Chapter 3: Metal Joining Processes

Repeated Questions:

1. Arc Welding Electrode Coating:

- **Q.** State the purpose of coating on an arc welding electrode. **(SUMMER 2022, 3 Marks; SUMMER 2025, 3 Marks; SUMMER 2025, 3 Marks)**

Answer:

Purpose of Electrode Coating:

- **Arc Stabilization** – Provides easier arc striking and maintains stable arc by ionizing the gap.
- **Shielding Gas Generation** – Burns to produce CO_2/CO gas that shields molten weld pool from atmospheric oxygen and nitrogen.
- **Slag Formation** – Forms protective slag over weld bead, slowing cooling and preventing oxidation.
- **Alloying & Deoxidation** – Adds alloying elements and deoxidizers to improve weld metal properties.
- **Spatter Reduction** – Improves metal transfer and reduces spatter.

---

2. TIG and MIG Welding:

- **Q.** Differentiate between TIG and MIG welding processes. **(SUMMER 2022, 4 Marks; WINTER 2023, 4 Marks; WINTER 2024, 4 Marks; WINTER 2025, 4 Marks)**

Answer:

Feature	TIG Welding	MIG Welding
Electrode	Non-consumable tungsten electrode	Consumable wire electrode
Filler Metal	Separate filler rod fed manually	Wire itself acts as filler; fed automatically
Shielding Gas	Argon or helium (inert)	Argon, CO_2, or mixtures
Application	Thin sheets, stainless steel, aluminium, precision work	Thick sections, mass production, automotive

---

3. Gas Welding:

- **Q.** Explain the Gas welding process. Sketch the types of flames used in oxy-acetylene welding and give their uses. **(SUMMER 2023, 3 & 7 Marks; WINTER 2024, 7 Marks; SUMMER 2025, 7 Marks; WINTER 2025, 3 Marks; SUMMER 2026, 4 Marks)**

Answer:

Gas Welding Process:

- A fuel gas (acetylene) and oxygen are mixed in a torch and ignited to produce a high-temperature flame.
- Flame melts the base metal and filler rod to form a weld joint.
- Typical oxy-acetylene flame temperature ≈ 3200°C.

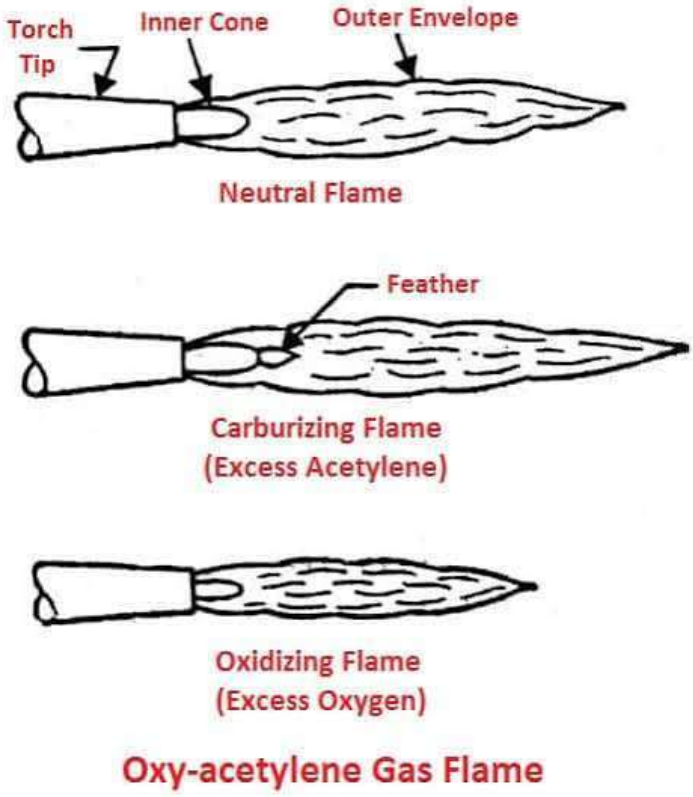
Types of Flames:

- **Neutral Flame** – Oxygen and acetylene in equal ratio (≈1:1).
  - **Appearance:** Sharp inner cone, no distinct outer zones.
  - **Use:** Welding steel, cast iron, copper, aluminium (most common).
- **Oxidizing Flame** – Excess oxygen (O_2:C_2H_2 > 1).

