Checkpoints Chapter 4 Momentum

Question 1

Momentum is conserved in all collisions, and energy is only conserved if the collision is elastic. It is reasonable to assume that KE is not conserved in this (and most) collisions.

∴ C (ANS)

Question 2

In every collision, momentum is conserved. So the initial momentum must equal the final momentum.

Momentum (p) = mv.

∴ $p_i = m \times 3 + m \times -6$

$p_i = -3m$

So $p_f = -3m$

A $\Sigma p = 4m - m = 3m$

B $\Sigma p = -3m + 0 = -3m$

C $\Sigma p = -1.5\,m - 1.5\,m = -3m$

D $\Sigma p = -5.5m + 2.5\,m = -3m$

At this stage B, C, and D are all possibilities, from a momentum perspective.

∴ A is impossible (ANS)

Question 3

In every collision, momentum is conserved. So the initial momentum must equal the final momentum, since the blocks stick together, they will both have the same speed.

∴ $p_i = 1.2 \times 3 + 2.4 \times 0$

∴ $p_i = 3.6$ kg m s^{-1}

Since $p_f = p_i$

$p_f = 3.6$

∴ $3.6 = (1.2 + 2.4) \times v$

∴ $v = 1.0$ m s^{-1}

∴ A (ANS)

Question 4

Momentum is always conserved. Initial momentum = 3.6 kg m s^{-1}.

Calculate the final momentums

A $1.2 \times 2 + 2.4 \times 1$

= 4.8

∴ momentum is not conserved

B $1.2 \times 1 + 2.4 \times 2$

= 6.0

∴ momentum is not conserved

C $1.2 \times 1.5 + 2.4 \times 1.5$

= 5.4

∴ momentum is not conserved

D $1.2 \times 0 + 2.4 \times 1.5$

= 3.6

∴ momentum is conserved

∴ From a simplistic momentum point of view, the only possible answer is D.

Since the collision is elastic, the initial KE must be the same as the final KE.

$KE_i = \frac{1}{2}mv^2$

∴ $KE_i = \frac{1}{2} \times 1.2 \times 3^2 + \frac{1}{2} \times 2.4 \times 0^2$

∴ $KE_i = 5.4$ J

Calculate the final KE.

A $KE_f = \frac{1}{2} \times 1.2 \times 2^2 + \frac{1}{2} \times 2.4 \times 1^2$

= 3.6 J

B $KE_f = \frac{1}{2} \times 1.2 \times 1^2 + \frac{1}{2} \times 2.4 \times 2^2$

= 5.4 J

C $KE_f = \frac{1}{2} \times 1.2 \times 1.5^2 + \frac{1}{2} \times 2.4 \times 1.5^2$

= 4.05 J

D $KE_f = \frac{1}{2} \times 1.2 \times 0^2 + \frac{1}{2} \times 2.4 \times 1.5^2$

= 2.7 J

∴ From an energy point of view, the only possible answer is B.

If we consider that the 1.2 kg block has a speed of 1 m s^{-1}, if this was to the left, then the momentum equation would look like

B $1.2 \times -1 + 2.4 \times 2$

= 3.6 kg m s^{-1}

∴ B (ANS)

Question 5

The impulse is the change in momentum of the ball. In this case that is the same as the final momentum of the ball.

Momentum u=is conserved in all collisions,

∴ $p_i = 0.250 \times 30 + 0.050 \times 0$

∴ $p_i = 7.5$ kg m s^{-1}

$p_{f\,(club\ head)} = 0.250 \times 22$

= 5.5 kg m s^{-1}

∴ loss of momentum (club head) is the same as the gain in momentum of the ball.

∴ 2.0 N s.

∴ C (ANS)

Question 6

Use p = mv

∴ $2.0 = 0.050 \times v$

∴ $v = 40$ m s^{-1}

∴ C (ANS)

Question 7

$KE_i = \frac{1}{2} \times 0.250 \times 30^2 + \frac{1}{2} \times 0.050 \times 0^2$

∴ $KE_i = 112.5$ J

$KE_f = \frac{1}{2} \times 0.250 \times 22^2 + \frac{1}{2} \times 0.050 \times 40^2$

∴ $KE_f = 100.5$ J

∴ B (ANS)

