Here is your complete, exam-ready summary of the chapter on Momentum.

Title Block

- **Chapter:** 1.6 Momentum
- **Book/PDF:** Chapter-1-6.pdf
- **Pages:** 55–59
- **Exam level:** Cambridge IGCSE (0610)

1) Big-Picture Overview

This chapter introduces the concept of **momentum**, which is a way of describing an object's motion by combining its mass and velocity. It's especially useful for understanding what happens during events like collisions and explosions (p. 55). The core idea is the **principle of conservation of momentum**: in any interaction between objects, the total momentum before the event is the same as the total momentum after, as long as no external forces like friction are involved (p. 56). You'll also learn about **impulse**, which connects force, the time it acts, and the resulting change in momentum. This explains real-world applications like why car crumple zones, airbags, and a cricketer pulling back their hands when catching a ball are all effective at reducing injury by increasing the time of impact to lower the force felt (p. 58).

2) Syllabus Mapping

Outcome Code (Implied)	Outcome Description	Where Covered (page)
Core	Define momentum as mass × velocity.	55
Core	Recall and use the equation $p = mv$.	55, 57
Core	Define impulse as force × time for which force acts.	57
Core	Recall and use the equation Impulse = F $Deltat =$	57

Outcome Code (Implied)	Outcome Description	Where Covered (page)
	$Delta(mv)$.	
Core	State the principle of conservation of momentum.	56
Core	Apply the principle of conservation of momentum to simple one-dimensional collisions and explosions.	56, 57
Supplement	Relate resultant force to the rate of change of momentum.	57
Supplement	Explain how impulse is used to reduce forces in real-world examples (e.g., car safety).	55, 58

3) Key Terms and Definitions

Term	One-Sentence Definition	First Appears (page)	Example/Application
Momentum	The product of an object's mass and its velocity (p. 55).	55	A 60 kg truck moving at 3 m/s has a momentum of 180 kg m/s (p. 56).
Conservation of Momentum	The principle that the total momentum of bodies acting on one another remains constant, provided no external forces act (p. 56).	56	When two trolleys collide and stick together, their combined momentum after the collision equals the initial momentum of the moving trolley (p. 56).
Impulse	The product of a force and the time interval for which it acts, which is equal to the change in	57	A cricketer 'follows through' with the bat to apply a force for a longer time, increasing the impulse and the ball's final momentum (p. 58).

Term	One-Sentence Definition	First Appears (page)	Example/Application
	momentum it produces (p. 57).		
Resultant Force	The rate of change in momentum per unit time (p. 57).	57	Calculating the force needed to stop a car in a crash by dividing its change in momentum by the collision time (p. 58).

4) Core Concepts Explained

Momentum (p. 55)

- [cite_start]Momentum is a measure of an object's motion that depends on both its **mass** and its **velocity**[cite: 6].
- [cite_start]The formula is **momentum = mass × velocity**, or $p = mv$[cite: 15, 16].
- [cite_start]The standard unit for momentum is the **kilogram metre per second (kg m/s)** or the **newton second (Ns)**[cite: 14].
- [cite_start]Momentum is a **vector quantity**, meaning it has both magnitude (size) and direction[cite: 87]. The direction of momentum is the same as the direction of the velocity.
- An object at rest has zero momentum because its velocity is zero.

Conservation of Momentum (p. 56)

- [cite_start]This principle states that when objects interact (e.g., in a collision), their **total momentum remains constant** unless an external force like friction acts on them[cite: 61].
- In other words: **Total momentum before collision = Total momentum after collision**.
- This applies to all types of collisions, including those where objects stick together (inelastic) and those where they bounce apart.
- For a simple collision where object 1 (mass m_1, velocity u_1) hits a stationary object 2 (mass m_2, velocity $u\_2 = 0$), and they stick together moving with a final velocity v, the equation is: $m\_1u\_1 + m\_2(0) = (m\_1 + m\_2)v$

Explosions and Recoil (p. 57)

- Momentum is also conserved in explosions.
- [cite_start]Before the explosion (e.g., firing a rifle), the total momentum is zero because everything is at rest[cite: 91].
- [cite_start]During the explosion, the objects move apart, but the total momentum must still be zero[cite: 92].
- [cite_start]This means the forward momentum of one part (e.g., the bullet) must be equal in size but opposite in direction to the backward momentum of the other part (e.g., the rifle)[cite: 92].
- **Momentum of bullet (forward) = Momentum of rifle (backward)**. This backward movement is called **recoil**. [cite_start]This principle also applies to rockets and jet engines, which gain forward momentum by ejecting hot gases with large backward momentum[cite: 104, 105].

