Grade 12 Physics

Knowledge area: Mechanics

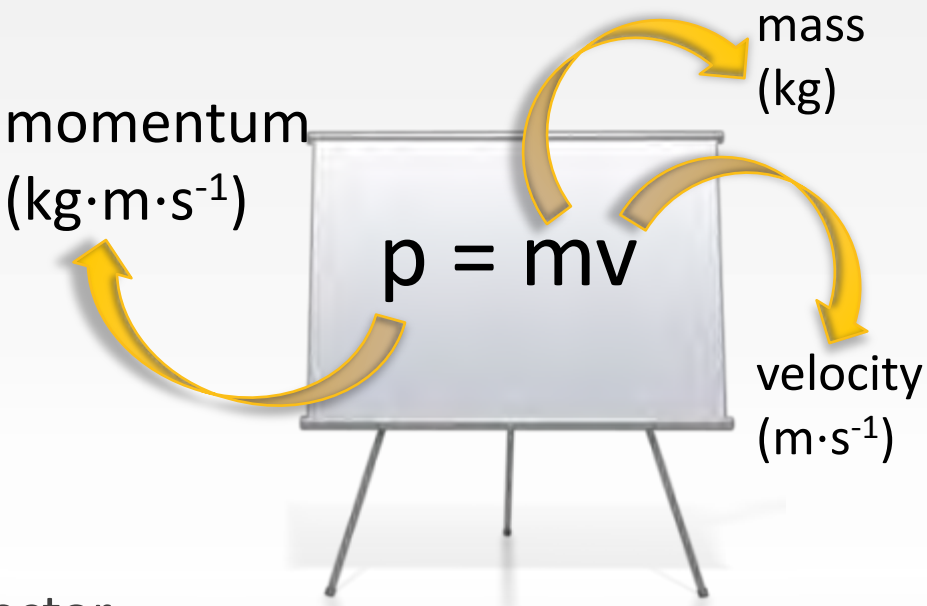
Momentum and impulse

1.1 Momentum

The momentum of an object is the product of the object's mass and velocity.

Definition

Symbol format:



Unit: $kg \cdot m \cdot s^{-1}$

Momentum is influenced by:

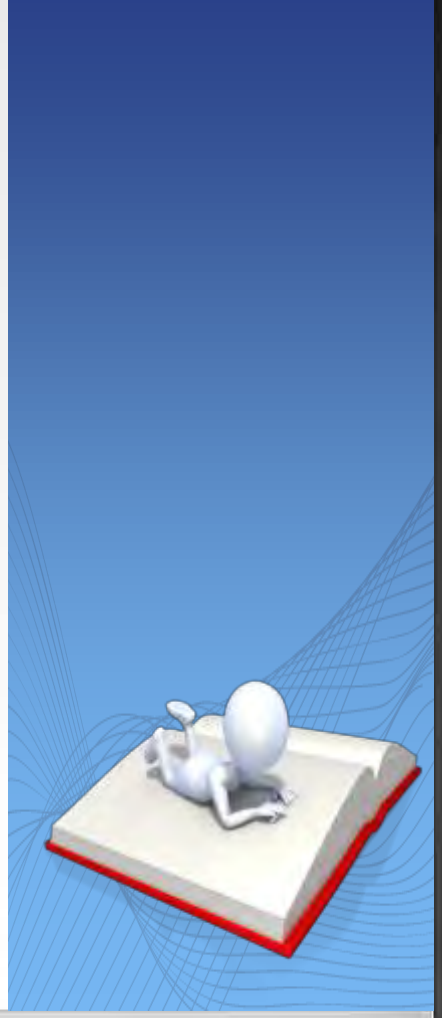
- mass
- velocity

Momentum is a vector.

Momentum and impulse

Examples

1. A car has a mass of 800 kg and moves at a velocity of 40 $m \cdot s^{-1}$ west.
   What is the momentum of the car?
   $p = mv$
   $= 800 \times 40$
   $= 32\ 000\ kg \cdot m \cdot s^{-1}$ west



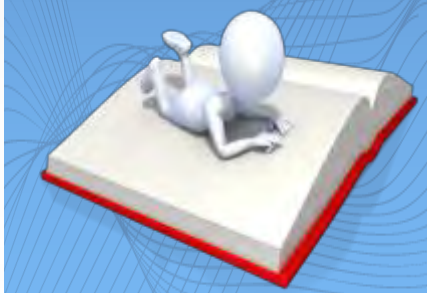
Momentum and impulse

2. A soccer ball with a mass of 420 g is kicked at a velocity of 20 $m \cdot s^{-1}$ toward the goal. Calculate the momentum of the ball.

