Automobiles

Turn off all electronic devices

Observations about Automobiles

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

6 Questions about Automobiles

1. How can an automobile run on thermal energy?
2. How efficient can an automobile engine be?
3. How is an automobile engine a heat engine?
4. Why do cars sometime "knock?"
5. How is a diesel engine different?
6. Why does the engine have a catalytic converter?

Question 1

Q: How can an automobile run on thermal energy?

A: An automobile engine is a heat engine

- An automobile
  - allows heat to flow from hot (flame) to cold (air)
  - would cause total entropy of world to increase greatly
  - were it not for the mechanical power it produces!
- It turns some thermal power to mechanical power
  - so the total entropy of world increases only modestly

Question 2

Q: How efficient can an automobile engine be?

A: Its efficiency is limited by the law of entropy

- A heat engine cannot decrease the world's overall entropy
  - Its efficiency increases with increasing temperature difference
  - because heat flowing from hot to cold then creates more entropy
  - so a larger fraction of that heat can be converted to work
- A heat pump also cannot decrease the world's overall entropy
  - Its efficiency decreases with increasing temperature difference
  - because heat pumped from cold to hot destroys more entropy
  - so a larger proportion of work must be converted to heat

Question 3

Q: How is an automobile engine a heat engine?

A: Heat flows from hot (flame) to cold (outside air)

- An internal combustion engine
  - burns a fuel-air mixture in an enclosed space to produce hot burned gases
  - As heat flows from hot to cold (outside air)
  - engine converts some heat into useful work, propelling the vehicle
- That engine uses 4 separate steps or "strokes":
  - Induction Stroke: fill cylinder with fuel & air
  - Compression Stroke: squeeze mixture
  - Power Stroke: burn and extract work
  - Exhaust Stroke: empty cylinder of exhaust

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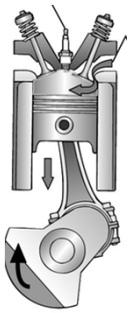
Induction Stroke

- Intake valve opens
- Engine pulls piston out of cylinder
  - Engine does work on piston
  - Low pressure produced inside cylinder
- Fuel-air mixture flows into cylinder
- Intake valve closes



Induction

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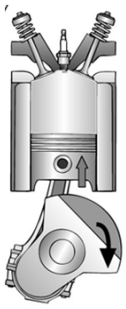
Compression Stroke

- Engine pushes piston into cylinder
  - Engine does work on piston
- Mixture is compressed
  - Mixture pressure increases
  - Mixture temperature increases
- Work becomes heat



Compression

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Power Stroke

- Spark plug ignites the fuel-air mixture
- Hot gas pushes piston out of cylinder
  - Piston does work on engine
- Burned gas expands
  - Gas pressure decreases
  - Gas temperature decreases
- Heat becomes work

Power

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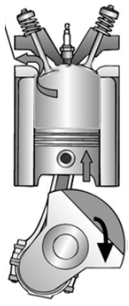
Exhaust Stroke

- Exhaust valve opens
- Engine pushes piston into cylinder
  - Engine does work on piston
  - High pressure produced inside cylinder
- Burned gas flows out of cylinder
- Exhaust valve closes



Exhaust

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Efficiency Limits

- Overall, an internal combustion engine
  - produces more work than it consumes
  - converts some heat into work
- Law of entropy limits heat becoming work
  - Some heat must be released into outside air
  - Efficiency increases with the temperature difference
  - Real engines never reach ideal efficiency

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Question 4

Q: Why do cars sometime "knock?"

A: Compressing a flammable gas mixture can ignite it

- During the compression stroke, fuel-air mixture
  - becomes extremely hot
  - can ignite spontaneously (knocking or preignition)
- To avoid knocking, car can
  - reduce its compression ratio to lower peak temperature
  - use fuel that is more resistant to ignition
- Higher octane fuels are simply harder to ignite

Question 5

Q: How is a diesel engine different?

A: It uses compression heating to ignite fuel

- Diesel engine
  - compresses air to very high pressure & temperature
  - injects fuel between compression and power strokes
  - lets fuel ignite upon entry into the superheated air
- Diesel engine has higher compression ratio, so
  - its fuel burns to a higher final temperature
  - it has a higher potential efficiency

Question 6

Q: Why does the engine have a catalytic converter?

A: To remove unwanted components form exhaust

- Imperfect fuel-air mixtures produce pollutants
  - Too rich: carbon monoxide and fuel in exhaust
  - Too lean: nitrogen oxides in exhaust
  - Imperfect diesel: carbonized particulates in exhaust
- Catalytic converter destroys unwanted molecules
  - Platinum particles helps oxidize carbon monoxide and fuel
  - Rhodium particles helps remove nitrogen oxides
- Filter removes and burns unwanted particulates

Summary about Automobiles

- Heat flows from hot (burned gas) to cold (air)
- Some of that heat is converted to work
- Energy efficiency is limited by thermodynamics
- Higher temperatures increase efficiency