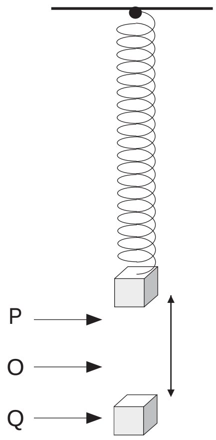


5. A mass oscillates on the end of a spring between two points *P* and *Q*. When the mass is at point *Q*, the extension is 50 cm. When the object is at point *P*, the spring is unstretched. The spring constant is 20 Nm^{-1}.

   a. Show that 2.5 J of work is needed to extend the spring from point *P* to *Q*.

   ____

   b. Hence write down the loss in gravitational potential energy from *P* to *Q*.

   ____

   c. Hence, calculate the mass of the object.

   ____

6. Consider the oscillating mass in the previous question.

   a. At which point (*O*, *P* or *Q*) does the mass have no kinetic energy? ____
   b. At which point does the mass have maximum kinetic energy? ____
   c. At which point does the mass have elastic potential energy only? ____
   d. At which point does the mass have gravitational potential energy only? ____
   e. In which part of the motion is there a decrease in gravitational energy? ____
   f. In which part of the motion is there a decrease in elastic energy? ____

Momentum

Newton's second law says that a force accelerates a mass $F = ma$
Recall that a = (v - u)/t. Hence F = ma means that $F = m(v_f - v_i)/t$
When we multiply out the brackets, we obtain $F = (mv_f - mv_i)/t$

Hence the force, F, changes the quantity ***mv****.*
This quantity of mass times velocity is called ***momentum, p*** $p = mv$
Hence Newton's second law can be expressed as
Force = change in momentum / time

We can write this as the equation $F = \Delta p / \Delta t$ or $\Delta p = F\Delta t$

Since momentum, mv, is based on velocity, this means that momentum is a vector quantity. For straight line motion, however, we simply use + and – for its direction.

Sir Isaac Newton
(1643 – 1727)

1. What are the units for momentum? ___________________________

2. Calculate the momentum, of each of these:

   a. A 0.50 kg bird flying at 7.0 ms^{-1}.

   ____

   b. A 20 g snail moving at 1.5 mms^{-1}.

   ____

   c. An 85 g tennis ball moving at 30 ms^{-1}.

   ____

   d. A 1.5 tonne van speeding at 144 km/hr.

   ____

3. A 2 kg ball travels at 5 ms^{-1} to the right. It catches up with a 3 kg ball which is travelling at 2 ms^{-1} to the right as shown opposite.

   a. Calculate the momentum of each ball.

   ____

   b. Calculate their total momentum.

   ____

4. The two balls opposite collide. After the collision, the 2 kg ball travels at 2 ms^{-1} to the right. The 3 kg ball travels at 4 ms^{-1} to the right as shown.

a. Calculate their total final momentum.

____

b. Calculate the change in momentum, Δp, of the 2 kg ball. (Use *final – initial*.)

____

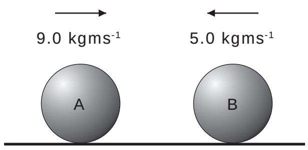
c. Calculate the change in momentum of the 3 kg ball.

____

d. Use Newton's second law to calculate the force acting on the 3 kg ball during the collision. Assume the balls are in contact for a time of 0.02 s.

____

5. Two balls are about to collide. The initial momentum of each one is shown in the diagram opposite.



a. Calculate their total momentum.

____

b. After the collision, both balls move in *opposite* directions. Ball *B* has a final momentum of +6.0 $kgms^{-1}$. Calculate the final momentum of ball *A* given that their total momentum is not changed by the collision.

____

c. In which direction does ball *B* move after the collision?

____

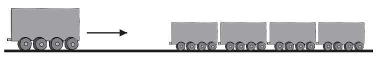
d. Calculate the change in momentum of ball *B*.

____

e. Ball *B* has a mass of 0.50 kg. Calculate its final speed.

____

6. Four identical railway wagons, each of mass 2 000 kg, are coupled together at rest on a smooth horizontal track. A fifth wagon of mass 4 000 kg, is moving at 5.0 ms^{-1} when it collides and joins with the stationary wagons.



a. Calculate the total mass of the wagons.

____

b. Calculate the total initial momentum of the wagons.

____

c. Calculate their combined speed after the impact, given the total momentum does not change.

____

d. Calculate the change in momentum of the fifth wagon as a result of the collision.

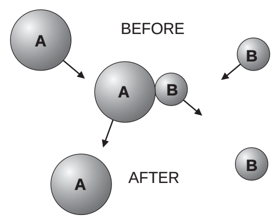
____

e. Calculate the force acting on the fifth wagon during the collision, given that the wagons are in contact for a time of 5 ms.

____

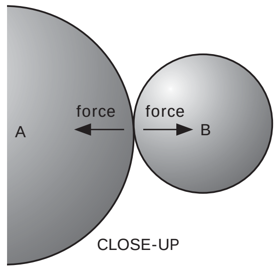
Conservation of Momentum

Momentum is often used to analyse collisions. The diagram opposite shows two unequal masses, A and B, which are on a collision course.



When they collide, each mass exerts a force on the other mass, so that each one bounces away on a new path. It is these two reaction forces that change the momentum of the two masses.

The close-up opposite shows how we think of these two 'action and reaction' forces. By Newton's third law these two forces are equal and opposite.



Remember that ***force = change in momentum/time****. Hence the change in momentum of the two masses is equal and opposite. The 'gain' in momentum of mass A is equal to the 'loss' in momentum of mass B.*

Because the gain in one is balanced by the loss in the other, the total momentum does not change.

Rule: *The total momentum* ***before*** *the collision is equal to the total momentum* ***after*** *the collision.*

1. A 1 kg ball travels at 6 ms^{-1} to the right. It catches up with a 3 kg ball which is also travelling at 4 ms^{-1} to the right.

   a. Calculate the total momentum of the balls.

   ____

   b. The two balls collide. Afterwards, the 1 kg ball travels slower at 3 ms^{-1} to the right. Let the 3 kg ball have a final speed v. Write down an expression for their total final momentum in terms of *v*.

   ____

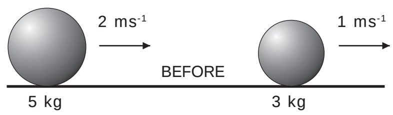
   c. Write down an equation for the total momentum before and the total momentum after the collision.

   ____

   d. Solve the equation for *v*.

   ____

2. A 5 kg ball travels at 2 ms^{-1} to the right. It collides with a 3 kg ball travelling at 1 ms^{-1} to the right.



   a. Calculate the total momentum of the balls.

   ____

   b. The two balls collide. After the collision, the 5 kg ball is seen to travel at 1 ms^{-1} to the *left*. Let the 3 kg ball have a final speed *v*. Write down an expression for the total final momentum in terms of *v*.

   ____

   c. Write down an equation about the conservation of momentum.

   ____

   d. Solve the equation for *v*.

   ____

3. A 4 kg ball travels right at 5 ms^{-1}. It collides with a 3 kg ball travelling at 6 ms^{-1} *left*. After the collision, the 3 kg ball moves off to the right at 2 ms^{-1}.

   a. Sketch the situation in the space opposite.

   b. Use momentum conservation to calculate the final speed of the 4 kg ball.

   ____

   ____