Practice examination questions for momentum

1. Jan 2005

2 A particle, A, of mass 12 kg is moving on a smooth horizontal surface with velocity $\begin{bmatrix} 4 \\ 7 \end{bmatrix}$ m s^{-1}. It then collides and coalesces with a second particle, B, of mass 4 kg.

(a) If before the collision the velocity of B was $\begin{bmatrix} 2 \\ 3 \end{bmatrix}$ m s^{-1}, find the velocity of the combined particle after the collision. *(4 marks)*

(b) If after the collision the velocity of the combined particle is $\begin{bmatrix} 1 \\ 4 \end{bmatrix}$ m s^{-1}, find the velocity of B before the collision. *(3 marks)*

2. June 2005

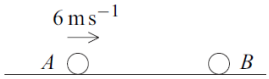
1 A particle of mass m has velocity $\begin{bmatrix} 4 \\ 2 \end{bmatrix}$ m s^{-1}. It then collides with a particle of mass 3 kg which has velocity $\begin{bmatrix} -1 \\ -1 \end{bmatrix}$ m s^{-1}. During the collision the particles coalesce and move with velocity $\begin{bmatrix} 1 \\ V \end{bmatrix}$ m s^{-1}.

(a) Show that $m = 2$. *(4 marks)*

(b) Find V. *(3 marks)*

3. Jan 2006

1 A particle A moves across a smooth horizontal surface in a straight line. The particle A has mass 2 kg and speed 6 m s^{-1}. A particle B, which has mass 3 kg, is at rest on the surface. The particle A collides with the particle B.



(a) If, after the collision, A is at rest and B moves away from A, find the speed of B. *(3 marks)*

(b) If, after the collision, A and B move away from each other with speeds v m s^{-1} and $4v$ m s^{-1} respectively, as shown in the diagram below, find the value of v.

(3 marks)

4. June 2006

8 Two particles, A and B, are moving on a smooth horizontal surface.

The particle A has mass m kg and is moving with velocity $\begin{bmatrix} 5 \\ -3 \end{bmatrix}$ m s^{-1}.

The particle B has mass 0.2 kg and is moving with velocity $\begin{bmatrix} 2 \\ 3 \end{bmatrix}$ m s^{-1}.

(a) Find, in terms of m, an expression for the total momentum of the particles. *(2 marks)*

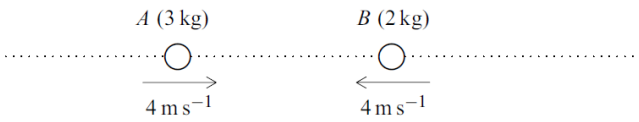
(b) The particles A and B collide and form a single particle C, which moves with velocity $\begin{bmatrix} k \\ 1 \end{bmatrix}$ m s^{-1}, where k is a constant.

(i) Show that $m = 0.1$. *(3 marks)*

(ii) Find the value of k. *(3 marks)*

5. Jan 2007

1 Two particles A and B have masses of 3 kg and 2 kg respectively. They are moving along a straight horizontal line towards each other. Each particle is moving with a speed of 4 m s^{-1} when they collide.



(a) If the particles coalesce during the collision to form a single particle, find the speed of the combined particle after the collision. *(3 marks)*

(b) If, after the collision, A moves in the same direction as before the collision with speed 0.4 m s^{-1}, find the speed of B after the collision. *(3 marks)*

6. June 2007

2 Two particles, A and B, are moving on a smooth horizontal surface. Particle A has mass 2 kg and velocity $\begin{bmatrix} 3 \\ -2 \end{bmatrix}$ m s^{-1}. Particle B has mass 3 kg and velocity $\begin{bmatrix} -4 \\ 1 \end{bmatrix}$ m s^{-1}. The two particles collide, and they coalesce during the collision.

