C - 85%
H - 15%

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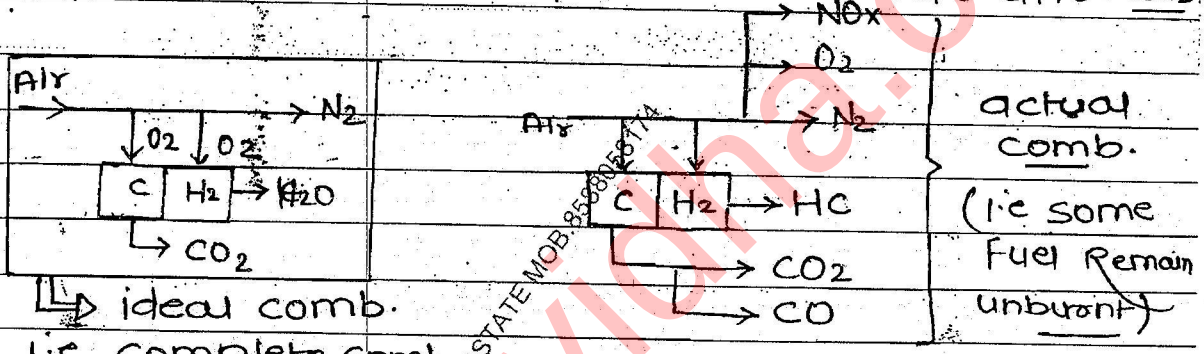
→ In Diesel engine all parameter is High but SFC = $\frac{2}{3}$ (SFC) petrol

✳ COMBUSTION IN SI ENGINE :- *****

1. Stoichiometric Air Fuel Ratio :-

↳ When the combustion of fuel take place in such a manner that there is no fuel Remaining in any form nor is any free Oxygen left after comb



i.e complete comb of Fuel.

then the comb. is known as ideal & perfect comb.

The AFR in such a comb. is known as ~~Setoichiometric~~ AFR

↳ The Stoichiometric AFR by mass b/w 13.4 To 15 & 9 to 9.6 by volm.

- Calorific value of Hydrogen is more than carbon
→ O_2 is first taken by Hydron & then carbon.

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✳ Equivalence Ratio (ϕ):

$$AFR = \frac{m_a}{m_f}$$

4 Fuel air Ratio (~~A~~FAR) $= \frac{m_f}{m_a} =$ FAR

↳ It is the Ratio of FAR under actual cond^n (when the engine is Running) to FAR under stoichiometric cond^n.

i.e $$\phi = \frac{(FAR)_{actual}}{(FAR)_{ideal}}$$

and $$\phi = \frac{(m_f)_a / (m_a)_a}{(m_f)_s / (m_a)_s}$$

$$\phi = \frac{(m_f)_a}{(m_f)_s} = \frac{\text{actual } m_f}{\text{ideal } m_f}$$

eg:- If $\phi = 1.2$ i.e $\phi = 1.2$
i.e 20% more fuel is supply.
and Temp.↑, Heat ↑ Knocking ↑
because more amount of fuel is burnt but

↳ when equivalence Ratio is less than 1 the temp of the charge will be less. as less Energy is available at the fuel. the power output is also less. For petrol engine knocking is also less.

↳ when the equivalence Ratio is more than 1, the fuel supply will be in excess. the temp of the charge will be higher.

There will be a higher power output. For petrol engine knocking will be more.

↳ when the equivalence Ratio is 1.4 the fuel supply is so much excess there should be a shortage of oxygen thus less fuel undergoes comb. The effect will be the same as that when equivalen Ratio is less than 1. The Remaining unburt fuel is known as unburnt Hydrocarbon (UHC) will flow along the gases until exhaust.

