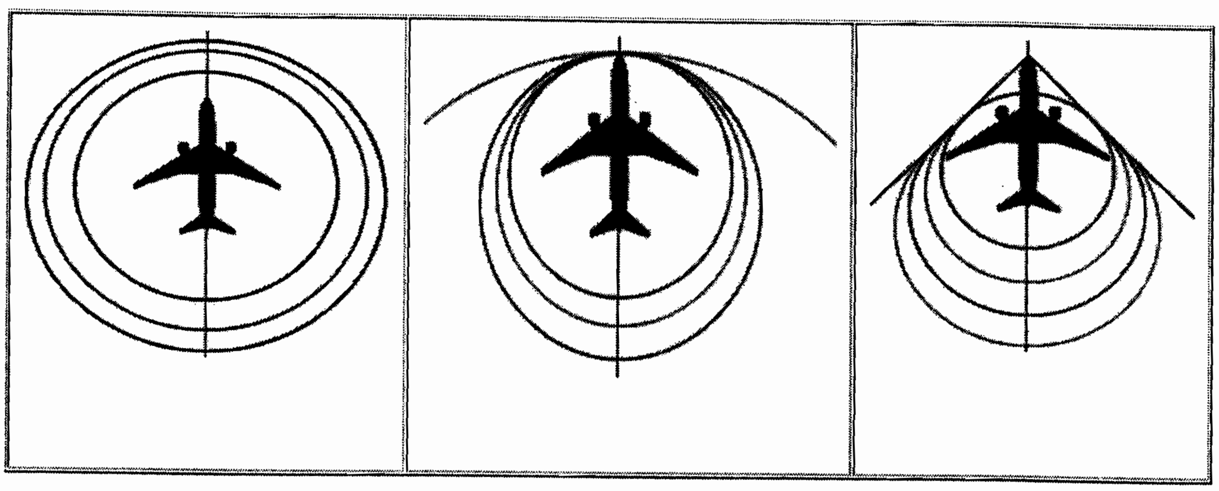
# King Fahd University of Petroleum and Minerals

## Aerospace Engineering Department

**AE-421**

**Aerospace Engineering Lab II**

## Sound Barrier



Sound is made up of molecules of air that move. They push together and gather together to form **sound waves.** Sound waves travel at the speed of about 750 mph at sea level. When a plane travels the **speed of sound** the air waves gather together and compress the air in front of the plane to keep it from moving forward. This compression causes a shock wave to form in front of the plane.

In order to travel faster than the speed of sound the plane needs to be able to break through the shock wave. When the airplane moves through the waves, it is makes the sound waves spread out and this creates a loud noise or **sonic boom**. The sonic boom is caused by a sudden change in the air pressure. When the plane travels faster than sound it is traveling at supersonic speed. A plane traveling at the speed of sound is traveling at **Mach 1** or about 760 MPH. Mach 2 is twice the speed of sound.

## Regimes of Flight

Sometimes called **speeds of flight**, each regime is a different level of flight speed.

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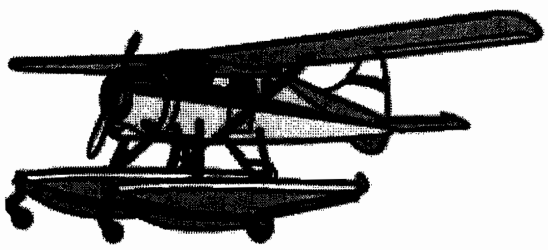
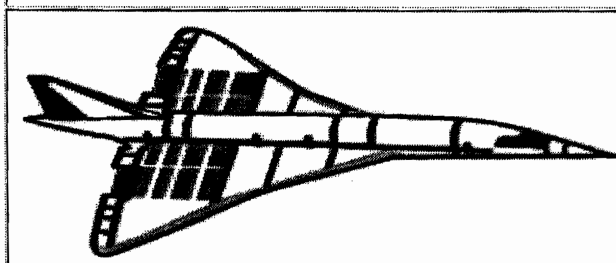
|  Seaplane | **General Aviation** (100-350 MPH).<br><br>Most of the early planes were only able to fly at this speed level. Early engines were not as powerful as they are today. However, this regime is still used today by smaller planes. Examples of this regime are the small crop dusters used by farmers for their fields, two and four seater passenger planes, and seaplanes that can land on water. |
|  Boeing 747 | **Subsonic** (350-750 MPH).<br><br>This category contains most of the commercial jets that are used today to move passengers and cargo. The speed is just below the speed of sound. Engines today are lighter and more powerful and can travel quickly with large loads of people or goods. |
|  | **Supersonic** (760-3500 MPH - Mach 1 - Mach 5).<br><br>760 MPH is the speed of sound. It is also called MACH 1. These planes can fly up to 5 times the |

**Fan** - The fan is the first component in a turbofan. The large spinning fan sucks in large quantities of air. Most blades of the fan are made of titanium. It then speeds this air up and splits it into two parts. One part continues through the "core" or center of the engine, where it is acted upon by the other engine components.