   $p = mv$

   $= 0,42 \times 20$ (Remember: convert mass to kg.)

   $= 8,4\ kg \cdot m \cdot s^{-1}$ in the original direction



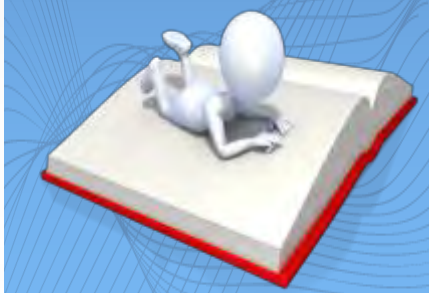
Momentum and impulse

1.2 Change in momentum

Changes when the velocity of the object changes

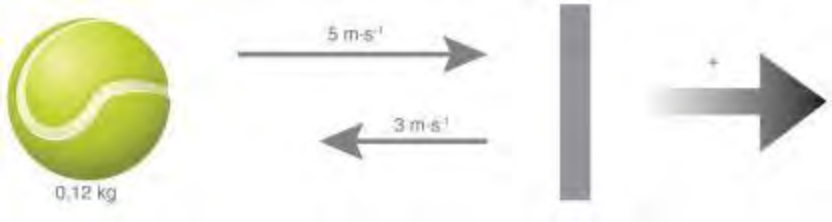
Examples

A tennis ball with a mass of 0,12 kg, is hit and moves toward the opponent's racket at a velocity of 5 $m \cdot s^{-1}$. This velocity is referred to as the initial velocity (v_i) of the ball, and its direction is chosen as positive.



Momentum and impulse

When the ball hits the racket (collision), the velocity of the ball changes to 3 $m \cdot s^{-1}$ in the opposite direction. This velocity is referred to as the final velocity (v_f) of the ball, and its direction is chosen as negative.

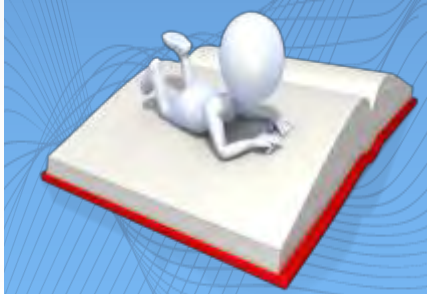


The momentum before the collision can be calculated as shown below:

$p_i = mv_i$

$= 0{,}12 \times (+5)$

$= 0{,}6\ kg \cdot m \cdot s^{-1}$ forward

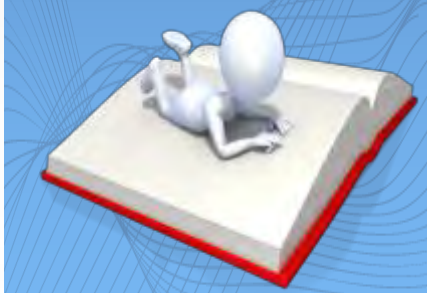


Momentum and impulse

The momentum after the collision can be calculated as shown below:

$p_f = mv_f$
$= 0,12 \times (-3)$
$= -0,36\ kg \cdot m \cdot s^{-1}$
$= 0,36\ kg \cdot m \cdot s^{-1}$ in the opposite direction

Can you see that the momentum of the ball has changed?



