23. A force in the negative direction of an x-axis is applied for 27ms to a 0.40kg ball initially moving at 14m/s in the positive direction of the axis. The force varies in magnitude, and the impulse has magnitude 32.4 N.s. What are the ball's

a) Speed and

b) Direction of travel just after the force is applied ?

c) What are the average magnitude of the force and

d) The direction of the impulse on the ball?

23. The initial direction of motion is in the +x direction. The magnitude of the average force F_{avg} is given by

$$F_{avg} = \frac{J}{\Delta t} = \frac{32.4 \text{ N}\cdot\text{s}}{2.70\times10^{-2} \text{ s}} = 1.20\times10^{3} \text{ N}$$

The force is in the negative direction. Using the linear momentum-impulse theorem stated in Eq. 9-31, we have

$$-F_{avg}\Delta t = mv_f - mv_i.$$

where m is the mass, v_i the initial velocity, and v_f the final velocity of the ball. Thus,

$$v_f = \frac{mv_i - F_{avg}\Delta t}{m} = \frac{(0.40\,\text{kg})(14\,\text{m/s}) - (1200\,\text{N})(27\times10^{-3}\,\text{s})}{0.40\,\text{kg}} = -67\,\text{m/s}.$$

(a) The final speed of the ball is $|v_f| = 67$ m/s.

(b) The negative sign indicates that the velocity is in the $-x$ direction, which is opposite to the initial direction of travel.

(c) From the above, the average magnitude of the force is $F_{avg} = 1.20\times10^{3}$ N.

(d) The direction of the impulse on the ball is $-x$, same as the applied force.

27. A 1.2 kg ball drops vertically onto floor, hitting with a speed of 25m/s. It rebounds with an initial speed of 10m/s

a) What impulse acts on the ball during the contact?

b) If the ball is in contact with the floor for 0.020s, what is the magnitude of the average force on the floor from the ball?

27. We choose $+y$ upward, which means $\vec{v}_i = -25\,\text{m/s}$ and $\vec{v}_f = +10\,\text{m/s}$. During the collision, we make the reasonable approximation that the net force on the ball is equal to F_{avg} – the average force exerted by the floor up on the ball.

(a) Using the impulse momentum theorem (Eq. 9-31) we find

$$\vec{J} = m\vec{v}_f - m\vec{v}_i = (1.2)(10) - (1.2)(-25) = 42\,\text{kg}\cdot\text{m/s}.$$

(b) From Eq. 9-35, we obtain

$$\vec{F}_{\text{avg}} = \frac{\vec{J}}{\Delta t} = \frac{42}{0.020} = 2.1\times 10^3\,\text{N}.$$

42. A 4.0 kg mess kit sliding on a frictionless surface explodes into two 2.0kg parts: 3.0m/s, due north, and 5.0m/s 30degree north of east. What is the original speed of the mess kit?

42. Our $+x$ direction is east and $+y$ direction is north. The linear momenta for the two m = 2.0 kg parts are then

$$\vec{p}_1 = m\vec{v}_1 = mv_1\,\hat{\text{j}}$$

where v_1 = 3.0 m/s, and

$$\vec{p}_2 = m\vec{v}_2 = m\left(v_{2x}\,\hat{\text{i}} + v_{2y}\,\hat{\text{j}}\right) = mv_2\left(\cos\theta\,\hat{\text{i}} + \sin\theta\,\hat{\text{j}}\right)$$

where v_2 = 5.0 m/s and θ = 30°. The combined linear momentum of both parts is then

$$\begin{aligned}\vec{P} = \vec{p}_1 + \vec{p}_2 &= mv_1\,\hat{\text{j}} + mv_2\left(\cos\theta\,\hat{\text{i}} + \sin\theta\,\hat{\text{j}}\right) = \left(mv_2\cos\theta\right)\hat{\text{i}} + \left(mv_1 + mv_2\sin\theta\right)\hat{\text{j}} \\ &= (2.0\text{ kg})(5.0\text{ m/s})(\cos 30°)\,\hat{\text{i}} + (2.0\text{ kg})\left(3.0\text{ m/s} + (5.0\text{ m/s})(\sin 30°)\right)\hat{\text{j}} \\ &= \left(8.66\,\hat{\text{i}} + 11\,\hat{\text{j}}\right)\text{ kg}\cdot\text{m/s}.\end{aligned}$$

