

Main Components of IC Engines

A Design Thinking Framework Approach

Mechanical Engineering | Internal Combustion Engines

EMPATHIZE

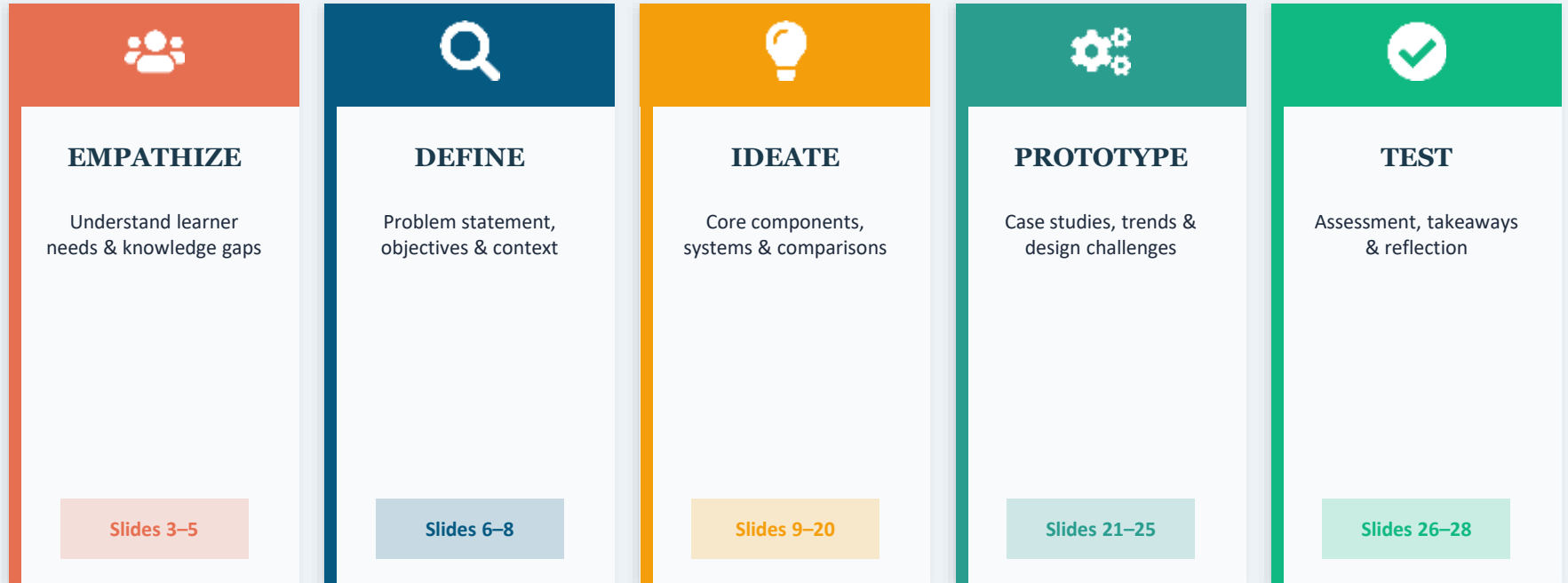
DEFINE

IDEATE

PROTOTYPE

TEST

Design Thinking Framework Overview



Who Are Our Learners?

- 2nd/3rd year Mechanical Engineering students
- Familiar with thermodynamics & basic mechanics
- Diverse backgrounds: urban, rural, varied lab exposure
- Goal: understand how engines convert fuel to motion
- Many lack hands-on engine disassembly experience

Empathy Map — Pain Points

"I can name engine parts but don't know how they interact."

