

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



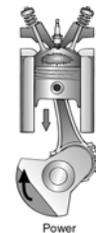
Compression Stroke

- 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