Virtual Internship Batch 1

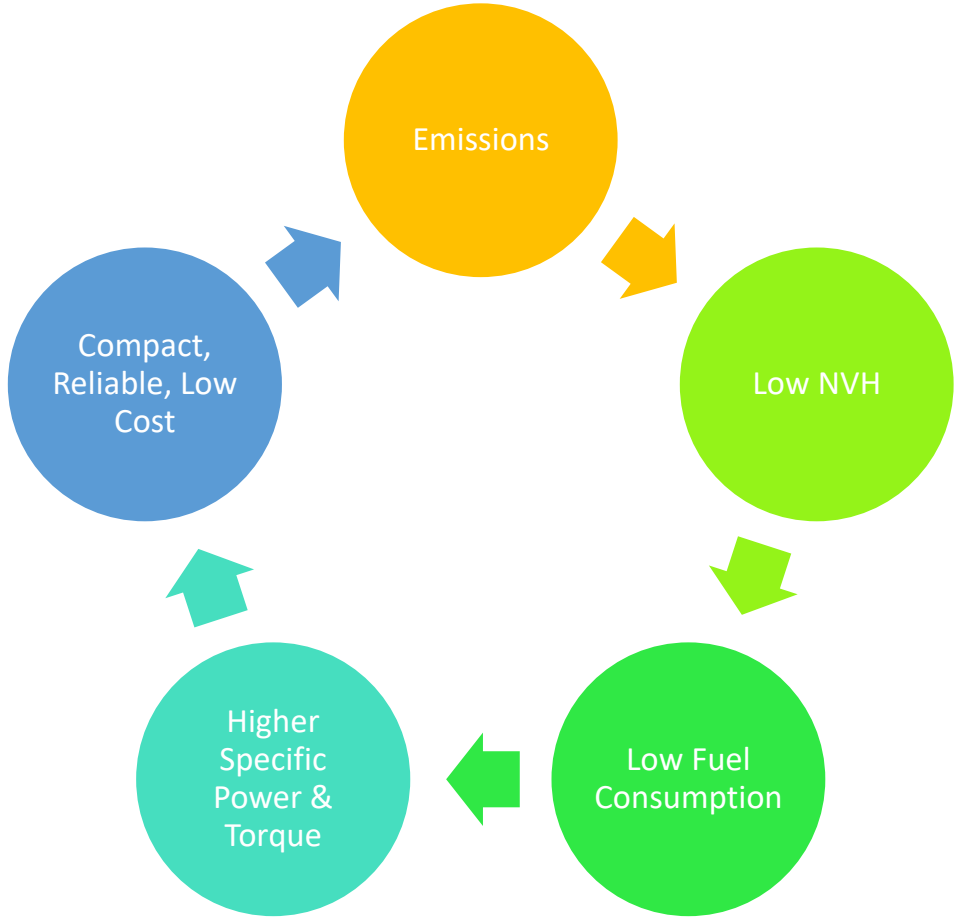
Engine Performance & Emissions

Engine Development

Engine Development Requirements from

- Customers
- Government

- Reliability & Driving Pleasure vs Emissions & Recycling



Engine Development

RevnLab

Sulphur content

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026

500 ppm | ROI 350ppm | Region1 | Region2 | Rest of India 50ppm | 10ppm

