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CHAPTER 9

GAS POWER CYCLES
PART 1

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INTRODUCTION

What is IC Engine?

An internal combustion engine is a thermal system (power plant) that converts heat obtained from chemical energy sources (gasoline, natural gas) into mechanical work.

Where are IC Engines Used?

IC engines are used as the propulsion systems for land transport vehicles such as automobiles (cars, etc.), marine vehicles (boats, etc.) and small airplanes.

IC engines are also used in portable electrical generators and as prime mover in grass cutting machine, etc.

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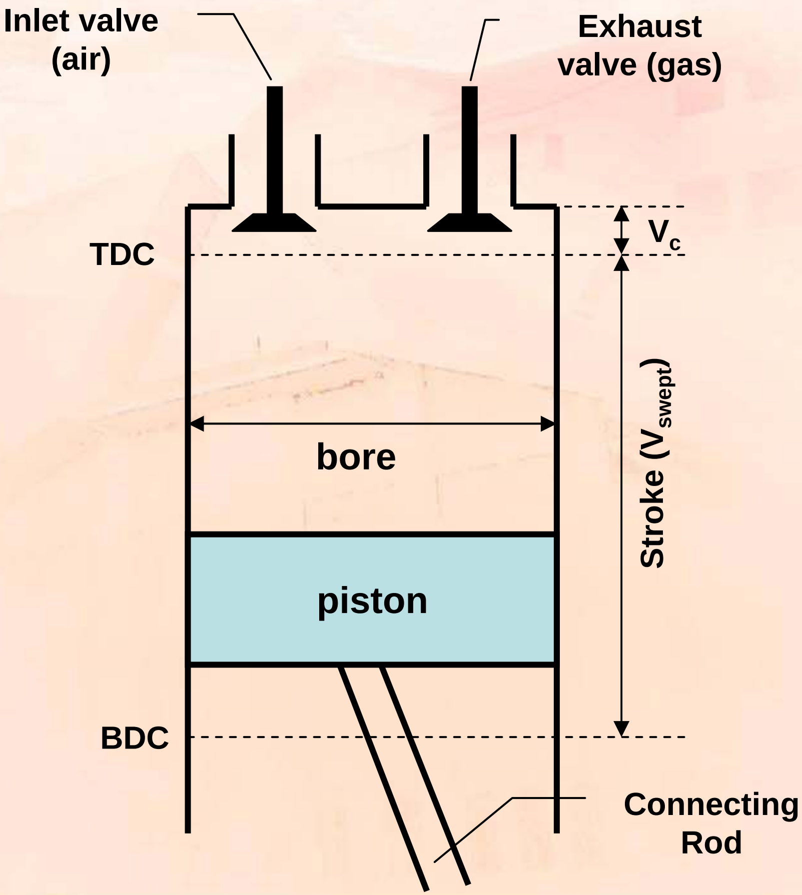
INTRODUCTION

Main Components of IC Engines

Main Components of IC Engines

- Cylinder, piston, inlet valve, exhaust valve and spark plug
- Piston moves from the top dead center (TDC) to the bottom dead center (BDC).
- Clearance volume, V_c is a spacing between the top of the piston and the valve's heads when the piston is at the end of the delivery troke.



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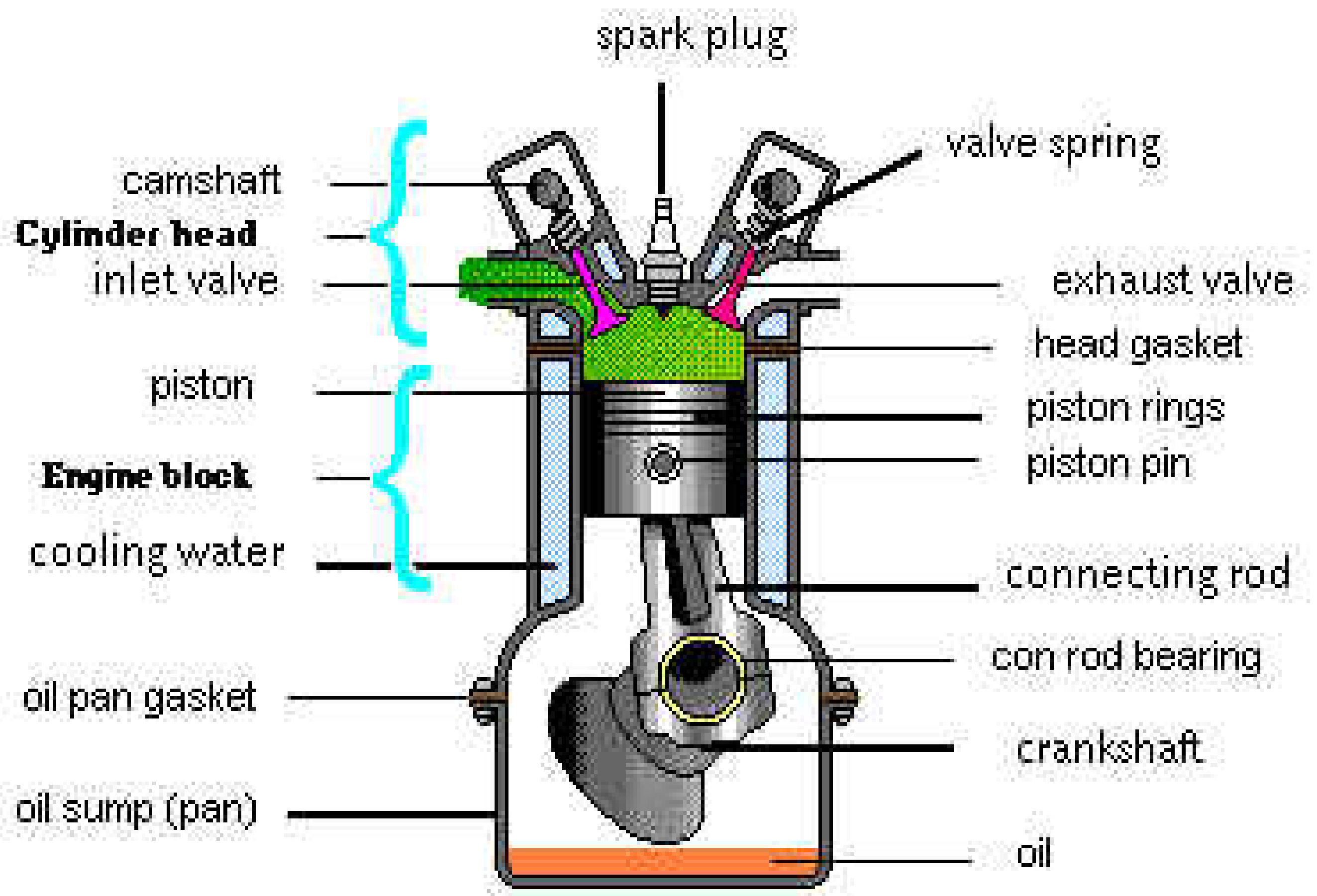
INTRODUCTION



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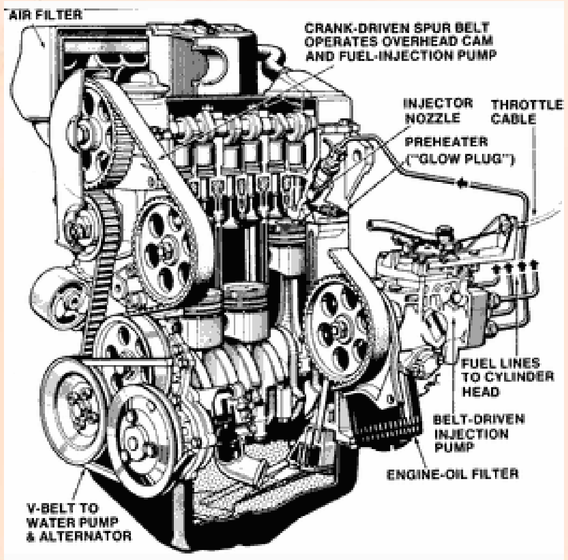
ENGINE CLASSIFICATION

Reciprocating internal combustion (IC) engines are classified into two general categories, depending on how the combustion process in the cylinder is initiated, i.e.:

a) **Spark-ignition (SI) engines;**
b) **Compression-ignition (CI) engines.**



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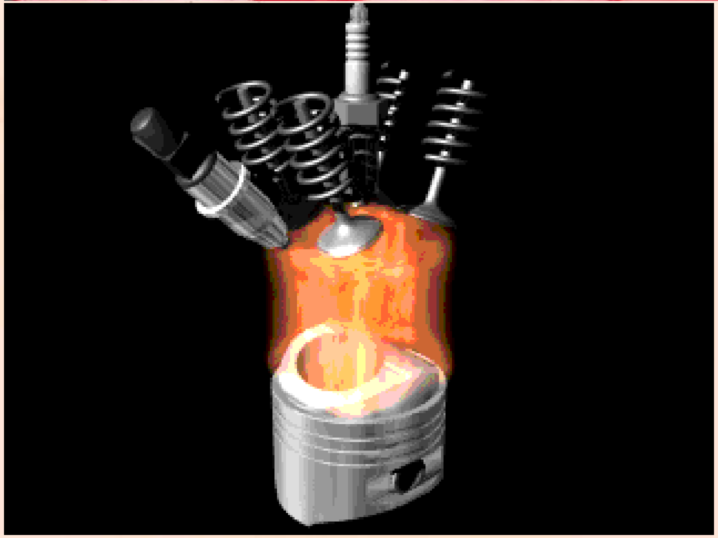
ENGINE CLASSIFICATION

Description of SI Engines

- Fuel : gasoline or petrol, which is mixed with air.
- The air-fuel mixture enters the cylinder and is compressed to a highest pressure and temperature.
- A spark from a spark-plug ignites the combustible air- fuel mixture.
- The high pressure gases pushes the piston downwards, producing a power stroke of the piston.
- The crankshaft transforms the reciprocating motion into rotational motion (rpm)



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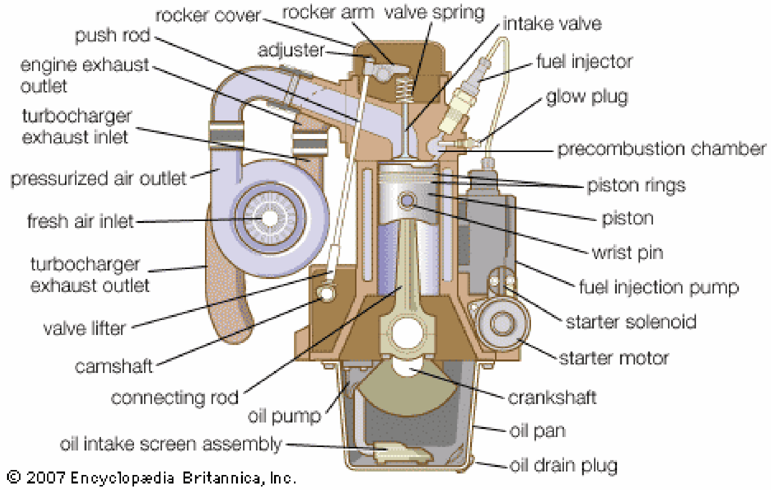
ENGINE CLASSIFICATION

Description of CI Engines

- ❑ Run on liquid diesel fuel
- ❑ The fresh air enters the cylinder and is compressed to about 1/22 of its original volume, causing its temperature to raise to about 540ºC (1000ºF) or higher.
- ❑ Diesel is then injected into the compressed air causes the diesel to burn.
- ❑ The combustion gases pushes the piston downward during the power stroke.piston.
- ❑ The crankshaft transforms the reciprocating motion into rotational motion (rpm)



ENGINE CLASSIFICATION

IN BOTH SI AND CI ENGINES, THE COMBUSTION GASES ARE EVENTUALLY EXHAUSTED OUT OF THE CYLINDER SO THAT FRESH-AIR MIXTURE CAN BE INDUCED INTO THE CYLINDER TO CONTINUE THE THERMODYNAMICS CYCLES – *therefore working on an open cycle is the characteristics of all internal combustion engines since the working fluid does not undergo a complete thermodynamic cycle*.

