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PHYSICS FOR THE LIFE SCIENCES

Solution Manual

Created by WebStraw

Physics for the Life Sciences – Momentum Solutions

Introduction:

Dear student,

Thank you for opening this solution manual for the Momentum chapter of the Physics for the Life Sciences Question Manual. This resource has been created by members of the Education Team at WebStraw who have previously taken an introductory university physics course.

Purpose:

This resource is meant to supplement the Physics for the Life Sciences Question Manual, by providing solutions to select questions. To access the full question manual, please click here.

Instructions

We recommend first trying to complete the problems in the question manual on your own. If you get stuck, you can use this resource to view the solution provided by one of our Education Team members. Once you are confident you understand how to solve that question, we recommend solving additional related problems in order to successfully master the topic.

Disclaimer

This resource assumes that you have a basic understanding of key concepts related to the Momentum unit in physics. If you are looking to improve your understanding of specific physics content, check out the additional resources provided at the end of the question manual.

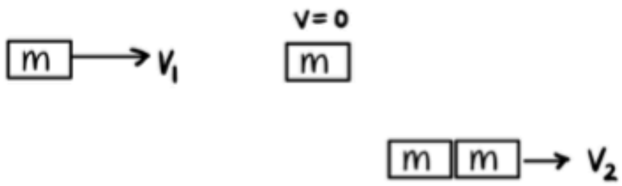
Note: There may be more than one correct method to solve some of the problems outlined in the question manual. Thus, the solutions provided may not represent the only acceptable solution.

If you have any comments or feedback regarding this resource or the solutions contained in it, please do not hesitate to contact us at team@webstraw.ca

We wish you the best of luck on your learning journey!

- The WebStraw Education Team

M1. Recall that, in a completely inelastic collision, two colliding objects stick together and continue moving in such a way as to conserve momentum.



If a moving body of mass *m* were initially travelling to the right at speed *v*, its kinetic energy would be equal to $E_k=\frac{1}{2}mv^2$ and its momentum would be equivalent to $p = mv$.

A completely inelastic collision with a stationary body of equal mass *m* will result in a new moving body of double the initial mass. That is, 2*m*. Since momentum must be conserved, the speed of motion following the collision must be half of its initial value.

$$P_1 = P_2$$
$$m_1 V_1 = m_2 V_2$$
$$m V = (2m) V_2$$
$$V_2 = \frac{\cancel{m} V}{2\cancel{m}}$$
$$V_2 = \frac{1}{2} V$$

Substituting the new mass and speed into the equation for kinetic energy, it can be seen that:

$$E_1 = \frac{1}{2} m v^2$$
$$E_2 = \frac{1}{2} (2m)\left(\frac{1}{2} v\right)^2$$
$$E_2 = \frac{1}{2} (2)(m)\left(\frac{1}{4}\right)(v^2)$$
$$E_2 = \frac{2}{4}\left(\frac{1}{2} m v^2\right)$$
$$\boxed{E_2 = \frac{1}{2} E_1}$$

Therefore, 50% of the kinetic energy originally contained in the moving body of mass *m* will be lost after it collides with a stationary body of equal mass.

M3. Let one baby have mass m_1. This baby is initially moving at speed v. Momentum is conserved after a completely inelastic collision with a second baby of unknown mass, m_2. Their final speed is $v/4$.

For baby of mass m_1:

$$m_1 v = (m_1 + m_2)\frac{v}{4}$$

$$4m_1 \cancel{v} = (m_1 + m_2)\cancel{v}$$

$$4m_1 = m_1 + m_2$$

$$\therefore \boxed{m_2 = 3m_1}$$

Therefore, the ratio of the two babies masses is 3:1.

M5. Since this is an elastic collision, both kinetic energy and momentum are conserved. We will need equations equating initial and final conditions for both.

V and M are both constants. The prime symbol (′) indicates a final condition.

① $p_1 = p_2$

$$MV + \cancel{3Mv_2}^{\to 0} = Mv_1' + 3Mv_2'$$

$$MV = Mv_1' + 3Mv_2'$$

$$V = v_1' + 3v_2'$$

② $E_{k1} = E_{k2}$

$$\frac{1}{2}MV^2 + \cancel{\frac{1}{2}(3M)v_2^2}^{\to 0} = \frac{1}{2}Mv_1'^2 + \frac{1}{2}(3M)v_2'^2$$

$$V^2 = v_1'^2 + 3v_2'^2$$

From ①

$$V = v_1' + 3v_2'$$

$$v_1' = V - 3v_2'$$

Sub into ②

$$V^2 = (V - 3v_2')^2 + 3v_2'^2$$

$$V^2 = V^2 - 6Vv_2' + 9v_2'^2 + 3v_2'^2$$

$$0 = 12v_2'^2 - 6Vv_2'$$

$$6V\cancel{v_2'} = 12v_2'^{\cancel{2}}$$

$$\frac{1}{2}V = v_2'$$

$$\boxed{v_2' = \frac{1}{2}V \text{ m/s}}$$

Therefore,

$$v_1' = V - 3v_2'$$

$$v_1' = V - \frac{3}{2}V$$

$$\boxed{v_1' = -\frac{1}{2}V \text{ m/s}}$$

The marble of mass *M* will have speed V/2 back in the direction it came from, while the marble of mass *3M* will have speed V/2 in the positive direction.

