DAVID SANG

Yes, it is rocket

The launch of a space rocket has become a familiar image. But how do rockets work, and what is the future for rocket science?

Rocket propulsion works by controlling an explosion. In conventional rockets, the explosion is the result of burning fuel. As the fuel is oxidised, energy is released. The exhaust gases are very hot, and they push out of the back of the rocket. The effect is a forward thrust on the rocket.

One of the problems with space rockets is that they have to take with them their own supply of oxygen — there's no oxygen in space. This adds to the overall load they must carry. One way to overcome this is with the new generation of solar-powered ion-propulsion rockets.

Take care with the pairs of forces in Newton's third law. They are equal in size and opposite in direction and, most importantly, they act on different objects.

SOLID ROCKET BOOSTERS

Solid rocket boosters (SRBs) are often used as the first propulsion system of a rocket. 'Yes, we have ignition!' — that's the SRBs starting to burn. The rocket is bound to lift off, because there's no way to turn off the SRBs. Within a few minutes, they are burnt out and jettisoned. They are the parts you see falling to Earth shortly after launch.

SRB fuel is often a mixture of nitrocellulose and nitroglycerine, with an added plasticiser to give the fuel a solid, rubbery consistency.

Space shuttle SRB fuel is a mixture of aluminium perchlorate (a source of oxygen) and aluminium powder, which burns.

● **A catherine wheel uses the action-and-reaction principle. Explain how.**

LIQUID FUEL ROCKETS

For a more controlled thrust, rocket engines use liquid hydrogen and liquid oxygen as their fuel mixture. The two liquids are pumped into a combustion chamber, where they are ignited.

Artist's impression of the launch of an Ariane 5 rocket. Two large solid rocket boosters flank the main liquid fuel rocket in the middle.

David Ducros/SPL

The temperature may reach 3000°C. The hot exhaust gases emerge from the back of the rocket at speeds of up to 5 km/s.

Other liquid fuels include kerosene in place of hydrogen, and nitrogen peroxide (N_2O_4) in place of oxygen.

Most rockets have a sequence of engines to lift them into space. The first stages are the most powerful, with engines providing up to 500 000 newtons of thrust. The later stages may provide only 20 000 newtons.

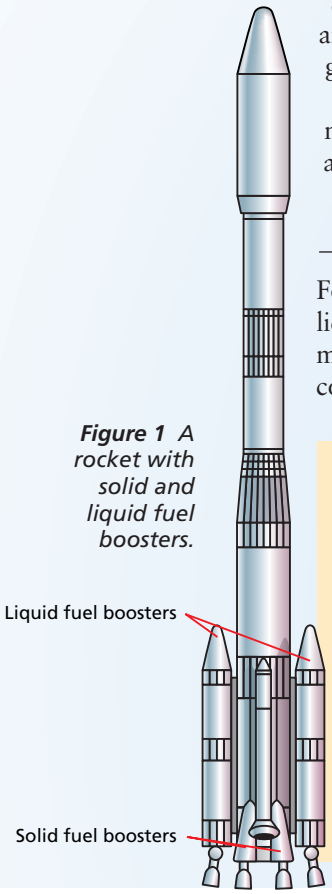


Figure 1 *A rocket with solid and liquid fuel boosters.*

BOX 1 ACTION AND REACTION

Blow up a balloon and let go. It flies around the room as the air rushes out. This is an example of Newton's third law of motion. As the air is pushed in one direction, the balloon is pushed by an equal force in the opposite direction.

A rocket works in the same way. Hot exhaust gases (or high-velocity xenon ions) are pushed out through the nozzles at the rear and the rocket feels an equal and opposite force in the opposite direction. (That's why both types of rocket have to take something with them to push out backwards — fuel and oxygen, or xenon gas.) These forces are often described as an 'action and reaction pair'.

Here's another way to think of it. Inside the rocket's combustion chamber, fuel and oxygen burn. Roughly speaking, half of the resulting molecules fly backwards, and half fly forwards. The molecules that fly forwards bounce off the inside of the combustion chamber, exerting a force on it. That's the physical origin of the force which pushes the rocket forwards.

