Chapter 1: Introduction To Manufacturing

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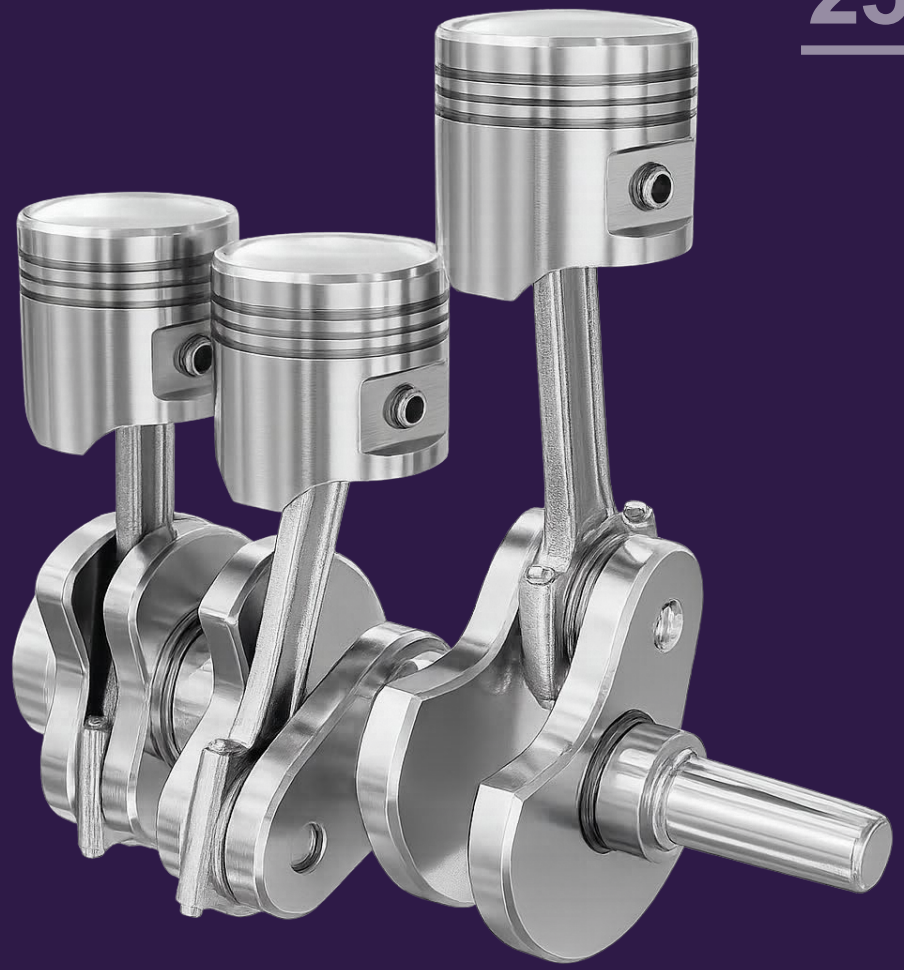

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2025

[1] https://www.siempelkamp.com/products-and-technologies/machine-and-plant-engineering/composites/?L=1

Outline

I. Manufacturing Families
   - A. Deformative Manufacturing
   - B. Subtractive Manufacturing
   - C. Additive Manufacturing
   - D. Assembly Operations

II. Manufacturing Evolution

III. Manufacturing and Materials
   - A. Engineering Materials
   - B. Composite Materials
   - C. Properties of Materials

Introduction

- Manufacturing is the cornerstone of a solid economy.
- Countries with innovation in manufacturing are capable of reducing the effects of economic crises leading to a faster return to economic stability.

[1]

$1 Manufacturing

$2.64 Economy

Facts About Manufacturing

The Top 18 Facts You Need to Know

1. Manufacturers contributed $2.90 trillion at the annual rate to the U.S. economy in Q1 2025.

Manufacturing value-added output decreased from $2.937 trillion at an annual rate in Q4 2024 to $2.899 trillion in Q1 2025. Value-added output rose in Q1 for durable goods (up from $1.562 trillion to $1.566 trillion) but fell for nondurable goods (down from $1.375 trillion to $1.333 trillion). Manufacturing accounted for 9.7% of value-added output in the U.S. economy in Q1. At the same time, real value-added output in the manufacturing sector remained the same at $2.407 trillion in Q1, as expressed in chained 2017 dollars. In Q1, real value-added output ticked up for durable goods (up from $1.283 trillion to $1.285 trillion) but edged down for nondurable goods (down from $1.122 trillion to $1.120 trillion). (Last Updated: 7/2/25; Source: Bureau of Economic Analysis)

2. For every $1.00 spent in manufacturing, there is a total impact of $2.64 to the overall economy.

Including indirect and induced impacts, for every $1.00 spent in manufacturing, there is a total impact of $2.64 to the overall U.S. economy. This figure represents one of the largest sectoral multipliers in the economy. In addition, for every one worker in manufacturing, 4.8 workers are added in the overall U.S. economy, including indirect and induced impacts, and for every $1.00 earned in direct labor income in the manufacturing sector, $3.92 in labor income earned is added to the overall U.S. economy. (Source: NAM calculations using 2023 IMPLAN data)

[1] Retrieved from https://www.nam.org/facts-about-manufacturing/

Introduction

- Manufacturing as a term no longer stands for its name origin.

- Nowadays, manufacturing is a term that incorporates a multitude of definitions that, even though they have different meanings; they refer to one of the aspects that leads a design to become a physical tangible product.

Manufacturing

=

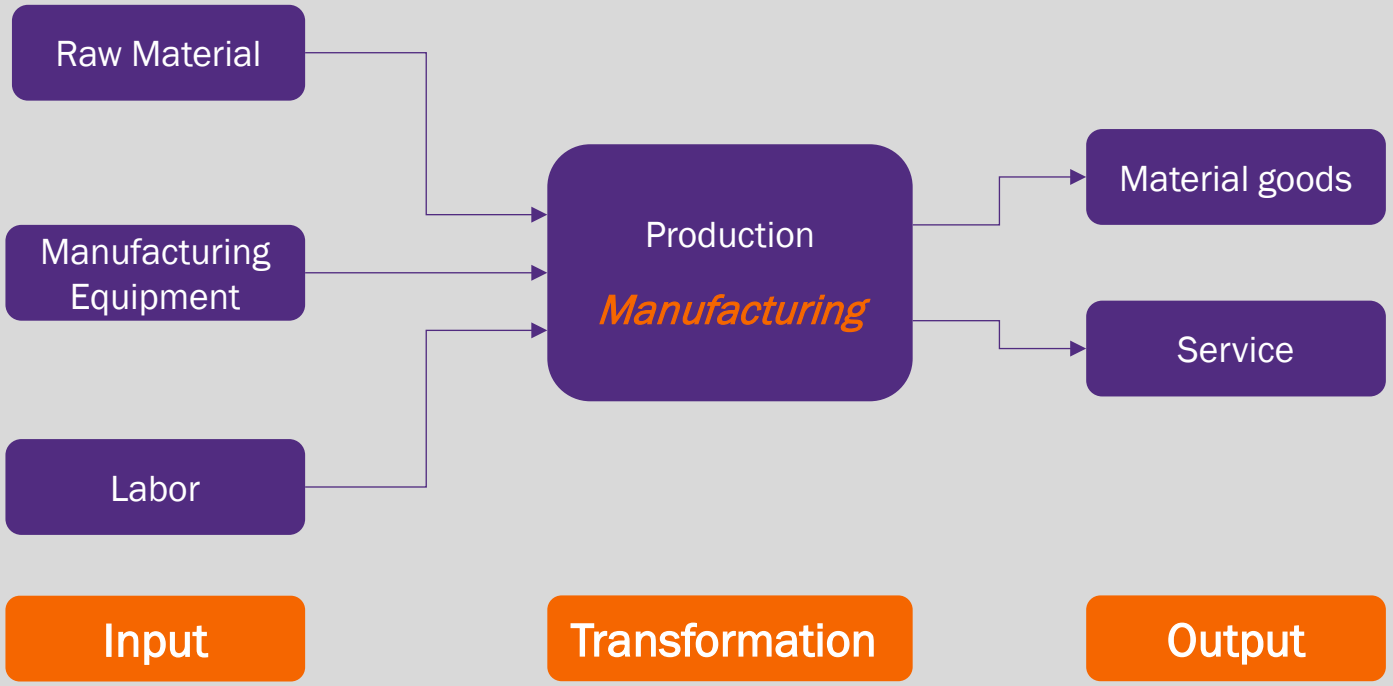
Manus + Factus

Hand Made

Introduction

- What is a manufacturing process?