The second part "bypasses" the core of the engine. It goes through a duct that surrounds the core to the back of the engine where it produces much of the force that propels the airplane forward. This cooler air helps to quiet the engine as well as adding thrust to the engine.

**Compressor** - The compressor is the first component in the engine core. The compressor is made up of fans with many blades and attached to a shaft. The compressor squeezes the air that enters it into progressively smaller areas, resulting in an increase in the air pressure. This results in an increase in the energy potential of the air. The squashed air is forced into the combustion chamber.

**Combustor** - In the combustor the air is mixed with fuel and then ignited. There are as many as 20 nozzles to spray fuel into the airstream. The mixture of air and fuel catches fire. This provides a high temperature, high-energy airflow. The fuel burns with the oxygen in the compressed air, producing hot expanding gases. The inside of the combustor is often made of ceramic materials to provide a heat-resistant chamber. The heat can reach 2700°.

**Turbine** - The high-energy airflow coming out of the combustor goes into the turbine, causing the turbine blades to rotate. The turbines are linked by a shaft to turn the blades in the compressor and to spin the intake fan at the front. This rotation takes some energy from the high-energy flow that is used to drive the fan and the compressor. The gases produced in the combustion chamber move through the turbine and spin its blades. The turbines of the jet spin around thousands of times. They are fixed on shafts which have several sets of ball-bearing in between them.

**Nozzle** - The nozzle is the exhaust duct of the engine. This is the engine part which actually produces the thrust for the plane. The energy depleted airflow that passed the turbine, in addition to the colder air that bypassed the engine core, produces a force when exiting the nozzle that acts to propel the engine, and therefore the airplane, forward. The combination of the hot air and cold air are expelled and produce an exhaust, which causes a forward thrust. The nozzle may be preceded by a **mixer**, which combines the high temperature air coming from the engine core with the lower temperature air that was bypassed in the fan. The mixer helps to make the engine quieter.

## The First Jet Engine - A Short History of Early Engines

**Sir Isaac Newton** in the 18th century was the first to theorize that a rearward-channeled explosion could propel a machine forward at a great rate of speed. This theory was based on his third law of motion. As the hot air blasts backwards through the nozzle the plane moves forward.

**Henri Giffard** built an airship which was powered by the first aircraft engine, a three-horse power steam engine. It was very heavy, too heavy to fly.

In 1874, **Felix de Temple,** built a monoplane that flew just a short hop down a hill with the help of a coal fired steam engine.

**Otto Daimler**, in the late 1800's invented the first gasoline engine.

In 1894, American **Hiram Maxim** tried to power his triple biplane with two coal fired steam engines. It only flew for a few seconds.

The early steam engines were powered by heated coal and were generally much too heavy for flight.

American **Samuel Langley** made a model airplanes that were powered by steam engines. In 1896, he was successful in flying an unmanned airplane with a steam-powered engine, called the *Aerodrome*. It flew about 1 mile before it ran out of steam. He then tried to build a full sized plane, the *Aerodrome A,* with a gas powered engine. In 1903, it crashed immediately after being launched from a house boat.

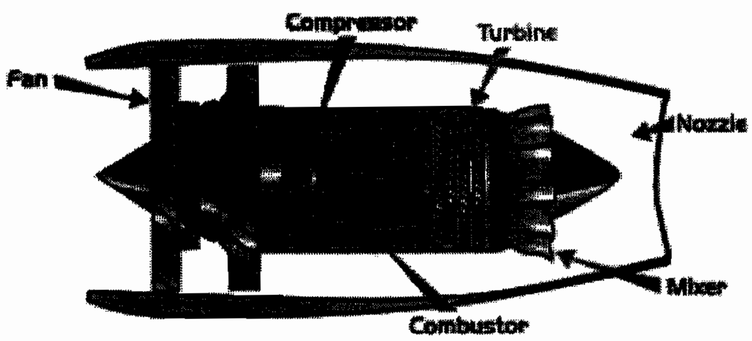
In 1903, the **Wright Brothers** flew, *The Flyer*, with a 12 horse power gas powered engine.

From 1903, the year of the Wright Brothers first flight, to the late 1930s the gas powered reciprocating internal-combustion engine with a propeller was the sole means used to propel aircraft.

It was **Frank Whittle,** a British pilot, who designed the first turbo jet engine in 1930. The first Whittle engine successfully flew in April, 1937. This engine featured a multistage compressor, and a combustion chamber, a single stage turbine and a nozzle.

The first jet airplane to successfully use this type of engine was the German Heinkel He 178. It was the world's first turbojet powered flight. General Electric for the US Army Air Force built the first American jet plane. It was the XP-59A experimental aircraft.