13 Cities | 33 Cities

Oct | Apr | Apr

Emission Regulation

BS2 | ROI BS3 | BS4 | BS6

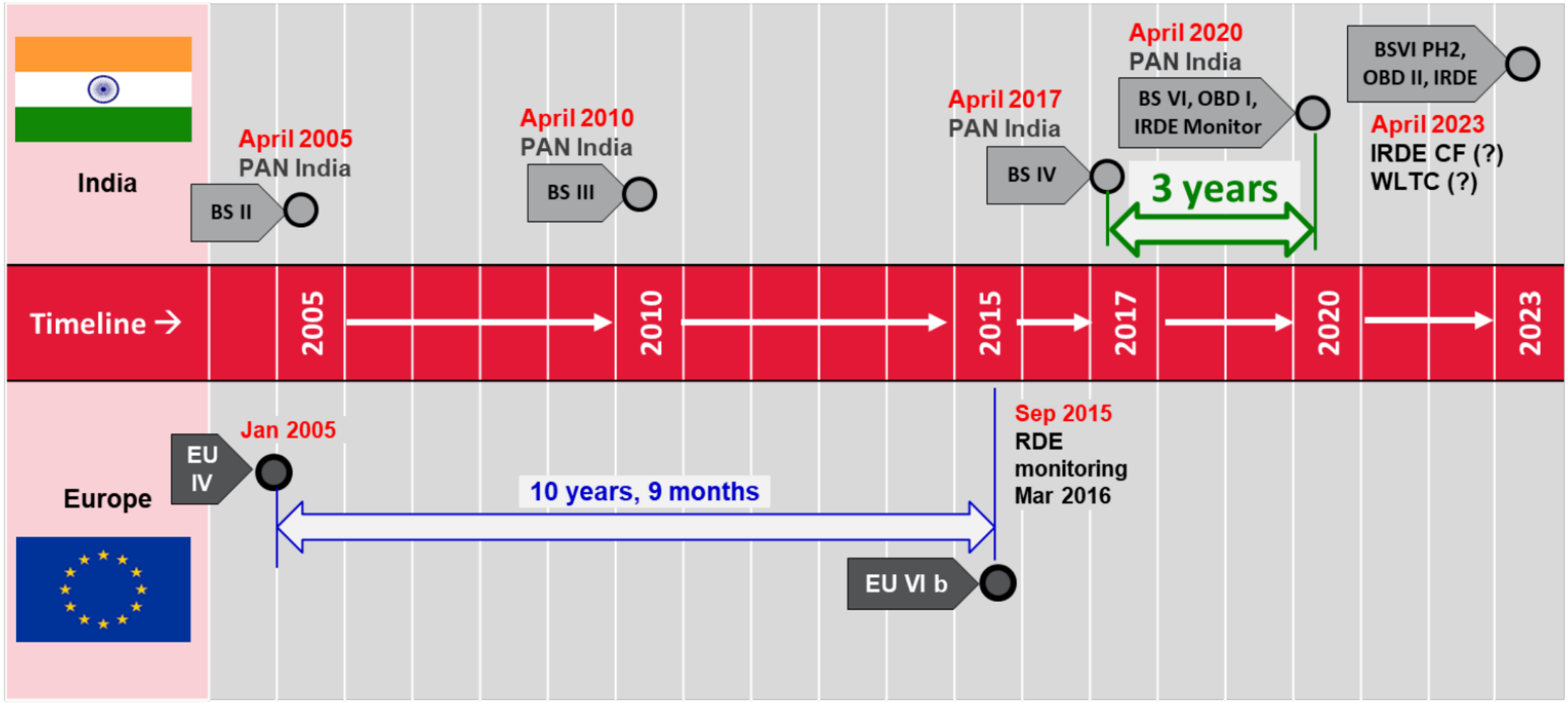
13 Metros BS4 | 33

MIDC max. 90km/h | MIDC max. 90km/h RDE definition | MIDC 90km/h RDE monitoring | MIDC RDE cf?

On Board Diagnosis

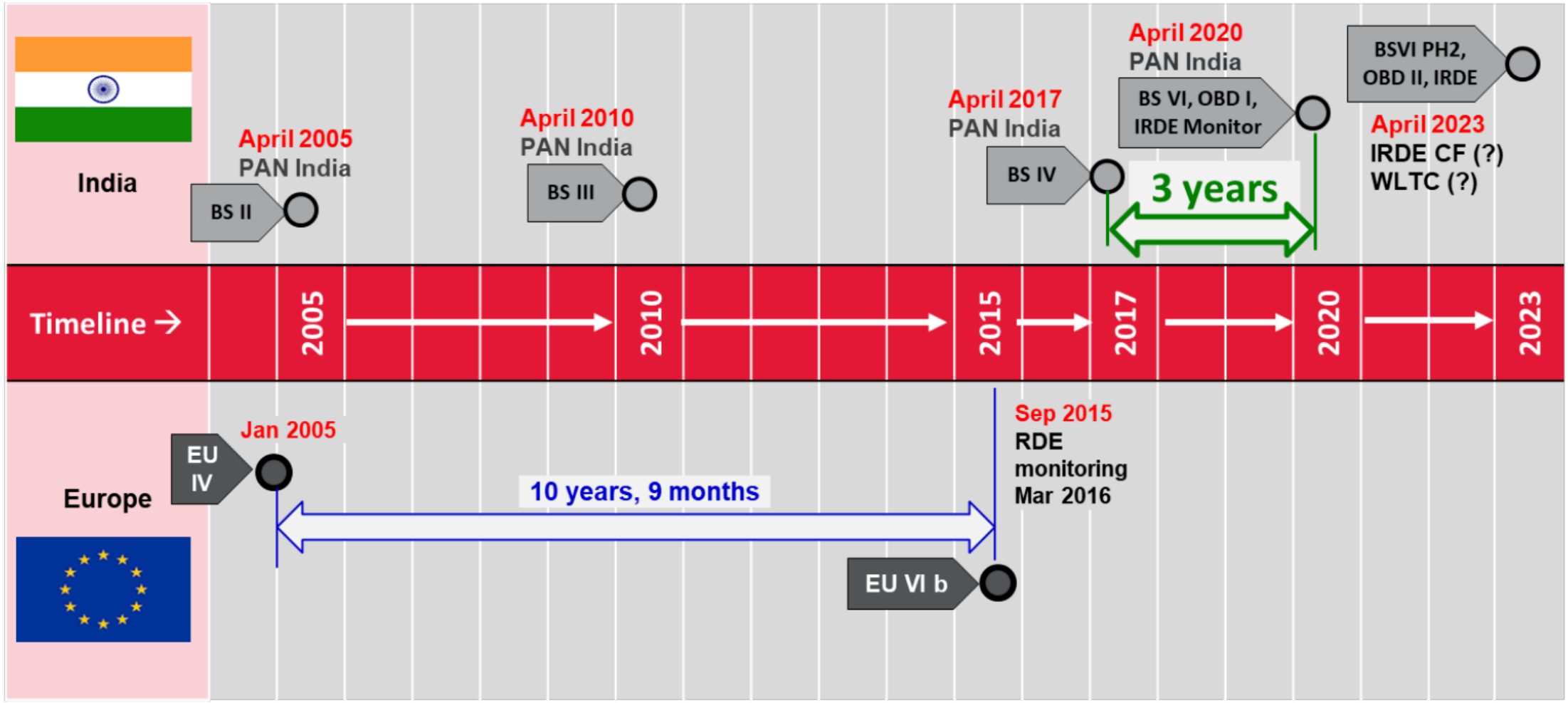
IOBD I | IOBD II | BSVI-OBD-I Without IUPR | BSVI-OBD-II with IUPR