M7.

Kinetic energy is a scalar quantity that can never be negative. Even though the two masses are moving in opposite directions (v and –v), kinetic energy is proportional to the square of velocity and thus is always positive. Therefore, K > 0.

The total momentum is the sum of each mass's momentum.

$$p = mv + m(-v)$$

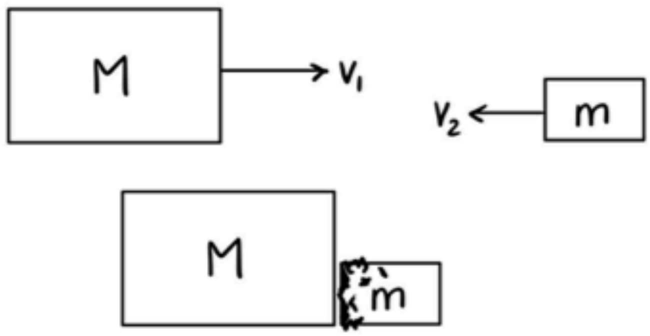
$$p = mv - mv$$

$$p = 0$$

Since the two equal masses are moving at velocities equal in magnitude and opposite in direction, their total momentum equals net zero. Therefore, p = 0.

The correct answer is thus **b)**.

M9.



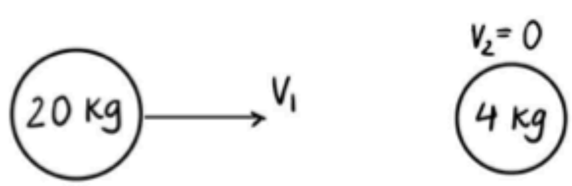
a) This collision is an inelastic collision. Since the bulldozer is so much more massive than the Fiat, it is reasonable to assume that the Fiat sticks to the bulldozer and this is how the Fiat becomes completely destroyed. This is a characteristic of an inelastic collision, and it is accompanied with a loss of kinetic energy.

If the collision were elastic, then the bulldozer and Fiat would rebound and continue moving in the opposite direction from which they came so that kinetic energy would be conserved. This is very unlikely in realistic scenarios, including car crashes.

b) Impulse, *J*, can be calculated as the product of net force and change in time. The bulldozer and Fiat can only impart a force on each other for the duration of time they are in contact and this contact force must be equally imparted on both vehicles by Newton's third law. If the Fiat were to exert a force of 400 N on the bulldozer, then the bulldozer would exert a reaction force of 400 N back on the Fiat. Therefore, it does not matter which of the two vehicles is larger in mass or which moves faster; the car will give the same impulse as the bulldozer gives it.

$$\boxed{J = \Delta p = F_{net}\,\Delta t}$$

M11. Taking the right to be the positive direction,



$$p_1 = p_2$$
$$m_1 v_1 + m_2 v_2 = m_1 v_1 + m_2 v_2$$
$$(20\ kg)\, v_1 + (4.0\ kg)(0\ m/s) = (20\ kg)(5\ m/s) + (4.0\ kg)(-5.0\ m/s)$$
$$(20\ kg)\, v_1 = 100\ \frac{kg\,m}{s} - 20\ \frac{kg\,m}{s}$$
$$(20\ kg)\, v_1 = 80\ \frac{kg\,m}{s}$$
$$\boxed{v_1 = 4\ m/s}$$

Therefore, the curling rock begins moving with a speed of 4 m/s.

M13. <u>Given</u>: $m_1 = 67\ kg$ $\quad v_1 = 0\ m/s$
$m_2 = 0.2\ kg$ $\quad v_2 = 11\ m/s$

$$p_1 = p_2$$
$$m_1 v_1 + m_2 v_2 = (m_1 + m_2)\, v_f$$
$$(67\ kg)(0\ m/s) + (0.2\ kg)(11\ m/s) = (67\ kg + 0.2\ kg)\, v_f$$
$$2.2\ \frac{kg\,m}{s} = (67.2\ kg)\, v_f$$
$$\boxed{v_f = 0.033\ m/s}$$

Therefore, the player will move with a horizontal speed of 0.033 m/s (3.3 cm/s) after catching the frisbee.