Manufacturing as a transformation process



Introduction

- Multiple manufacturing processes are needed to produce a product in most cases

Raw material → Workpiece I → Workpiece II → Final product

t

- For example:

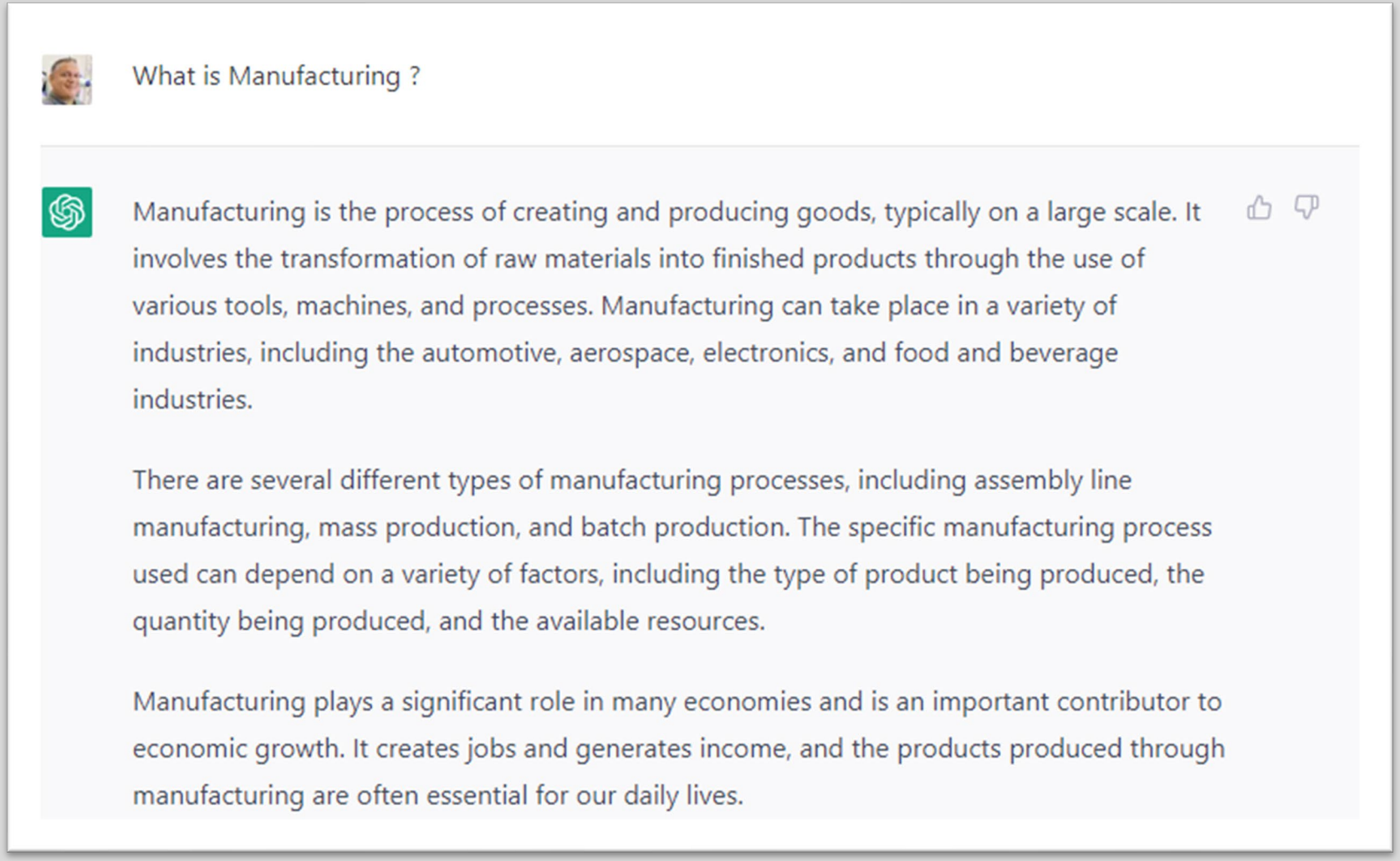
Manufacturing Program

Forging

Machining

Heat Treatment

Introduction



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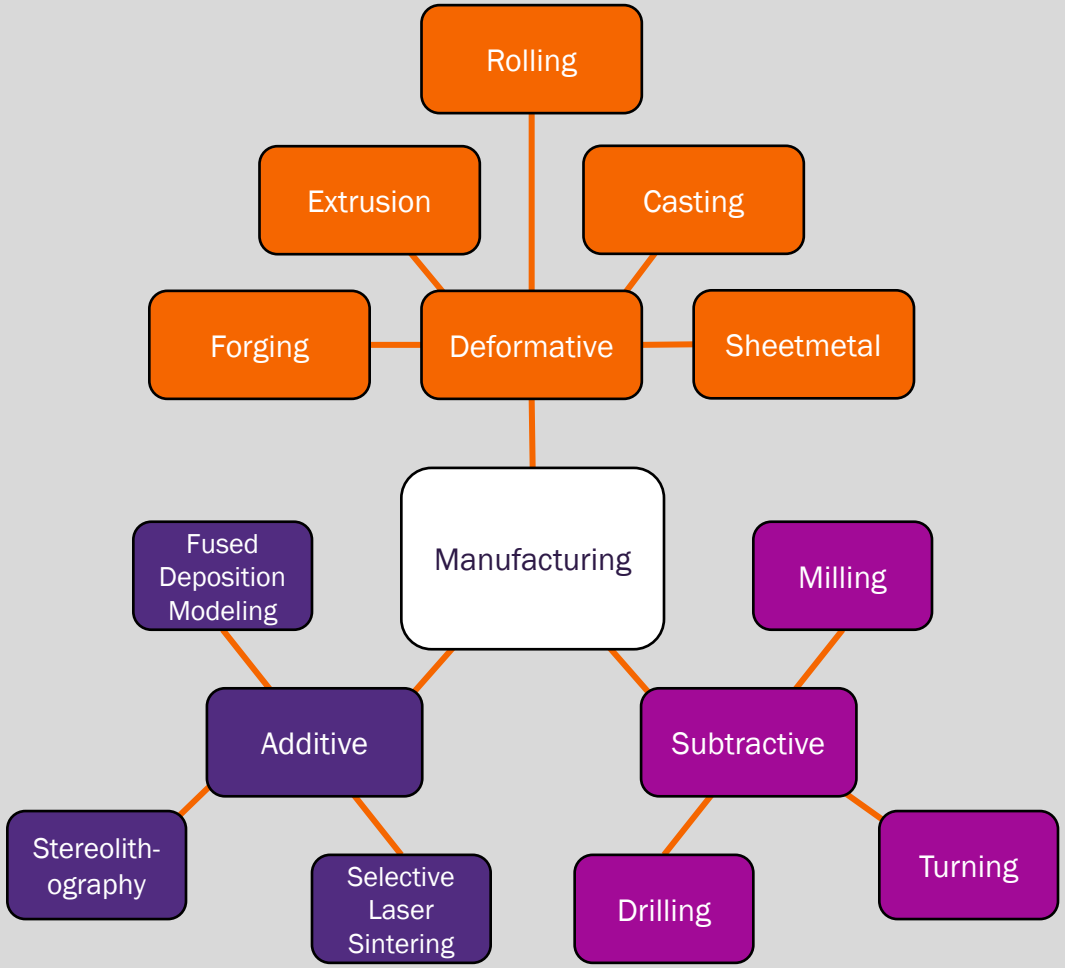
Manufacturing Families

Section I

I | Introduction

- A simple classification of manufacturing processes into three categories: Deformative, Subtractive and Additive.
- Polymers manufacturing is a subset of Deformative Manufacturing.
- Composites manufacturing is a subset of Additive Manufacturing.



I.A | Deformative Manufacturing

- Deformative manufacturing represents processes where we transform the material from Form A to Form B without the addition or subtraction of material.
- The fundamental concept is that the volume of materials remains unchanged throughout the process.
- Forging, Rolling, Casting are examples of Deformative Manufacturing that will be covered in chapter 2.

