ME 165
Mechanical Engineering Fundamentals

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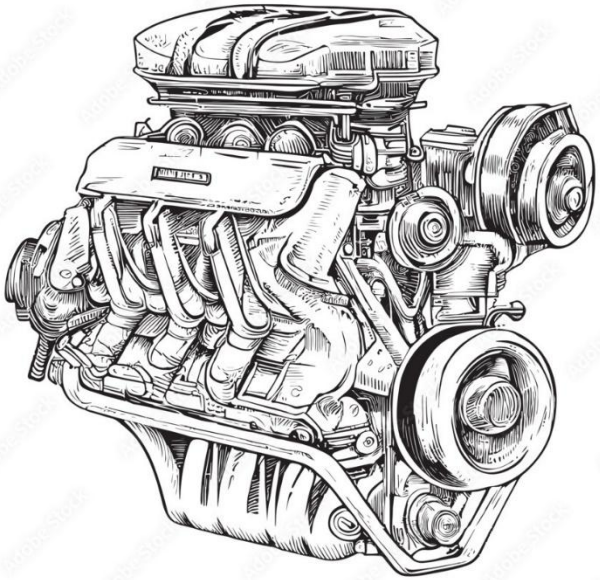
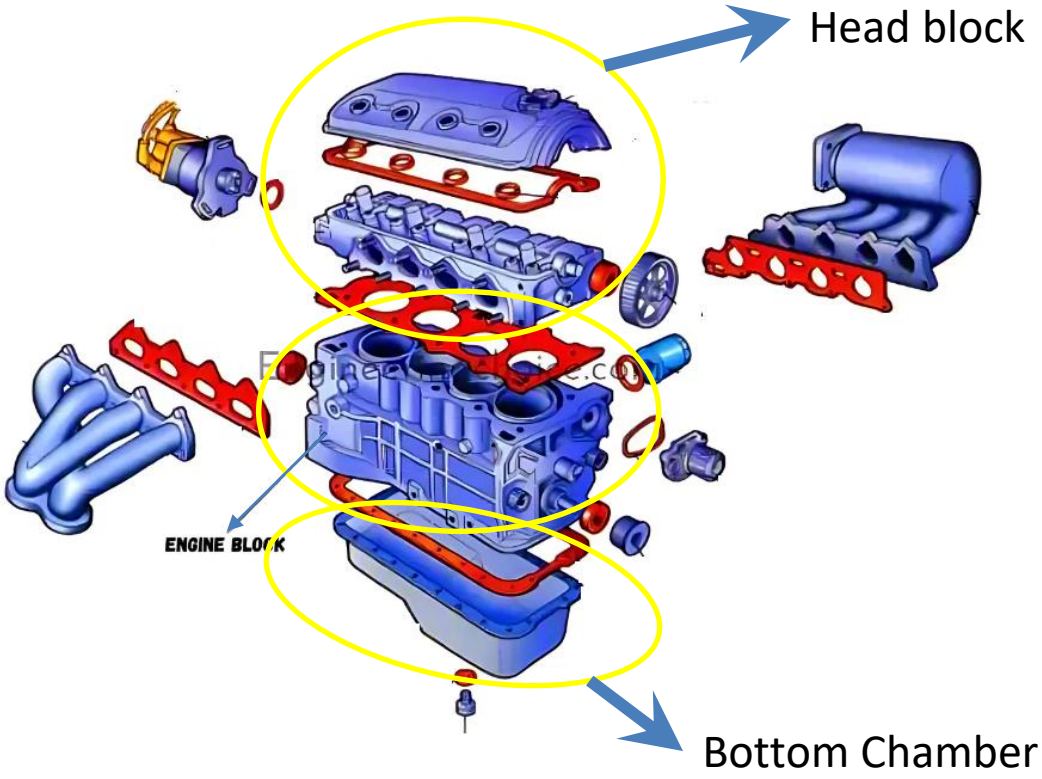
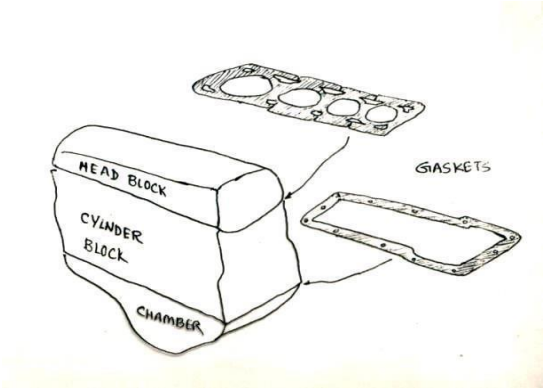
Internal Combustion Engines - Construction