Force, Momentum, and Impulse (p. 57)

- A force is required to change an object's momentum.
- [cite_start]The **resultant force** is defined as the rate of change of momentum, or $F = fracDeltapDeltat$[cite: 135, 136]. [cite_start]This is another way of stating Newton's second law[cite: 137].
- [cite_start]**Impulse** is the change in momentum, calculated as $Impulse = F$ $times$ $Deltat =$ $Deltap$[cite: 131].
- To produce a certain change in momentum (e.g., stopping a moving car), you can either apply a large force for a short time OR a small force for a long time.
- Safety features like **crumple zones** in cars, sandpits for long-jumpers, and extensible seat belts work by **increasing the collision time** ($Deltat$). [cite_start]This reduces the average force (F) required to bring the momentum to zero, thus reducing injury[cite: 12, 154, 156].

5) Diagrams and Micrographs (Figures)

- **Figure 1.6.1: Experimental Setup (p. 55)**
  - **What it shows:** A sloping runway with a trolley carrying an 'interrupt card'. Two photogates are positioned along the runway to measure the trolley's velocity before and after a collision.
  - **Labels:** Trolley with 'interrupt card', photogate 1, photogate 2, sloping runway, wires to timer.

    - **To redraw:** Draw a long, slightly tilted rectangle for the runway. Place two U-shaped 'photogates' over the runway. Draw a small rectangular trolley on the runway with a vertical card on top, shown once before photogate 1 and again between the gates.
- **Figure 1.6.2: Truck Collision (p. 56)**
    - **What it shows:** A two-part diagram illustrating the principle of conservation of momentum.
    - **Part a (Before):** A 60 kg truck moves at 3 m/s towards a stationary 30 kg truck.
    - **Part b (After):** The two trucks are coupled together and move with a common velocity, v.
- **Figure 1.6.3: Deflating Balloon (p. 57)**
    - **What it shows:** A simple demonstration of the principle behind rockets.
    - **Description:** An inflated balloon is shown moving to the right as air rushes out of its open neck to the left. [cite_start]The forward momentum of the balloon is equal and opposite to the backward momentum of the escaping air[cite: 103].
- **Figure 1.6.4 & 1.6.5: Sporting Examples of Impulse (p. 58)**
    - **What they show:** How changing the time of impact affects the force.
    - [cite_start]**Figure 1.6.4a:** A cricketer 'following through' with a bat to increase the contact time, thereby increasing the impulse and the ball's final momentum[cite: 146, 147].
    - **Figure 1.6.4b:** A cricketer drawing their hands back while catching a ball. [cite_start]This increases the time taken to reduce the ball's momentum to zero, which decreases the force on their hands[cite: 150, 151].
    - **Figure 1.6.5:** A long-jumper landing in sand. [cite_start]The sand increases the time over which the athlete's momentum is reduced to zero, resulting in a smaller stopping force[cite: 154].

6) Processes and Cycles

Applying Conservation of Momentum in a Collision

This process is used to find an unknown velocity after a collision.

1. **Identify the system:** The system consists of the two colliding objects (e.g., trolley 1 and trolley 2).
2. **Calculate total momentum BEFORE the collision:**
    - Find the momentum of each object individually using $p = mv$. Remember that stationary objects have zero momentum.
    - Add the momenta together, taking direction into account. (For one-dimensional problems, one direction is positive and the opposite is negative).

- **Equation:** $p\_total, before = m\_1u\_1 + m\_2u\_2$

3. **Calculate total momentum AFTER the collision:**
    - Identify the masses and velocities after the collision. [cite_start]If the objects stick together, their total mass is $(m\_1 + m\_2)$ and they share a common velocity, v[cite: 64].
    - **Equation:** $p\_total, after = (m\_1 + m\_2)v$
4. **Equate the 'before' and 'after' momenta:**
    - [cite_start]Apply the principle of conservation of momentum: $p\_total, before = p\_total, after$[cite: 61, 68].
    - **Equation:** $m\_1u\_1 + m\_2u\_2 = (m\_1 + m\_2)v$
5. **Solve for the unknown:** Rearrange the equation to find the unknown quantity, which is usually the final velocity, v.

