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Solutions to Physical Sciences Grade 12 Book 1 Textbook and Workbook

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Chapter 1 Momentum and Impulse

Exercise 1 Momentum (page 12)

1. 1.1 $p = mv$

   1.2 $kg{\cdot}m.s^{-1}$

   1.3 Momentum is the quantity and direction.
   The direction is in the same direction as the velocity.

2. 2.1
   • A **LARGE TRUCK** (greater mass) moving slowly will have greater momentum than a small pickup truck (smaller mass) moving at the same speed.
   • A **LARGE RUGBY PLAYER** (greater mass) moving slowly will have greater momentum than a smaller player (smaller mass) moving at the same speed.
   • A **CAR** (greater mass) will have greater momentum than a motorcycle (smaller mass) moving at the same speed.

   2.2
   • A **BULLET** (of 10 g) has a large momentum due to its velocity.
   • A **GOLF BALL** hit by a golfer has greater momentum than a soccer ball.
   • A **CRICKET BALL** hit by a cricket player has greater momentum than a tennis ball.

3. **Momentum** is the product of an object's mass and velocity.
   Inertia is the resistance of an object to any change in its state of motion.
   (The mass of an object is a quantitative measure of its inertia.)

4. 4.1 Yes. Momentum is a vector quantity with the direction of the momentum in the same direction as the velocity - thus, both objects must have their velocity in the same direction.

   4.2 No. $p = mv$, therefore the product of mass and velocity, and can be the same for a wide range of values.

5. 5.1 $2(24) = 48$ $kg{\cdot}m{\cdot}s^{-1}$ north ($p \propto v$ with m constant, if v doubles, p will also double)

   5.2 $4(24) = 96$ $kg{\cdot}m{\cdot}s^{-1}$ north ($p \propto v$ with m constant, if v increases fourfold, p will also increase fourfold)

   5.3 $2(24) = 48$ $kg{\cdot}m{\cdot}s^{-1}$ north ($p \propto m$ with v constant, if m doubles, p will also double)

   5.4 $(2)(2)(24) = 4(24) = 96$ $kg{\cdot}m{\cdot}s^{-1}$ north ($p \propto m$ and $p \propto v$, if both m and v double, p will become four times larger)

   5.5 $(3)(\tfrac{1}{2})(24) = 36$ $kg{\cdot}m{\cdot}s^{-1}$ north ($p \propto m$ and $p \propto v$, if m triples and v halves, p will decrease by $^3/_2$ times)

   5.6 $(3)(2)(24) = 6(24) = 144$ $kg{\cdot}m{\cdot}s^{-1}$ north ($p \propto m$ and $p \propto v$, if m triples and v doubles, p will become six times larger)

   5.7 $(\tfrac{1}{2})(2)(24) = 24$ $kg{\cdot}m{\cdot}s^{-1}$ north ($p \propto m$ and $p \propto v$, if m halves and v doubles, p will remain the same)

6. double ($p \propto v$ with m constant. If v doubles, p will also double AND $p \propto m$ with m constant. If m doubles, p will also double).

7. 7.1 $v_{flanker} = (2)(3) = 6$ $m{\cdot}s^{-1}$ in the direction of the goal line; $v_{wing} = (3)(3) = 9$ $m{\cdot}s^{-1}$ in the direction of the goal line

   7.2 $p_{prop} = mv = (120)(3) = 300$ $kg{\cdot}m{\cdot}s^{-1}$ in the direction of the goal line
   $p_{flanker} = mv = (90)(6) = 540$ $kg{\cdot}m{\cdot}s^{-1}$ in the direction of the goal line
   $p_{wing} = mv = (70)(9) = 630$ $kg{\cdot}m{\cdot}s^{-1}$ in the direction of the goal line

   7.3 The wing has the greatest momentum.

8. 8.1 Take North as positive.
   $p = mv$
   $= (2\ 000)(7,5)$
   $= 15\ 000$ $kg{\cdot}m{\cdot}s^{-1}$ North

   8.2 Take South as positive.
   $p = mv$
   $= (600)(0,04)$
   $= 24$ $kg{\cdot}m{\cdot}s^{-1}$ South

9. 9.1 Take North as positive.
   $p = mv$
   $v = \frac{p}{m}$
   $= \frac{2,1 \times 10^4}{3 \times 10^2}$
   $= 70$ $m{\cdot}s^{-1}$ north

   9.2 $p = mv$
   $m = \frac{p}{v}$
   $= \frac{760}{8}$
   $= 95$ kg

10. 10.1 Take West as positive.
   $p_{dog} = mv$
   $= (30)(8)$
   $= 240$ $kg{\cdot}m{\cdot}s^{-1}$ West

   10.2 Take West as positive.
   $p_{person} = mv$
   $v = \frac{p_{person}}{m}$
   $= \frac{240}{70}$
   $= 3,63$ $m{\cdot}s^{-1}$ west

11. 11.1 Take West as positive.
   $p_{car} = mv$
   $= (45)(3,5)$
   $= 157,5$ $kg{\cdot}m{\cdot}s^{-1}$ West

   11.2
   $p_{driver} = mv$
   $= (55)(3,5)$
   $= 192,5$ $kg{\cdot}m{\cdot}s^{-1}$ West

   11.3 $p_{car+driver} = mv$
   $= (45 + 55)(3,5)$
   $= 350$ $kg{\cdot}m{\cdot}s^{-1}$ West

   OR $p_{car+driver} = p_{car} + p_{driver}$
   $= 157,5$ $kg{\cdot}m.s^{-1}$ $+ 192,5$ $kg{\cdot}m.s^{-1}$
   $= 350$ $kg{\cdot}m{\cdot}s^{-1}$ West

   11.4 11.4.1
   $v_{car} = 3,5$ $m{\cdot}s^{-1}$ West
   $p_{car} = 157,5$ $kg{\cdot}m{\cdot}s^{-1}$ West

   11.4.2
   $v_{driver} = 3,5$ $m{\cdot}s^{-1}$ West
   $p_{driver} = 192,5$ $kg{\cdot}m{\cdot}s^{-1}$ West

   11.4.3
   $v_{car + driver} = 3,5$ $m{\cdot}s^{-1}$ West
   $p_{car + driver} = 350$ $kg{\cdot}m{\cdot}s^{-1}$ West

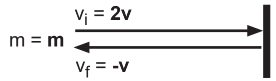
12. Take North as positive.
   $p_{dog} = mv$
   $= (40 \times 1\ 000)(2,5)$
   $= 100\ 000$ $kg{\cdot}m{\cdot}s^{-1}$ North

   $p_{motor} = p_{dog} = 100\ 000$ $kg{\cdot}m{\cdot}s^{-1}$ North
   $p_{motor} = mv$
   $v = \frac{p_{motor}}{m}$
   $= \frac{100\ 000}{1\ 500}$
   $= 66,67$ $m{\cdot}s^{-1}$ North

Exercise 2 Change in momentum (page 19)

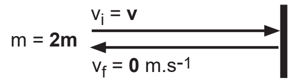
1. $\Delta p = mv_f - mv_i$

2. For ball **A**: Choose towards the wall as positive.



$\Delta p_A = mv_f - mv_i$
$= (m)(-v) - (m)(2v)$
$= -mv - 2mv$
$= -3mv$ $kg{\cdot}m{\cdot}s^{-1}$
$\therefore$ $3mv$ $kg{\cdot}m{\cdot}s^{-1}$ away from the wall.

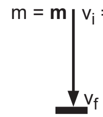
For ball **B**: Choose towards the wall as positive.