(a) Find the velocity of the combined particles after the collision. *(3 marks)*

(b) Find the speed of the combined particles after the collision. *(2 marks)*

7. Jan 2008

4 Two particles, A and B, are moving on a horizontal plane when they collide and coalesce to form a single particle. The mass of A is 5 kg and the mass of B is 15 kg. Before the collision, the velocity of A is $\begin{bmatrix} 2U \\ U \end{bmatrix}$ m s^{-1} and the velocity of B is $\begin{bmatrix} V \\ -1 \end{bmatrix}$ m s^{-1}. After the collision, the velocity of the combined particle is $\begin{bmatrix} V \\ 0 \end{bmatrix}$ m s^{-1}.

(a) Find:

(i) U; *(3 marks)*

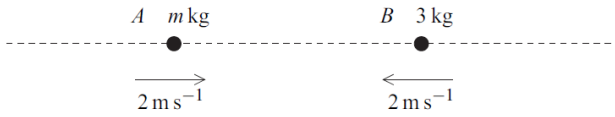
(ii) V. *(2 marks)*

(b) Find the speed of A before the collision. *(2 marks)*

8. June 2008

8 Two particles, A and B, are travelling towards each other along a straight horizontal line.

Particle A has velocity 2 m s^{-1} and mass m kg.
Particle B has velocity -2 m s^{-1} and mass 3 kg.



The particles collide.

(a) If the particles move in opposite directions after the collision, each with speed $0.5\,\text{m s}^{-1}$, find the value of m. *(3 marks)*

(b) If the particles coalesce during the collision, forming a single particle which moves with speed $0.5\,\text{m s}^{-1}$, find the two possible values of m. *(5 marks)*

9. Jan 2009

1 Two particles, A and B, are travelling in the same direction with constant speeds along a straight line when they collide. Particle A has mass 2.5 kg and speed $12\,\text{m s}^{-1}$. Particle B has mass 1.5 kg and speed $4\,\text{m s}^{-1}$. After the collision, the two particles move together at the same speed.

Find the speed of the particles after the collision. *(3 marks)*

10.June 2009

1 Two particles, A and B, are moving on a smooth horizontal surface when they collide. During the collision, the two particles coalesce to form a single combined particle. Particle A has mass 3 kg and particle B has mass 7 kg.

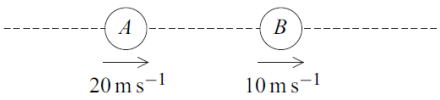
Before the collision, the velocity of A is $\begin{bmatrix} 6 \\ -2 \end{bmatrix}\text{m s}^{-1}$ and the velocity of B is $\begin{bmatrix} -1 \\ 4 \end{bmatrix}\text{m s}^{-1}$.

(a) Find the velocity of the combined particle after the collision. *(3 marks)*

(b) Find the speed of the combined particle after the collision. *(2 marks)*

11.Jan 2010

1 Two particles, A and B, are travelling in the same direction along a straight line on a smooth horizontal surface. Particle A has mass 3 kg and particle B has mass 7 kg. Particle A has a speed of $20\,\text{m s}^{-1}$ and particle B has a speed of $10\,\text{m s}^{-1}$, as shown in the diagram.



Particle A and particle B collide and coalesce to form a single particle. Find the speed of this single particle after the collision. *(3 marks)*

12.June 2010

3 Two particles, A and B, are moving on a smooth horizontal plane when they collide. The mass of A is 6 kg and the mass of B is m kg. Before the collision, the velocity of A is $\begin{bmatrix} 2 \\ 4 \end{bmatrix}$ m s^{-1} and the velocity of B is $\begin{bmatrix} 3 \\ -2 \end{bmatrix}$ m s^{-1}. After the collision, the velocity of A is $\begin{bmatrix} 1 \\ 3 \end{bmatrix}$ m s^{-1} and the velocity of B is $\begin{bmatrix} 7 \\ b \end{bmatrix}$ m s^{-1}.

(a) Find m. *(4 marks)*

(b) Find b. *(2 marks)*

13.Jan 2011

1 A trolley, of mass 5 kg, is moving in a straight line on a smooth horizontal surface. It has a velocity of 6 m s^{-1} when it collides with a stationary trolley, of mass m kg. Immediately after the collision, the trolleys move together with velocity 2.4 m s^{-1}.

