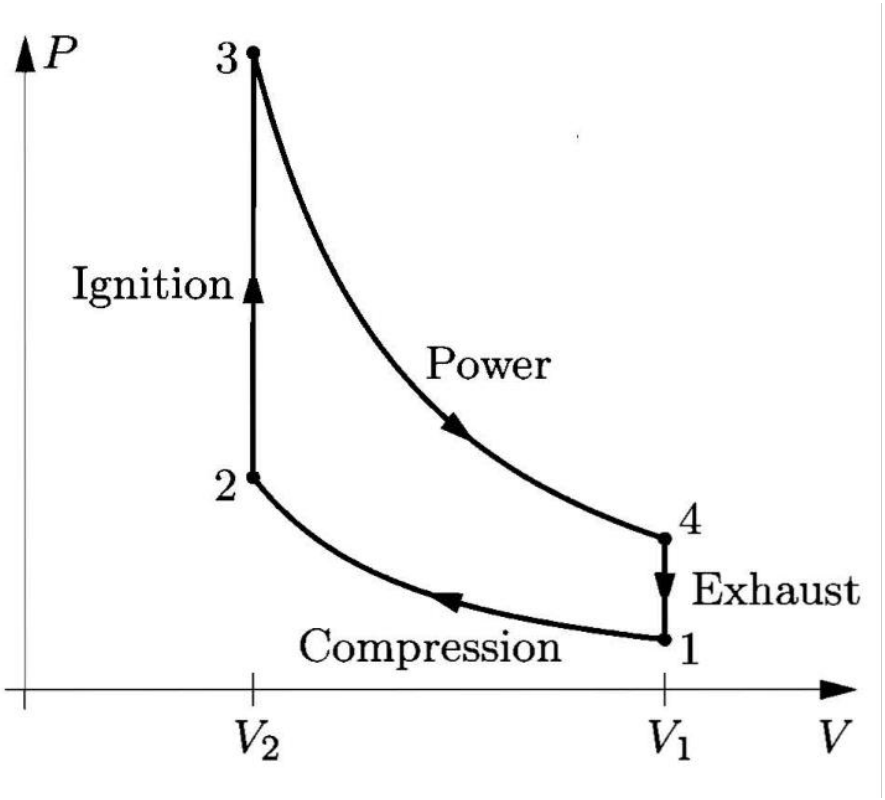
MATH327: Statistical Physics, Spring 2022

Tutorial problem — Otto cycle

The figure below shows the 'Otto cycle' that describes an idealized petrol engine. The compression and expansion ('power') stages are adiabatic, while the volume is fixed at V_2 for the 'ignition' stage that burns the fuel to produce heat, and at $V_1 > V_2$ for the 'exhaust' stage that replaces the burnt fuel with cooler, fresh gas. The **compression ratio** is defined as $r \equiv V_1/V_2 > 1$.



The efficiency η of the Otto cycle depends *only* on the compression ratio r. What is this efficiency? How does it compare to the efficiency of the Carnot cycle? How should V_1 and V_2 be chosen to maximize the efficiency?

Hint: Given the labels in the diagram above, T_1 would be the low temperature of the cold reservoir while T_3 would be the high temperature of the hot reservoir. The corresponding Carnot cycle efficiency is therefore $\eta_{\text{Carnot}} = 1 - \frac{T_1}{T_3}$, and the comparison is easiest if the Otto cycle efficiency is expressed in terms of temperatures rather than volumes.