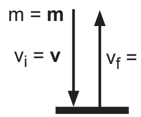
$\Delta p_B = mv_f - mv_i$
$= (m)(0) - (2m)(v)$
$= 0 - 2mv$
$= -2mv$ $kg{\cdot}m{\cdot}s^{-1}$
$\therefore$ $2mv$ $kg{\cdot}m{\cdot}s^{-1}$ away from the wall.

$\Delta p_A > \Delta p_B$. Both have the same direction.

3. 3.1 For the bear: Choose downward as positive.



For the ball: Choose downward as positive.



$\Delta p_{bear} = mv_f - mv_i$
$= (m)(0) - (m)(v)$
$= 0 - 2mv$
$= -mv$ kg·m·s^{-1}
∴ mv kg·m·s^{-1} upwards

$\Delta p_{ball} = mv_f - mv_i$
$= (m)(-v) - (m)(v)$
$= -mv - mv$
$= -2mv$ kg·m·s^{-1}
∴ 2mv kg·m·s^{-1} upwards

3.2 The Δp (change in momentum) of a moving object is greatest if the object is moving in the opposite direction after a collision.

3.3 Bear: $\Delta v = v_f - v_i = 0 - v = -v$ Ball: $\Delta v = v_f - v_i = -v - v = -2v$
The ball experienced the greatest change in velocity.

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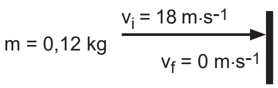
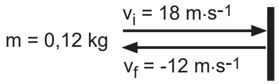
4. 4.1 Diagram **A** : Choose to the right as positive.

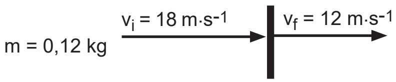


$\Delta p = mv_f - mv_i$
$= (0,12)(0) - (0,12)(18)$
$= 0 - 2,16$
$= -2,16$ kg·m·s^{-1}
∴ 2,16 kg·m·s^{-1} to the left (away from the target)

Diagram **B** : Choose to the right as positive.



$\Delta p = mv_f - mv_i$
$= (0,12)(-12) - (0,12)(18)$
$= -1,44 - 2,16$
$= -3,6$ kg·m·s^{-1}
∴ 3,6 kg·m·s^{-1} to the left (away from the target)



$\Delta p = mv_f - mv_i$
$= (0,12)(12) - (0,12)(18)$
$= 1,44 - 2,16$
$= -0,72$ kg·m·s^{-1}
∴ 0,72 kg·m·s^{-1} to the left (away from the target)

4.2 In Diagram B, the ball experienced the greatest change in momentum.

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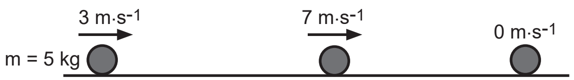
5. Let the original direction (to the right) of the motion be positive.

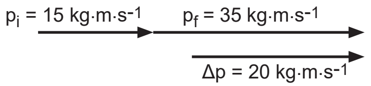


5.1 $p_i = mv_i$
$= (5)(3)$
$= 15$ kg·m·s^{-1} in the original direction of the motion (to the right)

5.2
$p_f = mv_f$
$= (5)(7)$
$= 35$ kg·m·s^{-1} in the original direction of the motion (to the right)

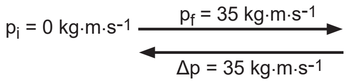
5.3 $\Delta p = p_f - p_i$
$= 35 - 15$
$= 20$ kg·m·s^{-1} in the original direction of the motion (to the right)

5.4

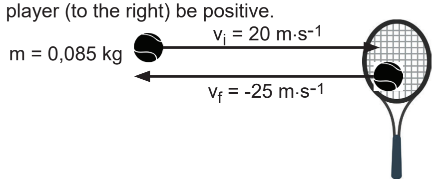


5.5 $\Delta p = mv_f - mv_i$
$= (5)(0) - (5)(7)$
$= 0 - 35$
$= -35$ kg·m·s^{-1}
∴ 35 kg·m·s^{-1} in the original direction of the motion (to the right)

5.6



6. Let towards the tennis player (to the right) be positive.

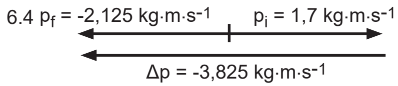


6.1 $p_i = mv_i$
$= (0,085)(20)$
$= 1,7$ kg·m·s^{-1} towards the tennis player (to the right)

6.2 $p_f = mv_f$
$= (0,085)(-25)$
$= -2,125$ kg·m·s^{-1}
∴ 2,125 kg·m·s^{-1} away from the tennis player (to the left)

6.3 $\Delta p = p_f - p_i$
$= -2,125 - 1,7$
$= -3,825$ kg·m·s^{-1}
∴ 3,825 kg·m·s^{-1} away from the tennis player (to the left)

6.4



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7. 7.1 7.1.1 v_{iA} = 10 m·s^{-1} Eastwards
7.1.2 v_{iB} = 10 m·s^{-1} Eastwards

7.2 7.2.1 v_{fA} = -6 m·s^{-1} = 6 m·s^{-1} Westwards
7.2.2 v_{fB} = -2 m·s^{-1} = 2 m·s^{-1} Westwards

7.3 A

7.4 7.4.1 Let eastward be positive.
$p_{iA} = m_A v_{iA}$
$= (5)(10)$
$= 50$ kg·m·s^{-1} Eastwards

7.4.2 $p_{iB} = m_B v_{iB}$
$= (5)(10)$
$= 50$ kg·m·s^{-1} Eastwards

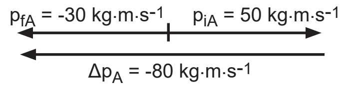
7.5 7.5.1 $p_{fA} = m_A v_{fA}$
$= (5)(-6)$
$= -30$ kg.m.s^{-1}
∴ 30 kg·m·s^{-1} Westwards

7.5.3 $p_{fB} = m_B v_{fB}$
$= (5)(-2)$
$= -10$ kg.m.s^{-1}
∴ 10 kg·m·s^{-1} Westwards

7.6 7.6.1 $\Delta p_A = p_{fA} - p_{iA}$
$= -30 - 50$
$= -80$ kg.m.s^{-1}
∴ 80 kg·m·s^{-1} Westwards

7.6.2 $\Delta p_B = p_{fB} - p_{iB}$
$= -10 - 50$
$= -60$ kg.m.s^{-1}
∴ 60 kg·m·s^{-1} Westwards

7.7



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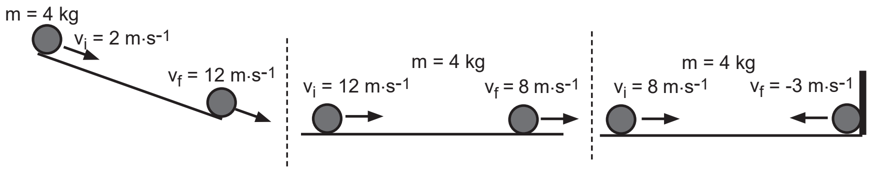
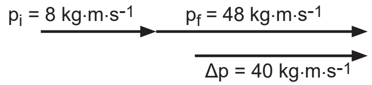
8. Let Eastward be positive.