Combustion in SI Engine :-

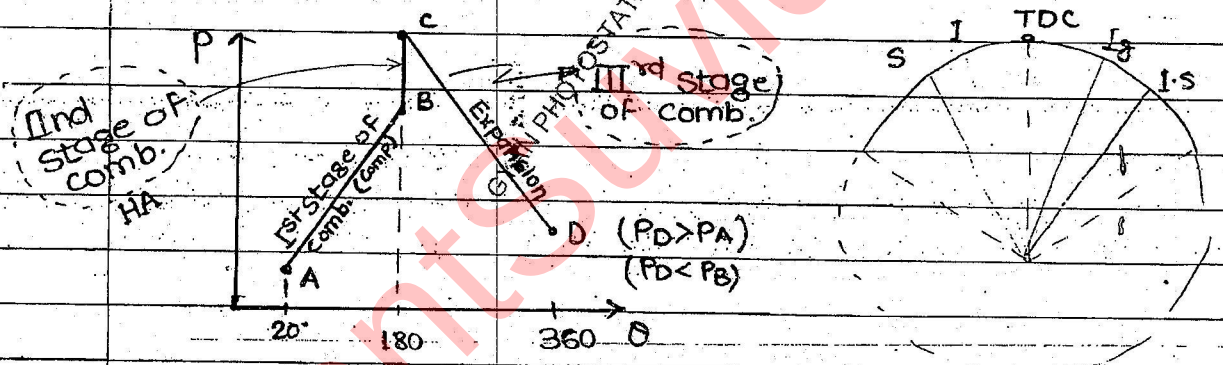


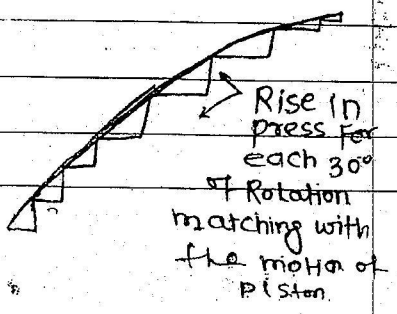
Fig : P–θ Dig. (Theoretical)

$\boxed{\Delta P \propto \theta}$ ⇨ $\Delta P = K\theta$

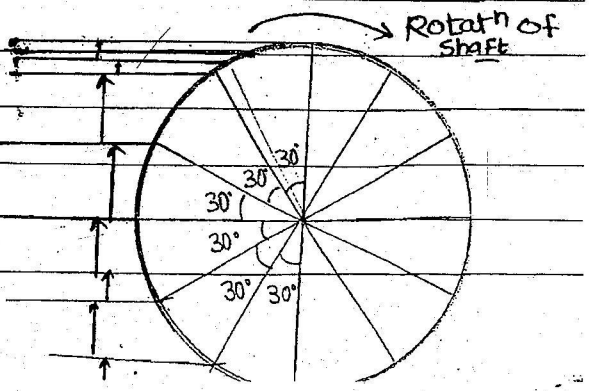
$y = mx$.

comb → combustion
comp :– Compression

↳ Due to Sparking fuel is not burnt, but temp of air increases



motion of piston (SHM)