From conservation of linear momentum we know that this is also the linear momentum of the whole kit before it splits. Thus the speed of the 4.0-kg kit is

$$v = \frac{P}{M} = \frac{\sqrt{P_x^2 + P_y^2}}{M} = \frac{\sqrt{(8.66\text{ kg}\cdot\text{m/s})^2 + (11\text{ kg}\cdot\text{m/s})^2}}{4.0\text{ kg}} = 3.5\text{ m/s}.$$

50. A 5.20g bullet moving at 672 m/s strikes a 700g wooden block at rest on a frictionless surface. The bullet emerges, traveling in the same direction with its peed reduced to 428 m/s.

a) What is the resulting speed of the block?

b) What is the speed of the bullet-block center of mass?

50. (a) We choose $+x$ along the initial direction of motion and apply momentum conservation:

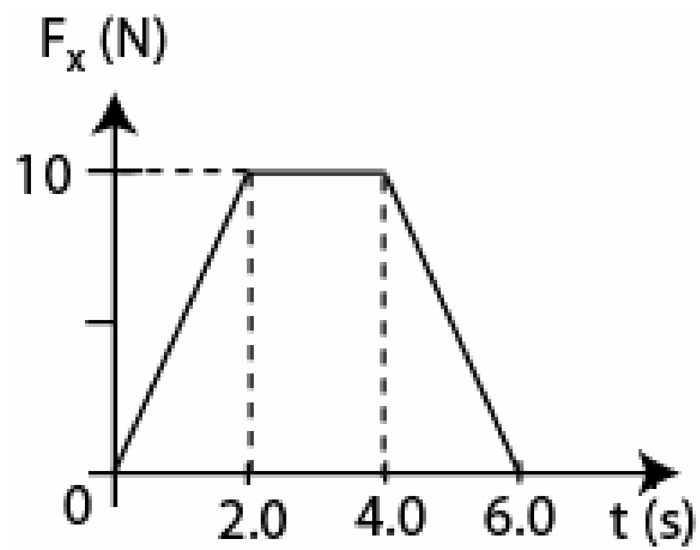
$$m_{\text{bullet}}\vec{v}_i = m_{\text{bullet}}\vec{v}_1 + m_{\text{block}}\vec{v}_2$$
$$(5.2\text{ g})(672\text{ m/s}) = (5.2\text{ g})(428\text{ m/s}) + (700\text{ g})\vec{v}_2$$

which yields $v_2 = 1.81$ m/s.

(b) It is a consequence of momentum conservation that the velocity of the center of mass is unchanged by the collision. We choose to evaluate it before the collision:

$$\vec{v}_{\text{com}} = \frac{m_{\text{bullet}}\vec{v}_i}{m_{\text{bullet}} + m_{\text{block}}} = \frac{(5.2\text{ g})(672\text{ m/s})}{5.2\text{ g} + 700\text{ g}} = 4.96\text{ m/s}.$$

A 10.0 kg toy car is moving along the x axis. The only force Fx acting on the car is shown in Fig. 5 as a function of time (t). At time t = 0 s the car has a speed of 4.0 m/s. What is its speed at time t = 6.0 s? (Ans: 8.0 m/s)



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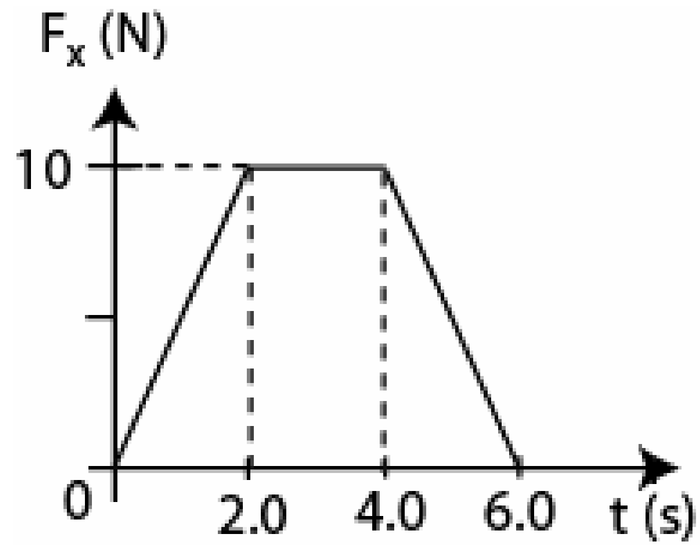
$$\vec{F} = \frac{d\vec{p}}{dt} \Rightarrow |\vec{p}| = \int \vec{F} dt = \text{ Area under the curve}$$