Chapter 2

Chapter 7

I.B | Subtractive Manufacturing

Chapter 3

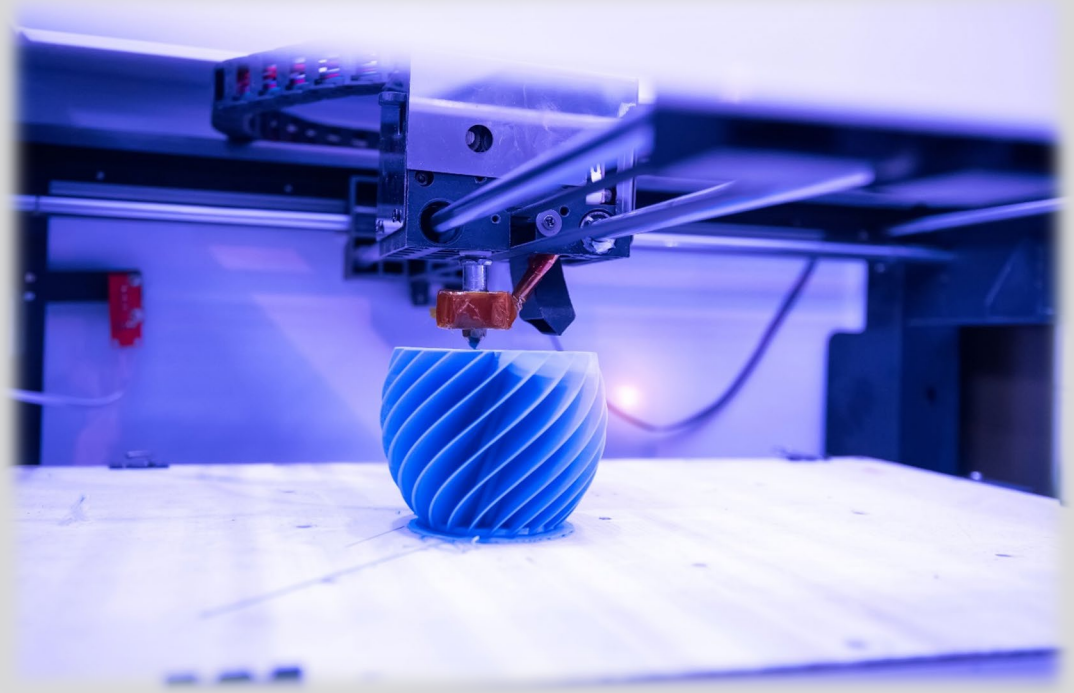
- Subtractive manufacturing represents processes where we transform the material from Form A to Form B by subtraction of material.
- The fundamental concept is that we reduce the volume of materials throughout the process.
- Milling, Drilling, Turning are examples of Subtractive Manufacturing and will be covered in detail in chapter 3.

I.C | Additive Manufacturing

- Additive manufacturing represents processes where we transform the material from Form A to Form B by addition of material.
- The fundamental concept is that we augment the volume of materials throughout the process.
- Composite manufacturing, 3d printing, SLS, SLA, FFF are examples of Additive Manufacturing.
- General additive manufacturing will be covered in chapter 4.
- Composites manufacturing will be covered in chapter 8.

Chapter 4

Chapter 8

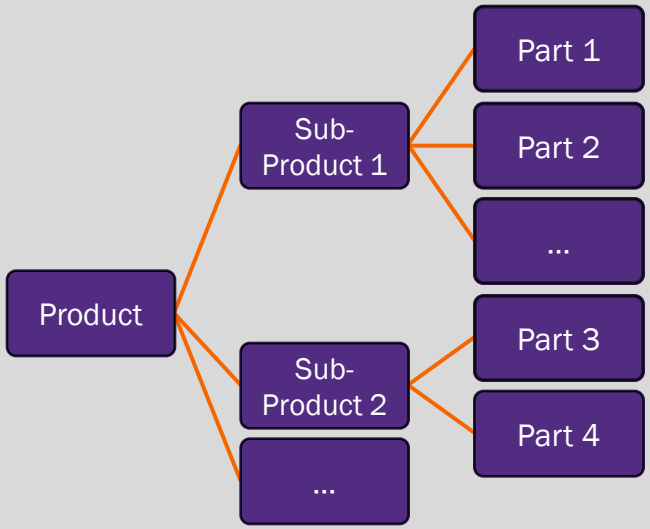


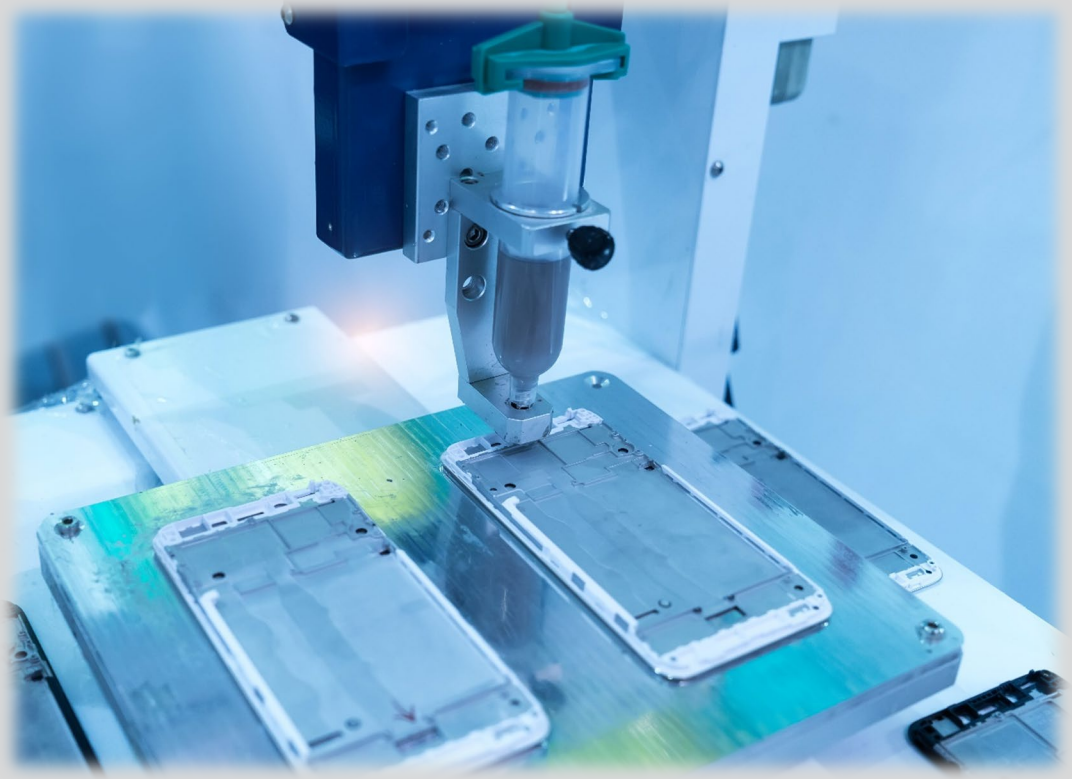
I.D | Assembly Operations

Chapter 5

- We obtain products (and sub-products) by performing assembly operations on individual parts.

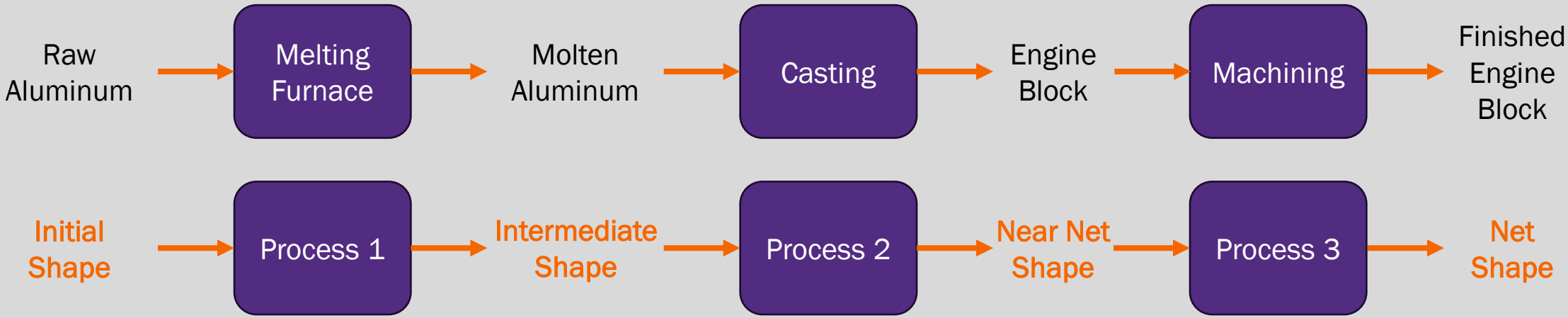
- Mechanical joining, welding and bonding are examples of Assembly Operations .



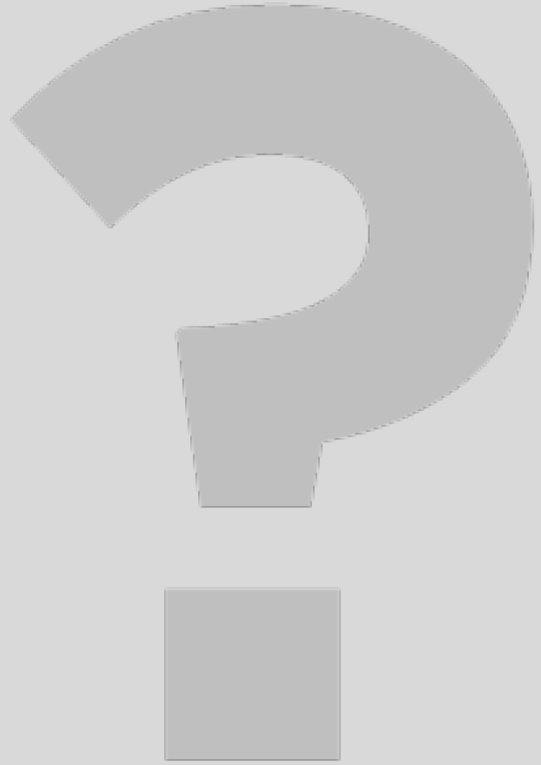


I | Introduction

- Manufacturing enable a progression of materials from an initial shape to a net shape.
- The different processes transforms the initial shape into multiple intermediate shapes.
- Only when the shape is ‘almost’ as intended we classify it as a near net shape.
- Final output is the net shape or the finished part.



