

## Automobiles

### 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?

### Observations About Automobiles

- They burn gas to obtain their power
- They are rated by horsepower and volume
- Their engines contain “cylinders”
- They have electrical systems
- They are propelled by their wheels

### Heat Engines

- A heat engine diverts some heat as it flows naturally from hot to cold and converts that heat into useful work
  - Natural heat flow increases entropy
  - Converting heat to work decreases entropy
- Entropy doesn't decrease
- Some heat becomes work

### Heat Pumps

- A heat pump transfers some heat from cold to hot, against the natural flow, as it converts useful work into heat
  - Reverse heat flow decreases entropy
  - Converting work to heat increases entropy
- Entropy doesn't decrease
- Some heat flows from cold to hot

### 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

- Burns fuel and air in enclosed space
- Produces hot burned gases
- Allows heat to flow to cold outside air
- Converts some heat into useful work

## Four Stroke Engine

- Induction Stroke: fill cylinder with fuel & 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 high voltage pulse
- Electric spark ignites fuel and air mixture
- Two basic types of ignition
  - Classic: points and spark coil
  - Electronic: transistors and pulse transformer

## Efficiency Limits

- Even ideal engine isn't perfect
  - Not all the thermal energy can become work
  - Some heat must be ejected into atmosphere
- However, ideal efficiency improves as
  - the burned gases become hotter
  - the outside air becomes colder
- Real engines never reach ideal efficiency

## Engine Step 1

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



## Engine Step 2

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



## Engine Step 3

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



## Engine Step 4

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



## Engine Step 4a

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



## Engine Step 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 (actually 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 turns impeller (fan) that pushes fluid
  - Moving fluid spins turbine (fan) and drive 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

## Summary About Automobiles

- Cylinders expand hot gas to do work
- Uses the flow of heat from hot burned gases to cold atmosphere to produce work
- Energy efficiency is limited by thermodyn.
- Higher temperatures increase efficiency