Momentum and Impulse

Conservation Laws

Name_______________ Date(YY/MM/DD) ______/________/_____

St.No. _ _ _ _ _ _ _ _ _ _ _ Section________

UNIT 8: ONE-DIMENSIONAL COLLISIONS

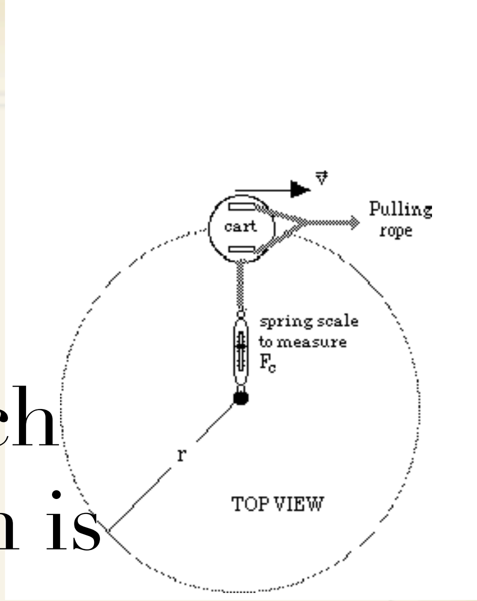
Approximate Classroom Time: Three 100 minute sessions

In any system of bodies which act on each other, action and reaction, estimated by momentum gained and lost, balance each other according to the laws of equilibrium.

Jean de la Rond D'Alembert
18th Century

OBJECTIVES

Review Question



A puller applies a force on the cart which is always tangent to the circle and which is just sufficient to overcome friction in the cart and maintain the cart's motion at a constant speed. The force in a direction perpendicular to the circle is

A. outward away from the centre

B. zero

C. inward, towards the centre

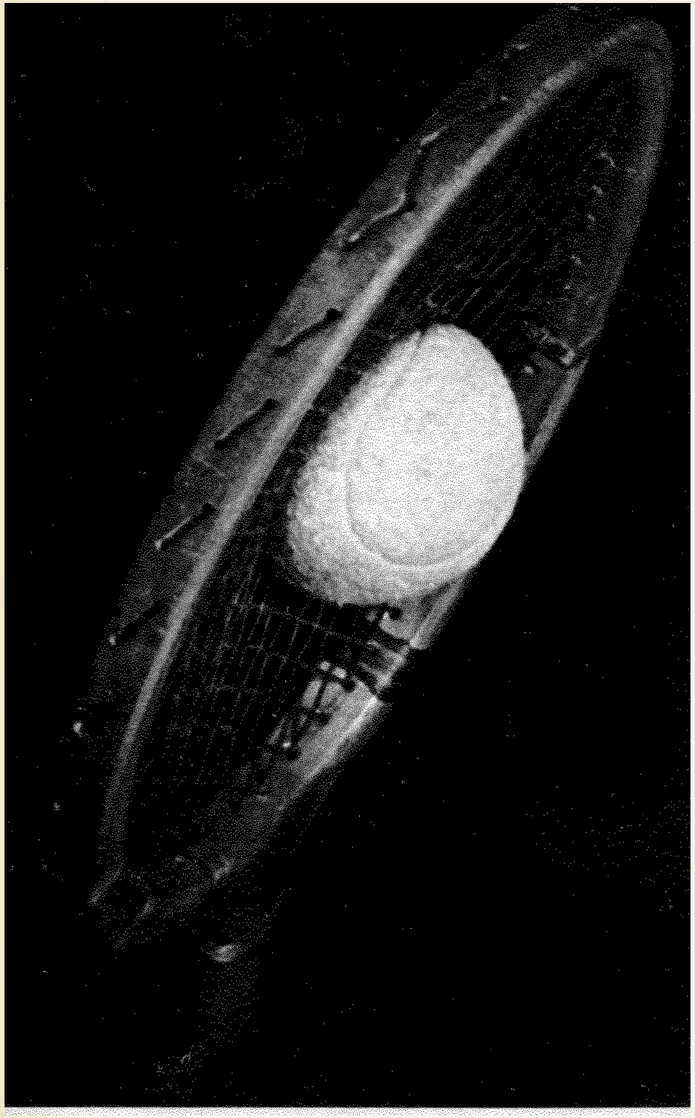
Momentum

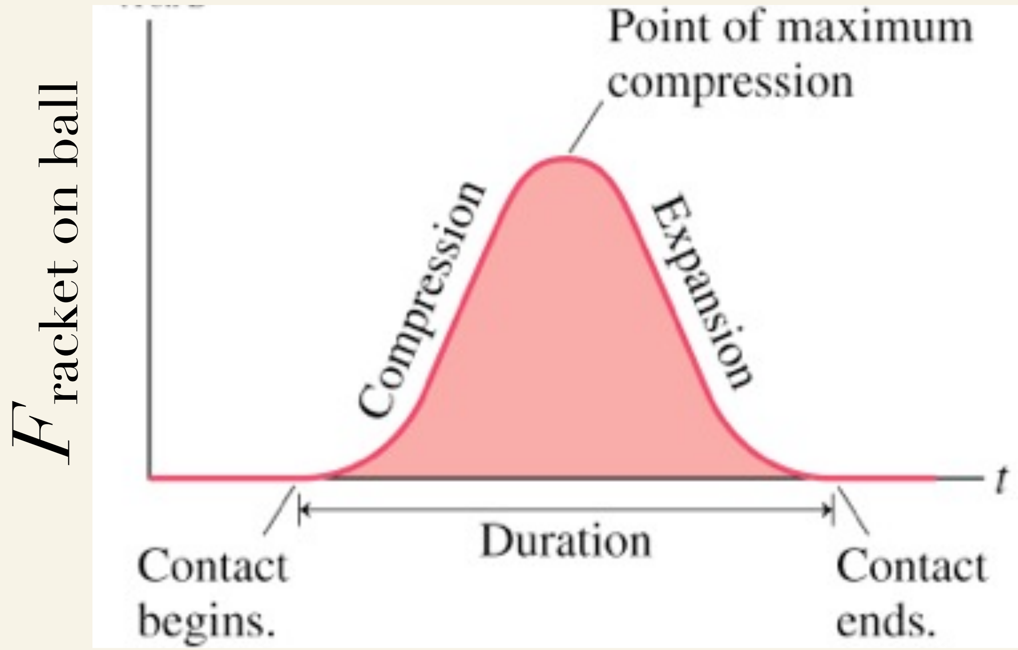
A. It’s a scalar
B. It’s a vector
C. No, It’s superman!

Impulse

A. It’s something else
B. It’s a scalar
C. It’s a vector

Impulse




$F_{\text{racket on ball}}$
Point of maximum compression
Compression
Expansion
t
Duration
Contact begins.
Contact ends.

