Announcements

1. Read Chapter 9 – notion of impulse and momentum
2. Feedback questionaire
3. Tutorials?

Review -- Work-Kinetic energy theorem:

$$W_{total}^{i\to f} = \tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2$$

Analyzing work in terms of "conservative" and "non-conservative":

$$W_{total}^{i\to f} = W_{conservative}^{i\to f} + W_{non-conservative}^{i\to f} = U(\mathbf{r}_i) - U(\mathbf{r}_f) + W_{non-conservative}^{i\to f}$$

Rearranging terms to form total mechanical energy:

$$\tfrac{1}{2} m v_f^2 + U(\mathbf{r}_f) = \tfrac{1}{2} m v_i^2 + U(\mathbf{r}_i) + W_{non-conservative}^{i\to f}$$

Statement of conservation of energy: If $W_{non-conservative}^{i\to f} = 0$

$$E_{mechanical} = \tfrac{1}{2} m v^2 + U(\mathbf{r}\ ) = (\text{constant}); \Rightarrow \frac{dE_{mech}}{dt} = 0$$

A new way to look at Newton's second law:

$$\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt} = \frac{d(m\mathbf{v})}{dt} \equiv \frac{d\mathbf{p}}{dt}$$

Define linear momentum **p** = m**v**

Consequences:

1. If $\mathbf{F} = 0$ ➔ $\frac{d\mathbf{p}}{dt} = 0$ ➔ $\mathbf{p} = \text{constant}$

2. Notion of impulse: $d\mathbf{p} = \mathbf{F}dt$

$$\int_i^f d\mathbf{p} = \Delta\mathbf{p}_{i\to f} = \int_i^f \mathbf{F}dt$$

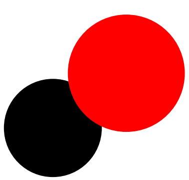
Conservation of (linear) momentum:

If $\frac{d\mathbf{p}}{dt} = \mathbf{F} = 0$, $\mathbf{p}$ = constant

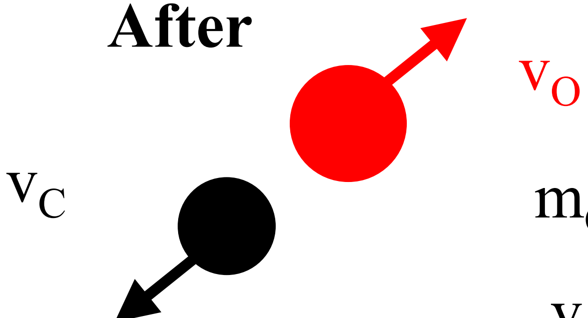
Example:

Suppose a molecule of CO is initially at rest, and it suddenly decomposes into separate C and O atoms. In this process the chemical binding energy E_0 is transformed into mechanical energy of the C and O atoms. What can you say about the motion of these atoms after the decomposition?

Before



After



$$m_C v_C - m_O v_O = 0$$

$$v_C = v_O \, m_O / m_C$$

Further analysis:

$$E_0 = \tfrac{1}{2} m_C v_C^2 + \tfrac{1}{2} m_O v_O^2 = \tfrac{1}{2} m_C v_C^2 (1 + m_C/m_O)$$

$$\Rightarrow \tfrac{1}{2} m_C v_C^2 = E_0/(1 + m_C/m_O) \sim E_0/(1 + 12/16) = 4/7\ E_0$$

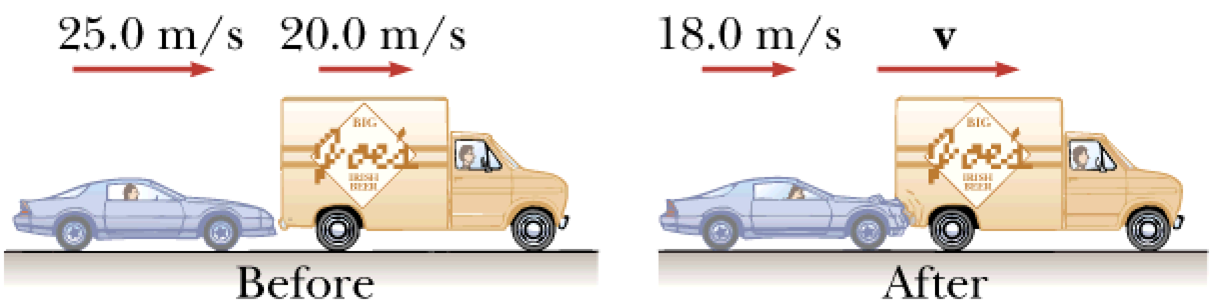
$$\Rightarrow \tfrac{1}{2} m_O v_O^2 \sim 3/7\ E_0$$

Extra credit opportunity:

Work through the details of the above analysis and verify the results for yourself (perhaps with a different diatomic molecule).