Knowledge Check



Deformative Manufacturing is when we add material to obtain the final shape

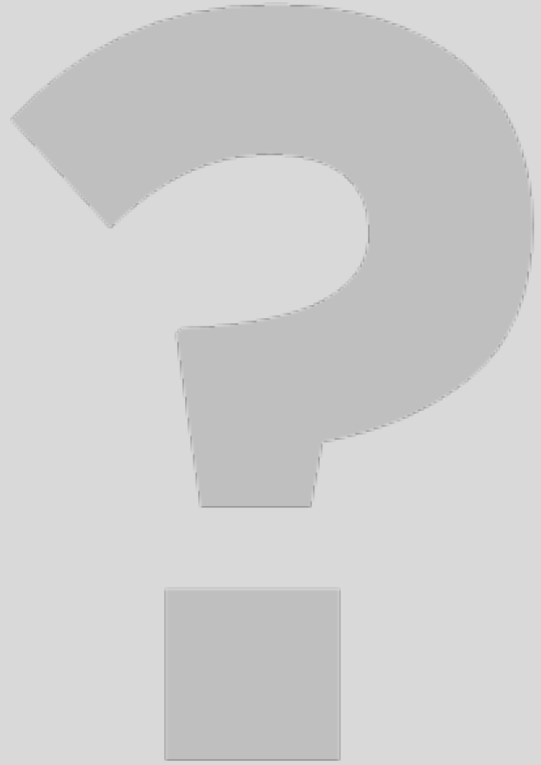
A. True
B. False

Knowledge Check

Deformative Manufacturing is when we add material to obtain the final shape

A. True
B. False

Knowledge Check



Drilling belongs to …

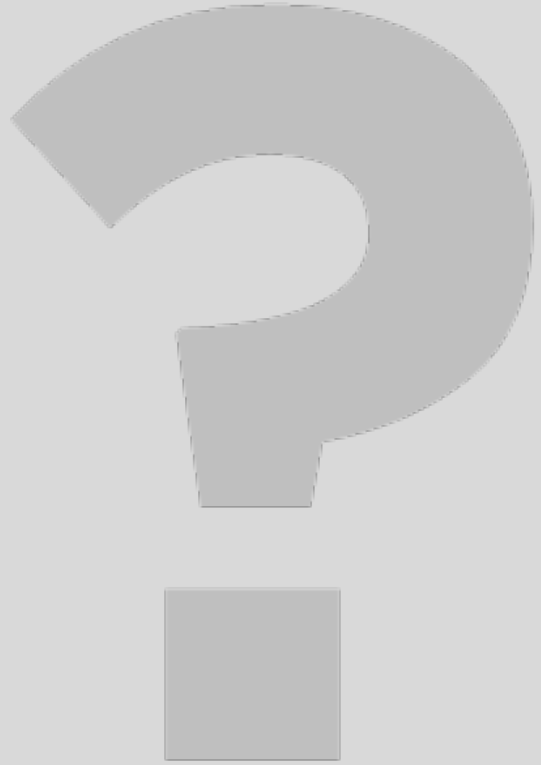
A. Additive Manufacturing
B. Subtractive Manufacturing
C. Deformative Manufacturing
D. Assembly Processes

Knowledge Check

Drilling belongs to …

A. Additive Manufacturing
B. **Subtractive Manufacturing**
C. Deformative Manufacturing
D. Assembly Processes

Knowledge Check



Additive Manufacturing Enables us to Obtain a …

A. Part
B. Product
C. All of the above

Knowledge Check

Additive Manufacturing Enables us to Obtain a …

A. Part
B. Product
C. All of the above

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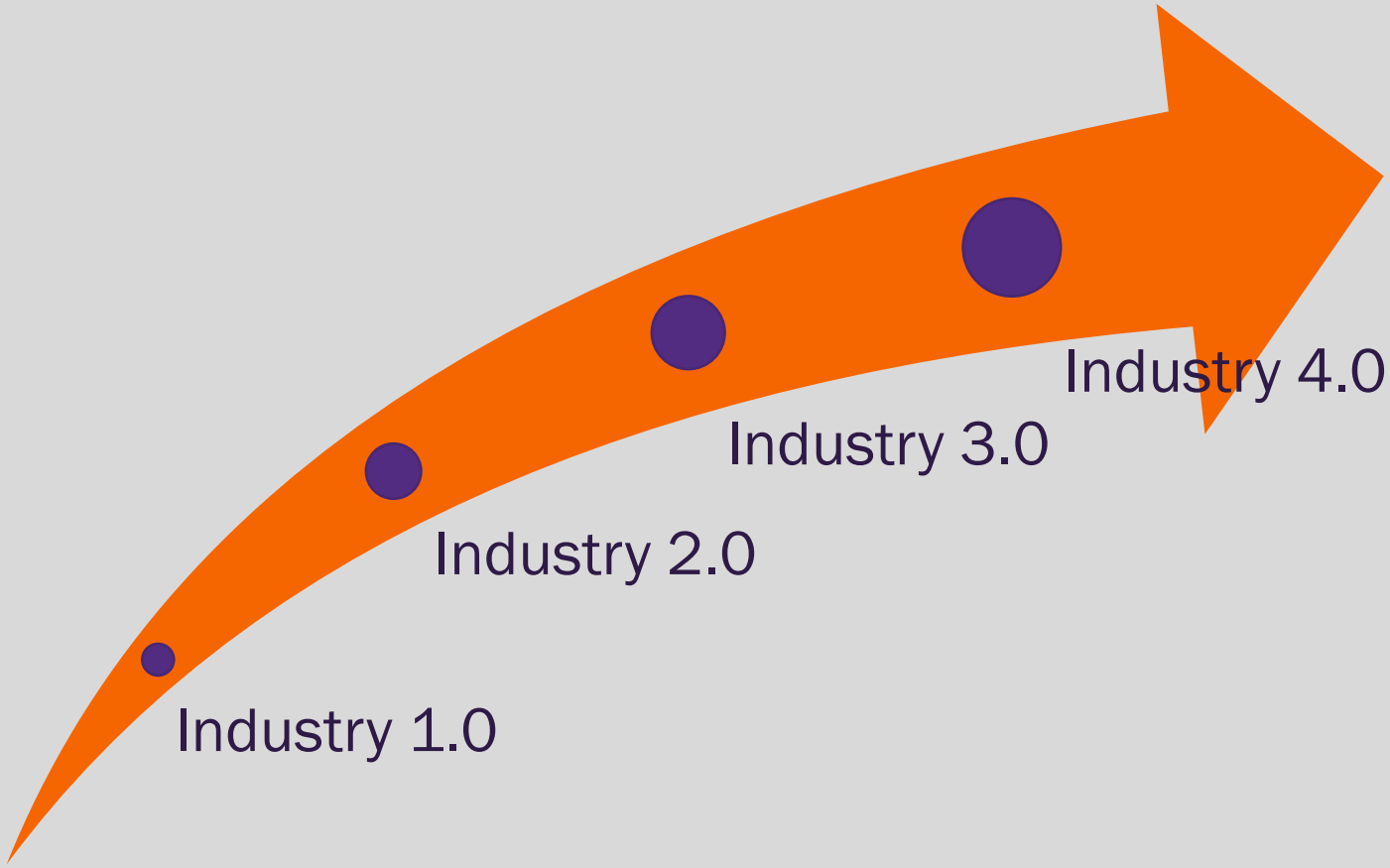
Manufacturing Evolution

Section II

II.A | Introduction

- Manufacturing continuously defines the world. Once, countries were able to win wars based on their ability to mass produce (Manufacturing 2.0) military equipment. In our present time, mass production is not as important as innovative manufacturing.