- **Appearance:** Short inner cone, bluish outer flame.
- **Use:** Welding brass and bronze (zinc oxide protective slag).

- **Carburizing (Reducing) Flame** – Excess acetylene (O_2:C_2H_2 < 1).
  - **Appearance:** Three zones; feathery white inner cone, acetylene feather, outer blue flame.
  - **Use:** Welding high-carbon steel, hard facing, aluminium.

Diagram Description: A welding torch tip showing three flame types: neutral (sharp inner cone), oxidizing (short inner cone), and carburizing (three distinct zones with feathery intermediate cone).



---

4. Soldering and Brazing:

- **Q.** Differentiate between soldering and brazing. **(WINTER 2023, 3 Marks; WINTER 2024, 3 Marks; SUMMER 2026, 3 Marks)**

Answer:

Feature	Soldering	Brazing
Filler Melting Point	< 450°C (e.g., tin-lead)	> 450°C (e.g., copper-zinc, silver)
Base Metal Melting	Base metal not melted	Base metal not melted
Joint Strength	Low strength	Higher strength than soldering
Applications	Electronics, sheet metal	Pipes, automotive, tool tips

---

5. Resistance Welding:

- **Q.** Explain the Resistance welding principle. Differentiate between Spot and Seam welding. **(SUMMER 2022, 7 Marks; WINTER 2024, 7 Marks; WINTER 2025, 7 Marks)**

Answer:

Resistance Welding Principle:

- Heat is generated by electrical resistance at the interface of two overlapping metal sheets when a high current passes through them.
- Pressure is applied by electrodes to forge the heated metal into a weld.
- **Formula:** $H = I^2Rt$ (H = heat, I = current, R = resistance, t = time).

Spot Welding:

- Electrodes are pressed at discrete points; current flows to create a local weld nugget.
- Used for lap joints in sheet metal (automotive bodies, appliances).

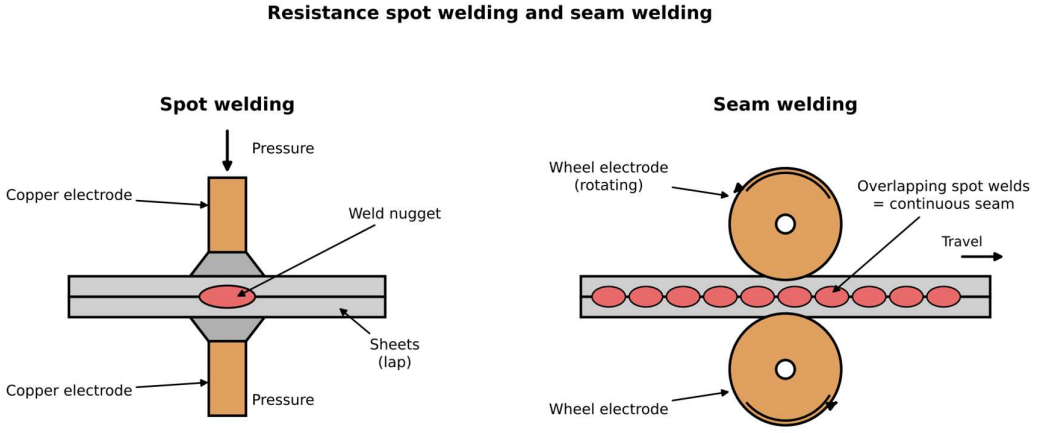
Seam Welding:

- Rotating wheel electrodes continuously roll along the joint; overlapping spot welds form a continuous seam.
- Used for leak-proof joints (fuel tanks, radiators, pipes).