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ENGINE CLASSIFICATION BY CYCLES

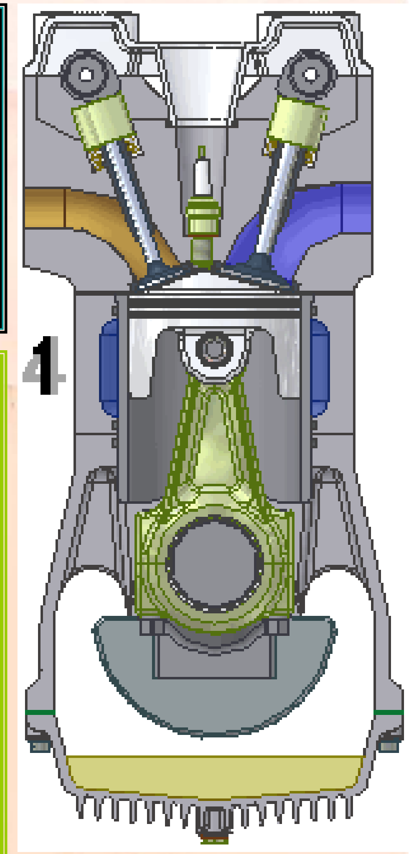
Reciprocating internal combustion engines operate either on two-stroke or four-stroke cycle

Four-stroke Cycle

- Most automotive engines operate on a 4-stroke cycle.
- Every fourth piston stroke is the power stroke.
- The crankshaft makes two revolutions to complete the cycle.

Two-stroke Cycle

- Commonly used in small and medium motorcycles and lawn movers
- The crankshaft makes one revolutions to complete the cycle.
- Less efficient than 4-stroke because incomplete expulsion of exhaust gases
- Simple and inexpensive
- Have high power to weight ratio



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ENGINE CLASSIFICATION BY CYCLES

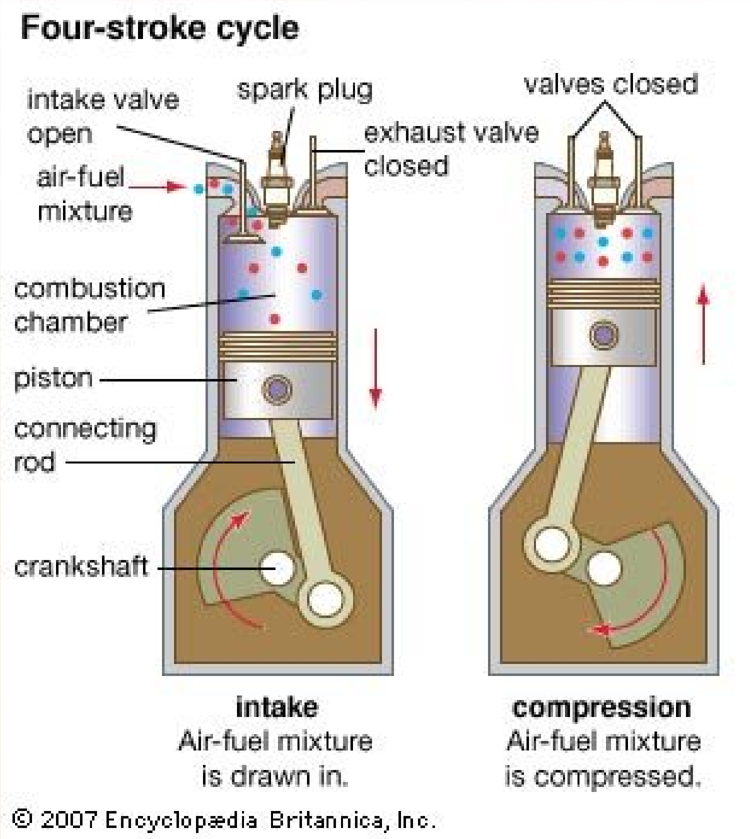
FOUR STROKE CYCLE

Intake stroke:

- The intake valve opened.
- The piston moving downward (from TDC to BDC), allowing the air-fuel mixture to enter the cylinder

Compression stroke:

- The intake valve closed.
- The piston is moving upward (BDC to TDC), compressing the mixture.



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ENGINE CLASSIFICATION BY CYCLES

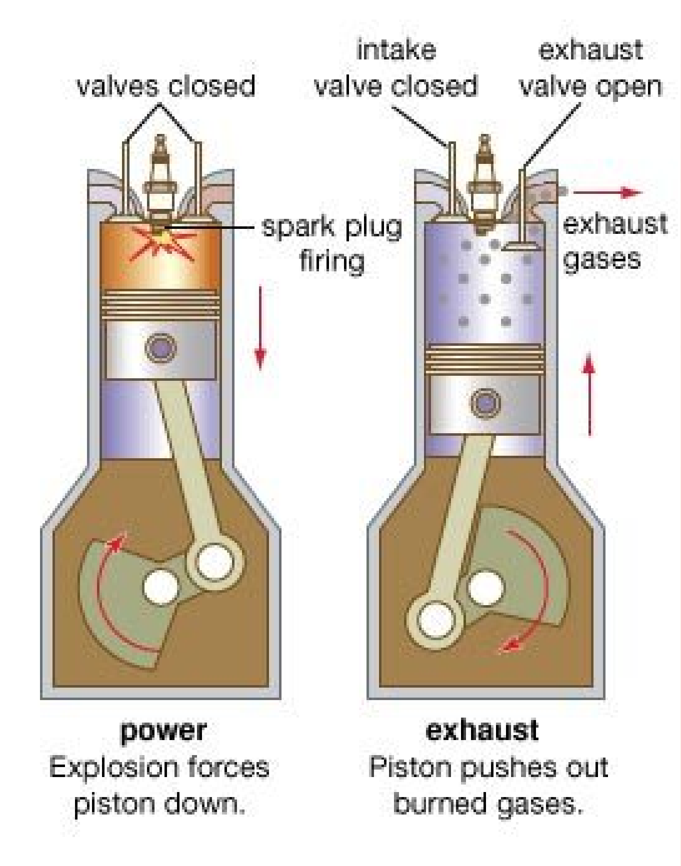
FOUR STROKE CYCLE

Power stroke:

- The ignition system delivers a spark to the spark plug to ignite the compressed mixture.
- As the mixture burns, it creates high pressure that pushes the piston down.

Exhaust stroke:

- The exhaust valve opened.
- The piston moves upward as the burned gases escape from the cylinder.



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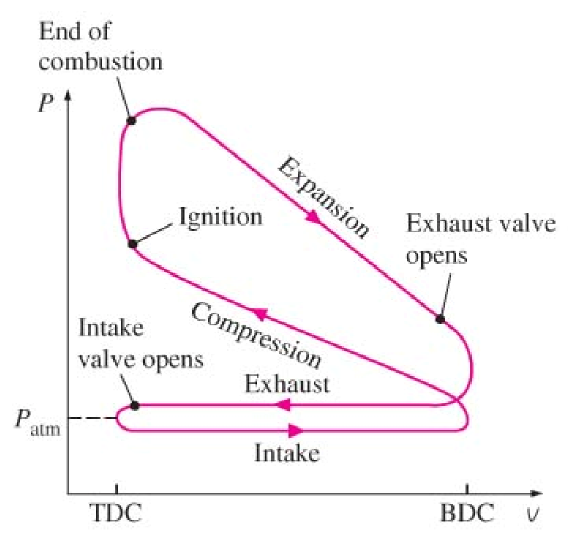
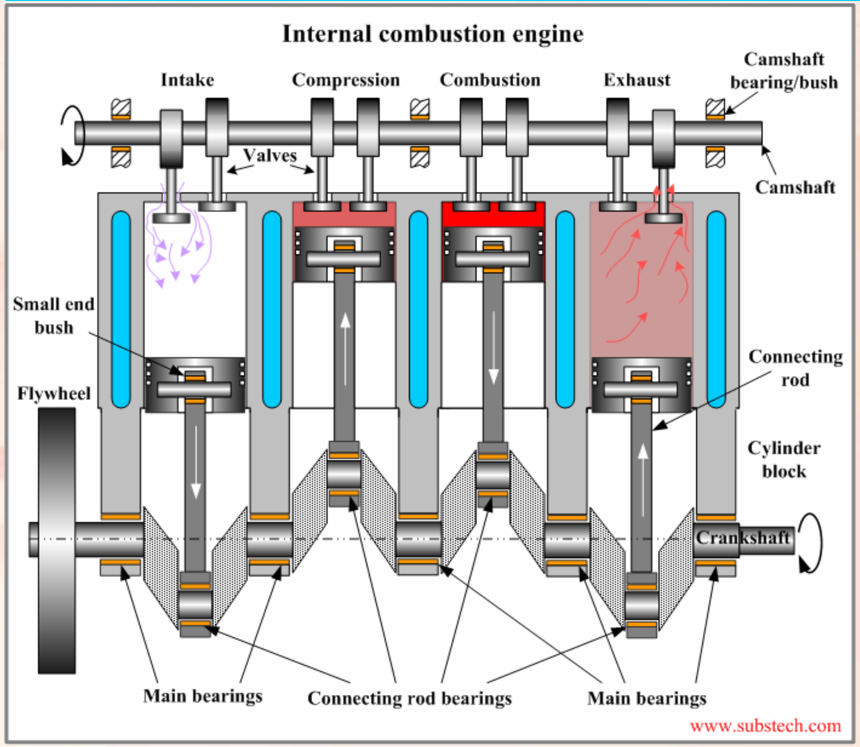
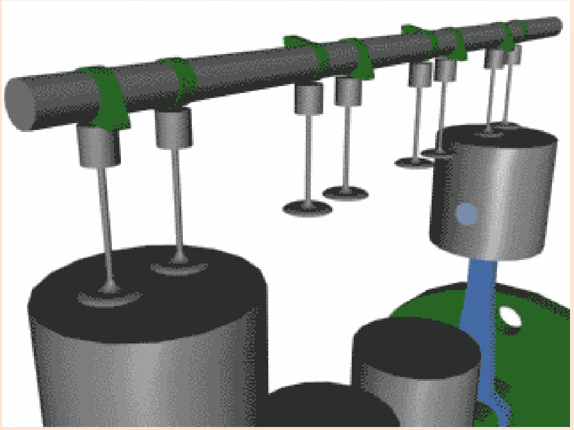
ENGINE CLASSIFICATION BY CYCLES

FOUR CYLINDER, FOUR STROKE ENGINE

- **The ignition occurs before the compression process end.**
- **$P_{sys} > P_{atm}$ during the exhaust stroke.**
- **$P_{sys} < P_{atm}$ during the intake stroke.**







