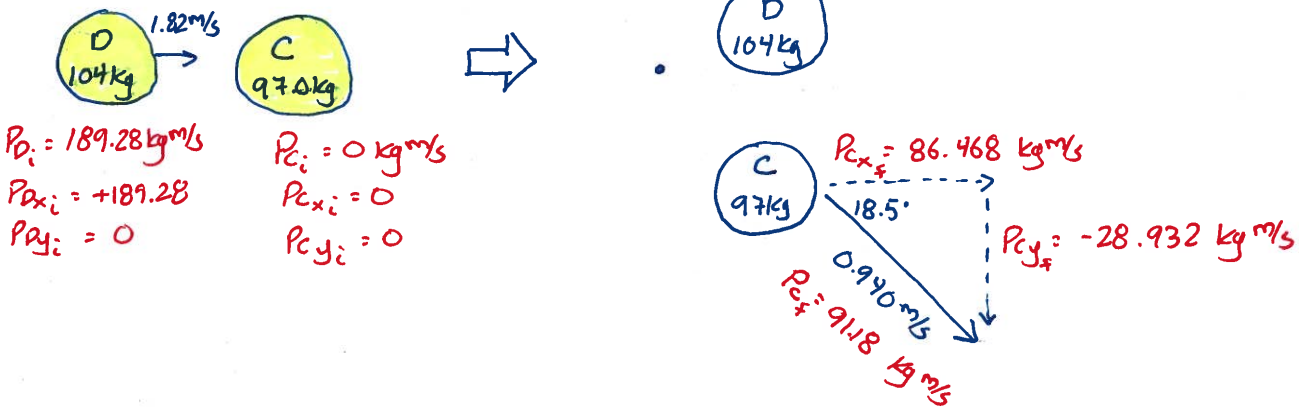
KEY

First Name:_____ Last Name:_____

## L07 – Worksheet – Collisions in 1-Dimensions

### Textbook Questions


**Pg 491 #1:** A 97.0-kg hockey center stops momentarily in front of the net. He is checked from the side by a 104-kg defenseman skating at 1.82 m/s [E], and bounces 0.940 m/s [18.5$^0$ S of E]. What is the velocity of the defenseman immediately after the check?




$P_{D_i} = 189.28\ kg\,m/s$
$P_{D_{x_i}} = +189.28$
$P_{D_{y_i}} = 0$

$P_{C_i} = 0\ kg\,m/s$
$P_{C_{x_i}} = 0$
$P_{C_{y_i}} = 0$

$P_{C_{x_f}} = 86.468\ kg\,m/s$
$P_{C_{y_f}} = -28.932\ kg\,m/s$
$P_{C_f} = 91.18\ kg\,m/s$

1. Diagram.
2. Show momentum values on diagram.
3. Break momentum values into components.
4. Conservation of momentum in x- and y-components.

**x-comp**

$P_i = P_f$

$P_{C_{x_i}} + P_{D_{x_i}} = P_{C_{x_f}} + P_{D_{x_f}}$

$0 + 189.28 = 86.468 + P_{D_{x_f}}$

$P_{D_{x_f}} = 102.812\ kg\,m/s$

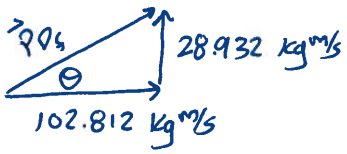
**y-comp**

$P_i = P_f$

$P_{C_{y_i}} + P_{D_{y_i}} = P_{C_{y_f}} + P_{D_{y_f}}$

$0 + 0 = -28.932 + P_{D_{y_f}}$

$P_{D_{y_f}} = +28.932\ kg\,m/s$




$\vec{P}_{D_f} = 106.805\ kg\,m/s\ [15.717°\ N\ of\ E]$

$\vec{v}_{D_f} = 1.027\ m/s\ [15.717°\ N\ of\ E]$

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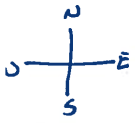
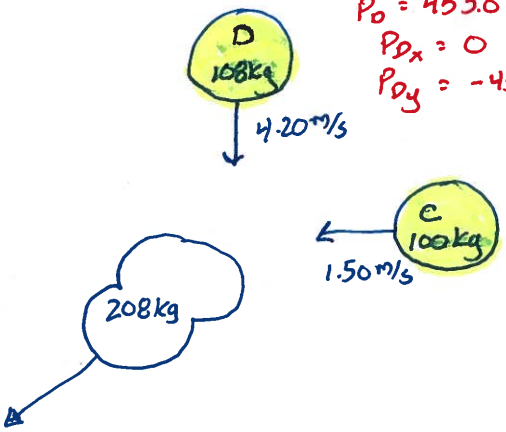



**Pg 492 #2:** A 100-kg hockey center is moving at 1.50 m/s [W] in front of the net. He is checked by a 108-kg defenseman skating at 4.20 m/s [S]. Both players move off together after the collision. What will be the velocity of the center of mass of the combination of the two players immediately after the check?




