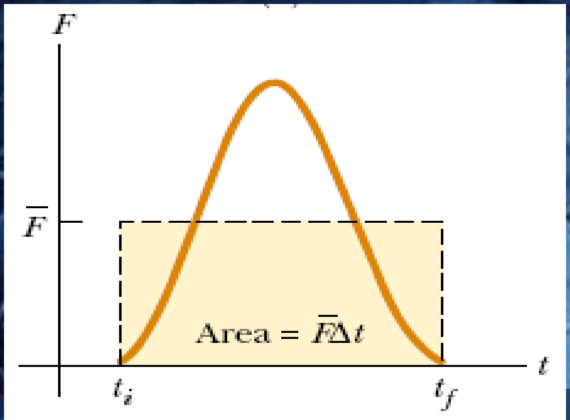
$$\overline{\mathbf{F}} = \frac{\Delta\mathbf{p}}{\Delta t} = \frac{2.64 \times 10^4\mathbf{i}\text{ kg}\cdot\text{m/s}}{0.150\text{ s}} = 1.76 \times 10^5\mathbf{i}\text{ N}$$

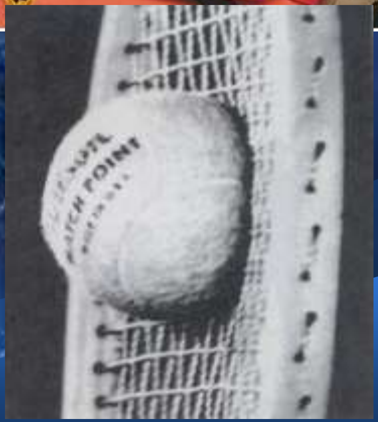
Impulse and Momentum

$$\mathbf{I} \equiv \int_{t_i}^{t_f} \mathbf{F}\, dt = \Delta \mathbf{p}$$



$$\overline{\mathbf{F}} \equiv \frac{1}{\Delta t}\int_{t_i}^{t_f} \mathbf{F}\, dt$$





$$\mathbf{I} \equiv \overline{\mathbf{F}}\,\Delta t$$

Elastic and Inelastic Collisions in One Dimension

Perfectly Inelastic Collisions

$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = (m_1 + m_2)\mathbf{v}_f$$

$$\mathbf{v}_f = \frac{m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i}}{m_1 + m_2}$$