Engine Development



Mahindra & Mahindra BS6 Presentation

Engine Development



Mahindra & Mahindra BS6 Presentation

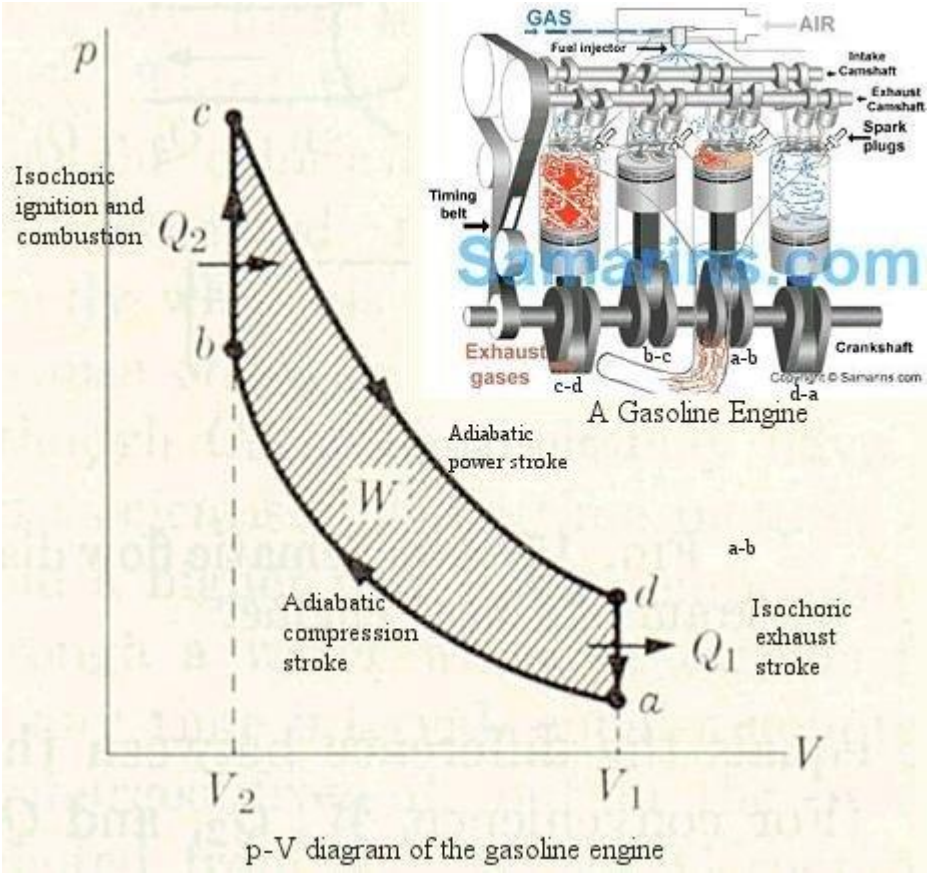
Engine Emissions

What are emissions?

- Unwanted by-products of combustion
- HC, NOX, SOX, PM, CO, SOC, CO_2
- Diesel Engines – NOX & PM
- Gasoline – CO, HC & CO_2
- Gasoline emit 20-25% more CO_2 than Diesels