Another example from homework set:

Serway, Physics for Scientists and Engineers, 5/e
Problem 9.21



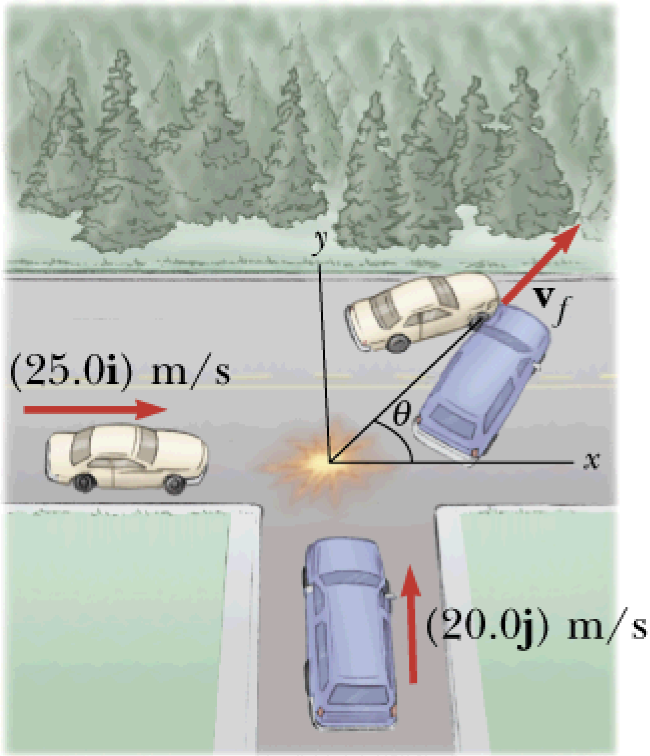
In this case, mechanical energy is not conserved. (Where does it go?) However, to our level of approximation, we will assume that momentum is conserved.

Before: After:

$$m_c v_{0c} + m_T v_{0T} \quad = \quad m_c v_c + m_T v$$

Note: In general, momentum is a **vector** quantity.

Serway, Physics for Scientists and Engineers, 5/e
Figure 9.15

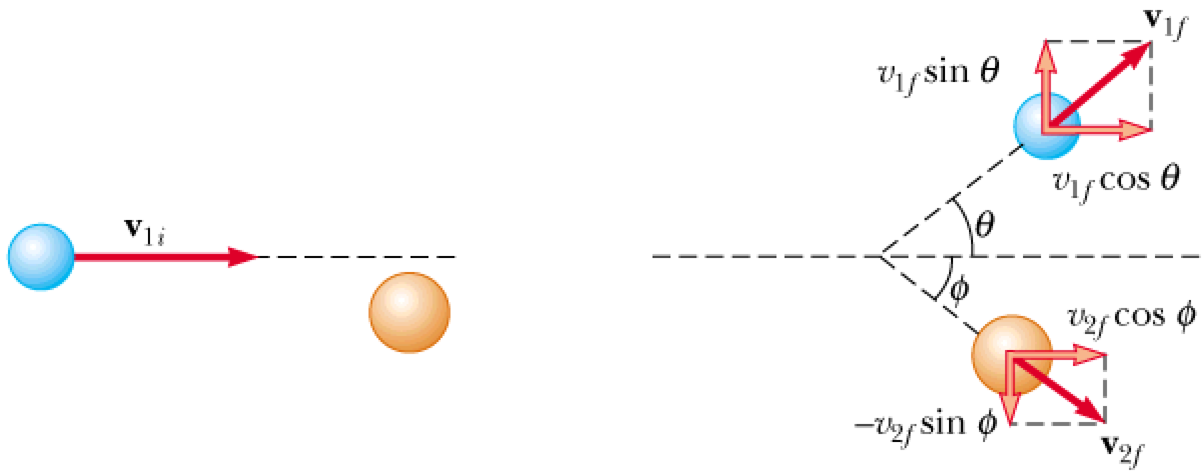


Harcourt, Inc.

$$m_c \mathbf{v}_{0c} + m_T \mathbf{v}_{0T} \quad = \quad (m_c + m_T)\, \mathbf{v}_f$$

$$\mathbf{v}_f = \frac{m_c}{m_c + m_T} v_{0c}\mathbf{i} + \frac{m_T}{m_c + m_T} v_{0T}\mathbf{j}$$

Serway, Physics for Scientists and Engineers, 5/e
Figure 9.14



(a) Before the collision (b) After the collision

Statement of conservation of momentum:

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$$m_1 v_{1i} = m_1 v_{1f} \cos\theta + m_2 v_{2f} \cos\varphi$$

$$0 = m_1 v_{1f} \sin\theta - m_2 v_{2f} \sin\varphi$$

If mechanical (kinetic) energy is conserved, then:

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

Peer instruction question:

Given the previous example, summarized with these equations:

$$m_1 v_{1i} = m_1 v_{1f} \cos\theta + m_2 v_{2f} \cos\varphi \qquad \tfrac{1}{2} m_1 v_{1i}^2 = \tfrac{1}{2} m_1 v_{1f}^2 + \tfrac{1}{2} m_2 v_{2f}^2$$

$$0 = m_1 v_{1f} \sin\theta - m_2 v_{2f} \sin\varphi$$

which of the following statements are true?

(a) It is in principle possible to solve the above equations uniquely.

(b) It is not possible to solve the above equations uniquely because the mathematics is too difficult.

(c) It is not possible to solve the above equations uniquely because there is missing physical information.