Question 8

If the two objects have masses m_1 and m_2, where $m_1 \neq m_2$.
This situation implies that (from a momentum point of view),
$m_1u_1 + m_2u_2 = (m_1 + m_2)v$, since they travel at the same speed.
A Implies that the final speed is zero, this will not ALWAYS happen. ∴ A is incorrect.
B Implies that the final speed is above zero, this can happen. ∴ B is correct.
C The solution for this becomes quite tricky, and well beyond the scope of the course. Don't worry if my algebra is a bit complicated.
For the collision to be elastic $KE_f = KE_i$
$\therefore \frac{1}{2} \times m_1 \times u_1^2 + \frac{1}{2} \times m_2 \times u_2^2 = \frac{1}{2}(m_1 + m_2)v^2$
and $m_1u_1 + m_2u_2 = (m_1 + m_2)v$
We need to solve these two simultaneous equations.
Square the second equation, to get
$(m_1u_1)^2 + 2m_1m_2u_1u_2 + (m_2u_2)^2 = (m_1 + m_2)^2v^2$

Multiply the first equation by $2(m_1 + m_2)$ to get
$m_1u_1^2(m_1 + m_2) + m_2u_2^2(m_1 + m_2) = (m_1 + m_2)^2v^2$

The LHS of these two equations must be equal.
$\therefore (m_1u_1)^2 + 2m_1m_2u_1u_2 + (m_2u_2)^2 =$
$m_1u_1^2(m_1 + m_2) + m_2u_2^2(m_1 + m_2)$
Expand RHS to get
$\therefore (m_1u_1)^2 + 2m_1m_2u_1u_2 + (m_2u_2)^2 = m_1^2u_1^2 +$
$m_1m_2u_1^2 + m_2m_1u_2^2 + m_2^2u_2^2$
$\therefore 2m_1m_2u_1u_2 = m_1m_2u_1^2 + m_2m_1u_2^2$
Divide BS by m_1m_2
$\therefore 2u_1u_2 = u_1^2 + u_2^2$
$\therefore u_1^2 - 2u_1u_2 + u_2^2 = 0$
$\therefore (u_1 - u_2)^2 = 0$
$\therefore u_1 = u_2$
If the two objects have the same velocity, then they will never collide, so C is not true.
D is not true.
∴ B (ANS)

Question 9 (2010 Q16, 2m, 60%)

Momentum is conserved in all collisions. Therefore the graph needs to be a constant straight line.
∴ B (ANS)

Question 10 (2010 Q17, 2m, 40%)

Momentum is conserved in all collisions. Therefore the graph needs to be a constant straight line. Conservation of Energy is independent of momentum.
∴ B (ANS)

Question 11 (2017 Q8, 1m, %)

Use $I = F \times \Delta t$
$\therefore I = 4.0 \times 5.0$
$\therefore I = 20$ N s
∴ C (ANS)

Question 12 (2017 Q9, 1m, %)

Use $F \times \Delta t = m \times \Delta v$
$\therefore 4 \times 10 = 2.0 \times \Delta v$
$\therefore \Delta v = 20 \text{ m s}^{-1}$
∴ C (ANS)

Question 13

Momentum is conserved in all collisions.
$\therefore p_i = 500 \times 5 = 2500$ Ns.
$\therefore p_f = 2500 = 3000 \times 1 + 500v$
$\therefore v = -1$ m/s
The answer is actually 1 m/s. The negative sign means that the car travels backwards.

Question 14

Momentum is conserved if $p_i = p_f$
$p_i = m \times 2 + m \times 0$
$= 2m$ (Ns)
$p_f = m \times 0.5 + m \times 1.5$
$= 2m$ (Ns)
∴ Momentum is conserved.

Question 15a

This is a question on conservation of momentum.
∴The initial momentum is equal to the final momentum.
$P_i = m_1u_1 + m_2u_2$
$= 55 \times 5 + 45 \times 1$
$= 275 + 45$
$= 320$

$P_f = v(m_1 + m_2)$
$= v \times 100$
$\therefore v = 320 \div 100$
$\mathbf{= 3.2 \text{ m s}^{-1}}$ **(ANS)**

Question 15b

Jack and Jill will continue at the same speed and direction as they were before they let go. This is because neither have had a net force acting on them (∴ no change in momentum to either)

Question 16a

In every collision you will need to consider momentum will always be conserved. So as soon as you see a collision problem, you immediately think momentum, this will give you all the velocities and the masses, you can then use these to see what happens to the energies in the collision.

$\therefore\ p_i = \Sigma mv$
$= 150 \times 6 + 150 \times 0$
$= 900$ kgm/s
$\therefore\ p_f = \Sigma mv = 450 \times v_f$
$\therefore\ v_f = 900 \div 450$
= 2 m s^{-1} (ANS)

Think about this answer. Does it make sense that when the car collides with another two the same size, and they all stick together, then the final speed will be a third of the initial speed.

