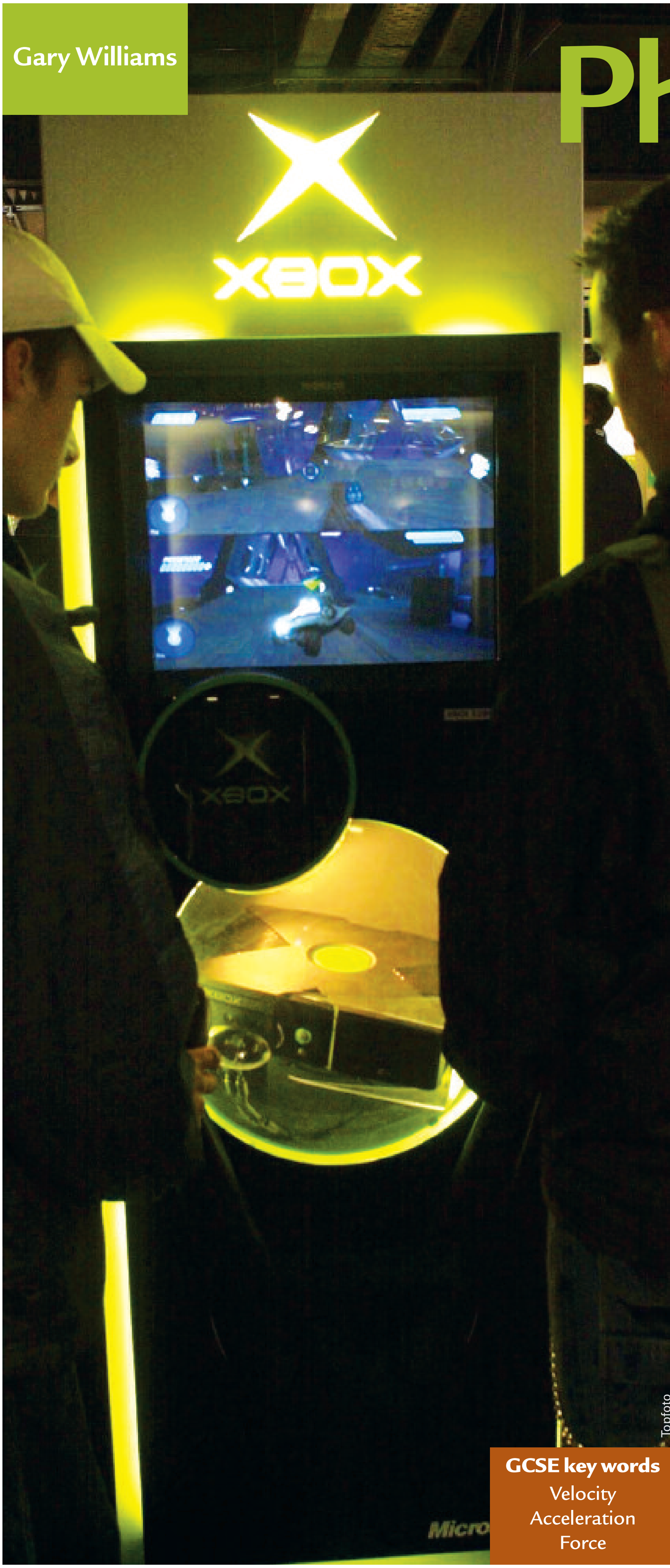
Gary Williams

Physics and



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GCSE key words
Velocity
Acceleration
Force

The video or computer games industry is now the biggest entertainment-based industry on the planet. Competition between games producers is fierce, and new games, concepts and hardware are constantly being developed — often by physicists. Part of the development of games involves striving to make certain aspects of them more realistic — but that isn't always the case.

Nowadays computer games are designed around games or physics 'engines'. In fact, quite often when a new game is seen as being innovative it isn't the game but the engine that's making all the difference.

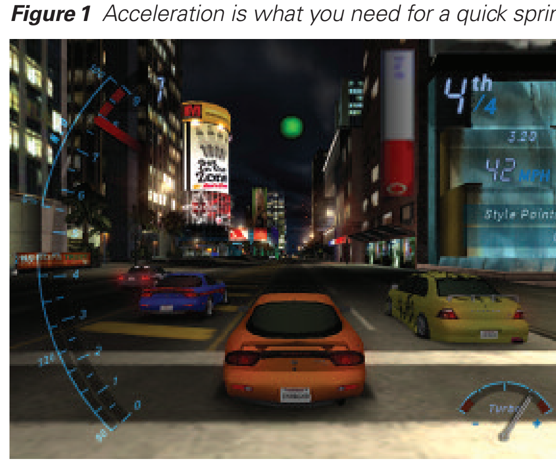
Take games like *Need for Speed* or *Gran Turismo*. These involve cars moving at high speed along complex tracks. If we want games to be realistic, the car's performance should be affected when it crashes. So what determines how much damage your car ends up with after a crash?