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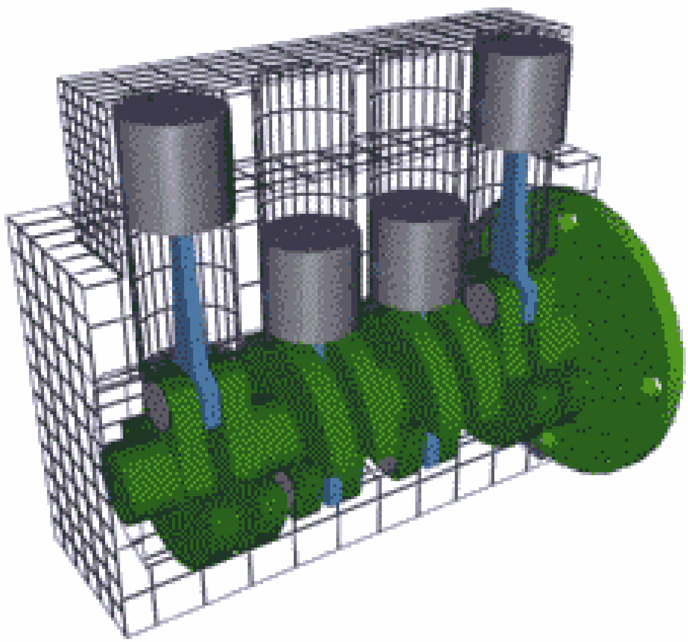
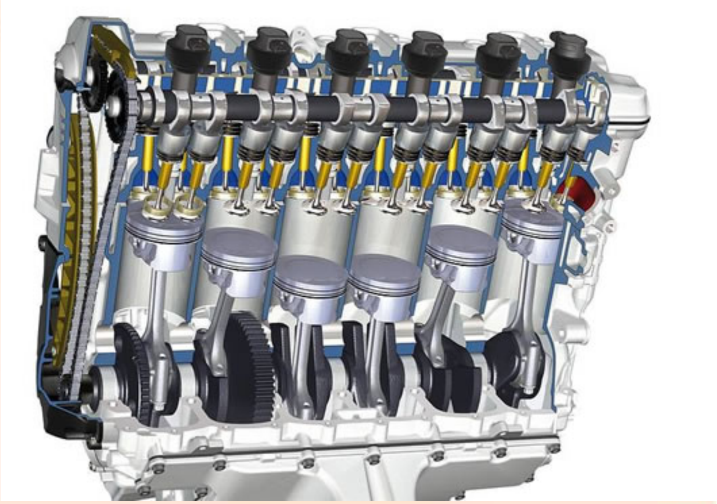
ENGINE CLASSIFICATION BY CYCLES

FOUR STROKE – IN-LINE CYLINDERS ARRANGEMENT

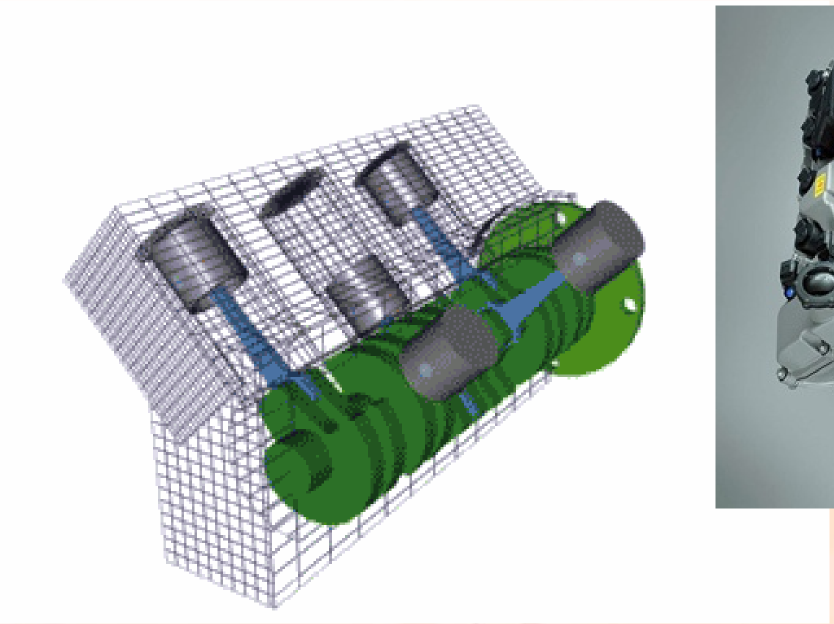


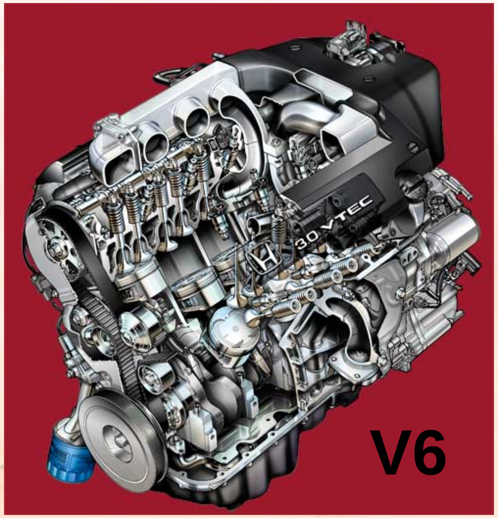


The cylinders are arranged in a line in a single bank.
i.e inline-3, inline-4, inline-5, inline-6

ENGINE CLASSIFICATION BY CYCLES

FOUR STROKE – V CYLINDERS ARRANGEMENT





The cylinders are arranged in 2 banks set at an angle to one another
i.e. V6, V8, V10, V12

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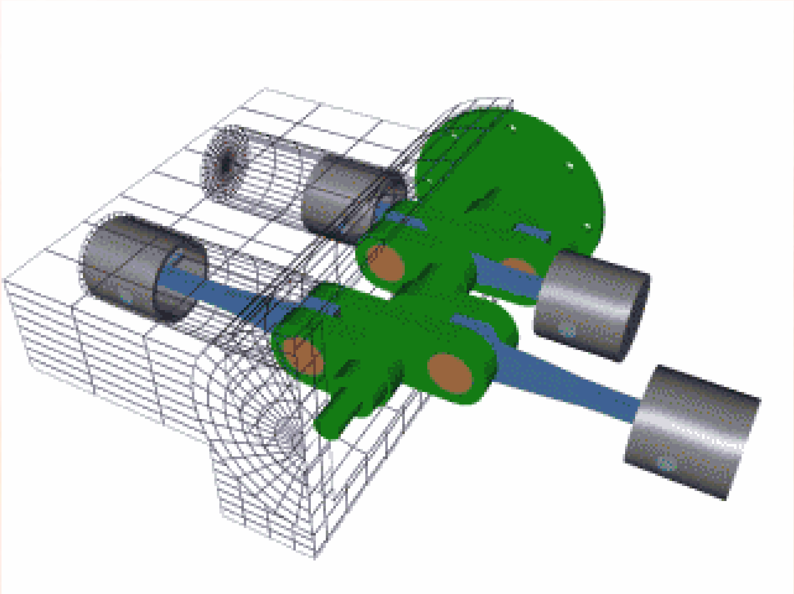
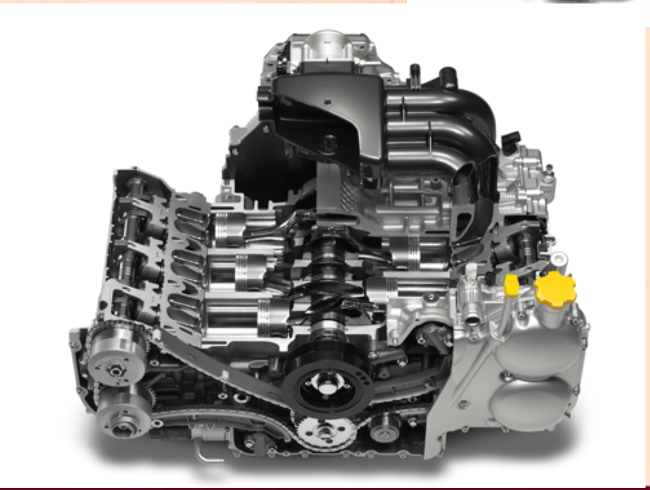
ENGINE CLASSIFICATION BY CYCLES

FOUR STROKE – HORIZONTAL OPPOSED CYLINDERS ARRANGEMENT



The cylinders are arranged in 2 banks on opposite sides of the engine



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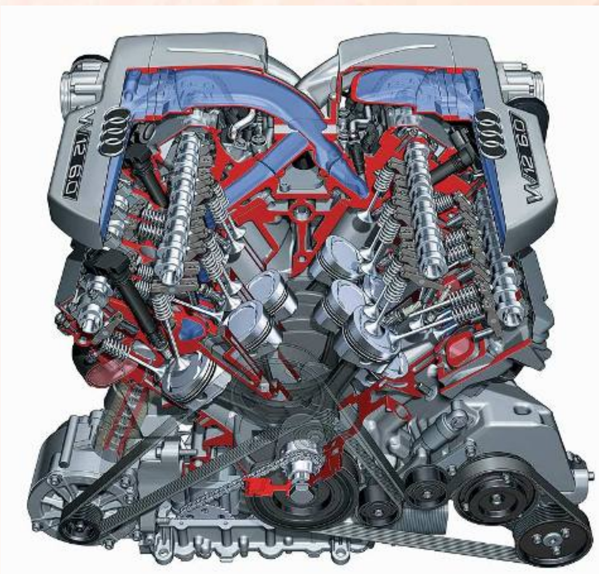
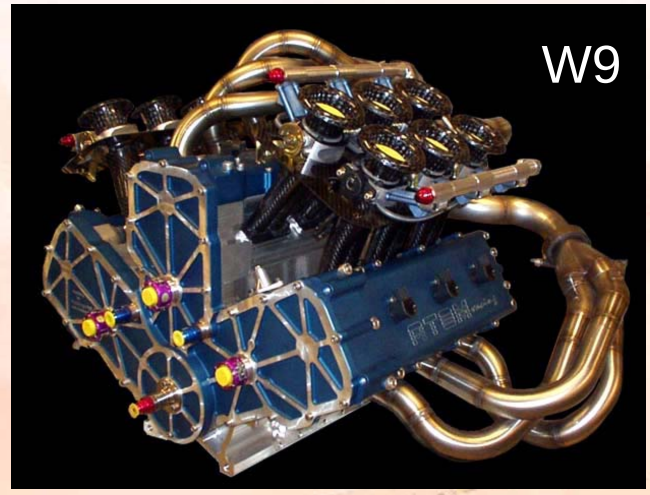
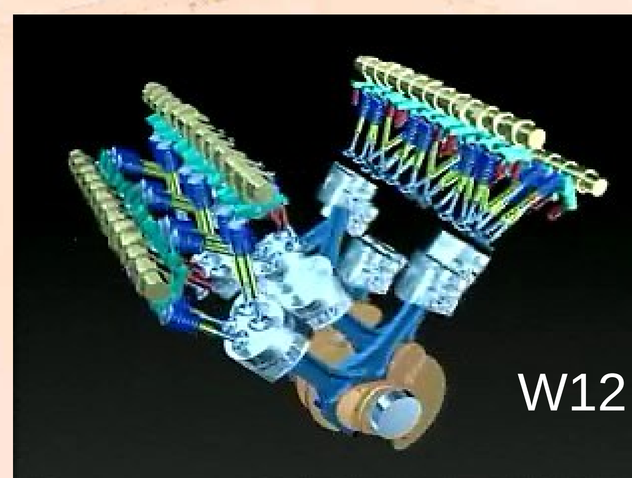
ENGINE CLASSIFICATION BY CYCLES

FOUR STROKE – W CYLINDERS ARRANGEMENT

The cylinders are arranged in 3/4 banks set at an angle to one another
i.e. W12, W18







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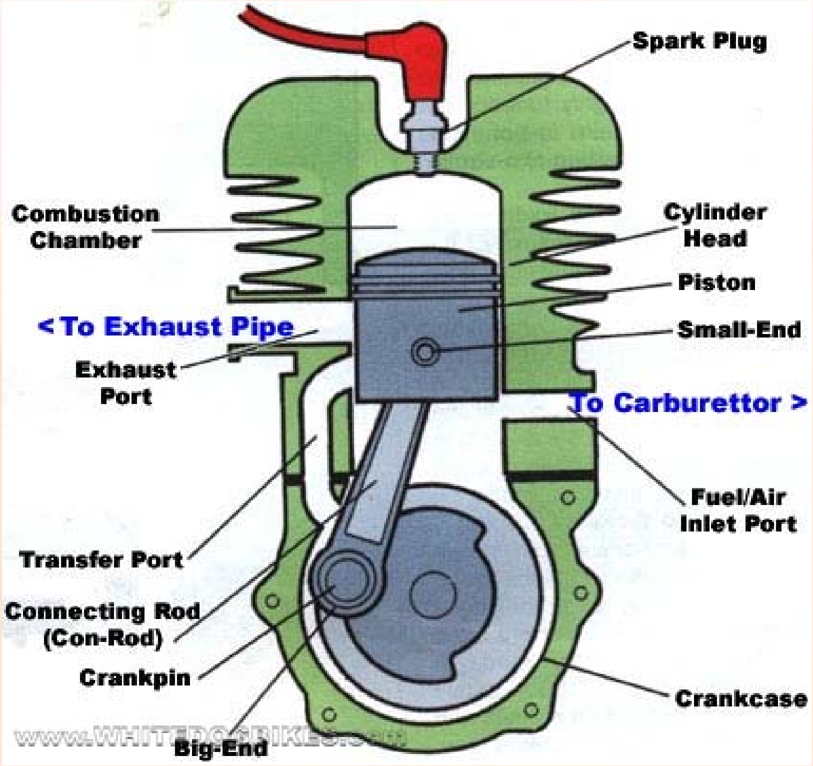
ENGINE CLASSIFICATION BY CYCLES

TWO STROKE CYCLE

- Only two strokes – power stroke and compression stroke.
- One revolution per cycle.
- The exhaust gases exits from the cylinder during the end of the power stroke, while the mixture of fuel/air enters the cylinder.
- This cycle is simple and cheap
- Suitable for low power consumption machine such as motorbike, etc.