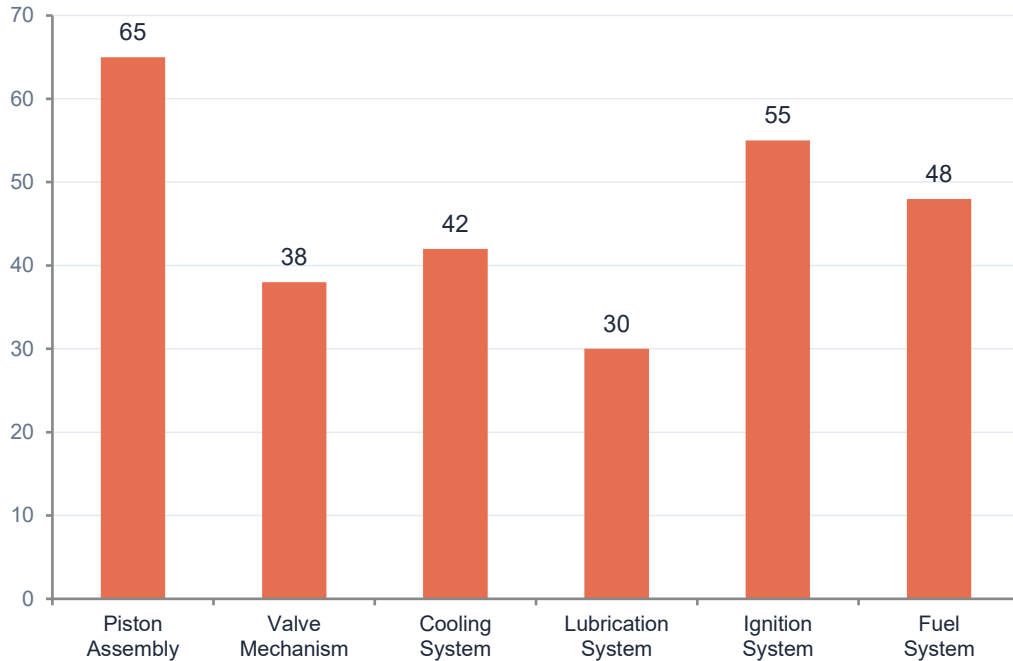
"Textbook diagrams feel abstract without real context."

"SI vs CI differences confuse me in practice."

"I wish I could see inside an actual running engine."

Needs Assessment Survey

PHASE 1



Key Insights

- Lubrication & valve mechanisms are least understood
- Piston assembly has highest confidence — good foundation
- Systems thinking (how parts interact) is the biggest gap
- Visual/hands-on learning strongly preferred

How Might We Statements

PHASE 1

1

How might we make engine internals visible and tangible?

Use cutaway models, animations, and AR overlays

2

How might we connect component function to overall performance?

Map each component to efficiency, power, and emissions

3

How might we bridge SI and CI engine confusion?

Side-by-side comparison tables with clear distinctions

4

How might we build systems thinking about engines?

Show component interactions through flow diagrams

5

How might we assess understanding beyond memorization?

Design challenges requiring component selection reasoning

Problem Statement & Learning Objectives

PHASE 2

Mechanical engineering students need a structured understanding of IC engine components and their interactions because fragmented knowledge prevents them from diagnosing, designing, and optimizing real-world engine systems.

1 Identify Components

Name & locate major stationary and moving parts

Remember

2 Explain Functions

Describe the role of each component in the engine cycle

Understand

3 Compare Engine Types

Differentiate SI vs CI engine components

Analyze

4 Analyze Interactions

Trace how subsystems (cooling, lubrication) support components

Analyze

5 Evaluate Materials

Justify material choices for key components

Evaluate

6 Design Solutions

Select components for a given engine specification

Create

What is an Internal Combustion Engine?

PHASE 2

An Internal Combustion Engine (ICE) is a heat engine in which the combustion of fuel occurs inside a working cylinder, directly converting chemical energy into mechanical work through the reciprocating motion of a piston.



Energy Conversion

Chemical → Thermal → Mechanical. Fuel combustion produces hot gases that push the piston.



Reciprocating Motion

Piston moves linearly; connecting rod and crankshaft convert this to rotary motion.



Controlled Combustion

Precise timing of intake, compression, power, and exhaust strokes governs efficiency.

Evolution of IC Engines — Historical Context

PHASE 2

1860

Lenoir's gas engine —
first commercial ICE

1893

Diesel patents
compression-ignition
engine

1970s

Emission regulations
drive component
refinement

1876

Otto 4-stroke cycle —
modern SI engine
basis

1920s

Mass production era
(Ford Model T)

2020s

Hybridization &
advanced engine
management

The Four-Stroke Cycle

PHASE 3

STROKE 1

INTAKE

Piston moves down, inlet valve opens. Fresh air-fuel mixture enters the cylinder.

STROKE 2

COMPRESSION

Both valves closed. Piston moves up, compressing the charge to high pressure and temperature.

STROKE 3

POWER

Combustion occurs (spark or compression). Hot gases expand, pushing the piston down — the working stroke.

STROKE 4

EXHAUST

Exhaust valve opens. Piston moves up, expelling burnt gases out through the exhaust port.