II.A1 | Industry 1.0

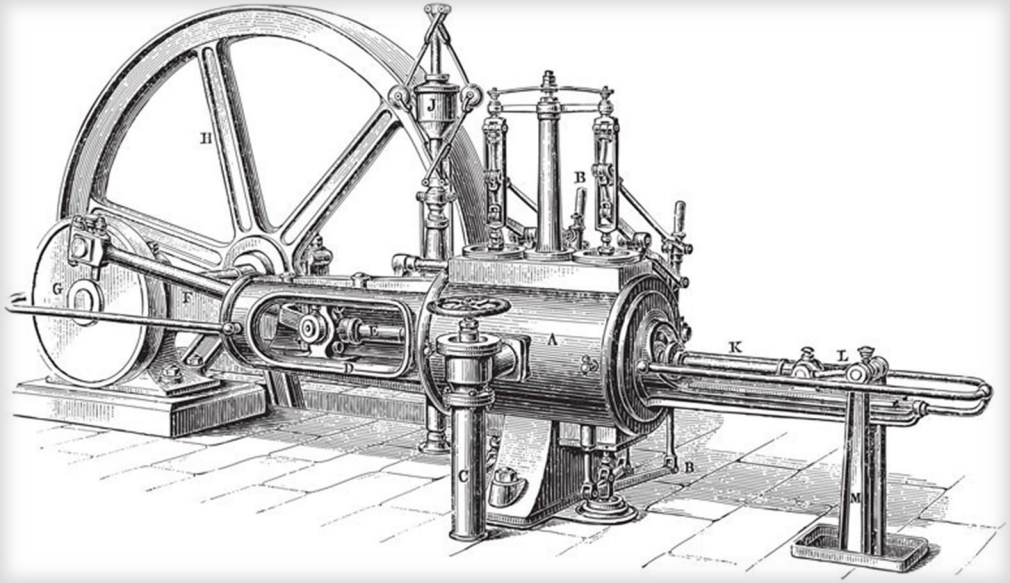
It stands for the mechanization of machinery in contrast to manual processing. The transformation of energy sources to produce goods highlights the first era in manufacturing evolution.

Industry 1.0

Industry 2.0

Industry 3.0

Industry 4.0



II.A2 | Industry 2.0

It stands for the mass production of products. This has been particularly encouraged by the arming race between countries. It led mass production of airplanes, transportation vehicles in parallel to civil goods.

Industry 1.0

Industry 2.0

Industry 3.0

Industry 4.0

II.A3 | Industry 3.0

It stands for the introduction of automation, robotics and computers into manufacturing. Computer Aided Manufacturing is one of the direct results of this era as well as the replacement of humans in hazardous working conditions by robotic arms.

Industry 1.0

Industry 2.0

Industry 3.0

Industry 4.0

II.A4 | Industry 4.0

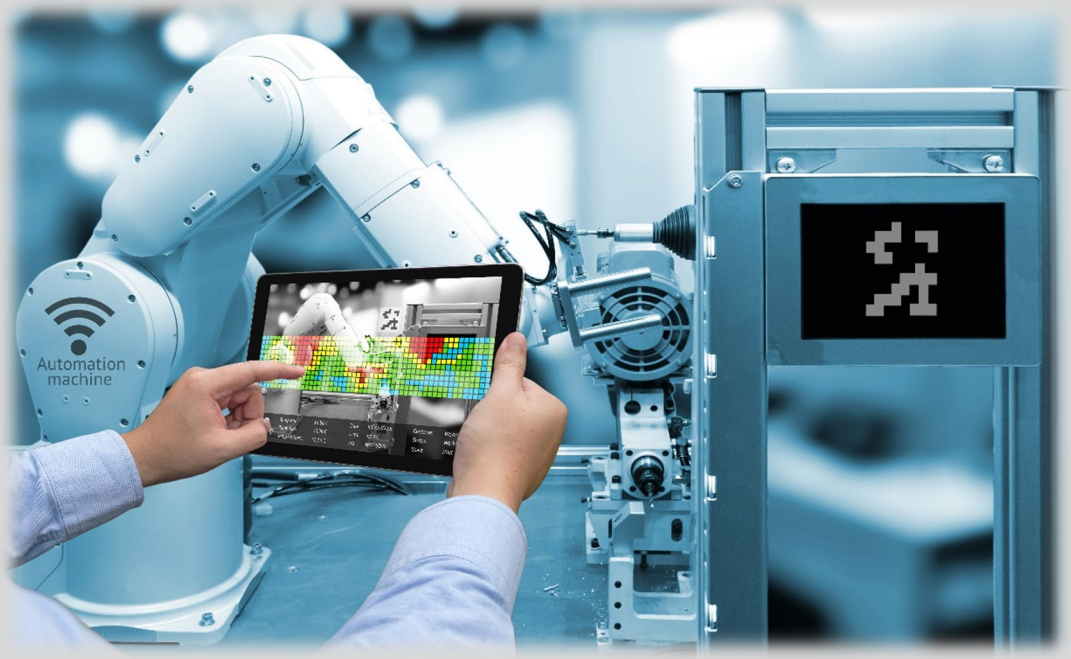
It stands for the integration of cyber-physical systems and the digital transformation of industries. The integration of cognitive manufacturing – smart systems that analyze and interprets data – is offering new insights and abilities for next generation industries.