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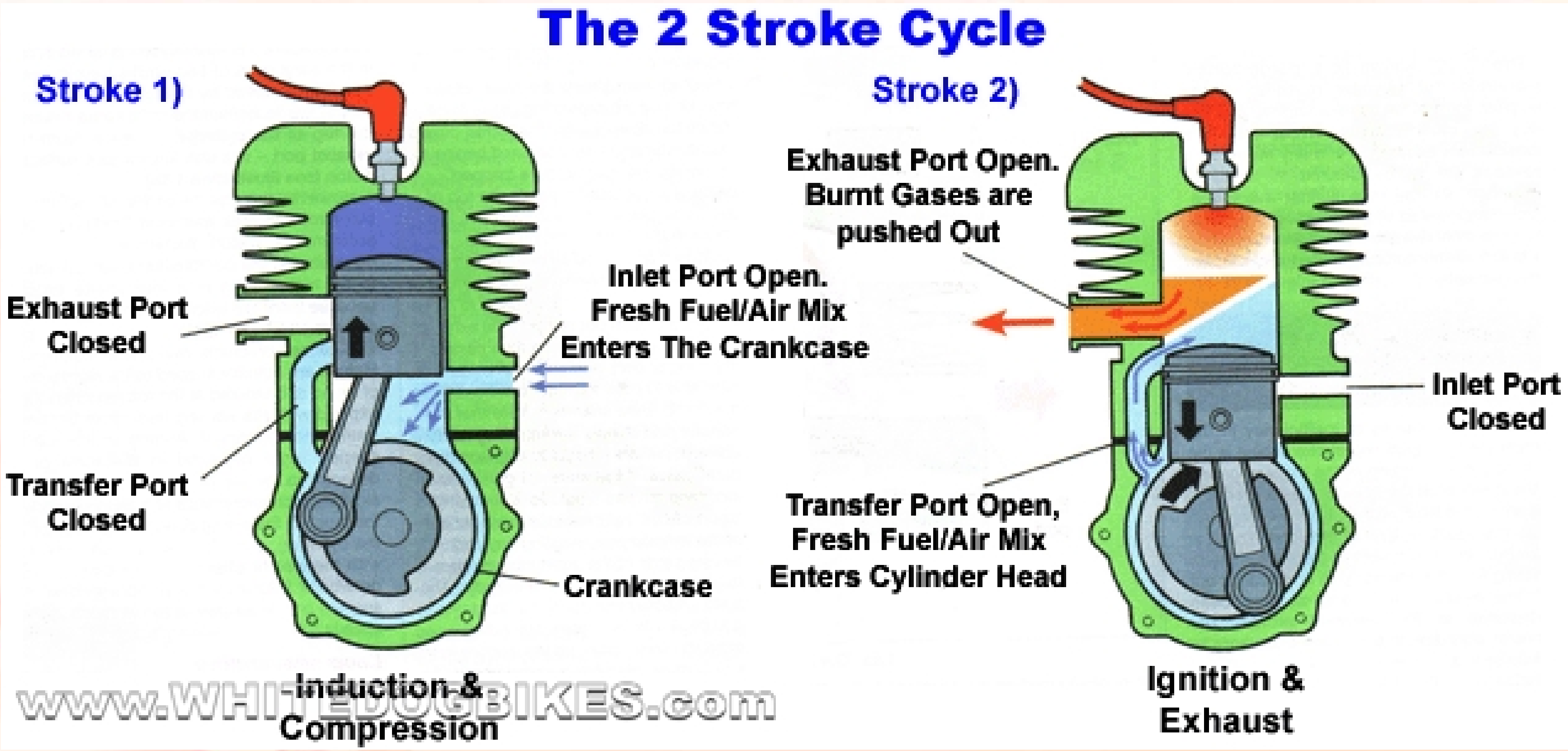
ENGINE CLASSIFICATION BY CYCLES

TWO STROKE CYCLE



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ENGINE TECHNOLOGIES

VVT (VTEC, MIVEC, VVTi, DVVT, CPS), DOHC/SOHC

VVT - Variable Valve Timing System
SOHC – Single Overhead Cam Shaft
DOHC -Double Overhead Cam Shaft

HONDA F23A – SOHC VTEC – 150 HP
HONDA H23A – DOHC VTEC – 220 HP

HONDA ENGINES
B16A (1.6L) – DOHC VTEC – 170 HP
B18C (1.8) – DOHC VTEC – 220 HP
H22A (2.2L) – DOHC VTEC – 200 HP
F20C (2.0L) – DOHC VTEC – 240 HP
K20A (2L) – DOHC iVTEC – 225 HP

MOST POWERFUL ENGINE
BUGATTI VEYRON 8L W18 QUAD TURBO - 1001 HP

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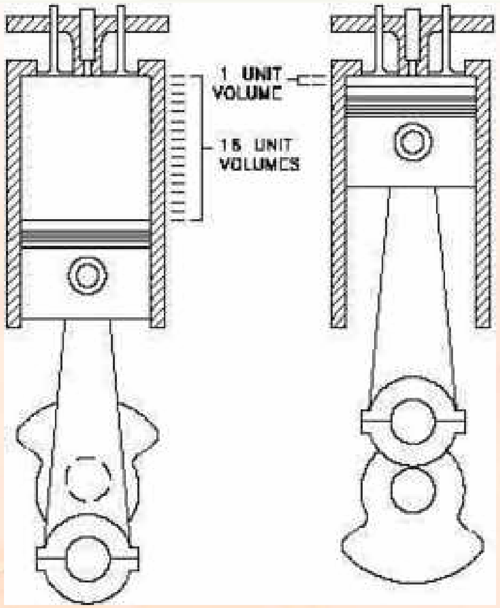
PERFORMANCE CRITERIA

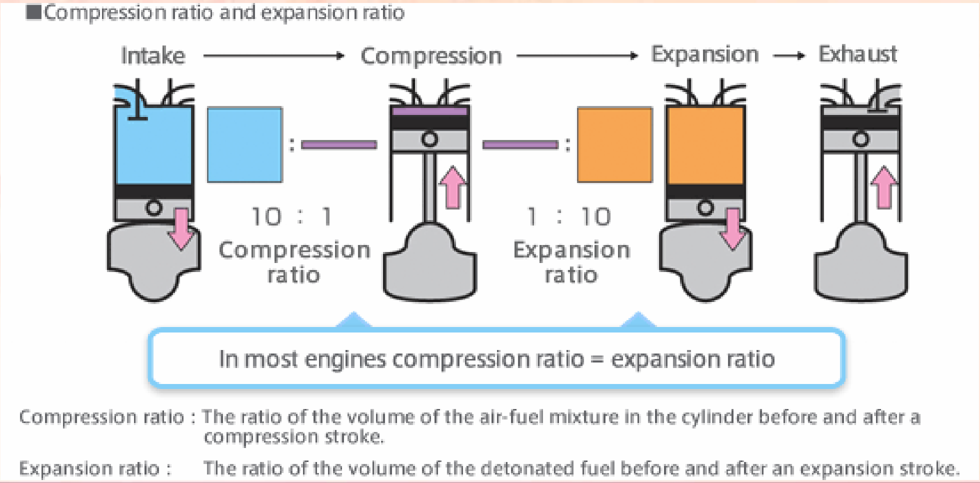
Compression Ratio, r_v

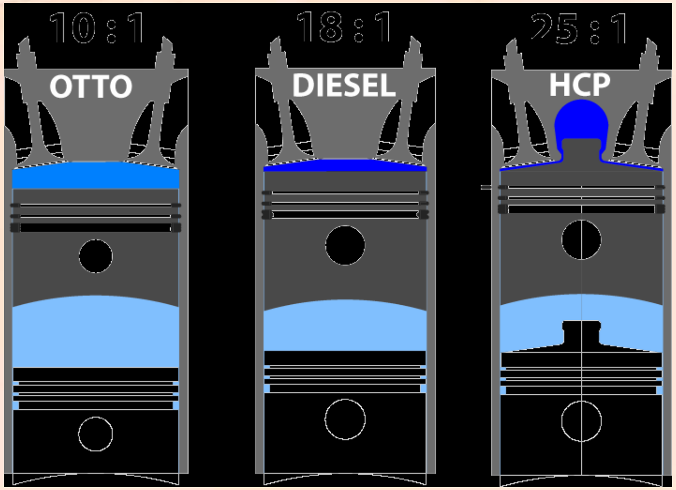
$$\textit{Compression ratio} = \frac{\textit{Maximum volume}}{\textit{Minimum volume}}$$

$$= \frac{V_{BDC}}{V_{TDC}} = \frac{V_c + V_s}{V_c}$$



Note: compression ratio is volume ratio and it is not a pressure ratio





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PERFORMANCE CRITERIA

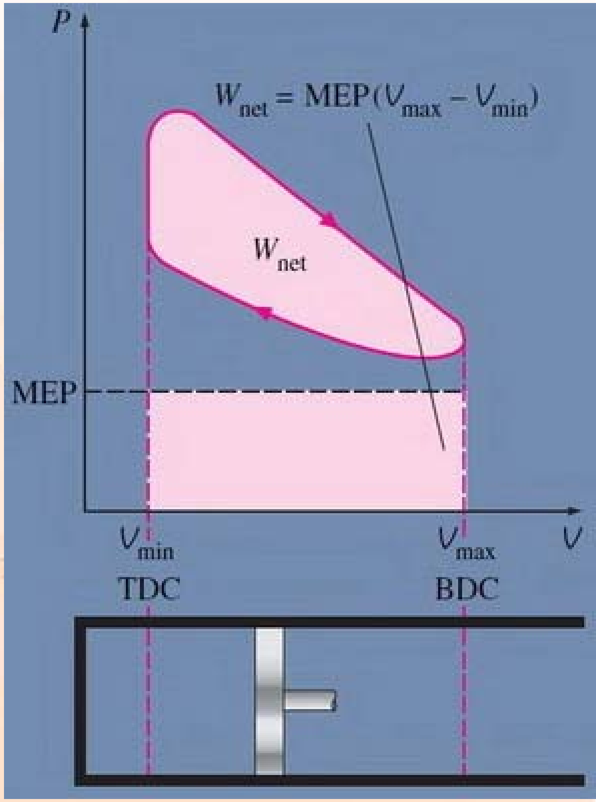
Mean Effective Pressure, MEP

- It is defined as the height of a rectangle on a pressure-volume (*P*-*v*) diagram.
- This pressure gives the same total net work as actual pressure.
- For the same engines size, MEP can be used as a criteria or parameter to compare the engines performance.

