Thermodynamics: Heat Engines & Refrigerators
If diesel engines are more efficient than gasoline engines, why don't we use diesel instead?

- There are other economic factors at work, including the relative price/supply of gasoline and diesel, as well as infrastructure considerations.

I found it interesting that the second law of thermodynamics only applies most of the time. I really like it because it is a scientific law that allows for 'miracles' to happen; entropy can happen backwards, it is just monumentally unlikely.

- Should we call it a “law” then?

Several questions similar to this: A better explanation of the properties of an engine would be much appreciated. I haven’t had much experience at all with engines, and their properties. I think most physics students seem to come in with a working knowledge of this and a mini-crash course would be great!

- So don’t worry – you’re probably not at as much of a disadvantage as you think!
Give your own example of some process or event where the first law of thermodynamics (what is that again?) is not violated, but the event will not happen because it violates the second law of thermodynamics.

- a pendulum that just starts swinging because it gathers energy from the environment.

- A spring never collects internal energy and begins to oscillate.
Review: Special Processes

- Constant Volume (isovolumetric aka isochoric)
- Constant Pressure (isobaric)
- Constant Temperature (isothermal)
- No heat added (adiabatic)
- General Process?
  - $\Delta E_{\text{int}} =$?
  - $W =$?
  - $Q =$?
Cyclical Processes

- $\Delta E_{\text{int}} = ?$
- $W = ?$
- $Q = ?$
Engines: Energy Transformation

Work is done by the gas

Heat in (Higher T) → Engine → Exhaust Out (Lower T)

Notation: $Q_h, Q_c, T_h, T_c, |W|$

$Q_{in} = |W| + Q_{out}$
Heat Engine Example

A) Piston at room temperature and atmospheric pressure
Heat Engine Example

A-B) Gas heated to keep volume constant as cart rolls onto piston
B-C) Gas heated to increase volume and lift the cart
Heat Engine Example

C-D) Gas cooled to keep volume constant as cart rolls off piston
Heat Engine Example

D-A) Gas cooled to reduce volume back to initial level
In the book's discussion of the gasoline engine, work is done on the gas during step 2 of the cyclic process. How can it work as an engine if we are doing work on it instead of getting work out?! Explain using your own words and using the P-V diagram.

- Work is done on the gas to compress it, but once the gas is ignited it performs a greater work pushing the piston back down.
- The area between the two curves is the net work produced from the entire cycle. We have to put in a bit of work to follow the cycle above and raise the temperature, but the engine does more work than what is put in. This means we still get a lot of work done out of it. Ideally, we want the area under the second curve to be close to zero, but that's impossible.
Comparing engines: efficiency

- We want an engine to do work: More work = better
- We have to pay a cost to get that work: More heat in = worse

\[
e = \frac{W}{Q_h} \quad Q_h = W + Q_c
\]

\[
e = 1 - \frac{Q_c}{Q_h}
\]
True or False: It is possible for heat to flow from a cold object to a hot object?
A. True
B. False
Refrigerators (or air conditioners)

COP: How good is your refrigerator?

$$COP_{cooling} = \frac{|Q_c|}{|W|}$$
Heat Pumps

COP: How good is your heat pump?

\[ COP_{heating} = \frac{|Q_h|}{|W|} \]
Worked Problem

- Make up a “three-legged cycle”.
- What is the efficiency of the cycle?
- Game Plan:
  1. Calculate $Q$ for each leg
  2. Calculate $Q_h$, $Q_c$, $|W|
  3. $e = |W|/Q_h$
  4. Test to make sure $e < e_{\text{max}}$ (next lecture)
- You should expect a question like this on the exam.