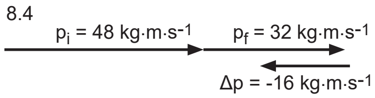
8.1 $\Delta p = mv_f - mv_i$
$= (4)(12) - (4)(2)$
$= 48 - 8$
$= 40$ kg·m·s^{-1} Eastward

8.2



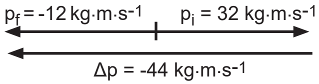
8.3 $\Delta p = mv_f - mv_i$
$= (4)(8) - (4)(12)$
$= 32 - 48$
$= -16\ kg{\cdot}m{\cdot}s^{-1}$
$\therefore$ 16 $kg{\cdot}m{\cdot}s^{-1}$ Westwards

8.4



8.5 $\Delta p = mv_f - mv_i$
$= (4)(-3) - (4)(8)$
$= -12 - 32$
$= -44\ kg{\cdot}m{\cdot}s^{-1}$
$\therefore$ 44 $kg{\cdot}m{\cdot}s^{-1}$ Westwards

8.6



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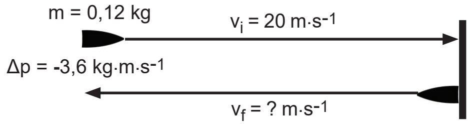
9. Take the direction towards the plate (i.e., to the right) as positive.



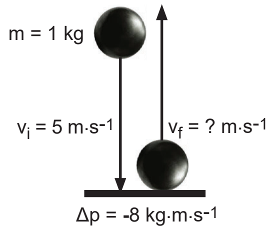
9.1 -3,6 $kg{\cdot}m{\cdot}s^{-1}$ i.e 3,6 $kg{\cdot}m{\cdot}s^{-1}$ away from the plate (in the opposite direction/to the left).

9.2 $\Delta p = mv_f - mv_i$
$-3{,}6 = (0{,}12)v_f - (0{,}12)(20)$
$-3{,}6 = 0{,}12v_f - 2{,}4$
$-1{,}2 = 0{,}12v_f$
$v_f = -10\ m{\cdot}s^{-1}$
$\therefore$ 10 $m{\cdot}s^{-1}$ away from the plate (in the opposite direction/to the left).

9.3 The bullet is now moving in the opposite direction to its initial movement.

---

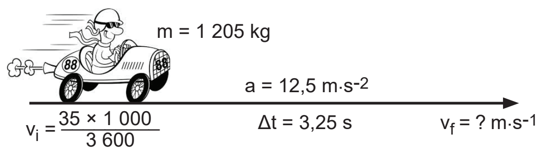
10. Take the initial direction (i.e., downward) as positive.



$\Delta p = mv_f - mv_i$
$-8 = (1)v_f - (1)(5)$
$-8 = v_f - 5$
$-3 = v_f$
$v_f = -3\ m{\cdot}s^{-1}$
$\therefore$ 3 $m{\cdot}s^{-1}$ in the opposite direction (upward)

---

11. Take the initial direction as Eastward.



$v_i = \frac{35 \times 1\ 000}{3\ 600}$
$= 9{,}72\ m{\cdot}s^{-1}$

$v_f = v_i + a\Delta t$
$= 9{,}72 + (12{,}5)(3{,}25)$
$= 9{,}72 + 40{,}625$
$= 30{,}35\ m{\cdot}s^{-1}$ Eastward

$\Delta p = mv_f - mv_i$
$= (1\ 205)(30{,}35) - (1\ 205)(9{,}72)$
$= 23\ 571{,}75 - 11\ 712{,}6$
$= 24\ 659{,}15\ kg{\cdot}m{\cdot}s^{-1}$ Eastward

Exercise 3 Newton's Second Law in terms of momentum (page 29)

1. 1.1 $F_{net} = \frac{\Delta p}{\Delta t}$

1.2 The net (or resulting) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force.

---

2. 2.1 $F_{net} \propto \Delta p$ with Δt constant

2.2 $F_{net} \propto \frac{1}{\Delta t}$ with Δp constant

---

3. 3.1 $F_{net} = \frac{\Delta p}{\Delta t} = \frac{mv_f - mv_i}{\Delta t} = \frac{m(0) - mv_i}{\Delta t} = \frac{-mv_i}{\Delta t}$

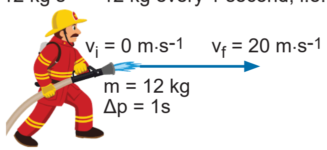
3.2 3.2.1 $F_{net} = \frac{-2mv_i}{\Delta t} = 2F_{net}$ **OR** $F_{net} \propto m$ $\therefore F_{net\ new} = 2F_{net}$

3.2.2 $F_{net} = \frac{m(2v_i)}{\Delta t} = 2F_{net}$ **OR** $F_{net} \propto v$ $\therefore F_{net\ new} = 2F_{net}$

3.2.3 $F_{net} = \frac{mv_i}{2\Delta t} = ½F_{net}$ **OR** $F_{net} \propto {}^{1}/_{\Delta t}$ $\therefore F_{net\ new} = ½F_{net}$

---

4. 4.1 Take the water flow to the right as positive.
12 $kg{\cdot}s^{-1}$ = 12 kg every 1 second, i.e., m = 12 kg and Δt = 1 s



$\Delta p = mv_f - mv_i$
$= (12)(20) - (12)(0)$
$= 240 - 0$
$\therefore$ 240 $kg{\cdot}m{\cdot}s^{-1}$ to the right

4.2 $F_{net} = \frac{\Delta p}{\Delta t}$
$= \frac{240}{1}$
= 240 N in opposite direction of motion of the water

4.3 The net force must be 0 N since the fire hose remains stationary.
F_{water} = 240, and therefore $F_{firefighter}$ = -240 N.
A force of 240 N must be exerted in the direction of the water movement.

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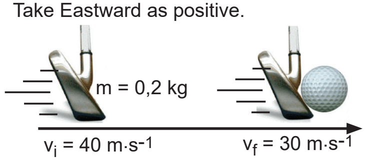
5. 5.1

5.2 Take Eastward as positive.



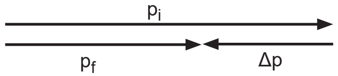
$\Delta p = mv_f - mv_i$
$= (0{,}2)(30) - (0{,}2)(40)$
$= 6 - 8$
$= -2\ kg{\cdot}m{\cdot}s^{-1}$
$\therefore$ 2 $kg{\cdot}m{\cdot}s^{-1}$ Westwards

5.3 $F_{ball\ on\ \mathbf{golf\ club\ head}} = \frac{\Delta p_{\mathbf{golf\ club\ head}}}{\Delta t}$
$= \frac{-2}{0{,}045}$
$= -44{,}44$ N
$\therefore$ 44,44 N Westwards

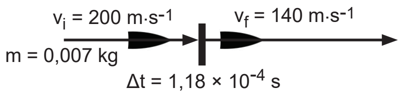
5.4 The ball experiences an equal but opposite force.

$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$= \frac{mv_f - mv_i}{\Delta t}$$
$$44{,}44 = \frac{(0{,}05)v_f - (0{,}05)(0)}{0{,}045}$$
$$v_f = 39{,}996 \text{ m·s}^{-1} \text{ Eastward}$$

6. 6.1



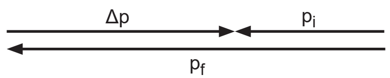
6.2 Take Eastward as positive.