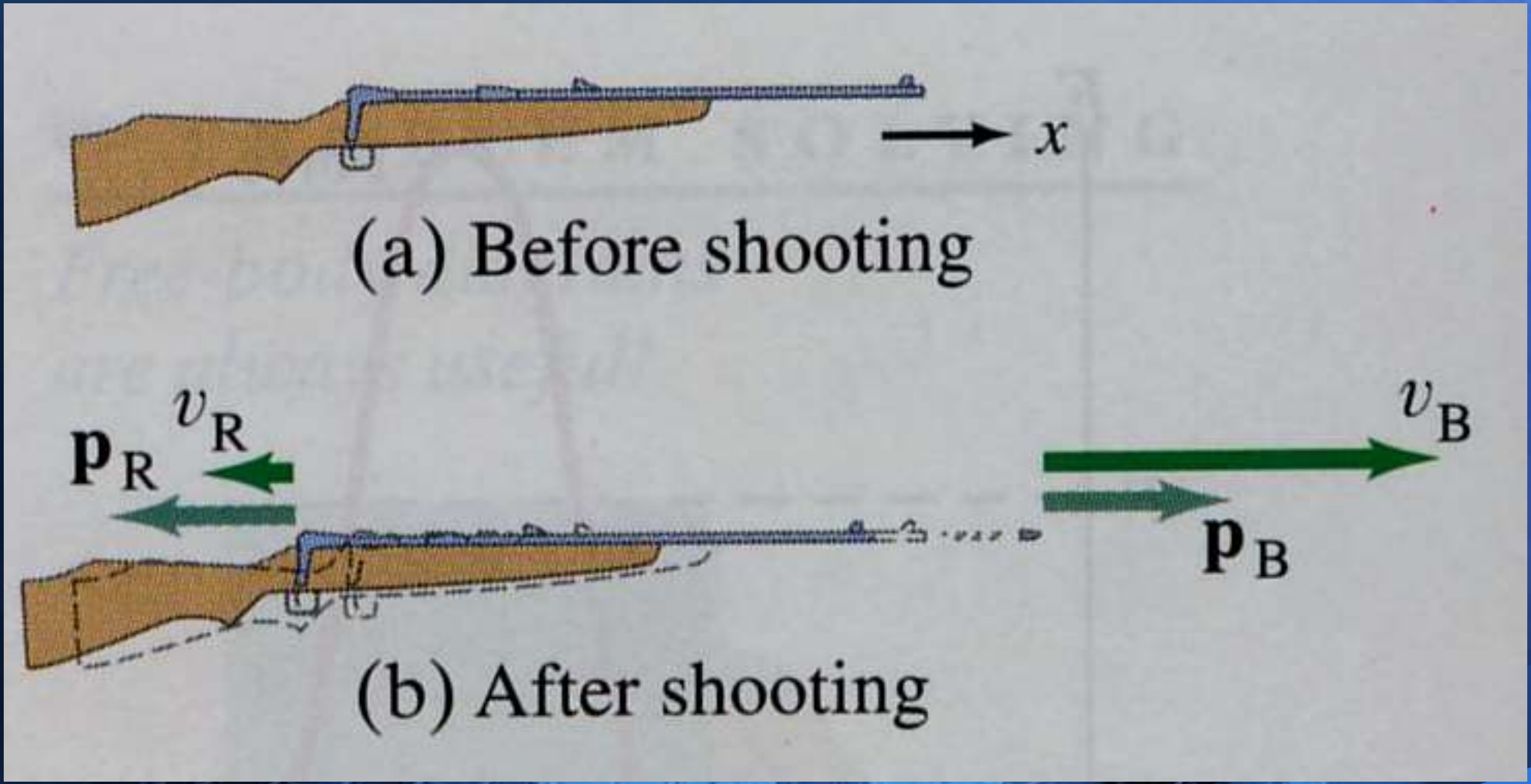
Elastic Collisions

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

$$\frac{1}{2}m_1 {v_{1i}}^2 + \frac{1}{2}m_2 {v_{2i}}^2 = \frac{1}{2}m_1 {v_{1f}}^2 + \frac{1}{2}m_2 {v_{2f}}^2$$

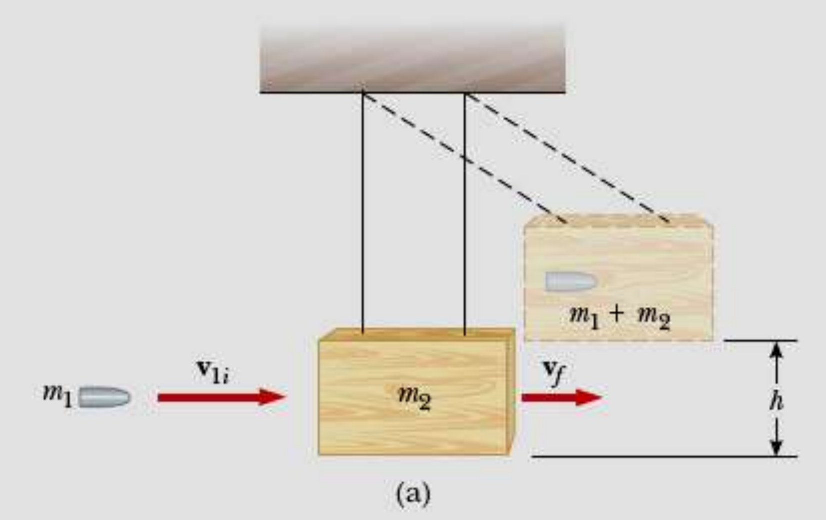
Contoh Soal 1

- Hitung kecepatan balik senapan 5,0 kg yang menembakkan peluru 0,050 kg dengan laju 120 m/s.



Contoh Soal 2. **The Ballistic Pendulum**

In a ballistic pendulum experiment, suppose that h=5.00 cm, m_1=5.00 g, and m_2=1.00 kg. Find (a) the initial speed of the bullet and (b) the loos in mechanical energy due to the collision.