Each stroke corresponds to 180° of crankshaft rotation — one full cycle = 720° = 2 crankshaft revolutions.

Classification of IC Engines

PHASE 3

Ignition

Spark Ignition (SI) — Petrol | Compression Ignition (CI) — Diesel

Cycle Type

Two-Stroke | Four-Stroke

Fuel

Petrol | Diesel | Gas (CNG/LPG) | Dual-fuel

Cooling

Air-Cooled | Water-Cooled (Liquid)

Cylinder Arrangement

Inline | V-type | Flat (Boxer) | Radial

No. of Cylinders

Single | Multi-cylinder (2, 3, 4, 6, 8, 12)

SI vs CI Engine Comparison

PHASE 3

Parameter	SI Engine (Petrol)	CI Engine (Diesel)
Ignition Method	Spark plug	Compression heat
Fuel	Petrol (Gasoline)	Diesel
Compression Ratio	6:1 – 12:1	14:1 – 25:1
Fuel System	Carburettor / MPFI	Fuel injection pump
Thermal Efficiency	25–35%	35–45%
Speed Range	High RPM	Low–medium RPM
Weight	Lighter	Heavier (robust build)
Typical Use	Cars, bikes, small engines	Trucks, buses, marine, generators

Cylinder Block

Houses cylinders, coolant passages, and crankcase. Provides structural rigidity for the entire engine.

Material: Cast iron or aluminium alloy

Cylinder Head

Seals the top of cylinders. Contains combustion chamber, valve ports, spark plug / injector bores.

Material: Aluminium alloy (for heat dissipation)

Cylinder Liner

Wear-resistant sleeve inside the cylinder bore. Can be wet (coolant contact) or dry.

Material: Centrifugally cast iron, hardened steel

Head Gasket

Seals the joint between block and head. Prevents leakage of combustion gases, coolant, and oil.

Material: Multi-layer steel (MLS) or composite

Moving Components — Piston Assembly & Crankshaft

PHASE 3

Piston

Receives gas pressure and transmits force to the connecting rod. Must withstand extreme heat and pressure.

Aluminium alloy (light, good thermal conductivity)

Piston Rings

Seal combustion gases (compression rings) and control oil film on cylinder wall (oil ring).

Cast iron, chrome-plated steel

Connecting Rod

Converts reciprocating piston motion to rotary crankshaft motion. Transmits both tensile and compressive loads.

Forged steel, I-beam cross-section

Crankshaft

Converts reciprocating motion to continuous rotary motion. Drives all engine accessories via front pulley.

Forged alloy steel, counterweighted

Flywheel

Stores rotational energy during power stroke. Provides inertia for smooth rotation through non-power strokes.

Cast iron (heavy for inertia)

Gudgeon Pin

Pivots the connecting rod on the piston. Allows angular motion while bearing combustion loads.

Case-hardened alloy steel

Inlet Valve

Opens to admit fresh charge; larger diameter than exhaust valve for better volumetric efficiency.

Exhaust Valve

Opens to expel burnt gases; made of heat-resistant alloy (Nimonic, Inconel) due to extreme temperatures.

Valve Spring

Returns the valve to its closed position. Dual springs prevent surge at high RPM.

Camshaft

Rotates at half the crankshaft speed (4-stroke). Cam profile determines valve lift, timing, and duration.

Push Rod & Rocker

Transfers cam motion to the valve in OHV layouts. DOHC engines eliminate pushrods for higher RPM capability.

Timing Chain/Belt

Synchronizes camshaft to crankshaft. Failure causes catastrophic valve-piston collision in interference engines.

Valve Train Configurations

Configuration	OHV (Pushrod)	SOHC	DOHC
Cam Location	In block	In head (one)	In head (two)
Valves/Cylinder	2	2–3	4 (typical)
Complexity	Simple	Moderate	Complex
RPM Capability	Low–Medium	Medium–High	High
Typical Use	Trucks, V8 muscle cars	Economy sedans	Sports cars, modern engines
Advantage	Compact, cheap	Good compromise	Best breathing, most power

Cooling System Components

PHASE 3

Radiator

Heat exchanger that dissipates coolant heat to the atmosphere via airflow

Water Pump

Circulates coolant through engine and radiator; belt-driven from crankshaft

Thermostat

Temperature-controlled valve that regulates coolant flow; remains closed until optimal temp