Find m. *(3 marks)*

14. June 2011

4 Two particles, A and B, are moving on a smooth horizontal surface when they collide. The mass of A is 6 kg and the mass of B is m kg. Before the collision, the velocity of A is $(5\mathbf{i} + 18\mathbf{j})$ m s^{-1} and the velocity of B is $(2\mathbf{i} - 5\mathbf{j})$ m s^{-1}. After the collision, the velocity of A is $8\mathbf{i}$ m s^{-1} and the velocity of B is $V\mathbf{j}$ m s^{-1}.

(a) Find m. *(3 marks)*

(b) Find V. *(3 marks)*

15. Jan 2012

1 Two particles, A of mass 7 kg and B of mass 3 kg, are moving on a smooth horizontal plane when they collide. Just before the collision, the velocity of A is $(3\mathbf{i} + 8\mathbf{j})$ m s^{-1} and the velocity of B is $(6\mathbf{i} - 5\mathbf{j})$ m s^{-1}. During the collision, the particles coalesce to form a single combined particle.

Find the velocity of the single combined particle after the collision. *(3 marks)*

16. June 2012

2 Two toy trains, A and B, are moving in the same direction on a straight horizontal track when they collide. As they collide, the speed of A is $4\,\mathrm{m\,s^{-1}}$ and the speed of B is $3\,\mathrm{m\,s^{-1}}$. Immediately after the collision, they move together with a speed of $3.8\,\mathrm{m\,s^{-1}}$.

The mass of A is 2 kg. Find the mass of B. *(3 marks)*

17. Jan 2013

5 Two particles, A and B, are moving towards each other along the same straight horizontal line when they collide. Particle A has mass 5 kg and particle B has mass 4 kg. Just before the collision, the speed of A is $4\,\mathrm{m\,s^{-1}}$ and the speed of B is $3\,\mathrm{m\,s^{-1}}$. After the collision, the speed of A is $0.6\,\mathrm{m\,s^{-1}}$ and both particles move on the same straight horizontal line.

Find the two possible speeds of B after the collision. *(6 marks)*

Answers

1. Jan 2005

2(a)	$12\begin{bmatrix}4\\7\end{bmatrix}+4\begin{bmatrix}2\\3\end{bmatrix}=16\mathbf{v}$	M1 A1		Three term momentum equation Correct equation
	$\mathbf{v}=\frac{1}{16}\begin{bmatrix}56\\96\end{bmatrix}=\begin{bmatrix}3.5\\6.0\end{bmatrix}$ ms^{-1}	m1 A1	4	Solving for **v** Correct velocity
(b)	$12\begin{bmatrix}4\\7\end{bmatrix}+4\mathbf{u}=16\begin{bmatrix}1\\4\end{bmatrix}$	M1 A1		Three term momentum equation Correct equation
	$\mathbf{u}=\frac{1}{4}\begin{bmatrix}-32\\-20\end{bmatrix}=\begin{bmatrix}-8\\-5\end{bmatrix}$ ms^{-1}	A1	3	Correct velocity
	Total		**7**	

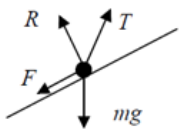
2. June 2005

1(a)	$m\begin{bmatrix}4\\2\end{bmatrix}+3\begin{bmatrix}-1\\-1\end{bmatrix}=(m+3)\begin{bmatrix}1\\V\end{bmatrix}$	M1		M1: Conservation of momentum equation with 3 terms
	$4m-3=m+3$ **AG**	A1		A1: Correct momentum equation
	$3m=6$	M1		M1: Solving equation
	$m=2$	A1	4	A1: Correct m from correct working Note: Deduct one mark for using mg instead of m
(b)	$4-3=5V$	M1		M1: Conservation of momentum equation for component containing V
		A1		A1: Correct equation
	$V=0.2$	A1	3	A1: Correct V
	Total		**7**	

