

Practise Test 2

Momentum and Impulse

Q1

A white snooker ball travelling at 3m/s hits into a stationary red ball and then moves in the same direction with a speed of 1 m/s what is the speed of the red ball after the collision? Each ball has a mass of 0.2Kg.

Initial Momentum

$$m_1 u_1 + m_2 u_2 =$$

$$(0.2 \times 3) + (0.2 \times 0) = 0.6 \text{ kg ms}^{-1}$$

Final Momentum

$$m_1 v_1 + m_2 v_2 = 0.6 \text{ kg ms}^{-1}$$

$$0.2 \times (1) + 0.2 \times v_2 = 0.6 \text{ kg ms}^{-1}$$

$$0.2 \times v_2 = 0.6 - 0.2$$

$$0.2 \times v_2 = 0.4 \text{ kg ms}^{-1}$$

$$v_2 = \frac{0.4 \text{ kg ms}^{-1}}{0.2 \text{ kg}} = 2 \text{ ms}^{-1}$$

Q2

A 0.5kg cannon ball is fired from a 500kg cannon with a velocity of 25 m/s. What is the recoil velocity of the cannon?

Initial Momentum

0 kg m s⁻¹ !! Nothing is moving

Final Momentum

$$M_1 V_1 + M_2 V_2 = 0$$

$$500 V_1 + (0.5 \times 25) = 0$$

$$500 V_1 = -12.5 \text{ kg m s}^{-1}$$

$$V_1 = -12.5 / 500 = 0.025 \text{ m s}^{-1}$$

Q3

A loose train carriage of 5000Kg traveling at 5m/s couples with a second carriage at rest of mass 8000Kg. What is the final speed of the combined carriages?

Initial Momentum

$$m_1 u_1 + m_2 u_2 = (5000 \times 5) + (8000 \times 0) \\ = 25000 \text{ kg m s}^{-1}$$

Final Momentum

$$m_1 v_1 + m_2 v_2 \rightarrow \text{Carriages couple}$$

$$v_1 = v_2$$

$$(m_1 + m_2) v = 25000$$

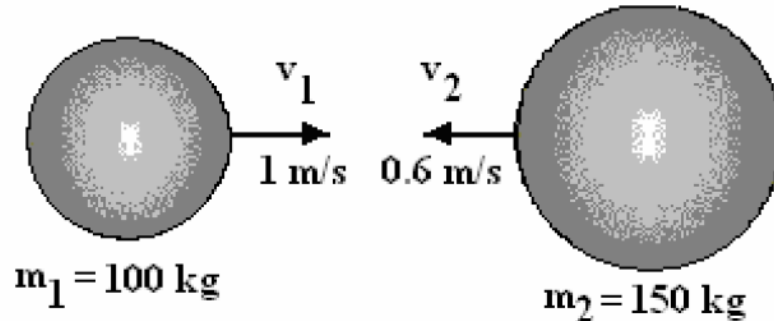
$$(5000 + 8000) v = 25000 \text{ kg m s}^{-1}$$

$$13000 v = 25000$$

$$v = 25000 / 13000 \approx 1.9 \text{ m s}^{-1}$$

Q4

A mass of 100 kg moves along a straight line at 1 m/s. It collides with a mass of 150 kg moving the opposite way along the same straight line at 0.6 m/s. The two masses join together on colliding to form one mass. Determine the velocity of the joint mass.



The normal sign convention must be used namely that motion from left to right is positive and from right to left is negative.

$$m_1 = 100 \text{ kg}$$
$$u_1 = 1 \text{ m/s}$$

$$m_2 = 150 \text{ kg}$$
$$u_2 = -0.6 \text{ m/s}$$

$$\text{Initial momentum} = (100 \times 1) + \{150 \times (-0.6)\} = 10 \text{ kg m/s}$$

$$\text{Final momentum} = 10 \text{ kg m/s (conserved)}$$

After collision the mass is 250 kg and the velocity is v .