7) Formulae and Calculations

Quantity	Formula	Units	Typical Values (from text)	Worked Example (with sig. figs.)
Momentum	[cite_start]$p = m timesv$ [cite: 16]	kg m/s	A 2 kg trolley at 0.2 m/s has $p = 0.4$ kg m/s (p. 56, Q3a).	[cite_start]What is the momentum of a 50 kg boy running at 5 m/s? [cite: 121] $p = mv = 50 times5 = 250$ kg m/s (2 s.f.)
Change in Momentum	[cite_start] $Deltap = mv - mu$ [cite: 129]	kg m/s	A 1000 kg car stopping from 24 m/s has $Deltap = -24000$ kg m/s (p. 58, Q6a).	A 10 kg object speeds up from 4 m/s to 8 m/s. [cite_start]What is its change in momentum? [cite: 201] $Deltap = 10(8) - 10(4) = 80 - 40 = 40$ kg m/s (1 s.f.)
Impulse	[cite_start]$Impulse = F$	Ns (or kg	A 5 N force acting for 0.02	A cue exerts a 50 N force on a billiard ball

Quantity	Formula	Units	Typical Values (from text)	Worked Example (with sig. figs.)
	$times Deltat$ [cite: 139]	m/s)	s gives an impulse of 0.1 Ns (p. 58, Q5a).	for 0.001 s. [cite_start]Calculate the impulse. [cite: 205] $Impulse = 50 times0.001 = 0.050$ Ns (1 s.f.)
Resultant Force	[cite_start]$F = fracDeltapDeltat = fracmv - muDeltat$ [cite: 135]	N	A 1000 kg car stopping from 24 m/s in 1.2 s requires a force of 20000 N (p. 58, Q6b).	[cite_start]What force is needed to change the momentum of an object by 40 kg m/s in 2 s? [cite: 201, 208, 209] $F = frac402 = 20$ N (1 s.f.)

8) Required Practicals / Experiments

Investigating Conservation of Momentum in Collisions (p. 55-56)

- **Aim:** To verify that momentum is conserved in a collision between two trolleys.
- [cite_start]**Apparatus:** Sloping runway, two trolleys, two photogates connected to a timer, metre rule, balance, Velcro strips (to make trolleys stick together)[cite: 24, 41].
- **Method:**
    i. [cite_start]Set up the runway with a slight tilt to compensate for friction[cite: 41, 51]. The trolley should roll at a constant velocity.
    ii. Measure the mass of the trolleys (m_1, m_2) and the length of the interrupt card (l) on top of trolley 1.
    iii. [cite_start]Place one trolley (m_2) at rest between the two photogates[cite: 42].
    iv. [cite_start]Place photogate 1 before the collision point and photogate 2 after it[cite: 26].
    v. [cite_start]Push trolley 1 (m_1) from the top of the runway so it passes through photogate 1, collides and sticks to trolley 2, and then the combined mass passes through photogate 2[cite: 42, 43].

vi. [cite_start]The timer records the time (t_1) for the card to pass through photogate 1 and the time (t_2) for it to pass through photogate 2[cite: 44].
vii. [cite_start]Calculate the velocity before collision ($v\_1 = l/t\_1$) and the velocity after collision ($v\_1 + 2 = l/t\_2$)[cite: 25, 44].
viii. Calculate the momentum before ($p\_before = m\_1v\_1$) and momentum after ($p\_after = (m\_1 + m\_2)v\_1 + 2$).
ix. Compare p_before and p_after. [cite_start]Repeat for different masses (e.g., stacking trolleys)[cite: 45].

- **Variables:**
  - **Independent Variable (IV):** The mass of the trolleys involved (e.g., 1 trolley hitting 1, or 2 trolleys hitting 1).
  - **Dependent Variable (DV):** The velocities before and after the collision, used to calculate momentum.
  - **Control Variables:** The length of the interrupt card, the angle of the runway.
- [cite_start]**Safety:** Ensure the runway is clear at the bottom and has barriers to prevent trolleys from falling off[cite: 23].
- **Sources of Error:**
  - Friction is not perfectly compensated for, causing momentum loss.
  - The runway may not be perfectly level or smooth.
  - Measurement error in the length of the interrupt card.
- [cite_start]**Improvements:** Use a motion sensor instead of photogates for more detailed velocity data[cite: 38]. Use an air track to minimize friction.
- [cite_start]**Expected Results:** The momentum before the collision should be approximately equal to the momentum after the collision, demonstrating conservation of momentum[cite: 50].