Comparison Table:

Feature	Spot Welding	Seam Welding
Electrode Type	Stationary pointed electrodes	Rotating wheel electrodes
Weld Type	Discrete spot welds	Continuous seam of overlapping welds
Application	Automotive panels, brackets	Leak-proof tanks, radiators

Diagram Description: Two overlapping metal sheets between copper electrodes; spot welding shows a single nugget at electrode tip; seam welding shows rotating wheels producing a continuous weld line.



---

6. Polarity in Arc Welding:

- **Q.** Explain Polarity in arc welding. **(SUMMER 2024, 3 Marks; SUMMER 2026, 3 Marks OR)**

Answer:

Polarity in Arc Welding:

- Polarity refers to the electrical connection of the electrode and workpiece to the power source terminals.

- **DC Straight Polarity (DCSP):** Electrode connected to negative terminal, workpiece to positive.
    - Heat concentrated at workpiece; deeper penetration; used for thick plates.
- **DC Reverse Polarity (DCRP):** Electrode connected to positive, workpiece to negative.
    - Heat concentrated at electrode; good for thin sheets and overhead welding.
- **AC Polarity:** Alternating current; polarity reverses every half cycle; moderate penetration, good for general welding.

---

7. Welding Defects:

- **Q.** Enlist the defects that are generally found in welding. Describe their cause and remedies. **(SUMMER 2022, 4 Marks; SUMMER 2023, 7 Marks; WINTER 2025, 7 Marks OR)**

Answer:

Welding Defects, Causes & Remedies:

- **Porosity** – Gas cavities in weld metal.
    - **Cause:** Moisture, oil, dirt on surface; inadequate shielding.
    - **Remedy:** Clean surfaces, proper shielding gas flow, dry electrodes.
- **Slag Inclusion** – Non-metallic slag trapped in weld.
    - **Cause:** Poor slag removal between passes, incorrect electrode angle.
    - **Remedy:** Clean each pass, proper technique.
- **Incomplete Penetration** – Weld metal does not reach root.
    - **Cause:** Low current, fast travel, wrong joint design.
    - **Remedy:** Increase current, slow travel, proper gap.
- **Lack of Fusion** – Weld metal does not fuse with base metal.
    - **Cause:** Low heat input, dirty surface, wrong electrode.
    - **Remedy:** Proper current, clean surface, correct electrode.
- **Undercut** – Groove melted into base metal along weld toe.
    - **Cause:** Excessive current, long arc, wrong electrode angle.
    - **Remedy:** Reduce current, correct arc length and angle.
- **Spatter** – Metal droplets on surface.
    - **Cause:** High current, long arc, damp electrodes.
    - **Remedy:** Proper current, short arc, dry electrodes.
- **Cracks (Hot/Cold)** – Fractures in weld or HAZ.
    - **Cause:** High restraint, rapid cooling, impurities (S, P).
    - **Remedy:** Preheating, slow cooling, clean metal.

---

8. Plasma and Laser Beam Welding:

- **Q.** Distinguish between Plasma and Laser Beam welding processes. **(WINTER 2022, 7 Marks; SUMMER 2024, 7 Marks)**

Answer:

Feature	Plasma Arc Welding	Laser Beam Welding
Heat Source	Constricted plasma arc (ionized gas)	Coherent monochromatic light beam
Temperature	~20,000–30,000°C	Very high; focused spot
Spot Size	~0.1–1 mm	Very small (0.1–0.5 mm)
Shielding	Inert gas (argon, helium)	Usually no shielding; sometimes inert gas
Penetration	Keyhole mode for thick sections	Deep penetration, narrow HAZ
Applications	Stainless steel, titanium, aerospace	Precision parts, electronics, automotive

---

Other Important Questions:

1. Classification of Welding and Joining Processes:

- **Q.** Classify the welding process in detail. **(SUMMER 2025, 3 Marks)**

Answer:

Classification of Metal Joining Processes:

- **Welding (Coalescence Processes):**
  - **Fusion Welding:** Arc welding (SMAW, TIG, MIG, SAW), Gas welding, Thermit welding, Electron beam, Laser beam, Plasma.
  - **Solid-State Welding:** Friction welding, Ultrasonic, Explosive, Diffusion bonding, Forge welding.
  - **Resistance Welding:** Spot, Seam, Projection, Butt.
- **Brazing:** Filler melts >450°C; base metal not melted.
- **Soldering:** Filler melts <450°C; base metal not melted.
- **Adhesive Bonding:** Joining with adhesives (non-metallic).

- **Q.** Distinguish between welding, soldering, Brazing joining processes. **(WINTER 2025, 3 Marks OR)**

Answer:

Process	Filler Melting Temp	Base Metal	Joint Strength
Welding	Filler (if used) melts at base metal temp	Base metal melts	Highest
Brazing	> 450°C	Base metal not melted	Medium–high
Soldering	< 450°C	Base metal not melted	Low

- **Q.** Classify metal joining processes. **(SUMMER 2026, 3 Marks OR)**

Answer:

Classification of Metal Joining Processes:

- **Welding (Coalescence Processes):**
  - **Fusion Welding:** Arc welding (SMAW, TIG, MIG, SAW), Gas welding, Thermit welding, Electron beam, Laser beam, Plasma.
  - **Solid-State Welding:** Friction welding, Ultrasonic, Explosive, Diffusion bonding, Forge welding.
  - **Resistance Welding:** Spot, Seam, Projection, Butt.
- **Brazing:** Filler melts >450°C; base metal not melted.
- **Soldering:** Filler melts <450°C; base metal not melted.
- **Adhesive Bonding:** Joining with adhesives (non-metallic).

- **Q.** List the types of welding joints and explain any one in brief with required sketch. **(SUMMER 2026, 4 Marks OR)**

Answer:

Types of Welding Joints:

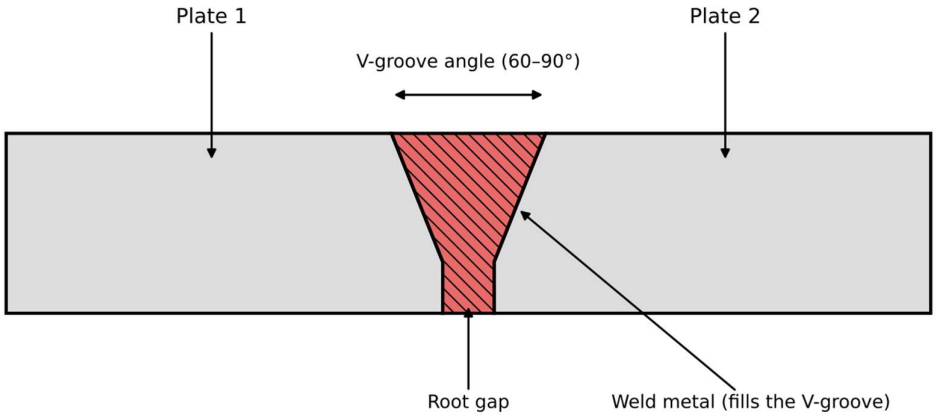
- **Butt Joint** – Two plates aligned edge-to-edge.
- **Lap Joint** – One plate overlaps another.
- **T-Joint** – One plate perpendicular to another.
- **Corner Joint** – Two plates at right angle at edges.
- **Edge Joint** – Edges of two plates joined.

Butt Joint (Explanation):

- Two plates are placed end-to-end in the same plane.
- Edges may be square, single-V, double-V, or U-groove depending on thickness.
- Provides strong joint with good load-bearing capacity; requires proper edge preparation.

Diagram Description: Two flat plates aligned edge-to-edge with a V-groove between them; weld bead fills the groove to join the plates.