Impulse

- When the racket hits the ball
  - $\mathbf{F}(t)_{\text{racket on ball}} = -\mathbf{F}(t)_{\text{ball on racket}}$
  - Time interval from t_i to t_f is the same
    - $F_{r\,on\,b} = m_b\,(dv_b/dt)$
    - $F_{r\,on\,b}\,dt = m_b\,dv_b$
    - Define "Impulse"

$$J_{\text{on ball}} = \int_{t_i}^{t_f} F_{\text{r on b}}\,dt$$

Momentum

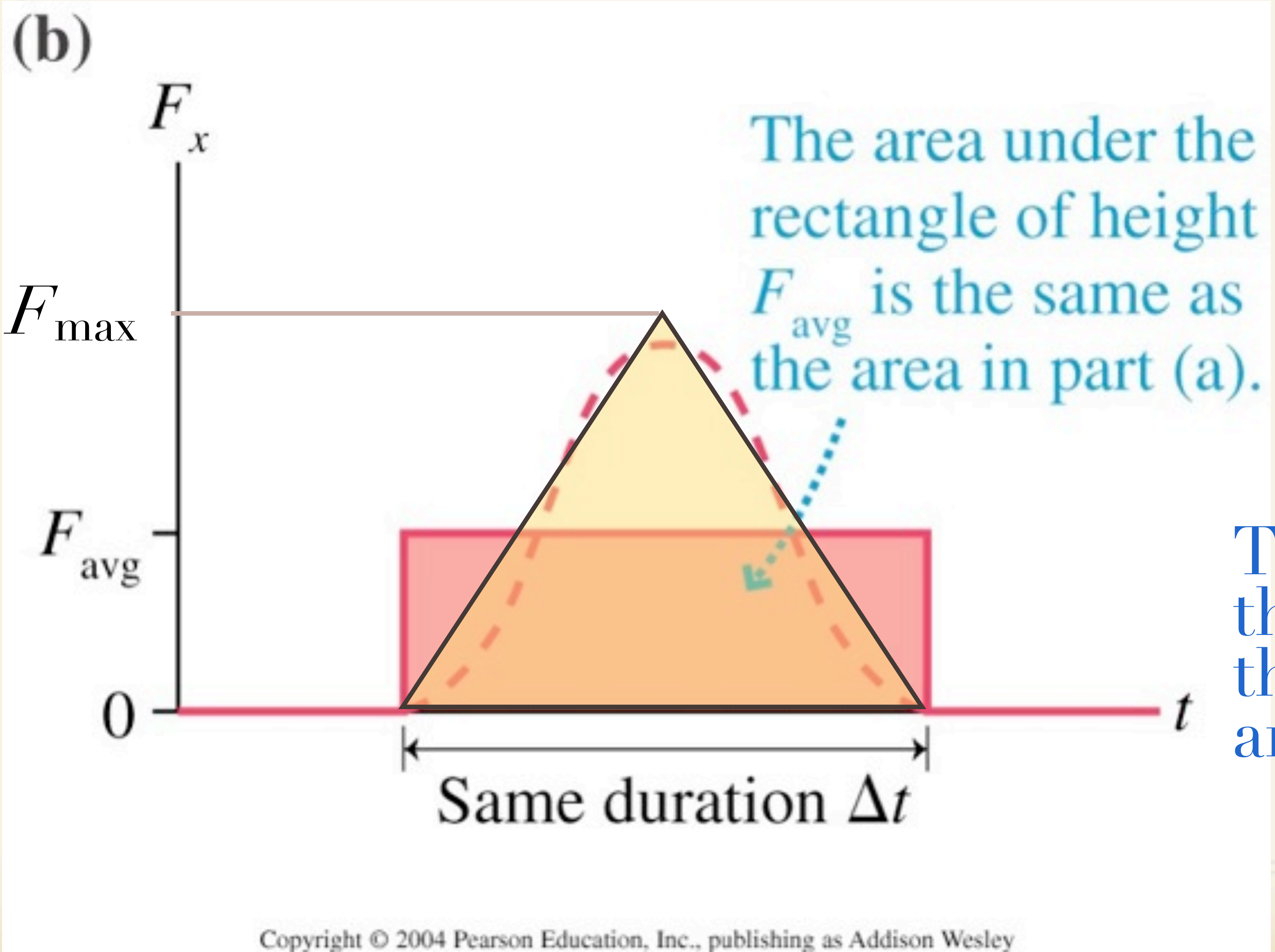
- $F_{r\,on\,b}\,dt = m_b\,dv_b = d\,(m_b\,v_b)$
  - Mass x Velocity = Momentum
  - $p_b = m_b\,v_b$
- $F_{r\,on\,b}\,dt = d\,p_b$

$$J_{\text{on ball}} = \int_{t_i}^{t_f} F_{\text{r on b}}\,dt = \int_{t_i}^{t_f} dp_b = p_f - p_i$$

Impulse Momentum

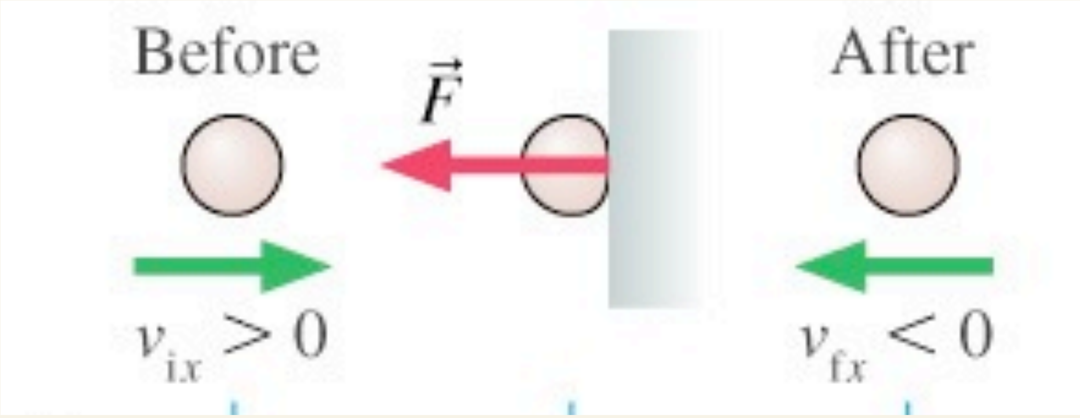
The impulse on an object in a time interval equals the object's change of momentum.

Average Force Maximum Force



The area under the triangle is the same as the area in part (a)

A ball hits the wall.
What direction is the momentum change?



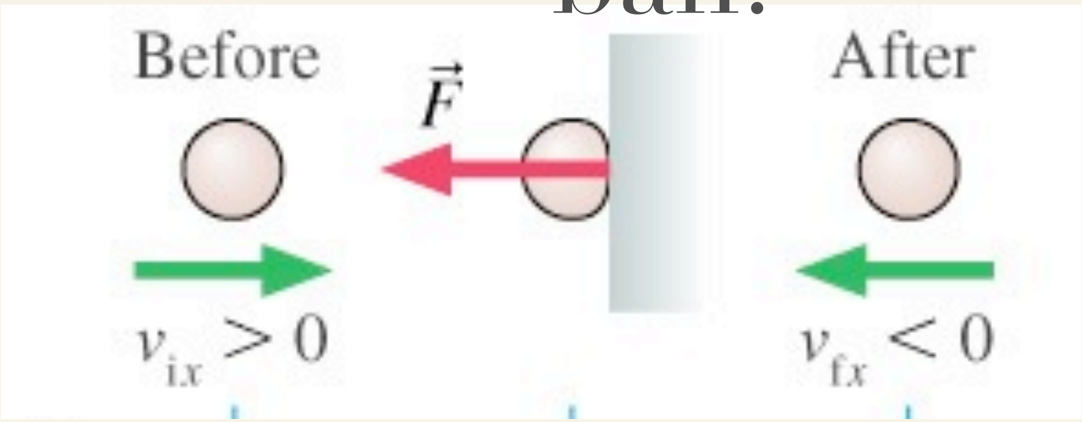
A. To the right

B. To the left

C. Up

D. Down

A ball hits the wall.
What direction is the impulse on the ball?