$\vec{P}_D = 453.6\ kg\,m/s\ [S]$

$P_{D_x} = 0$

$P_{D_y} = -453.6$

$\vec{P}_C = 150\ kg\,m/s\ [W]$

$P_{C_x} = -150$

$P_{C_y} = 0$

1. Diagram
2. Show momentum values on diagram.
3. Break momentum values into components.
4. Conservation of momentum in x- and y-components.

x-comp

$P_i = P_f$

$P_{C_{i_x}} + P_{D_{i_x}} = P_{f_x}$

$-150 + 0 = P_{f_x}$

$P_{f_x} = -150\ kg\,m/s$

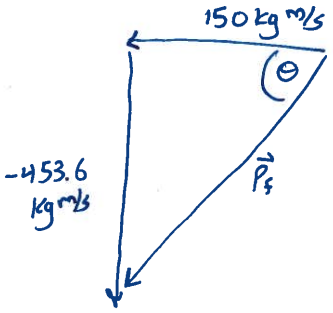
y-comp

$P_i = P_f$

$P_{C_{iy}} + P_{D_{iy}} = P_{f_y}$

$0 + (-453.6) = P_{f_y}$

$P_{f_y} = -453.6\ kg\,m/s$

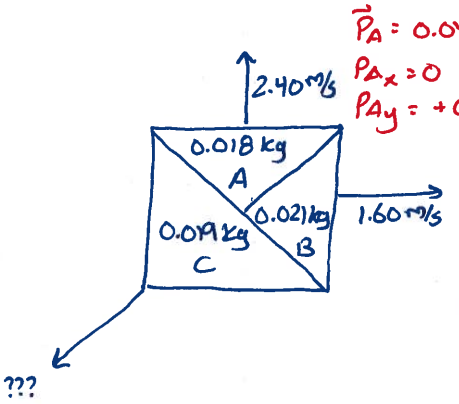



$\vec{P}_{sys_f} = 477.76\ kg\,m/s\ [71.7°\ S\ of\ W]$

$\vec{v}_{sys} = 2.297\ m/s\ [71.7°\ S\ of\ W]$

KEY

**Pg 494 #1:** A 0.058-kg firecracker that is at rest explodes into three fragments. A 0.018-kg fragment moves at 2.40 m/s [N] while a 0.021-kg fragment moves at 1.60 m/s [E]. What will be the velocity of the third fragment? Assume that no mass is lost, and that the motion of the fragments lies in a plane.




$\vec{P}_A = 0.0432\ kg\,m/s$

$P_{Ax} = 0$

$P_{Ay} = +0.0432$

$m_{TOT} = m_A + m_B + m_C$

$0.058 = 0.018 + 0.021 + m_C$

$m_C = 0.019\ kg$

$\vec{P}_B = 0.0336\ kg\,m/s$

$P_{Bx} = +0.0336$

$P_{By} = 0$

1. Diagram
2. Show momentum values on diagram
3. Break momentum values into components
4. Conservation of momentum into x- and y-components.