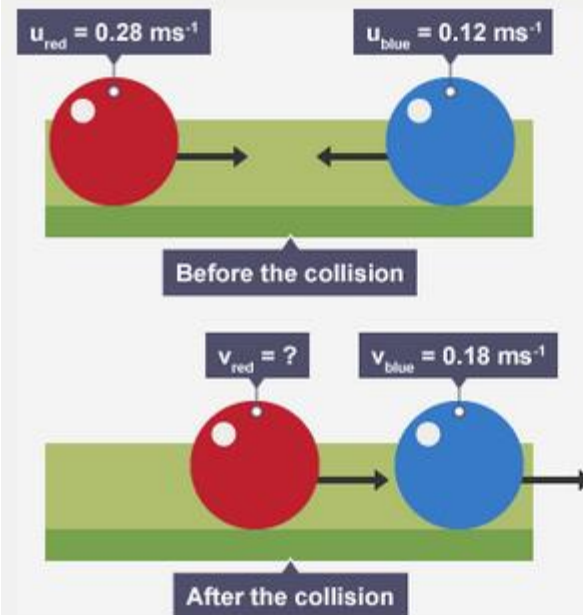
$$\text{Final momentum} = 250 v = 10 \quad v = 10/250 = 0.04 \text{ m/s}$$

The combined mass ends up moving to the left at 0.04 m/s.

Q5

A red and a blue snooker ball both having a mass of 160 g collide with speeds and directions as shown in the diagram below.

Before and after collision.



Calculate the velocity of the red ball after the collision and use kinetic energy to determine whether the collision was elastic or not.

Q5 continued

Total momentum before = total momentum after

$$m_{red}u_{red} + m_{blue}u_{blue} = m_{red}v_{red} + m_{blue}v_{blue}$$

$$0.16 \times 0.28 + 0.160 \times (-0.12) = 0.16 \times v_{red} + 0.16 \times 0.18$$

Rearranging:

$$0.16 \times v_{red} = (0.0448 - 0.0192) - 0.0288$$

$$= 0.0256 - 0.0288$$

$$= \frac{-0.0032}{0.16}$$

$$v_{red} = -0.02 \text{ m s}^{-1} \text{ ie right to left}$$

To determine if the collision is elastic or not, you must work out the kinetic energy before and after the collision.

Remember the equation for calculating kinetic energy in general is:

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

This example deals with two objects. The kinetic energy before the collision involves their initial speed, so the equation becomes:

$$E_k = \frac{1}{2}m_{red}(u_{red})^2 + \frac{1}{2}m_{blue}(u_{blue})^2$$

$$= 0.5 \times 0.16 \times (0.28)^2 + 0.5 \times 0.16 \times (0.12)^2$$

$$= 0.00627 + 0.00115$$

$$= 0.00742 \text{ J}$$

Total kinetic energy after collision:

$$\frac{1}{2}m_{red}(v_{red})^2 + \frac{1}{2}m_{blue}(v_{blue})^2$$

$$= 0.5 \times 0.16 \times (0.02)^2 + 0.5 \times 0.16 \times (0.18)^2$$

$$= 0.000032 + 0.00259$$

$$= 0.00262 \text{ J}$$

Total kinetic energy lost:

$$= 0.00742 - 0.00262$$

$$= 0.0048$$

48 mJ of energy is lost so the collision is inelastic.

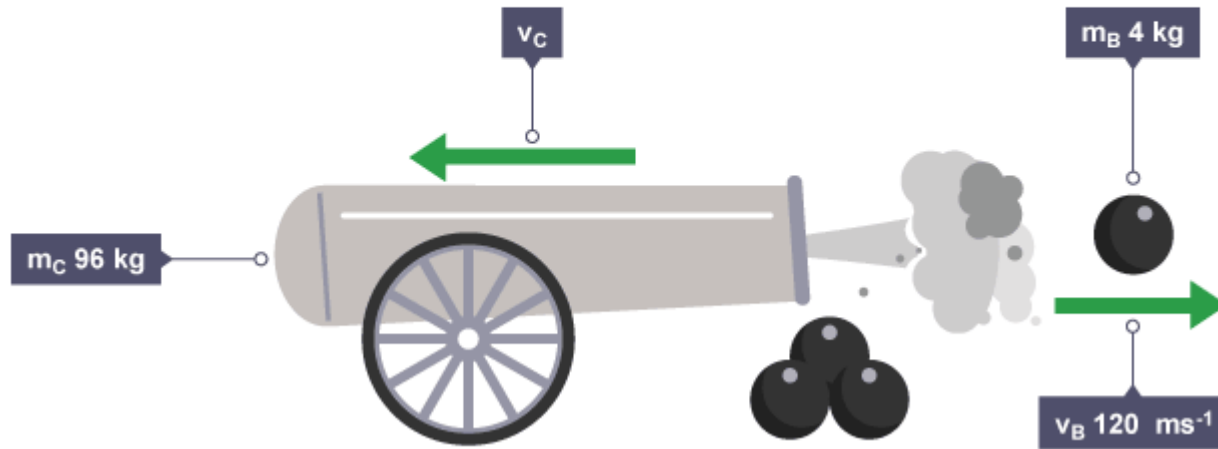
Q6

If two bumper cars collide head-on in a fairground and both cars come to a stop due to the collision, kinetic energy is obviously not conserved. Is momentum conserved even though both cars stop?