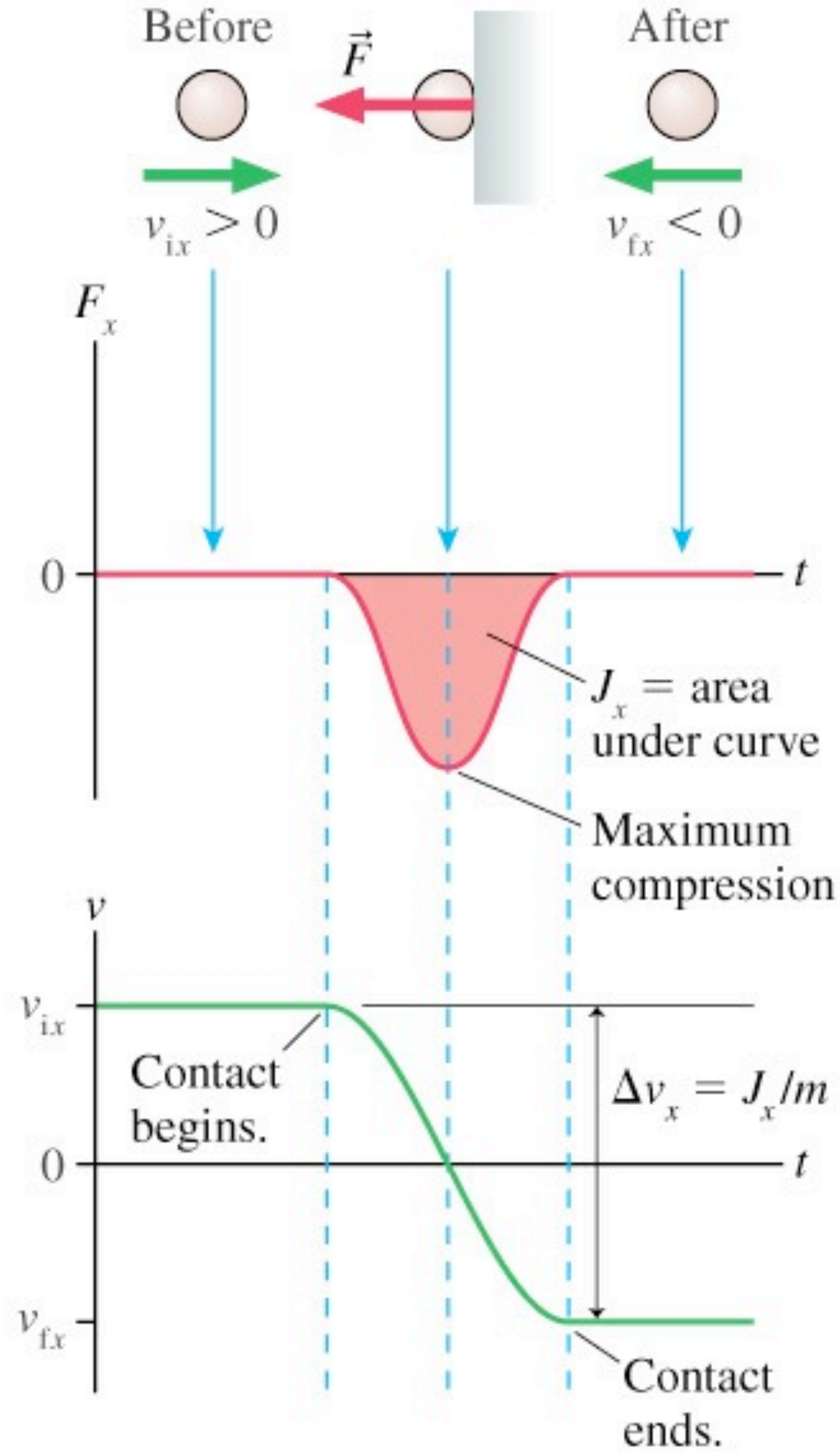


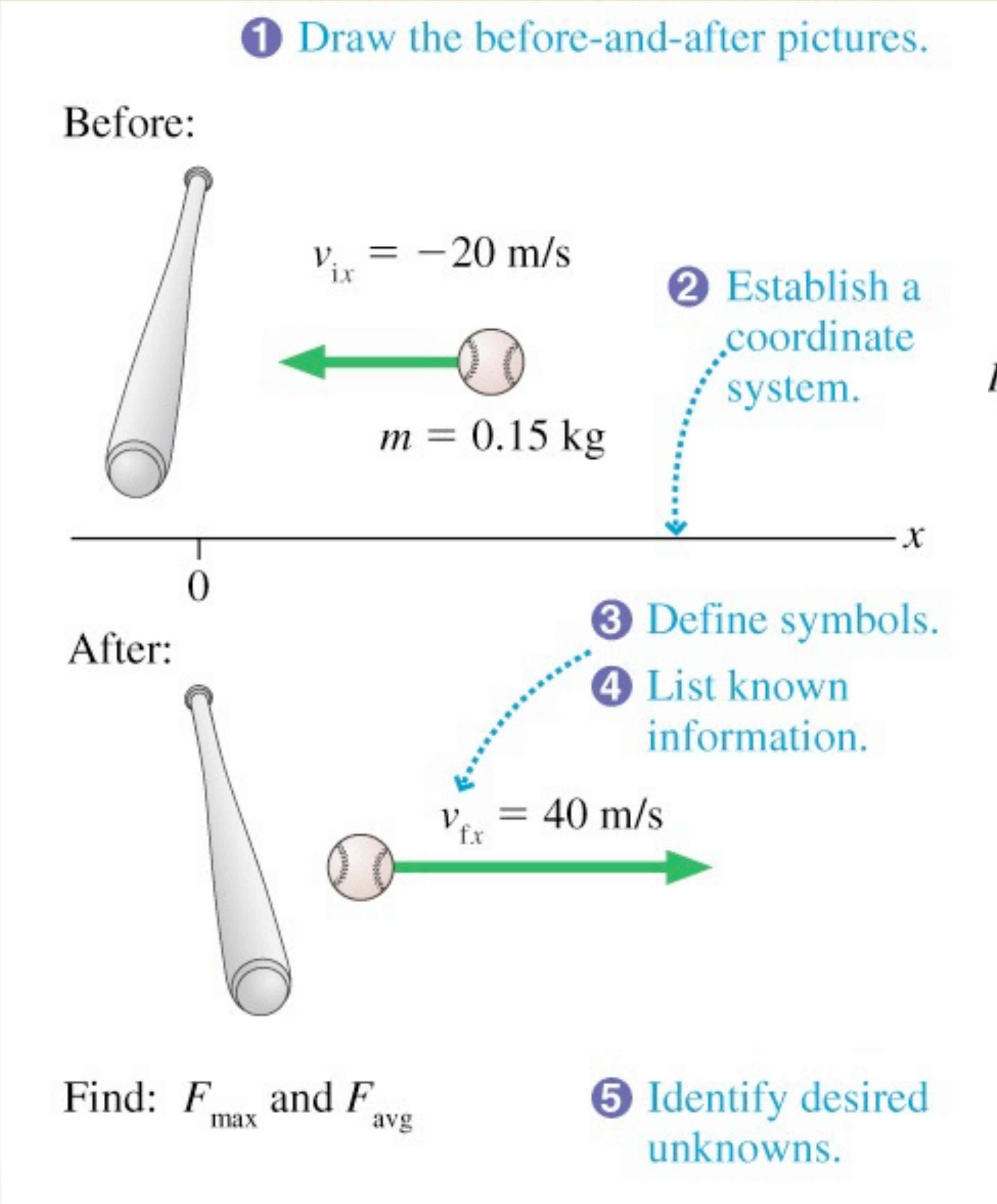
A. To the right

B. To the left

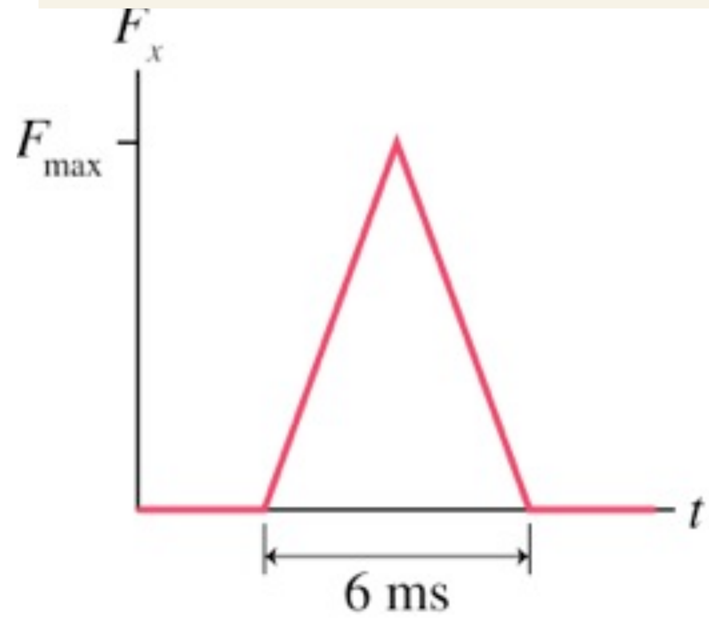
C. Up

D. Down