Momentum and impulse

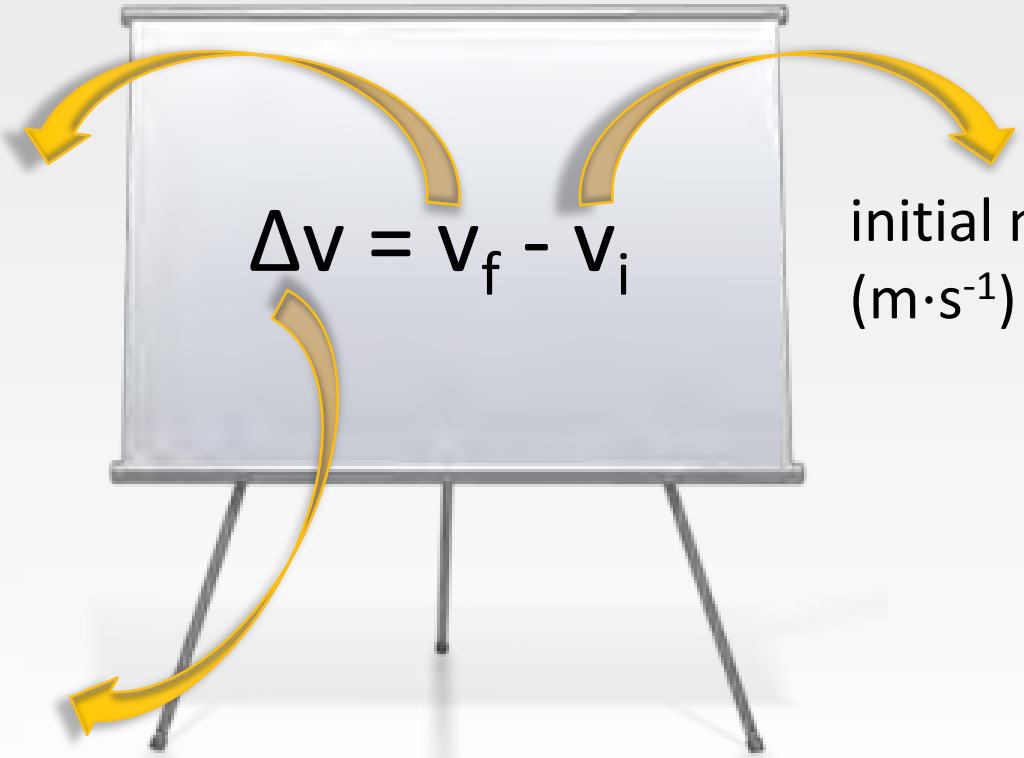
final momentum ($kg \cdot m \cdot s^{-1}$)

$$\Delta p = p_f - p_i$$
$$= mv_f - mv_i$$
$$= m(v_f - v_i)$$

initial momentum ($kg \cdot m \cdot s^{-1}$)

change in momentum ($kg \cdot m \cdot s^{-1}$)

Momentum and impulse



final velocity ($m \cdot s^{-1}$)

initial momentum ($m \cdot s^{-1}$)

change in velocity ($m \cdot s^{-1}$)

Momentum and impulse

The change in momentum for this example is therefore:

$\Delta p = p_f - p_i$

$= mv_f - mv_i$

(Remember: the mass of the ball did not change.

$= m(v_f - v_i)$

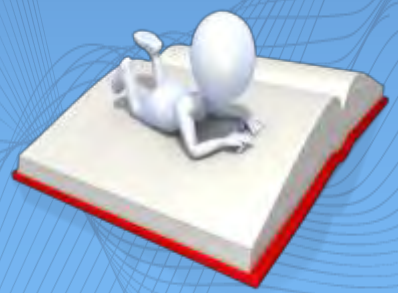
$= 0{,}12(-3 - 5)$

$= -0{,}96\ kg \cdot m \cdot s^{-1}$

$= 0{,}96\ kg \cdot m \cdot s^{-1}$ in the opposite direction (backward)

Quick facts

Remember to choose one direction as positive.



Momentum and impulse

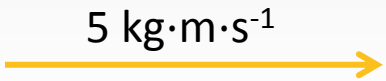
Change in momentum can be caused by

- Change in mass.
- Increasing velocity.
- Decreasing velocity.
- Change in direction of motion.

