... 3, 2, 1, lift-off!

Rocket engines are sometimes called **reaction engines**, as they use the action/reaction pair of forces to provide the thrust needed for launch. Rockets expel massive quantities of gases in one direction, which push the rocket in the opposite direction, usually upwards.

Fig 5.5.2 The space shuttle and all rockets lift off because of action/reaction.

The exhaust gases are tiny particles but their effect is dramatic due to their high acceleration.

The exhaust is produced when fuel, called **propellant**, undergoes chemical combustion.

A liquid propellant engine uses two liquefied gases (for example, hydrogen and oxygen), which are combined in a combustion chamber. The resulting exhaust stream produces **thrust**—the force which propels the rocket. The thrust produced by the space shuttle at lift-off is 35 meganewtons (35 000 000 newtons), and accelerates the vehicle at three times the acceleration of gravity, or 3 g (i.e. 30 m/s^2).

Initially the thrust is not enough to overcome the weight of the rocket, so the rocket sits on the launchpad, making a lot of flames, but not going anywhere. When thrust equals weight the rocket begins to hover, and when thrust is larger than weight, it lifts off.

Rockets may also contain engines that use solid propellant. These engines are generally simpler, cheaper and safer than liquid fuel engines. The solid fuel is composed of several chemicals in proportions that allow it to burn quickly without exploding. Once started, a solid fuel engine cannot be stopped until all the fuel is used. The space shuttle uses two **solid rocket boosters** (SRBs), which burn for a little over two minutes before falling into the ocean by parachute to be retrieved and re-used in future missions. These are the two thin engines on the side of the main tank attached to the shuttle.

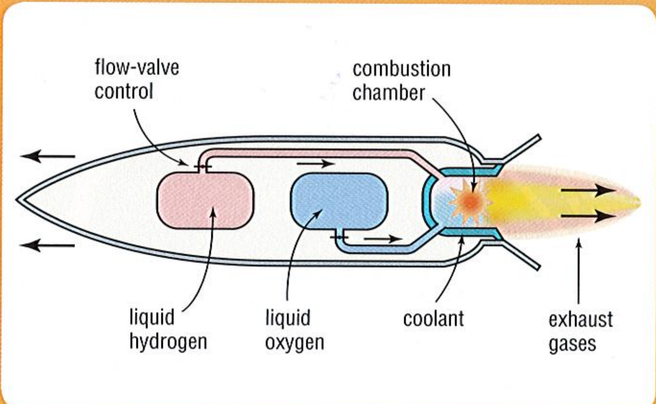
Jet engines work in a similar way to rocket engines: air is compressed by a series of large fans, and is then pushed out the rear of the engine with high acceleration.

Science Focus

Animal rockets

The purpleback flying squid (*Sthenoteuthis oualaniesis*) squirts out jets of water in order to leap out of the sea to feed. It can then easily glide a distance of over 10 metres in the air.

Fig 5.5.3 Exhaust gases push a rocket in the opposite direction.



Science Focus

Flying frozen chickens!

Birdstrikes have been around as long as aviation. It is estimated that 30 000 occur worldwide each year, leading to damaged aircraft windscreens and even engine failure. The US Federal Aviation Administration (FAA) designed a unique device for testing the strength of windscreens on aeroplanes. It is a gun that launches a dead chicken at a plane's windscreen at about the speed the plane flies. The theory is that if the windscreen doesn't crack from the impact of the carcass, it will survive a real collision with a bird during flight. The British needed to test a windscreen on a new ultra-fast train. They borrowed the FAA's chicken launcher, loaded a chicken and fired. The ballistic chicken shattered the windscreen, smashed the driver's seat and embedded itself in the aluminium back wall. The British were stunned and contacted the FAA to see if everything had been done correctly. The FAA reviewed the test and had only one recommendation: 'Don't use a frozen chicken'.