M15. <u>Given</u>: $m = 0.005\ kg$ $\quad \vec{a} = 3.00\ m/s^2$
$v = 2\ m/s$ $\quad \Delta t = 5\ s$

① <u>Initial momentum</u>

$$p_1 = mv = (0.005\ kg)(2\ m/s) = 0.01\ \frac{kg\,m}{s}$$

② Δp

$$\Delta p = F_{net} \cdot \Delta t$$
$$\Delta p = m \cdot a \cdot \Delta t$$
$$\Delta p = (0.005\ kg)(3.00\ m/s^2)(5\ s)$$
$$\Delta p = 0.075\ \frac{kgm}{s}$$

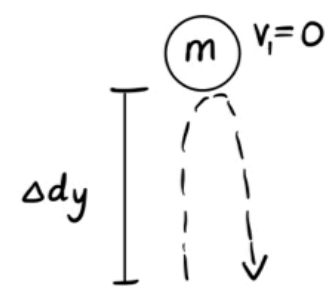
③ final momentum

$$\Delta p = p_2 - p_1$$
$$p_2 = \Delta p + p_1$$
$$p_2 = 0.075\ \frac{kgm}{s} + 0.01\ \frac{kgm}{s}$$
$$p_2 = 0.085\ \frac{kgm}{s}$$
$$\boxed{p_2 \doteq 0.08\ \frac{kgm}{s}}$$

∴ The plane's momentum as it exits the tunnel is $0.08\ \frac{kg \cdot m}{s}$.

M17. Given:

$$\vec{\Delta d_y} = -2.5\,m$$
$$\vec{a}_y = -9.8\,m/s^2$$
$$\vec{V}_{1y} = 0\,m/s$$
$$m = 0.625\,kg$$



① V_2

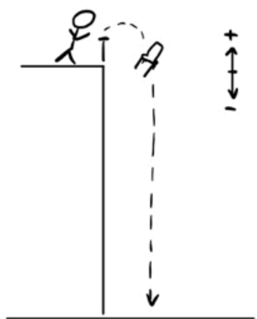
$$V_2^{\,2} = \cancel{V_1^{\,2}}^{\,0} + 2a\Delta d_y$$
$$V_2^{\,2} = 2(-9.8\,m/s^2)(-2.5\,m)$$
$$V_2 = \sqrt{49\ m^2/s^2}$$
$$V_2 = 7.0\ m/s$$

②

$$p = mv$$
$$p = (0.625\ kg)(7.0\ m/s)$$
$$\boxed{p = 4.4\ \frac{kgm}{s}}$$

The ball's momentum as it reaches the ground is $4.4\ \frac{kgm}{s}$.

M19.



Given

$m = 9\ kg$
$\Delta\vec{d}_y = -195\ m$
$\vec{a}_y = -9.8\ m/s^2$
$\vec{V}_1 = 0\ m/s$

$$p_1 = mv$$
$$p_1 = (9\ kg)(0\ m/s)$$
$$p_1 = 0$$

① V_2

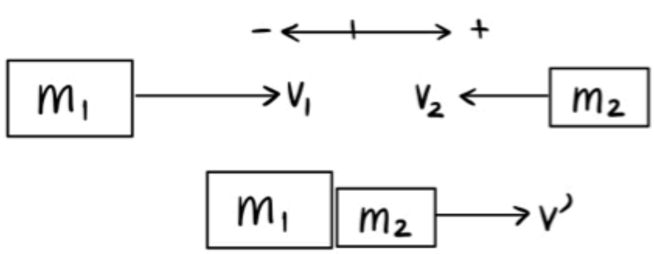
$$V_2^2 = \cancel{V_1^2}^{\,0} + 2a\Delta d_y$$
$$V_2^2 = 2(-9.8\ m/s^2)(-195\ m)$$
$$V_2 = \sqrt{3822\ m^2/s^2}$$
$$V_2 = 61.82\ m/s\ [\text{down}]$$

② Δp

$$\Delta p = p_2 - p_1$$
$$\Delta p = m(V_2 - V_1)$$
$$\Delta p = (9\ kg)(61.82\ \tfrac{m}{s} - 0)$$
$$\Delta p = 556.4\ \frac{kgm}{s}$$
$$\boxed{\Delta p \doteq 6 \times 10^2\ \frac{kgm}{s}\ [\text{down}]}$$

Therefore, the chair will experience an impulse of $6 \times 10^2\ \frac{kgm}{s}$ [down].

M21.

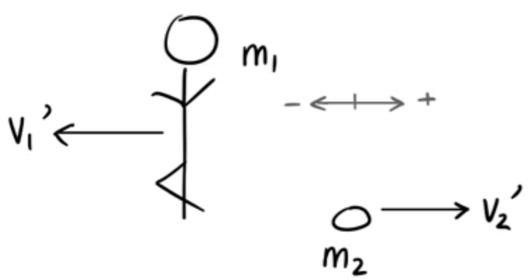


Given $m_1 = 1440$ kg $\quad v_1 = 144$ km/h $\quad (40$ m/s$)$
$m_2 = 1350$ kg $\quad v_2 = 100$ km/h $\quad (27.8$ m/s$)$

$$p_1 = p_2$$
$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v'$$
$$(1440\text{ kg})(40\text{ m/s}) + (1350\text{ kg})(-27.8\text{ m/s}) = (1440\text{ kg} + 1350\text{ kg}) v'$$
$$20\,070 \frac{\text{kg}\cdot\text{m}}{\text{s}} = (2790\text{ kg}) v'$$
$$\boxed{v' = 7.2\text{ m/s}}$$

Therefore, the cars are moving together at 7.2 m/s to the right.