x-comp

$P_{ix} = P_{fx}$

$P_{ix} = P_{Ax_i} + P_{Bx_i} + P_{Cx_i}$

$0 = 0 + 0.0336 + P_{Cx_i}$

$P_{Cx_i} = -0.0336\ kg\,m/s$

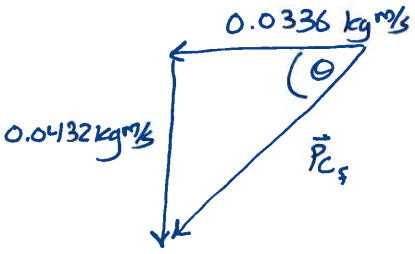
y-comp

$P_{iy} = P_{fy}$

$P_{iy} = P_{Ay_i} + P_{By_i} + P_{Cy_i}$

$0 = 0.0432 + 0 + P_{Cy_i}$

$P_{Cy_i} = -0.0432\ kg\,m/s$

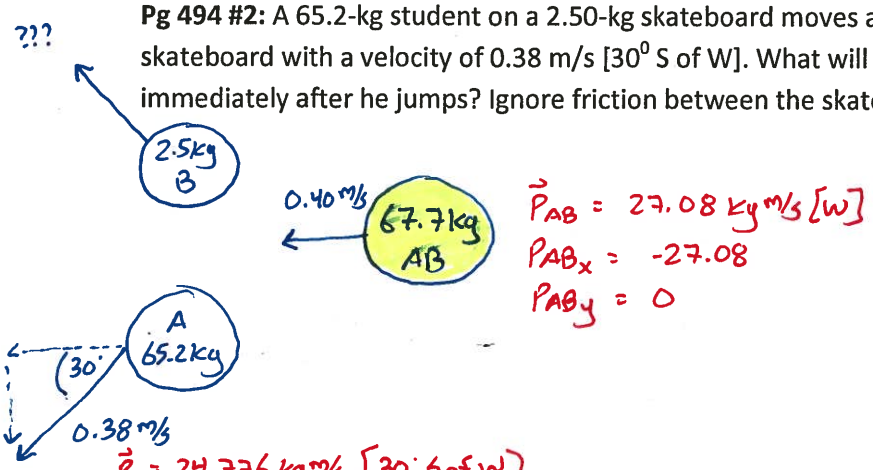



$\vec{P}_{C_f} = 0.054728\ kg\,m/s\ [52.1^\circ\ S\ of\ W]$

$\vec{v}_{C_f} = 2.880\ m/s\ [52.1^\circ\ S\ of\ W]$

KEY

**Pg 494 #2:** A 65.2-kg student on a 2.50-kg skateboard moves at 0.40 m/s [W]. He jumps off the skateboard with a velocity of 0.38 m/s [30° S of W]. What will be the velocity of the skateboard immediately after he jumps? Ignore friction between the skateboard and the ground.




$\vec{P}_{AB} = 27.08\ kg\,m/s\ [W]$

$P_{ABx} = -27.08$

$P_{ABy} = 0$

$\vec{P}_A = 24.776\ kg\,m/s\ [30°\ S\ of\ W]$

$P_{Ax} = -21.4566$

$P_{Ay} = -12.388$

1. Diagram
2. Show momentum values on diagram
3. Break momentum values into components
4. Conservation of momentum in x- and y-components.

x-comp

$P_{ix} = P_{fx}$

$P_{ABx_i} = P_{Ax_f} + P_{Bx_f}$

$-27.08 = -21.4566 + P_{Bx_f}$

$P_{Bx_f} = -5.6234\ kg\,m/s$

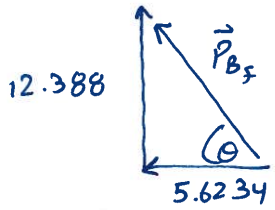
y-comp

$P_{iy} = P_{fy}$

$P_{ABy_i} = P_{Ay_f} + P_{By_f}$

$0 = -12.388 + P_{By_f}$

$P_{By_f} = +12.388\ kg\,m/s$

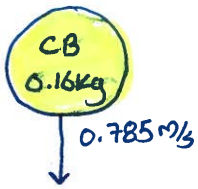



$\vec{P}_{B_f} = 13.6046\ kg\,m/s\ [65.58°\ N\ of\ W]$

$\vec{V}_{B_f} = 5.4418\ m/s\ [65.58°\ N\ of\ W]$

KEY


**Pg 499 #5:** A cue ball travelling at 0.785 m/s [270$^0$] strikes a stationary five-ball, causing it to move at 0.601 m/s [230$^0$]. The cue ball and the five-ball each have a mass of 160g. What will be the velocity fo the cue ball immediately after impact? Ignore frictional and rotational effects.