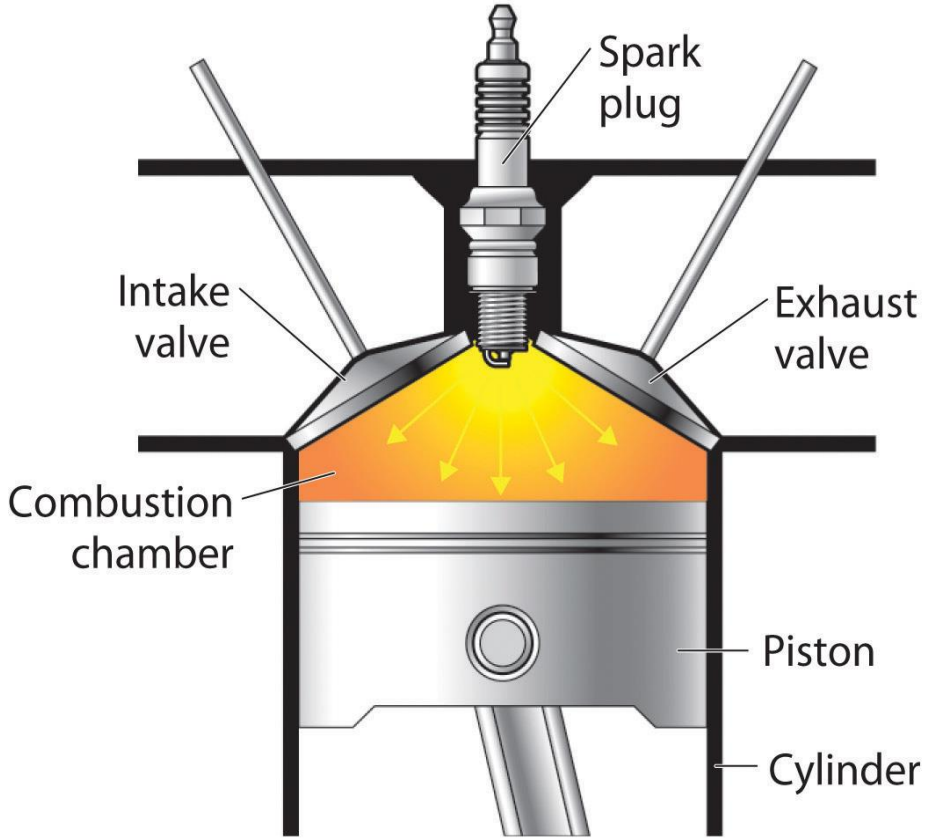
Engine Emissions

- Why emissions form?
- Combustions is a complex chemical reaction
- $C_nH_{(2n+2)} + (n+1)\ O_2 \Rightarrow nCO_2 + (n+1)\ H_2O + heat$
- Gasoline - C_8H_{18}
- Diesel - $C_{12}H_{24}$
- Fuel : Air Ratio – Stoichiometric Ratio
- Gasoline – 14.7
- Diesel – 14.6
- Stoich ratios should ensure only CO_2 and H_2O
- Deviations from Stoich?
- At 3000 rpm – One 4 Stroke Cycle every 40 mS



IC Engine Combustion

- Chemical Conversion involving reactants
- Conversion depends on many factors
  - Concentration of reactants
  - Temperature among others
- Higher temperature – Higher rate of reaction
- Temperature refers to the flame temperature
- Flame travels outward from spark plug



(a) Normal combustion

IC Engine Combustion

- Flame Temperature Depends On
  - Heat energy released – Chemical Energy
  - Composition of burned mixture
  - Initial temperatures
  - Final temperatures
- Flame temperature determines end products

Emission Constituents

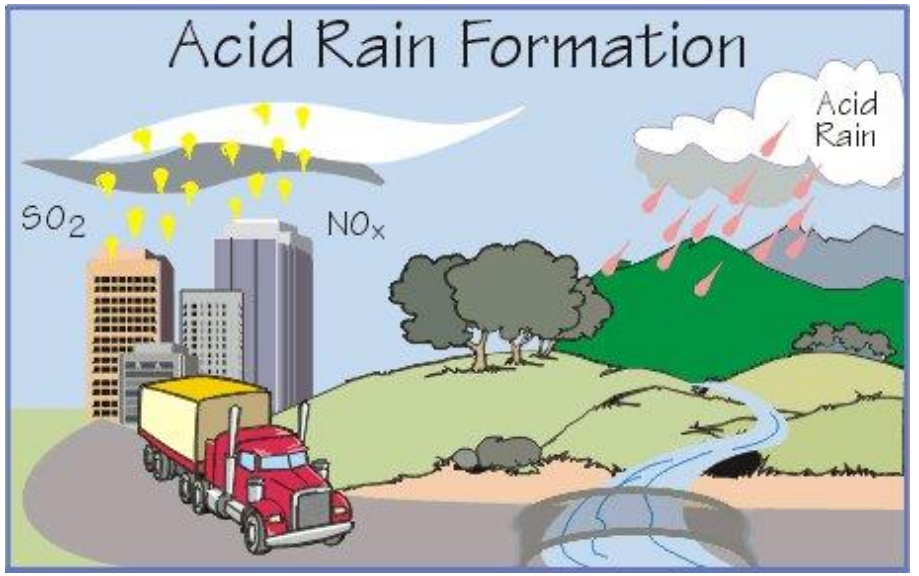
HC & CO

- Formed when there is Oxygen deficiency
- Rich mixtures, typically
- Also formed when mixture is not homogenous or uniform – localised rich / lean pockets
- Fuel avoiding flame zones – Crevasses and pockets in piston
- Weak flame front – in sufficient advances
- Absent or Minimal when running lean
- CO is colourless and odourless and very harmful to human
- HC forms ground level smog / petrochemical smog
- HC emissions is not same as PM