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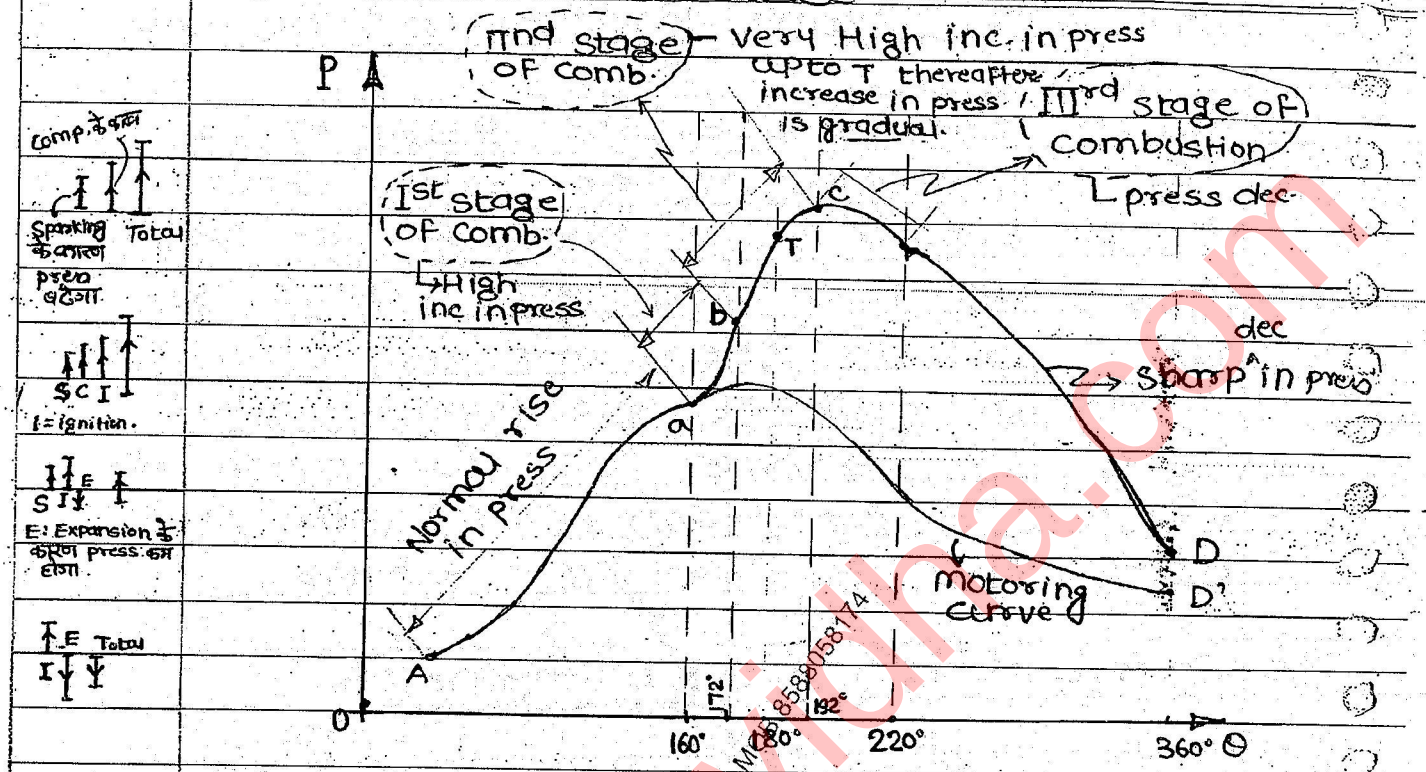
P-θ Diagram (Actual) :



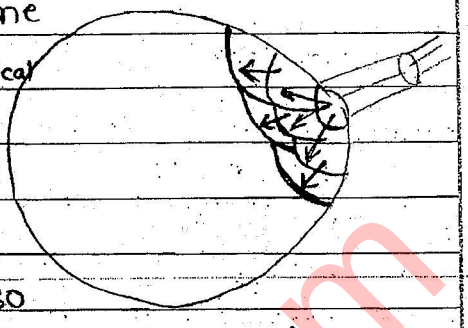
→ The piston & shaft is connected with connecting Rod.

→ For motoring curve:
It is a curve trace by a similar engine in which only compression & expansion takes place (there is no comb) It may be seen from two curve a good press rise during ignition which is the main cause of higher eff. of the engine. (cost of comb chamber = Vc)

Ist Stage of Combustion :-

- when the spark contact some area of fuel then chemical action begine
- → The C.G of a molecule is called Nucleous (may be consider)
- → Spark is also a part of comb.
- → Ist stage comb. is not a comb. state but a cause of comb. for IInd stage. (i.e preparation is going on in Ist stage)

↳ When the spark contacts some area of the fuel, then chemical action begin in this area. Heat is generated that spreads to the other areas of the fuel. There are also a rise in temp. of the fuel particle. As the area for the chemical RKN is increase there is a propagation of the nucleas of the area in which chemical action taking place. At the end of the chemical rkn of entire fuel, if the temp of the fuel particle is below the self ignition temp, this fuel does not burnt and is known as unburnt HC (UBHC).



↳ During the increase in the chemical action, different amount of heat is collected in different areas of fuel. If the temp. of the fuel particle is equal to or greater than the self-ignition temp. then there is distribution of heat over the entire area of the fuel. There is no change in temp during this heat distribution. When equal amount of heat is stored in equal different area of the fuel. The ignition begine for the fuel particle.

