

Question:

A car burns gasoline to obtain energy but allows some heat to escape into the air. Could a mechanically perfect car avoid releasing heat altogether?

Heat Engines

- As heat flows naturally from hot to cold, a heat engine diverts some heat and converts it into useful work
- Natural heat flow increases entropy
- Converting heat to work decreases entropy
- Overall, entropy doesn't decrease!

Heat Pumps

- As it converts useful work into heat, a heat pump is able to transfer some heat from cold to hot
- Reverse heat flow decreases entropy
- Converting work to heat increases entropy
- Overall, entropy doesn't decrease!

Question:

A car burns gasoline to obtain energy but allows some heat to escape into the air. Could a mechanically perfect car avoid releasing heat altogether?

Efficiency

- As the temperature difference between hot and cold increases
 - Heat's change in entropy increases
 - A heat pump becomes less efficient
 - A heat engine becomes more efficient

Internal Combustion Engine

- Burn fuel and air in enclosed space
- Produce hot burned gases
- Allow heat to flow to cold outside air
- Convert some of this heat into useful work

Four Stroke Engine

- Induction Stroke: fill cylinder with fuel and air
- Compression Stroke: squeeze mixture
- Power Stroke: burn and extract work
- Exhaust Stroke: empty cylinder of exhaust

Induction Stroke

- Engine pulls piston out of cylinder
- Low pressure inside cylinder
- Atmospheric pressure pushes fuel and air mixture into cylinder
- Engine does work on the gases during this stroke



Compression Stroke

- Engine pushes piston into cylinder
- Mixture is compressed to high pressure and temperature
- Engine does work on the gases during this stroke



Power Stroke

- Mixture burns to form hot gases
- Gases push piston out of cylinder
- Gases expand to lower pressure and temperature
- Gases do work on engine during this stroke



Exhaust Stroke

- Engine pushes piston into cylinder
- High pressure inside cylinder
- Pressure pushes burned gases out of cylinder
- Engine does work on the gases during this stroke



Ignition System

- Car stores energy in an electromagnet
- Energy is released as a pulse of high voltage electricity
- Electric spark ignites fuel and air mixture
- Two basic types of ignition
 - Classic: points and spark coil
 - Electronic: transistors and pulse transformer

Efficiency Limits

- The engine can't extract all of the thermal energy as work
- Some heat is ejected into the atmosphere
- The hotter the burned gases and the colder the outside air, the more efficient the engine can be
- Real engines never reach ideal efficiency

Engine Cycle 1



- Fuel and air mixture after induction stroke
- Pressure = Atmospheric
- Temperature = Ambient

Engine Cycle 2



- Fuel and air mixture after compression stroke
- Pressure = High
- Temperature = Hot

Engine Cycle 3



- Burned gases after ignition
- Pressure = Very high
- Temperature = Very hot

Engine Cycle 4



- Burned gases after power stroke
- Pressure = Moderate
- Temperature = High

Engine Cycle 4a



- Burned gases after extra expansion
- Pressure = Atmospheric
- Temperature = Moderate

Engine Cycle 4b



- Burned gases after even more expansion
- Pressure = Below atmospheric
- Temperature = Ambient

Diesel Engine

- Uses compression heating to ignite fuel
 - Squeezes pure air to high pressure/temperature
 - Injects fuel into air between compression and power strokes
 - Fuel burns upon entry into superheated air
- Power stroke extracts work from burned gases
- High compression allows for high efficiency

Vehicle Pollution

- Incomplete burning leaves carbon monoxide and hydrocarbons in exhaust
- Accidental oxidization of nitrogen produces nitrogen oxides in exhaust
- Diesel exhaust includes many carbonized particulates

Catalytic Converter

- Platinum assists oxidization of carbon monoxide and hydrocarbons to carbon dioxide and water
- Rhodium assists reduction of nitrogen oxides to nitrogen and oxygen.
- Catalysts supported on high specific surface structure in exhaust duct: catalytic converter

Transmissions

- Changes force/distance (or more accurately torque/rotation rate) relationships between the engine and the wheels
- Two basic types
 - Manual: clutch and gears
 - Automatic: fluid coupling and gears

Manual Transmission

- Clutch uses friction to convey torque from engine to drive shaft
 - Opening clutch decouples engine and shaft
 - Closing clutch allows engine to twist shaft
- Gears control mechanical advantage

Automatic Transmission

- Fluid coupling uses moving fluid to convey torque to drive shaft
 - Engine turn impeller (fan) which pushes fluid
 - Moving fluid spins turbine (fan) which twists shaft
 - Decoupling isn't required
- Gears control mechanical advantage

Brakes

- Use sliding friction to reduce car's energy
- Two basic types
 - Drum: cylindrical drum and curved pads
 - Disk: disk-shaped rotor and flat pads
- Brakes are operated hydraulically
 - Pedal squeezes fluid out of master cylinder
 - Fluid entering slave cylinder activates brake