When a car crashes, its **velocity** (speed and direction) changes. This change is called **acceleration**, and you can't have acceleration without **forces**. Forces do any combination of:

- changing an object's speed
- changing the direction an object is moving in
- changing an object's shape

When a car hits an object the first two are definitely going to happen as the car bounces off the wall, rolls over and dies. But how is the third one represented?

Figure 1 *Acceleration is what you need for a quick sprint*



computer games

Figure 2 *Passengers sit inside the rigid passenger cell, shown in red. Crumple zones are the parts in front of and behind the cell. They are designed to be weak, so that they crumple and absorb the energy of an impact. Games designers must make their on-screen cars collapse in a convincing way*

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Above: *The car is designed to crumple when it hits the lorry*

Cars are designed with **crumple zones** which are meant to change shape to prevent the forces of impact being passed on to other objects or parts of the vehicle (Figure 2). Of course, at some stage the crumple zones won't crumple any more and the car will be a write-off. Games programmers need to know the force so that they can show the car with the right amount of damage or end the game if the force is too great. How do they calculate the force?

Calculating forces

Nearly 400 years ago Isaac Newton (1642–1727) came up with three laws of motion (see Box 1). The second one can be written as:

force = mass x acceleration

This means that if the mass of an object stays the same then when it accelerates (or decelerates), there must be a force acting that is proportional to the acceleration. Similarly, if you double the size of the force that is being applied to an object you will double the acceleration.

Acceleration, in mathematical terms, is the change in speed divided by the time taken for that change to take place:

$$\text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

$$= \frac{v - u}{t}$$

u **= initial velocity**

v **= final velocity**

In a crash, the time over which the impact takes place is t. Notice that it's on the bottom of the

Box 1 Newton's laws of motion

(1) A body at rest remains at rest, and a body in motion moves with uniform speed in a straight line, unless a force acts on it.

(2) The acceleration of a body is proportional to the impressed force and takes place in the direction of that force.

(3) If a force acts on a body then an equal and opposite force must act on another body.

Although we are used to expressing laws such as Newton's laws of motion in words, they must be translated into equations if they are to be used by a computer.

Figure 3 *This car is totalled, but does it look it?*

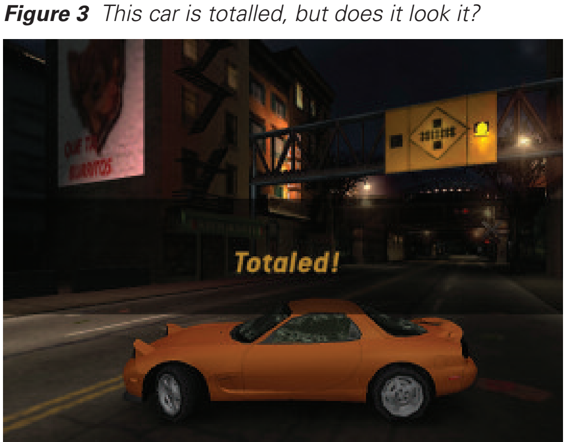
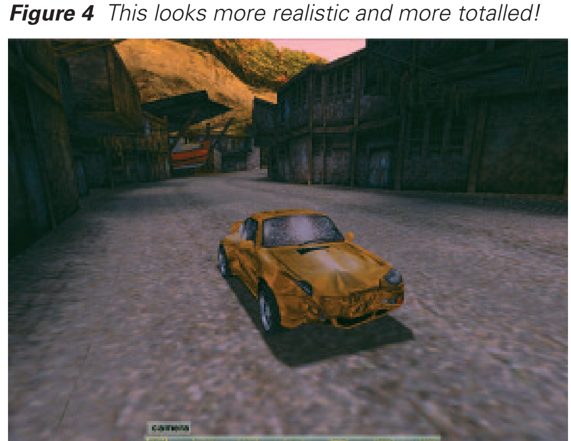