3. Jan 2006

1(a)(i)	$40=12+100a$	M1		Use of a constant acceleration equation to form equation for a
	$a=\frac{40-12}{100}=0.28$ ms^{-2} AG	A1	2	AG; correct answer from correct working
(ii)	$s=\frac{1}{2}(12+40)\times100$	M1		Expression for distance, using t =100
	$=2600$ m	A1	2	Correct final distance
(c)	$F-40000=200\times1000\times0.28$	M1		Three term equation of motion
	$F=40000+56000=96000$ N	A1		Correct equation
		A1	3	Correct force
	Total		**7**	

4. June 2006

8(a)		B1	1	B1: Correct force diagram

(b)	$R + 20\sin 30° = 6g\cos 10°$ $R = 6g\cos 10° - 20\sin 30°$ $R = 47.9$ N (to 3 sf) **AG**	M1 A1 dM1 A1	4	M1: Resolving perpendicular to the slope with 3 terms A1: Correct equation dM1 Solving for R A1: Correct R from correct working
(c)	$F = \mu R$ $6 \times 0.4 = 20\cos 30° - 6g\sin 10° - \mu R$ $\mu R = 4.710$ $\mu = \frac{4.710}{47.91} = 0.0983$	M1 M1 A1 A1 dM1 A1	6	M1: Use of F = μR M1: Resolving parallel to slope to get 4 term equation of motion A1: Correct equation A1: Correct F / μR dM1: Solving for μ A1: AWRT 0.098
	Total		**11**	

5. Jan 2007

1(a)	$3 \times 4 + 2 \times (-4) = 5v$ $4 = 5v$ $v = \frac{4}{5} = 0.8$	M1 A1 A1	 3	Three term equation for conservation of momentum. Correct equation Correct speed (for use of mg instead of m deduct the first A1)
(b)	$3 \times 4 + 2 \times (-4) = 3 \times 0.4 + 2v$ $4 = 1.2 + 2v$ $v = \frac{4 - 1.2}{2} = 1.4$	M1 A1 A1	 3	Four term equation for conservation of momentum. Correct equation Correct speed (for use of mg instead of m deduct the first A1)
			6	

6. June 2007

2(a)	$2\begin{bmatrix} 3 \\ -2 \end{bmatrix} + 3\begin{bmatrix} -4 \\ 1 \end{bmatrix} = 5\mathbf{v}$ $\mathbf{v} = \frac{1}{5}\begin{bmatrix} -6 \\ -1 \end{bmatrix} = \begin{bmatrix} -1.2 \\ -0.2 \end{bmatrix}$	M1 A1 A1	 3	Three term vector equation, with a '+' sign, for conservation of momentum Correct equation Deduct this first A mark for use of mg Correct velocity
(b)	$v = \sqrt{1.2^2 + 0.2^2} = 1.22 \text{ ms}^{-1}$	M1 A1F	 2	Finding speed from their velocity in part (a) (Must include addition of two terms) Correct speed from their velocity Accept 1.21
	Total		**5**	

7. Jan 2008

4. (a)(i)	$5\begin{bmatrix} 2U \\ U \end{bmatrix} + 15\begin{bmatrix} V \\ -1 \end{bmatrix} = 20\begin{bmatrix} V \\ 0 \end{bmatrix}$ $5U - 15 = 0$ $U = 3$	M1 dM1 A1F	 3	Three term equation for conservation of momentum. Equation for U based on conservation of momentum. Correct value for U. Deduct one mark for using weight instead of mass.