$$= \frac{10 \times (6+2)}{2} = 40$$

$$\because |\vec{p}| = m\left(v_f - v_i\right)$$

$$\therefore v_f = \frac{|\vec{p}|}{m} + v_i = \frac{40}{10} + 4 = \underline{8 \text{ m/s}}$$



A 0.20 kg steel ball, travels along the x-axis at 10 m/s, undergoes an elastic collision with a 0.50 kg steel ball traveling along the y-axis at 4.0 m/s. The total kinetic energy of the two balls after collision is:

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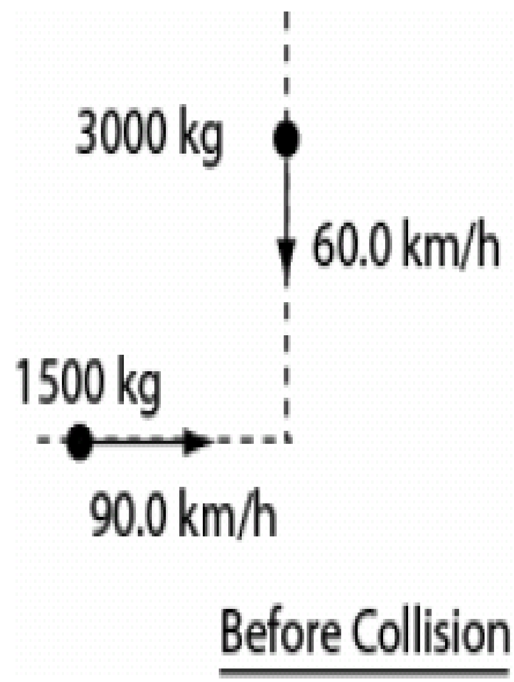
$$\frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 = \frac{1}{2}\times 0.2\times 10^2 + \frac{1}{2}\times 0.5\times 4^2 = 10 + 4$$

$$= 14 \text{ J.}$$

A 1500 kg car traveling at 90.0 km/h east collides with a 3000 kg car traveling at 60.0 km/h south. The two cars stick together after the collision (see Fig 2). What is the speed of the cars after collision?



