Automobiles

Turn off all electronic devices

Observations about Automobiles

They burn gas to obtain their power
They are rated by 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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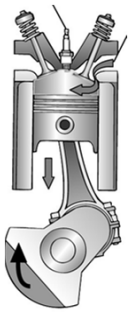
Induction Stroke

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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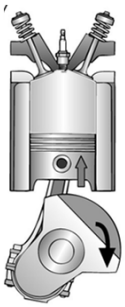
Compression Stroke

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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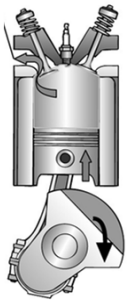
Exhaust Stroke

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