$\vec{P}_{CB_i} = 0.1256\ kg\ m/s\ [270^\circ]$

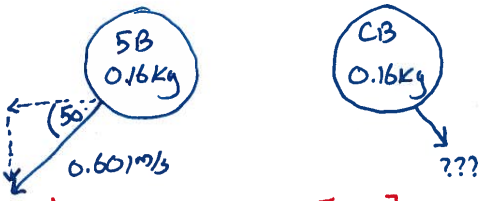
$P_{CB_{x_i}} = 0$

$P_{CB_{y_i}} = -0.1256$


$\vec{P}_{5B} = 0\ kg\ m/s$

$P_{5B_{x_i}} = 0$

$P_{5B_{y_i}} = 0$




$\vec{P}_{5B_f} = 0.09616\ kg\ m/s\ [230^\circ]$

$P_{5B_{x_f}} = -0.0618$

$P_{5B_{y_f}} = -0.0737$

1. Diagram
2. Show momentum values on diagram
3. Break momentum values into components
4. Conservation of momentum in x- and y- components.

x-comp

$P_{ix} = P_{fx}$

$P_{CB_{x_i}} + P_{5B_{x_i}} = P_{CB_{x_f}} + P_{5B_{x_f}}$

$0 + 0 = -0.0618 + P_{5B_{x_f}}$

$P_{5B_{x_f}} = +0.0618\ kg\ m/s$

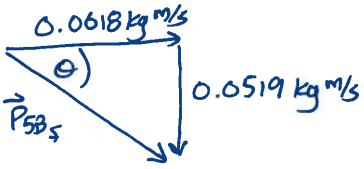
y-comp

$P_{iy} = P_{fy}$

$P_{CB_{y_i}} + P_{5B_{y_i}} = P_{CB_{y_f}} + P_{5B_{y_f}}$

$-0.1256 + 0 = -0.0737 + P_{5B_{y_f}}$

$P_{5B_{y_f}} = -0.0519\ kg\ m/s$

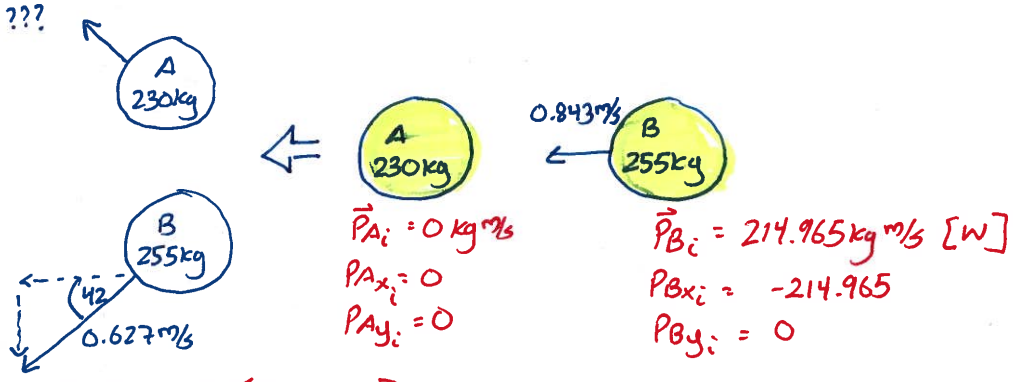



$\vec{P}_{5B_f} = 0.0807\ kg\ m/s\ [319.97^\circ]$

$\vec{v}_{5B_f} = 0.5044\ m/s\ [319.97^\circ]$

KEY

**Pg 499 #6:** A stationary 230-kg bumper car in a carnival is struck off center from behind by a 255-kg bumper car moving at 0.843 m/s [W]. The more massive car bounces off at 0.627 m/s [42.0$^0$ S of W]. What will be the velocity of the other bumper car immediately after collision?




$\vec{P}_{A_i} = 0\ kg\ m/s$
$P_{Ax_i} = 0$
$P_{Ay_i} = 0$

$\vec{P}_{B_i} = 214.965\ kg\ m/s\ [W]$
$P_{Bx_i} = -214.965$
$P_{By_i} = 0$

$\vec{P}_{B_f} = 159.885\ kg\ m/s\ [42^\circ S\ of\ W]$
$P_{Bx_f} = -118.8177$
$P_{By_f} = -106.9839$

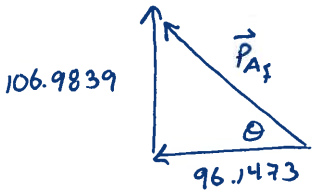
1. Diagram
2. Show momentum values on diagram
3. Break momentum values into components
4. Conservation of momentum in x- and y-components

x-comp

$P_{ix} = P_{fx}$
$P_{Ax_i} + P_{Bx_i} = P_{Ax_f} + P_{Bx_f}$
$0 + (-214.965) = P_{Ax_f} + (-118.8177)$
$P_{Ax_f} = -96.1473$

y-comp

$P_{iy} = P_{fy}$
$P_{Ay_i} + P_{By_i} = P_{Ay_f} + P_{By_f}$
$0 + 0 = P_{Ay_f} + (-106.9839)$
$P_{Ay_f} = +106.9839$