M23.



Given $m_1 = 45.0$ kg
$v_1 = 0$ m/s
$v_1' = -0.0024$ m/s
$m_2 = 3.2$ kg
$v_2 = 0$ m/s

$$\cancelto{0}{m_1 v_1} + \cancelto{0}{m_2 v_2} = m_1 v_1' + m_2 v_2'$$
$$0 = (45.0\text{ kg})(-0.0024\text{ m/s}) + (3.2\text{ kg}) v_2'$$
$$0.108 \frac{\text{kg m}}{\text{s}} = (3.2\text{ kg}) v_2'$$
$$\boxed{v_2' = 0.034\text{ m/s}}$$

Therefore, the puck moves with a velocity of 0.034 m/s forwards. That is, away from the boy.

M25. Visual of the situation:

Given:

$m_N = 2.62\,kg$ $\quad m_d = 1.1g = 1.1 \times 10^{-3}\,kg$ $\quad m_c = 12g = 1.2 \times 10^{-2}\,kg$

$V_{dcf} = 1.6\,m/s$

Asked For:

$V_{di\,(\text{before cup collision})} = ?$ $\quad V_{Nf} = ?$

Work:

Formula:

conservation of momentum: $P_i = P_f$

1^{st} collision ($\bar{w}$ NERF & Dart)

$$P_i = P_F$$

$$\cancel{m_N V_{Ni}}^{\,0} + \cancel{m_D V_{Di}}^{\,0} = m_N V_{NF} + m_D V_{Df}$$

b)

$$-m_N V_{NF} = m_D V_{Df}$$

$$V_{NF} = \frac{m_D V_{Df}}{-m_N}$$

$$V_{NF} = \frac{(1.1 \times 10^{-3}\,kg)(19.05\,m/s)}{-2.62\,kg}$$

$$\boxed{V_{NF} = -8.0 \times 10^{-3}\,m/s}$$

∴ the recoil speed of NERF gun is $-8.0 \times 10^{-3}\,m/s$ to the left according to convention used.

velocity of the dart initially for collision 2 is same as velocity of dart finally for collision 1

2^{nd} collision ($\bar{w}$ Dart & cup) *inelastic

$$P_i = P_F$$

$$m_D V_{Di} + \cancel{m_c V_{ci}}^{\,0} = (m_D + m_c) V_{dcf}$$

$$m_D V_{Di} = (m_D + m_c) V_{dcf}$$

$$V_{Di} = \frac{(m_D + m_c) V_{dcf}}{m_D}$$

$$V_{Di} = \frac{(1.1 \times 10^{-3} + 1.2 \times 10^{-2})(1.6)}{1.1 \times 10^{-3}}$$

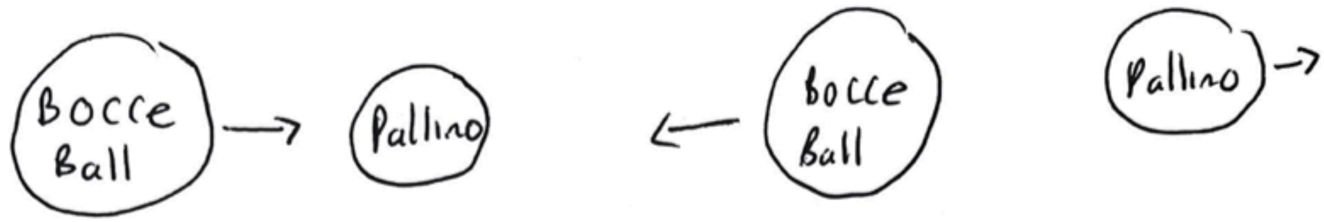
a)

$$\boxed{V_{Di} = 19.05\,m/s}$$

∴ the velocity of the dart prior to impact $\bar{w}$ cup is 19 m/s

M27. Visual of the situation: * elastic collision

Before collision: $\rightarrow +x$ After collision: $\rightarrow +x$



* note that $-V_{Bf} = V_{pf}$

Conservation of momentum

$$P_i = P_f$$

$$m_B V_{Bi} + \cancel{m_p V_{pi}} = m_B V_{Bf} + m_p V_{pf}$$

$$m_B V_{Bi} = m_B(-V_{pf}) + m_p V_{pf}$$

$$m_B V_{pf} + m_B V_{Bi} = m_p V_{pf}$$

$$m_B(V_{pf} + V_{Bi}) = m_p V_{pf}$$

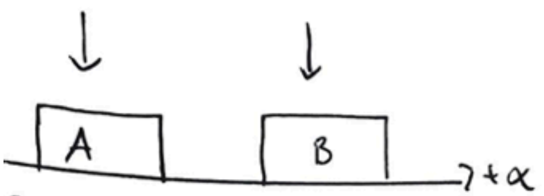
$$\therefore \boxed{m_B = \frac{m_p V_{pf}}{V_{pf} + V_{Bi}}}$$ represents the mass of the bocce ball.