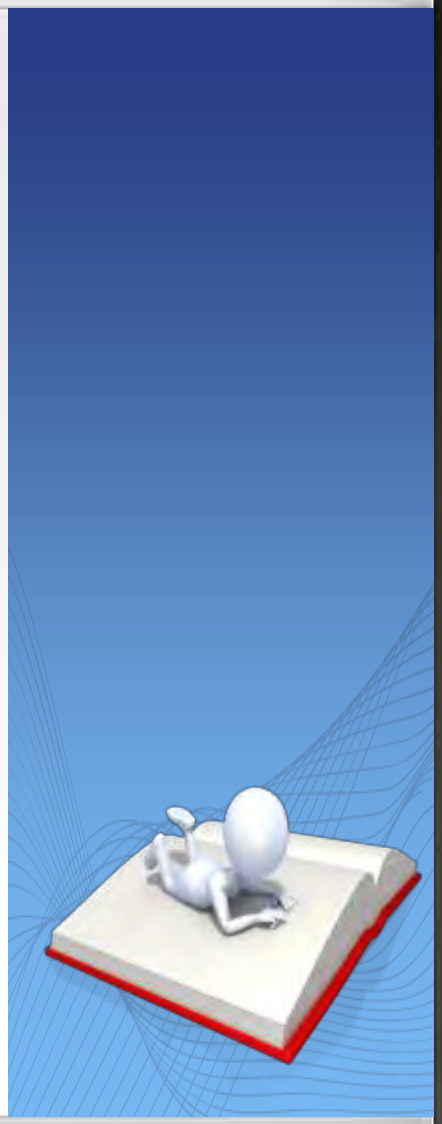
Vector diagrams

Vectors are always drawn as arrows.

- Momentum of 5 $kg \cdot m \cdot s^{-1}$ to the right:

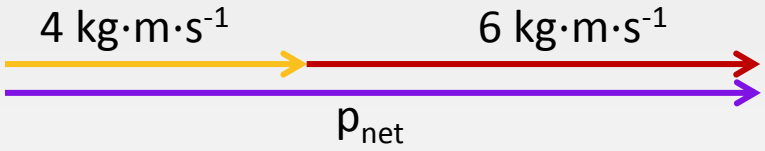


- Momentum of 3 $kg \cdot m \cdot s^{-1}$ to the left:

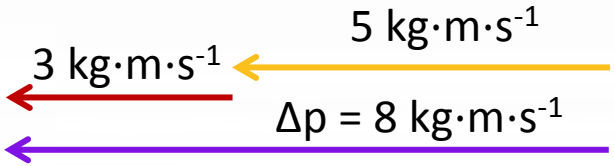


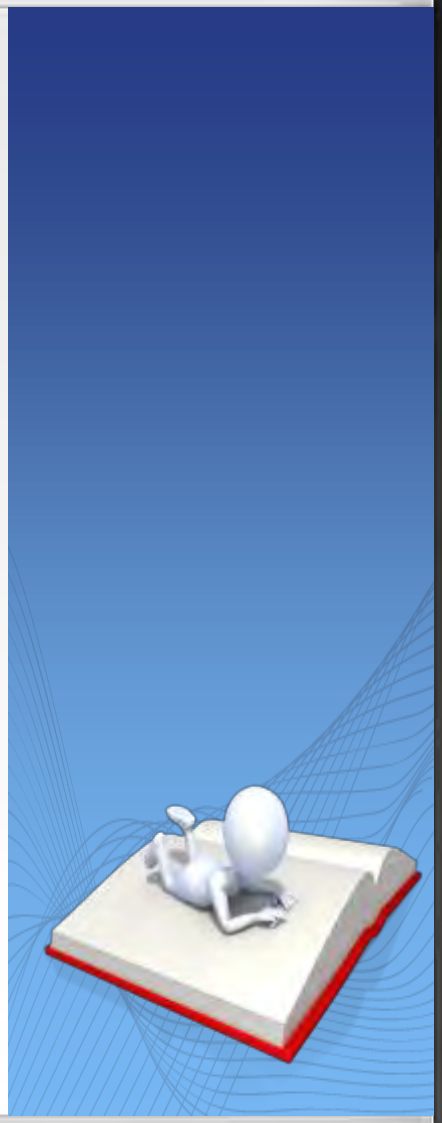
Momentum and impulse

- Momentum in the same direction must be added: e.g. 4 $kg \cdot m \cdot s^{-1}$ east and 6 $kg \cdot m \cdot s^{-1}$ east.



- Change in momentum between the first two examples above: The two vectors must be subtracted from each other. The direction of the vector that is subtracted, is changed. $\Delta p = -3 - (+5) = -8\ kg \cdot m \cdot s^{-1}$ east





Momentum and impulse

- Change in momentum if the momentum of both vectors is in the same direction, e.g. 8 $kg \cdot m \cdot s^{-1}$ east and 12 $kg \cdot m \cdot s^{-1}$ east. The direction of the vector that is subtracted changes.
  $\Delta p = +12 - (+8) = 4\ kg \cdot m \cdot s^{-1}$ east