$\vec{P}_{A_f} = 143.8397\ kg\ m/s\ [48.1^\circ N\ of\ W]$
$\vec{V}_{A_f} = 0.6254\ m/s\ [48.1^\circ N\ of\ W]$

KEY

## Diploma Worksheet Questions

*Use the following information to answer Q50:*

> A 1000 kg car travelling east at 29.4 m/s on an icy road hits a parked truck that has a mass of 1500 kg. Immediately after the collision, the car was moving at 20.0 m/s in the direction $20.0^0$ N of E, and the truck was moving at an unknown speed in the direction $45.0^0$ S of E.

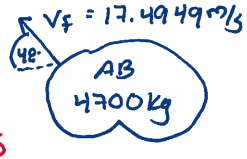
**Q50:** What physics principles do police use to determine the speed of the truck?

a. Conservation of kinetic energy but not conservation of momentum
(b.) Conservation of momentum but not conservation of kinetic energy
c. Both conservation of momentum and conservation of kinetic energy
d. Neither conservation of momentum nor conservation of kinetic energy

## Challenge Question

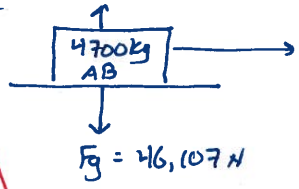
**Q1:** A 2200kg car travelling west is struck by a 2500kg truck travelling north. The vehicles stick together upon impact and skid for 20m [$48^0$ N of W]. The coefficient of friction for the tires on the road surface is 0.78. Both drivers claim to have been travelling at 90km/h before the crash. Determine the truth of their statements.

$\vec{P}_{AB} = 82,226.03$ kgm/s [48° N of W]
$P_{ABx} = -55,019.95$
$P_{ABy} = +61,105.85$






DYNAMICS




$F_f = \mu_k F_N$
$= (0.78)(46,107\ N)$
$= 35,963.46 N$

$a = \frac{F_{net}}{m} = \frac{35,963.46}{4700}$
$a = 7.6518$ m/s²

KINEMATICS

$V_i = ?$
$V_f = 0$
$a = -7.6518$
$d = 20$

$V_f^2 = V_i^2 + 2ad$
$0^2 = V_i^2 + 2(-7.6518)(20)$
$V_i^2 = 306.072$
$V_i = 17.4949$ m/s

x-comp

$P_{i_x} = P_{f_x}$
$P_{Ax_i} + P_{Bx_i} = P_{ABx_f}$
$P_{Ax_i} + 0 = -55,019.95$
$P_{Ax_i} = -55,019.95$
$\vec{P}_{A_i} = 55,019.95$ kgm/s [W]
$V_{A_i} = 25.01$ m/s [W]
$\approx 90.03$ kph [W]

y-comp

$P_{iy} = P_{fy}$
$P_{Ay_i} + P_{By_i} = P_{ABy_f}$
$0 + P_{By_i} = 61,105.85$
$P_{By_i} = 61,105.85$
$\vec{P}_{B_i} = 61,105.85$ kgm/s [N]
$P_{B_i} = 24.44$ m/s [N]
$\approx 87.99$ kph [N]

Both are telling the truth.

KEY

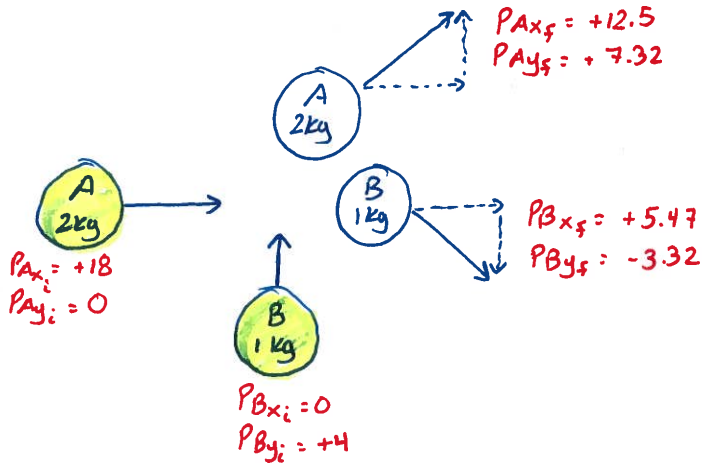
*Use the following information to answer Q2-Q5:*