M29. Visual of the situation

Before collision

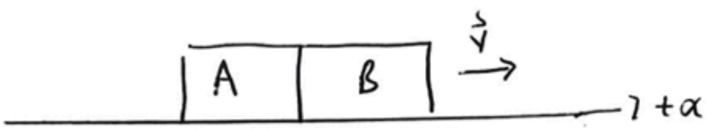
Braking Truck

Rear-ended Truck



After collision

a) inelastic



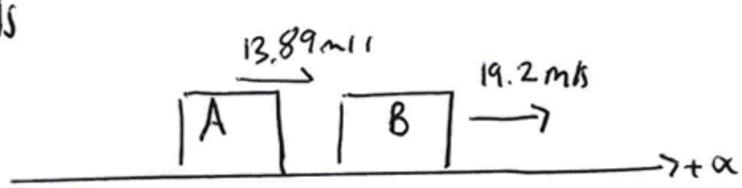
Given:

$m_A = 3400kg$ $m_B = 2700kg$

$V_{iA} = 70km/hr$ $V_{iB} = 44km/hr$

$V_{iA} = 19.44m/s$ $V_{iB} = 12.22m/s$

b) Elastic



Formula:

Conservation of Momentum

$P_i = P_f$

Work:

a) inelastic

$P_i = P_f$ same v

$m_A V_{Ai} + m_B V_{Bi} = m_A V_{Af} + m_B V_{Bf}$

$m_A V_{Ai} + m_B V_{Bi} = (m_A + m_B) V_{ABf}$

$V_{ABf} = \dfrac{m_A V_{iA} + m_B V_{iB}}{(m_A + m_B)}$

$= \dfrac{(3400kg)(19.44\frac{m}{s}) + (2700kg)(12.22\frac{m}{s})}{3400kg + 2700kg}$

$\boxed{V_{ABf} = 16.24 m/s = 16 m/s \text{ +ve x dir}}$

∴ in an inelastic scenario the trucks move together at 16m/s.

b) Elastic $V_{Af} = 50km/hr = 13.89 m/s$

$P_i = P_f$

$m_A V_{iA} + m_B V_{iB} = m_A V_{Af} + m_B V_{Bf}$

$(3400kg)(19.44\frac{m}{s}) + (2700kg)(12.22m/s) = (3400kg)(13.89\frac{m}{s}) + m$

$51864 = m_B V_{Bf}$

$V_{Bf} = \dfrac{(51864)}{2700}$

$\boxed{V_{Bf} = 19.2 m/s}$

∴ the rear-ended truck will move at 19.2m/s in same dir as braking truck

M31. Given:

$m_v = 260\ g = 2.6 \times 10^{-1}\ kg$

$V_i = 15.0 m/s$

$V_f = -19.5 m/s$

$\Delta t = 0.3 s$

Asked For: $F = ?$

Formula: $J = m\Delta V = P_1 - P_2 = \Delta t\ F$

$$F = \frac{m_v \Delta V}{\Delta t}$$

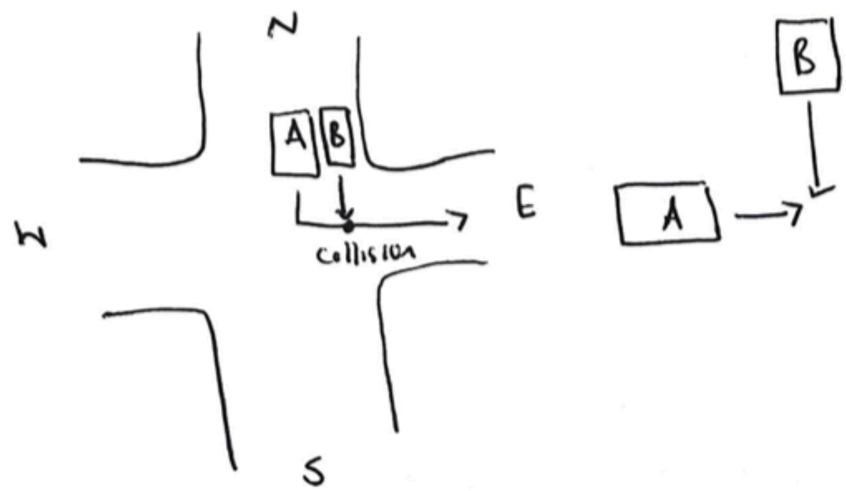
$$= \frac{m_v (V_f - V_i)}{\Delta t}$$

$$= \frac{(2.6 \times 10^{-1} kg)(-19.5 m/s - 15.0 m/s)}{0.3 s}$$

$= -30N$ or $30 N$ away from player onto ball

∴ the force applied by the volleyball player onto the ball was 30N.

