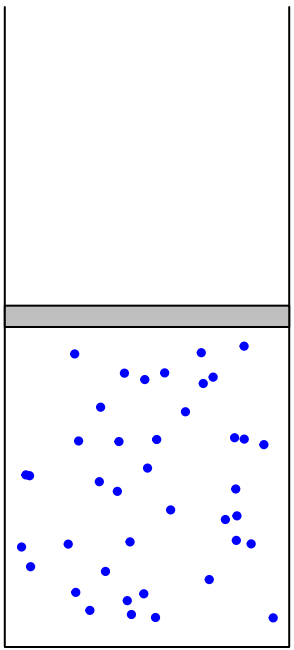
A basic heatpump

Why more energy is transferred than you put in

Consider a cold heat source, a warm sink and a cylinder of gas, contained by a moveable piston, that can be connected to either...

initial state

cold heat source



gas at external pressure

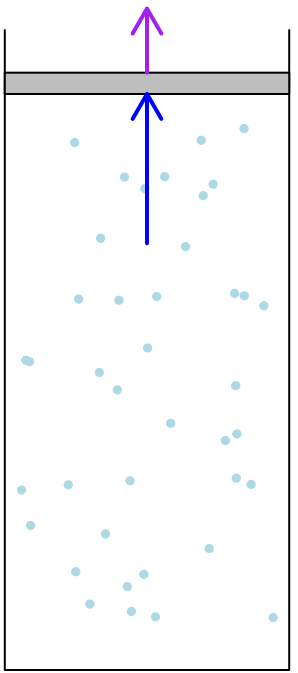
gas at temperature of cold source

Temperature measures average Kinetic Energy (KE) of molecules

Energy (heat) only flows from higher to lower temperatures

expand the gas

cold heat source

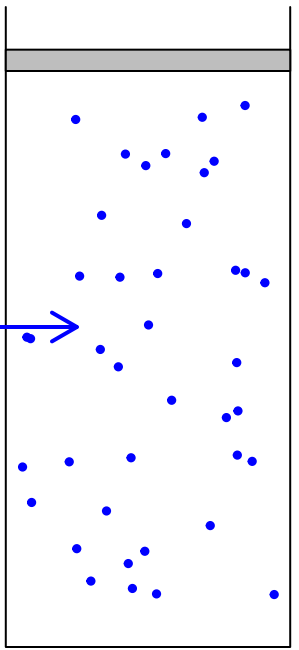


gas pressure does work so molecules lose KE and cool

some extra work needed to overcome difference to external pressure

Work is transfer of energy by a force causing a displacement

let gas rewarm



cold heat source

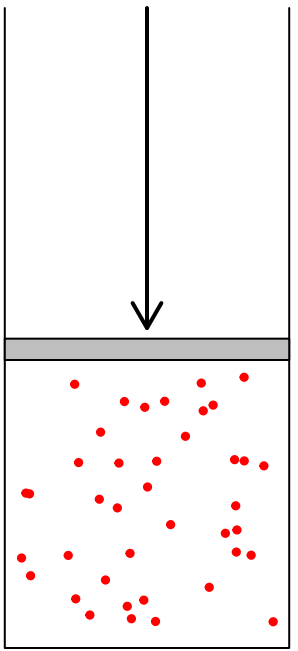
gas regains lost energy from cold heat source

gas still low pressure

compress gas, isolate from cold

release piston and pressure difference returns work done to to the gas, heating it

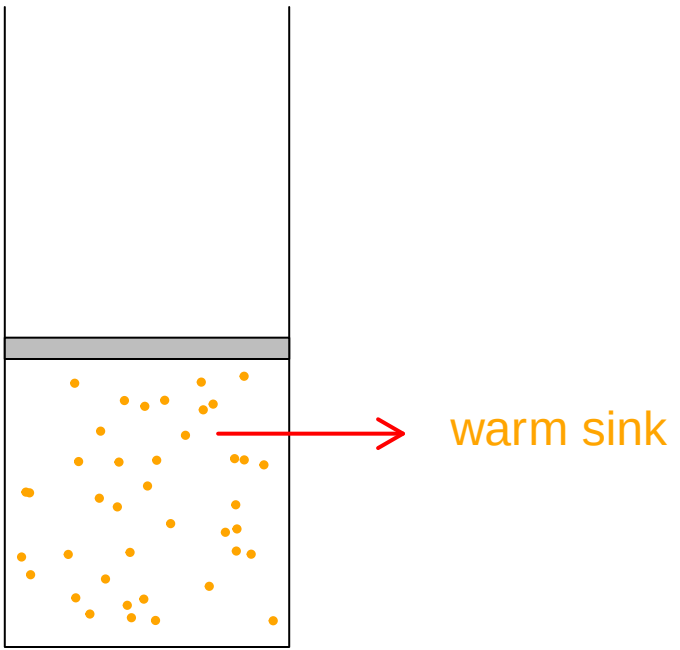
add a little extra work/ pressure, to later release



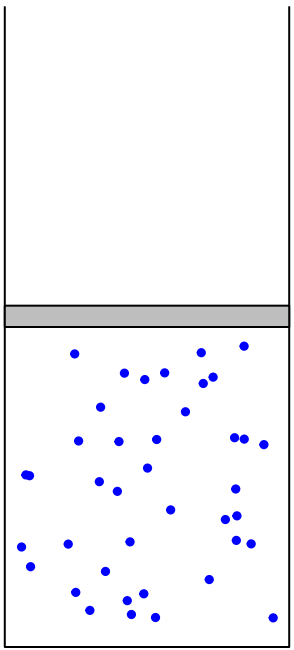
warm sink

let gas cool to warm temperature

gas cools to warm temperature, transferring heat energy to warm sink



return to initial state



release slight pressure excess, reclaiming energy and cooling gas to original temperature

Notes

The above supplied external energy at the expansion step. We could just as well supply it at the compression step.

Real heatpumps do not use a piston, but a continuous compression and expansion circuit.

A gas that undergoes a phase transition from liquid to gas and back allows higher rates of energy transfer.

External energy required per unit heat energy transferred depends on the source to sink temperature difference.

The theoretical lower limit on external energy required is derived from the Carnot cycle. A real domestic heatpump can manage about 20% at best.