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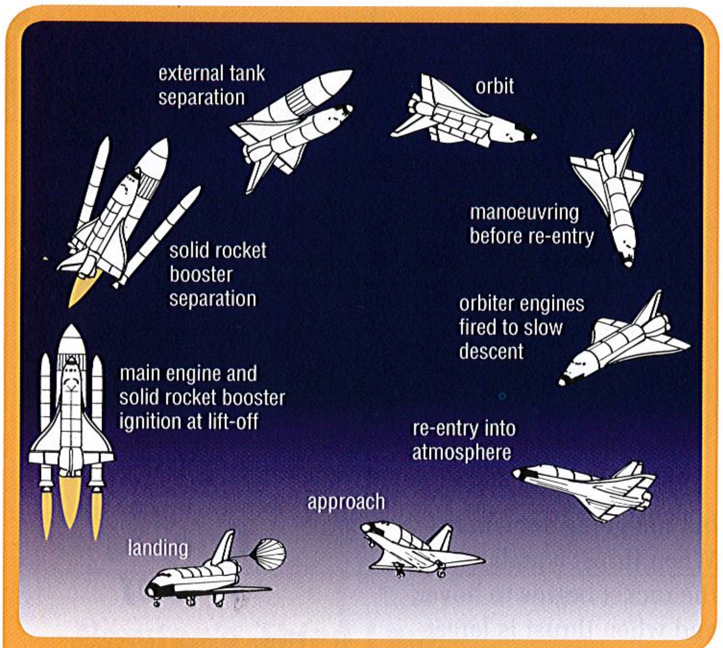
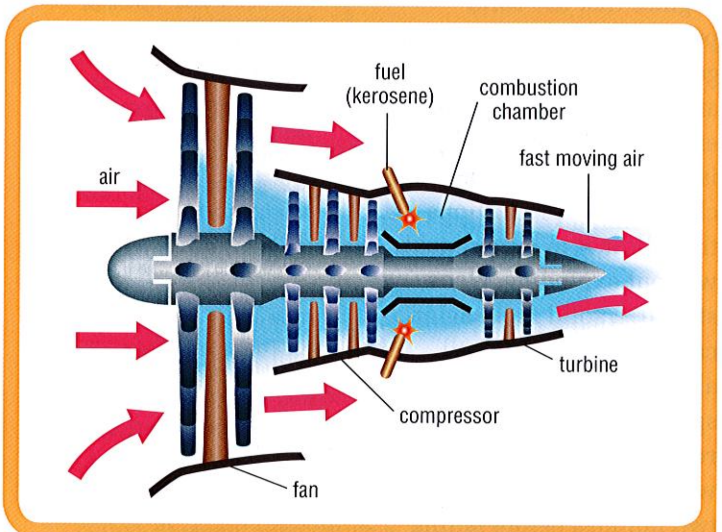


Fig 5.5.4 The main stages of a space shuttle mission



A jet engine works by action/reaction. Fig 5.5.5

UNIT 5·5 [Questions]

Checkpoint

Newton's Third Law

1 **State** Newton's Third Law of Motion.

2 **Describe** three examples that show Newton's Third Law of Motion in action.

Summary: Newton's three laws

3 For each of the following statements, **identify** the correct Newton's Law:

a The larger the force the bigger the change in motion.

b Any object at rest will stay that way unless pushed or pulled.

c For every action there is an equal and opposite reaction.

d Any object that is moving will keep moving at the same speed and in the same direction unless a force changes it.

... 3, 2, 1, lift-off!

4 Use Newton's Third Law to **outline** how a rocket achieves 'lift-off'.

5 Use a diagram to **demonstrate** how a jet engine works using Newton's Third Law.

Think

6 **Explain** why a balloon shoots around the room when it is allowed to deflate.

7 a Firefighters often need to brace themselves or have extra help to hold a firehose while it is on. **Explain** why.

b **Predict** what would happen if they did not have this help.

8 Michael is stranded on ice that is so slippery that he cannot walk. **Recommend** a way that he could get himself to nearby hard ground.

9 Pat throws a netball.

a **Identify** the action force.

b **Explain** what the action force did in this situation.

c **Identify** the reaction force.

d **Explain** what the reaction force did in this situation.

10 **Deduce** which part of the launch these rockets are in:

a thrust = weight of rocket

b thrust > weight of rocket

c thrust < weight of rocket

d thrust = 0

11 **Explain** why the acceleration of a rocket increases as its fuel is consumed.

12 Rockets normally discard used fuel tanks soon after launch. **Discuss** the advantage of this.

Analyse

13 Ben kicks a football. Use a diagram to **demonstrate** the action/reaction pair of forces acting on the football:

a as it lies on the ground before being kicked