9) Data Handling and Graphing

- **Tables:** The primary method of data handling in this chapter is using tables to organize measurements and calculations from the collision experiment (p. 56).
  - [cite_start]A 'Before collision' table would have columns for Mass (m_1), Velocity (v), and Momentum (m_1v)[cite: 47].
  - [cite_start]An 'After collision' table would have columns for Total Mass ($m\_1 + m\_2$), Velocity (v_1), and Momentum ($(m\_1 + m\_2)v\_1$)[cite: 49].
- **Graphs:** No graphs are explicitly used or plotted in this chapter. However, an exam question could ask you to plot a graph, for example, of force vs. time during an impact. The area under such a graph would represent the impulse (change in momentum).

- **Exam Prompts:** You will be expected to calculate momentum from given data and fill in the results tables. A common question is to compare the total momentum before and after and comment on whether momentum was conserved, giving reasons for any small discrepancies (e.g., friction).

10) Common Misconceptions and Exam Tips

- **Misconception:** Momentum and kinetic energy are the same thing.
    - **Correct Understanding:** Momentum ($p = mv$) is a vector, while kinetic energy ($KE = frac12mv^2$) is a scalar. Momentum is always conserved in collisions (without external forces), but kinetic energy is often lost as heat and sound, unless the collision is perfectly elastic.
    - **Quick Tip:** Remember **V** for **V**elocity and **V**ector. Momentum has direction.
- **Misconception:** Any object with a large mass has more momentum than a light object.
    - **Correct Understanding:** Momentum depends on *both* mass and velocity. A light object moving very fast can have more momentum than a massive object moving very slowly.
    - **Quick Tip:** Always calculate $p = mv$ before comparing.
- **Misconception:** Forgetting that momentum is a vector.
    - **Correct Understanding:** In calculations involving objects moving in opposite directions (e.g., recoil), one direction must be treated as positive and the other as negative.
    - **Quick Tip:** In explosion or recoil problems, if the bullet's momentum is $+p$, the gun's momentum is $-p$. The total is still zero.
- **Exam Tip:** When a question mentions "crumple zones", "airbags", "catching a ball", or "bending knees", the answer must involve **increasing the time of impact** to **decrease the resultant force** for a given change in momentum. Memorize this causal link.

11) Exam-Style Practice

Multiple-Choice Questions (MCQs)

1. What is the correct unit for momentum?
   A. kg/s
   B. N/m
   C. kg m/s

D. J/s

Answer: C. Momentum is mass (kg) times velocity (m/s).

2. A 1500 kg car accelerates from rest to 10 m/s. What is its change in momentum?

   A. 150 kg m/s

   B. 1500 kg m/s

   C. 7500 kg m/s

   D. 15000 kg m/s

   Answer: D.
   $Deltap = m(v - u) = 1500$
   $times(10 - 0) = 15000$ kg m/s.

3. The principle of conservation of momentum states that in the absence of external forces...

   A. ...kinetic energy is always conserved.

   B. ...the total momentum of a system remains constant.

   C. ...velocity is always conserved.

   D. ...the impulse is always zero.

   [cite_start]**Answer: B.** This is the definition of the principle[cite: 61].

4. A cannon fires a 5 kg cannonball forwards with a momentum of 1000 kg m/s. What is the recoil momentum of the cannon?

   A. 0 kg m/s

   B. -200 kg m/s

   C. -1000 kg m/s

   D. -5000 kg m/s

   [cite_start]**Answer: C.** By conservation of momentum, the recoil momentum is equal and opposite[cite: 92].

5. A force of 20 N acts on an object for 0.5 s. What is the impulse delivered to the object?

   A. 10 Ns

   B. 20 Ns

   C. 40 Ns

   D. 100 Ns

   [cite_start]**Answer: A.** Impulse = F
   $times$
   $Deltat = 20$
   $times 0.5 = 10$ Ns[cite: 139].

6. Crumple zones on a car reduce injury in a crash because they...

   A. ...decrease the mass of the car.

   B. ...decrease the total change in momentum.

   C. ...increase the force of the impact.

   D. ...increase the time of the impact.

[cite_start]**Answer: D.** Increasing time reduces the force for the same change in momentum[cite: 12].