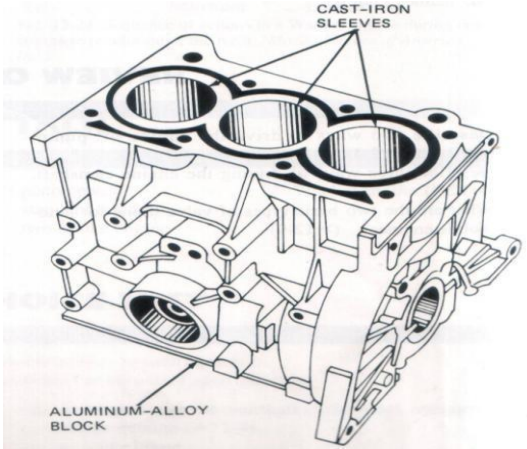


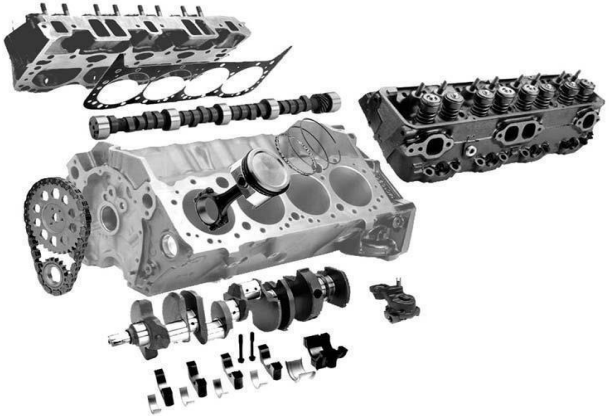


Internal Combustion Engines - Construction

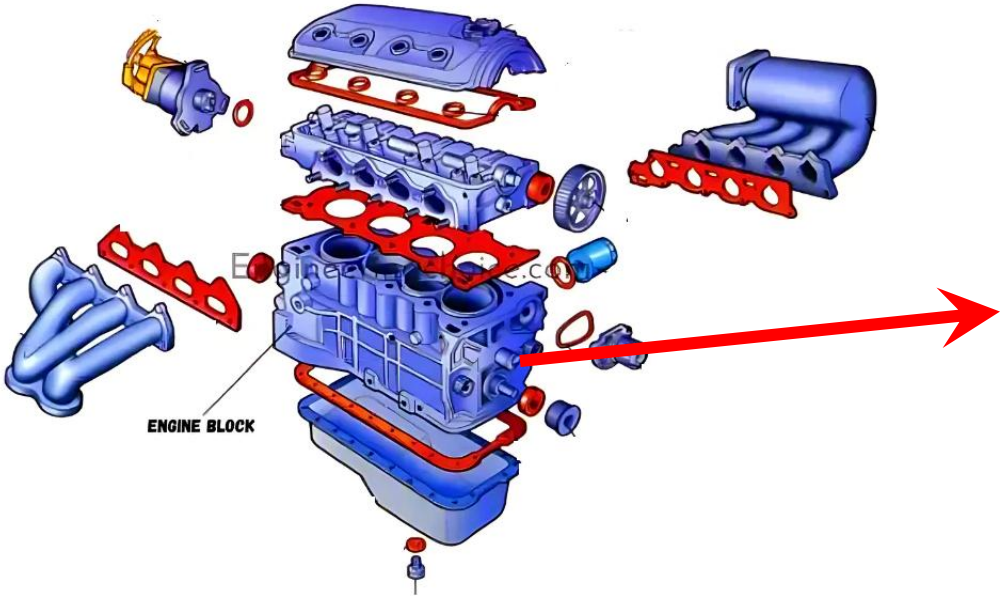
- The three main portions of an IC engine are
  - Head block: Top Part
  - Cylinder Block: Middle Part
  - Chamber or Sump: Bottom Part

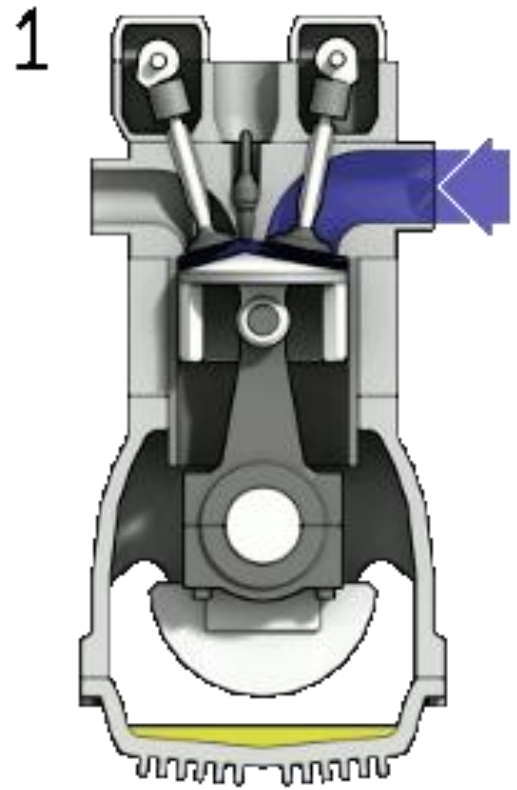






Internal Combustion Engine (IC Engine)





Spark Ignition (SI) Engine

https://www.youtube.com/watch?v=DKF5dKo_r_Y&t=136s

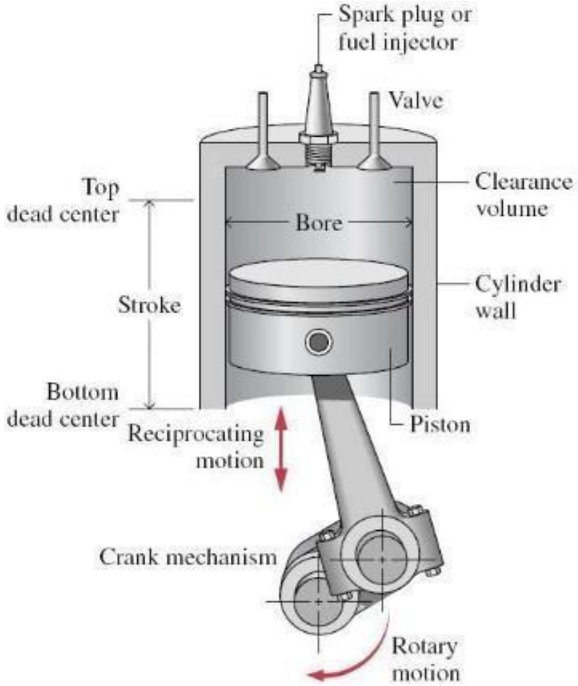
Spark Ignition (SI) Engine

4 stroke SI (Petrol) engine operation

- ***Four stroke engines:*** the cycle of operation is completed in four strokes of the piston or two revolution of the crank shaft. Each stroke consists of 180^0 of crank shaft rotation.