↳ The time taken from the begining of chemical action to the begining of fuel ignition is known as chemical Lag. For petrol engine, chemical Lag is also known as ignition Lag.

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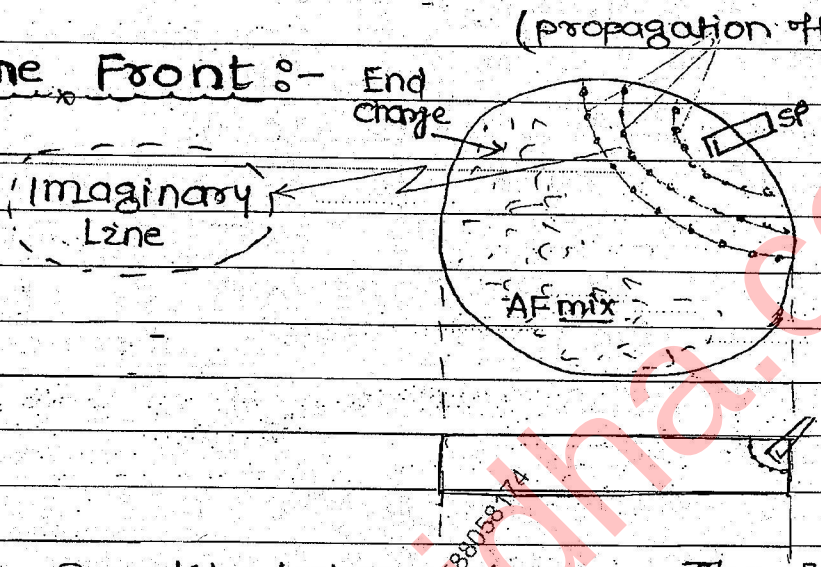
↳ The chemical lag and Ist stage of comb is also known as preparatory phase.

or,

Flame Front :-



↳ When Sparking takes place, The fuel particle near the spark plug gets ignited. The line joining (imaginary) the ignited fuel particle is known as Flame front.

↳ Propagation of Flame front :-

after Ist Flame front, Heat flows from this flame front to neibhouring area & another Flame front is form. At the same time the fuel particle in the Ist Flame front gets complitly burnt & this Flame front vanishes. It is thus ~~appear~~ appear that the First Flame front has only reaches the new position This imaginary movement of the Flame Front is known as the propagation of Flame front.

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✳ END CHARGE :-

↳ The AF mixture at the opposite end of the flame front propagation is known as End charge.

→ The temp. of end charge is always increases if temp. reaches to self ignition temp of fuel the a flame is extra produce in this region. when this flame and propagating flame front is attack then detonation/ knocking takes place.

→ Knocking and Detonation is same things

↳ The following events takes place for the end charge during the flame front propagation

1) During the propagation of the flame front, heat flows to the near by the particle & these air particle expand. This expansion brings compression of the end charge. temp. of the end charge increases

2. Due to the increase in the temp. of the end charge, chemical action begins for the fuel particle in the end charge. the temp of the end charge increases further.

3. There is transfer of heat from the flame front to the end charge. The temp. of the end charge continuous to increase further. If the temp. of the end charge becomes equal to or more than the self ignitation temp due to the above Reason, a separate flame front is form at end charge

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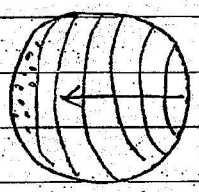
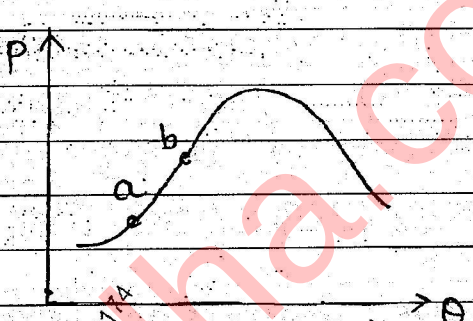
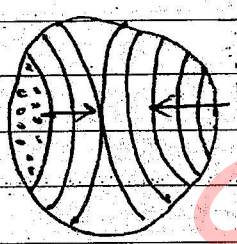
The two flame front moves in opposite dirn and collide with one another. This collision is known as Detonation.