M33. Visual of situation:



- Let A represent the car moving south that turns left (∴ moving East)
- Let B represent the car moving south

Given:

$\vec{P} = m\vec{v}$

$m_A = 1200\ kg$ $\quad m_B = 2000\ kg$

$\vec{v}_A = 33km/hr$ $\quad \vec{v}_B = 24km/hr$

$= 9.17m/s$ $\quad = 6.67m/s$

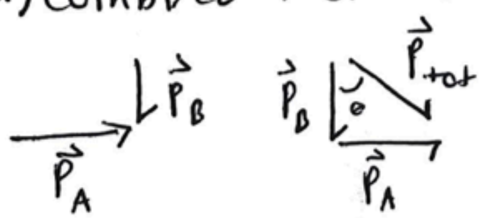
$\vec{P}_A = 11004\ kg \cdot \frac{m}{s}$ $\quad \vec{P}_B = 13340\ kg \cdot m/s$

* inelastic collision

Formula/method: (involves vector addition), $a^2 + b^2 = c^2$

work:

a) combined momentum



$\theta = \tan^{-1}\left(\frac{\vec{P}_A}{\vec{P}_B}\right)$

$\theta = \tan^{-1}\left(\frac{11004}{13340}\right)$

$\theta = 39.52°$

$P_{tot} = \sqrt{(\vec{P}_B)^2 + (\vec{P}_A)^2}$

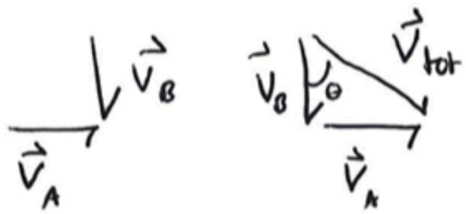
$= \sqrt{(13340\ \frac{kgm}{s})^2 + (11004\ kg \cdot \frac{m}{s})^2}$

$= \sqrt{299043616}$

∴ the combined momentum after inelastic collision is $17000\ kg \cdot \frac{m}{s}$ directed $40°$ east of south (w Proper sig dis

$|P_{tot}| = 17293\ kg \cdot \frac{m}{s}$

b) Combined velocity



$\vec{V}_{tot} = \sqrt{(\vec{V}_B)^2 + (\vec{V}_A)^2}$

$= \sqrt{(6.67\frac{m}{s})^2 + (9.17\frac{m}{s})^2}$

$= 11.33\ m/s$

$= 11\ m/s$ or $41\ km/hr$

$\theta = \tan^{-1}\left(\frac{\vec{V}_A}{\vec{V}_B}\right)$

$= \tan^{-1}\left(\frac{9.17}{6.67}\right)$

$= 53.9°$

$= 54°$

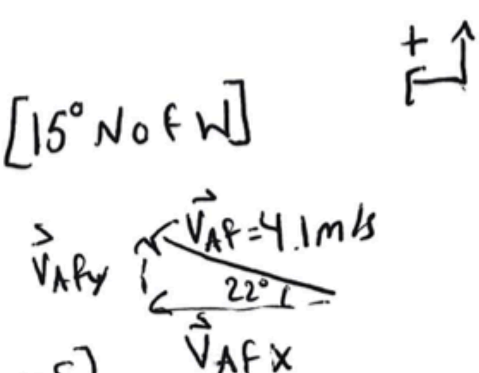
∴ the combined velocity after inelastic collision is 41 km/hr directed 54° East of south.

M35. Given:

$m_A = 5kg$ $m_B = 5kg$

$V_{Ai} = 4.5 m/s$ [N] $V_{Bi} = 3.9 m/s$ [15° N of W]

$V_{Af} = 4.1 m/s$ [22° N of W]



$\vec{V}_{Afx} = \cos(22) 4.1$

$= 3.80 m/s$

$\vec{V}_{Afy} = \sin(22) 4.1$

$= 1.54 m/s$

X-dir (E or W)

$V_{Aix} = 0$

$V_{Afx} = 3.80 m/s$

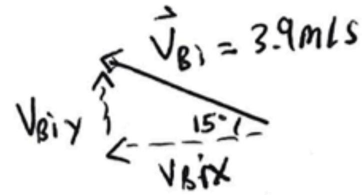
Y-dir (N or S)

$V_{Aiy} = 4.5 m/s$

$V_{Afy} = 1.54 m/s$

$V_{Bfx} = 3.77 m/s$ $V_{Biy} = 1.009 m/s$

Asked for: $V_{Bfx} = ?$ $V_{BFy} = ?$



$\sin 15° = \frac{V_{Biy}}{3.9 m/s}$

$V_{Biy} = 1.009 m$

$\cos 15 = \frac{V_{Bix}}{3.9 m/s}$

$V_{Bix} = 3.77 m/s$

momentum in x-dir

$$P_{ix} = P_{fx}$$

$$m_A \cancel{V_{Aix}}^{0} + m_B V_{Bix} = m_A V_{Afx} + m_B V_{Bfx}$$

$$m_B V_{Bix} - m_A V_{Afx} = m_B V_{Bfx}$$

$$V_{Bfx} = \frac{m_B V_{Bix} - m_A V_{Afx}}{m_B}$$

$$= \frac{(5kg)(3.77 m/s) - (5kg)(3.80 m/s)}{(5kg)}$$

$$= -0.03 m/s$$

Momentum in y-dir

$$P_{iy} = P_{fy}$$

$$m_A V_{Aiy} + m_B V_{Biy} = m_A V_{Afy} + m_B V_{Bfy}$$

Factor out & cancel

$$V_{Bfy} = \frac{\cancel{m_A} V_{Aiy} + \cancel{m_B} V_{Biy} - \cancel{m_A} V_{Afy}}{\cancel{m_B}}$$