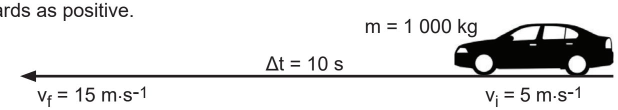
$$\Delta p = mv_f - mv_i$$
$$= (0{,}007)(140) - (0{,}007)(200)$$
$$= 0{,}98 - 1{,}4$$
$$= -0{,}42 \text{ kg·m·s}^{-1}$$
$\therefore$ 0,42 kg·m·s^{-1} Westwards

6.3
$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$= \frac{-0{,}42}{1{,}18 \times 10^{-4}}$$
$$= -3\,559{,}32 \text{ N}$$
$\therefore$ 3 559,32 N Westwards

7. 7.1



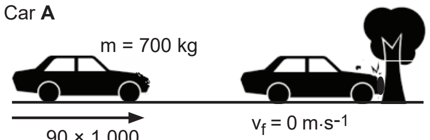
7.2 Take Westwards as positive.



$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$= \frac{mv_f - mv_i}{\Delta t}$$
$$= \frac{(1\,000)(15) - (1\,000)(5)}{10}$$
$$= 1\,000 \text{ N Westwards}$$

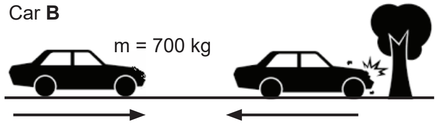
8. 8.1 Take Eastward as positive.

Car **A**



$$v_i = \frac{90 \times 1\,000}{3\,600}$$
$$= 25 \text{ m·s}^{-1}$$
$$\Delta p = mv_f - mv_i$$
$$= (700)(0) - (700)(25)$$
$$= 0 - 17\,500$$
$$= -17\,500 \text{ kg·m·s}^{-1}$$
$\therefore$ 17 500 kg·m·s^{-1} Westwards

Car **B**



$$v_i = \frac{90 \times 1\,000}{3\,600}$$
$$= 25 \text{ m·s}^{-1}$$
$$v_f = \frac{-28{,}8 \times 1\,000}{3\,600}$$
$$= -8 \text{ m·s}^{-1}$$
$$\Delta p = mv_f - mv_i$$
$$= (700)(-8) - (700)(25)$$
$$= -5\,600 - 17\,500$$
$$= -23\,100 \text{ kg·m·s}^{-1}$$
$\therefore$ 23 100 kg·m·s^{-1} Westwards

The Δp (change in momentum) of motor B (which moves in the opposite direction after the collision) is greater than the Δp of motor A (which comes to a stop during the collision).

8.2 Car A

$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$= \frac{-17\,500}{0{,}4}$$
$$= -43\,750 \text{ N}$$
$\therefore$ 43 750 N Westwards

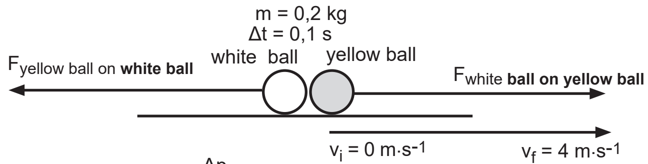
Car B

$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$= \frac{-23\,100}{0{,}4}$$
$$= -57\,750 \text{ N}$$
$\therefore$ 57 750 N Westwards

The F_{net} of car B (which moves in the opposite direction after the collision) is greater than the F_{net} of car A (which comes to a stop during the collision).

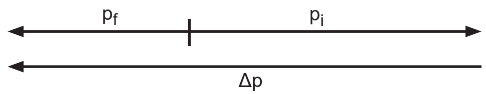
8.3 Vehicles coming to a stop will have a smaller change in momentum and therefore a smaller force exerted on them.

9. 9.1 Take motion to the right as positive.

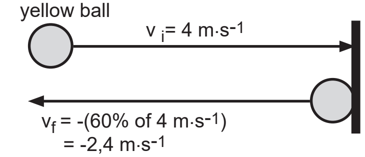


$$F_{\text{white ball on yellow ball}} = \frac{\Delta p_{\text{yellow ball}}}{\Delta t}$$
$$= \frac{mv_f - mv_i}{\Delta t}$$
$$= \frac{(0{,}2)(4) - (0{,}2)(0)}{0{,}1}$$
$$= 8 \text{ N to the right}$$

9.2



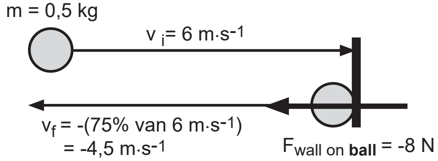
9.3



$$\Delta p = mv_f - mv_i$$
$$= (0{,}2)(-2{,}4) - (0{,}2)(4)$$
$$= -0{,}48 - 0{,}8$$
$$= -1{,}28 \text{ kg·m·s}^{-1}$$
$\therefore$ 1,28 kg·m·s^{-1} to the left

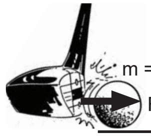
9.4
$$F_{\text{cushion on yellow ball}} = \frac{\Delta p_{\text{yellow ball}}}{\Delta t}$$
$$= \frac{-1{,}28}{0{,}2}$$
$$= -6{,}4 \text{ N}$$
$\therefore$ 6,4 N to the left

10. Take the initial direction to the right.



$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$\Delta t = \frac{mv_f - mv_i}{F_{\text{wall on ball}}}$$
$$= \frac{(0{,}5)(-4{,}5) - (0{,}5)(6)}{-8}$$
$$= 0{,}66 \text{ s}$$

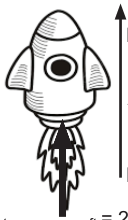
11. Let the original direction (to the right) be positive.



m = 0,047 kg
$F_{\text{club on ball}}$ = 2 500 N
$v_i = 0\ m\cdot s^{-1}$ $1{,}2 \times 10^{-3}$ s $v_f = ?\ m\cdot s^{-1}$

$$F_{\text{club on ball}} = \frac{\Delta p_{\text{bal}}}{\Delta t}$$
$$F_{\text{club on ball}} = \frac{mv_f - mv_i}{\Delta t}$$
$$2\,500 = \frac{(0{,}047)v_f - (0{,}047)(0)}{1{,}2 \times 10^{-3}}$$
$$3 = 0{,}047v_f$$
$v_f = 63{,}83\ m\cdot s^{-1}$ in the original direction (to the right)

12. Take upward as positive.

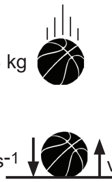


$p_f = ?\ kg\cdot m\cdot s^{-1}$
Δt = 10 s
$p_i = 8 \times 10^7\ kg\cdot m\cdot s^{-1}$
$F_{\text{rocket on spacecraft}} = 2 \times 10^6$ N

$$F_{\text{rocket on spacecraft}} = \frac{\Delta p_{\text{spacecraft}}}{\Delta t}$$
$$F_{\text{rocket on spacecraft}} = \frac{p_f - p_i}{\Delta t}$$
$$2 \times 10^6 = \frac{p_f - 8 \times 10^7}{10}$$
$$20 \times 10^6 = p_f - 8 \times 10^7$$
$$p_f = -6 \times 10^7\ kg\cdot m\cdot s^{-1}$$
$\therefore p_f = -6 \times 10^7\ kg\cdot m\cdot s^{-1}$ downwards

13. 13.1 Consider the downward movement of the ball as positive.

m = 0,8 kg



$v_i = 15\ m\cdot s^{-1}$ $v_f = -10\ m\cdot s^{-1}$
Δt = 0,16 s

$$\Delta p = mv_f - mv_i$$
$$= (0{,}8)(-10) - (0{,}8)(15)$$
$$= -8 - 12$$
$$= -20\ kg\cdot m\cdot s^{-1}$$
$\therefore$ 20 $kg\cdot m\cdot s^{-1}$ upwards

