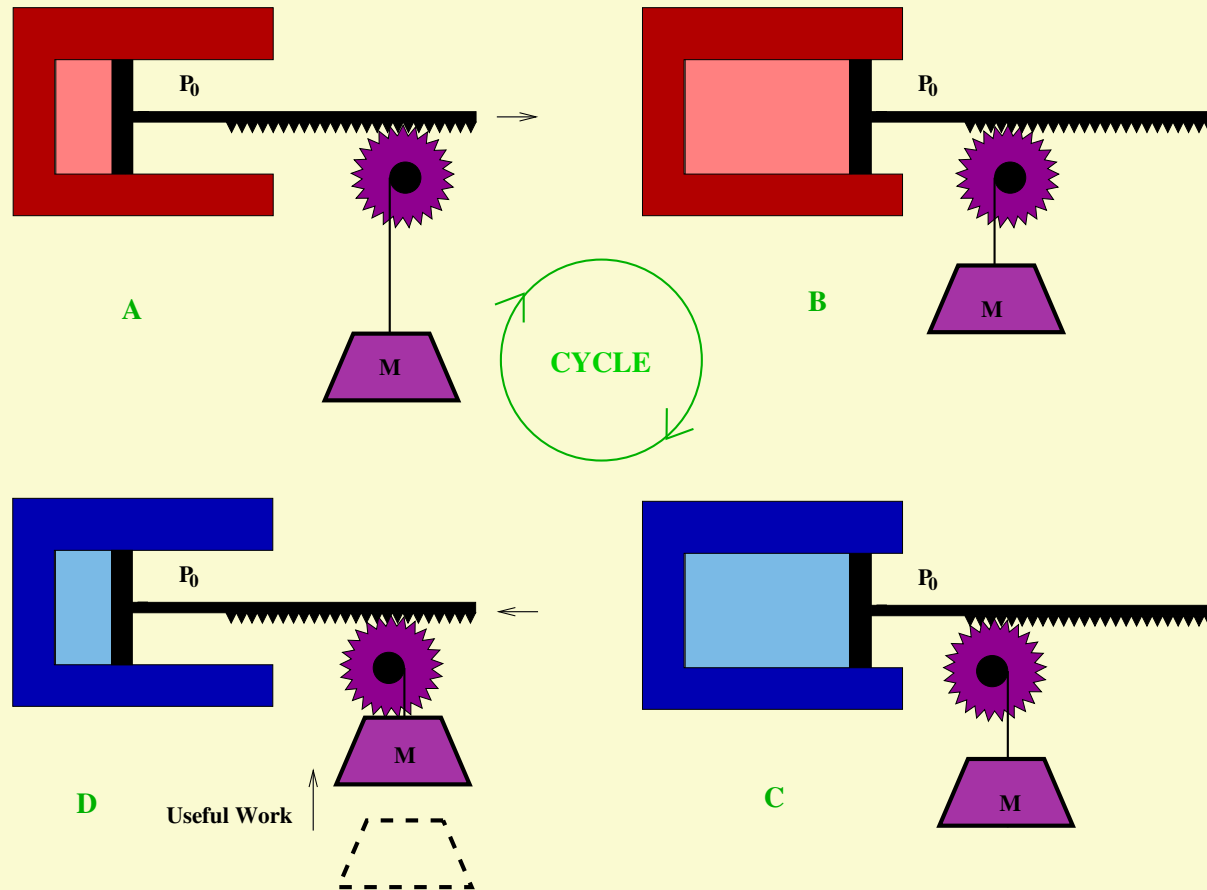


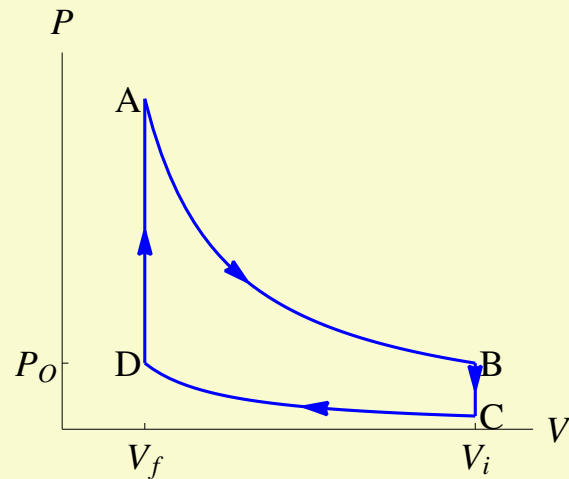
Introduction to Heat Engines



It is easy to turn heat into work. The first stage (A→B) of the picture above illustrates the process: hot gas compressed above atmospheric pressure will expand and the movement of the piston can be harnessed to do work. If the expansion is isothermal the gas will draw heat from the reservoir and convert it into work.

But it is not so easy to continue. To re-compress the gas we would need to do an equivalent amount of work! A useful heat engine is not a one-off stroke, it is a cyclical process during which the system periodically returns to its initial state, and the process can be repeated again and again.

To continue the cycle, we can cool the gas (B→C), after which it can be compressed with less work than before (C→D). If we cool it enough, we can even get the atmosphere to do work on it during the compression phase, as suggested above. Or we might need to supply some work externally, but less than we got out during the main power stroke (A→B). Finally we heat the gas again and repeat the cycle. On returning to A, the engine is unchanged but the surroundings are not. The mass has been raised (useful work has been obtained), heat has been supplied from the hot reservoir (D→B), and, crucially, *waste heat has been supplied to the cold reservoir* (B→D). By conservation of energy, of course, the net work done on the gas equals the difference in the heat supplied and the heat discarded.



This is a crude approximation of a Stirling engine, in which the gas cycles between two reservoirs. A→B and C→D are shown as isothermal expansion and contraction, and the other two processes as isochoric (constant volume). The net work done by the gas is the area within the curve; the parameters chosen for the sketch are somewhat unrealistic. The gas in the cylinder is called the *working fluid*. By drawing the cycle with solid lines on a *PV* diagram, we are implicitly assuming quasi-static, frictionless processes—rather a strong idealisation!

Most other engines do not actually keep the same working fluid throughout, for instance drawing in steam from a reservoir and getting rid of exhausts, but the concept of a cycle with the initial state recurring periodically is common to all.

The Newcomen engine used steam as the working fluid, and cold water to condense it making for a powerful return stroke with essentially a vacuum in the cylinder. Internal combustion engines use the Otto or Diesel cycles; in these ignition of the fuel-air mix takes place when the gas is compressed and takes the place of contact with a hot reservoir. These have an extra (constant pressure) stroke in which the piston drives out the exhaust gases and draws in air and fuel. In the absence of heat reservoirs, the main working strokes of the Otto and Diesel cycles are adiabatic rather than isothermal.

It is also important that real engines run continuously, and most make use of the momentum of a flywheel (or of the driven vehicle) to power the compression phase.

[This link](#), courtesy of Xing Min Wang, has clear and helpful animations of the idealised Otto, Diesel and Carnot cycles.

[Animated Engines](#) has animations of a large variety of realistic engines, though without the accompanying cycles.