7. A trolley of mass 2 kg moving at 3 m/s collides and sticks to a stationary trolley of mass 1 kg. What is their common velocity after the collision?
   A. 1 m/s
   B. 2 m/s
   C. 3 m/s
   D. 6 m/s
   Answer: B. $(2$
   $times3) + (1$
   $times0) = (2 + 1)v$
   $implies6 = 3v$
   $impliesv = 2$ m/s.
8. Which quantity is a vector?
   A. Mass
   B. Time
   C. Momentum
   D. Speed
   [cite_start]**Answer: C.** Momentum has both magnitude and direction[cite: 87].
9. A ball hits a wall and bounces back. The change in momentum is greatest if the ball...
   A. ...stops at the wall.
   B. ...bounces back with the same speed.
   C. ...bounces back with a lower speed.
   D. ...bounces back with a higher speed.
   Answer: B. The change in velocity is largest (from $+v$ to $-v$, a change of $2v$).
10. A rocket moves forwards by...
   A. ...pushing against the air.
   B. ...conserving its mass.
   C. ...ejecting gas with backwards momentum.
   D. ...reducing the force of gravity.
   [cite_start]**Answer: C.** The rocket gains forward momentum equal to the backward momentum of the exhaust gas[cite: 105].

Short-Answer Questions

1. **Define** momentum and state its formula. (2 marks)
   - **Answer:** Momentum is the product of an object's mass and velocity [1]. [cite_start]The formula is $p = mv$ [1][cite: 6, 15].

2. A girl of mass 50 kg jumps from a stationary boat of mass 300 kg with a horizontal velocity of 3 m/s. **Calculate** the velocity with which the boat moves backwards. (3 marks)
   - **Answer:** Total momentum before = 0 [1]. Forward momentum of girl = 50
     $times3 = 150$ kg m/s. By conservation of momentum, backward momentum of boat must be 150 kg m/s [1]. [cite_start]So, 300
     $timesv = 150$
     $impliesv = 150/300 = 0.5$ m/s [1][cite: 123, 124].
3. A cricketer catches a hard-hit ball. **Explain**, using the concept of impulse, why they pull their hands back during the catch. (3 marks)
   - **Answer:** To stop the ball, its momentum must be changed, which requires an impulse (F
     $Deltat$) [1]. By pulling their hands back, the cricketer increases the time (
     $Deltat$) over which the ball's momentum is reduced to zero [1]. [cite_start]For the same change in momentum, a larger time results in a smaller average force (F), which reduces the sting on the hands [1][cite: 150, 151].
4. **Calculate** the force required to bring a 1000 kg car from 24 m/s to rest in 1.2 s. (3 marks)
   - **Answer:** Initial momentum $p\_i = 1000$
     $times24 = 24000$ kg m/s. Final momentum $p\_f = 0$ [1]. Change in momentum
     $Deltap = -24000$ kg m/s [1]. Force $F =$
     $Deltap/$
     $Deltat = -24000/1.2 = -20000$ N [1]. (The negative sign indicates a stopping force) [cite_start][cite: 167-171].
5. A 10 kg truck travelling at 5 m/s has a momentum of 50 kg m/s. **Calculate** its momentum if it travels at 36 km/h. (3 marks)
   - **Answer:** First, convert 36 km/h to m/s. 36
     $textkm/h = 36000$
     $textm/3600$
     $texts = 10$ m/s [2]. [cite_start]Momentum $p = mv = 10$
     $textkg$
     $times10$
     $textm/s = 100$ kg m/s [1][cite: 111, 117].

Structured Questions

1. A truck A of mass 500 kg moving at 4 m/s collides with another truck B of mass 1500 kg moving in the same direction at 2 m/s. After the collision, they stick together.
   a) **State** the principle of conservation of momentum. (2 marks)
   b) **Calculate** the total momentum of both trucks before the collision. (3 marks)
   c) **Determine** the common velocity of the trucks immediately after the collision. (3 marks)