Industry 1.0

Industry 2.0

Industry 3.0

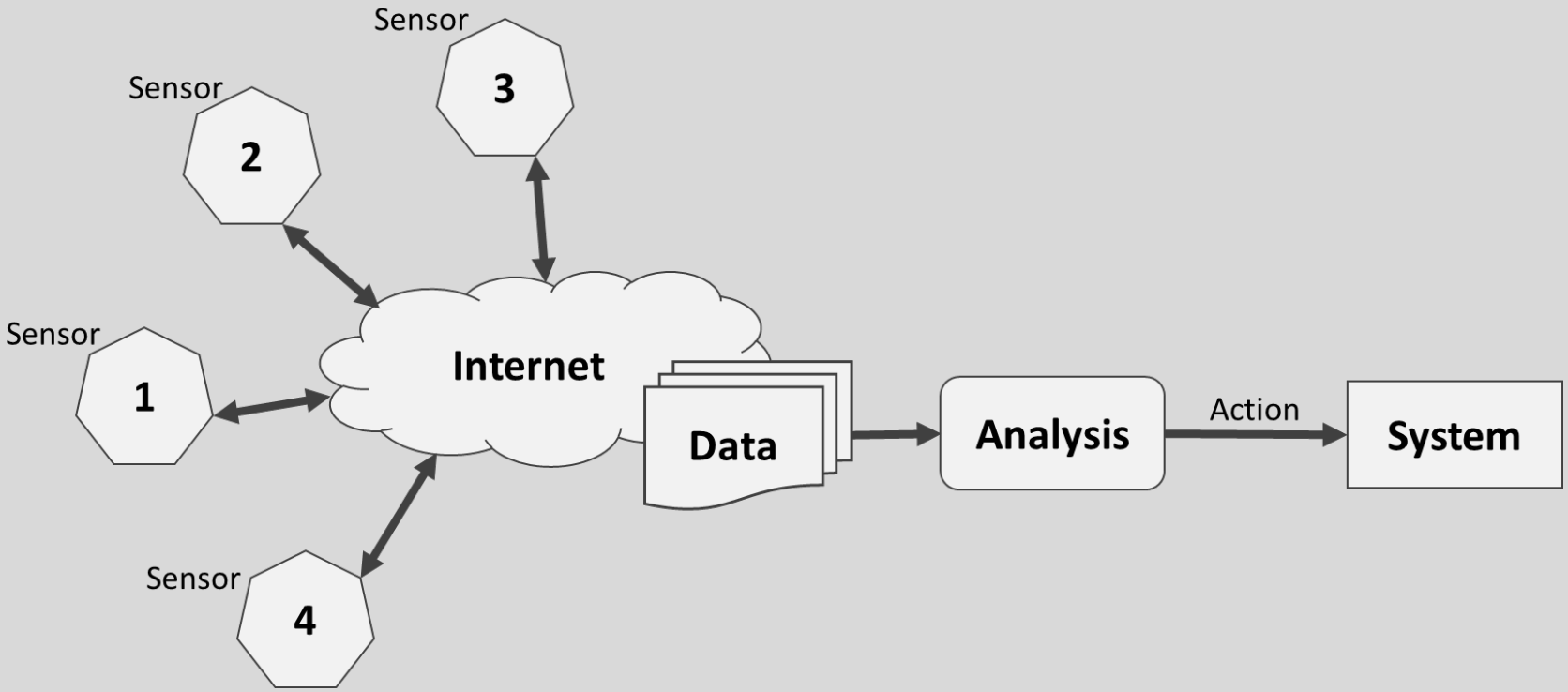
Industry 4.0



II.B1 | Internet of Things

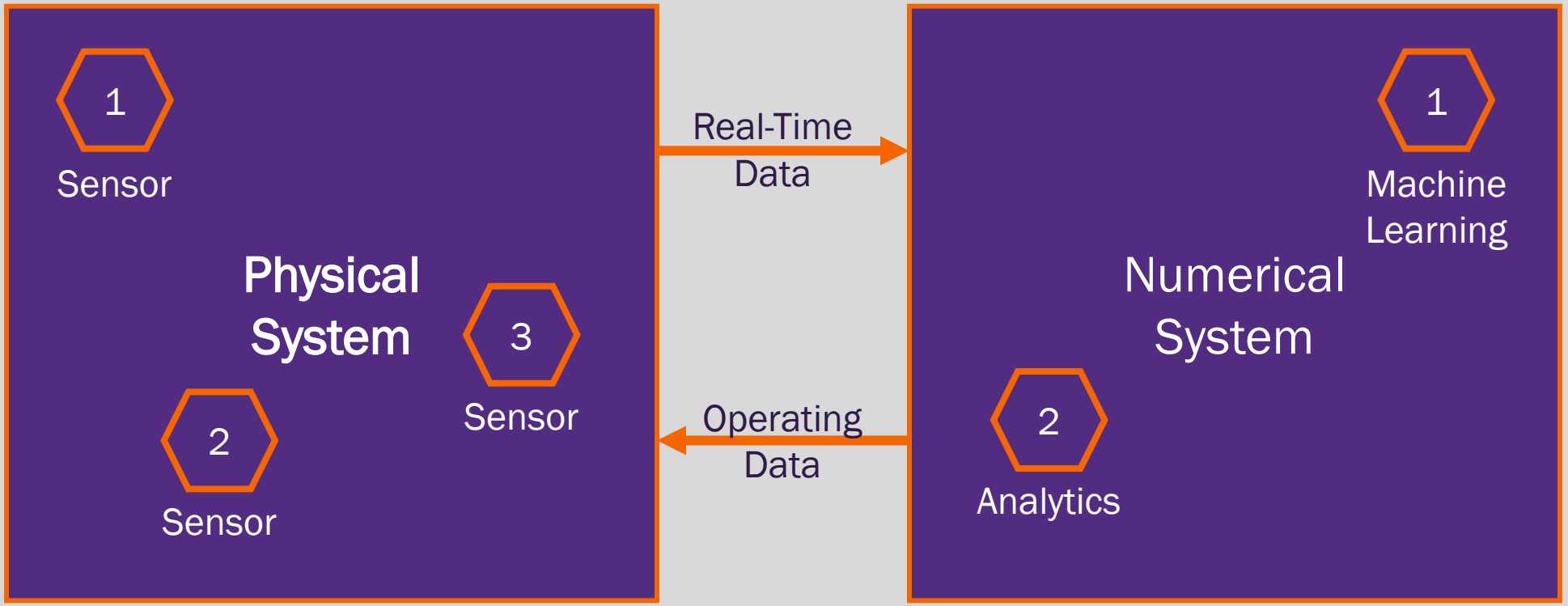
- Healthcare
- Transportation
- Industry

- The concept is dependent on:
  1) The capacity to collect the massive amount of data,
  2) The ability to analyze the data, and
  3) The ability to make accurate conclusions/propositions.

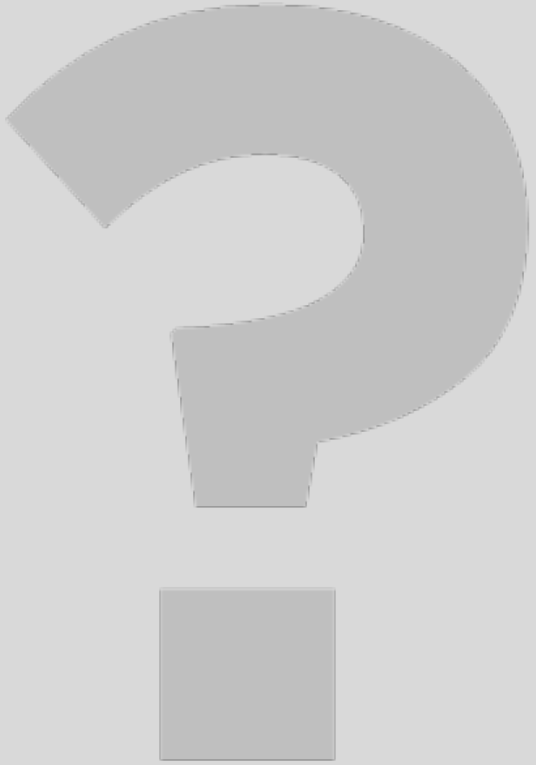


II.B2 | Digital Twin

- The digital twin is an exact numerical replicate of the physical system.
- The concept of the digital twin is to create an interactive blueprint of systems that enhance design, manufacturing and servicing operations.



Knowledge Check



Industry 2.0 is …

A. When machines were mechanized
B. When robots became part of the manufacturing industries
C. When mass production started

Knowledge Check

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B. When robots became part of the manufacturing industries
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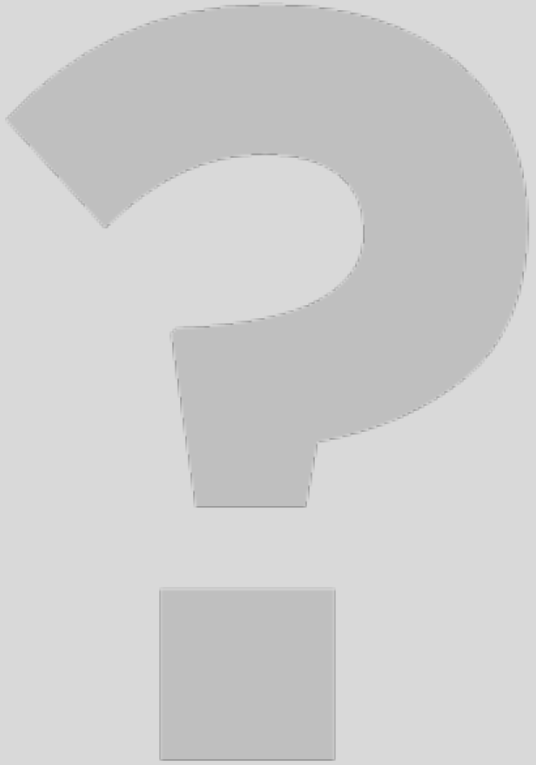
Knowledge Check



Internet of Things Does Not Include

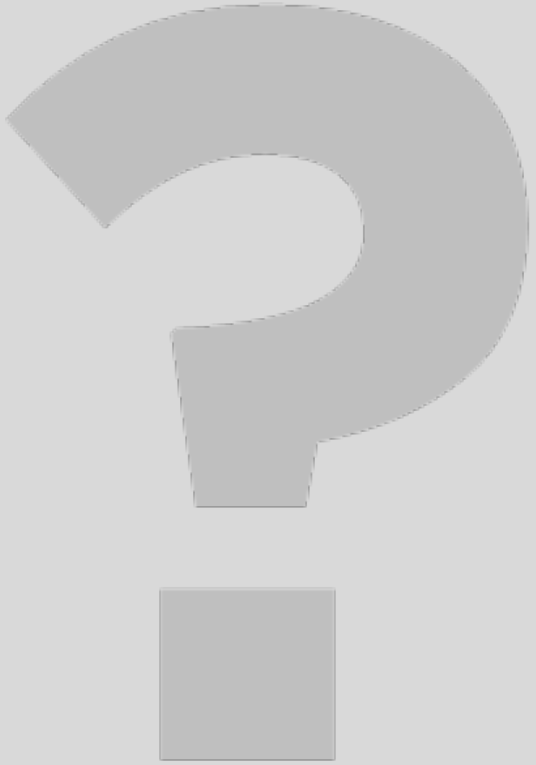
A. Collection of data
B. Analysis of data
C. Interpretation of data
D. Protection of data
E. None of the above

Knowledge Check

Internet of Things Does Not Include

A. Collection of data
B. Analysis of data
C. Interpretation of data
D. Protection of data
E. None of the above

Knowledge Check



Cyber-manufacturing enables perpetuation of manufacturing knowledge beyond retirement of skilled manufacturers

A. True
B. False

Knowledge Check

Cyber-manufacturing enables perpetuation of manufacturing knowledge beyond retirement of skilled manufacturers