Cooling Fan

Pulls air through radiator at low speeds or idle; electric or viscous clutch type

Water Jacket

Passages cast into block and head through which coolant flows around cylinders

Coolant

50/50 mix of ethylene glycol & water — prevents freezing, raises boiling point, inhibits corrosion

Lubrication System Components

PHASE 3

Oil Sump / Pan

Reservoir at the bottom of the engine storing lubricating oil

Oil Pump

Gear or rotor type; pressurizes oil and circulates it through the engine

Oil Filter

Removes contaminants and metal particles from circulating oil

Oil Galleries

Network of drilled passages distributing oil to crankshaft bearings, camshaft, and valve train

Pressure Relief Valve

Limits maximum oil pressure to prevent seal and gasket damage

Oil Cooler

Heat exchanger (water-to-oil or air-to-oil) that maintains oil viscosity at high loads

Fuel System

- Fuel Tank — stores fuel safely
- Fuel Pump — mechanical or electric, supplies fuel at required pressure
- Fuel Filter — removes impurities before injection
- Carburettor (SI) — mixes fuel with air in correct ratio
- Fuel Injector — atomizes and sprays fuel precisely (MPFI/GDI/CRDI)
- Fuel Rail — distributes pressurized fuel to all injectors

Ignition System (SI Engines)

- Battery — provides electrical energy
- Ignition Coil — steps up 12V to 25,000–40,000V
- Distributor — routes HT current to correct cylinder (older systems)
- Spark Plug — produces spark across electrode gap to ignite mixture
- ECU — electronic control unit manages ignition timing in modern engines
- Crank Position Sensor — provides RPM/position data to ECU

Complete Component Reference Table

PHASE 3

Component	Primary Function	Typical Material
Cylinder Block	Houses cylinders; structural base	Cast iron / Al alloy
Cylinder Head	Seals combustion chamber; holds valves	Aluminium alloy
Piston	Transmits gas force to con rod	Al alloy (forged/cast)
Connecting Rod	Links piston to crankshaft	Forged steel
Crankshaft	Converts reciprocating → rotary motion	Forged alloy steel
Camshaft	Operates valves via cam lobes	Chilled cast iron / steel
Valves (In/Ex)	Control gas flow in & out	Alloy steel / Nimonic
Spark Plug / Injector	Initiates combustion	Ceramic insulator / steel
Flywheel	Stores inertia; smooths rotation	Cast iron
Gaskets & Seals	Prevent fluid/gas leakage	MLS / rubber / cork

Bore

$$D \text{ (mm)}$$

Internal diameter of the cylinder

Stroke

$$L \text{ (mm)}$$

Distance the piston travels from TDC to BDC

Compression Ratio

$$r = V_1/V_2$$

Total volume ÷ Clearance volume

Displacement

$$V_s = \pi/4 \times D^2 \times L$$

Volume swept by the piston in one stroke

Brake Power

$$BP = 2\pi NT / 60$$

Useful power output at the crankshaft

Thermal Efficiency

$$\eta = BP / (\dot{m}f \times CV)$$

Ratio of useful work to fuel energy input

Technical Specifications

- Type: 4-cylinder inline, SI, DOHC 16V
- Displacement: 1,798 cc
- Compression Ratio: 13:1 (Atkinson cycle)
- Power: 98 hp @ 5,200 rpm
- Thermal Efficiency: ~41% (world-leading for SI)
- Cooling: Water-cooled with electric water pump
- Notable: Uses Atkinson cycle for maximum efficiency

DT Analysis

Empathize

Rising fuel costs; drivers need maximum fuel economy

Define

Achieve >40% thermal efficiency in a mass-market SI engine

Ideate

Atkinson cycle, high CR, EGR, electric water pump

Prototype

2ZR-FXE with cooled EGR and variable valve timing

Test

41% efficiency achieved; 50+ mpg in real-world driving

Case Study 2 — Cummins ISX15 Diesel Engine

PHASE 4

15L

Displacement

600hp

Max Power

2050

Nm Torque

46%

Peak Efficiency

Key Engineering Decisions

- Cast-iron block for extreme duty cycle durability — aluminium not viable at these loads
- Common-rail direct injection (CRDI) at 2,400 bar for precise fuel atomization
- Variable geometry turbocharger (VGT) optimizes boost across the entire RPM range
- Aftertreatment: DPF + SCR + DEF reduces NOx and PM to meet EPA standards

Future Trends in IC Engine Components

PHASE 4

Opposed-Piston Engines

No cylinder head; two pistons per cylinder.
Achatas Power targets 50%+ efficiency.