$$Work = Force\ x\ Distance = PAL = PV$$

$$W_{net} = MEP\ x\ Swept\ \ Volume$$
$$= MEP\left(V_{max} - V_{min}\right)$$

$$MEP = \frac{W_{net}}{V_{max} - V_{min}}$$



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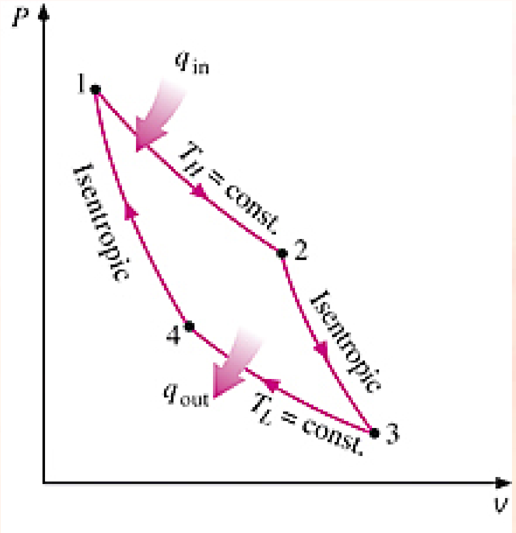
CARNOT CYCLE

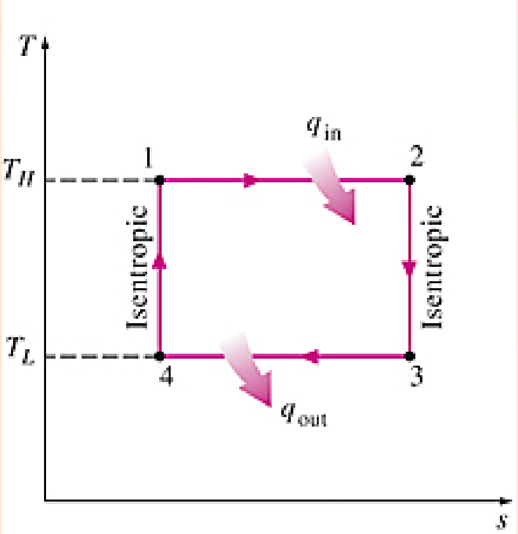


<u>Recall</u> -The Carnot Cycle

- Is the most efficient cycle that can be executed between a heat source, T_H and a heat sink, T_L.
- Operate on a totally reversible cycle.

<u>The Carnot cycle is composed of 4 totally reversible processes:</u>

1 - 2: isothermal heat addition at T_H
2 – 3: isentropic expansion, temp drops from T_H to T_L
3 – 4: isothermal heat rejection at T_L
4 – 1: isentropic compression, temp increases from T_L to T_H



$$\textit{Carnot efficiency}, \eta_{th,Carnot} = \frac{W_{net}}{Q_{sup\,ply}} = 1 - \frac{T_L}{T_H}$$

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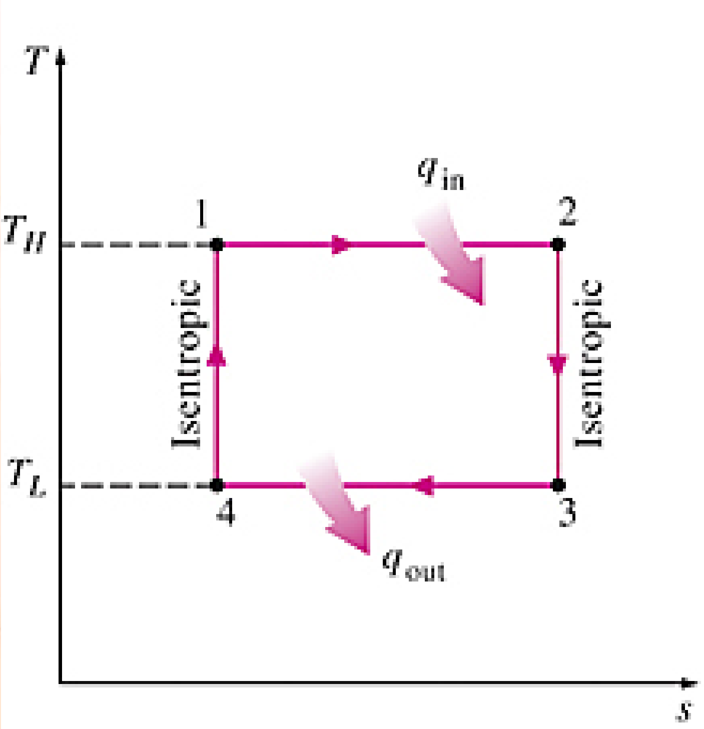
CARNOT CYCLE

Why we cannot use the Carnot cycle as the model cycle for all heat engines?

- Hard-ware related.
- Reversible isothermal heat transfer is very difficult to achieve in reality since it would require very large heat exchanger and it would take a very long time.



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EXAMPLE 9-1

Show that the thermal efficiency of a Carnot Cycle operating between the temperature limits of T_H and T_L is solely a function of these two temperatures and is given

Analysis :

$$q_{in} = T_H(s_2 - s_1)$$

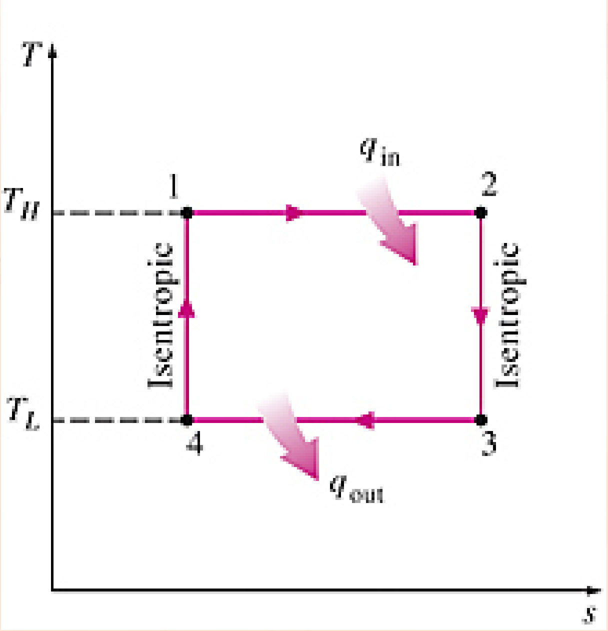
and

$$q_{out} = T_L(s_3 - s_4) = T_L(s_2 - s_1)$$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$$

$$= 1 - \frac{T_L(s_2 - s_1)}{T_H(s_2 - s_1)}$$

$$= 1 - \frac{T_L}{T_H}$$



$s_1 = s_4$ and $s_2 = s_3$

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IDEAL CYCLES

- Actual cycles are difficult to analyze because of the present of complicating effects such as friction and non-equilibrium conditions.
- Ideal cycle is used to simplify the analysis.
- Ideal cycle is a cycle that resemble the actual cycle with less complexities than actual cycles
- All processes involve are assume totally reversible
- To make an analytical study of a cycle practicable, the complexities are kept at a manageable level and utilize some idealizations.
- Models developed from these idealizations are simple and able to study the effects of major parameters towards actual engines performance, since they still retain the general characteristics of the actual engines they represent.

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AIR STANDARD ASSUMPTIONS

The actual gas power cycles are complex, thus approximations, known as air standard assumptions is used.

- The working fluid is air, continuously circulates in a closed loop and always behave as an ideal gas
- All the processes that make up the cycle are internally reversible.
- The combustion process is replaced by a heat-addition process from an external source.
- The exhaust gas is replaced by a heat-rejection process that restores the working fluid to its initial state
- Air has constant specific heats

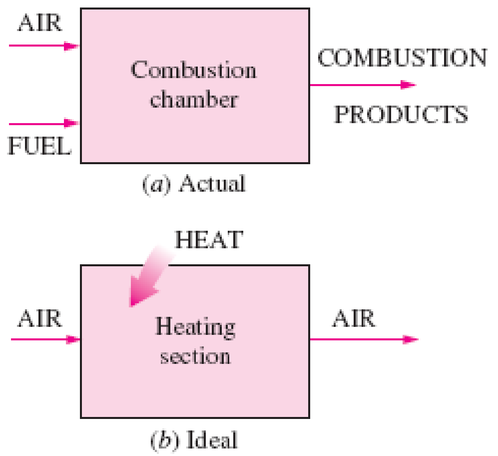

FIGURE 9–9

The combustion process is replaced by a heat-addition process in ideal cycles.

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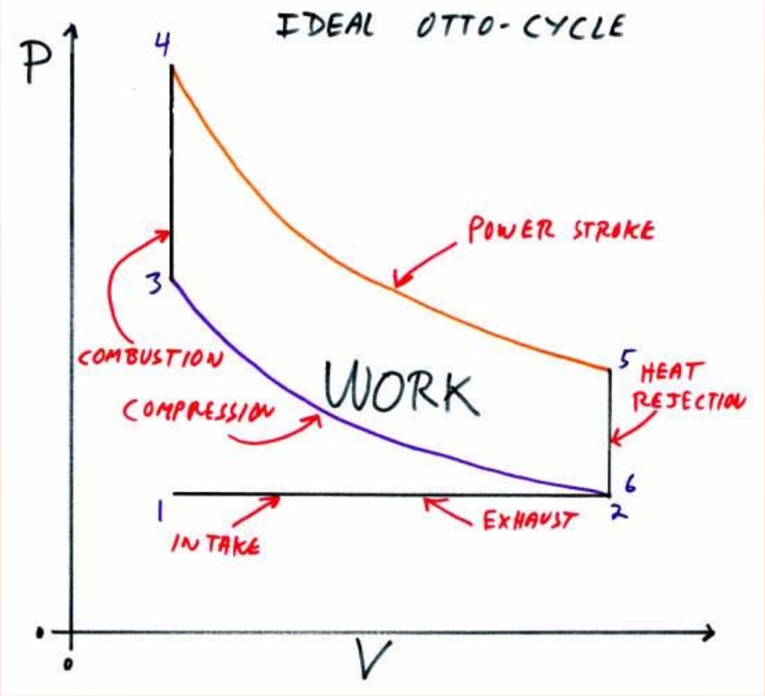
OTTO CYCLE

- The ideal cycle for spark ignition reciprocating engines
- Named after Nikolaus A.Otta, who built a four stroke engine in 1876 in Germany