13.2
$$F_{\text{ground on ball}} = \frac{\Delta p_{\text{ball}}}{\Delta t}$$
$$= \frac{-20}{0{,}16}$$
$$= -125 \text{ N}$$
$\therefore$ 125 N upwards

14. 14.1 Take initial movement to the right as positive.

f_k = 1 000 N F_{applied} = 3 000 N

14.2
$$F_{net} = F_{applied} + (-f_k)$$
$$= 3\,000 + (-1\,000)$$
$$= 2\,000 \text{ N to the right}$$

14.3
$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$\Delta t = \frac{mv_f - mv_i}{F_{net}}$$
$$= \frac{(5\,000)(2{,}5) - (5\,000)(0{,}5)}{2\,000}$$
$$= 5 \text{ s}$$

F_{net} = 2 000 N
$v_i = 0{,}5\ m\cdot s^{-1}$ m = 5 000 kg $v_f = 2{,}5\ m\cdot s^{-1}$
Δt = 0,? s

14.4
$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$\Delta t = \frac{mv_f - mv_i}{F_{net}}$$
$$= \frac{(5\,000)(2{,}5) - (5\,000)(0{,}5)}{4\,200 - 1\,000}$$
$$= 3{,}125 \text{ s}$$

F_{net} = 4 200 N - 1 000 N
$v_i = 0{,}5\ m\cdot s^{-1}$ m = 5 000 kg $v_f = 2{,}5\ m\cdot s^{-1}$
Δt = ? s

15. 15.1 Take initial movement to the right as positive.

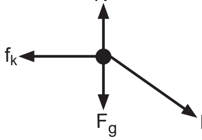
f_k = 1,5 N $F_x = F\cos\theta$

$$F_{net} = F_x + (-f_k)$$
$$= F\cos\theta + (-1{,}5)$$
$$= 9\cos 60^\circ - 1{,}5$$
$$= 4{,}5 - 1{,}5$$
$$= 3 \text{ N to the right}$$

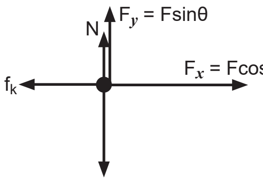
15.2
F_{net} = 3 N
$v_i = 0\ m\cdot s^{-1}$ m = 5 kg $v_f = 8\ m\cdot s^{-1}$
Δt = ? s

$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$\Delta t = \frac{mv_f - mv_i}{F_{net}}$$
$$= \frac{(5)(8) - (8)(0)}{3}$$
$$= 13{,}33 \text{ s}$$

16. 16.1



...OR...



16.2 Take initial movement to the right as positive.

f_k = 100 N $F_x = F\cos\theta$

$$F_{net} = F_x + (-f_k)$$
$$= F\cos\theta + (-100)$$
$$= 450\cos 30^\circ - 100$$
$$= 389{,}71 - 100$$
$$= 289{,}71 \text{ N to the right}$$

16.3
F_{net} = 289,71 N
$v_i = 0\ m\cdot s^{-1}$ m = 25 kg $v_f = ?\ m\cdot s^{-1}$
Δt = 20 s

$$F_{net} = \frac{\Delta p}{\Delta t}$$
$$F_{net} = \frac{mv_f - mv_i}{\Delta t}$$
$$289{,}71 = \frac{(25)v_f - (25)(0)}{20}$$
$$5\,794{,}2 = 25v_f$$
$v_f = 231{,}77\ m\cdot s^{-1}$ to the right

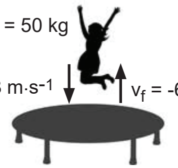
17. 17.1

17.2 Take upward motion as positive.

$$F_{net} = T + (-F_g)$$
$$= T - mg$$
$$= T - (1\,800)(9{,}8)$$
$$= T - 17\,640 \text{ N}$$
$$F_{net} = \frac{\Delta p}{\Delta t} = \frac{mv_f - mv_i}{\Delta t}$$
$$T - 17\,640 = \frac{(1\,800)(5{,}4) - (1\,800)(0)}{8{,}5}$$
$$5{,}8T - 149\,940 = 9\,720$$
$$T = 18\,763{,}53 \text{ N upwards}$$

18\. 18.1 Consider the downward movement as positive.

m = 50 kg



$v_i = 8\ m{\cdot}s^{-1}$ $v_f = -6\ m{\cdot}s^{-1}$

$p_i = mv_i$
$= (50)(8)$
$= 400\ kg{\cdot}m{\cdot}s^{-1}$ upwards

18.2 $p_f = mv_f$
$= (50)(-6)$
$= -300\ kg{\cdot}m.s^{-1}$
$\therefore 300\ kg{\cdot}m{\cdot}s^{-1}$ upwards

18.3 $\Delta p = p_f - p_i$
$= -300 - 400$
$= -700\ kg{\cdot}m{\cdot}s^{-1}$
$\therefore$ 700 $kg{\cdot}m{\cdot}s^{-1}$ upwards

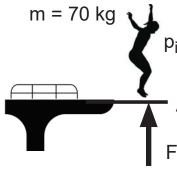
18.4 $F_{trampoline}$ (up), F_g (down)

18.5 $F_{trampoline\ on\ gymnast} = \dfrac{\Delta p_{gymnast}}{\Delta t}$
$= \dfrac{-700}{0,7}$
$= -1\ 000$ N
$\therefore$ 1 000 N upwards

19\. 19.1 Consider the downward movement as positive.

$F_{diving\ board}$ (up), F_g (down)

m = 70 kg



$p_i = 560\ kg{\cdot}m{\cdot}s^{-1}$

$\Delta t = 0,8$ s

$F_{diving\ bord\ on\ Linda}$
$= -2\ 436$ N

19.2 $F_{net}\Delta t = \Delta p$
$\Delta p = F_{diving\ bord\ on\ Linda}\Delta t$
$= (-2\ 436)(0,8)$
$= -1\ 948,8\ kg{\cdot}m{\cdot}s^{-1}$
$\therefore 1\ 948,8\ kg{\cdot}m{\cdot}s^{-1}$ upwards

19.3 $\Delta p = p_f - p_i$
$\Delta p = mv_f - p_i$
$-1\ 948,8 = (70)v_f - 560$
$-1\ 388,8 = 70v_f$
$v_f = -19,84\ m{\cdot}s^{-1}$
$\therefore$ 19,84 $m{\cdot}s^{-1}$ upwards

20\. 20.1 Consider the upward movement as positive.

