stops the car) is insufficient. The wheels stop spinning as the brakes are applied, but the car continues moving, leaving a trail of black rubber behind each tyre. A low-friction surface results in longer skid marks.

How can the skid marks be interpreted? One way is to drive a car at a known speed on the road surface in question and to cause it to skid deliberately. From the length of its skid marks, the deceleration of the car can be deduced. Box 2 shows the **equation of motion** used.

Example

A car travelling at 20 m/s (72 km/h) skids to a halt in a distance of 25 m. What is its deceleration (negative acceleration)?

$v^2 = u^2 + 2as$

$0 = 400 + 2a \times 25$

$a = -400/50 = -8\ \text{m/s}^2$

Any car travelling on the same stretch of road is assumed to decelerate at this rate when it skids. So, given the length of a skid mark, the car's initial speed can be calculated. A driver who can be shown to have been exceeding the speed limit could be in big trouble.

Friction

Deceleration is often expressed in terms of the acceleration due to gravity (g), which has a value of about 10 m/s^2:

$a = -\mu g$ (where μ is the coefficient of friction of the road surface)

In the example above, the coefficient of friction (μ) is 0.8, a good value for a road surface. On a smooth road surface, μ might be 0.6 or less.

If the stretch of road concerned is short, or too busy to interrupt the traffic with test skids, an alternative method is used. A small 'sled' fitted with sections of tyre is dragged along the road (Figure 2). The pulling force (F) is compared with the weight (μg) of the sled, and the coefficient of friction is calculated using:

$\mu = F/mg$

Momentum calculations

Another method of deducing a car's speed before a collision uses the idea of **momentum**. An object's momentum is found by multiplying its mass (m) and velocity (v):

momentum = mv

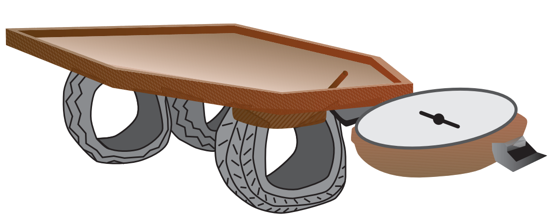

Figure 2 *'Sled' used for friction/skid testing*

Box 2 Equations of motion

There are three equations which relate the initial and final velocities (u and v) of an object to its acceleration (a), displacement (s) and time (t). These equations only apply to an object whose acceleration is constant.

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

The third of these is the most relevant to accident investigations because after the event it is difficult to discover the time (t) in which a vehicle's velocity changed during an accident.

Suppose a fast-moving van collides with a stationary car (Figure 3). The two move off together. From the distance they move, the total velocity of the van and car can be found. But what about the original velocity of the van? After the collision, the combined momentum of the two vehicles is equal to the original momentum of the van.

Example

A van (mass 2000 kg) collides with a stationary car (mass 1200 kg). They move off at 15 m/s. How fast was the van travelling at impact?

Total momentum after collision = 3200 kg × 15 m/s = 48 000 kg m/s

This must have been the value of mv for the van before the collision, so:

2000 kg × v = 48 000 kg m/s

We can calculate that in this example the van's velocity was 24 m/s (about 86 km/h). Investigators would be interested in comparing this with the speed limit, or the safe driving speed for the situation in question.

Passenger safety

Ideas about momentum are also important when considering the safety of people in a vehicle when it is involved in a collision. Most modern cars have air bags, and seat belts are fitted as standard.

Momentum is a quantity that is conserved — there is always the same total amount before and after a collision or other event, but it is shared out differently between the interacting objects.

It is useful to remember that 10 m/s is equal to 36 km/h or about 22.5 mph.

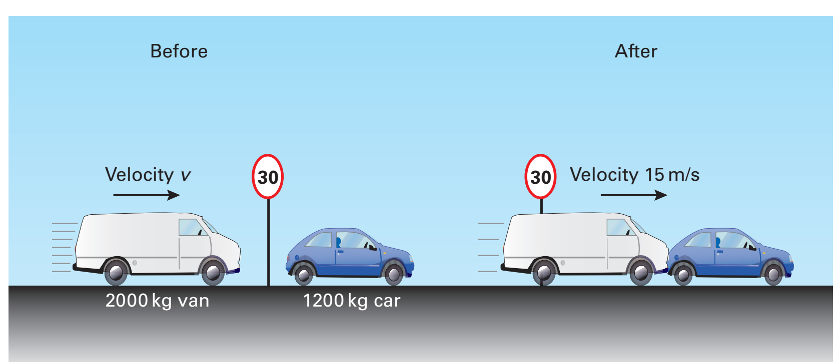

Figure 3 *Van colliding with stationary car*

Right: *The European New Car Assessment Programme (**www.euroncap.com**) tests the latest cars for safety. Here you can see the dummy driver and child seat; these are fitted with sensors to measure the effects of a head-on impact*

www.euroncap.com

Below: *It is important to protect pets, too, when travelling. A 20 kg dog flying around the passenger compartment of a car is a serious hazard*

- **Check out the safety equipment for dogs and other pets at www.petsafetybelts.com**

- **Find out more about the work of TRL at www.trl.co.uk. Its 'Online Store' includes many downloadable images and reports.**

The quantity force × time is known as the impulse of the force.

A passenger in a moving car has momentum. When the car stops in a collision, the passenger's momentum is reduced to zero. A force acts on the passenger: this can be a big force acting for a short time, or a small force acting for a longer time.

force × time = change in momentum

A large force could seriously harm the passenger, so seat belts are designed to allow the passenger to move forwards slightly during the impact. This means that the impact takes longer and the average force is less. Similarly, an air bag provides the force needed to prevent the passenger from flying forwards into the windscreen. The bag inflates almost instantaneously on impact, and then deflates gently as the passenger presses into it.

Box 3 Understanding teenagers

TRL (the Transport Research Laboratory) is an organisation which tests cars, investigates accidents and monitors traffic flow. In its efforts to reduce road accidents, it also looks at the psychology of drivers and pedestrians. A recent survey of teenagers found that more than half of all accidents to pedestrians aged 11–16 occur when they are out with friends.

Teenagers surveyed by TRL admitted that they went in for 'risk-taking behaviour', such as crossing the road in hazardous conditions, mainly to impress their friends. TRL hopes that its findings will allow it to develop road safety strategies to reduce the death rate on the roads further.

How did TRL find out about the behaviour of teenage road users? It used a number of techniques: interviews, roadside videos, analysis of police accident files, surveys of students and a review of published studies. Each of these on its own could not give a full picture, but together they provide a strong body of scientific evidence.

Cars themselves are designed to reduce the impact on the occupants. At the front and back are two **crumple zones**; these collapse during a collision, absorbing much of the energy of the moving car. At the same time, the passengers are contained in a rigid central compartment. This rides up over the engine, which is a massive solid object that could do great harm to the passengers.

David Sang *writes textbooks and is an editor of* CATALYST.