Single-V butt joint



---

2. Arc Welding Processes:

- **Q.** Discuss the TIG welding process setup with a neat sketch. **(SUMMER 2025, 7 Marks)**

Answer:

TIG (Tungsten Inert Gas) Welding Setup:

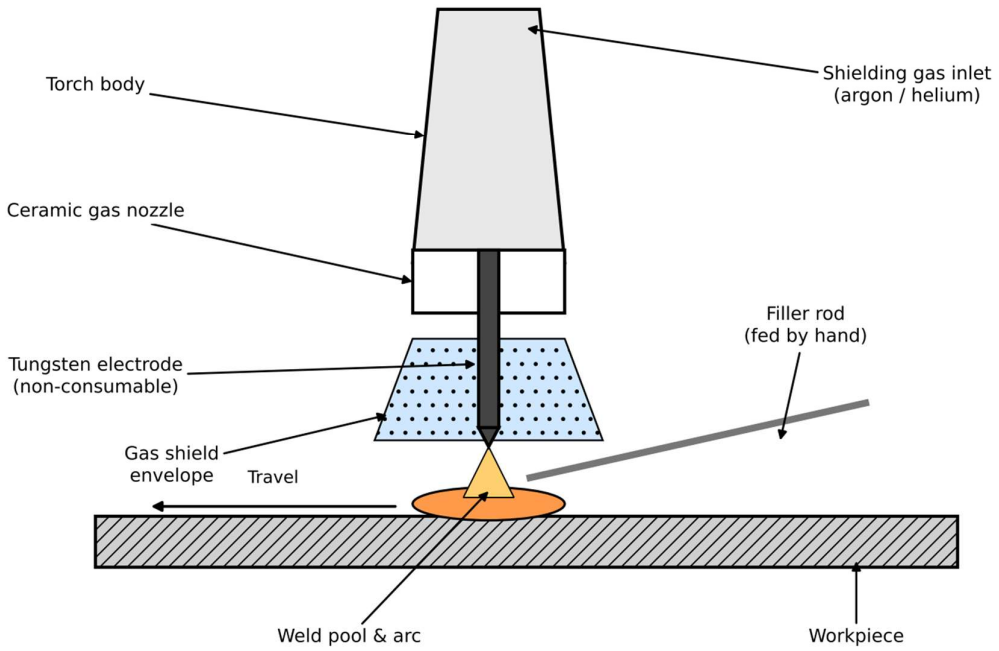
- **Power Source:** AC/DC constant current source.
- **Torch:** Holds non-consumable tungsten electrode, ceramic nozzle, and gas passage.
- **Shielding Gas:** Argon or helium supplied to torch nozzle.
- **Filler Rod:** Fed manually into arc (if required).
- **Workpiece:** Connected to return cable.
- **Cooling:** Water-cooled torch for high currents.

Working:

- Arc struck between tungsten electrode and workpiece.
- Shielding gas flows around electrode to protect molten pool.
- Filler rod added manually as needed.
- Arc moved along joint to complete weld.
- **Advantages:** Clean welds, no spatter, precise control, suitable for thin sheets and reactive metals.
- **Applications:** Stainless steel, aluminium, titanium, aerospace, nuclear.

Diagram Description: TIG torch with tungsten electrode, ceramic cup, gas inlet, and cable; arc between electrode and workpiece; filler rod fed from side; shielding gas envelope around arc.

TIG welding setup



- **Q.** What is arc blow? How to reduce it? **(SUMMER 2023, 4 Marks)**

Answer:

Arc Blow:

- Deflection of welding arc from its intended path due to magnetic forces.

- Caused by non-uniform magnetic fields around the arc (e.g., DC welding, thick sections, ground connection position).

Remedies:

- Use AC instead of DC where possible.
- Change ground connection position (move farther or symmetrically).
- Reduce current or use short arc.
- Use backstep welding technique.
- Wrap ground cable around workpiece to neutralize field.