$F_{applied} = 2,95 \times 10^6$ N

$F_g = mg$
$= (250\ 00)9,8)$
$= 2,45 \times 10^6$ N

$F_{net} = F_{applied} + (-F_g)$
$= 2,95 \times 10^6 - 2,45 \times 10^6$ N
$= 500\ 000$ N upwards
$(= 5 \times 10^5$ N upwards)

20.2 $F_{applied} = 2,22 \times 10^6$ N

$F_g = mg$
$= (150\ 00)9,8)$
$= 1,47 \times 10^6$ N

$F_{net} = F_{applied} + (-F_g)$
$= 2,22 \times 10^6 - 1,47 \times 10^6$ N
$= 750\ 000$ N upwards
$(= 7,5 \times 10^5$ N upwards)

20.3 Phase 1:

$v_f = ?\ m{\cdot}s^{-1}$
$\Delta t = 4$ s
$a = 2\ m{\cdot}s^{-2}$
$v_i = 0\ m{\cdot}s^{-1}$

$v_f = v_i + a\Delta t$
$= 0 + (2)(4)$
$= 8\ m{\cdot}s^{-1}$ upwards

Phase 2:

$v_f = ?\ m{\cdot}s^{-1}$
$\Delta t = 8$ s
$a = 5\ m{\cdot}s^{-2}$
$v_i = 8\ m{\cdot}s^{-1}$

$v_f = v_i + a\Delta t$
$= 8 + (5)(8)$
$= 48\ m{\cdot}s^{-1}$ upwards

20.3 Phase 1:

$v_f = 8\ m{\cdot}s^{-1}$
$\Delta p = ?\ kg{\cdot}m{\cdot}s^{-1}$
$m = 250\ 000$ kg
$v_i = 0\ m{\cdot}s^{-1}$

$\Delta p = mv_f - mv_i$
$= (250\ 000)(8) - (2\ 500)(0)$
$= 2 \times 10^6\ kg{\cdot}m{\cdot}s^{-1}$ upwards

Phase 2:

$v_f = 48\ m{\cdot}s^{-1}$
$\Delta p = ?\ kg{\cdot}m{\cdot}s^{-1}$
$m = 150\ 000$ kg
$v_i = 8\ m{\cdot}s^{-1}$

$\Delta p = mv_f - mv_i$
$= (150\ 000)(48) - (1\ 500)(8)$
$= 6 \times 10^6\ kg{\cdot}m{\cdot}s^{-1}$upwards

Exercise 4 Impulse (page 46)

1\. 1.1 Impulse is the product of the net (resultant) force acting on an object and the time during which the net force acts on the object.

1.2 Vector quantity

1.3 Impulse = N·s and momentum = $kg{\cdot}m{\cdot}s^{-1}$
$N{\cdot}s = kg{\cdot}m{\cdot}s^{-2} \times s = kg{\cdot}m{\cdot}s^{-1}$

2\. 2.1 Impulse is equal to the change in momentum (Impulse = Δp).
If the impulse increases, the change in momentum will also increase.

2.2 The force (of the impulse) required to bring the glass to a stop depends on Δp and Δt.
In both cases, the glass hits the cement floor and mat with the same velocity and momentum.
To come to a stop, the momentum must change to zero. In both cases, the glass experiences the same change in momentum and impulse. By falling on the mat, the time (Δt) during which the momentum changes is increased." According to Fnet = $\Delta p/\Delta t$, the force (Fnet) exerted by the mat on the glass will be smaller, and consequently, the glass will not break. When the glass falls on the cement floor, the time (Δt) is short, and the force acting on it is large for the same change in momentum and impulse, causing the glass to break.

2.3 The clay will exert the greatest impulse on the wall if it bounces back. When the final velocity is in the opposite direction of the motion, the change in momentum is the greatest, and therefore, the impulse will be the greatest.

3\. 3.1 Car A has the greatest acceleration. The change in speed (Δv) for each car is the same.
(They start with the same speed and each ends with a zero speed.)
However, Car A achieves this change in less time. a = $\Delta v/\Delta t$, so car A accelerates the fastest.

3.2 The change in momentum is the same for each car. The change in speed for each car is the same (they start with the same speed and end with zero speed), and the mass of each car is the same. $\Delta p = mv_f - mv_i = m\Delta v$, Both have the same v_i and v_f. Therefore, the change in momentum is the same for each car."

3.3 The impulse is the same for each car. The impulse is equal to the change in momentum. If the change in momentum is the same for each car, the impulse must also be the same.

3.4 A. The time it takes to stop is the shortest for A. (Impulse = $F_{net}\Delta t$).

4\. 4.1 Case A has the greatest change in speed.
$\Delta v_A = v_f - v_i = (-4) - 5 = -9\ m{\cdot}s^{-1}$
$\Delta v_B = v_f - v_i = (0) - 5 = -5\ m{\cdot}s^{-1}$

4.2 The impulse is the greatest for Car A. The impulse is equal to the change in momentum.
If the acceleration in momentum is the greatest for Car A, then the impulse must also be.

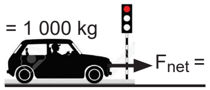
4.3 7 200

5\.
- Largest Δv in diagram 2.
  The change in speed is the greatest in case B. The speed changes from +30 $m{\cdot}s^{-1}$ to -28 $m{\cdot}s^{-1}$.
  This is a change of -58 $m{\cdot}s^{-1}$ and is greater than in case A (-15 $m{\cdot}s^{-1}$).
- Largest a in diagram 2.
  Acceleration depends on the change in speed, and the change in speed is the greatest in case B (as mentioned above)."

- Δp is the largest in diagram 2.
  The change in momentum depends on the change in speed, and the change in speed is the greatest in case B (as mentioned above).
- $F_{net}\Delta t$ (impulse) is the largest in diagram 2.
  Impulse is equal to the change in momentum, and the change in momentum is the largest in case B (as mentioned above).

6. 6.1 6.1.1 Both the same 6.1.2 Both the same 6.1.3 Both the same 6.1.4 Golf ball
   6.2 6.2.1 Both the same 6.2.2 Both the same 6.2.3 Both the same 6.2.4 Lady
   6.3 6.3.1 Both the same 6.3.2 Both the same 6.3.3 Both the same 6.3.4 Both the same
   [6.1.2 The same force and the same contact time between the two objects are also the same.]
   [6.1.4 The golf ball has the smallest mass]
   [6.2.2 The same force and the same contact time between the two objects are also the same.]
   [6.3.4 The two balls have the same masses, and frictional force is ignored, so the moving ball will transfer all its energy to the stationary ball. The stationary ball will start moving with the same speed as the moving ball before the collision, and the initially moving ball will now come to a stop.]

7. 7.1 Consider motion to the right as positive.



$F_{net} = ma$
$2\ 000 = 1\ 000a$
$a = 2\ m\cdot s^{-2}$ to the right

7.2 $F_{net}\Delta t = m\Delta v$
$(2\ 000)(10) = 1\ 000\Delta v$
$\Delta v = 20\ m\cdot s^{-1}$ to the right

7.3 Impulse $= F_{net}\Delta t$
$= (2\ 000)(10)$
$= 20\ 000$ N·s to the right

7.4 Δp = Impulse
$= 20\ 000\ kg\cdot m\cdot s^{-1}$ to the right

7.5 $\Delta p = mv_f - p_i$
$20\ 000 = (1\ 000)v_f - (1\ 000)(0)$
$20\ 000 = 1\ 000v_f$
$v_f = 20\ m\cdot s^{-1}$ to the right

7.6 $\Delta p = mv_f - mv_i$
$= (1\ 000)(20) - (1\ 000)(20)$
$= 0\ kg\cdot m\cdot s^{-1}$

7.7 Impulse $= F_{net}\Delta t$
$= \Delta p$
$= 0$ N·s

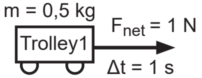
7.8 $\Delta p = mv_f - mv_i$
$= (1\ 000)(0) - (1\ 000)(20)$
$= -20\ 000\ kg\cdot m\cdot s^{-1}$
$\therefore 20\ 000\ kg\cdot m\cdot s^{-1}$ to the left

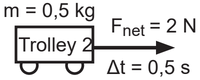
7.9 Impulse $= F_{net}\Delta t$
$= \Delta p$
$= 20\ 000$ N·s to the left

7.10 $v_f = v_i + a\Delta t$
$0 = 20 + a(4)$
$a = -5\ m\cdot s^{-2}$
$\therefore 5\ m\cdot s^{-2}$ to the left

7.11 $F_{net} = ma$
$= (1\ 000)(-5)$
$= -5\ 000$ N
$\therefore 5\ 000$ N to the left

8. Consider motion to the right as positive.





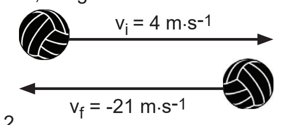
8.1 Trolley 2. $F_{net} = ma \rightarrow$ Same mass, larger force = larger a.
8.2 Impulse is the same for both trolleys, namely 1 N·s.
For trolley 1: Impulse $= F_{net}\Delta t = (1)(1) = 1$ N·s. **For trolley 2**: Impulse $= F_{net}\Delta t = (2)(0,5) = 1$ N·s

8.3 Δp = Impulse is the same for both trolleys.