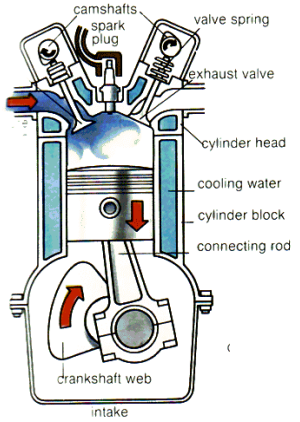
- In an internal combustion engine, the piston executes four distinct strokes within the cylinder for every two revolutions of the crankshaft. The four strokes are termed as –

  I. Intake Stroke
  II. Compression Stroke
  III. Power Stroke
  IV. Exhaust Stroke

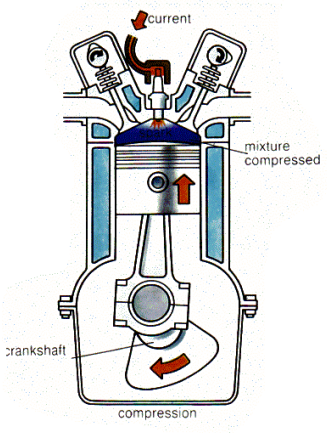


4 stroke SI (Petrol) engine operation

- **First stroke: intake or induction**
  - Intake valve opens, and exhaust valve closes
  - Piston travels from TDC (top dead center) to BDC (bottom dead center)
  - Volume increases in combustion chamber and creates vacuum
  - Fresh charge is drawn into the cylinder due to suction.
  - For SI engine the charge is a mixture of fuel and air. For CI engines charge is only air (air passes through intake system, fuel is added)

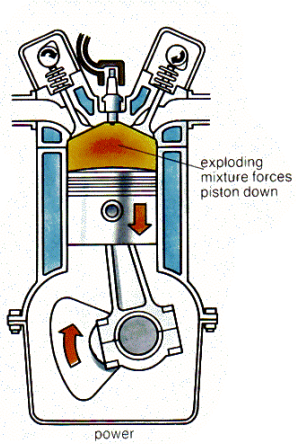


- **Second stroke: compression**
  - Piston reaches BDC, both intake and exhaust valves close.
  - Now piston rises from BDC back to TDC with all valves closed, compresses the charge (air-fuel mixture) raising the temperature and pressure. This stroke requires work input from Piston to the charge.
  - Near end of compression stroke, spark plug fires and combustion is initiated. In SI engines it is induced by spark plug. In CI engines combustion is initiated by injecting fuel into the hot-compressed air using fuel injectors.

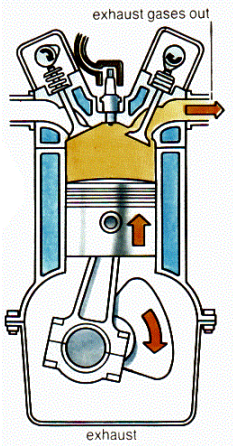


4 stroke SI (Petrol) engine operation

- **Third Stroke: Expansion or Power Stroke**
  - Piston near TDC: nearly constant-volume combustion occurs.
  - Changes composition of gas mixture to exhaust products occurs due to exothermic blast and temperature and pressure increases.
  - High pressure pushes piston away from TDC. Work is done on the Piston as thermal energy is converted to mechanical energy.
  - Piston moves from TDC to BDC, volume increases and pressure and temperature drop

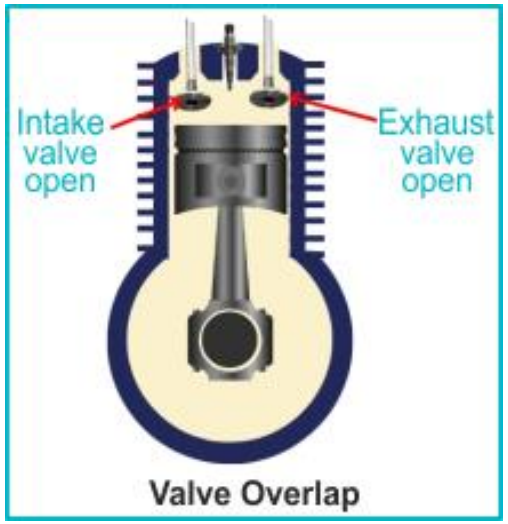


- **Fourth Stroke: Exhaust blowdown**
  - Late in power cycle exhaust valve is opened.
  - Piston moves from BDC to TDC due to momentum gained
  - Pressure differential pushes hot exhaust gas out of cylinder and. through exhaust system when piston is at BDC.
  - Exhaust gas carries away high amount of enthalpy, which lowers cycle thermal efficiency