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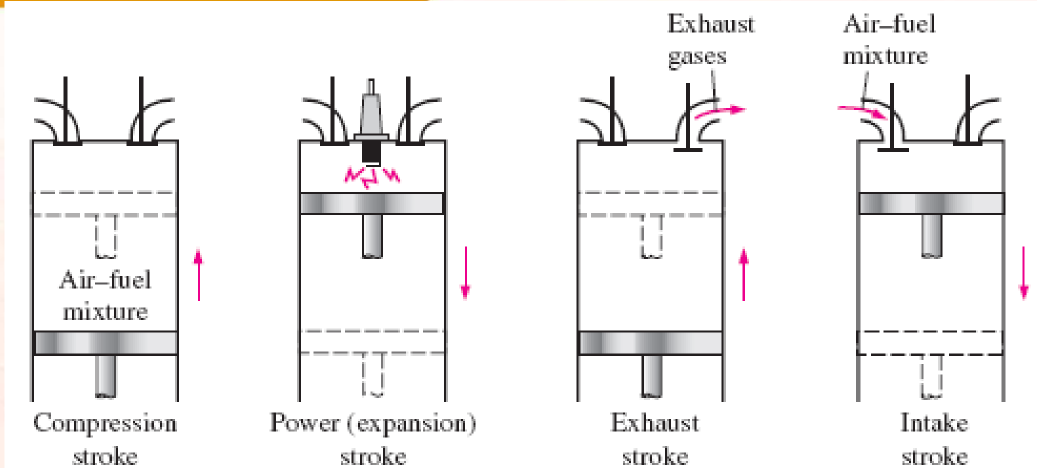
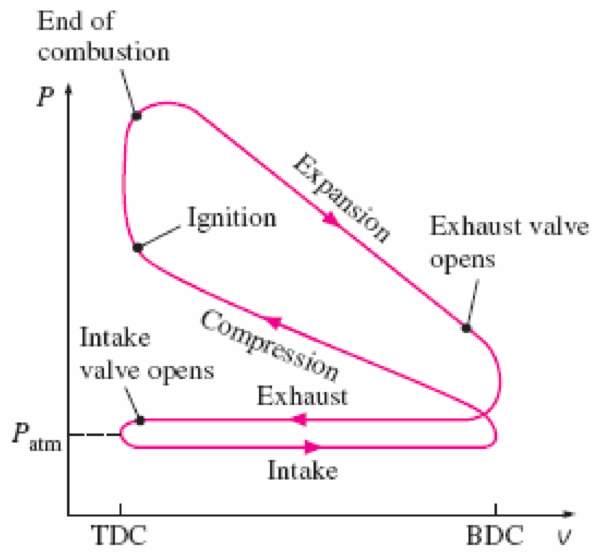
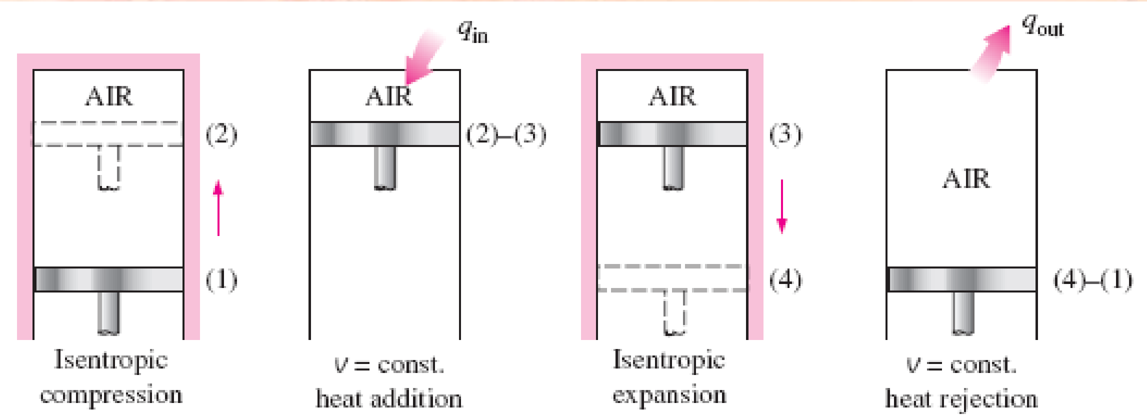
OTTO CYCLE

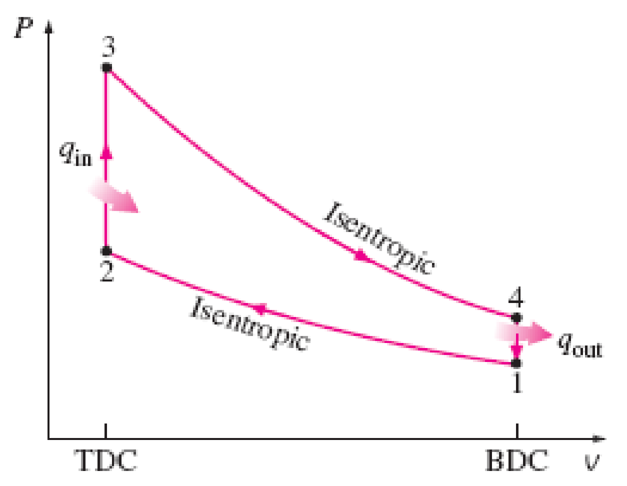


(*a*) Actual four-stroke spark-ignition engine





(*b*) Ideal Otto cycle



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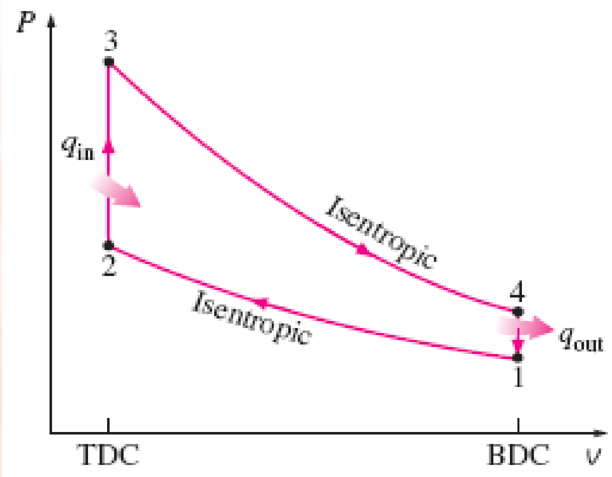
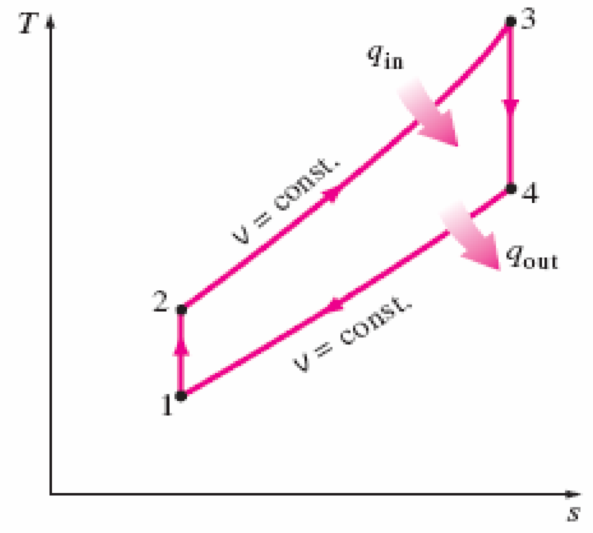
OTTO CYCLE

Otto cycle consists of four internally reversible processes:

- 1-2 Isentropic compression
- 2-3 Constant-volume heat addition
- 3-4 Isentropic expansion
- 4-1 Constant-volume heat rejection





Note:
In the Otto cycle, the working fluid is alternately expanded and compressed in a piston-cylinder device, therefore, *equations pertaining to closed systems are used in the analysis*.

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OTTO CYCLE

The Analysis

From 1st Law of Thermodynamics for Closed System,

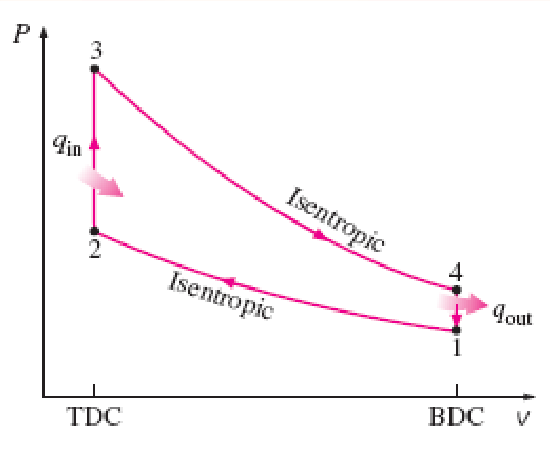
$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = \Delta u$$

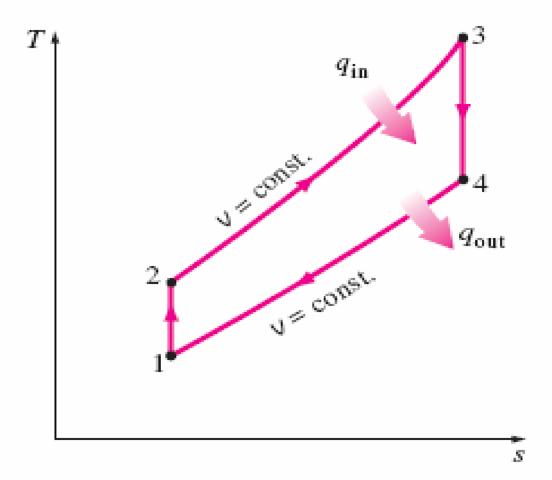
$$q_{in} = u_3 - u_2 = c_v(T_3 - T_2)$$

and $$q_{out} = u_4 - u_1 = c_v(T_4 - T_1)$$

$$\eta_{th,Otto} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{c_v(T_4 - T_1)}{c_v(T_3 - T_2)}$$

$$= 1 - \frac{T_1(T_4/T_1 - 1)}{T_2(T_3/T_2 - 1)}$$





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OTTO CYCLE

The Analysis

$$\eta_{th,Otto} = 1 - \frac{T_1(T_4/T_1 - 1)}{T_2(T_3/T_2 - 1)}$$

$$= 1 - \frac{T_1}{T_2}$$

$$= 1 - \left(\frac{v_2}{v_1}\right)^{k-1}$$

$$= 1 - \frac{1}{r^{k-1}}$$

$$\frac{T_1}{T_2} = \frac{T_4}{T_3} \Rightarrow \frac{T_4}{T_1} = \frac{T_3}{T_2}$$

Process 1 - 2 and 3 - 4 are isentropic and $v_2 = v_3$ and $v_4 = v_1$, thus

$$\frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{k-1} = \left(\frac{v_3}{v_4}\right)^{k-1} = \frac{T_4}{T_3}$$

$$r = \frac{v_{max}}{v_{min}} = \frac{v_1}{v_2}$$

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OTTO CYCLE

Some Formulas to recall

Under the cold-air standard assumptions, the relations between state '1' and '2' of isentropic expansion process or isentropic compression process can be related by the following equations.

$$\frac{P_2}{P_1} = \left(\frac{v_1}{v_2}\right)^k \quad , \quad \frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\left(\frac{k-1}{k}\right)} \quad \text{and} \quad \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{(k-1)}$$

$$\text{where} \quad k = \frac{c_p}{c_v} \quad \text{and} \quad c_p - c_v = R$$

k for standard air can be taken as 1.4

Note :

- The above equation is only valid for the ideal Otto cycle under the cold air-standard assumptions
- The above equation shows that the thermal efficiency of Otto cycle depends on the compression ratio and the specific heat ratio of the working fluid.

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OTTO CYCLE

Summary

$$\eta_{otto} = \frac{W_{net}}{Q_{in}} \quad \cdots \text{basic}$$

$$\eta_{otto} = 1 - \left(\frac{T_4 - T_1}{T_3 - T_2} \right) \quad \cdots \text{function of temperatures}$$

$$\eta_{otto} = 1 - \frac{1}{r_v^{\,k-1}} \quad \cdots \text{function of compression ratio and index } k$$

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Example 9-2

An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 100 kPa and 17ºC and 800 kJ/kg of heat is transferred to air during the constant-volume heat addition process. Assuming the specific heats of air are constant, determine , determine

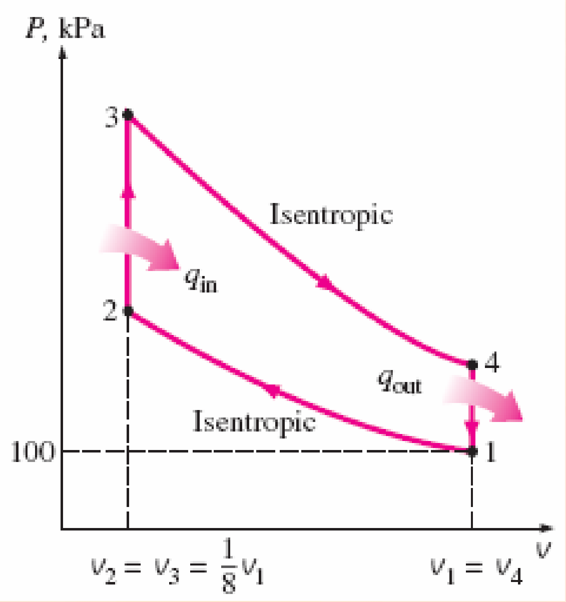
a) The maximum temperature and pressure that occur during the cycle
b) The net work output
c) The thermal efficiency
d) The mean effective pressure for the cycle