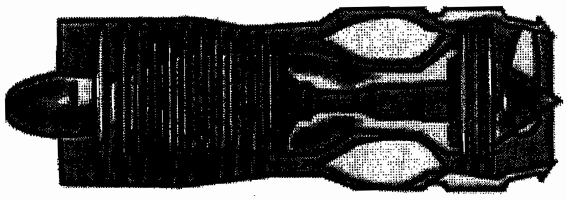
## Types of Jet Engines




## Turbojets

The basic idea of the turbojet engine is simple. Air taken in from an opening in the front of the engine is compressed to 3 to 12 times its original pressure in compressor. Fuel is added to the air and burned in a combustion chamber to raise the temperature of the fluid mixture to about 1,100°F to 1,300° F. The resulting hot air is passed through a turbine, which drives the compressor. If the turbine and compressor are efficient, the pressure at the turbine discharge will be nearly twice the atmospheric pressure, and this excess pressure is sent to the nozzle to produce a high-velocity stream of gas which produces a thrust. Substantial increases in thrust can be obtained by employing an afterburner. It is a second combustion chamber positioned after the turbine and before the nozzle. The afterburner increases the temperature of the gas ahead of the nozzle. The result of this increase in temperature is an increase of about 40 percent in thrust at takeoff and a much larger percentage at high speeds once the plane is in the air.

The turbojet engine is a reaction engine. In a reaction engine, expanding gases push hard against the front of the engine. The turbojet sucks in air and compresses or squeezes it. The gases flow through the turbine and make it spin. These gases bounce back and shoot our of the rear of the exhaust, pushing the plane forward.

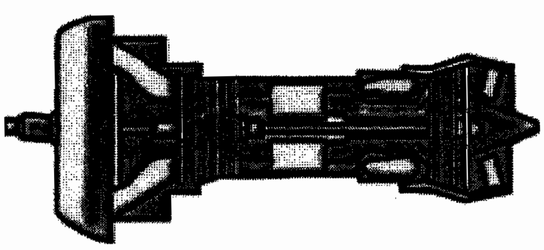


**Picture of Turbojet Engine**

## Turboprops

A turboprop engine is a jet engine attached to a propellor. The turbine at the back is turned by the hot gases, and this turns a shaft that drives the propellor. Some small airliners and transport aircraft are powered by turboprops.

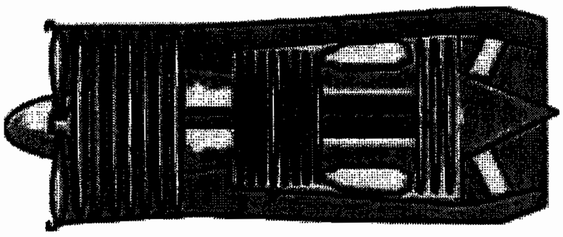
Like the turbojet, the turboprop engine consists of a compressor, combustion chamber, and turbine, the air and gas pressure is used to run the turbine, which then creates power to drive the compressor. Compared with a turbojet engine, the turboprop has better propulsion efficiency at flight speeds below about 500 miles per hour. Modern turboprop engines are equipped with propellers that have a smaller diameter but a larger number of blades for efficient operation at much higher flight speeds. To accommodate the higher flight speeds, the blades are scimitar-shaped with swept-back leading edges at the blade tips. Engines featuring such propellers are called **propfans**.



**Picture of turboprop engine**

## Turbofans

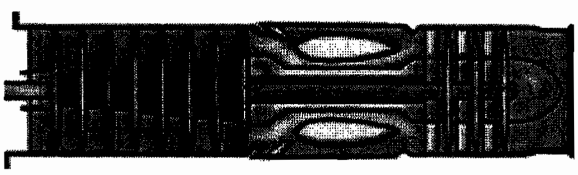
A turbofan engine has a large fan at the front, which sucks in air. Most of the air flows around the outside of the engine, making it quieter and giving more thrust at low speeds. Most of today's airliners are powered by turbofans. In a turbojet all the air entering the intake passes through the gas generator, which is composed of the compressor, combustion chamber, and turbine. In a turbofan engine only a portion of the incoming air goes into the combustion chamber. The remainder passes through a fan, or low-pressure compressor, and is ejected directly as a "cold" jet or mixed with the gas-generator exhaust to produce a "hot" jet. The objective of this sort of bypass system is to increase thrust without increasing fuel consumption. It achieves this by increasing the total air-mass flow and reducing the velocity within the same total energy supply.



**Picture of Turbofan Engine**

## Turboshafts

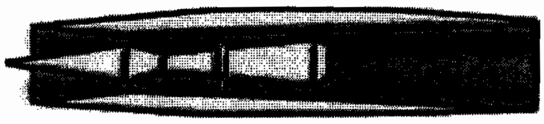
This is another form of gas-turbine engine that operates much like a turboprop system. It does not drive a propellor. Instead, it provides power for a helicopter rotor. The turboshaft engine is designed so that the speed of the helicopter rotor is independent of the rotating speed of the gas generator. This permits the rotor speed to be kept constant even when the speed of the generator is varied to modulate the amount of power produced.



**Picture of Turboshaft Engine**

## Ramjets

The simplest jet engine has no moving parts. The speed of the jet "rams" or forces air into the engine. It is essentially a turbojet in which rotating machinery has been omitted. Its application is restricted by the fact that its compression ratio depends wholly on forward speed. The ramjet develops no static thrust and very little thrust in general below the speed of sound. As a consequence, a ramjet vehicle requires some form of assisted takeoff, such as another aircraft. It has been used primarily in guided-missile systems. Space vehicles use this type of jet.



**Picture of Ramjet Engine**