Yes, although there is no momentum after the collision, there was no total momentum before the collision. The positive momentum of one car must have been balanced out by the negative momentum of the other car.

Q7

Consider a cannon ball of mass m_B 4 kg fired at velocity v_B 120 ms^{-1} from a cannon of mass m_C 96 kg. This allows determination of the recoil **speed** of the cannon v_C .



The total momentum before is zero so by the law of conservation of momentum the momentum after the ball is fired is also zero.

$$m_B v_B + m_C v_C = 0 \text{ so:}$$

$$4 \times 120 + 96 \times v_C = 0$$

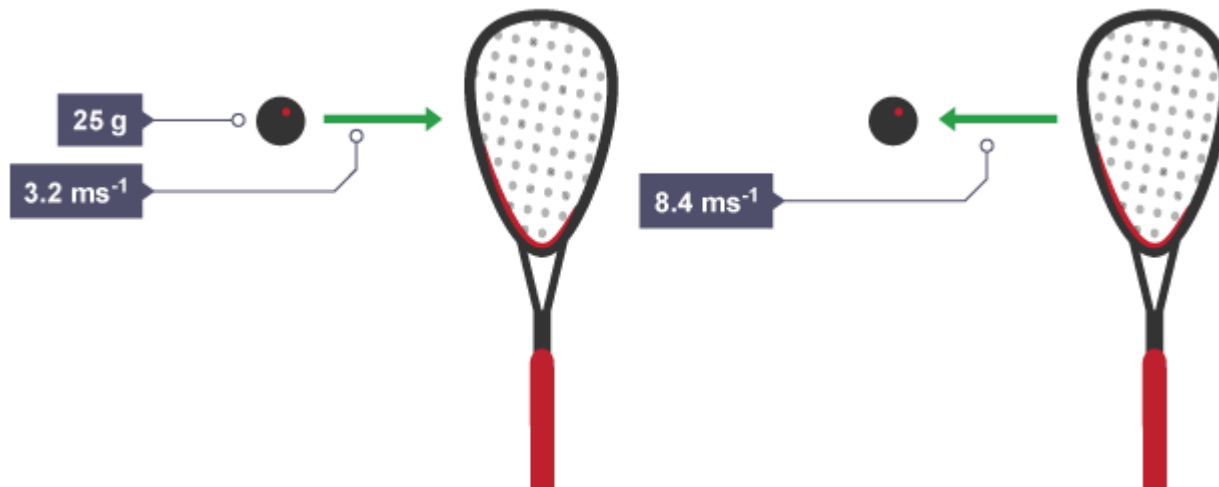
$$v_C = \frac{-480}{96}$$

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

The negative sign means the cannon moves backwards to conserve the momentum in the explosion, this effect is known as 'recoil'.

Q8

During a friendly Scotland verse South African game a squash ball of mass 25 g is moving from left to right at 3.2 ms^{-1} . It is hit by a squash racquet which applies a force for 4 milliseconds, so that the ball leaves the racquet at 8.4 ms^{-1} moving from right to left. Impulse-momentum can be used to calculate the average force on the ball.



Q8 continued

Initial momentum of ball:

$$= 0.025 \times 3.2$$

$$= 0.08 \text{ kg ms}^{-1} \text{ (to the right)}$$

Final momentum of ball:

$$= 0.025 \times -8.4$$

$$= -0.21 \text{ kg ms}^{-1} \text{ (to the left)}$$

Change in momentum = final momentum – initial momentum

$$= -0.21 - 0.08$$

$$= -0.29 \text{ kg ms}^{-1} \text{ (to the left)}$$

This change in momentum is equal to the impulse so:

$$F \times t = -0.29$$

$$F = \frac{-0.29}{0.004}$$

$$F = -72.5 \text{ N (to the left)}$$

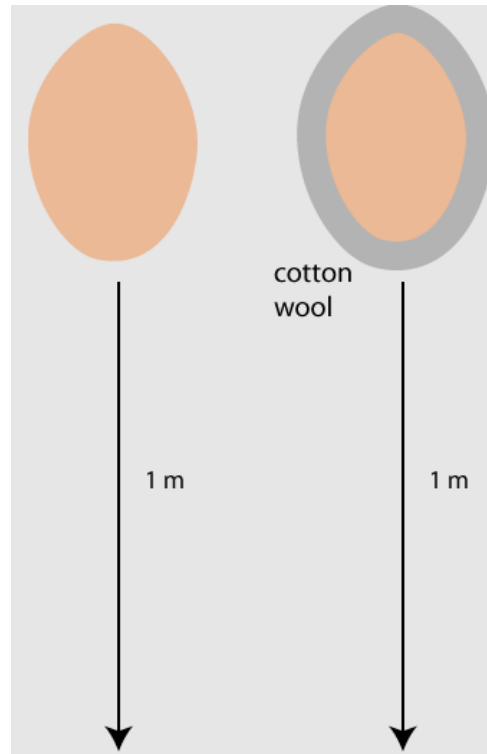
The negative sign in front of the -72.5 N indicates that the movement is to the left, but you can also write this down in order to make it clear.

Q9

Suppose two eggs of mass 60 g fall 1 m to the ground and come to rest. One egg is covered in cotton wool of negligible mass. Suppose the egg shell will crack if it experiences a force of 20 N. Calculate the change in momentum of each egg.

What impulse did the ground exert on each egg.

Suppose the egg with no cotton wool came to rest in 0.02 s and the egg in cotton wool came to rest on 0.5s Calculate, F_{EG} the force exerted on each egg by the ground and state which egg, if any, crack.



Q9 continued

1. $\Delta P_{\text{egg}} = mV - mU$

$0 - 0.06(-4.4) = 0.26 \text{ kgms}^{-1}$ (for each egg)

2. $I = \Delta P = 0.26 \text{ Ns}$ for each egg.

3. i) Egg with no cotton wool, $t = 0.01 \text{ s}$

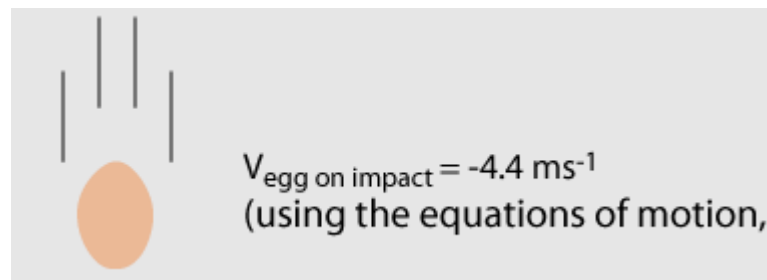
$Ft = 0.26 \text{ Ns}$

$F = 0.26/0.01 = 26 \text{ N}$ (cracked egg)

i) Egg with cotton wool, $t = 0.02 \text{ s}$

$Ft = 0.26 \text{ Ns}$

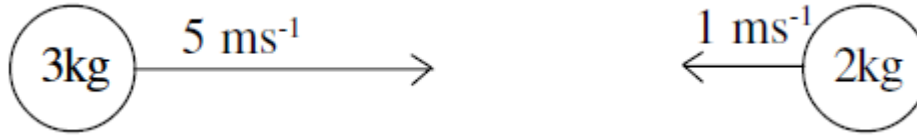
$F = 0.26/0.02 = 13 \text{ N}$ (not cracked)



$V_{\text{egg on impact}} = -4.4 \text{ ms}^{-1}$
(using the equations of motion,

Q10

The two balls shown stick together when they collide.



Momentum before: $3 \times 5 + 2 \times (-1) = 13 \text{ kgms}^{-1}$.

Momentum after: $(3+2)v$.

Momentum conserved: $5v = 13$, $v = 2.6 \text{ ms}^{-1}$ towards the right.

KE before: $(\frac{1}{2} \times 3 \times 5^2) + (\frac{1}{2} \times 2 \times 1^2) = 38.5 \text{ J}$.

