1) Momentum and impulse

1.1) Momentum in one direction

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Worked example

Momentum = Mass x Velocity

Mass	Velocity	Momentum
6 kg	5 m/s	
	13 ms^{-1}	65 $kgms^{-1}$
523 kg		0 Ns
3kg	4i + 7j ms^{-1}	

Your turn

Momentum = Mass x Velocity

Mass	Velocity	Momentum
523 kg	0 ms^{-1}	0 Ns
0.2 kg	7i + 7j ms^{-1}	1.4i + 1.4j $kgms^{-1}$
0.002 tonnes	3i + 9j ms^{-1}	6i + 18j Ns
600g	36 km/h	6 Ns

Worked example	Your turn
Calculate the impulse exerted on the object: • A force of 30 N exerted on an object for 0.5 seconds	Calculate the impulse exerted on the object: • A rocket of mass 100 kg travelling at 2000 ms^{-1} hits the ground and stops. $200000\ Ns$
• A ball of mass 3 kg was travelling at 10 ms^{-1}, is hit, and slows to 6 ms^{-1} without changing direction	• A ball of mass 3 kg was travelling at 10 ms^{-1}, is hit and returns in the opposite direction at a speed of 6 ms^{-1} $48\ Ns$
• The momentum before impact is 6**i** + 3**j** Ns and the momentum after impact is 10**i** + 5**j** Ns	• The momentum before impact is 6**i** - 5**j** Ns and the momentum after impact is -10**i** + 5**j** Ns $-16\boldsymbol{i} + 10\boldsymbol{j}\ Ns$

Worked example	Your turn
A ball of mass 0.4 kg hits a vertical wall at right angles with a speed of 7 ms^{-1}. The ball rebounds with speed 5 ms^{-1}. Find the magnitude of the impulse exerted on the wall by the ball.	A ball of mass 0.2 kg hits a vertical wall at right angles with a speed of 3.5 ms^{-1}. The ball rebounds with speed 2.5 ms^{-1}. Find the magnitude of the impulse exerted on the wall by the ball. $1.2\ Ns$

Worked example	Your turn
Two particles A and B, of mass $0.6\ kg$ and m kg respectively, are moving in opposite directions along the same straight horizontal line so that the particles collide directly. Immediately before the collision, the speeds of A and B are $4\ ms^{-1}$ and $2\ ms^{-1}$ respectively. In the collision the direction of motion of each particle is reversed and, immediately after the collision, the speed of each particle is $2\ ms^{-1}$. Find the magnitude of the impulse exerted by B on A in the collision.	Two particles A and B, of mass $0.3\ kg$ and m kg respectively, are moving in opposite directions along the same straight horizontal line so that the particles collide directly. Immediately before the collision, the speeds of A and B are $8\ ms^{-1}$ and $4\ ms^{-1}$ respectively. In the collision the direction of motion of each particle is reversed and, immediately after the collision, the speed of each particle is $2\ ms^{-1}$. Find the magnitude of the impulse exerted by B on A in the collision. $3\ Ns$

1.2) Conservation of momentum

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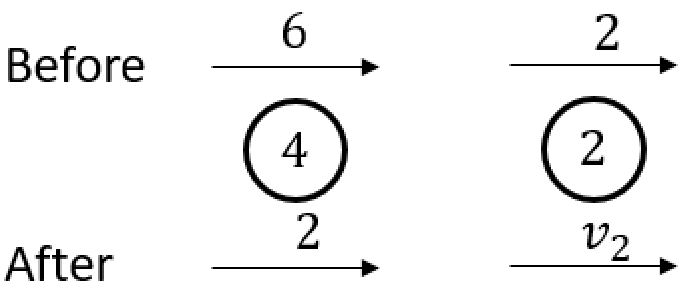
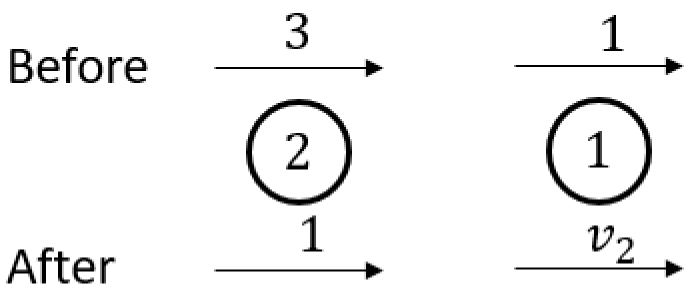
Worked example

Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.