Emission Constituents

NOX

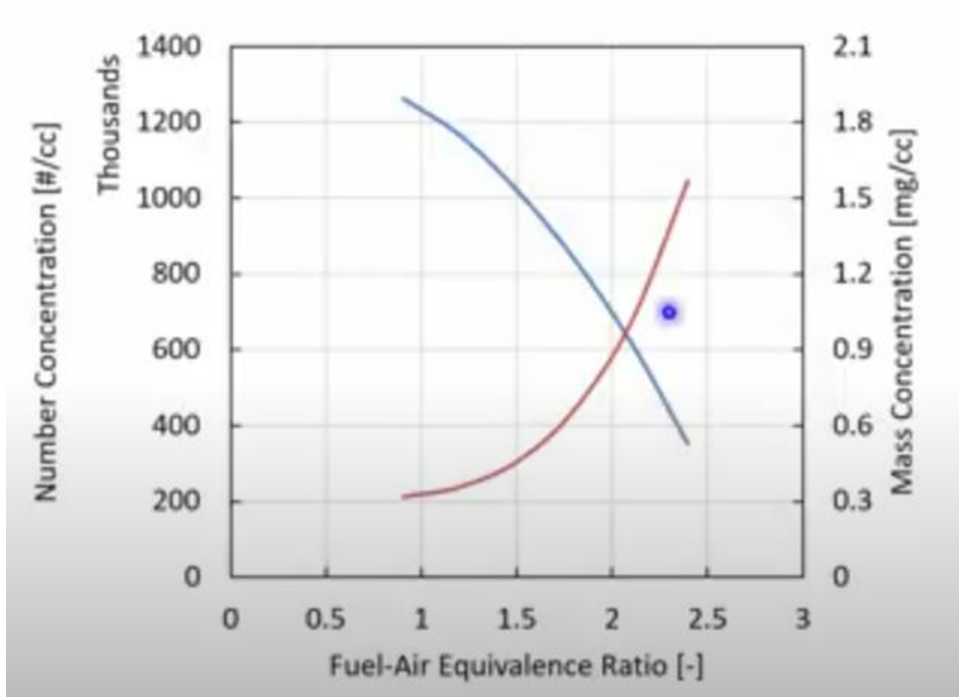
- Formed when Nitrogen in air / fuel mixes with oxygen
- Thermal NOX and Fuel NOX
- Prompt NOX – Formed by process other than above
- Nitrogen reacts with radicals - CH2 or C or CH
- Though nitrogen is usually inert, high temperatures activate it
- NOX formation occurs at high temperatures
- Gas law T α P, higher in-cylinder pressure raises NOX
- Rich mixtures produce less NOX – Less O_2 present
- Stoichiometric Ratio – High NOX – Flame temp is high
- Slightly Lean – Max NOX – Excessive O_2
- Excessively Lean – Low NOX – Flame temp is low
- Usually invisible, though NO is brownish colour



Emission Constituents

PM

- Particulate Matter – Formed because of incomplete combustion
- Exact formation is still unknown
- Nucleation – one possible reason
- Classified as PM_{10} and $PM_{2.5}$ – Refers to particle sizes
- Small particles, extremely harmful
- Penetrates lungs and blood streams – Asthma and Cancer
- Linked to air fuel ratio directly



Emission Constituents

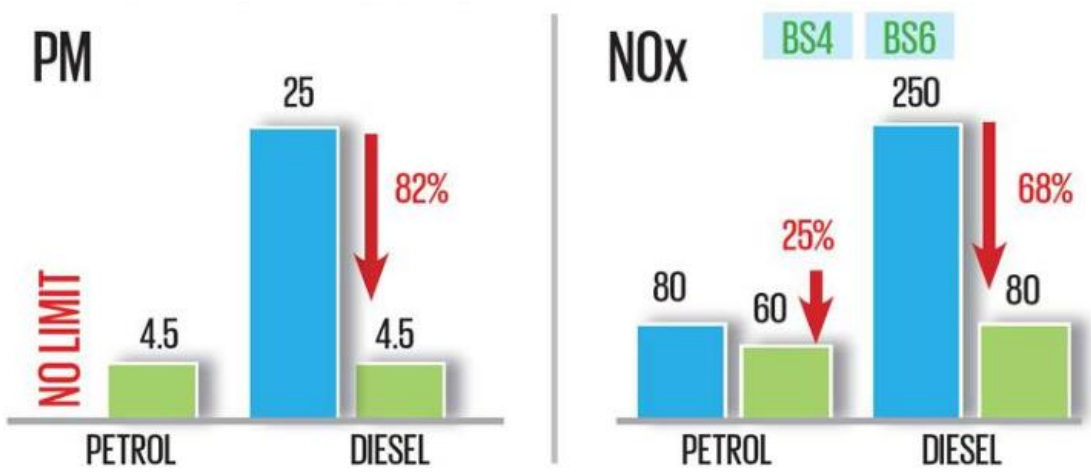
SOX

- Sulphur present in fuels – primarily diesels
- Sulphur oxides irritate nasal passages
- Also causes acid rain – Sulphuric Acid

Statutory Requirements

BS6

- Stipulations on maximum permissible emissions
- Measured in PPM or g/100km or g/kWh
- Emissions measurement devices – 5 gas analysers
- Testing procedures need to be followed



Vehicle Classification

ReynLab

L1e		L2e	L3e	L4e	L5		L6e		L7e		
Light two-wheeled vehicle		***Three-wheel moped***	***Motorcycle***	***With side car***	***Tricycle***		***Light quadricycle***		***Heavy quadricycle***		
L1e-A *Powered cycles*	**L1e-B** *Moped*	**L2e**	**L3e**	**L4e**	**L5e-A** *Tricycle*	**L5e-B** *Commercial tricycle*	**L6e-A** *Light quad*	**L6e-B** *Light quadrimobile*	**L7e-A** *Heavy on-road quad*	**L7e-B** *Heavy all terrain quad*	**L7e-C** *Heavy Quadmobile*
		L2e-P 	L3e-A1 	L4e-A1 				L6Be-P 	L7e-A1 	L7e-B1 	L7e-CU 
	Limited speed 	L2e-U 	L3e-A2 	L4e-A2				L6Be-U 	L7e-A2 	L7e-B2 	L7e-CP 
			L3e-A3 								
≤50cc, ≤25 km/h, 250W--1kW	≤50cc, ≤45 km/h, <4 kW	≤50cc, ≤45 km/h, <4 kW, ≤270 kg	<= 11 kW, A2: <=35 kW		3W, <1000 kg,	3W, <1000 kg, max 2 seats, V 0.6m^3	<4kW, ≤425 kg, ≤45 km/h (D, G)	<6kW, <425 kg, ≤45 km/h (D, G)	<15kW, ≤450 kg	W/G<6, ≤450 kg	P: ≤450 kg, U: ≤600 kg, (D, G)