Question 16b

The change in momentum is given by
$p_f - p_i = 150 \times 2 - 150 \times 6$
= 600 kg m s^{-1}(ANS)

Question 16c

Impulse = change in momentum
$= p_f - p_i$
$= 300 \times 2 - 300 \times 0$
= 600 kg m s^{-1} (ANS)

This answer must be the same as the previous question, because the momentum lost by the first car must be the same as the impulse given to the other 2.

Question 17a

The total momentum is given by the sum of the individual momentums. You need to consider the vector nature of momentum.
Assume that to the left is positive.

$\therefore\ \Sigma p = M \times U - m \times U$
$\therefore\ \Sigma p = MU - mU$

Question 17b

The question has a slight typo in it. You are expected to use the variables U, m and M.
Since momentum is always conserved, the final momentum must be the same as the initial.

$\therefore\ MU - mU = (M + m)V$

$$\therefore\ V = \frac{(M - m)U}{(M + m)}$$ **(ANS)**

Question 18a

Use $F\Delta t = m\Delta v$.
$\therefore\ F\Delta t = 7.0 \times 8.0$
= **56 N s (ANS)**

Question 18b

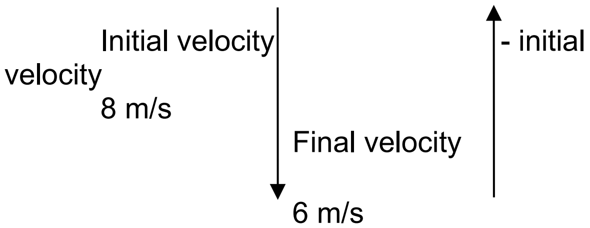
The airbag is designed to increase the time of the collision. It expands rapidly and is already deflating by the time the head comes into contact with it. This deflating bag increases the time of collision greatly.
From the equation $F\Delta t = m\Delta v$ it can be seen that an increase in Δt for a fixed value of $m\Delta v$ will lead to a decrease in F.
The larger F is, the greater the risk that parts of the body will undergo forces that will push the body beyond its elastic limit, resulting in injury.

Question 19

Momentum is conserved.
$\therefore$ initial momentum = final momentum
$\therefore 6.6 \times 10^{-23} = 1.1 \times 10^{-22} + p_{\text{photon after collision}}$
$\therefore 6.6 \times 10^{-23} = 11 \times 10^{-23} + p_{\text{photon after collision}}$
$\therefore$ **$p_{\text{photon after collision}} = 4.4 \times 10^{-23}$ N s (ANS)**
(to the left), since momentum is a vector.

Question 20a

The definition of change in velocity is final velocity - initial velocity.



So the change in velocity is

Which is **14 m s^{-1} up (ANS)**

Question 20b

The definition of Impulse is the change in momentum. $\Delta p = m\Delta v$
$\therefore \Delta p = 0.400 \times 14$
= 5.6 N s (ANS)
make sure that you use the correct units; the mass needs to be in kg.

Question 20c

Use $F\Delta t = m\Delta v$

$$F = \frac{\Delta p}{\Delta t}$$
$$= \frac{5.6}{80 \times 10^{-3}}$$
$$= \mathbf{70\ N} \quad \textbf{(ANS)}$$

Question 21

In a car accident, the object (human body) needs to come to rest from its initial speed. This means that it needs to lose momentum. This loss of momentum is given by Impulse = $F\Delta t = m\Delta v$.
For a body of fixed mass, and a set speed, then the larger 't' is then the smaller 'F' is.
This smaller 'F' means that the seatbelts etc. exert a smaller force on the body, leading to fewer injuries.

Question 22

If we assume that it is a frictionless environment in space, and since momentum is conserved in the collision, if they stick together, they will move off at the same speed.
On a table on Earth, the combined system will lose energy due to the friction between the masses and the table. Whilst this is happening the masses are transferring momentum to the table, because the masses are effectively colliding with the table as the slide along this surface involving friction.
The principle of conservation of momentum applies in both scenarios.

Question 23 (2012 Q2, 3m, 30%)

Initial momentum is given by
$mv = 1.2 \times v$ to the right

The block rebounds, so its new momentum is to the left.

As the change in momentum of the 1.2 kg block is given by final momentum – initial momentum, when the change in direction is taken into consideration, this is effectively the scalar sum of the momenta, but to the left.

This will be greater than the initial momentum of the 1.2 kg mass.

From conservation of momentum, this change in momentum of the 1.2 kg mass must be equal to the change in momentum of the 2.4 kg mass.