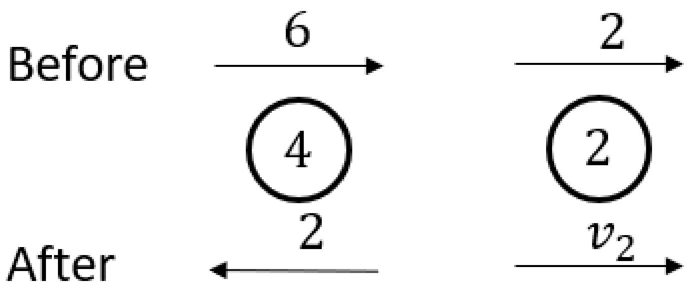
Your turn

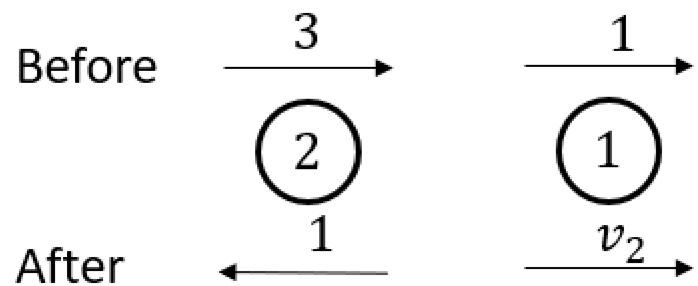
Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.



$v_2 = 5\ ms^{-1}$

Worked example	Your turn
Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.	Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.





$v_2 = 9\ ms^{-1}$

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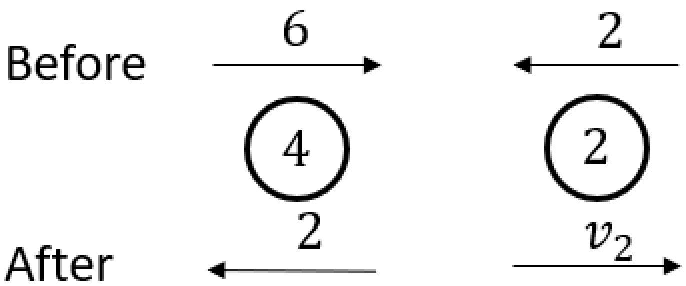
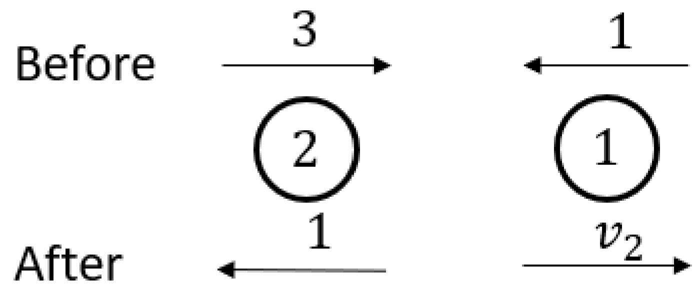
Worked example

Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.



Your turn

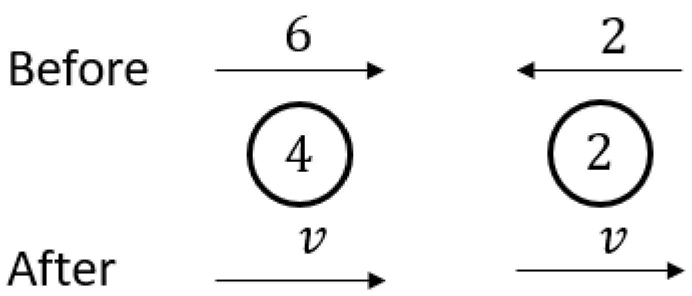
Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.