(a)(ii)	$30+15V=20V$ $30=5V$ $V=\frac{30}{5}=6$	M1 A1F	 2	Equation for V based on conservation of momentum. Correct value for V. Deduct one mark for using weight instead of mass.
(b)	$v=\sqrt{3^2+6^2}=3\sqrt{5}=6.71\ \text{ms}^{-1}$	M1 A1F	 2	Calculation of speed. Correct speed. Allow $\sqrt{45}$
	Total		**7**	

8. June 2008

8(a)	$2m-2\times3=m\times(-0.5)+3\times0.5$ $2.5m=7.5$ $m=3$ kg	M1 A1 A1	 3	Equation for conservation of momentum with four terms: $2m$, 2×3, $0.5m$ and 3×0.5 regardless of signs. Correct equation with correct signs Correct mass Arguments based on the symmetry of the situation that lead to $m = 3$ can be awarded full marks. Note: Consistent use of mg instead of m: deduct one mark. Note: Use of all positive signs leads to $m = -3$, which might be changed to +3 by candidates (M1A0A0). Note: $m = 3$ can be obtained via $1.5m = 4.5$, which will usually score M1A0A0
(b)	$2m-2\times3=m\times0.5+3\times0.5$ $1.5m=7.5$ $m=5$ kg or $2m-2\times3=m\times(-0.5)+3\times(-0.5)$ $2.5m=4.5$ $m=1.8$ kg	M1 A1 A1 M1 A1	 5	Four term equation for conservation of momentum with ±0.5 for both velocities (no marks for $3m\times0.5$) Correct equation Correct mass for velocity used Equation for conservation of momentum with opposite sign for the 0.5 Correct mass for the velocity used
	Total		**8**	

9. Jan 2009

1	$2.5\times12+1.5\times4=4v$ $v=\frac{36}{4}=9\ \text{ms}^{-1}$	M1 A1 A1	 3	M1: Three term momentum equation, correct values but condone incorrect signs. A1: Correct equation with correct signs. A1: Correct speed Note: Consistent use of mg instead of m throughout deduct 1 mark.
	Total		**3**	

10.June 2009

1(a)	$3\begin{bmatrix}6\\-2\end{bmatrix}+7\begin{bmatrix}-1\\4\end{bmatrix}=10\mathbf{v}$	M1 A1		M1: Forming three term equation for conservation of momentum, but condone incorrect signs. Must see combined mass of 10. A1: Correct equation with correct signs.

		A1		A1: Correct equation with correct signs. Accept $3\begin{bmatrix}6\\-2\end{bmatrix}+7\begin{bmatrix}-1\\4\end{bmatrix}=3\mathbf{v}+7\mathbf{v}$ oe
	$\mathbf{v}=\frac{1}{10}\begin{bmatrix}11\\22\end{bmatrix}=\begin{bmatrix}1.1\\2.2\end{bmatrix}$	A1	3	A1: Correct velocity Consistent use of mg instead of m throughout deduct 1 mark
(b)	$v=\sqrt{1.1^2+2.2^2}$	M1		M1: Finding speed. Must be + inside square root.
	$v=2.46\ \text{ms}^{-1}$	A1F	2	A1F: Correct speed for their velocity Accept $1.1\sqrt{5}$ or $\frac{11\sqrt{5}}{10}$ or 2.45 or AWRT 2.46
	Total		**5**	

11.Jan 2010

1	$7\times10+3\times20=10v$	M1 A1		M1: Three term equation for conservation of momentum. Do not penalise inclusion of negative signs. Must see a combined mass of 10. A1: Correct equation. Accept $3v+7v$ in place of $10v$.
	$v=\frac{130}{10}=13\ \text{ms}^{-1}$	A1	3	A1: Correct speed. Consistent use of mg instead m throughout deduct 1 mark.
	Total		**3**	

12.June 2010

3(a)	$6\begin{bmatrix}2\\4\end{bmatrix}+m\begin{bmatrix}3\\-2\end{bmatrix}=6\begin{bmatrix}1\\3\end{bmatrix}+m\begin{bmatrix}7\\b\end{bmatrix}$	M1 A1		M1: Four term conservation of momentum equation. Allow sign errors. A1: Correct equation with correct signs. Vector equation may be implied by later correct working in this part of the question.
	$6\times2+3m=6\times1+7m$	A1		A1: Correct equation for correct component.
	$12+3m=6+7m$ $6=4m$ $m=1.5$	A1	4	A1: Correct m. Example if only $12+3m=6-7m$ without a vector equation award M1A0A0A0.
(b)	$6\times4+1.5\times(-2)=6\times3+1.5b$	B1F		B1F: Correct equation using m or candidates m from (a).
	$24-3=18+1.5b$ $3=1.5b$ $b=2$	B1F	2	B1F: Correct b from candidate's m from (a). Note: $b=\frac{6}{m}-2$
	Total		**6**	
				Consistent use of mg instead of m throughout penalise 1 mark.