Vehicle Classification

Category L1

- Motorcycle with engine capcity less than 50cc or electric drive less than 500W
- Max speed not to exceed 45 kmph

Category L2

- Other than L1, subdivisions as in previous slide
- Quadricycle is a new classification in India – Bajaj

Category M1

- Motor vehicle for carrying passengers, not more than 8 seats in addition to driver

Category M2

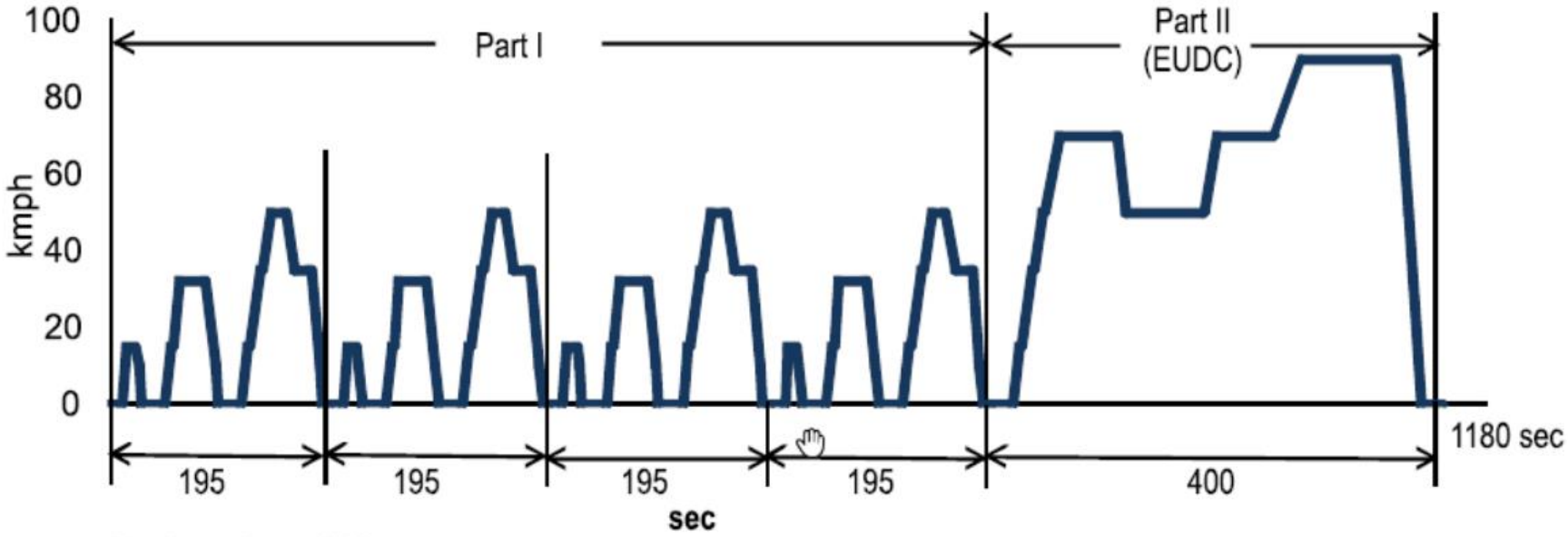
- Motor vehicle for carrying passengers, 9 or more seats in addition to driver
- Gross vehicle weight not to exceed 5T

Category M3

- Motor vehicle for carrying passengers, 9 or more seats in addition to driver
- Gross vehicle weight exceeding 5T