Variable Compression

Infiniti VC-Turbo varies CR from 8:1 to 14:1
dynamically for power vs efficiency.

HCCI / SPCCI

Homogeneous Charge Compression Ignition
blends SI & CI advantages. Mazda Skyactiv-X.

Additive Manufacturing

3D-printed metal components enable optimized
cooling channels and weight reduction.

E-Turbocharging

Electrically assisted turbos eliminate lag;
integrated with 48V mild-hybrid systems.

Hydrogen ICE

Direct injection of H₂ into conventional engines.
Near-zero CO₂; Toyota and BMW investing.

Challenge: Design the component specifications for a 1.5L turbocharged 4-cylinder engine optimized for a small SUV application. Select components, materials, and configurations to balance power, efficiency, and emission compliance.

1

Determine Parameters

Calculate bore, stroke, CR for 1.5L with target 150 hp

2

Select Components

Choose block material, valve train config, cooling type, fuel system

3

Justify Choices

Explain trade-offs: weight vs strength, cost vs performance

4

Present & Peer Review

5-min pitch; class votes on best balanced design (DT Test phase)

Reference Data for Design Challenge

PHASE 4

Parameter	Typical Range	Notes
Bore (small turbo)	70 – 85 mm	Smaller bore = better combustion
Stroke	80 – 100 mm	Long stroke = more torque
Compression Ratio (turbo SI)	9.5:1 – 11:1	Limited by knock
Block Material	Al alloy or Cast iron	Al saves 40% weight
Valve Config	DOHC 16V recommended	Best VE at high RPM
Cooling	Liquid (pressurized)	Required for turbo application
Fuel System	GDI or port + direct	GDI improves turbo efficiency
Target BSFC	230 – 260 g/kWh	Lower = more efficient

Sources: SAE International, Heywood (2018) Internal Combustion Engine Fundamentals, OEM published data.

Component Identification Quiz

Label all major parts on a cutaway engine diagram. Timed (10 min).

LO1

Function Matching Exercise

Match 15 components to their functions and justify one material choice.

LO2, LO5

SI vs CI Comparison Essay

Write a structured comparison of component differences for both engine types.

LO3

Design Challenge Presentation Reflection Prompts

Present your 1.5L turbo engine design with component justifications.

LO4, LO6

- Which component surprised you most in its complexity?
- How does understanding components change how you see everyday vehicles?

Key Takeaways

- 1 IC engines convert chemical energy to mechanical work through controlled combustion in a cylinder.
- 2 Stationary components (block, head, liner) provide structure; moving components (piston, con rod, crankshaft) convert motion.
- 3 The valve mechanism precisely controls gas exchange — its configuration directly affects power and efficiency.
- 4 Supporting systems (cooling, lubrication, fuel, ignition) are essential for reliable engine operation.
- 5 Material selection involves trade-offs between weight, strength, thermal properties, and cost.
- 6 Modern IC engines continue evolving through technologies like variable CR, HCCI, and hydrogen injection.

1. Heywood, J.B. (2018). Internal Combustion Engine Fundamentals, 2nd Ed. McGraw-Hill.
2. Pulkrabek, W. (2014). Engineering Fundamentals of the Internal Combustion Engine, 2nd Ed. Pearson.
3. Stone, R. (2012). Introduction to Internal Combustion Engines, 4th Ed. Palgrave Macmillan.
4. Taylor, C.F. (1985). The Internal Combustion Engine in Theory and Practice, Vols 1 & 2. MIT Press.
5. SAE International — www.sae.org — Technical papers and standards.
6. NPTEL IC Engines Course — nptel.ac.in — Free video lectures (IIT faculty).