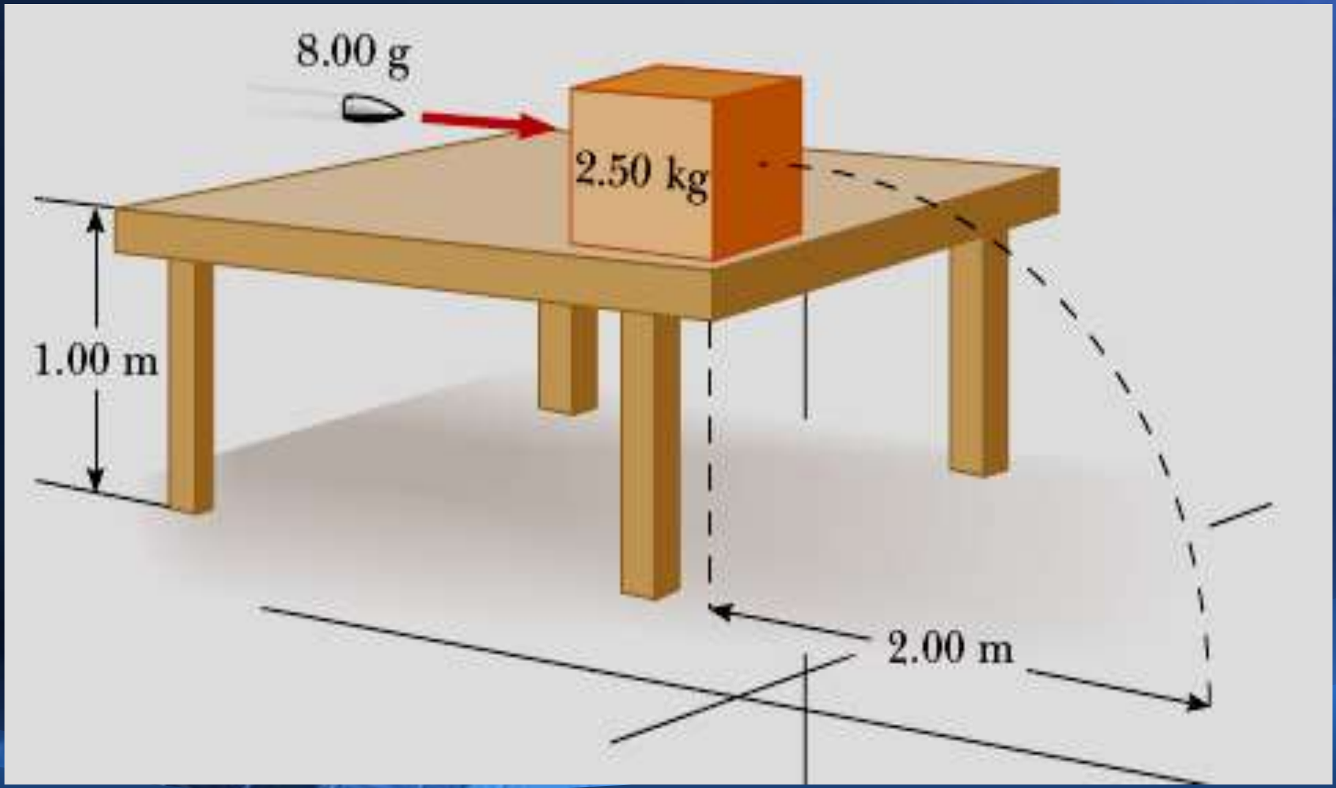


$$v_{1i} = \left(\frac{m_1 + m_2}{m_1}\right)\sqrt{2gh}$$

$$K_f = \frac{m_1{}^2 v_{1i}{}^2}{2(m_1 + m_2)}$$

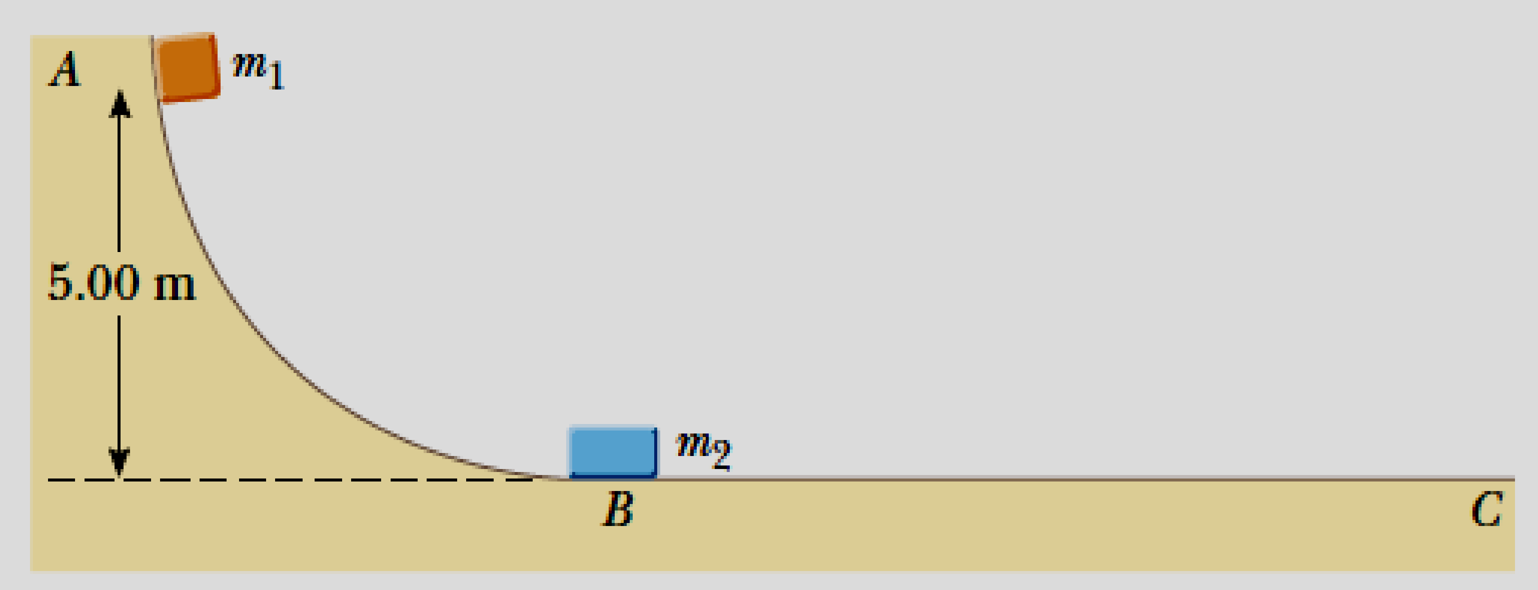
Contoh Soal 3

- Peluru 8,0 g ditembakkan ke dalam 2,5 kg balok kayu yang dalam keadaan diam di atas meja tanpa gesekan dengan tinggi meja 1,0 m. Setelah tertembak, balok kayu mendarat di lantai pada jarak 2,0 m dari batas sisi meja, sedangkan peluru terbenam di dalamnya. Tentukan kecepatan awal peluru.