$$V_{Bfy} = V_{Aiy} + V_{Biy} - V_{Afy}$$

$$= 4.5 m/s + 1.009 m/s - 1.54 m/s$$

$= 3.969\ m/s$

$\approx 4.0\ m/s$

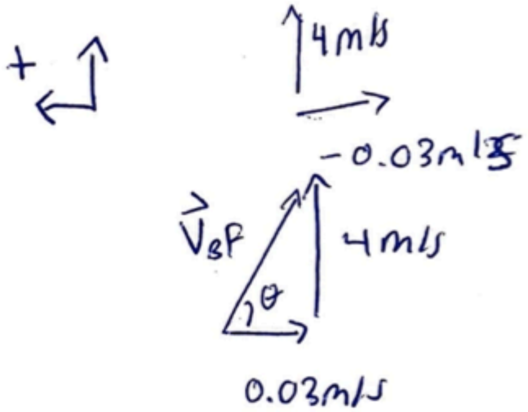
$V_{BFx} = -0.03\ m/s$

$V_{BFy} = 4.0\ m/s$

$$|V_{BF}| = \sqrt{(V_{BFx})^2 + (V_{BFy})^2}$$

$$= \sqrt{(4)^2 + (0.03)^2}$$

$$\approx 4\ m/s$$



$\therefore$ final velocity of 2^{nd} ball is 4.0 m/s North ($90° \approx 89.6°$)

$$\tan\theta = \frac{4}{0.03}$$

$$\theta = \tan^{-1}\left(\frac{4}{0.03}\right)$$

$= 89.6°$ from $-ve$ x axis as defined by convention chosen.

M37.

Given:

$m_D = 1.1\,g = 1.1 \times 10^{-3}\,kg$

$m_N = 2.62\,kg$

$\vec{V}_T = 34\,km/hr = 9.44\,m/s\ [N]$

$\vec{V}_D = 5\,m/s\ [S]$ ← if dart moves towards caboose which is at rear of train it opposes motion of train

$= -5\,m/s\ [N]$

Asked For:

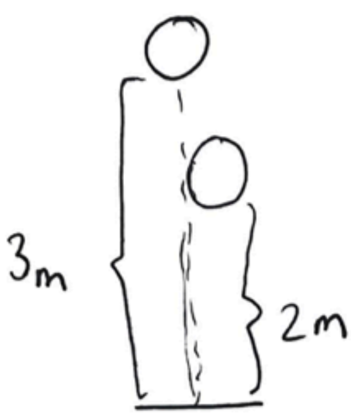
Darts ground speed aka Vector sum of $\vec{V}_T$ and $\vec{V}_D$

Work:

$$\vec{V}_{Total} = \vec{V}_{Train} + \vec{V}_{Dart}$$
$$= 9.44 m/s - 5 m/s$$
$$= 4.44 m/s$$

∴ the dart is moving 4.44 m/s North relative to the ground. or 4.40 ($\bar{w}$ sig digs).

M39. Visual of the situation:



Given:

$m_B = 40 g = 4.0 \times 10^{-2} kg$

$h_i = 3m$

$h_f = 2m$

$F = 15 N$

Cons. of energy: PE = KE

$$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$$
$$v = \sqrt{2gh}$$

∴ the ball makes contact $\bar{w}$ the floor for 3.8×10^{-3} s.

$v_1 = \sqrt{2gh_1}$ $\quad$ $v_f = \sqrt{2gh_2}$

$= \sqrt{2(9.80m/s^2)(3m)}$ $\quad$ $= \sqrt{2(9.80m/s^2)(2m)}$

$= 7.67m/s$ $\quad$ $= 6.26m/s$

$P_1 = mV_1$ $\quad$ $P_2 = mV_2$

$= (4.0\times10^{-2}kg)(7.67m/s)$ $\quad$ $= (4.0\times10^{-2}kg)(6.26\frac{m}{s})$

$= 0.3068\ kg\cdot\frac{m}{s}$ $\quad$ $= 0.2504\ kg\cdot\frac{m}{s}$

$J = m\Delta V = P_1 - P_2 = F\Delta t$

$0.3068\frac{kg\,m}{s} - 0.2504\frac{kg\,m}{s} = (15N)\Delta t$

$\Delta t = 3.76\times10^{-3}s$

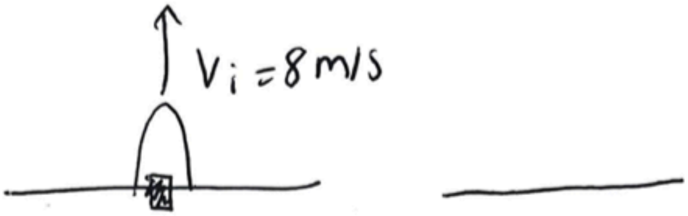
M41. $+y$

$V_{FR} = 0m/s$

$V_{FB} = 12m/s$

Let R denote racket
Let B denote box

$V_i = 8m/s$



$m_B = 1kg$

Asked For:

$M_T = m_B + m_R = ?$

Conservation of momentum

$P_i = P_f$

$$(m_B + m_R) V_i = m_B V_{fB} + m_R V_{fR}$$

$$m_R V_i + m_B V_i = m_B V_{fB} + m_R V_{fR}$$

$$m_R (V_i - V_{fR}) = m_B V_{fB} - m_B V_i$$

$$m_R = \frac{m_B V_{fB} - m_B V_i}{V_i - V_{fR}}$$

$$= \frac{(1kg)(12m/s) - (1kg)(8m/s)}{8\frac{m}{s} - 6m/s}$$

$$= 2kg$$

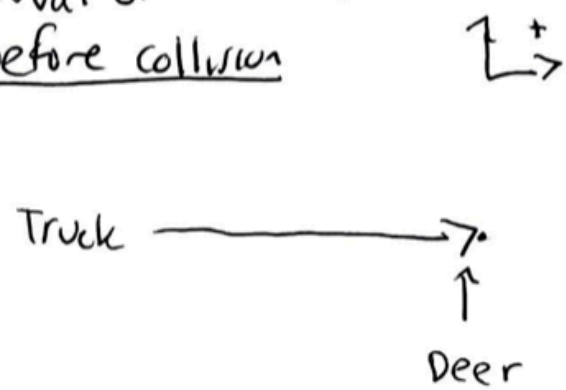
$$m_T = 2kg + 1kg = 3kg$$

$\therefore$ the mass initally for the system is 3kg.

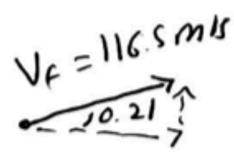
M43.

Visual of the situation

Before collision



After collision



Truck	Deer
$m_T = 2700kg$	$m_D = 80kg$
$V_{T1x} = 120m/s$	$V_{D1x} = 0$
$V_{T1y} = 0$	$V_{D1y} = 15m/s$

Conservation of Momentum

$$P_{ix} = P_{fx}$$

$$m_T v_{T1x} + \cancel{m_D v_{D1x}} = (m_T + m_D) v_{fx}$$

$$v_{fx} = \frac{m_T v_{T1x}}{m_T + m_D}$$

$$= \frac{(2700\,kg)(120\,m/s)}{2700\,kg + 80\,kg}$$

$$= 116.5\,m/s$$

$$p_{1y} = p_{fy}$$

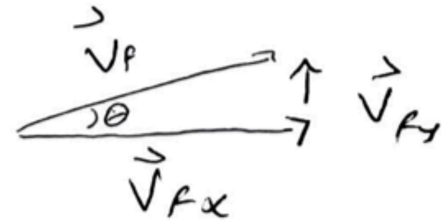
$$m_T \cancel{v_{T1y}} + m_D v_{D1y} = (m_T + m_D) v_{fy}$$

$$v_{fy} = \frac{m_D v_{D1y}}{m_T + m_D}$$

$$= \frac{(80\,kg)(15\,m/s)}{2700\,kg + 80\,kg}$$

$$= 0.43165\,m/s$$

Vector Addition



$$a^2 + b^2 = c^2$$

$$v_f = \sqrt{(0.43165\,\tfrac{m}{s})^2 + (116.5)^2}$$

$$\approx 116.5\,m/s$$

$$\tan\theta = \frac{v_{fy}}{v_{fx}}$$

$$\theta = 0.21^\circ$$

$\therefore$ the final velocity of both Truck and deer is 116 m/s. See diagram for direction

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M45. Given:

ATV	Hare
$m_A = 170\,kg$	$m_H = 10\,kg$
$v_{Ai} = 19\,km/hr$	$v_{Hi} = 0$
$v_{Ai} = 5.28\,m/s$	$v_{Hf} = 12\,km/hr$
	$= 3.33\,m/s$

Asked For:

$V_{Af} = ?$

conservation of momentum:

$$P_i = P_F$$

$$m_A V_{Ai} + \cancel{m_H V_{Hi}} = m_A V_{Af} + m_H V_{Hf}$$

$$\frac{m_A V_{Ai} - m_H V_{Hf}}{m_A} = V_{Af}$$

$$\frac{(170kg)(5.28\frac{m}{s}) - (10kg)(3.33\frac{m}{s})}{170kg} = V_{Af}$$

$$V_{Af} = 5.084\frac{m}{s}$$

$$V_{Af} = 18.3\ km/hr$$

∴ the ATV will move slower post-collision. specfically at 18 km/hr.