The maximum temperature = T_3 and P_{max} = P_3

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{(k-1)} \Rightarrow T_2 = T_1\left(\frac{v_1}{v_2}\right)^{(k-1)} = (290)(8)^{0.4} = 666.2\ K$$

$$q_{in} = c_v(T_3 - T_2) \Rightarrow T_3 = \frac{q_{in}}{c_v} + T_2$$

$$= \frac{800}{0.718} + 666.2 = 1780.4\ K$$



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Example 9-2

$$\frac{P_2 v_2}{T_2} = \frac{P_1 v_1}{T_1} \Rightarrow P_2 = P_1\left(\frac{T_2}{T_1}\right)\left(\frac{v_1}{v_2}\right) = 100\left(\frac{666.2}{290}\right)(8) = 1837.8 \text{ kPa}$$

$$\frac{P_3 v_3}{T_3} = \frac{P_2 v_2}{T_2} \Rightarrow P_3 = P_2\left(\frac{T_3}{T_2}\right)\left(\frac{v_2}{v_3}\right) = 1837.8\left(\frac{1780.4}{666.2}\right)(1) = 4911.5 \text{ kPa}$$

b) $q_{out} = c_v(T_4 - T_1)$

$$\frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{k-1} \Rightarrow T_4 = T_3\left(\frac{v_3}{v_4}\right)^{k-1} = 1780.4\left(\frac{1}{8}\right)^{k-1} = 775.0 \text{ K}$$

$$q_{out} = 0.718(775.0 - 290) = 384.2 \text{ kJ/kg}$$

$$w_{net} = q_{net} = q_{in} - q_{out} = 800 - 384.2 = 415.8 \text{ kJ/kg}$$

c) $$\eta_{th} = \frac{w_{net}}{q_{in}} = \frac{415.8}{800} = 0.520 \text{ or } 52.0\%$$

$$\eta_{th} = 1 - \frac{1}{r^{k-1}} = 1 - r^{1-k} = 1 - (8)^{1-1.4} = 0.565 \text{ or } 56.5\%$$

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Example 9-2

$$d)\ MEP = \frac{w_{net}}{v_1 - v_2} = \frac{w_{net}}{v_1 - v_1/r} = \frac{w_{net}}{v_1(1 - 1/r)}$$

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.287)(290)}{100} = 0.832\ m^3/kg$$

$$MEP = \frac{w_{net}}{v_1(1-1/r)} = \frac{415.8}{0.832(1-1/8)} = 571.2\ kPa$$

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Example 9-3

Reconsider the ideal Otto cycle in Problem 9-2. Assuming that the specific heats vary with temperature, determine:

a) the pressure & temperature at the end of heat addition process,
b) the net work output,
c) the thermal efficiency, and
d) the mean effective pressure for the cycle.

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Problem 9-35 Pg 537

The compression ratio of an air-standard Otto cycle is 9.5. Prior to the isentropic compression process, the air is at 100 kPa, 35°C and 600 cm^3. The temperature at the end of the isentropic expansion process is 800 K. Using specific heat values at room temperature, determine,

a) the highest temperature and pressure in the cycle
b) the amount of heat transferred in
c) the thermal efficiency, and
d) the mean effective pressure for the cycle.

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ASSIGNMENT 3

Problem 9-39 Pg 537

A 4-cylinder, 4-stroke, 1.6 L gasoline engine operates on the Otto cycle with a compression ratio of 11. The air is at 100 kPa and 37^{o}C at the beginning of the compression process, and the maximum pressure in the cycle is 8 MPa. The compression and expansion processes may be modeled as polytropic with a polytropic constant of 1.3. The air-fuel ratio is 16. Using constant specific heats at 850 K, determine,

a)The temperature at the end of the expansion process
b)The net work output
c)The thermal efficiency
d)The mean effective pressure;
e)The engine speed for a net power output of 50 Kw
f)The specific fuel consumption (g/kWh).

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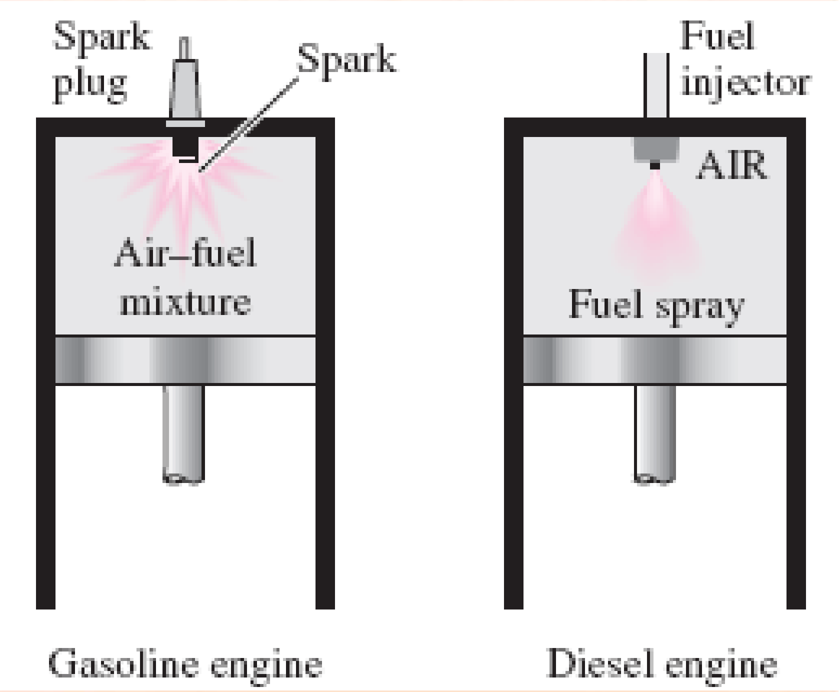
DIESEL CYCLE

- **Diesel cycle is the ideal air-standard cycle for compression ignition (CI) reciprocating engines.**

- **First proposed by Rudolph Diesel in 1890**



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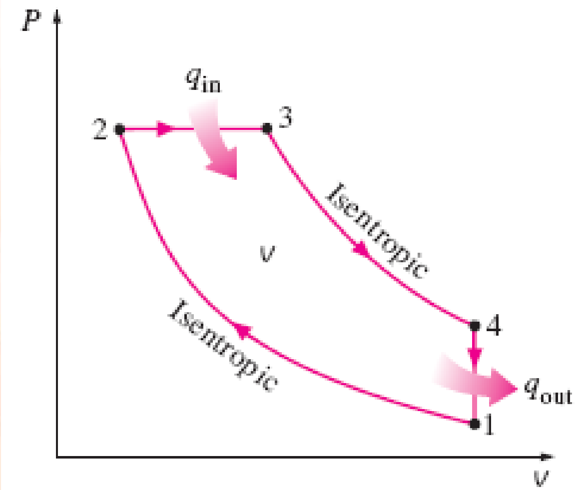
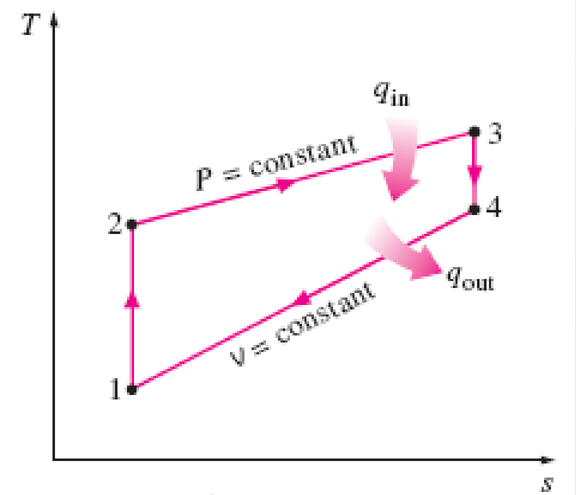
DIESEL CYCLE

Diesel cycle consists of four internally reversible processes are,

1-2 Isentropic compression
2-3 Constant pressure heat addition
3-4 Isentropic expansion
4-1 Constant volume heat rejection



(*a*) *P*- *v* diagram



(*b*) *T*-*s* diagram

Note : $p_3 = p_2$ and $v_1 = v_4$

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DIESEL CYCLE

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THE ANALYSIS

The Diesel Cycle Analysis – under the cold air-standard assumptions

Heat added to the engine

$$q_{in} = q_{23} = c_p\left(T_3 - T_2\right)$$

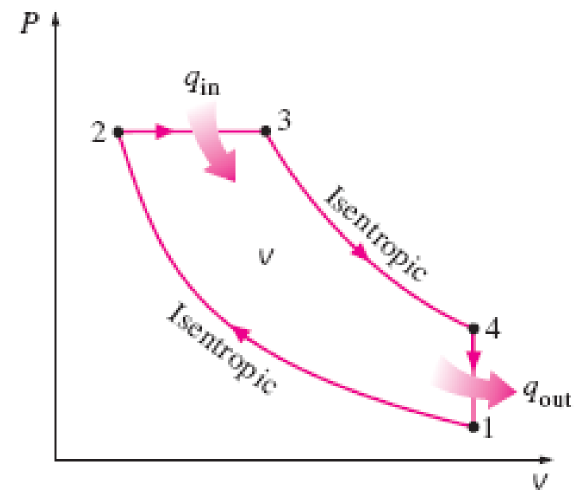
Heat rejected from the engine

$$q_{out} = q_{41} = c_v\left(T_4 - T_1\right)$$

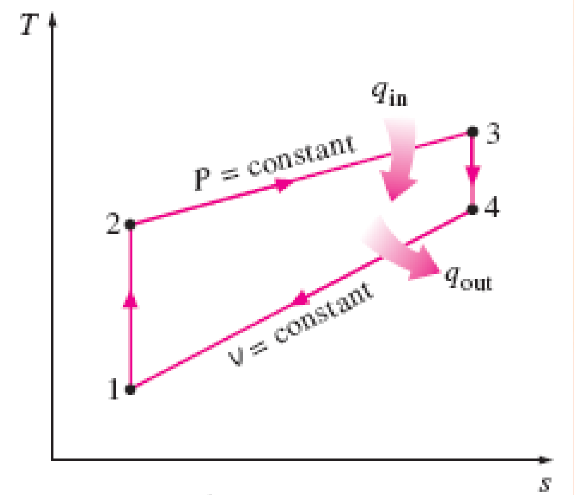
The thermal efficiency,

$$\eta_{th,Diesel} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{c_v\left(T_4 - T_1\right)}{c_p\left(T_3 - T_2\right)}$$

$$= 1 - \frac{\left(T_4 - T_1\right)}{k\left(T_3 - T_2\right)}$$



(a) P- v diagram



(b) T-s diagram

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DIESEL CYCLE

THE ANALYSIS

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{k-1} \quad \rightarrow \quad T_1 = \frac{T_2}{\left(\frac{v_1}{v_2}\right)^{k-1}} = \frac{T_2}{r_v^{\,k-1}}$$

$$\frac{T_3}{T_2} = \frac{v_3}{v_2} = r_c \quad \cdots \textit{cut-off ratio for isobaric process} \quad 2 \rightarrow 3 \rightarrow T_3 = T_2 r_c$$

$$\textit{Also,} \quad \frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{k-1} = \left(\frac{v_3}{v_2} \times \frac{v_2}{v_4}\right)^{k-1} = \left(\frac{r_c}{r_v}\right)^{k-1}$$

$$T_4 = T_3\left(\frac{r_c}{r_v}\right)^{k-1} = T_2\, r_c\left(\frac{r_c}{r_v}\right)^{k-1} = T_2\left(\frac{r_c^{\,k}}{r_v^{\,k-1}}\right)$$

$$\eta_{Diesel} = \eta_{th,Diesel} = 1 - \frac{(T_4 - T_1)}{k(T_3 - T_2)} = 1 - \frac{\left[r_c^{\,k} - 1\right]}{r_v^{\,k-1}\left[k(r_c - 1)\right]}$$