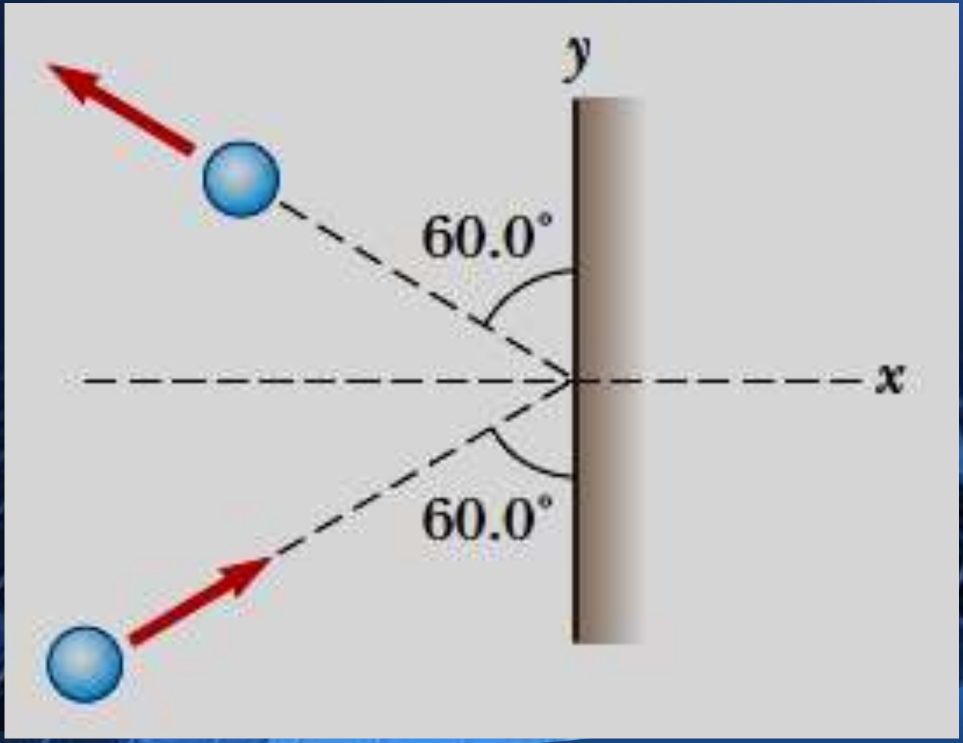
Contoh Soal 4

- Consider a frictionless track ABC as shown in Figure. A block of mass m_1=5.0 kg is released from A. It makes a head-on elastic collision at B with a block of mass m_2=10.0 kg that is initially at rest. Calculate the maximum height to which m_1 rises after the collision.



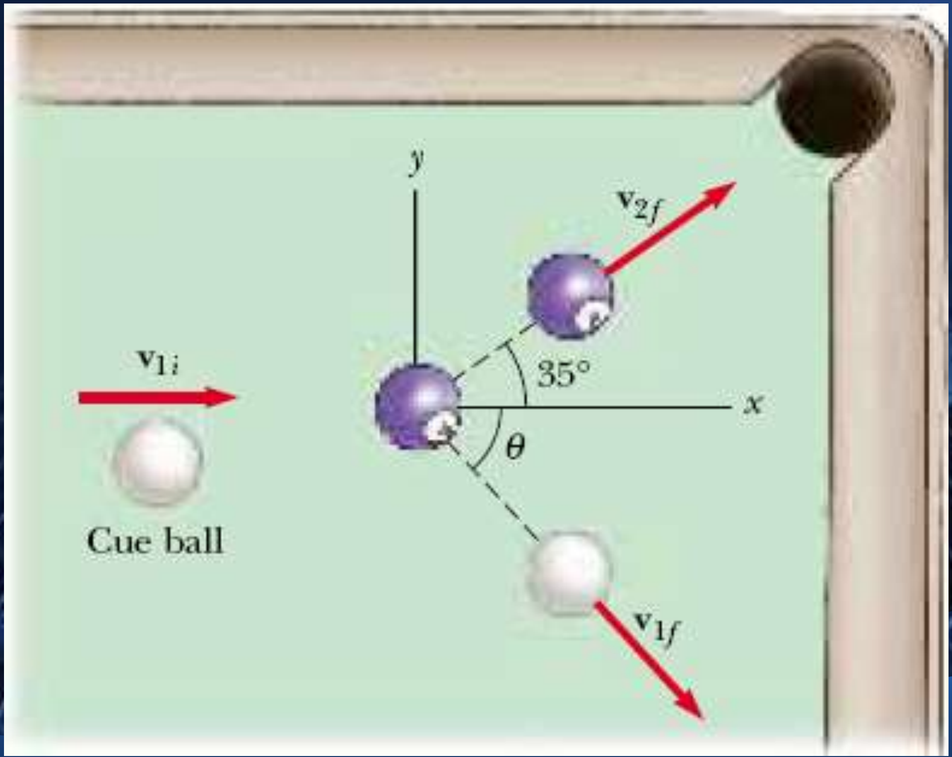
Contoh Soal 5

- A 3.00 kg steel ball strikes a wall with a speed of 10.0 m/s at an angle of 60.0° with the surface. It bounces off with the same speed and angle. If the ball is in contact with the wall for 0.200 s, what is the average force exerted on the ball by the wall?



