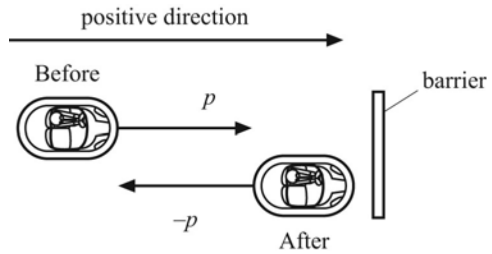
1 Marking scheme: Worksheet

1 Momentum = mass × velocity [1]
SI unit of momentum is kg m s^{-1}. [1]

2 Momentum is a vector quantity – it has both direction and magnitude. [1]

If the initial momentum of the car is $+p$, then its final momentum must be $-p$ (see diagram).



Change in momentum, Δp = final momentum – initial momentum

$\Delta p = -p - p = -2p$ (the change is not zero) [1]

3 a $\Delta p = (2.0 \times 8.0) - (2.0 \times 4.0)$ [1]
$\Delta p = +8.0$ kg m s^{-1} [1]
b $\Delta p = (2.0 \times -4.0) - (2.0 \times 3.0)$ [1]
$\Delta p = -14$ kg m s^{-1} [1]
c $\Delta p = (2.0 \times 8.0) - (2.0 \times -5.0)$ [1]
$\Delta p = +26$ kg m s^{-1} [1]

4 Momentum = mass × velocity

Lorry: $p = mv = 10 \times 10^3 \times 20 = 2.0 \times 10^5$ kg m s^{-1} [1]

Dust: $p = mv = 1.5 \times 10^{-3} \times (20 \times 10^3) = 30$ kg m s^{-1} [1]

The lorry has greater momentum. [1]

5 a $v^2 = u^2 + 2as$; $u = 0$ [1]
$v^2 = 0 + (2 \times 9.81 \times 1.5) = 29.43$ m^2 s^{-2} [1]
Hence, $v = \sqrt{29.43} = 5.4249$ m $s^{-1} \approx 5.4$ m s^{-1} [1]

b Final speed of ball = $\dfrac{5.42}{2}$ = 2.71 m s^{-1}

Δp = final momentum – initial momentum
$\Delta p = -(0.200 \times 2.71) - (0.200 \times 5.42)$ [1]
$\Delta p \approx 1.6$ kg m s^{-1} (magnitude only) [1]

6 a $p = mv = 20 \times 180$ [1]
$p = 3.6 \times 10^3$ kg m s^{-1} [1]
b The momentum is conserved in this explosion. The momentum of the cannon is equal in magnitude but opposite in direction to that of the shell. [1]
Momentum of the cannon = 3.6×10^3 kg m s^{-1} [1]
c Using the answer from **b**, we have:
$850 \times V = 3.6 \times 10^3$ [1]
$V = \dfrac{3.6 \times 10^3}{850}$ [1]
$V \approx 4.2$ m s^{-1} [1]

7 a Initial momentum = final momentum [1]

$900 \times 28 = (1500 + 900) \times V$ (V = combined velocity) [1]

$V = \dfrac{900 \times 28}{2400}$ [1]

$V = 10.5\ \text{m s}^{-1} \approx 11\ \text{m s}^{-1}$ [1]

b Kinetic energy $= \dfrac{1}{2}mv^2$ [1]

initial kinetic energy $= \dfrac{1}{2} \times 900 \times 28^2 = 3.53 \times 10^5\ \text{J} \approx 3.5 \times 10^5\ \text{J}$ [1]

final kinetic energy $= \dfrac{1}{2} \times 2400 \times 10.5^2 = 1.32 \times 10^5\ \text{J} \approx 1.3 \times 10^5\ \text{J}$ [1]

c The collision is inelastic because there is a decrease in the kinetic energy of the system. Some of the initial kinetic energy is transformed to other forms, such as heat. [1]

8 Initial momentum = final momentum [1]

$(1.2 \times 4.0) + (0.80 \times -2.5) = (1.2 \times 1.0) + (0.80 \times v)$ [1]

$2.80 = 1.20 + 0.80v$

$v = \dfrac{2.80 - 1.20}{0.80}$ [1]