13.Jan 2011

1	$5\times6=(m+5)\times2.4$ $30=2.4m+12$ $m=\frac{30-12}{2.4}=7.5$	M1A1 A1	3	M1: Equation for conservation of momentum with correct number of terms. A1: Correct equation. A1: Correct mass CAO Consistent use of weight instead of mass penalise final A1 mark.
	Total		**3**	

14.June 2011

4 (a)	$6(5\mathbf{i}+18\mathbf{j})+m(2\mathbf{i}-5\mathbf{j})=6(8\mathbf{i})+m(V\mathbf{j})$ $6\times5+2m=6\times8$ $30+2m=48$ $m=\frac{48-30}{2}=9$	M1 A1 A1	3	M1: Conservation of momentum, with addition of terms, as either 4 term vector equation (seen either in part (a) or part (b) **OR** three term equation for **i** component. Allow one error, for example switching masses. A1: Correct equation for **i** components. A1: Correct m.
(b)	$6\times18-5\times9=9V$ $108-45=9V$ $V=\frac{108-45}{9}=7$	M1A1F A1F	3	M1: Conservation of momentum for **j** component with correct signs. Allow one error, for example switching masses. Note: omitting any mass scores M0. A1F: Correct equation. Allow m instead of 9 at this stage. A1F: Correct velocity. Condone 7**j** FT candidate's mass from part (a). Only award FT marks if mass positive. Note $V=\frac{108}{m}-5$
	Total		**6**	

15.Jan 2012

1	$7(3\mathbf{i}+8\mathbf{j})+3(6\mathbf{i}-5\mathbf{j})=10\mathbf{v}$ $\mathbf{v}=3.9\mathbf{i}+4.1\mathbf{j}$	M1A1 A1	3	M1: Three term equation for conservation of momentum with addition of terms and total mass of 10. Allow one error, for example switching masses or omitting negative sign in velocity. A1: Correct equation for velocity. A1: Correct velocity. Accept $\begin{bmatrix}3.9\\4.1\end{bmatrix}$ Finding speed as 5.66 without showing velocity scores M1 A0 A0 Finding speed after having correct velocity should be considered as further work and not penalised. Note: For consistent use of weight deduct one mark.
	Total		**3**	

16.June 2012

2	$2\times4+3m=3.8(2+m)$ $8+3m=7.6+3.8m$ $0.4=0.8m$ $m=\frac{0.4}{0.8}=0.5$ kg	M1A1 A1	 3	M1: Three term equation for conservation of momentum with correct RHS. Allow $2\times4-3m$ on the LHS A1: Correct equation. A1: Correct answer. Note for consistent use of weight instead of mass penalise by one mark. Allow use of any letter for the mass.
	Total		**3**	

17.Jan 2013

5	Case 1: where 0.6 is taken as positive $5\times4-4\times3=5\times0.6+4v$ $8=3+4v$ $v=1.25$ m s^{-1} Case 2: where 0.6 is taken as negative $5\times4-4\times3=5\times(-0.6)+4v$ $8=-3+4v$ $v=2.75$ m s^{-1}	M1A1 A1 M1A1 A1	 6	M1: Conservation of momentum, with left hand side as $5\times4\pm4\times3$. A1: Correct equation ($8=3+4v$ OE). A1: Correct speed (1.25). M1: Seeing one of $8=-3\pm4v$ or $-8=3\pm4v$ or $32=-3\pm4v$ or $-32=3\pm4v$ OE A1: Seeing ±2.75 or $\pm\frac{11}{4}$ A1: Correct speed. Accept $\frac{11}{4}$ If mg used consistently instead of m deduct one mark, to give a maximum of 5 marks.
	Total		**6**	