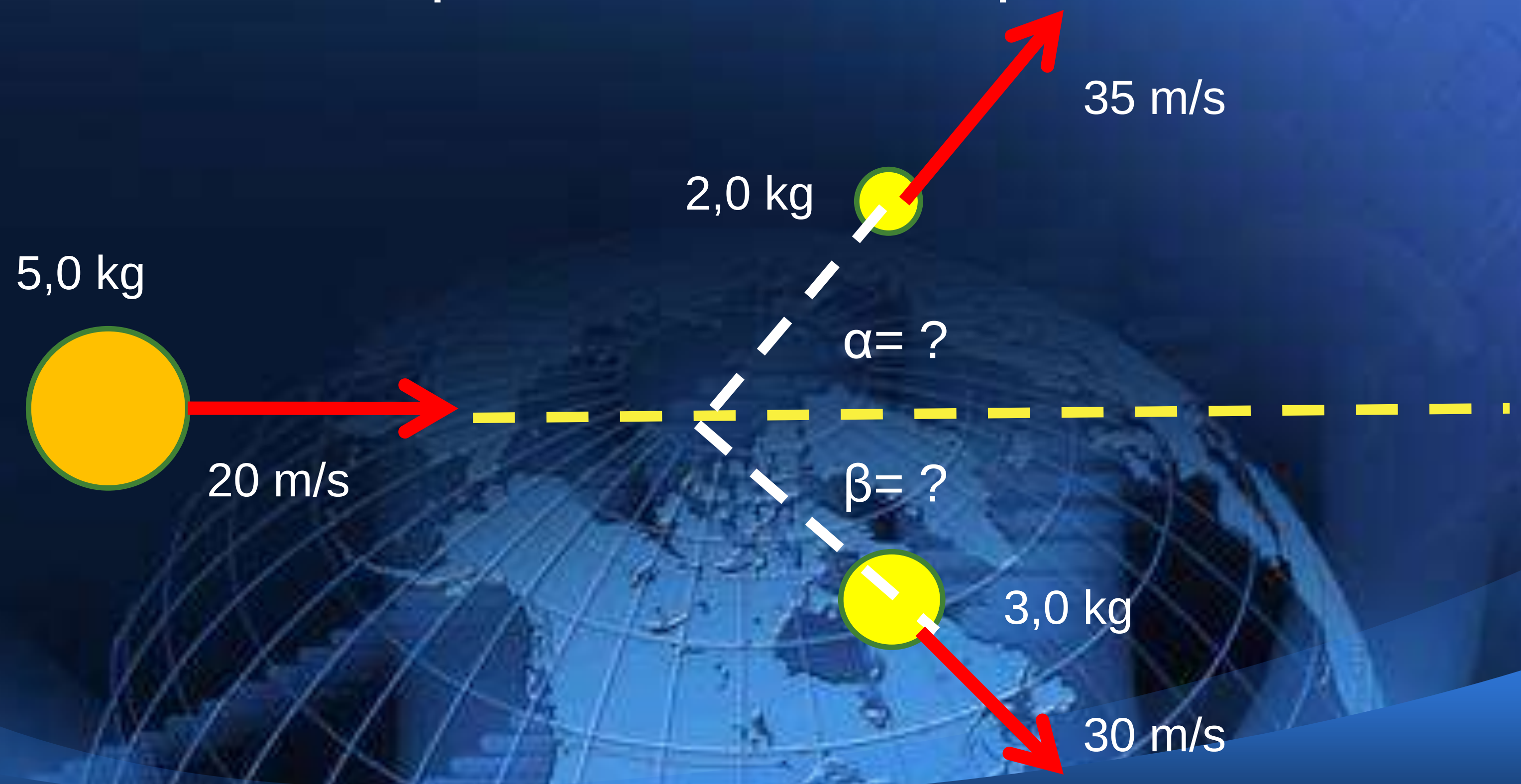
Contoh Soal 6

- In a game of billiards, a player wishes to sink a target ball 2 in the corner pocket, as shown in Figure . If the angle to the corner pocket is 35°, at what angle θ is the cue ball 1 deflected? Assume that friction and rotational motion are unimportant and that the collision is elastic.

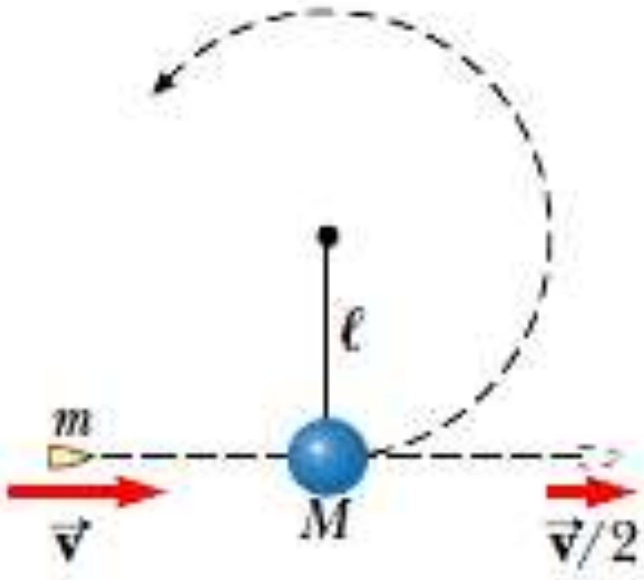


Contoh Soal 7

- A 5,0 kg body moving with a speed of 20 m/s explodes into 2,0 kg mass moving at 35 m/s and 3,0 kg mass moving at 30 m/s. Determine the direction of motion, relative to the initial direction of motion of the 5,0 kg body, of each of the two pieces after the explosion.