A. True
B. False

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Manufacturing and Materials

Section III

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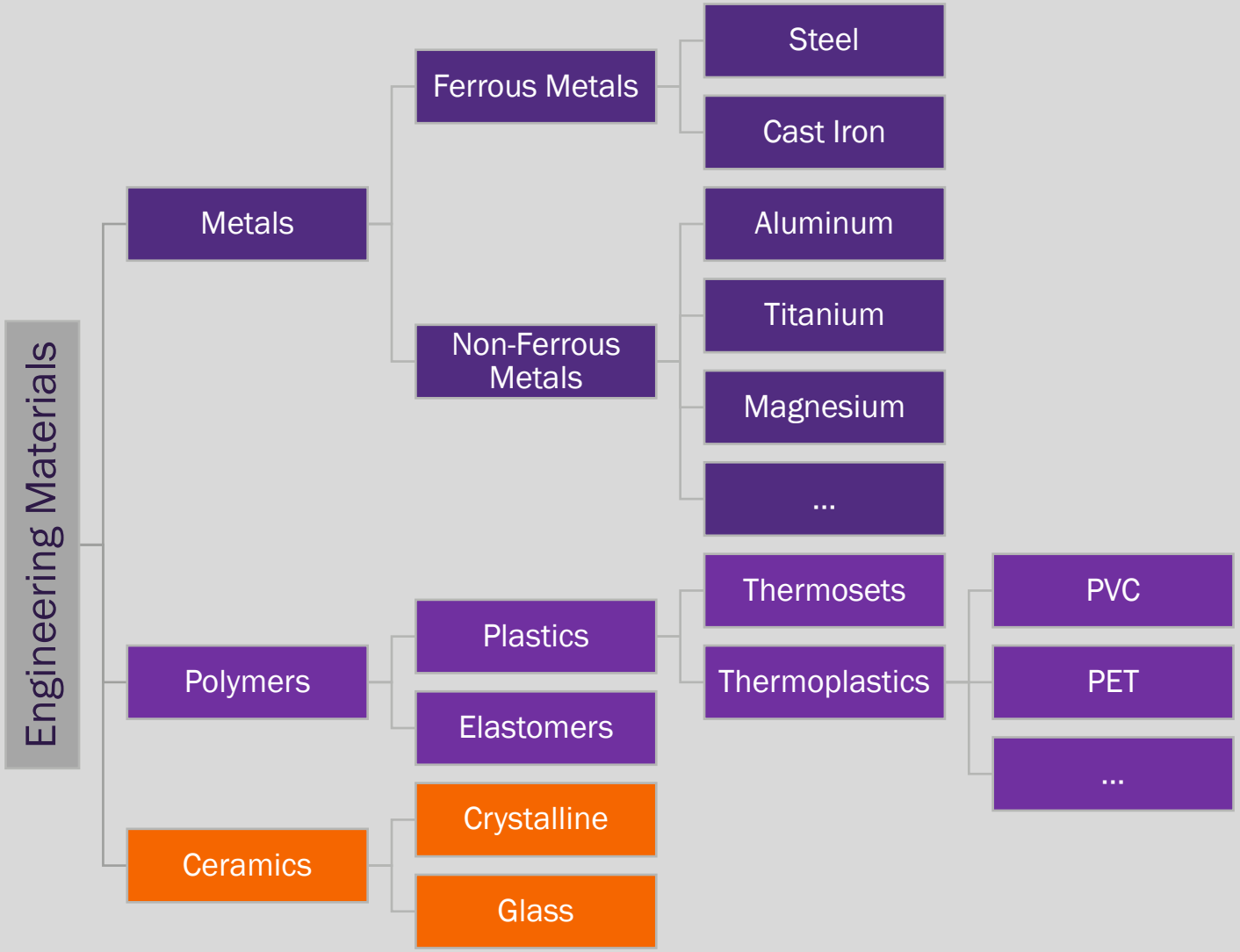
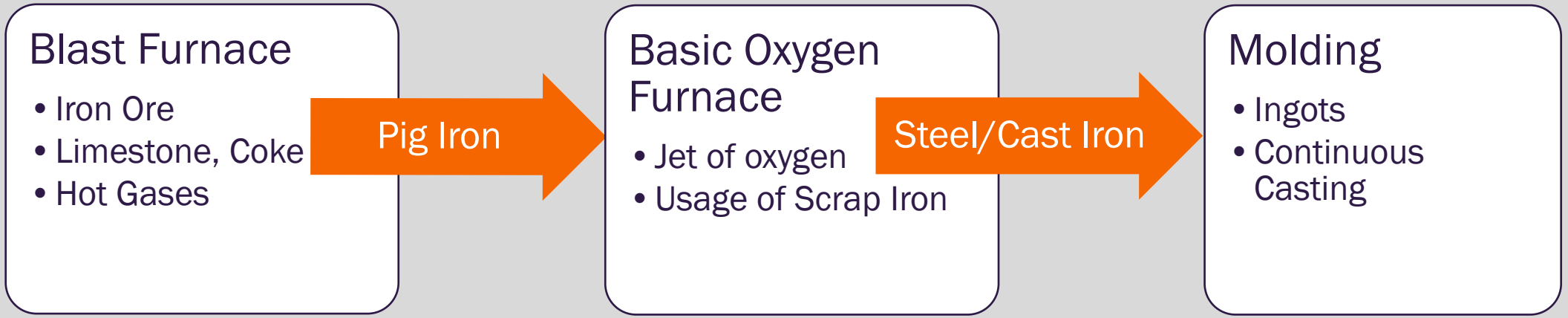
III.A | Classification



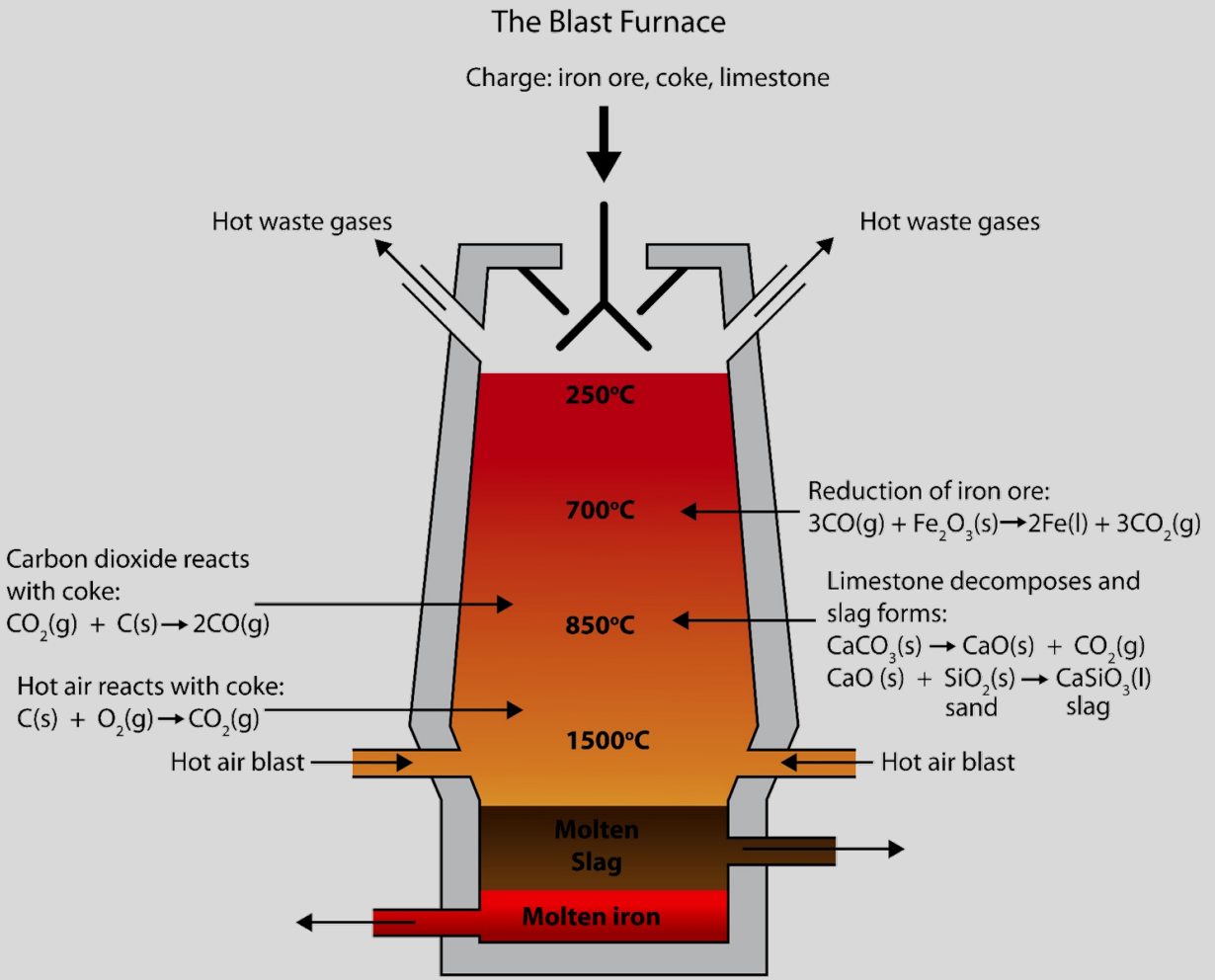
III.B1 | Metals

Name	Ore	T_m (°C)	Hardness (HB)	E (GPa)	Misc	Application
Iron	Fe_2O_3	1540	100-300	210	Most used metal	70-80% world usage
Aluminum	Al_2O_3	660	20-90	70	Most abundant metal; Competes iron due to weight	Cans, Containers, Automotive
Magnesium	$MgCl_2$	650	70	50	Lightest Metal	Aerospace, missiles, bicycles
Copper	$CuFeS_2$	1083	45-100	110	Oldest known metal	Electric Wires
Nickel	$(Fe,Ni)_9S_8$	1450	75	200	Iron copy cat	Alloying to avoid corrosion
Titanium	TiO_2	1668	200	116	Strength to weight ratio	Aircrafts, Jet engines
Zinc	ZnS	419	30	90	Suitable for Die Casting	Alloy with Copper (Brass)
Lead	PbS	327	4	21	Heavy metal	Plumbing, x-ray shields
Tin	SnO_2	232	50-440	42	Suitable for solders	Alloy with Copper (Bronze)