Figure 4 *This looks more realistic and more totalled!*



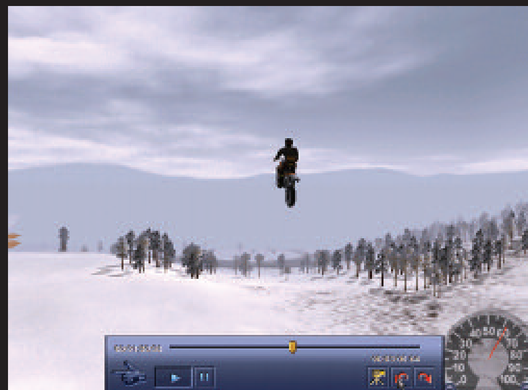


Figure 5 *You spend a long time up in the air…*

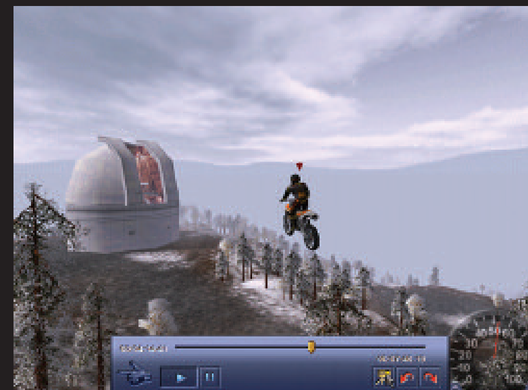


Figure 6 *…but is this realistic?*

equation. As the time taken for the impact increases the force decreases. The crumple zones increase the time the impact takes.

You could have a car made of really rigid material. If this hit a wall it would bounce straight off and as there would be very little deformation of the material the time, *t,* would be small. That would make the acceleration big, and hence the force would be big. If all of the car was rigid then the forces would end up being transmitted to the driver.

The writer develops the idea for the game.

If the change in speed is big and the time over which the impact happens is small, then the force will be big.

Forces in practice

The storyboard artist sketches the different scenes.

How does this work in a computer game? Picture the image of a car moving across the screen. It is approaching a brick wall. The computer calculates the distance between the front of the car and the wall. When this reaches zero, it calculates the effect on the car.

The physics engine has been programmed with details of the strength and stiffness of the car. The computer calculates the force that the wall will exert on the car, and for how long it will act. It can then calculate the effect on the car. It generates a new image of the car, suitably deformed, and decides on how the car will move. At the same time, it calculates how the wall will look after the impact.

The programmer writes the software equations which make things move correctly on the screen.

All this is possible because computers can perform millions of calculations every second. Computers were much slower 20 years ago, and the possibilities for interesting effects were much more limited.

Galileo, Lara Croft and gravity

Computer games often involve falling objects or people. These also have to look right. But how do objects fall? On Earth, if you ignore air resistance, the important word to remember is **acceleration**. When objects fall they accelerate – their velocity increases. We have to go back to before Newton's time to get the first glimpse of this bit of physics.

The designer draws the images which move across the screen.

Galileo (1564–1642) is reputed to have done an experiment at Pisa. He dropped two balls of identical volume and surface area but with different masses from the leaning tower of Pisa. He found, as he had predicted, that the mass of the ball doesn't matter; they both fell at the same rate (ignoring air resistance). That rate is governed by the acceleration due to **gravity**, about 10 m/s^2.

Lara Croft jumps into the air and then comes back down. Is her speed always the same as she jumps? No. Of course she accelerates, and if she accelerates as she jumps off a part of a building, when she hits the floor she'll experience a force. In *Motocross Madness*, bikes jump off cliffs and hit the floor. A little play will easily convince you that something isn't very realistic in these games.

The problem here is the need for games to be fun. It isn't much fun if you jump off a 2 m high object and break a leg. Lara jumps off some very high objects and gets away with it because the value of the acceleration due to gravity in the game has been reduced. Lara doesn't accelerate as quickly when she falls and hence isn't travelling as fast when she hits the floor as she would be in real life. You could experience this yourself if you went to the Moon, where gravity is about one sixth as strong as on Earth.

Getting real

People don't always want a realistic model of the world in their games. Some car racing games have not sold well because being realistic has made them too difficult. There's not a lot of point buying a motocross computer game that requires you to have all the skills that a real motocross rider has – you may as well ride the bike!

***Gary Williams** started his career as a lab technician, then taught physics and IT at a number of schools, ending up at Christ College in Brecon, Wales. He is now the editor of the journal* Physics Education *and sometimes gets paid to play computer games. His favourite game is* Vanishing Point.