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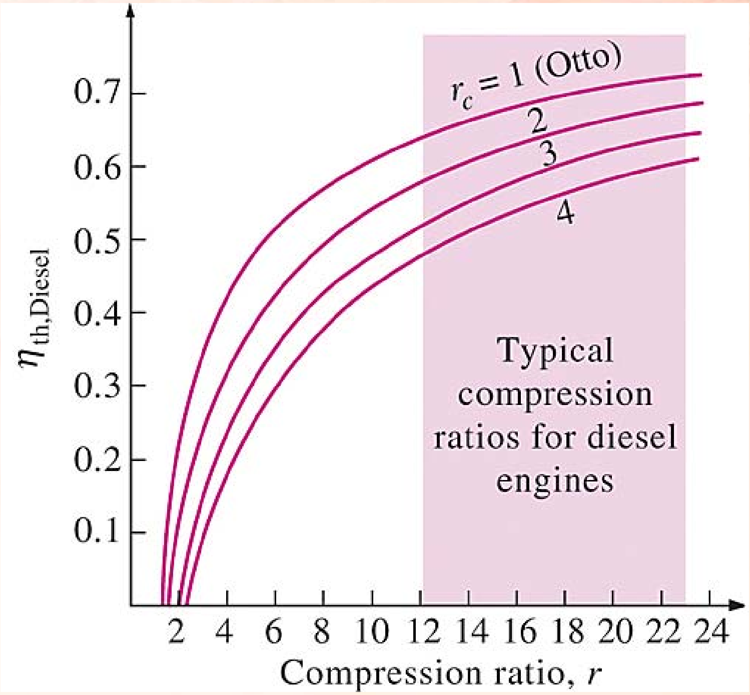
DIESEL CYCLE

For the same compression ratio, thermal efficiency of Otto cycle is **greater** than that of the Diesel cycle

$$\eta_{\text{th,Otto}} > \eta_{\text{th,Diesel}}$$

As the cutoff ratio decreases, the thermal efficiency of the Diesel cycle increases.

When $r_c = 1$, *the* efficiencies of the Otto and Diesel cycles are identical.



Thermal efficiencies of large diesel engines range from about **35 to 40** percent.

Higher efficiency and **lower fuel costs** make diesel engines attractive in applications such as in locomotive engines, emergency power generation units, large ships, and heavy trucks.

FIGURE 9–22

Thermal efficiency of the ideal Diesel cycle as a function of compression and cutoff ratios ($k = 1.4$).

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EXAMPLE 9-4

An ideal Diesel cycle with air as the working fluid has a compression ratio of 18 and cutoff ratio of 2. At the beginning of the compression process, the working fluid is at 100 kPa, 27°C and 1917 cm³. Utilizing the cold-air standard assumptions, determine

a) The temperature and pressure of air at the end of each process

b) The net work output and the thermal efficiency

c) The mean effective pressure

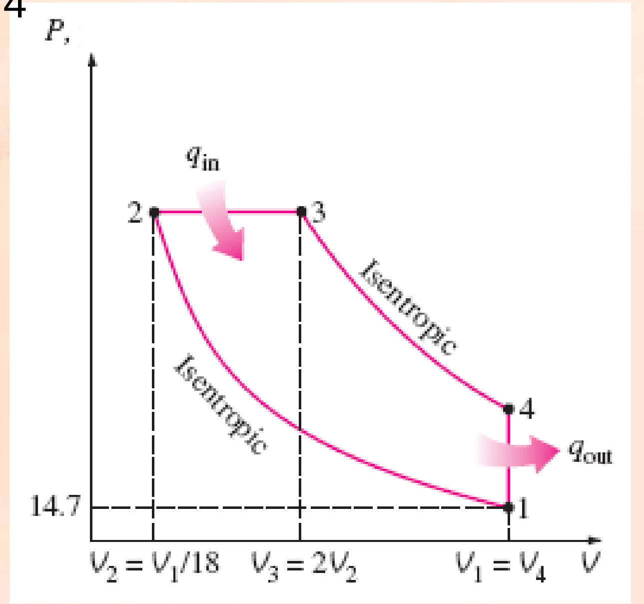
Assumptions : R = 0.287 kJ/kgK, c_p = 1.005 kJ/kgK, k = 1.4

a) The temperature and pressure at end each process

$$V_2 = \frac{V_1}{r} = \frac{1917}{18} = 106.5\ cm^3$$

$$V_3 = r_c V_2 = (2)(106.5) = 213\ cm^3$$

$$V_4 = V_1 = 1917\ cm^3$$



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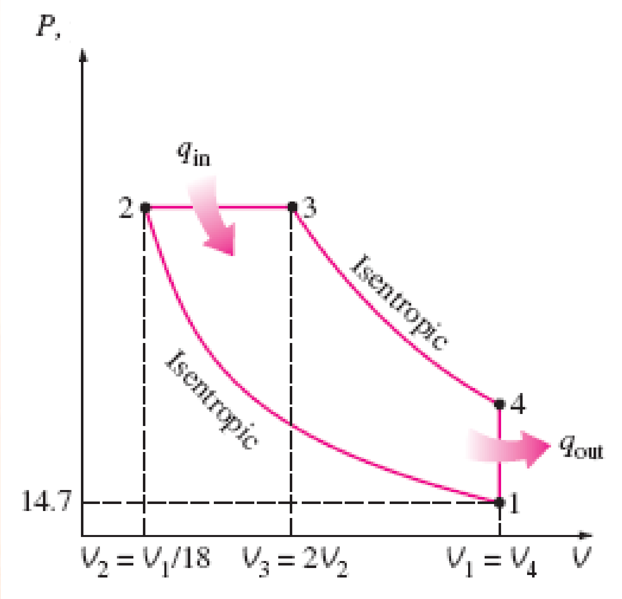
EXAMPLE 9-4



Process 1-2 : isentropic compression process

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{k-1} = (300)(18)^{1.4-1} = 953\ K$$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{k} = (100)(18)^{1.4} = 5720\ kPa$$

Process 2-3 : constant pressure expansion

$$P_3 = P_2 = 5720\ kPa$$

$$\frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3} \rightarrow T_3 = T_2\left(\frac{V_3}{V_2}\right) = (953)(2) = 1960\ K$$

Process 3-4 : isentropic expansion

$$T_4 = T_3\left(\frac{V_3}{V_4}\right)^{k-1} = (1960)\left(\frac{213}{1917}\right)^{1.4-1} = 791\ K$$

$$P_4 = P_3\left(\frac{V_3}{V_4}\right)^{k} = (5720)\left(\frac{213}{1917}\right)^{1.4} = 264\ kPa$$

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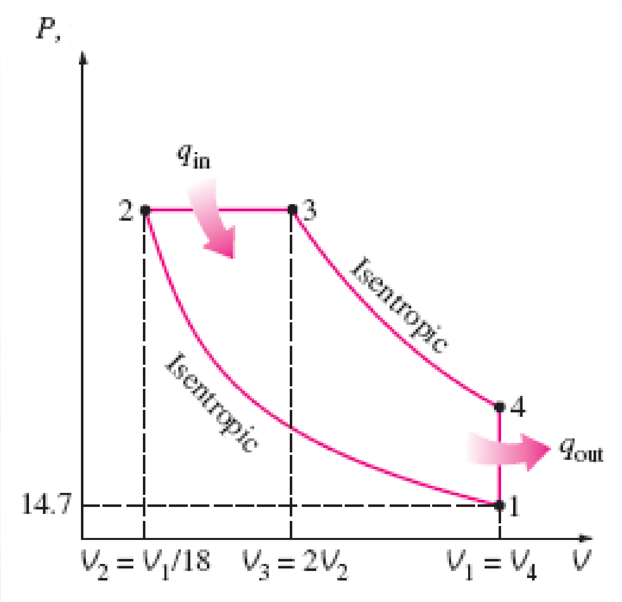
EXAMPLE 9-4



b) The net work is equivalent to the net heat transfer

$$m = \frac{P_1V_1}{RT_1} = \frac{(100)(1917\,x10^{-6})}{(0.287)(300)} = 0.00223\ kg$$

$$Q_{in} = mc_p(T_3 - T_2) = (0.00223)(1.005)(1906 - 953)$$

$$= 2.136\ kJ$$

$$Q_{out} = mc_v(T_4 - T_1) = (0.00223)(0.718)(791 - 300)$$

$$= 0.786\ kJ$$

$$W_{net} = Q_{in} - Q_{out} = 2.136 - 0.786 = 1.35\ kJ$$

$$\eta_{th} = \frac{W_{net}}{Q_{in}} = \frac{1.35}{2.136} = 0.632\ \text{or}\ 63.2\%$$

c) $$MEP = \frac{W_{net}}{V_{max} - V_{min}} = \frac{W_{net}}{V_1 - V_2} = \frac{1.35}{(1917 - 106.5)x10^{-6}} = 746\ kPa$$

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EXAMPLE 5

Test 2 Sept 2005

The engine operating on the air standard Diesel cycle has a compression ratio of 17/1 and the maximum and minimum cycle temperatures are 1527^{o}C and 45^{o}C respectively. If the maximum cycle pressure is 5200 kN/m2 calculate,

a) the volume ratio of the combustion;
b) the temperature and pressure at the end of the expansion stroke;
c) the thermal efficiency of the cycle;
d) the mean effective pressure.

For air assume R = 0.287 kJ/kgK; k = 1.4; c_p = 1.005 kJ/kgK and c_v = 0.718 kJ/kgK.

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ASSIGNMENT 4

Problem 9-60 Pg 538

A six-cylinder, four-stroke, 3.2-L compression-ignition engine operates on the ideal Diesel cycle with a compression ratio of 19. The air is at 95 kPa and 67°C at the beginning of the compression process and the engine speed is 1750 rpm. The engine uses light diesel fuel with a heating value of 42,500 kJ/kg, an air–fuel ratio of 28, and a combustion efficiency of 98 percent. Using constant specific heats at 850 K, determine:

a) the maximum temperature in the cycle and the cutoff ratio,
b) the net work output per cycle and the thermal efficiency,
c) the mean effective pressure,
d) the net power output, and
e) the specific fuel consumption, in g/kWh.

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Dual Cycle: Realistic Ideal Cycle for CI Engines

- Approximating the combustion process as a constant-volume or a constant-pressure heat-addition process is overly simplistic and not quite realistic.
- A better approach would be to model the combustion process in both SI and CI engines as a combination of two heat-transfer processes, one at constant volume and the other at constant pressure.
- The ideal cycle based on this concept is called the **dual cycle.**

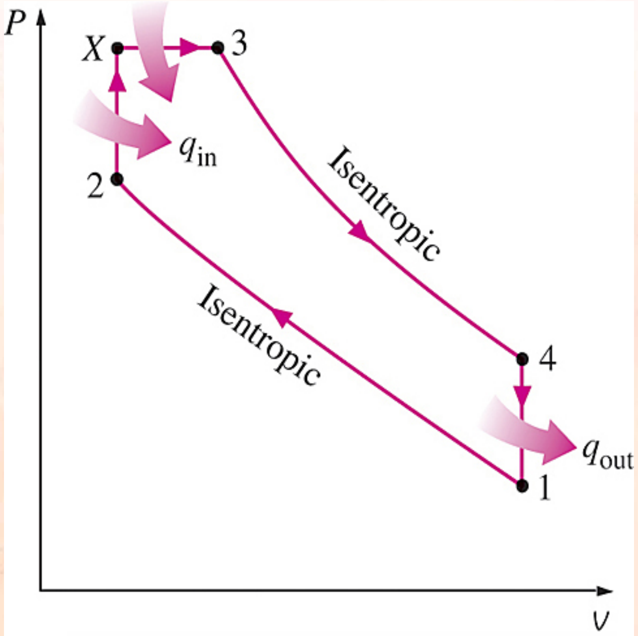

FIGURE 9–23
P-v diagram of an ideal dual cycle.

Note: Both the Otto and the Diesel cycles can be obtained as special cases of the dual cycle.

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THE END