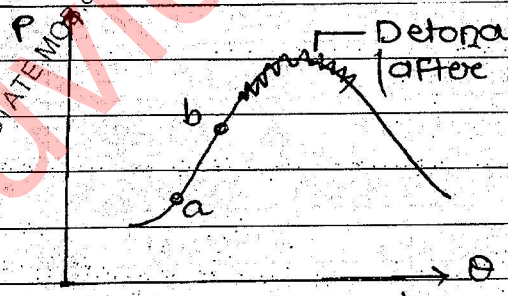
Abnormal Combustion IN SI Engine :-



a = sparking begin
b = ignition "







↳ If the flame front from the spark plug reaches the end charge before formation of a flame front at the end charge, then detonation will not occure.

→ For a good engine 1-2 time Detonatn occure in 1 lakh cycle.

↳ The following are disadv. of Detonation.

1. When the two flame front collid (detonatn), a high energy wave is developed at the point of collision which can move in any dirn at a speed of above (2,5000 to 5000 cycle per sec) If this wave is directed towards the piston, the piston knocks against the cylinder Hence detonatn is also known as knocking

Due to knocking, a crack may develop in the piston or in the cylinder.

II) Due to knocking, a huge metalic sound is produce known as "pinging". Hence Detonation & knocking is also known as pinging.

III) Mechanical vibrations are set-up for the engine.

4. There is loss of work.

Temp - Time graph during the chemical action of Fuel.

→ Fig. 1 show the chemical of a fuel particle whose temp is below the self ign. temp at the end of chemical action (point B_1). This fuel will remain unburnt (UBHC) & will be in circulation with hot gases. During this circulation, the temp of UBHC decreases (B_1 to C_1) until exhaust. (point C_1)

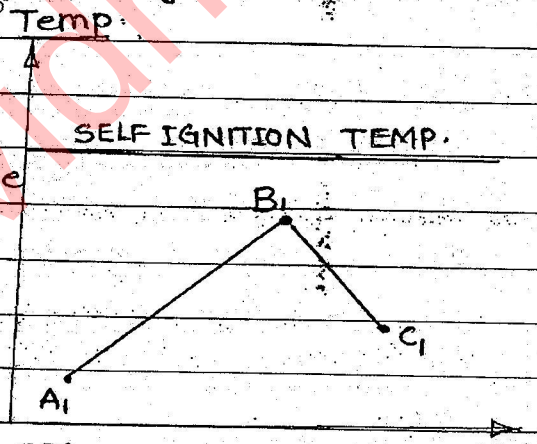


FIG: 1.

↳ In Fig 2 it is clear that the chemical lag for the fuel particle is less if its temp is higher (about self-ign. temp) Hence for petrol engine if the temp of the end

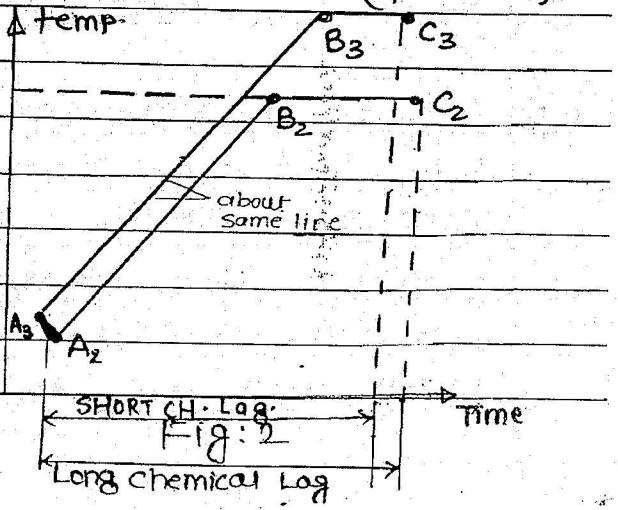


Fig: 2

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charge is above the self-ign temp, the chemical lag of the fuel particles at the charge will be less and a flame front is definetly form at the end charge before the ~~end ch~~ flame front from the spark plug reaches the end charge, then knocking will definitely takes place. Thus to avoid knocking in petrol engine the temp of the end charge must be closed to the self-ign temp.