- **Q.** Discuss submerged arc welding process in the context of its characteristic features, types of current, power sources, process variables. **(SUMMER 2026, 7 Marks)**

Answer:

Submerged Arc Welding (SAW):

- Arc is struck under a blanket of granular flux; no visible arc.
- Consumable wire electrode fed continuously; flux fed from hopper.
- High deposition rate; deep penetration; suitable for thick plates.

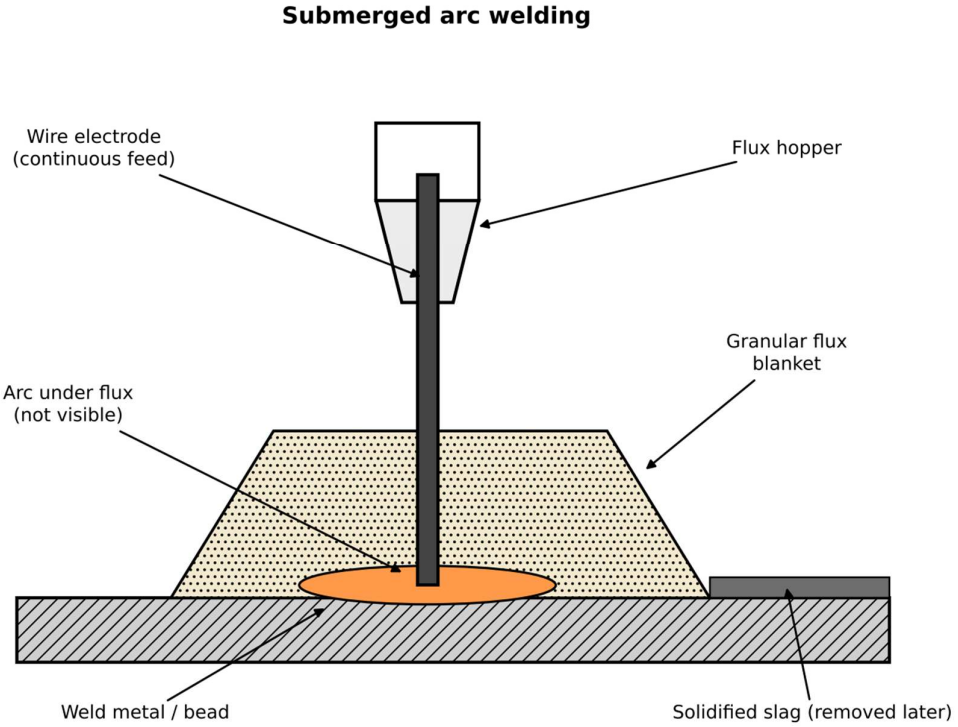
Characteristic Features:

- High current (up to 1000 A), high deposition rate.
- Excellent arc stability; no spatter; good surface finish.
- Used for longitudinal/ circumferential seams of pipes, pressure vessels.
- **Types of Current:** AC or DC (DC more common for deep penetration).
- **Power Sources:** Constant voltage (CV) for self-regulating arc; high current capacity.

Process Variables:

- Current, voltage, travel speed, wire feed rate, electrode diameter, flux type, stick-out.

Diagram Description: Welding head with wire electrode and flux hopper; granular flux covers arc and weld zone; molten slag and weld bead form under flux layer.



