Checkpoints Chapter 4 Momentum

Question 136

C, D, E (ANS)
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 $\Sigma p = -7m + 4m = -3m$
B $\Sigma p = 4m - m = 3m$
C $\Sigma p = -3m + 0 = -3m$
D $\Sigma p = -1.5m - 1.5m = -3m$
E $\Sigma p = -5.5m + 2.5m = -3m$
At this stage A, C, D, E are all possibilities. In any collision the energy (KE + PE) must be conserved or lost to other forms. If you consider the $KE_i = \frac{1}{2} \times m \times 3^2 + \frac{1}{2} \times m \times 6^2$
$= \frac{1}{2} \times m \times 45 = 22.5m$
The final KE must be no greater than this.
In 'A' KE = $\frac{1}{2} \times m \times 7^2 + \frac{1}{2} \times m \times 4^2 = 32.5m$.
This is greater than 22.5m.
∴ A is impossible. C, D, E remain possible.

Question 137

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

Question 138

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 139

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

$P_f = v(m_1 + m_2)$
$= v \times 100$
∴ $v = 320 \div 100$
= 3.2 m/s (ANS)

Question 140

The momentum is conserved in all collisions.
$KE_i = ½ \times 55 \times 5^2 + ½ \times 45 \times 1^2$
687.5 + 22.5 = 710 J
$KE_f = ½ \times 100 \times 3.2^2$
= 512 J
∴ Kinetic Energy is lost in this collision.
∴ C (ANS)

Question 141

Malachi and Sarah 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 142

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.
∴ $p_i = \Sigma mv$
$= 150 \times 6 + 150 \times 0$
= 900 kgm/s
∴ $p_f = \Sigma mv = 450 \times v_f$
∴ $v_f = 900 \div 450$
= 2 m/s (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 143

The change in momentum is given by
$p_f - p_i = 150 \times 2 - 150 \times 6$
= 600 kgm/s (ANS)

Question 144

Impulse = change in momentum
$= p_f - p_i$
$= 300 \times 2 - 300 \times 0$
= 600 kgm/s (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 145

Injuries are caused when a force acts on the body. If this force is large enough to take a part of the body past its elastic limit, then damage will be done to that part of the body. If the body inside the car is not restrained by seatbelts, then when the car comes to a sudden halt, there isn't anything to stop the body, so it will continue at the speed that it was travelling. The collision of the body with parts of the interior of the car at this speed are most likely to cause a lot of injury.

The impulse equation $F\Delta t = m\Delta v$, indicates that for a fixed change in momentum (ie. the car and body come to rest) then the larger Δt the smaller F will be.

Question 146

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.

$\therefore\ \Sigma p = M \times 5 - m \times 5$

$\therefore\ \Sigma p = 5M - 5m$

The other way of considering this is to use the final velocity. As momentum is conserved, the final momentum is also equal to the initial momentum. $P_f = (M + m) \times 1.5$

Question 147

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

$\therefore\ F\Delta t = 7.0 \times 8.0$

$= \mathbf{56\ Ns}$ **(ANS)**

Question 148

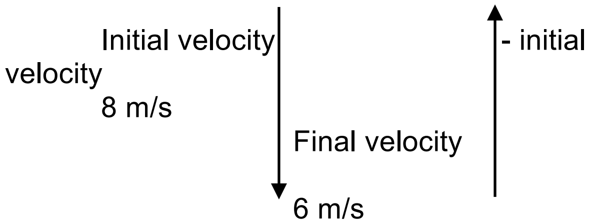
The airbag is designed to increase the time of the collision. It expands rapidly and is already deflating by the time the head comes into contact with it. This deflating bag increases the time of collision greatly.

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 149

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



So the change in velocity is

Which is **14 m/s up** **(ANS)**

Question 150

The definition of Impulse is the change in momentum. $\Delta p = m\Delta v$

$\therefore\ \Delta p = 0.400 \times 14$

$= \mathbf{5.6\ Ns}$ **(ANS)**

make sure that you use the correct units; the mass needs to be in kg.

Question 151

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

$$F = \frac{\Delta p}{\Delta t}$$

$$= \frac{5.6}{80 \times 10^{-3}}$$

$= \mathbf{70N}$ **(ANS)**

Question 152

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.

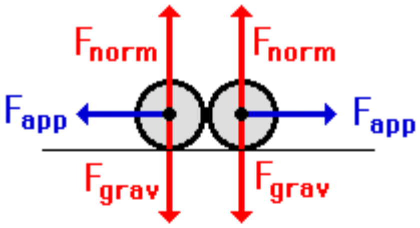
Question 153

If we assume that before the collision the surface is frictionless then momentum is conserved in the collision. Straight after the collision the speed of the combined masses will be 1m/s. The combined system will lose energy due to the friction between the blocks and the table. Whilst this is happening the blocks are transferring momentum to the table, because the blocks are effectively colliding with the table as the slide along this surface involving friction. The principle of conservation of momentum applies in both scenarios.
Note that the answer in the back of the book is for another question.

Question 154

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 155 (2010 Q16, 2m, 60%)

Momentum is conserved in all collisions. Therefore the graph needs to be a constant straight line.

∴ **B (ANS)**

Question 156 (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 157 (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 158 (2013 Q3a, 1m, 80%)

$P_{total} = P_{initial}$
$= 2 \times 6 + 4 \times 0$
$= 12$ kg m s^{-1} (ANS)

Question 159 (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 160 (2014 Q1c, 2m, 80%)

Momentum is conserved therefore the initial momentum will be equal to the final momentum.
$p_i = 40\,000 \times 4 = 160\,000$
$\therefore 160\,000 = (40\,000 + 40\,000) \times v$
$\therefore 160\,000 / 80\,000 = 2.0$
∴ **2.0 ms^{-1} (ANS)**