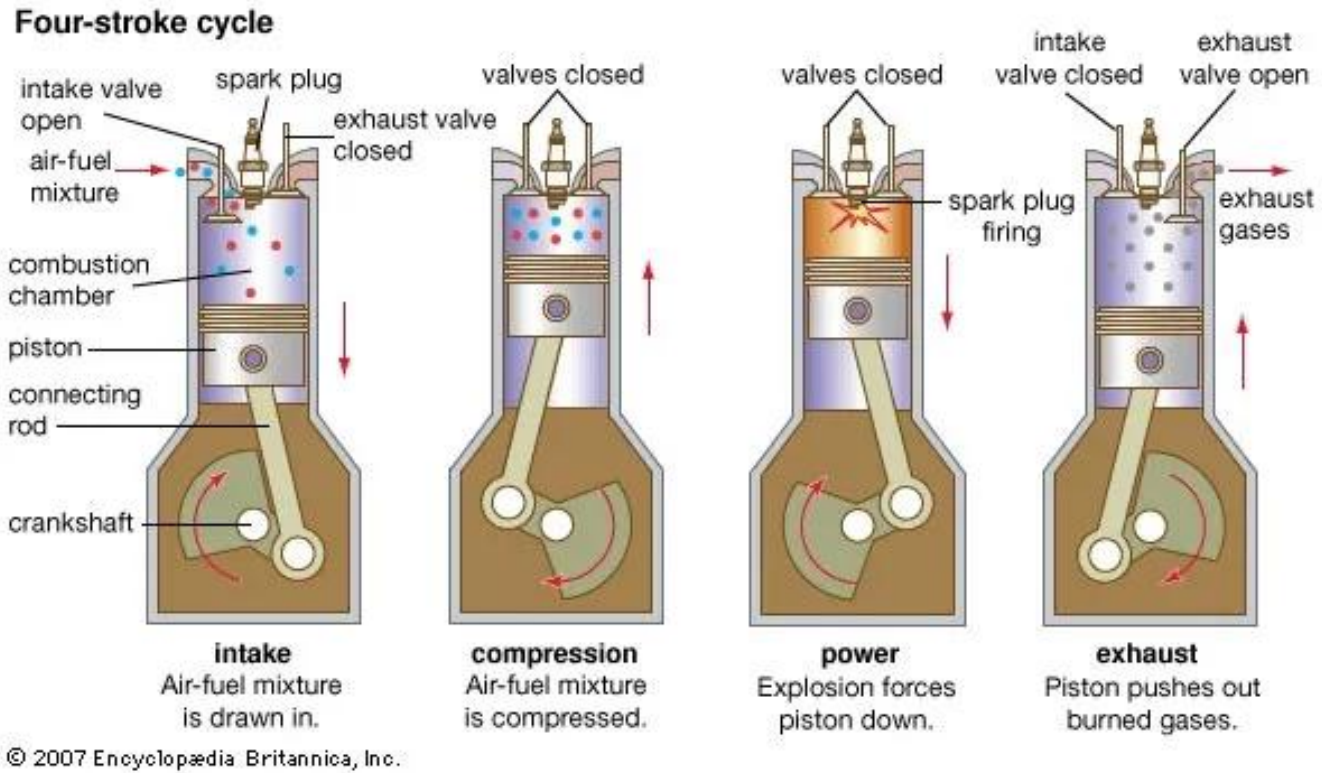


4 stroke SI (Petrol) engine operation

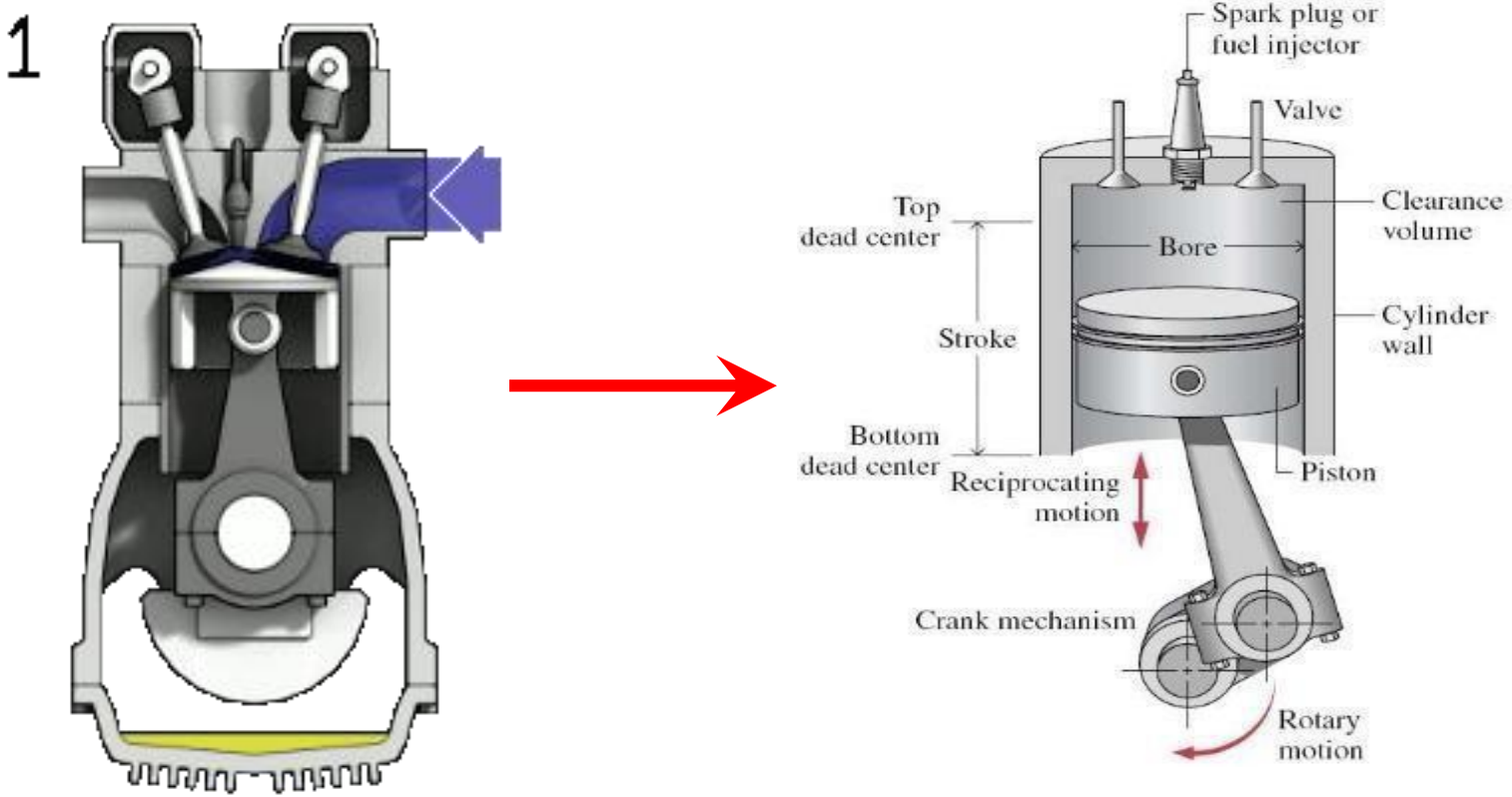
- Near end of exhaust stroke before TDC, intake valve starts to open and is fully open by TDC when intake stroke starts next cycle
- Near TDC the exhaust valve starts to close and is fully closed sometime after TDC.
- Period where both intake valve and exhaust valve are open is called valve overlap