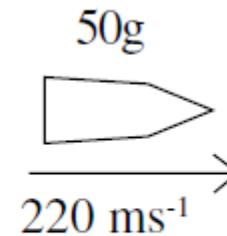
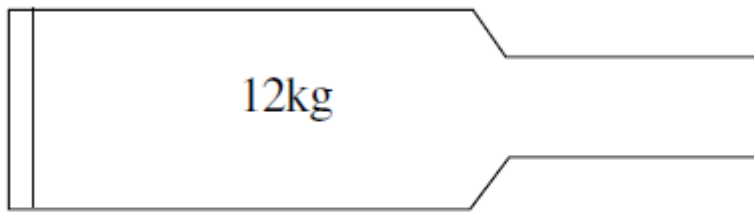
KE after: $(\frac{1}{2} \times 5 \times 2.6^2) = 16.9 \text{ J}$.

KE lost to heat and sound: 21.6 J .

*This collision is said to be **inelastic**.*

Q11

A 50g shell is fired from a gun of mass 12 kg. The initial velocity of the shell is 220 ms⁻¹ in the direction shown.



Find the recoil velocity of the gun.

$$\text{Momentum before} = 0 \text{ kgms}^{-1}$$

$$\text{Momentum after} = (0.050 \times 220) + 12v.$$

$$12v + 11.0 = 0, v = -0.92 \text{ ms}^{-1}.$$

So the recoil velocity is 0.92 ms⁻¹ towards the left.

Q12

Two particles A and B have masses 4 kg and $m \text{ kg}$ respectively. They are moving towards each other in opposite directions on a smooth horizontal table when they collide directly. Immediately before the collision, the speed of A is 5 m s^{-1} and the speed of B is 3 m s^{-1} . Immediately after the collision, the direction of motion of A is unchanged and the speed of A is 1 m s^{-1} .

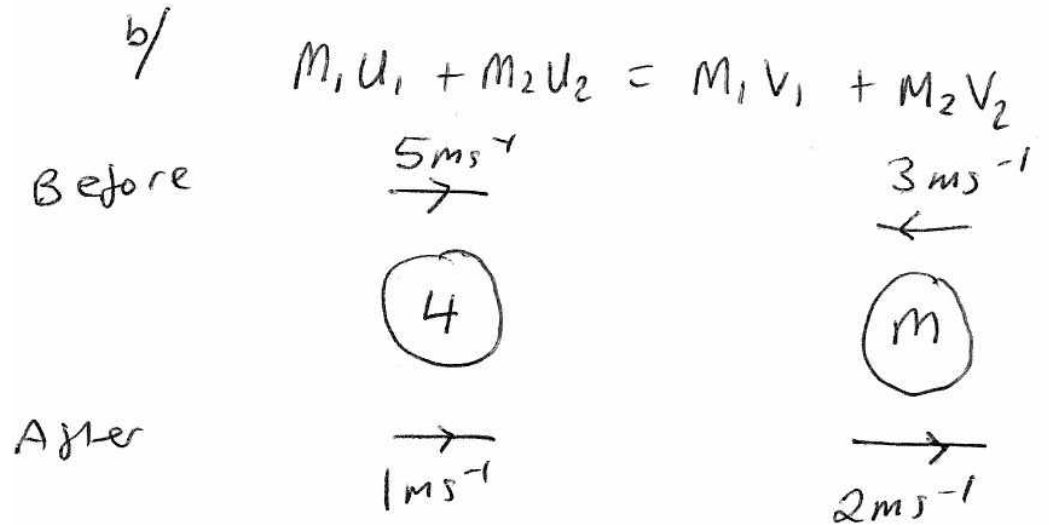
(a) Find the magnitude of the impulse exerted on A in the collision.

$$\begin{aligned} \text{a)} \quad I &= mv - mu \\ &= |4(1) - 4(5)| \\ &= \underline{\underline{16 \text{ kgms}^{-1}}} \end{aligned}$$

Q12 continued

(b) Find the value of m .

Immediately after the collision, the speed of B is 2 m s^{-1} .



$$4(5) + m(-3) = 4(1) + m(2)$$

$$20 - 3m = 4 + 2m$$

$$16 = 5m$$

$$m = \frac{16}{5} \text{ kg}$$

Q13

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 m s⁻¹ and 4 m s⁻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 m s⁻¹.