Drive Cycles

1. Modified Indian Driving Cycle (Bharat stage Norms)



Total test time: 1180 sec

Total distance: 10.647 km

Max. speed: 90 km/h

Maximal Acceleration: 0.833 m/s^2

Maximal Deceleration:1.389 m/s^2

Drive Cycles

Drive Cycles

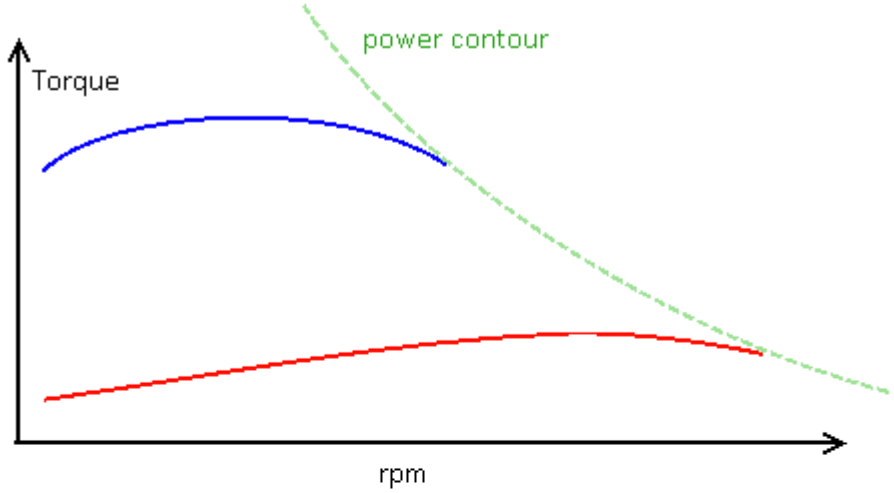
- Representative of real world conditions in a lab
- Change vehicle velocity over time to simulate driving conditions
- Urban, rural and highway drive cycles
- Country Specific, India – MIDC, Europe – NEDC, USA – FTP75, Global – WLTP
- More information available from ARAI website – Link attached
- Test cycles are repeated, say 4 cycles for MIDC 2 wheelers

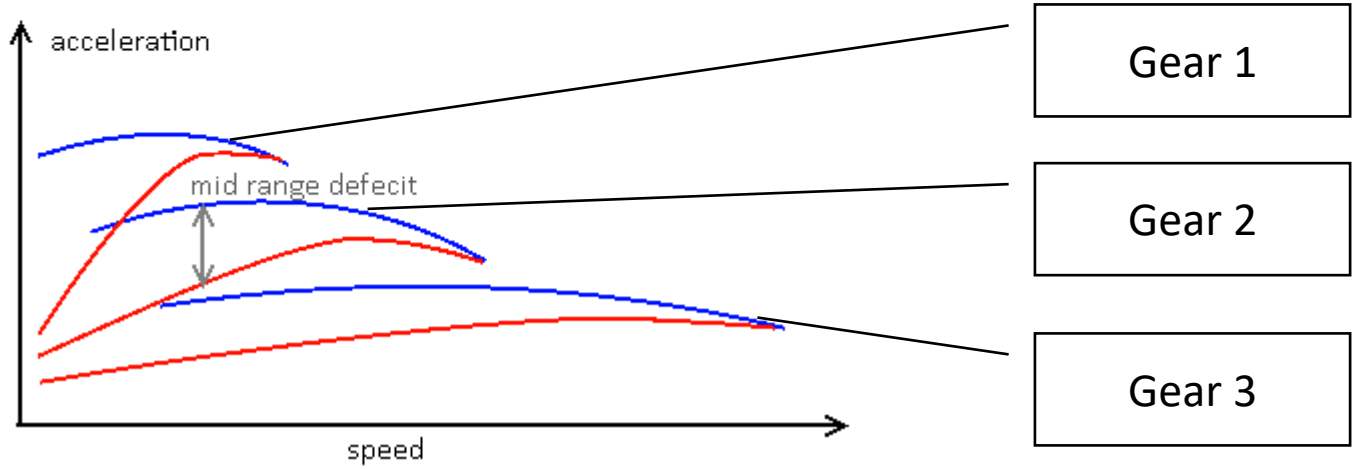
Drive Cycles and Torque

Torque Requirement

- Required for accelerating the vehicle
- Vehicle has to accelerate to meet drive cycle requirement (primary target, since if it does not clear drive cycle, it cannot be sold in the market)
- Torque required at wheels < = torque from engine
- If the other way, drive cycle not met
- Torque can be varied by using gears
- Torque can also be varied by changing engine parameters