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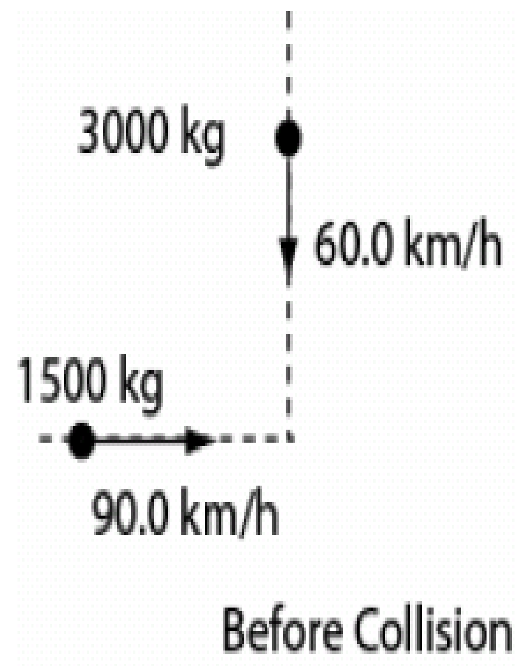
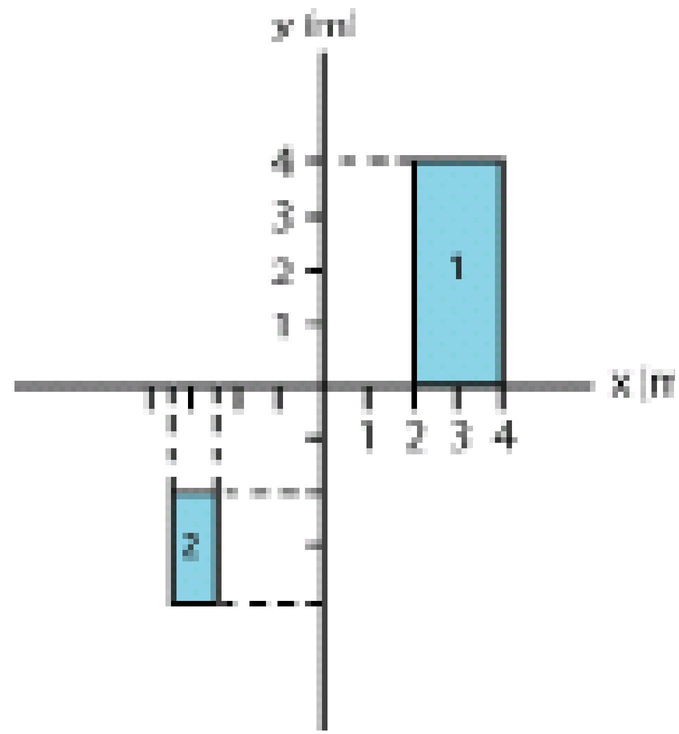


$$M\vec{v} = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$(1500+3000)\vec{v} = 1500\times 90\,\hat{i} - 3000\times 60\,\hat{j}$$

$$\Rightarrow |\vec{v}| = \sqrt{(30^2+40^2)} = 50\,\frac{\text{km}}{\text{hour}} = 13.9\,\underline{\text{m/s}}$$

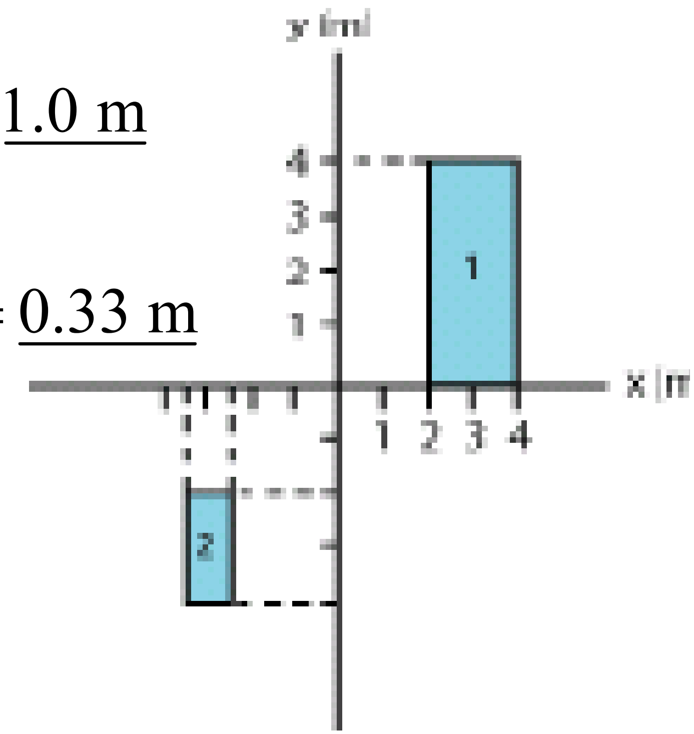
The location of two thin flat objects of masses m1= 4.0 kg and m2 = 2.0 kg are shown in the figure, where the units are in m. The x and y coordinates of the center of mass of this system are:



The location of two thin flat objects of masses m1= 4.0 kg and m2 = 2.0 kg are shown in the figure, where the units are in m. The x and y coordinates of the center of mass of this system are:

$$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} = \frac{4.0\times 3.0 + 2.0\times(-3.0)}{6.0} = \underline{1.0\ \text{m}}$$

$$y_{cm} = \frac{m_1 y_1 + m_2 y_2}{m_1 + m_2} = \frac{4.0\times 2.0 + 2.0\times(-3.0)}{6.0} = \underline{0.33\ \text{m}}$$



