Exercise 4.1 Newton's second law in terms of momentum

The questions in this section will help you to become familiar with the concept of linear momentum and the more formal definition of Newton's second law of motion.

1 **a** Define the term *linear momentum*.

b Show that the units for momentum, $kgms^{-1}$, can also be written as Ns.

c Calculate the momentum of

i a girl of mass 50 kg running westwards at a speed of 6 ms^{-1}.

ii an electron of mass 9.1×10^{-31} kg travelling at a speed of 2.0×10^{7} ms^{-1} towards an anode.

iii a hockey ball of mass 110 g travelling at 60 ms^{-1} towards a goal.

TIP

Remember that momentum is a vector quantity and so it needs a direction.

2 Two bodies, A of mass 3.2 kg, and B of mass 5.0 kg, are both moving. A moves northwards at 2.5 ms^{-1} whilst B moves southwards at 1.5 ms^{-1}.

a Determine the total linear momentum of the system.

b A 400 = g mass moves horizontally at a speed of 3 ms^{-1}, and a 250 g mass moves vertically upwards at 4 ms^{-1}. Determine the total linear momentum of the system.

3 A mass of 4.0 kg, moving horizontally at 2.5 ms^{-1}, is acted on by a force for a time of 5.0 s, which makes the mass come to a stop. Use your knowledge of SUVAT equations to answer the following:

a What was the change in the velocity of the mass?

b What was the acceleration of the mass?

c Calculate the size of the force that acted on the mass.

d How does your answer show the direction of the force?

4 **a** State Newton's second law in terms of momentum.

b Show that, if a body's mass does not change during an interaction, Newton's second law can be written $F = ma$.

5 A mass of 4.0 kg, moving horizontally at 2.5 ms^{-1}, is acted on by a force for a time of 5.0 s, which makes the mass come to a stop. Answer the following questions **without** referring to SUVAT equations.

a Determine the change in the momentum of the mass.

b Hence use Newton's second law to find the size of the force.

6 A mass of 12.0 kg experiences a force of 180 N for a time of 2.5 s. By how much will the speed of the mass change?

7 A mass of 600 g moving at 3.0 ms^{-1} horizontally experiences a force of 180 N in the same direction as its travel. The mass accelerates to a speed of 4.5 ms^{-1}. Calculate the time for which the force acted on the mass.

8 A car travelling at 10 ms^{-1} accelerates under a driving force of 5200 N for 5 s until its speed has increased to 30 ms^{-1}. Calculate the mass of the car.

TIP

Remember that

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

9 A hose pipe squirts water horizontally at a wall. If the water jet has a cross-sectional area of A and the water, of density, ρ, hits the wall at a speed of v—and then falls off vertically:

a Give an expression for the mass of the water that hits the wall per second

b Hence determine an expression for the size of the force exerted by the wall on the water.

c State the force—and its direction—exerted by the water on the wall.

d A high-pressure washer emits water at a speed of 100 ms^{-1} from a nozzle that is 1.5 mm in diameter. Calculate the size of this force. (ρ_{water} = 1000 kgm^{-3}) Assume that the jet of water does not spread out after leaving the nozzle.

e The pressure due to the atmosphere is about 1.0×10^5 Pa. How does the pressure exerted by the water jet compare to the atmospheric pressure?

10 Photons of sunlight have a momentum of 1.3×10^{-27} N s and a kinetic energy of 2.5×10^{-9} J.

If the received power of a solar panel is 1.0 kWm^{-2},

a calculate the number of photons hitting the solar panel per second.

b calculate the average force exerted on a square metre of the solar panel due to the photons.

c if a typical solar panel has a collecting area of 12 m^2, calculate the total force on the solar panel.

d should one be concerned about the force from the sunlight on an array of 10 solar panels fitted to the flat roof of a house?