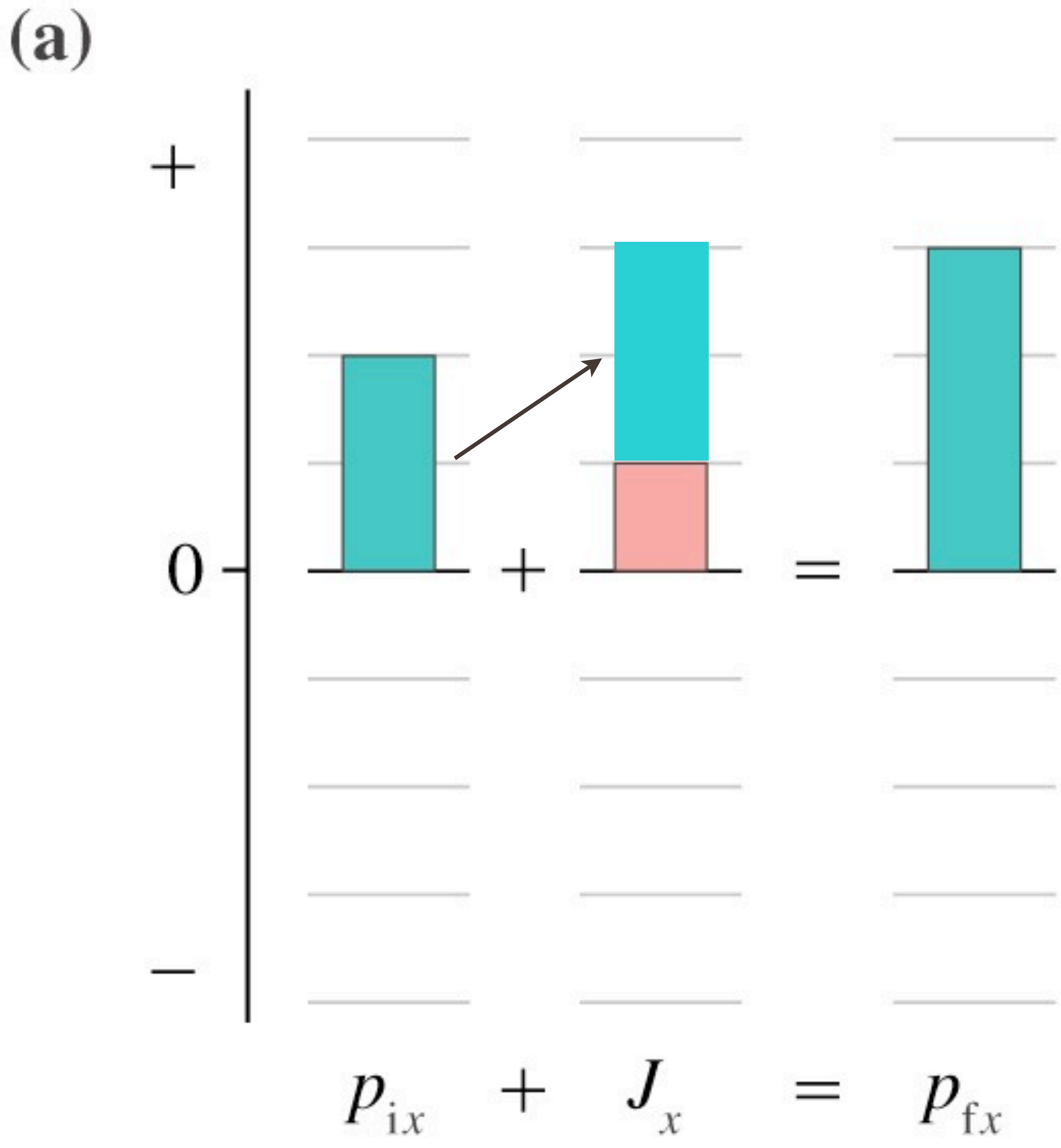

Before
$\vec{F}$
After
$v_{ix} > 0$
$v_{fx} < 0$
F_x
0
t
J_x = area under curve
Maximum compression
v
v_{ix}
Contact begins.
$\Delta v_x = J_x/m$
0
t
v_{fx}
Contact ends.