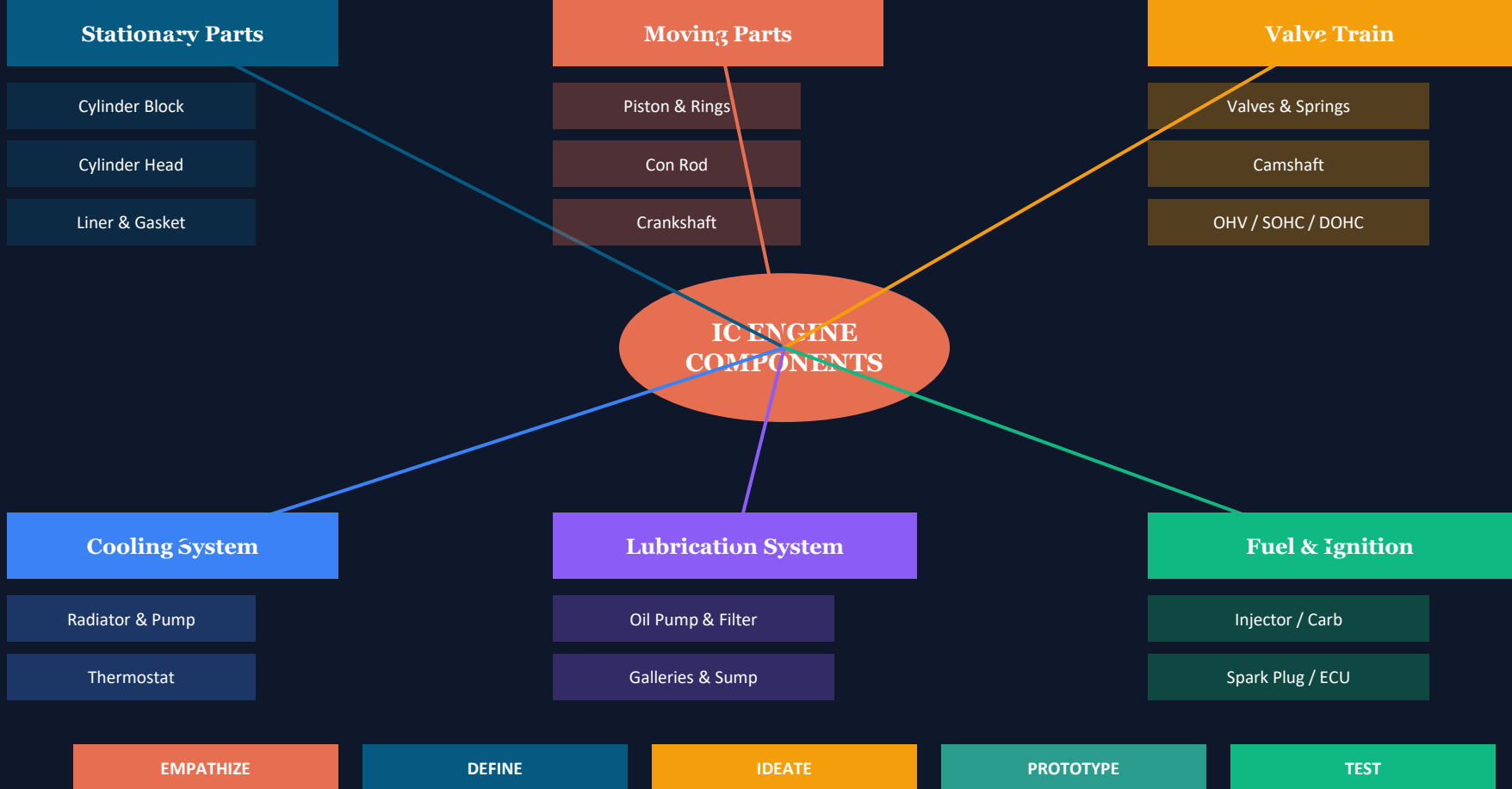
Online Resources

- Animagraffs — 3D engine animations: animagraffs.com
- Engineering Explained (YouTube) — IC engine component deep dives
- EPA Emission Standards Database — epa.gov/emission-standards-reference-guide

Appendix — Diagram Descriptions & Data Sources

Slide	Visual Element	Description / Source
4	Bar Chart	Pre-assessment survey data (representative sample, N=120)
9	4-Stroke Cards	Based on Otto/Diesel cycle theory (Heywood Ch.2)
11	SI vs CI Table	Compiled from Pulkrabek Ch.1 and Stone Ch.3
21	Prius Engine Data	Toyota technical press release (2015)
22	Cummins ISX15 Data	Cummins product specification sheets
25	Reference Data	SAE papers and Heywood (2018) Chapter 13

Comprehensive Mind Map — IC Engine Components



Thank You

"Design Thinking is a human-centered approach to innovation that integrates the needs of people, the possibilities of technology, and the requirements for success." — Tim Brown, IDEO

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