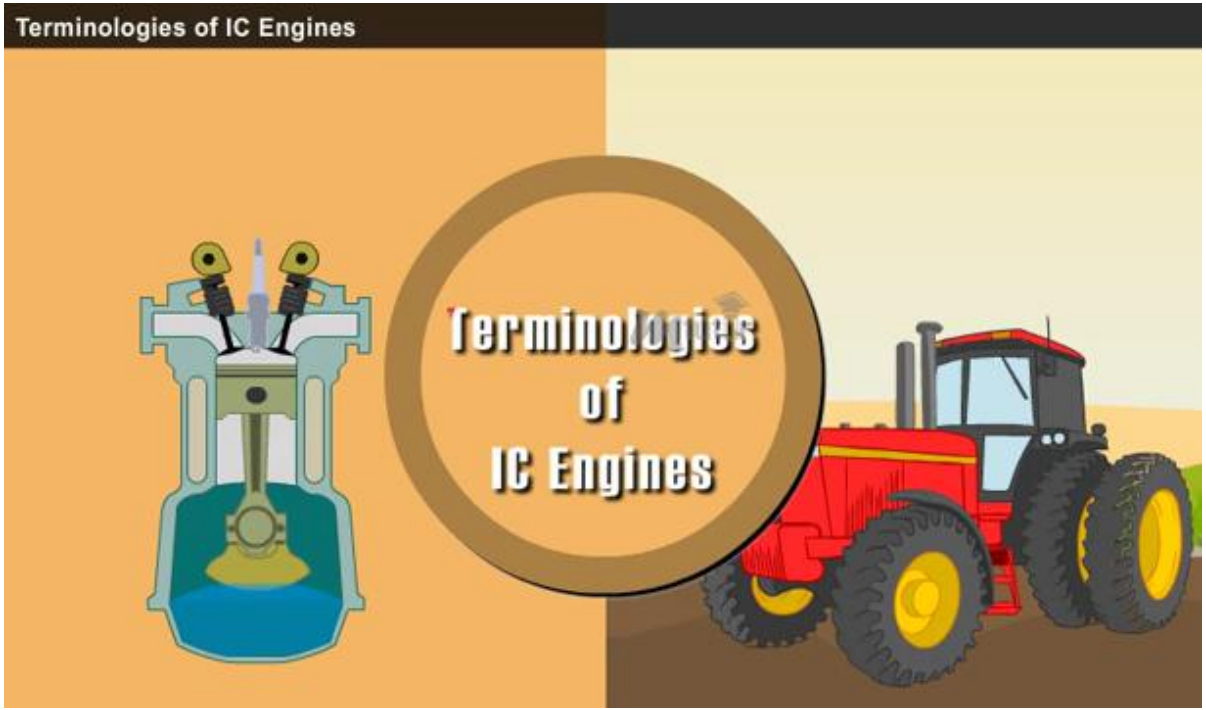
4 stroke SI (Petrol) engine operation



Engine Terminology

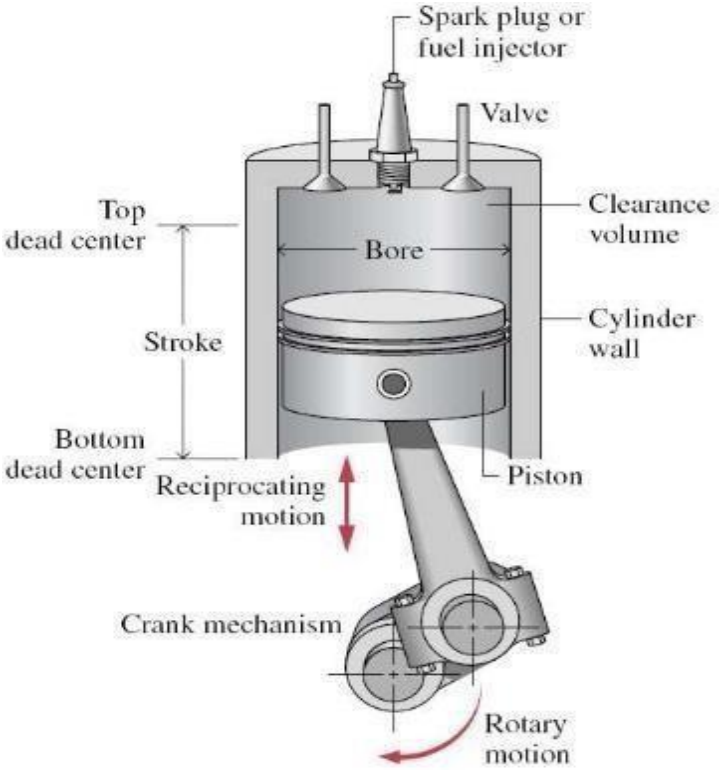


Engine Terminology



https://www.youtube.com/watch?v=SvJM4e1OotE

Engine Terminology



Swept or Displacement Volume

$$Vs = \frac{\pi}{4} d^2 \times l$$

Compression Ratio

$$r = \frac{V}{Vc} = \frac{Vc + Vs}{Vc}$$

Engine Terminology

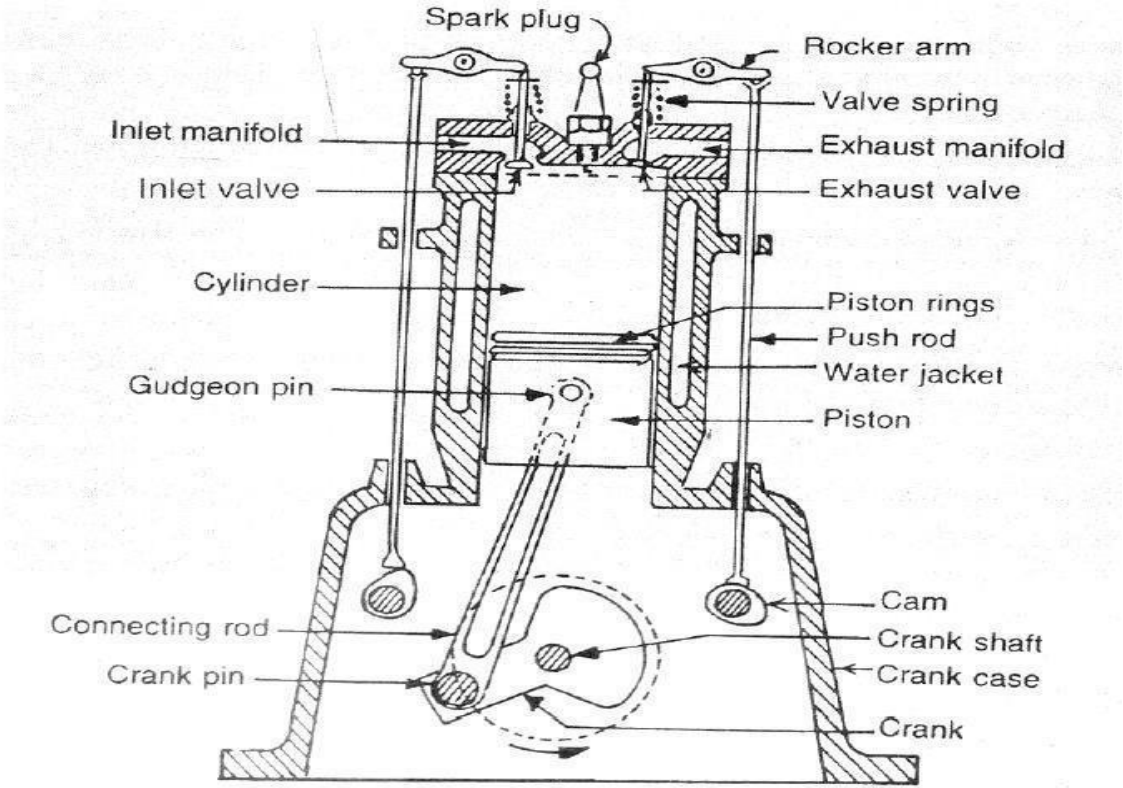


Fig. 1: Major Components of a reciprocating single cylinder Petrol Engine.

Engine Terminology

- Piston Cylinder Assembly: It is the assembly for manipulating the working fluid. The assembly is characterized by a piston moving inside the confined cylinder.
- Inlet Valve: The valve through which air fuel mixture (in case of SI engine) or air (in case of CI engine) is introduced inside the cylinder.
- Exhaust Valve: The valve through which the products of combustion leave the cylinder.
- Crank Mechanism: Mechanism to convert reciprocating piston motion to rotary motion.
- Bore: Diameter of Cylinder.
- Top Dead Center (TDC): Position of Piston where Cylinder Volume is minimum.
- Bottom Dead Center (BDC): Position of Piston where Cylinder Volume is maximum.
- Stroke: It is the maximum distance that the piston moves in one direction. It is the distance between TDC to BDC.
- Clearance Volume (V_c): Minimum Cylinder volume when Piston is at TDC.

Engine Terminology

Clearance Volume (V_c): Minimum Cylinder volume when Piston is at TDC.

Swept or Displacement Volume (Vs or Vd): Volume swept out by the piston as it moves from TDC to BDC.

$$Vs = \frac{\pi}{4} d^2 \times l$$

Where d is the cylinder bore and l the stroke

Compression Ratio (r_v): Ratio of maximum volume at BDC and minimum volume at TDC.

$$r = \frac{V}{Vc} = \frac{Vc + Vs}{Vc}$$

Mean piston speed: the distance traveled by the piston per unit of time.

$$V_m = \frac{2lN}{60} m/s$$

What is meant by cc in Engine?

- The size of an **engine** is measured in cubic centimetres (**cc**) and refers to the displacement volume of the engine.

Problem-1: A four cylinder car engine has bore x stroke = 79 mm x 77 mm. What is the capacity of the engine in cc?