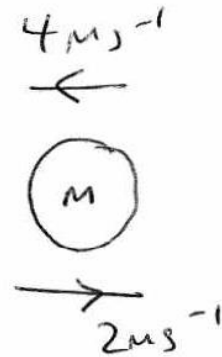
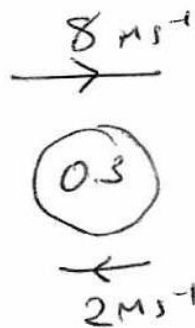
(a) the magnitude of the impulse exerted by B on A in the collision,

$$\begin{aligned}\bar{I} &= mv - mu \\ &= 0.3(8) - 0.3(-2) \\ &= 3 \text{ kg ms}^{-1}\end{aligned}$$

Q13 continued

(b) the value of m .

Before



$$M_1 U_1 + M_2 U_2 = M_1 V_1 + M_2 V_2$$
$$0.3(8) + m(-4) = 0.3(-2) + m(2)$$

$$2.4 - 4m = -0.6 + 2m$$

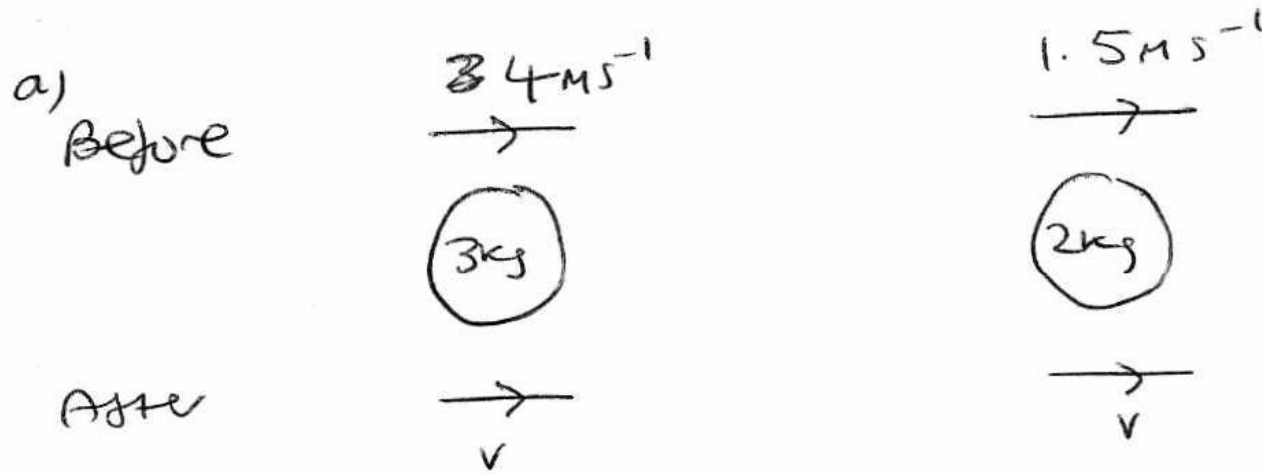
$$3 = 6m$$

$$m = 0.5 \text{ kg}$$

Q14

Two particles A and B , of mass 3 kg and 2 kg respectively, are moving in the same direction on a smooth horizontal table when they collide directly. Immediately before the collision, the speed of A is 4 m s^{-1} and the speed of B is 1.5 m s^{-1} . In the collision, the particles join to form a single particle C .

(a) Find the speed of C immediately after the collision.



$$m_1 u_1 + m_2 u_2 = M_1 v_1 + M_2 v_2$$

$$3(4) + 2(1.5) = 3v + 2v$$

$$15 = 5v$$

$$v = 3\text{ m s}^{-1}$$

Q14 continued

Two particles P and Q have mass 3 kg and $m \text{ kg}$ respectively. They are moving towards each other in opposite directions on a smooth horizontal table. Each particle has speed 4 m s^{-1} , when they collide directly. In this collision, the direction of motion of each particle is reversed. The speed of P immediately after the collision is 2 m s^{-1} and the speed of Q is 1 m s^{-1} .

(b) Find

(i) the value of m ,

(ii) the magnitude of the impulse exerted on Q in the collision.

Q14 continued

b/

Before

\rightarrow
 4ms^{-1}



\leftarrow
 2ms^{-1}

\leftarrow
 4ms^{-1}



\rightarrow
 1ms^{-1}

$$3(4) + m(-4) = 3(-2) + m(1)$$

$$12 - 4m = -6 + m$$

$$18 = 5m$$

$$m = \frac{18}{5} \quad 4$$

Q14 continued

$$\begin{aligned} I &= mv - mu \\ &= 3.6(\overrightarrow{24}) - 3.6(\overleftarrow{4}) \\ &= 18 \text{ kg ms}^{-1} \end{aligned}$$