9.

F_{net} (N)	Δt (s)	Impulse (N·s)	Δp ($kg\cdot m\cdot s^{-1}$)	m (kg)	Δv ($m\cdot s^{-1}$)
-4 000	0,01	-40	-40	10	-4
-400	0,1	-40	-40	10	-4
-20 000	0,01	-200	-200	50	-4
-20 000	0,1	-200	-200	25	-8
-200	1	-200	-200	50	-4

10. 10.1 Consider motion to the right as positive.



Impulse $= \Delta p = mv_f - mv_i$
$= (0,35)(-21) - (0,35)(4)$
$= -7,35 - 1,4$
$= -8,75$ N·s
$\therefore 8,75$ N·s to the left

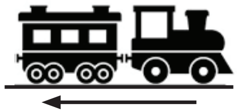
10.2
$p_f = -7,35\ kg\cdot m\cdot s^{-1}$ $p_f = 1,4\ kg\cdot m\cdot s^{-1}$
$\Delta p = -8,75\ kg\cdot m\cdot s^{-1}$

11. 11.1 During the swing, the contact time between the ball and racket will increase. For a longer contact time, the impulse for the same applied force will be greater. This results in an increased change in momentum for the ball, and the ball experiences a greater change in speed if the contact time is shorter. The ball leaves the racket with a higher velocity v_f. $F_{net}\Delta t = mv_f - mv_i$.
    11.2 The ball comes with a specific momentum towards the fielder. To stop the ball, the fielder must change the momentum of the ball to zero. By pulling back the hands, the contact time between the incoming ball and his hands increases. Consequently, the force exerted on his hands is smaller (the net force of the impulse on his hands decreases) according to the equation $F_{net} = {}^{\Delta p}/_{\Delta t}$.
    11.3 The elastic rope, if they were to fall, extends the time during which the mountain climber's momentum changes to zero and, therefore, reduces the force exerted on the mountain climber (the net force of the impulse on the mountain climber decreases). $F_{net} = {}^{\Delta p}/_{\Delta t}$. Thus, the mountain

12. 12.1 When the airbag inflates during a collision, the contact time of the passenger/driver with an airbag is longer than without an airbag, and thus, the force on the passenger/driver is smaller. According to $F_{net} = {}^{\Delta p}/_{\Delta t}$ the force during impact is reduced.
    12.2 The crumple zone crumples during a collision, increasing so that cars bounce back during a collision. Crumpling also extends the contact time during which the momentum of the cars changes to zero, consequently reducing the force the cars exert on each other. $F_{net} = {}^{\Delta p}/_{\Delta t}$. Therefore, the passengers experience a smaller force during the collision.

13. Crumpling is safer. Crumpling increases the contact time during which the cars' momentum changes to zero, consequently reducing the force the cars exert on each other. $F_{net} = {}^{\Delta p}/_{\Delta t}$. Therefore, the passengers experience a smaller force during the collision. During bouncing back, the change in momentum is greater, and thus, the force on the passengers is greater over the same time.

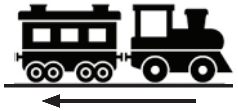
14\. 14.1 Consider motion to the right as positive.



$F_{net} = -2 \times 10^5$ N
$\Delta t = 50$ s

Impulse $= F_{net}\Delta t$
$= (-2 \times 10^5)(50)$
$= -1 \times 10^7$ N·s
∴ 1×10^7 N·s to the left

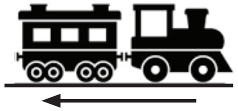
14.2



Δp = impulse $= -1 \times 10^7$ kg·m·s^{-1}
$\Delta t = 25$ s

$F_{net}\Delta t = \Delta p$
$F_{net}(25) = -1 \times 10^7$
$F_{net} = -4 \times 10^5$ N
∴ 4×10^5 N to the left

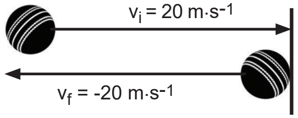
14.3



Δp = impulse $= -1 \times 10^7$ kg·m·s^{-1}
$F_{net} = -1 \times 10^5$ N

$F_{net}\Delta t = \Delta p$
$(-1 \times 10^5 \text{ N})\Delta t = -1 \times 10^7$
$\Delta t = 100$ s

15\. 15.1 Consider motion to the right as positive.
m = 0,2 kg

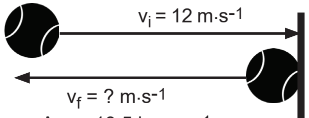


$\Delta t = 0{,}01$ s

Impulse $= \Delta p_{ball} = mv_f - mv_i$
$= (0{,}2)(-20) - (0{,}2)(20)$
$= -4 - 4$
$= -8$ N·s
∴ 8 N·s to the left

15.2 $F_{\text{wall on ball}} = \dfrac{\Delta p_{ball}}{\Delta t}$
$= \dfrac{-13{,}5}{0{,}05}$
$= -270$ N
∴ 270 N to left on ball

16\. 16.1 Consider motion to the right as positive.
m = 0,5 kg



$\Delta p = -13{,}5$ kg·m·s^{-1}
$\Delta t = 0{,}05$ s

Impulse from wall on ball $= \Delta p_{ball}$
$= -13{,}5$ N·s
∴ 13,5 N·s to the left

16.2 $F_{\text{wall on ball}} = \dfrac{\Delta p_{ball}}{\Delta t}$
$= \dfrac{-13{,}5}{0{,}05}$
$= -270$ N
∴ 270 N to left on ball

16.3 $\Delta p = mv_f - mv_i$
$-13{,}5 = (0{,}5)v_f - (0{,}5)(12)$
$-13{,}5 = 0{,}5v_f = 6$
$0{,}5v_f = -7.5$
$v_f = -15$ m·s^{-1}
∴ 15 m·s^{-1} to the left

16.4 The negative answer indicates that the final velocity is in the opposite direction to the initial direction.

17\. 17.1 Take downward as positive.

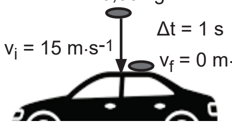
Impulse = -30 N·s
∴ 8 N·s upwards

$p_i = 20$ kg·m·s^{-1}
Impulse = -30 N·s

17.2
Δp_{bal} = impulse $= -30$ kg·m·s^{-1}
∴ 30 kg·m·s^{-1} upwards

17.3 $\Delta p = p_f - p_i$
$-30 = p_f - 20$
$p_f = -10$ kg·m·s^{-1}
∴ 10 kg·m·s^{-1} upwards

18\. 18.1 Consider downward motion as positive
m = 0,06 kg



$F_{\text{roof on clay}} = \dfrac{\Delta p_{clay}}{\Delta t}$
$= \dfrac{mv_f - mv_i}{\Delta t}$
$= \dfrac{(0{,}06)(0) - (0{,}06)(15)}{1}$
$= -0{,}9$ N
∴ 0,9 N Upwards through roof on clay.
Force of clay on roof = 0,9 N downwards.