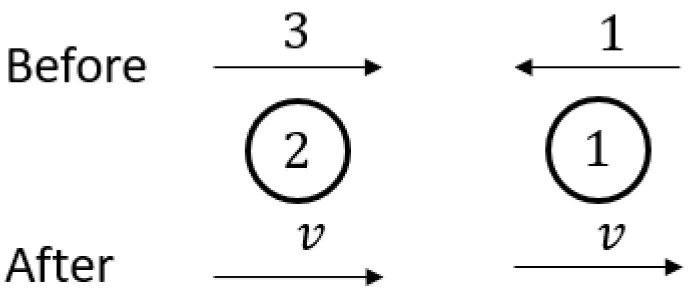


$v_2 = 7\ ms^{-1}$

Diagrams used with permission from DrFrostMaths: https://www.drfrostmaths.com/

Worked example	Your turn
Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.	Calculate the value of the unknown in the following isolated systems. All velocities are marked in ms^{-1} and all masses in kg.





$v = 1.67\ ms^{-1}$ (3 sf)

Worked example	Your turn
A particle P of mass $4\ kg$ is moving with speed $6\ ms^{-1}$ on a smooth horizontal plane. Particle Q of mass $6\ kg$ is at rest on the plane. Particle P collides with particle Q and after the collision Q moves with speed $\frac{14}{3}ms^{-1}$. Find: a) The speed and direction of motion of P after the collision b) The magnitude of the impulse received by P in the collision	A particle P of mass $2\ kg$ is moving with speed $3\ ms^{-1}$ on a smooth horizontal plane. Particle Q of mass $3\ kg$ is at rest on the plane. Particle P collides with particle Q and after the collision Q moves with speed $\frac{7}{3}ms^{-1}$. Find: a) The speed and direction of motion of P after the collision b) The magnitude of the impulse received by P in the collision a) $0.5\ ms^{-1}$; direction of motion is reversed. b) $7\ Ns$

Worked example	Your turn
Two particles A and B of masses 2 kg and 4 kg respectively are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide. Before the collision the speeds of A and B are 3 ms^{-1} and 2 ms^{-1} respectively. After the collision the direction of motion of A is reversed and its speed is 2 ms^{-1}. Find: a) The speed and direction of B after the collision b) The magnitude of the impulse given by A to B in the collision	Two particles A and B of masses 2 kg and 4 kg respectively are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide. Before the collision the speeds of A and B are 3 ms^{-1} and 2 ms^{-1} respectively. After the collision the direction of motion of A is reversed and its speed is 2 ms^{-1}. Find: a) The speed and direction of B after the collision b) The magnitude of the impulse given by A to B in the collision a) 0.5 ms^{-1} ; direction of motion is reversed. b) 10 Ns

Worked example

Two particles P and Q, of masses 8kg and 4kg respectively, are connected by a light inextensible string.
The particles are at rest on a smooth horizontal plane with the string slack.
Particle P is projected directly away from Q with speed $2ms^{-1}$.

a) Find the common speed of the particles after the string goes taut.
b) Find the magnitude of the impulse transmitted through the string when it goes taught.

Your turn

Two particles P and Q, of masses 8kg and 2kg respectively, are connected by a light inextensible string.
The particles are at rest on a smooth horizontal plane with the string slack.
Particle P is projected directly away from Q with speed $4ms^{-1}$.

a) Find the common speed of the particles after the string goes taut.
b) Find the magnitude of the impulse transmitted through the string when it goes taught.

a) $3.2\ ms^{-1}$
b) $6.4\ Ns$

Worked example	Your turn
Two particles A and B of masses $4\ kg$ and $2\ kg$ respectively are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide. Before the collision the speeds of A and B are $6\ ms^{-1}$ and $4\ ms^{-1}$ respectively. Given that the magnitude of the impulse due to the collision is $14\ Ns$, find: a) The velocity of A after the collision b) The velocity of B after the collision	Two particles A and B of masses $2\ kg$ and $4\ kg$ respectively are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide. Before the collision the speeds of A and B are $3\ ms^{-1}$ and $2\ ms^{-1}$ respectively. Given that the magnitude of the impulse due to the collision is $7\ Ns$, find: a) The velocity of A after the collision b) The velocity of B after the collision a) $0.5\ ms^{-1}$; direction of motion is reversed b) $0.25\ ms^{-1}$; direction of motion is unchanged.