Factors affecting Detonation In SI engine

1: Compression Ratio:
Higher CR will result in higher temp of charge, tendency to knock will increase. It is for this ~~region~~ reason that the CR in SI engine is limited to b/w 6 and 10 only.

2) The effect will be the same if the inlet valve temp. is high OR a supercharger is used. On using a S.C an intercooler must be provided.

2. ~~#~~ Higher engine load.
Higher engine load Result in higher work output & power. More fuel must be supply. temp. of the charge ~~ma~~ will increase, knocking tendency will be more. Thus petrol engine must run at less load condⁿ.

* maxm dia for petrol engine — 15cm (to avoid knocking)
To increase power increase no. of cyl. not inc. dia..
* If two spark plug is available then we kept some large dia.

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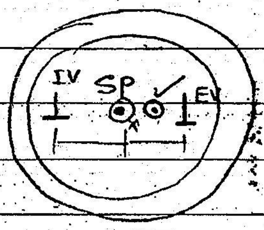
3. Advancing the Spark :

↳ Advancing the spark Result in more duration for sparking. The temp. of a charge will be higher. Tendency to knock will increase. Thus the sparking should not be ~~ins~~ advanced. instead of sparking can be Retarded.

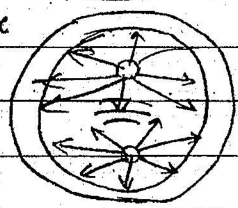
4. Distance of Flame travell :-

The distance travelled by a flame front is such that the time taken by it ~~the~~ should be less than the chemical Lag of the Fuel (must be less than the chemic Lag of ~~th~~ the fuel) for this purpose the cyl. dia of petrol engine is limited to a maxm of 15cm.

5. Location of Spark plug :-



@— In Double SP, knocking also occure. but we kept distance b/w the two SP. in such a manner that before collide the flame front all the fuel burnt.



↳ A SP must be located nearest to the centre and away from the inlet valve. The ~~region~~ reason is that more ~~fla~~ time will be taken by the flame front to reach the inlet valve — in the mean where suction is begine for another cycle

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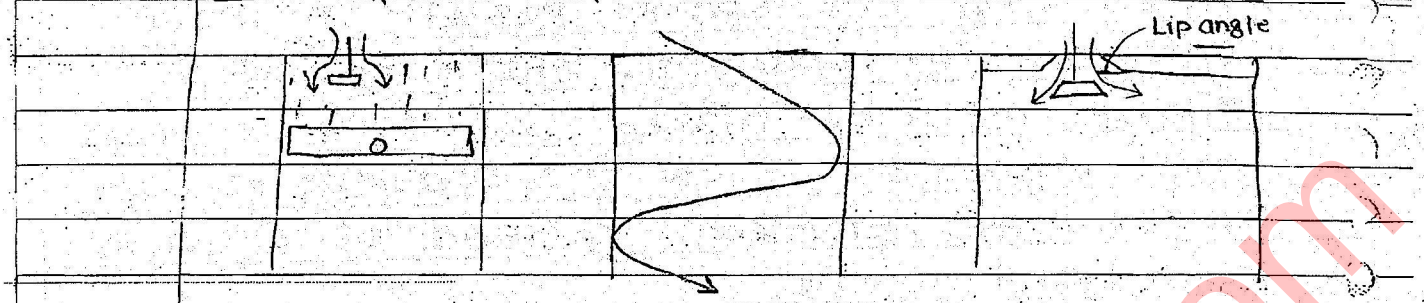
6. # Higher Engine Speed :-



– Higher engine speed will Result in turbulence. The flame front will reach the end charge fast in all dirn, terbulence will be set-up. ——
Tendency to Knock will ~~increase~~ Reduce. Hence the ideal combinatn for preventing Detonation is high speed at low load.