18.2 Greater than.
The change in momentum is greater than that of clay (because there was a change in direction).
Since m and Δt remain the same, therefore $F_{net} \alpha \Delta v$ en $F_{net} \alpha\ v_f - mv_i$

19\. 19.1 Consider downward motion as positive.

m = 70 kg
v_i = 10 m·s^{-1}
$\Delta t = 0{,}5$ s
v_f = 0 m·s^{-1}

$F_{\text{ground on boy}} = \dfrac{\Delta p_{boy}}{\Delta t}$
$= \dfrac{mv_f - mv_i}{\Delta t}$
$= \dfrac{(70)(0) - (70)(10)}{0{,}5}$
$= -1\ 400$ N
∴ 1 400 N upward ground on boy

19.2

m = 70 kg
v_i = 10 m·s^{-1}
$\Delta t = 0{,}8$ s
v_f = 0 m·s^{-1}

$F_{\text{ground on boy}} = \dfrac{\Delta p_{boy}}{\Delta t}$
$= \dfrac{mv_f - mv_i}{\Delta t}$
$= \dfrac{(70)(0) - (70)(10)}{0{,}8}$
$= -875$ N
∴ 875 N upward ground on boy

19.3 If the boy does not bend his knees, he comes to a stop over a shorter time interval, Δt. $F_{net} = {}^{\Delta p}/_{\Delta t}$ thus increases, i.e., the ground exerts a greater force on the boy. OR If the boy bends his knees, he comes to a stop over a longer time interval, $\Delta t.F_{net} = {}^{\Delta p}/_{\Delta t}$ thus decreases, i.e., the ground exerts a smaller force on the boy."

20. 20.1

SYMBOL	FULL DESCRIPTION	SI-UNIT	VECTOR/SCALAR
F_{net}	The force exerted by the hockey stick on the ball.	Newton (N)	Vector
Δt	The time during which the ball and stick make contact.	Seconds (s)	Scalar
m	The mass of the ball.	Kilograms (kg)	Scalar
Δv	The change in speed of the ball.	meters per second ($m{\cdot}s^{-1}$)	Vector
$F_{net}\Delta t$	The impulse exerted by the stick on the ball.	Newton second($N{\cdot}s$)	Vector
$m\Delta v$	The change in momentum of the ball.	Kilogram meter per second ($kg{\cdot}m{\cdot}s^{-1}$)	Vector

20.2 Study the graph. The horizontal axis represents time, and the vertical axis represents force. The area of the graph represents force × time ($F_{net}\Delta t$) which is equal to impulse.

Impulse = area under the force-time graph
= ½ base × height
= ½(0,5)((150)
= 37,5 N·s (by stick on ball)

20.3

Impulse of stick on ball = Δp_{ball}

$= mv_f - mv_i$

$37,5 = (0,15)v_f - (0,15)(0)$

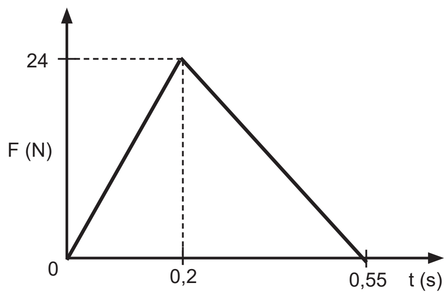
$0,15v_f = 37,5$

$v_f = 250\ m{\cdot}s^{-1}$ (away from the hockey stick)

20.4 Because the ball is softer, it means that the ball will deform when the stick hits it. This implies that there will be longer contact between the ball and the stick. Therefore, the force (a smaller force) will act on the ball for a longer time.

- The **AREA** of the graph **decreases**. (Because $\Delta p = m\Delta v$ remains the same, $F_{net}\Delta t$ must also remain the same.)
- The **HEIGHT** of the graph **decreases.** (Because F_{net} is smaller.)
- The **BASE** of the graph **increases**. (Because the contact time is longer.)

21. 21.1



21.2

Impulse = area under the force-time graph
= ½ base × height
= ½(0,55)(24)
= 6,6 N·s (by player on ball)

21.3 Impulse of player on ball = Δp_{ball}

$= mv_f - mv_i$

$6,6 = (0,85)v_f - (0,85)(0)$

$0,85v_f = 6,6$

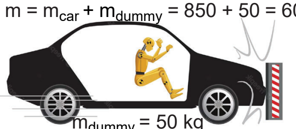
$v_f = 7,76\ m{\cdot}s^{-1}$ (through player's hand upwards)

21.4 v_f will increase if m decreases. The same impulse refers to $m\Delta v = \Delta p$ = impulse.
If m decreases, Δv must decrease so that $m\Delta v = \Delta p$ = impulse remains the same.

22. 22.1 Consider motion to the right as positive.

$v_i = 24\ m{\cdot}s^{-1}$ $\quad v_f = 0\ m{\cdot}s^{-1}$

$m = m_{car} + m_{dummy} = 850 + 50 = 600$ kg



$m_{dummy} = 50$ kg

$F_{net} = -36\ 000$ N

$$F_{net} = \frac{\Delta p}{\Delta t}$$

$$\Delta t = \frac{mv_f - mv_i}{F_{net}}$$

$$= \frac{(600)(0) - (600)(24)}{-36\ 000}$$

$= 0,4$ s

22.2 Newton's Second Law (in terms of Δp)

22.3 Newton's First Law

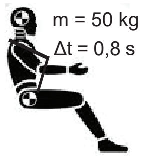
22.4 SMALLER
When the airbag inflates during a collision, the contact time of the dummy with an airbag is longer than without an airbag, and therefore, the force on the dummy is smaller for the same change in momentum. Thus, according to $F_{net} = {}^{\Delta p}/_{\Delta t}$, the force during impact will be reduced.

22.5 $72\ km{\cdot}h^{-1} = (72 \times 1\ 000) \div 3\ 600 = 20\ m{\cdot}s^{-1}$
800 ms = 800 ÷ 1 000 = 0,8 s

$v_i = 20\ m{\cdot}s^{-1}$ $\quad v_f = 0\ m{\cdot}s^{-1}$

m = 50 kg

$\Delta t = 0,8$ s



$$F_{\text{safety belt on dummy}} = \frac{\Delta p_{dummy}}{\Delta t}$$

$$= \frac{mv_f - mv_i}{\Delta t}$$

$$= \frac{(50)(0) - (50)(20)}{0,8}$$

$= -1\ 250$ N

∴ 1 250 N to the left on dummy by seat belt

22.6

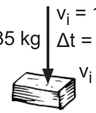
Impulse = area under the force-time graph
$F_{net}\Delta t$ = ½ base × height
(-1 250)(0,8) = ½(0,8)h
0,4h = -1000
h = -2 500 N
∴ The maximum force is 2,500 N in the opposite direction (to the left) on the dummy.

23. 23.1 Consider the downward direction as positive.

$v_i = 10\ m{\cdot}s^{-1}$

m = 0,35 kg $\quad \Delta t = 3$ ms = 0,003 s

$v_i = 0\ m{\cdot}s^{-1}$



$$F_{\text{stone on hand}} = \frac{\Delta p_{hand}}{\Delta t}$$

$$= \frac{mv_f - mv_i}{\Delta t}$$

$$= \frac{(0,35)(0) - (0,35)(10)}{0,003}$$

$= -1\ 166,67$ N

∴ 1 166,67 N upwards