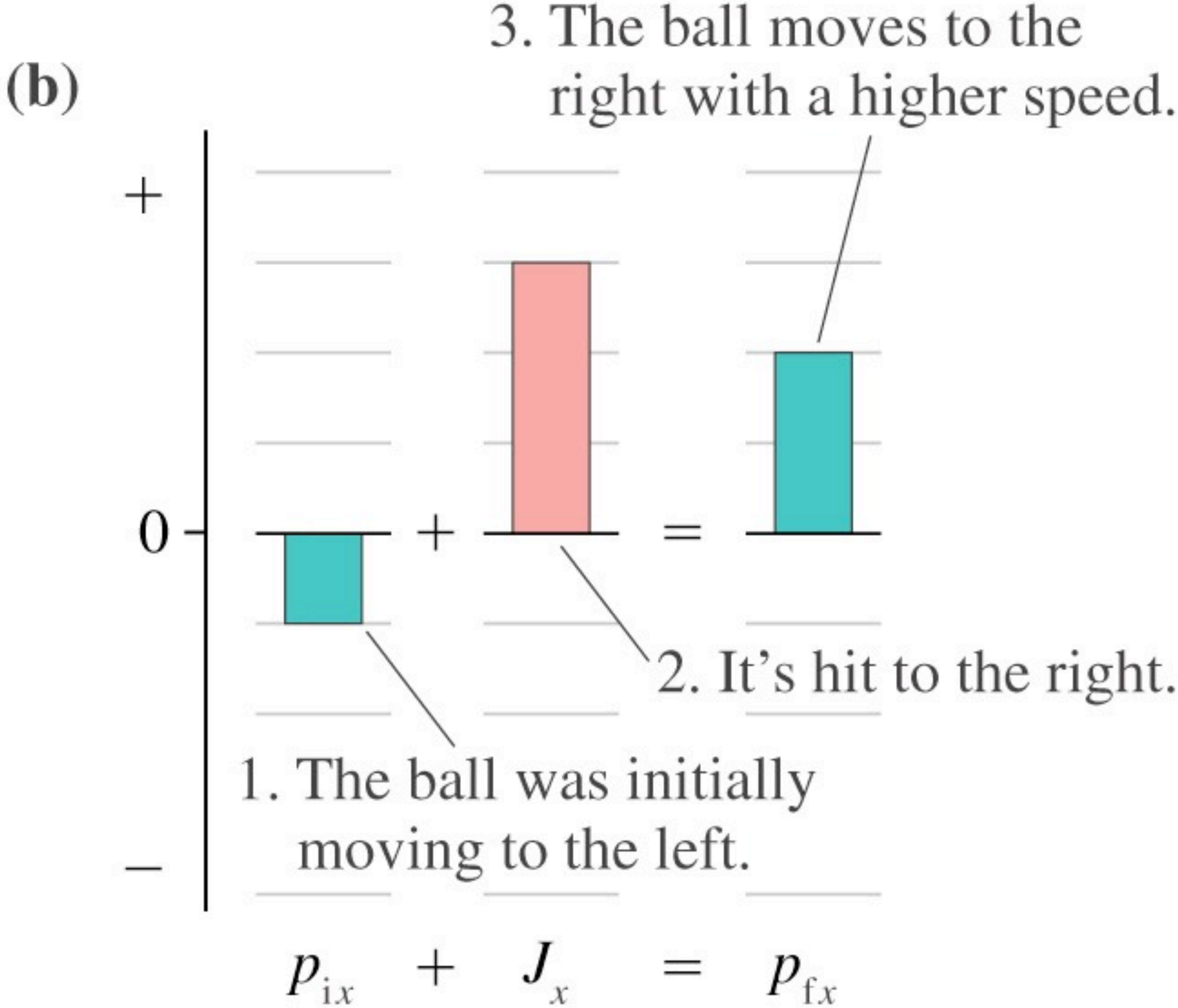


1 Draw the before-and-after pictures.
Before:
$v_{ix} = -20$ m/s
$m = 0.15$ kg
2 Establish a coordinate system.
x
0
After:
3 Define symbols.
4 List known information.
$v_{fx} = 40$ m/s
Find: F_{max} and F_{avg}
5 Identify desired unknowns.

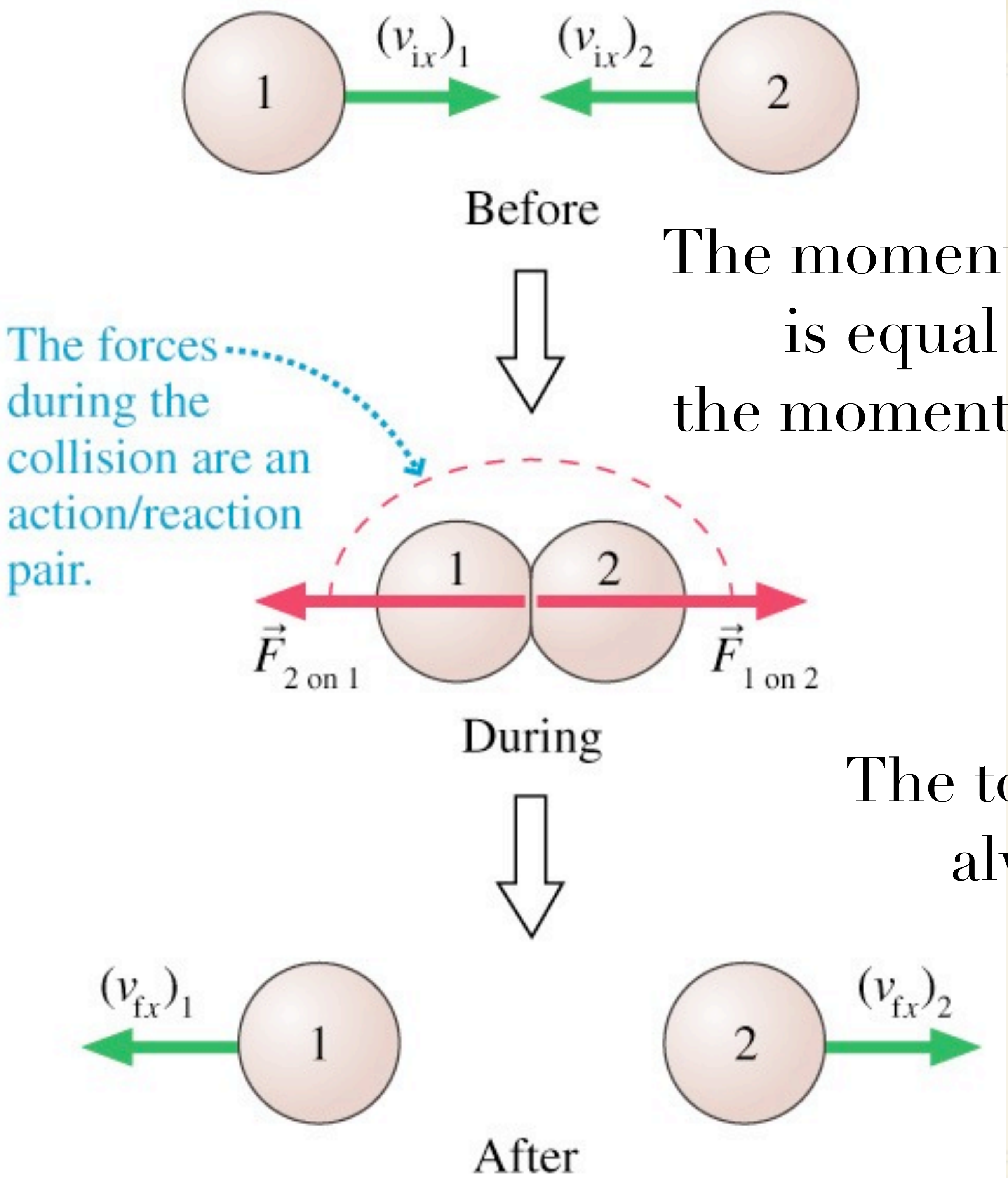


F_x
F_{max}
t
6 ms


(a)
+
0
−
+
=
p_{ix} + J_x = p_{fx}


(b)
3. The ball moves to the right with a higher speed.
+
0
–
2. It's hit to the right.
1. The ball was initially moving to the left.
p_{ix} + J_x = p_{fx}