7) Quality of Fuel :-
Iso-octane – (ZERO Knock)
Normal heptane (Readily Knock)
TEL and TML → X Not mix with fuel
Ethylene di-bromide → ✓
– Catalitic agent :
- Palladium – CO to CO_2
- Platinum → HC to H_2O & CO_2
- Rhodium → Nox to N_2 & O_2

i) The antiknock quantity of fuel is determine by comparing petrol with a standard fuel in lab. The standard fuel is mixtr of two other fuel. One is iso-octane (ZERO Knock) & other is normal heptane (Readily Knock). The %age of the fuel in the standard fuel is determined that matches with the anti-knock quality of petrol. If the octane ~~no~~ in the mixtr is 70% the normal petrol is supposed to have an octane no. of 70.

↳ Higher the octane no. of petrol better will be the quality of fuel.

↳ In India the octane no. of fuel is b/w 70-80 and for ~~extra~~ special quality fuel like extra premium speed etc the octane no. is b/w 90-94.

Unleaded Petrol :-

To improve the antiknock quality of petrol chemical agents like Tetra ethyl lead (TEL) OR Tetra methyl lead (TML) is added to the fuel. During comb^n, lead ~~form~~ from the compound gets separated & will be in circulation as lead itself in the exhaust gas. This lead corrodes the catalytic agents in the catalytic converter placed in the path of exhaust gas. Thus ethylene di-bromide is used instead of the lead compounds. Such a fuel is known as unleaded petrol.

Catalytic convertor :-

1. It consists of a stainless steel box & is kept in the path of the exhaust gas.
2. Hence alumina inside in the form of honeycomb.
3. Contains the following catalytic agents.
   a) palladium → CO to CO_2
   b) platinum → HC to H_2O and CO_2
   c) Rhodium → NOx to N_2 and O_2
4. Catalytic convertor is used to convert the harmful pollutants as above (CO, HC & NOx) into harmless gases.
5. Catalytic convertor is also known as a 3 way convertor.
6. Catalytic agents are used to speed up the Reaction & by itself does not participate in the Reaction.

7) Rhodium is placed at the start of the catalytic convertor so that the oxygen librated from it can be used for the oxidation of the other pollutants.

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Ques: what is the value of FAR in the normal operating range for conventional IC Engines

a) 0.056 to 0.083 | FAR = .086/.083 = 0.675
b) 0.083 to 0.56 | FAR = .083/.56 = .148
c) 0.0056 to 0.83 | FAR = .0056/.83 = 0.00675
d) 0.056 to 0.83 | FAR = .056/.83 =

→ For a normal operating condⁿ

AFR=16 or FAR = 1/16 = 0.0625

↳ choice (d) is matches with normal operating condⁿ

Ques:- IES 2008 In an SI engine, Comb state I takes 1 ms (millisec) and in stage II takes 1.5 millisec when the speed of the engine is 1000 rpm. The stage I time is independent of the speed. Det. the spark advance when the engine speed double.

a) 0° b) 6° c) 12° d) 24°

when we got two data for same inforation then first prepared data table (in all sub)

N (rpm)	Stage I	Stage II
1000	I millsec	1.5 msec
2000	I millsec	?

Now $N = 1000 \text{ rpm} = \frac{1000}{60 \times 1000} = 0.0167$ Rev/millsec

$= 0.0167 \times 360$ degree/millisec

$= 6°$/millisec

For 2000 RPM angle covered = 12°

∴ Spark advance = $12 - 6° = 6°$ Ans (b)

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Ans :- To prevent detonation in SI engine the end charge should have
a) Low temp b) low density c) long ignition delay.

→ long ingition delay means, temp is close to self-ign. temp.

→ water vapour at superheated state follow all gas law (so it is a gas), fuel is mix with air so fuel also behaves as gas.

↳ all above choice are correct.

→ $\rho = \frac{m}{V}$, volm of end charge is not change (but const)

↳ low density :
For a low density of end charge, the mass of the fuel particle in the end charge will be less. Less heat will be generated during the chemical action of the fuel particle in the end charge. Hence the chemical lag will be longer. The Flame Front from the spark plug will reach the end charge before a separt end Flam front is formed at the end charge. Thus detonation will be prevented.

So, All the 3 choices are correct. ✓