$v = 2.0\ \text{m s}^{-1}$ to the right [1]

9 a Initial momentum of bullet = final momentum of bullet and block [1]

$0.030 \times 140 = 0.490v$ (final total mass = 460 + 30 = 490 g) [1]

$v = \dfrac{0.030 \times 140}{0.490}$ [1]

$v = 8.57\ \text{m s}^{-1} \approx 8.6\ \text{m s}^{-1}$ [1]

b Kinetic energy $= \dfrac{1}{2}mv^2$ [1]

initial kinetic energy $= \dfrac{1}{2} \times 0.030 \times 140^2 = 294 \approx 290\ \text{J}$ [1]

final kinetic energy $= \dfrac{1}{2} \times 0.490 \times 8.57^2 \approx 18\ \text{J}$ (~ 6% of initial KE) [1]

c Kinetic energy is not conserved, so the collision is inelastic. [1]

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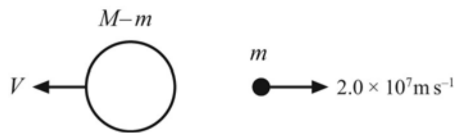


Momentum is conserved so $p_{\text{nucleus}-\alpha} = p_\alpha = p$ [1]

Kinetic energy KE $= \dfrac{1}{2}mv^2$ and momentum $= mv$, so KE $= \dfrac{p^2}{2m}$ [1]

$\text{KE}_\alpha = \dfrac{p^2}{2m}$

$\text{KE}_{\text{nucleus}-\alpha} = \dfrac{p^2}{2(M-m)} = \dfrac{p^2}{2(55-1)m} = \dfrac{1}{54}\left(\dfrac{p^2}{2m}\right)$ [1]

$\text{KE}_{\text{total}} = \dfrac{p^2}{2m} + \dfrac{1}{54}\left(\dfrac{p^2}{2m}\right) = \dfrac{55}{54}\left(\dfrac{p^2}{2m}\right)$ [1]

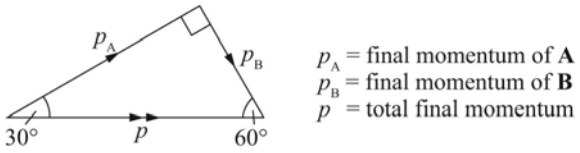
ratio $= \dfrac{\text{KE}_\alpha}{\text{KE}_{\text{total}}} = \dfrac{p^2}{2m} \Big/ \dfrac{55}{54}\left(\dfrac{p^2}{2m}\right) = \dfrac{54}{55} = 0.982 \approx 0.98$ [1]

The kinetic energy of the α-particle is about 98% of the final total kinetic energy. [1]

11 a Momentum is a vector quantity and is conserved.
It has no component at right-angles ($p \cos 90° = 0$), hence momentum in a direction at right angles to the initial momentum must be zero. [1]
Hence, $2.6 \sin 30° = 1.5 \sin \theta$ [1]
$\theta = \sin^{-1}\left(\frac{2.6 \sin 30}{1.5}\right) = 60°$ [1]

b Initial momentum = $1.2 \times 3.0 = 3.6$ kg m s^{-1} in the direction of **A**'s initial velocity. [1]

Momentum can be added vectorially.



The angle between the final velocities (and hence momentum) of **A** and **B** is 90°. [1]
The final momentum p is the vector sum of the momentum of **A** and the momentum of **B**.
final momentum $p = \sqrt{(1.2 \times 2.6)^2 + (1.2 \times 1.5)^2} = 3.6$ kg m s^{-1} [1]
The initial momentum and the final momentum are the same.
OR
Initial momentum = $1.2 \times 3.0 = 3.6$ kg m s^{-1} in the direction of **A**'s initial velocity. [1]
final momentum = sum of momentum components [1]
final momentum parallel to **A**'s initial velocity = $(1.2 \times 2.6) \cos 30° + (1.2 \times 1.5) \cos 60°$
$= 3.6$ kg m s^{-1} [1]
The initial momentum and the final momentum are the same. (From part **a**, the components of momentum at right-angles to **A**'s initial velocity are zero.)