Conservation of Momentum



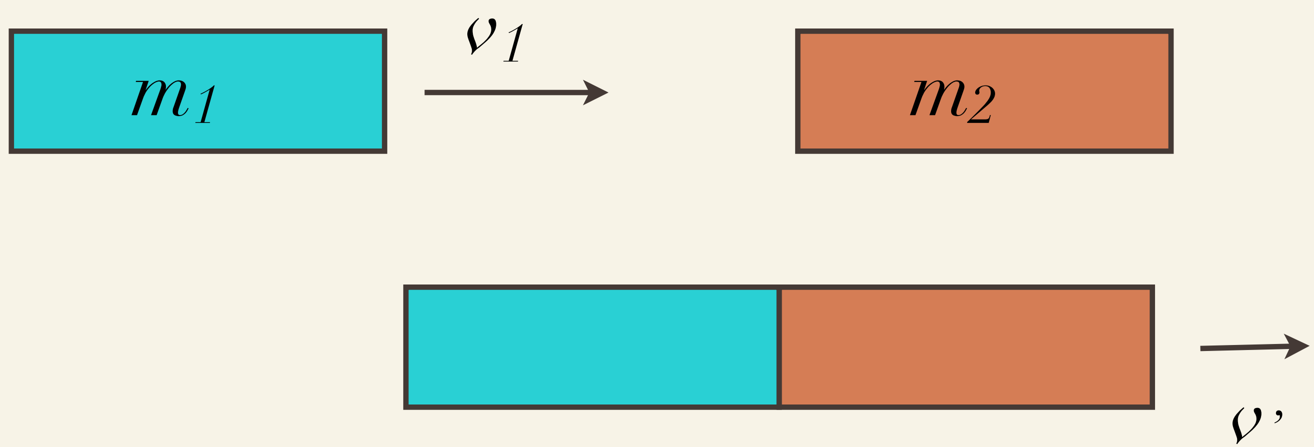
The momentum change of ball 1 is equal and opposite to the momentum change of ball 2

The total momentum is always the same

Inelastic Collision

before collision

after collision



stuck together

Use conservation of momentum to find v'

Inelastic Collision
1-D

before | after

$$p_{\text{total}} = m_1 v_1 \quad = \quad p'_{\text{total}} = (m_1 + m_2)v'$$

$$m_1 v_1 = (m_1 + m_2)v'$$

$$v' = \frac{m_1}{(m_1 + m_2)} v_1$$

Inelastic Collision equal masses

$$v' = \frac{m_1}{(m_1 + m_2)} v_1$$

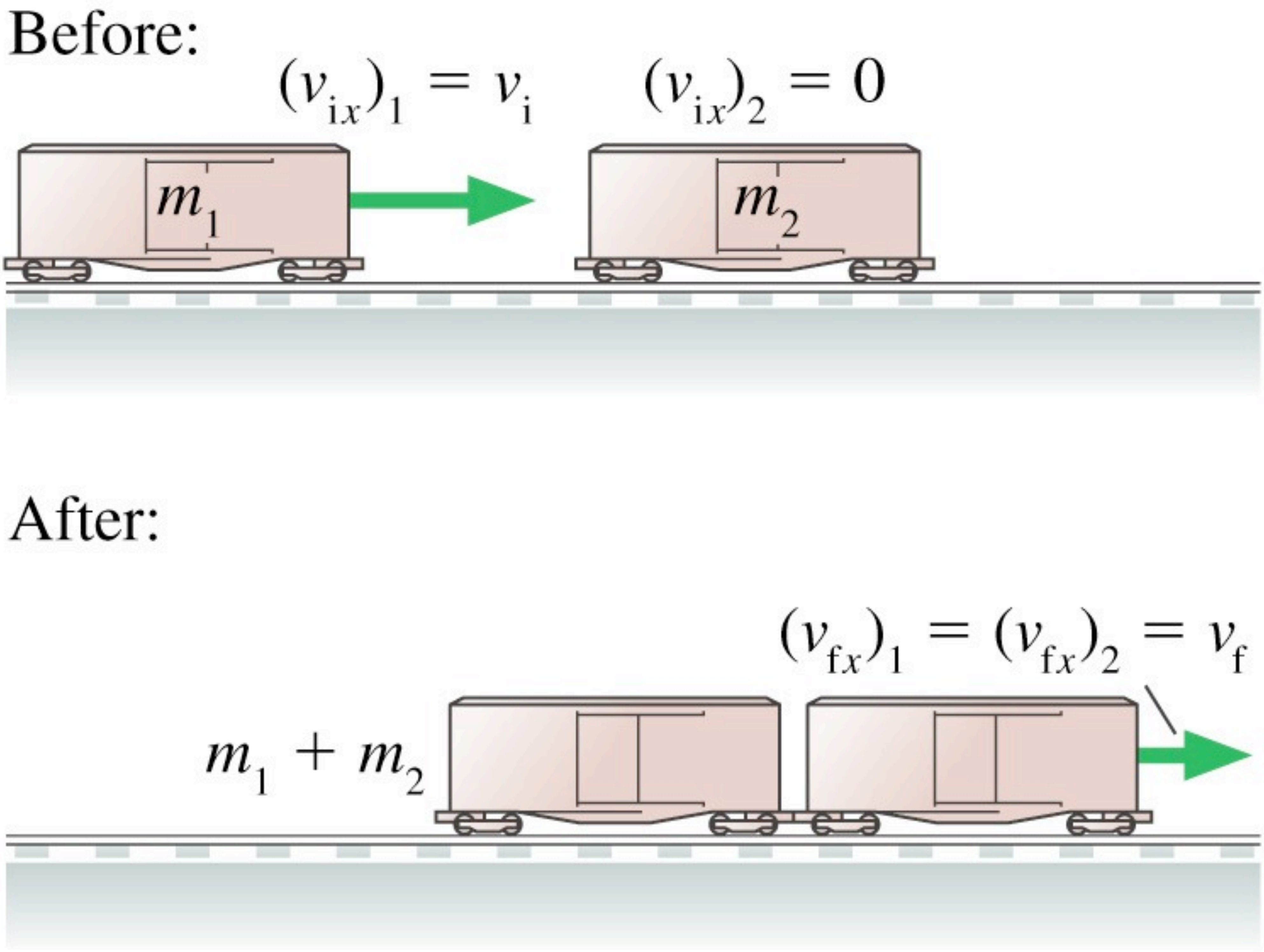
$$m_1 = m_2$$

$$v' = \frac{m_1}{(2m_1)} v_1 = \frac{v_1}{2}$$

Inelastic Collision

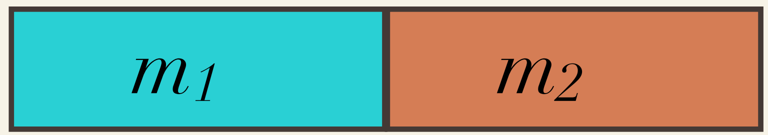
$$m_2 = 2\,m_1$$

$$v' = ?$$


Before:
$(v_{ix})_1 = v_i$
$(v_{ix})_2 = 0$
m_1
m_2
After:
$(v_{fx})_1 = (v_{fx})_2 = v_f$
$m_1 + m_2$