56. A bullet of mass m and speed v passes completely through a pendulum bob of mass M as shown in Figure P6.56. The bullet emerges with a speed of $v/2$. The pendulum bob is suspended by a stiff rod of length ℓ and negligible mass. What is the minimum value of v such that the bob will barely swing through a complete vertical circle?

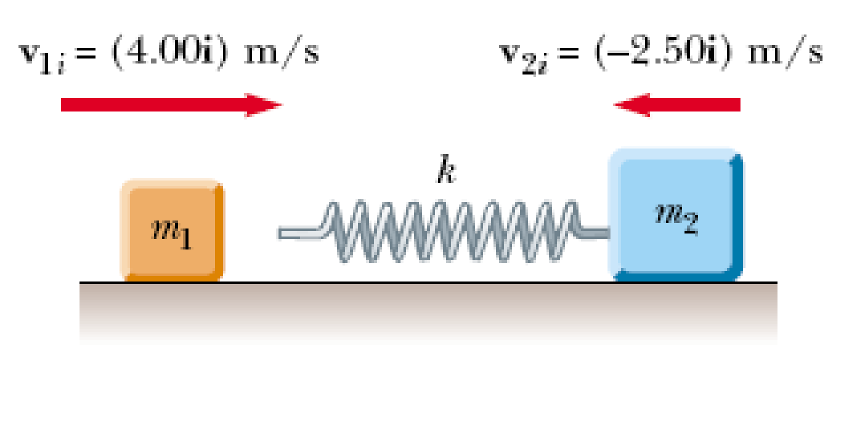


Contoh Soal 8

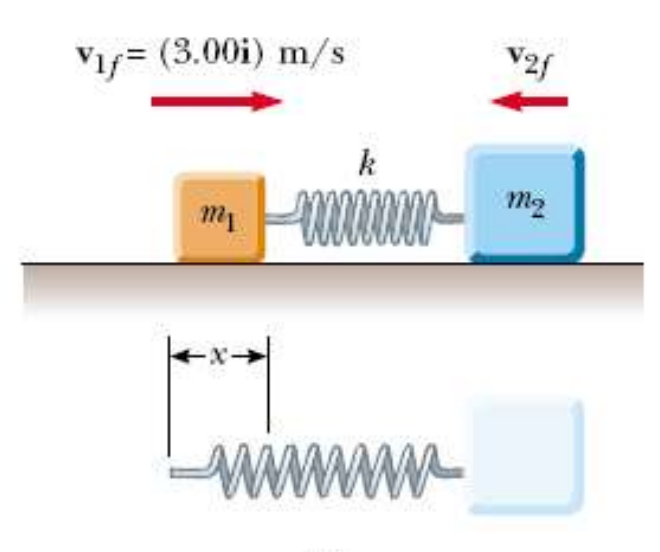
- How Good are the Bumpers? In a particuler crash test, an autobobile of mass 1500 kg collides with a wall, as shown in figure. The initial and final velocities of the aotomobile are $\mathbf{v}_i$=-15**i** m/s and v_f=2.60**i** m/s, respectively. If the collision last for 0.150 s, find the impuls caused by the collision and the average force exerted on the automobile.

Problem

- A block of mass m_1 = 1.60 kg initially moving to the right with a speed of 4.00 m/s on a frictionless horizontal track collides with a spring attached to a second block of mass m_2 = 2.10 kg initially moving to the left with a speed of 2.50 m/s, as shown in Figure a. The spring constant is 600 N/m. (a) At the instant block 1 is moving to the right with a speed of 3.00 m/s, as in Figure b, determine the velocity of block 2. (b) Determine the distance the spring is compressed at that instant.



(a)



(b)

Tugas Rumah: Merangkum

- Buku Sears & Zemansky Fisika Universitas I
  - Contoh 8-2
  - Contoh 8-3
  - Contoh 8-6
  - Contoh 8-10
  - Contoh 8-13