Question 24 (2014 Q1c, 2m, 80%)

Momentum is conserved therefore the initial momentum will be equal to the final momentum.

$p_i = 40\,000 \times 4 = 160\,000$

$\therefore\ 160\,000 = (40\,000 + 40\,000) \times v$

$\therefore\ 160\,000 / 80\,000 = 2.0$

$\therefore$ 2.0 m s^{-1} (ANS)

Question 25a (2013 Q3a, 1m, 80%)

$P_{total} = P_{initial}$

$= 2 \times 6 + 4 \times 0$

= 12 kg m s^{-1} (ANS)

Question 25b (2013 Q3c, 2m, 55%)

Impulse = Δp

$\therefore \Delta p_1 = m \times \Delta v$

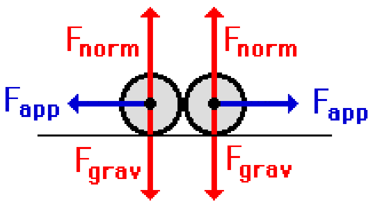
$= 2 \times 4$

= 8 N s to the Left (ANS)

Question 26

A system is a collection of two or more objects. An isolated system is a system which is free from the influence of a net external force which alters the momentum of the system.

A system in which the only forces which contribute to the momentum change of an individual object are the forces acting between the objects themselves can be considered an isolated system.



Example

Consider the collision of two balls on the billiards table. The collision occurs in an isolated system as long as friction is small enough that its influence upon the momentum of the billiard balls can be neglected. If so, then the only unbalanced forces acting upon the two balls are the contact forces which they apply to one another. For such a collision, total system momentum is conserved.

Question 27a (2015 Q1a 2m, 45%)

Momentum is conserved, so the final momentum is equal to the initial momentum.

$p_i = 4.0 \times 8.0 + 8.0 \times 0$

$\therefore\ p_i = 32.0$

The key word in this question is “rebounds”. This means that block A ends up travelling in the opposite direction.

$\therefore\ p_f = 32.0$

$\therefore\ 32.0 = 8.0 \times v - 4.0 \times 2$

$\therefore\ 32 = 8v - 8$

$\therefore$ v = 5 m s^{-1} (ANS)

Question 27b (2015 Q1c 3m, 63%)

The impulse by block B on block A is the change in momentum of block A. The direction of the change in momentum will be given by the final momentum minus the initial momentum. This is in the direction of the final momentum. The magnitude of the impulse by block B on block A i the same as the magnitude of the impulse by block A on Block B. For Block B, its initial momentum was zero, therefore its change in momentum is p_f.

$\therefore\ p_f = m\ \Delta v$

$\therefore\ p_f = 8 \times 5$

$\therefore\ p_f = 40$

$\therefore$ I = 40 N s left (ANS)

Question 28a (2016 Q1c 2m, 88%)

Momentum is conserved.

$\therefore\ p_i = p_f$

$\therefore\ 20\,000 \times 3 + 10\,000 \times 0 = 30\,000 \times v$

$\therefore\ 60\,000 = 30\,000 \times v$

$\therefore$ v = 2 m s^{-1} (ANS)

Question 28b (2016 Q1e 3m, 80%)

Momentum is conserved.

$\therefore\ p_i = p_f$

$\therefore\ 20\,000 \times 2 + 10\,000 \times 0 = 20\,000 \times v + 10\,000 \times 2$

$\therefore\ 40\,000 = 20\,000 \times v + 20\,000$

$\therefore\ 20\,000 = 20\,000 \times v$

$\therefore$ v = 1 m s^{-1} Right (ANS)

Question 29 (2016 Q4c 2m, 65%)

The Impulse will give rise to the change in momentum.

The change in momentum = m Δv

$\therefore\ 4 \times 2 = 8$

$\therefore$ 8 N s (ANS)

I prefer N s for Impulse and kg m s^{-1} for change in momentum.

Question 30 (2017 Q12 3m, %)

Use momentum to find the final velocity.

$\therefore\ 4.0 \times 5.0 + 2.0 \times 2.0 = 6.0 \times v$

$\therefore$ 24.0 = 6.0 × v
$\therefore$ v = 4.0 m s^{-1}

The initial KE is

$\frac{1}{2} \times 4.0 \times 5.0^2 + \frac{1}{2} \times 2.0 \times 2.0^2$
= 50 + 4
= 54 J

Final KE is

$\frac{1}{2} \times 6.0 \times 4.0^2$
48 J

$\therefore$ KE is not conserved, so the collision is inelastic.