Worked example	Your turn
A truck P of mass $4M$ is moving with speed U on smooth straight horizontal rails. It collides directly with another truck Q of mass $6M$ which is moving with speed $2U$ in the opposite direction on the same rails. The trucks join so that immediately after the collision they move together. By modelling the trucks as particles, find: a) The speed of the trucks immediately after the collision b) The magnitude of the impulse exerted on P by Q in the collision	A truck P of mass $2M$ is moving with speed U on smooth straight horizontal rails. It collides directly with another truck Q of mass $3M$ which is moving with speed $4U$ in the opposite direction on the same rails. The trucks join so that immediately after the collision they move together. By modelling the trucks as particles, find: a) The speed of the trucks immediately after the collision b) The magnitude of the impulse exerted on P by Q in the collision a) $2U$ b) $6MU$

1.3) Momentum as a vector

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Worked example	Your turn
A particle of mass 0.4kg is moving with velocity (5**i** –10**j**) ms^{-1} when it receives an impulse (2**i** – 3**j**)Ns. Find the new velocity of the particle.	A particle of mass 0.2kg is moving with velocity (10**i** – 5**j**) ms^{-1} when it receives an impulse (3**i** – 2**j**)Ns. Find the new velocity of the particle. $(25\boldsymbol{i} - 15\boldsymbol{j})\ ms^{-1}$

Worked example	Your turn
An ice hockey puck of mass 0.34 kg receives an impulse **Q** Ns . Immediately before the impulse the velocity of the puck is (5**i** + 10**j**) ms^{-1} and immediately afterwards its velocity is (7**i** – 15**j**) ms^{-1}. Find the magnitude of **Q** and the angle between **Q** and **i**.	An ice hockey puck of mass 0.17 kg receives an impulse **Q** Ns . Immediately before the impulse the velocity of the puck is (10**i** + 5**j**) ms^{-1} and immediately afterwards its velocity is (15**i** – 7**j**) ms^{-1}. Find the magnitude of **Q** and the angle between **Q** and **i**. $\|\boldsymbol{Q}\| = 2.21$ Angle between $\boldsymbol{Q}$ and $\boldsymbol{i} = 67.4°$ (1 dp)

Worked example	Your turn
A squash ball of mass $0.05\ kg$ is moving with velocity $(44\boldsymbol{i} + 74\boldsymbol{j})\ ms^{-1}$ when it hits a wall. It rebounds with velocity $(20\boldsymbol{i} - 22\boldsymbol{j})\ ms^{-1}$. Find the impulse exerted by the wall on the squash ball.	A squash ball of mass $0.025\ kg$ is moving with velocity $(22\boldsymbol{i} + 37\boldsymbol{j})\ ms^{-1}$ when it hits a wall. It rebounds with velocity $(10\boldsymbol{i} - 11\boldsymbol{j})\ ms^{-1}$. Find the impulse exerted by the wall on the squash ball. $(-0.3\boldsymbol{i} - 1.2\boldsymbol{j})\ Ns$

Worked example	Your turn
A particle of mass $0.3\ kg$ is moving with velocity $(10\boldsymbol{i} - 20\boldsymbol{j})\ ms^{-1}$ when it collides with a particle of mass $0.5\ kg$ moving with velocity $(8\boldsymbol{i} - 16\boldsymbol{j})\ ms^{-1}$. The two particles coalesce and move as one particle of mass $0.8\ kg$. Find the velocity of the combined particle.	A particle of mass $0.15\ kg$ is moving with velocity $(20\boldsymbol{i} - 10\boldsymbol{j})\ ms^{-1}$ when it collides with a particle of mass $0.25\ kg$ moving with velocity $(16\boldsymbol{i} - 8\boldsymbol{j})\ ms^{-1}$. The two particles coalesce and move as one particle of mass $0.4\ kg$. Find the velocity of the combined particle. $(17.5\boldsymbol{i} - 8.75\boldsymbol{j})\ ms^{-1}$