A 2.00 kg pistol is loaded with a bullet of mass 3.00 g. The pistol fires the bullet at a speed of 400 m/s. The recoil speed of the pistol when the bullet was fired is: (Ans: 0.600 m/s)

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$$0 = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$0 = 2\times\vec{v} + 0.003\times 400 \Rightarrow |v| = 0.6\frac{\text{m}}{\text{s}}.$$

Sphere A has a mass M and is moving with speed 10 m/s. It makes a head-on elastic collision with a stationary sphere B of mass 3M. After the collision the speed of B is:

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$$v_{Bf} = \frac{2m_A}{m_A + m_B} v_{1i} + \frac{m_A - m_B}{m_A + m_B} v_{2i}$$

$$\Rightarrow v_{Bf} = \frac{2M}{3M + M}(10) + \frac{3M - 2M}{3M + 1M}(0) = \underline{5}$$

An object of 12.0 kg at rest explodes into two pieces of masses 4.00 kg and 8.00 kg. The velocity of the 8.00 kg mass is 6.00 m/s in the +ve x-direction. The change in the kinetic is:

An object of 12.0 kg at rest explodes into two pieces of masses 4.00 kg and 8.00 kg. The velocity of the 8.00 kg mass is 6.00 m/s in the +ve x-direction. The change in the kinetic is:

$$M\vec{v} = m_4\vec{v}_4 + m_8\vec{v}_8 \Rightarrow 0 = 4\times\vec{v}_4 + 8\times 6\hat{i} \quad \Rightarrow \vec{v}_4 = -12\hat{i},$$

$$\Delta K = K_f - \cancel{K_i} = \frac{1}{2}m_4\left(\vec{v}_4\right)^2 + \frac{1}{2}m_8\left(\vec{v}_8\right)^2 = \frac{4}{2}(12)^2 + \frac{8}{2}(6)^2$$

$$= \underline{432\ \text{J}}$$

A 6.0 kg body moving with velocity v breaks up (explodes) into two equal masses. One mass travels east at 3.0 m/s and the other mass travels north at 2.0 m/s. The speed v of the 6.0 kg mass is:

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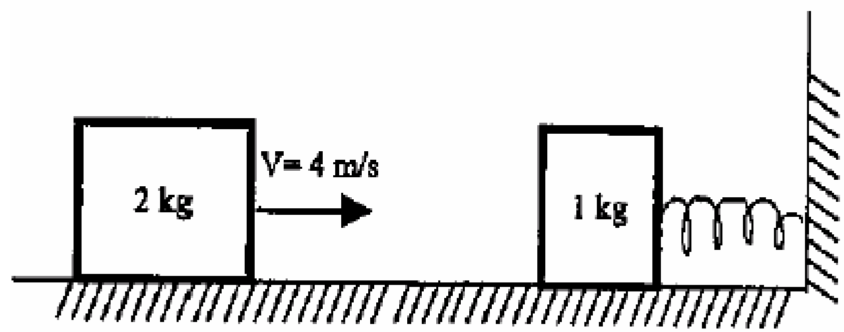
$$M\,\vec{v} = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$6\vec{v} = 3\times 3\,\hat{i} + 3\times 2\,\hat{j} \quad \Rightarrow \quad |\vec{v}| = \sqrt{\frac{1}{6}}\left(3^2 + 4^2\right) = 1.8\,\frac{\text{m}}{\text{s}}$$

A 1.0-kg block at rest on a horizontal frictionless surface is connected to a spring (k = 200 N/m) whose other end is fixed (see figure). A 2.0-kg block moving at 4.0 m/s collides with the 1.0-kg block. If the two blocks stick together after the one-dimensional collision, what maximum compression of the spring does occur when the blocks momentarily stop?