Solution: Capacity in cc = $N.(\pi/4).B^2.S$

Here, N= number of cylinders

B= bore diameter in cm

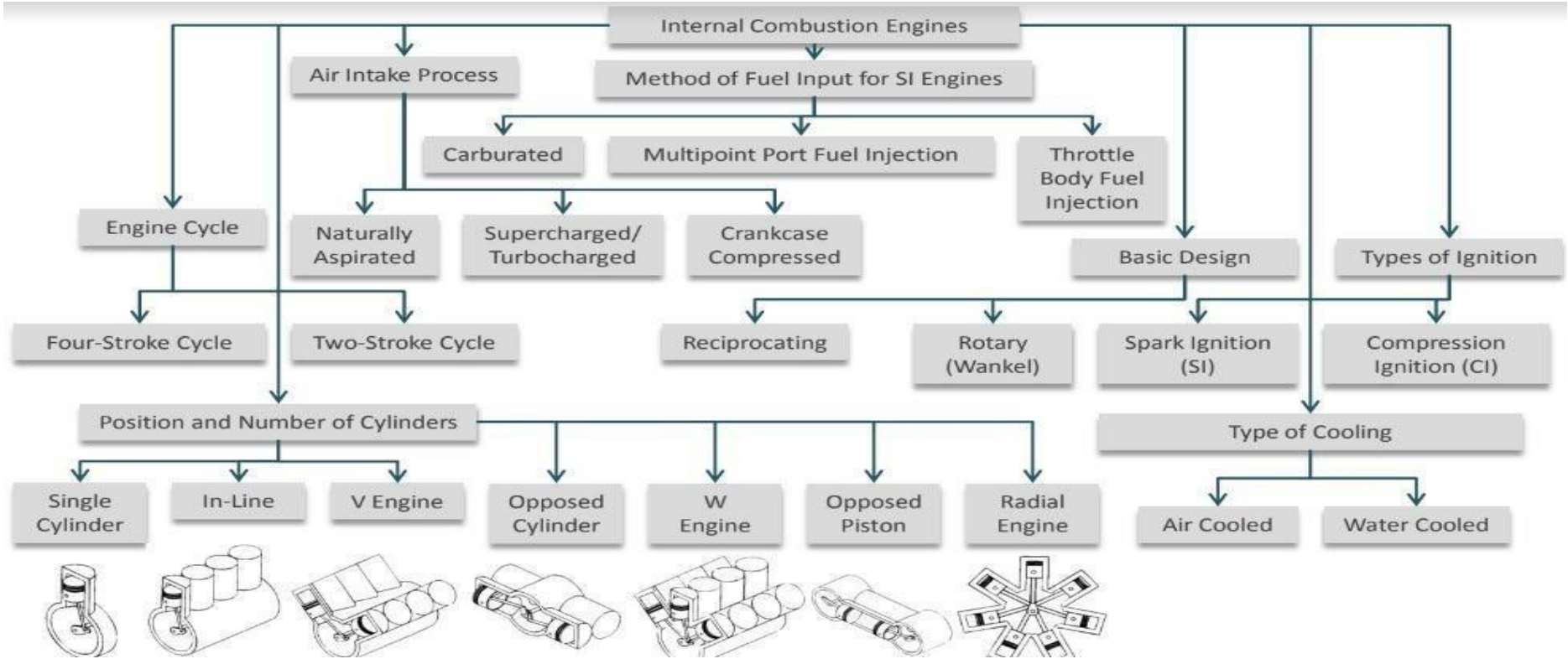
S= stroke length in cm

$$Vs = \frac{\pi}{4} d^2 \times l$$

Therefore, Engine Capacity in cc

$= 4 \times (\pi/4) \times (7.9)^2 \times (7.7) = 1509 \approx$ **1500 cc Ans.**

Engine Classification



Engine Classification

- **Method of Ignition**
  - **Spark ignition (SI):** High-voltage electrical discharge between two electrodes ignites air-fuel mixture in combustion chamber surrounding spark plug. Example: **Petrol Engine**
  - **Compression ignition (CI):** Air-fuel mixture self-ignites due to high temperature in combustion chamber caused by high compression. Example: **Diesel engine**
- **Number of strokes per cycle**
  - **Four-stroke**: Four piston movements over two engine revolutions for each engine cycle.
  - **Two-stroke**: Two piston movements over one revolution for each engine cycle.

Engine Classification

- **The type of fuel**
  - Gasoline, Diesel or fuel oil, Gas (natural gas or methane), Liquefied petroleum gas (LPG): mainly propane, propylene, butane, and butylene
  - Alcohol (ethyl, methyl), Dual fuel (e.g. methane/diesel), Gasohol (e.g. 90% gasoline, 10% alcohol)compression.
  - Biodiesel: cleaner-burning diesel fuel made from natural, renewable sources such as vegetable oils.
- **The cycle of operation**
  - Otto cycle (also known as constant volume cycle) engine
  - Diesel cycle (also known as constant pressure cycle) engines
  - Dual combustion cycle (also known as semi-diesel cycle) engines

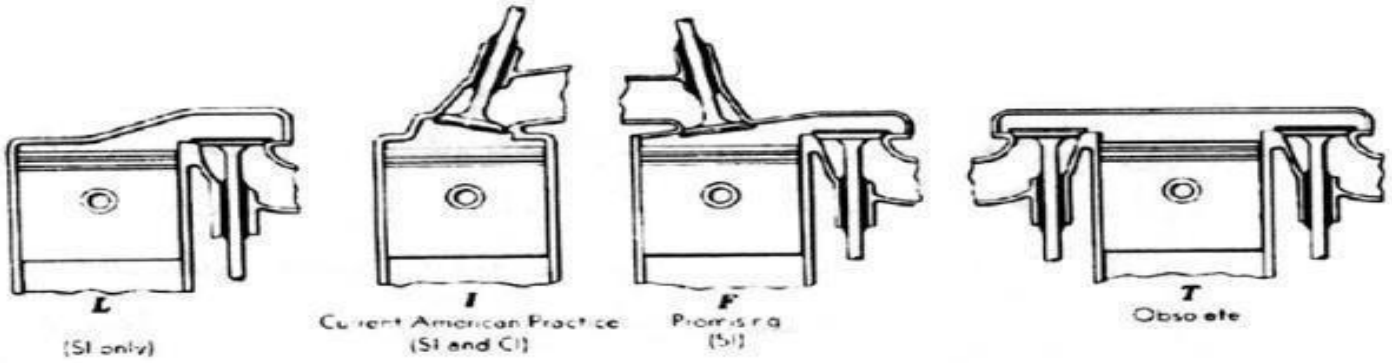
Engine Classification

- Valve location

(a) Valves in head

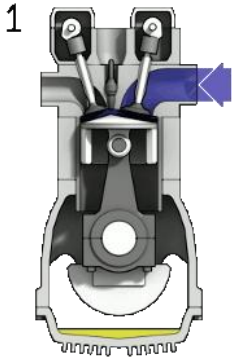
(b) Valves in block

(c) One valve in head and one in block (less common)

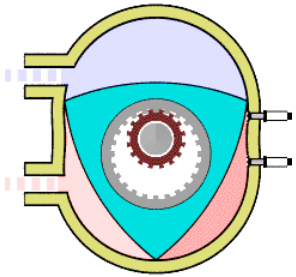


Engine Classification

- **Design**



Reciprocating



Rotary

- **Number of cylinders**

  (a) Single cylinder engines (e.g. lawnmowers),

  (b) Multi-cylinder engines.