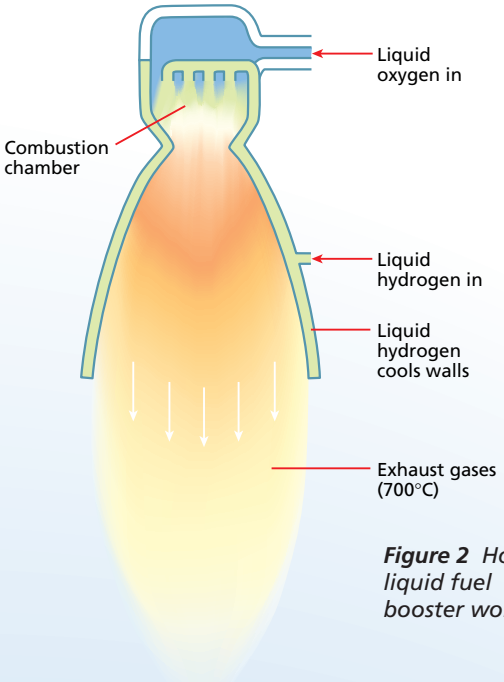
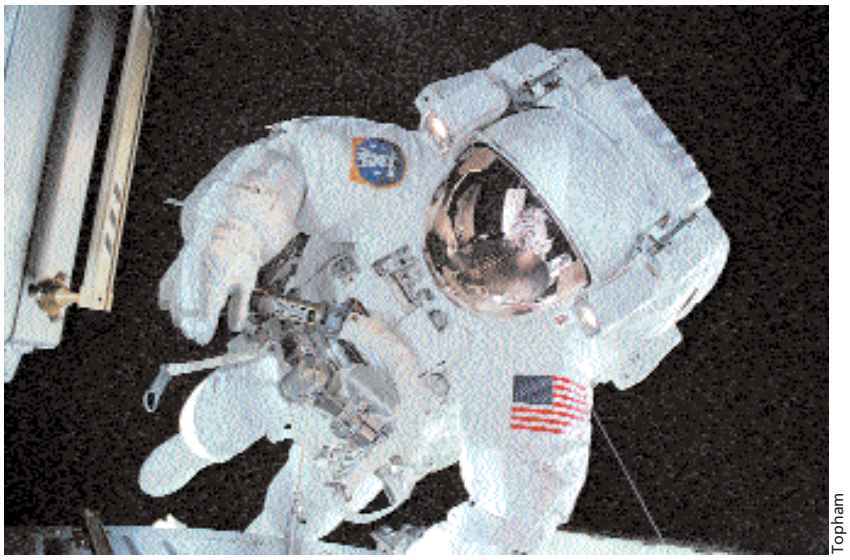


Figure 2 *How a liquid fuel booster works.*



Topham

Above: *When walking in space, astronauts use cylinders of compressed nitrogen to push themselves about. The gas is fired through 24 nozzles, and is controlled by a joystick.*

BOX 2 IMPULSE OF A FORCE

A fuel-and-oxygen rocket provides a large force. An ion-propulsion motor provides a much smaller force, but it acts for a long time. A small force acting for a long time can have a greater effect than a large force acting for a short time.

The quantity force × time is known as the impulse of the force, and tells us how much the rocket's momentum is changed by the force.

SOLAR POWER

Most spacecraft have solar cells to provide electrical power during their mission in space. This normally only powers the on-board instrumentation. However, the first solar-powered craft are now being produced.

The European Space Agency's SMART-1 mission to the Moon will be launched early in 2003, and will make use of the latest ion-propelled motor. This works as follows. Solar panels generate electricity which has two functions. First, it is used to ionise xenon gas. Second, the xenon ions are accelerated by high-voltage electricity, so that they emerge from the back of the motor at a speed of 30 km/s, much faster than the exhaust gases of a conventional rocket.

These motors have the great advantage that they do not require an oxygen supply. They produce only a tiny thrust — perhaps 70 millinewtons, less than a millionth of the thrust of a giant *Ariane* rocket. However, they can operate for months on end, gradually accelerating a spacecraft to speeds approaching 5 km/s (11 000 miles per hour).

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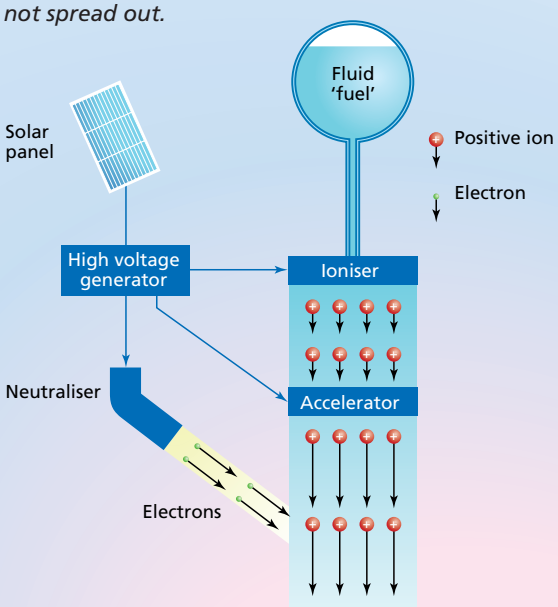
Xenon is a noble gas, like helium and argon.

Xenon ions are atoms which have lost one electron, leaving them positively charged.

Ion-propelled motors may be used for the first manned spaceflights to Mars.

Figure 3 *An ion-propulsion booster. The solar panel is the ultimate source of energy for an ion-propulsion system. Liquid xenon gas is fed to the ioniser, where the atoms are ionised before being accelerated by a high voltage. Electrons are also fed into the beam of ions so that it is neutral and does not spread out.*



ANSWERS TO FIREWORKS QUIZ, PAGE 17

1 gunpowder
2 potassium nitrate
3 charcoal
4 potassium perchlorate
5 magnesium
6 strontium chloride
7 shellac
8 barium nitrate
9 copper chloride
10 magnalium alloy

Corel