- **Marking Points:**
    - [cite_start]a) When two or more bodies act on one another, their total momentum remains constant [1], provided no external forces act [1][cite: 61].
    - b) Momentum of A = 500
      $times4 = 2000$ kg m/s [1]. Momentum of B = 1500
      $times2 = 3000$ kg m/s [1]. [cite_start]Total momentum = $2000 + 3000 = 5000$ kg m/s [1][cite: 179].
    - c) Total mass after collision = $500 + 1500 = 2000$ kg [1]. Total momentum after = Total momentum before = 5000 kg m/s [1]. 2000
      $timesv = 5000$
      $impliesv = 5000/2000 = 2.5$ m/s [1].
2. A force acts on an object of mass 10 kg, increasing its velocity from 4 m/s to 8 m/s over a period of 2 s.
   a) **Calculate** the initial and final momentum of the object. (2 marks)
   b) **Calculate** the impulse of the force. (2 marks)
   c) **Determine** the magnitude of the force. (2 marks)
    - **Marking Points:**
        - a) Initial momentum = 10
          $times4 = 40$ kg m/s. [cite_start]Final momentum = 10
          $times8 = 80$ kg m/s [2][cite: 201, 202, 206].
        - [cite_start]b) Impulse = change in momentum = $80 - 40 = 40$ Ns [2][cite: 208, 211].
        - [cite_start]c) Force = change in momentum / time = $40/2 = 20$ N [2][cite: 209].

12) Quick Revision Checklist

- [ ] I can define momentum as the product of mass and velocity ($p = mv$).
- [ ] I know the units of momentum are kg m/s or Ns.
- [ ] I understand that momentum is a vector quantity with direction.
- [ ] I can state the principle of conservation of momentum.
- [ ] I can apply the conservation of momentum principle to simple collisions where objects stick together.
- [ ] I can apply the conservation of momentum principle to explosions and recoil situations.
- [ ] I can define impulse as the product of force and time (F
  $Deltat$).
- [ ] I know that impulse is equal to the change in momentum (
  $Deltap$).

- [ ] I can calculate force as the rate of change of momentum ($F = Deltap/Deltat$).
- [ ] I can explain how safety features like crumple zones and airbags work by increasing impact time to reduce force.
- [ ] I can solve numerical problems involving momentum, impulse, and force.
- [ ] I can describe an experiment to investigate the conservation of momentum.

13) Flashcards (Ready-to-use)

Question	Answer
What is momentum?	The product of mass and velocity ($p = mv$). (p. 55)
What are the units of momentum?	kg m/s or Ns. (p. 55)
Is momentum a scalar or a vector?	Vector. It has magnitude and direction. (p. 57)
State the principle of conservation of momentum.	The total momentum of an interacting system is constant if no external forces act. (p. 56)
What is the total momentum of a rifle and bullet before firing?	Zero. (p. 57)
What is impulse?	The product of force and the time it acts ($F Deltat$), which equals the change in momentum. (p. 57)
How do crumple zones on cars make them safer?	They increase the time of impact, which reduces the force needed to stop the car for a given change in momentum. (p. 55)
How do you calculate force from momentum?	Force is the rate of change of momentum, $F = Deltap/Deltat$. (p. 57)
What happens to the total momentum in an explosion?	It is conserved (remains zero). The forward momentum of one part equals the backward momentum of the other. (p. 57)

Question	Answer
Why does a cricketer pull their hands back when catching a ball?	To increase the time of impact, which reduces the stopping force on their hands. (p. 58)
A 4 kg ball moves at 5 m/s. What is its momentum?	$p = 4$ $times5 = 20$ kg m/s.
What is the momentum of a 1000 kg car that is parked?	Zero, because its velocity is zero.
What is another name for Newton's second law in terms of momentum?	Resultant force is the rate of change of momentum. (p. 57)
How does a rocket work in the vacuum of space?	It ejects hot gas with large backward momentum, causing the rocket to gain an equal amount of forward momentum. It doesn't need air to push against. (p. 57)
What is recoil?	The backward movement experienced by a gun when it is fired, due to the conservation of momentum. (p. 57)

14) 60-Second Recap

This chapter covers **momentum**, defined as mass times velocity ($p = mv$). The most important rule is the **principle of conservation of momentum**: for any collision or explosion with no external forces, the total momentum before equals the total momentum after. This explains why a rifle recoils and how rockets work. We also learned about **impulse**, which is force multiplied by time, and is equal to the change in momentum. This is key to safety features like crumple zones and airbags, which work by increasing the collision time to reduce the overall force, minimizing injury. You need to be able to solve one-dimensional problems for both collisions where objects stick together and explosions where they fly apart.

15) References to Pages

- **Momentum Definition:** 55

16) Excluded "Going Further" Sections (Not Summarized)

Section Title	Pages
Not covered in this chapter.	N/A

- **Total excluded:** 0