Explosions

before "explosion"



$p_{\text{total}} = 0$

after "explosion"

$p'_{\text{total}} = 0$

$$m_1 v_1' + m_2 v_2' = 0$$

$$\frac{v_1'}{v_2'} = \frac{m_2}{m_1}$$

Inverse Relationship

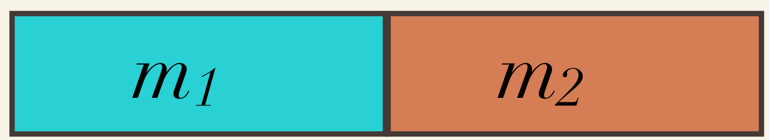
Reverse Explosion

before

$p_{\text{total}} = 0$

$$\frac{v_1'}{v_2'} = \frac{m_2}{m_1}$$

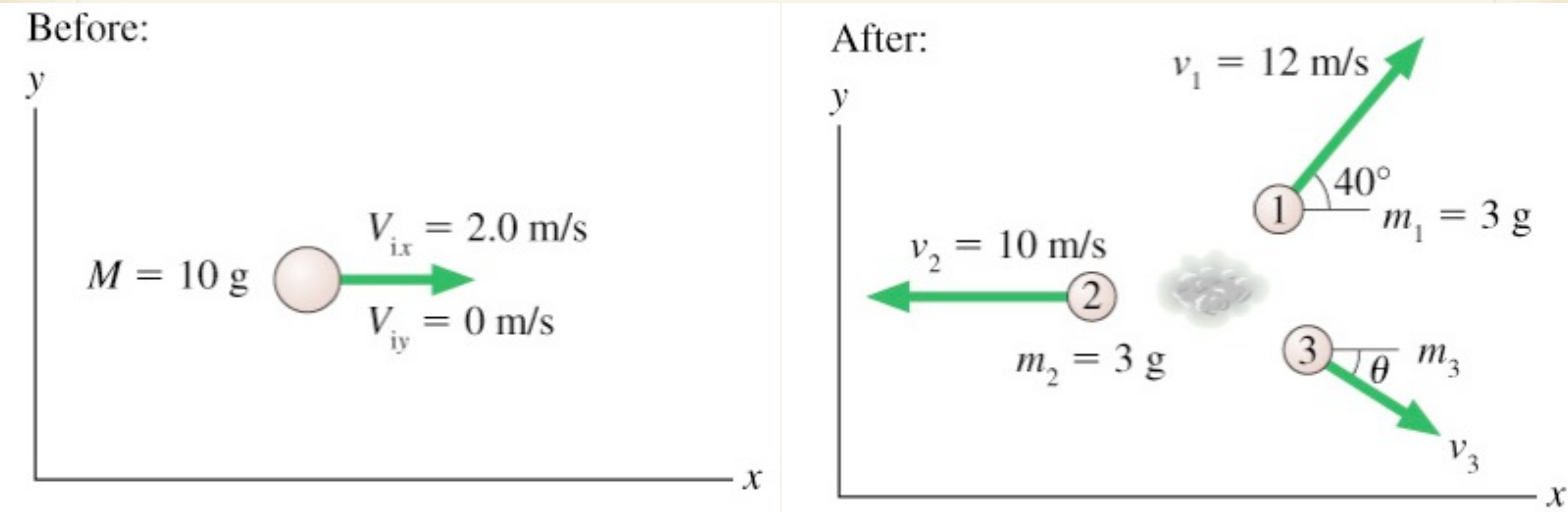
after



$p'_{\text{total}} = 0$

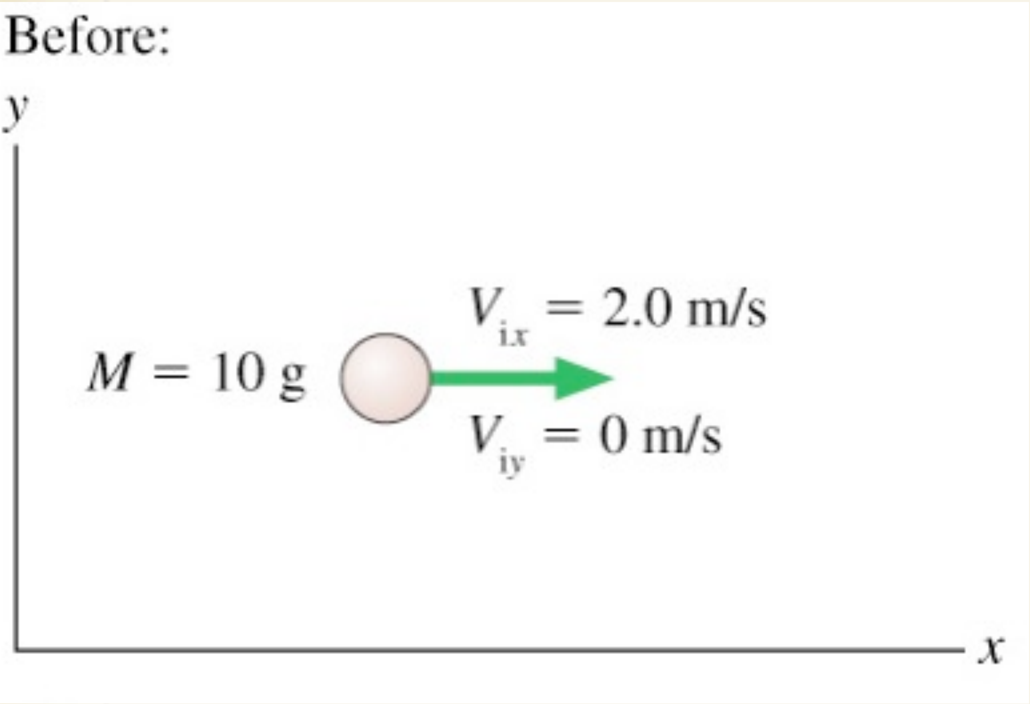
Note that if you sit on one of the blocks, the "explosion" looks like a collision: Change of reference frame.