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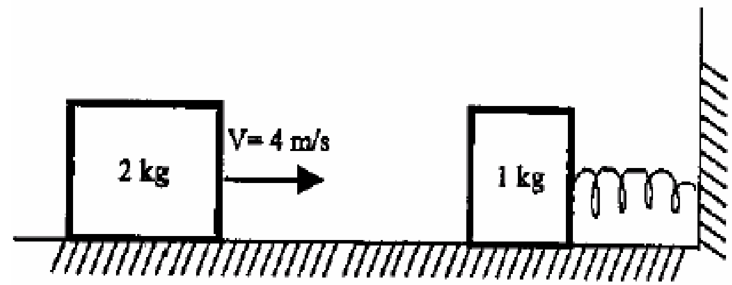

Consrevation of momentum $\Rightarrow \quad mv = (m+M)V$

$$\Rightarrow \quad V = \frac{2 \times 4}{(2+1)} \approx 2.67 \frac{\text{m}}{\text{s}}$$

Conservation of K.E. after collision $\Rightarrow \quad \frac{1}{2}(m+M)V^2 = \frac{1}{2}k\,x^2$

$$\Rightarrow \quad x = V\sqrt{\frac{(m+M)}{k}} = 2.67\sqrt{\frac{3}{200}} = \underline{0.33 \text{ m}}$$

A 10 gram bullet is shot in the +x-direction with a speed of Vo = 500 m/s into a stationary block of wood that has a mass of 5.0 kg (see Fig 3). The bullet embeds itself in the block. What distance (d) will the block slide on a surface having a coefficient of kinetic friction equal to 0.5?