III.B2 | Iron Making



III.B3 | Blast Furnace

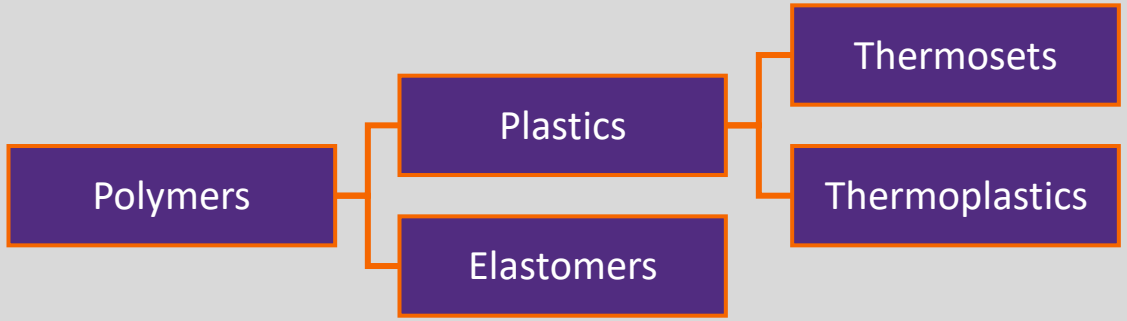


III.B4 | Iron Designations

A	B	CD
Major Classification	Secondary Classification	Carbon content % by weight
1	0	50
Plain Carbon		0.5% carbon by weight
3	4	20
Nickel-Chromium Steel	3% Nickel and 0.77% Chromium	0.2% carbon by weight

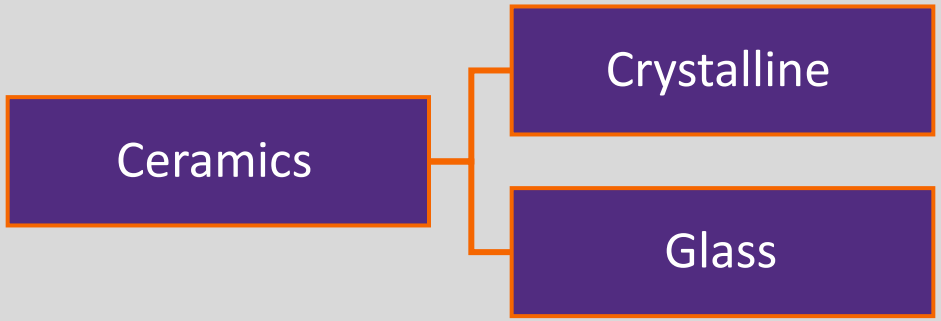
III.C | Polymers

- Polymers are chains of monomers grouped together.
- We identify three categories of polymers: Thermoplastics, Thermosets and Elastomers.
- Thermoplastics are commercially the most important and have over 70% of the polymer market share.
- To facilitate their recycling the Society of Plastics Industry created visible labels.



III.D | Ceramics

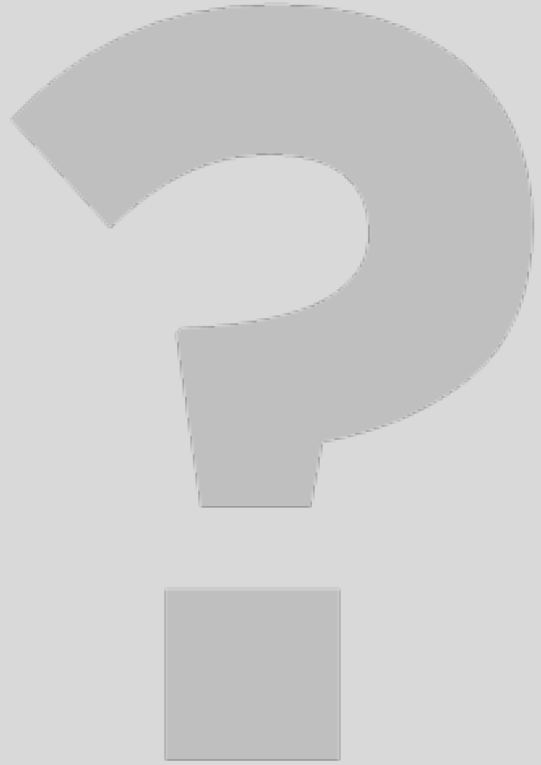
- Crystalline ceramics and glass constitutes the two categories of Ceramics.
- Crystalline ceramics includes traditional ceramics such as pottery, and advanced ceramics such as tungsten carbide.
- Glass is a non-crystalline amorphous solid with widespread usage.



III.E | Composites

- When we join materials in their heterogeneous form, we obtain a composite material.
- Composites consists typically of two phases: Forming and Strengthening.
- The forming phase, labeled as matrix/resin, provides the formability and ductility property.
- The strengthening phase, labeled as reinforcement/fibers, provides the strength to the final part.

Knowledge Check



Iron Belongs to Which Family of Engineering Materials?

A. Metals
B. Ceramics
C. Polymers
D. Composites
E. None of the Above

Knowledge Check

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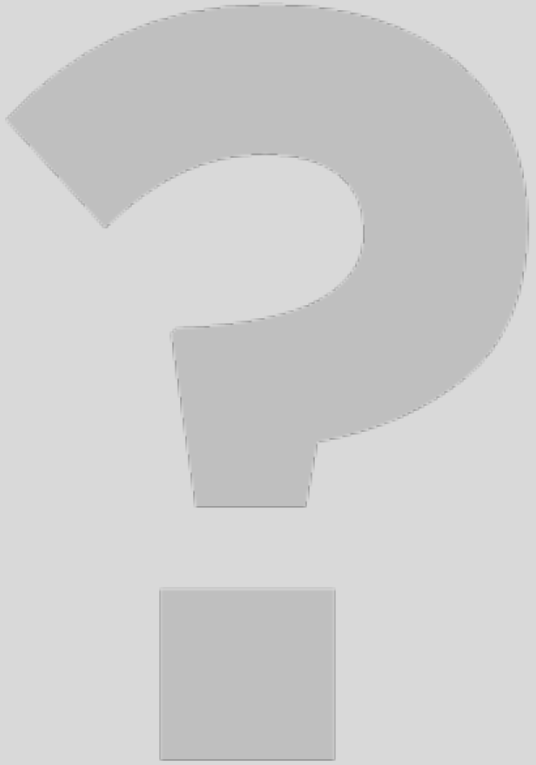
Knowledge Check



A Blast Furnace Operation Results In …

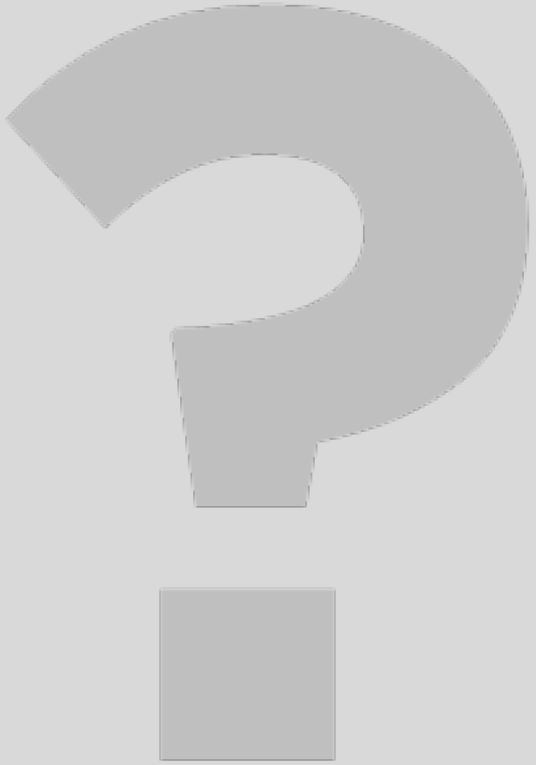
A. Steel
B. Stainless Steel
C. Cast Iron
D. Pig Iron

Knowledge Check

A Blast Furnace Operation Results In …

A. Steel
B. Stainless Steel
C. Cast Iron
D. **Pig Iron**

Knowledge Check



To Assess Performance of Structures we Compare Their …

A. Strength
B. Weight
C. Strength/Weight Ratio

Knowledge Check

To Assess Performance of Structures we Compare Their …

A. Strength
B. Weight
C. **Strength/Weight Ratio**

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Manufacturing Pictures

Section IV

[1] https://cen.acs.org/materials/inorganic-chemistry/s-fiberglass-does-delicate-material/96/i38

1 | Evolution of Wheel Making

2 | Tig Welding

3 | Computer Aided Design of Products

4 | Robotic Assembly Cell

5 | Bicycle With Carbon Fiber Wheel

6 | Blacksmith is a Deformation Manufacturing Process

THANK YOU

- This set of slides is retrieved from the textbook: Intro to Advanced Manufacturing, Harik/Wuest, ISBN 978-0-7680-9327-8 978-0-7680-9327-8
- Link of the textbook: https://www.sae.org/publications/books/content/r-463/
- For more information:

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