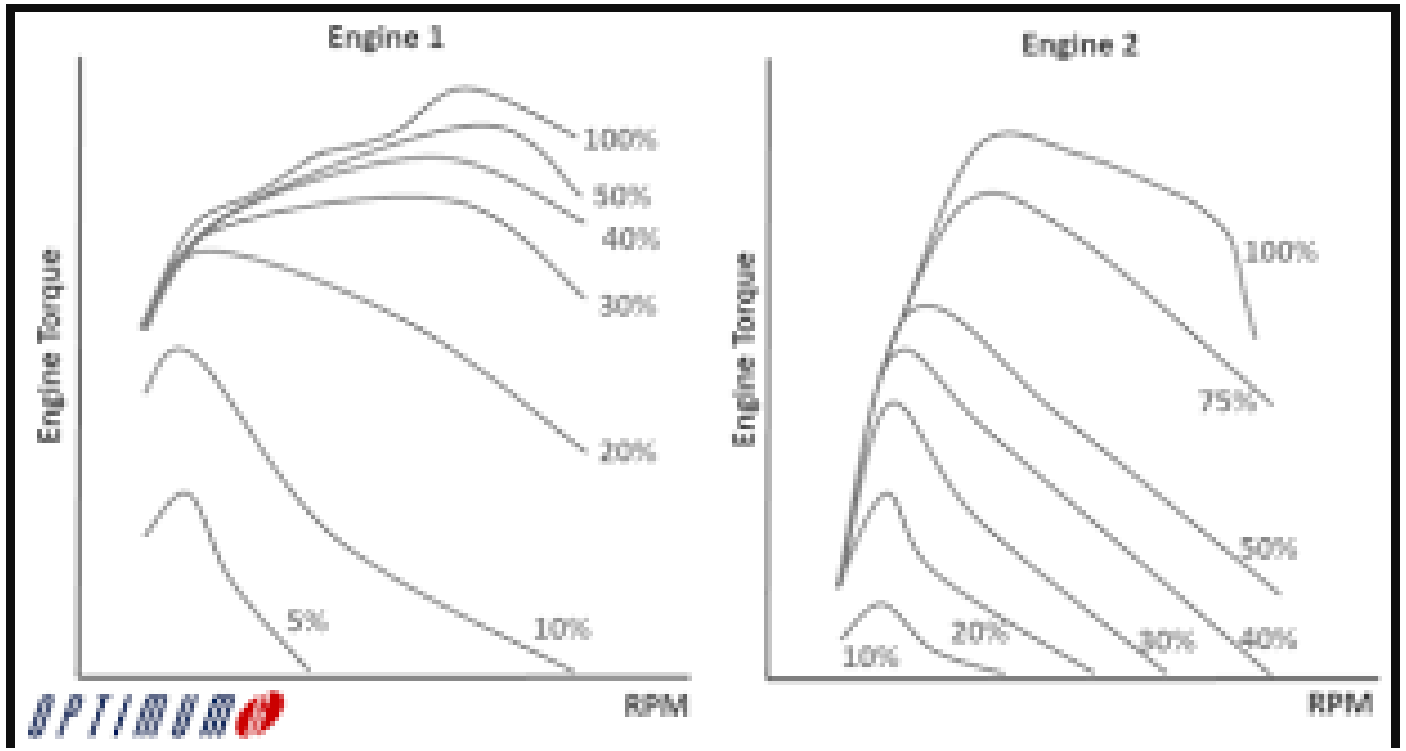
Drive Cycles and Torque





- Curves represent 100% throttle opening
- Curves vary based on throttle opening as well (Gasoline)

Drive Cycles and Torque



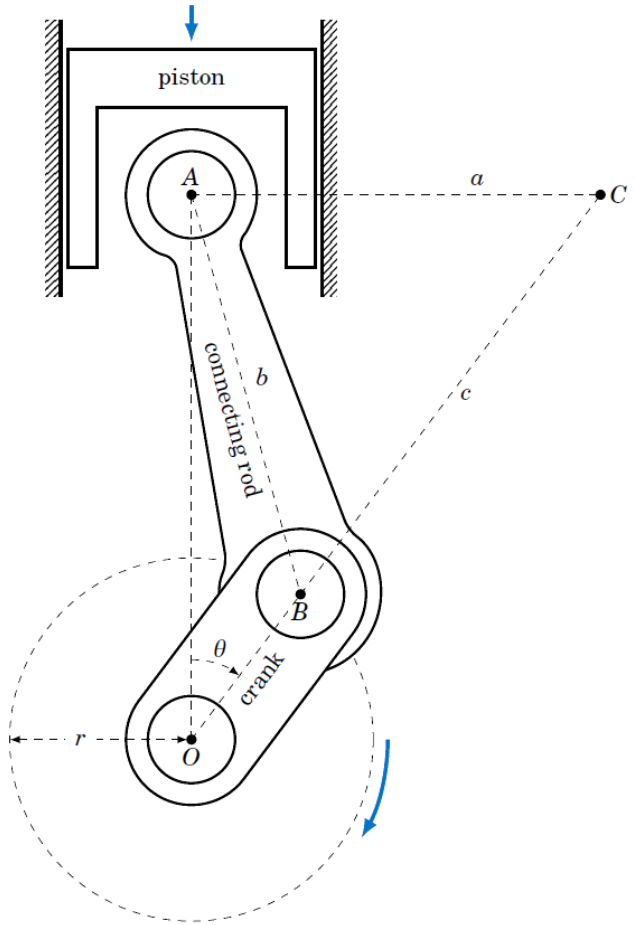
- Lower throttle openings – Lower peak torque
- Lower throttle openings also produce their peak torques at lower rpms

Torque and Emissions

Torque Development

- Torque at crank = Force on Con Rod* Stroke Length
- Force on Con Rod – Exerted because of pressure on piston
- Pressure on piston – Combustion Pressure
- Combustion pressure – Heat release and Volume

$$bmep = \frac{2\pi NT}{V_d}$$



Torque and Emissions

Torque and Emissions

- Higher torque output requires a higher BMEP inside the cylinder
- Usually higher BMEP means
  - More fuel – More heat energy – Rich AFR
  - More BMEP – More Temperature $P\alpha T$
  - Higher Torque at
    - Stoichiometric ratios – More NOX
    - Richer AFR – More HC and CO
- Torque delivery usually associated with higher emissions of one kind or the other

Torque and Emissions

Challenges

- How do we deliver torque without sacrificing emissions performance?
- Is there a safe / acceptable way of delivering torque?
- If we do have higher emissions, how do we control them?

Activity

Activity 1

- Select a vehicle of your choice, it can be a two / three or four wheeler
- Figure out what the classification of your vehicle is
- Find out the relevant drive cycle for your target vehicle
- Find out the emissions performance of the vehicle (if possible)

Torque and Emissions

Reference Books

- Internal Combustion Engine Fundamentals – John Heywood