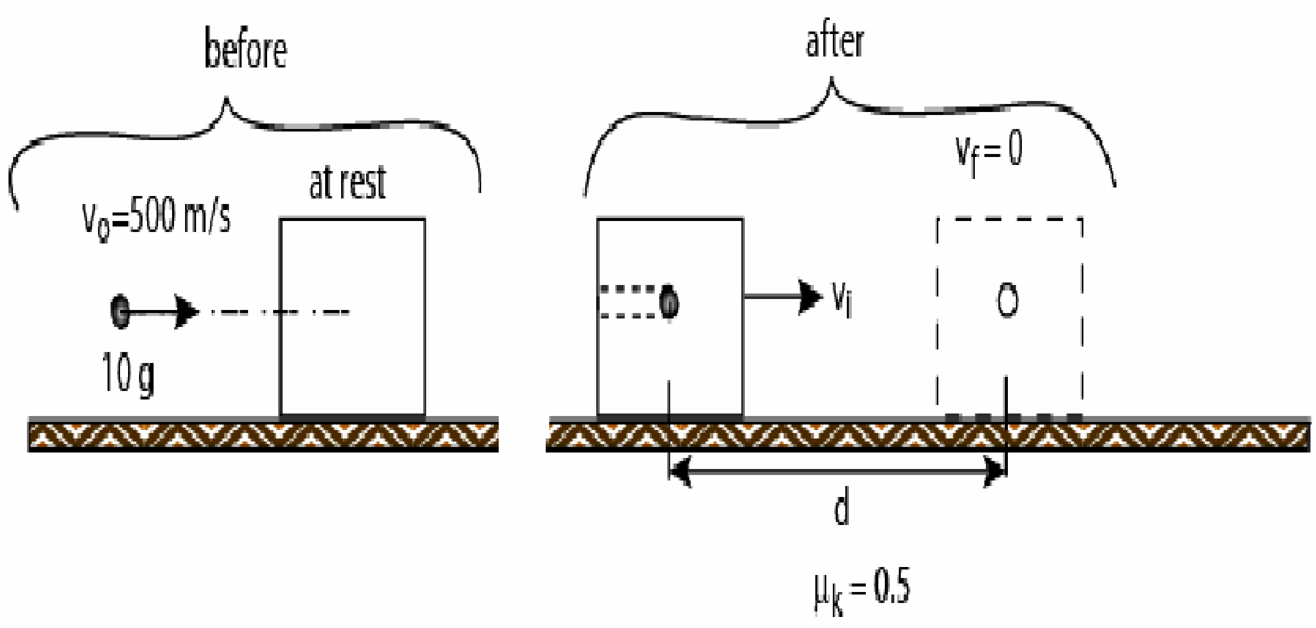

Figure 3

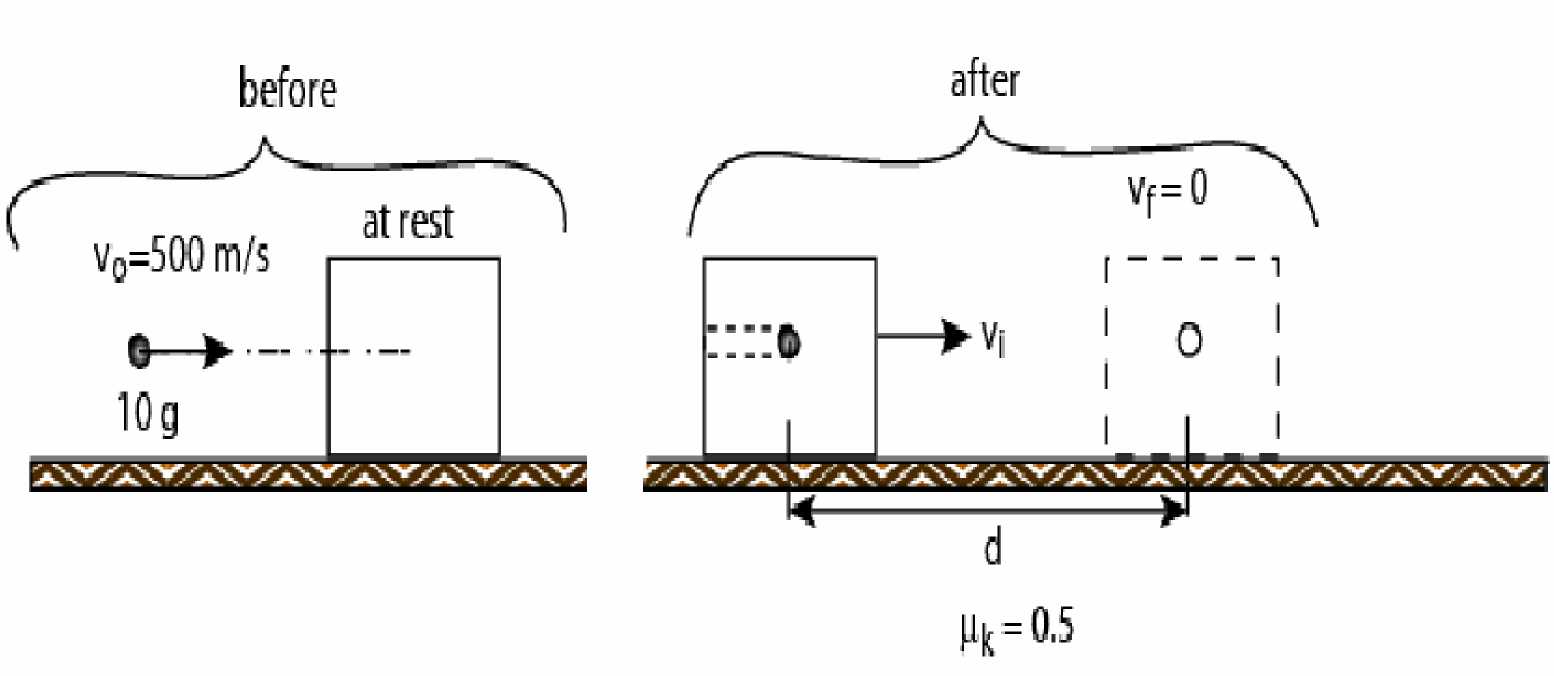

Figure 3

Consrevation of momentum $\Rightarrow \quad mv = (m + M)V$

$$\Rightarrow \quad V = \frac{.001 \times 500}{(5.0 + 0.001)} \approx 1.0 \text{ m/s}$$

Change in K.E. after collision $\Rightarrow \quad -\frac{1}{2}(m + M)V^{2} = -\mu(m + M)gd$

$$\Rightarrow \quad d = \frac{V^{2}}{2\mu g} = \frac{1.0^{2}}{2 \times 0.5 \times 9.8} = \underline{0.1 \text{ m}}$$