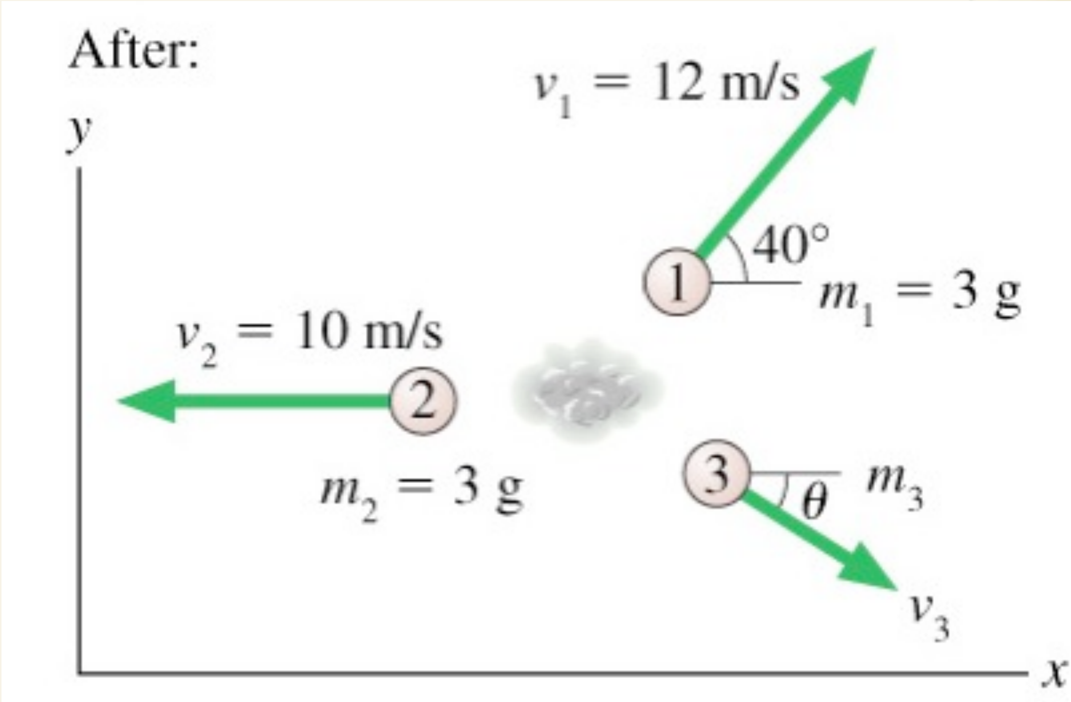
Explosions in 2-D



Find v_3 and θ

Explosions in 2-D





$$p_{ix} = p_{1x} + p_{2x} + p_{3x}$$

unknowns

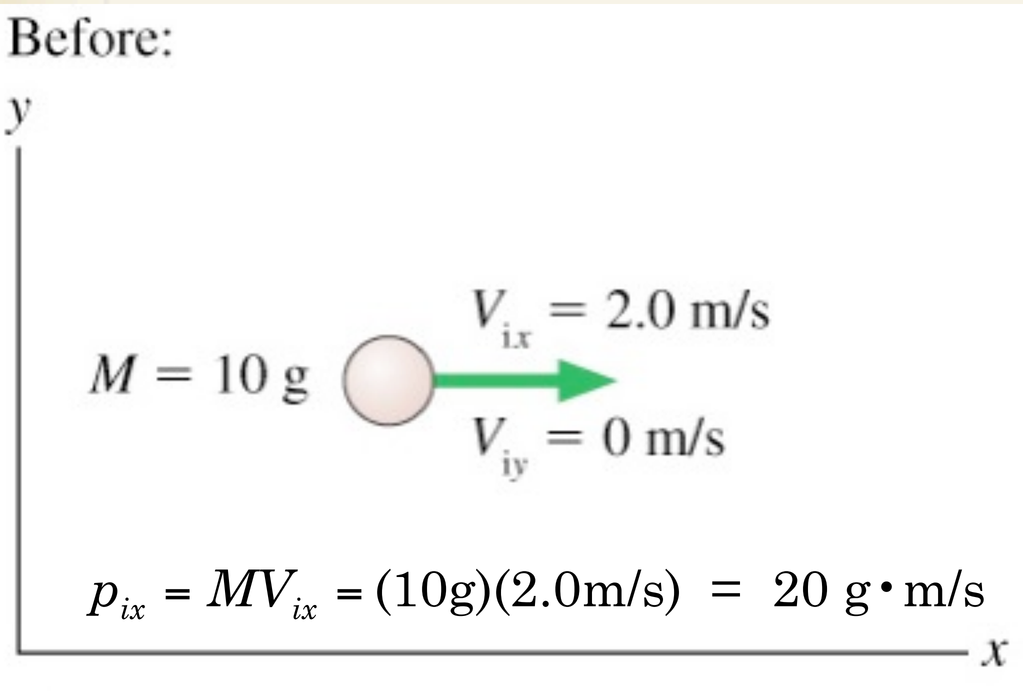
$$p_{iy} = p_{1y} + p_{2y} + p_{3y} = 0$$

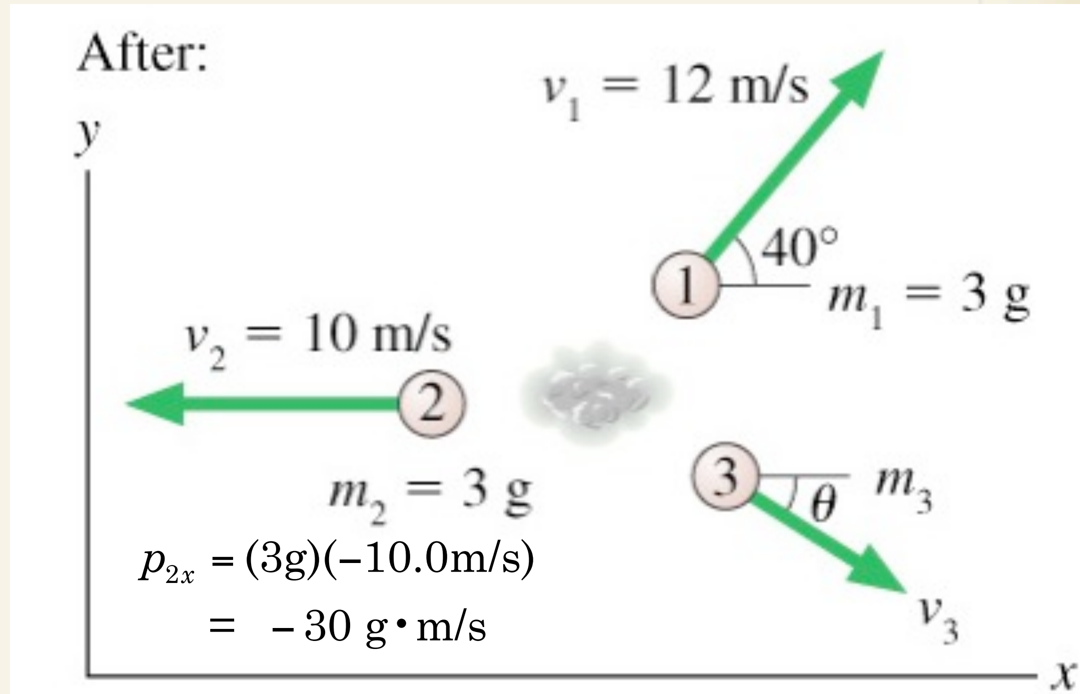
Accountancy 101

$$p_{1x} = (3\text{g})(12.0\text{m/s})\cos 40° = 27.6\ \text{g}\cdot\text{ms}$$

$$p_{1y} = (3\text{g})(12.0\text{m/s})\sin 40$$¡

$$= 23.1\ \text{g}\cdot\text{m/s}$$





$$p_{3x} = p_{ix} - (p_{1x} + p_{2x}) = 22.4\ \text{g}\cdot\text{m/s}$$

0

$$p_{3y} = -(p_{1y} + p_{2y}) = -23.1\ \text{g}\cdot\text{m/s}$$

Find θ and v_3.