A 2.00kg ball and 1.00kg ball collide. A computer program that simulates this collision generated the data below.

| | Computer-Generated Data | | | | | |
|---|---|---|---|---|---|---|
| | (A) 2.00 kg | | | (B) 1.00 kg | | |
| Tims (s) | $p_x$ kg*m/s | $p_y$ kg*m/s | \|p\| kg*m/s | $p_x$ kg*m/s | $p_y$ kg*m/s | \|p\| kg*m/s |
| 0.000 | 18.0 | 0.00 | 18.0 | 0.00 | 4.00 | 4.00 |
| 0.020 | 18.0 | 0.00 | 18.0 | 0.00 | 4.00 | 4.00 |
| 0.040 | 18.0 | 0.00 | 18.0 | 0.00 | 4.00 | 4.00 |
| 0.060 | 18.0 | 0.00 | 18.0 | 0.00 | 4.00 | 4.00 |
| 0.080 | 18.0 | 0.00 | 18.0 | 0.00 | 4.00 | 4.00 |
| | | | | | | |
| 0.100 | 18.0 | 0.00 | 18.0 | 0.00 | 4.00 | 4.00 |
| 0.120 | 18.0 | 0.00 | 18.0 | 0.00 | 4.00 | 4.00 |
| | | | | | | |
| INITIAL → 0.160 | $p_{Ax_i}$ = 18.0 | $p_{Ay_i}$ = 0.00 | 18.0 | $p_{Bx_i}$ = 0.00 | $p_{By_i}$ = 4.00 | 4.00 |
| FINAL → 0.180 | $p_{Ax_f}$ = 12.5 | $p_{Ay_f}$ = 7.32 | 14.5 | $p_{Bx_f}$ = 5.47 | $p_{By_f}$ = -3.32 | 6.40 |
| | | | | | | |
| 0.200 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.220 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.240 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.260 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.280 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| | | | | | | |
| 0.300 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.320 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.340 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.360 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.380 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |
| 0.400 | 12.5 | 7.32 | 14.5 | 5.47 | -3.32 | 6.40 |

**Note:** $p_x$ and $p_y$ are the x and y components of the momentum vector $\vec{p}$.

**Q2:** Draw a diagram of the approximate direction for each ball before and after the collision.



■ KEY ■

**Q3:** Determine the speed of each ball before and after the collision.

$|\vec{p}_{A_i}| = 18.0 \text{ kg m/s}$ (from table)

$|\vec{v}_{A_i}| = 9.0 \text{ m/s}$

$|\vec{p}_{B_i}| = 4.0 \text{ kg m/s}$ (from table)

$|\vec{v}_{B_i}| = 4.0 \text{ m/s}$

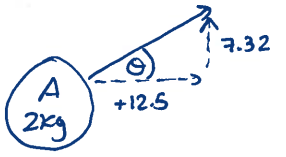
$|\vec{p}_{A_f}| = 14.5 \text{ kg m/s}$ (from table)

$|\vec{v}_{A_f}| = 7.25 \text{ m/s}$

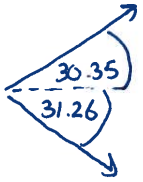
$|\vec{p}_{B_f}| = 6.40 \text{ kg m/s}$ (from table)

$|\vec{v}_{B_f}| = 6.40 \text{ m/s}$

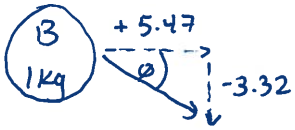
**Q4:** Determine the angle between the balls after the collision.




$\theta = 30.35°$




Angle between is 61.6°




$\phi = 31.26°$

**Q5:** Show that the total momentum before the collision is equal to the total momentum after the collision.

x-comp

$p_i = p_f$

$p_{A_i} + p_{B_i} = p_{A_f} + p_{B_f}$

$18 + 0 = 12.5 + 5.47$

$18 = 17.97$

Momentum conserved in x-component.

y-comp

$p_i = p_f$

$p_{A_i} + p_{B_i} = p_{A_f} + p_{B_f}$

$0 + 4 = 7.32 + (-3.32)$

$4 = 4$

Momentum conserved in y-component.