- **The cooling system**

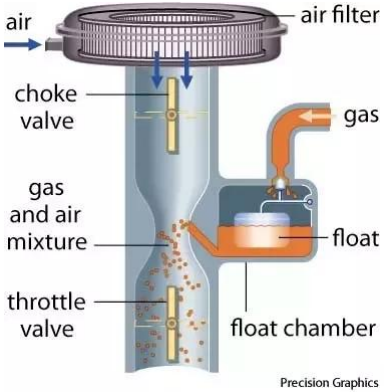
  (a) Air cooled engine, (b) Water cooled engine,

  (c) Evaporative cooling engines

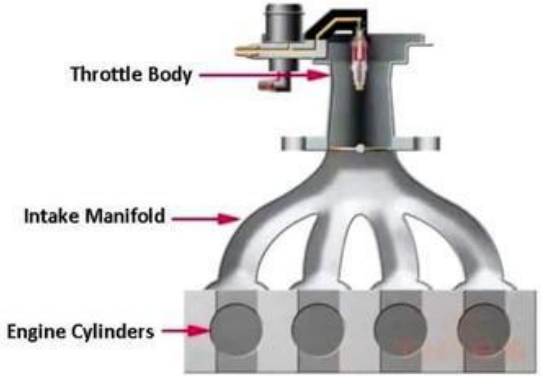
Engine Classification

- **Method of Fuel Injection**

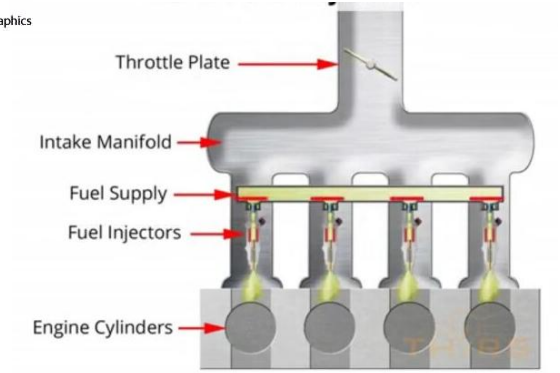
Carburetor



Throttle body Fuel Injection



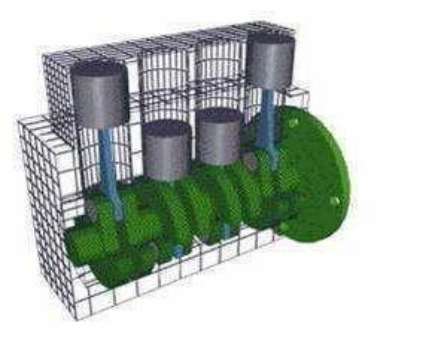
Multi port Fuel Injection



Engine Classification

- **Arrangement of cylinders:**

In-line or straight: cylinders in straight line, one behind the other in length of crankshaft.

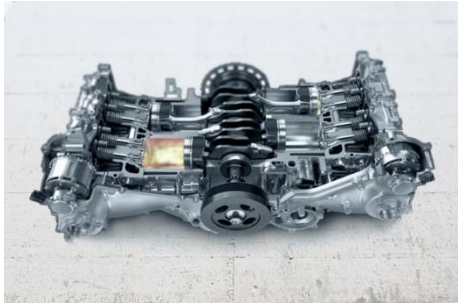


V:
two banks of cylinders at an angle with each other along a single crankshaft, angle typically 60-90^0

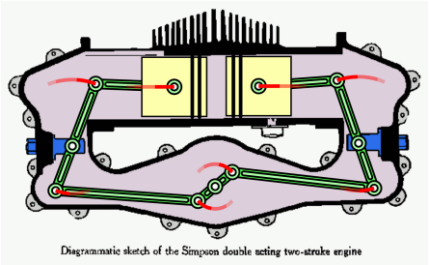
Engine Classification

- **Arrangement of cylinders:**

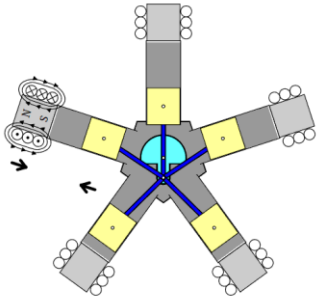
Flat or opposed cylinder (V with 180^0):
two banks of cylinders opposite each other on a single crankshaft (smallaircrafts)



Opposed piston engine:
two pistons in each cylinder, combustion chamber between pistons



Radial engine:
cylinders positioned radially around crankshaft.



Problem 1

A six-cylinder two-stroke engine with a compression ratio r = 9 produces a torque of 1100 Nm at a speed of 2100 rpm. It has a bore b of 123 mm and a stroke s of 127 mm.

a) What is the displacement volume and the clearance volume of a cylinder?

b) mean piston speed

Solution:

$V_d = (\pi/4) * b^2 * L$

We know that $r = (V_d + V_c)/ V_c$

$U_p = 2NL/60$

Problem 1

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a) What is the displacement volume and the clearance volume of a cylinder?

b) mean piston speed

Solution:

$V_d = (\pi/4) * b^2 * L$

$= 1.51 \times 10^{-3} m^3$

We know that $r = (V_d + V_c)/ V_c$

The clearance volume, $V_c = V_d /(r - 1)$

$= 1.89 \times 10^{-4} m^3$

$U_p = 2NL/60 = 2 * (2100/60) * 0.127 = 8.89$ m/s

Problem 2

A three-liter SI V6 engine that operates on a four-stroke cycle at 3600 RPM. The compression ratio is 9.5, length of the connecting rods is 16.6 cm, the engine is square (B=L) Calculate:

a) Cylinder bore
b) Stroke length
c) Average piston speed
d) Clearance volume of one cylinder

Solution:a. Given, Swept volume,
$V_s = 3 \times 10^{-3} m^3$ RPM of engine, N = 3600
The engine bore, B=? Stroke length, L =?

We know, $V_s = n \times (\pi/4 \times B^2 \times L)$
(here n is no. of cylinder)/

Problem 2

b. Since B = L, so L = 0.086 m

c. Average piston speed Sp =?

We know, Sp = 2NL
= 2×3600×0.086 m
= 2×(3600/60)×0.086 m
= 10.32 m/s

d. Clearance volume of one cylinder: the clearance volume for one cylinder,

We know that $r = (V_d + V_c)/ V_c$

The clearance volume, $V_c = V_d/(r - 1) = 352.941\ cm^3$

$V_C = 352.941/6\ cm^3 = 58.82\ cm^3 \approx 59\ cm^3$

Acknowledgement

- Slide Courtesy:
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