---

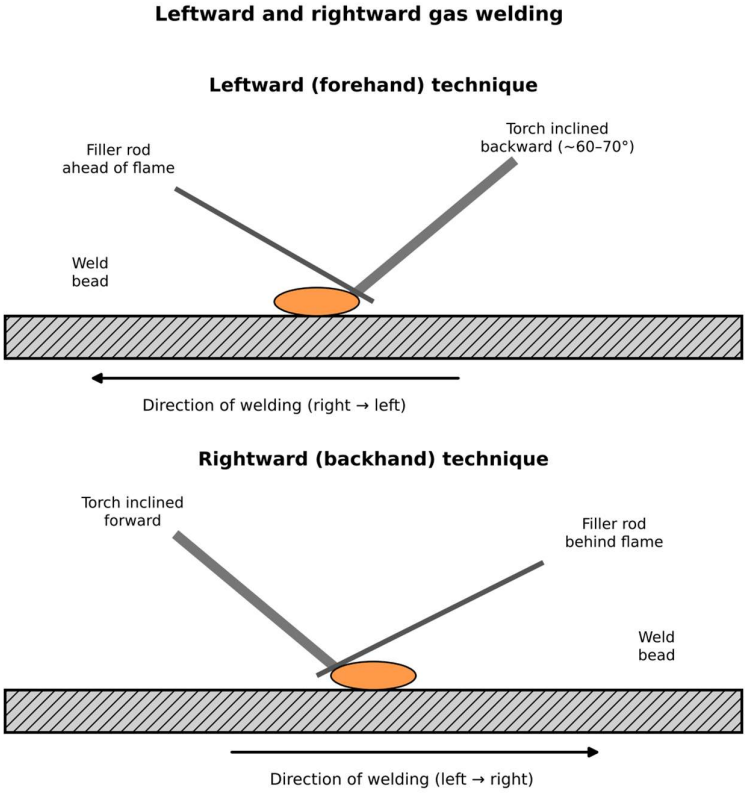
3. Gas Welding Techniques:

- **Q.** Compare the leftward and rightward welding technique with diagram. **(WINTER 2025, 4 Marks OR)**

Answer:

Feature	Leftward Technique	Rightward Technique
Direction	Torch moves right to left; filler rod ahead of flame	Torch moves left to right; filler rod follows flame
Plate Thickness	Thin plates (< 5 mm)	Thick plates (> 5 mm)
Flame Type	Neutral or slightly reducing	Slightly oxidizing
Penetration & Speed	Less penetration, slower	Better penetration, faster

Diagram Description: Leftward: torch inclined backward, filler rod ahead, moving right to left. Rightward: torch inclined forward, filler rod behind flame, moving left to right.



---

4. Other Welding Processes:

- **Q.** Describe the thermit welding process. **(SUMMER 2023, 7 Marks)**

Answer:

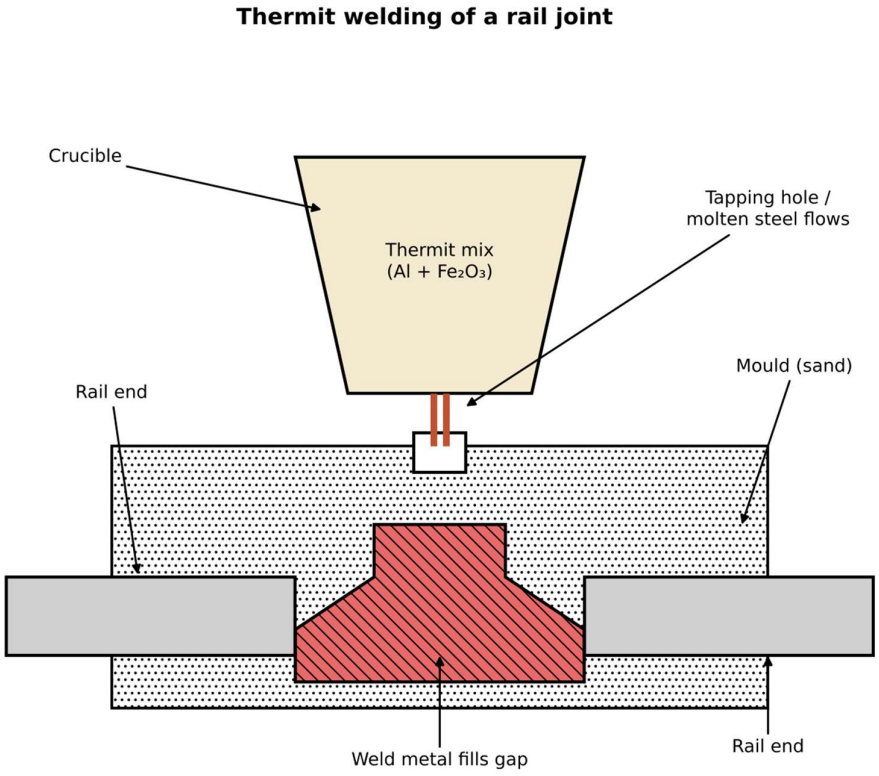
Thermit Welding:

- Exothermic reaction between aluminium powder and iron oxide produces molten iron and slag.
- **Reaction:** $3Fe_3O_4 + 8Al \rightarrow 9Fe + 4Al_2O_3 +$ heat (≈ 2500°C).
- Used mainly for joining rails, large shafts, and repair work.

Steps:

- Clean and align parts; preheat if necessary.
- Place crucible with thermit mixture above joint.
- Ignite mixture with ignition powder.
- Molten iron flows into mould around joint.
- Slag separates and rises; metal solidifies to form weld.
- **Advantages:** No external power; portable; strong joints.
- **Applications:** Railway tracks, large shafts, marine repairs.

Diagram Description: Crucible with thermit mixture above a mould around rail joint; molten iron pours into mould; slag layer on top.



- **Q.** Explain electron beam welding process with required diagram. **(SUMMER 2026, 4 Marks OR)**

Answer:

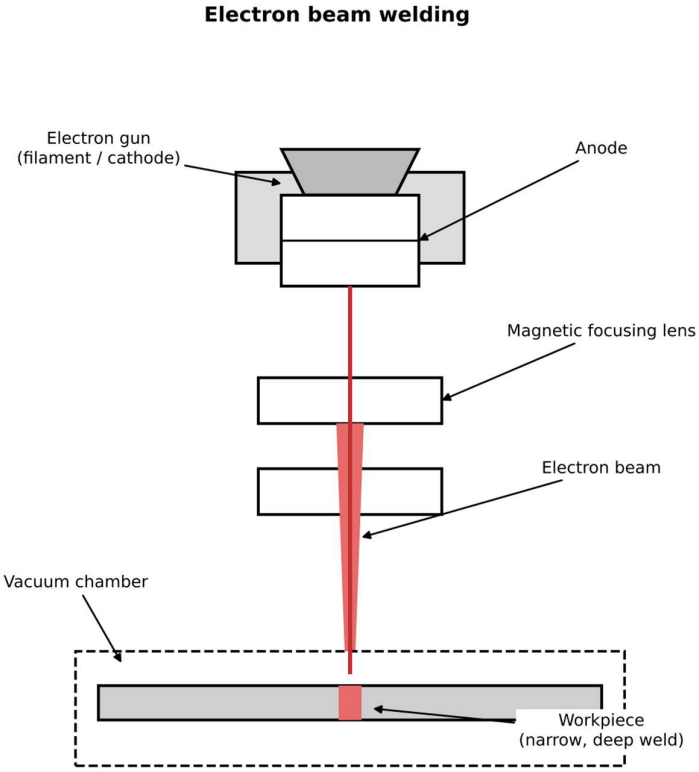
Electron Beam Welding (EBW):

- A focused beam of high-velocity electrons strikes workpiece, converting kinetic energy into heat.
- Performed in vacuum to prevent electron scattering.
- Produces narrow, deep welds with minimal distortion.

Working:

- Electron gun generates and accelerates electrons.
- Magnetic lenses focus beam to small spot.
- Beam strikes joint; melts and fuses metal.
- Vacuum chamber prevents contamination.
- **Advantages:** High depth-to-width ratio, precise, low distortion.
- **Applications:** Aerospace, nuclear, precision components.

Diagram Description: Electron gun at top, magnetic focusing lens, electron beam directed at workpiece in vacuum chamber; narrow weld zone.



- **Q.** Discuss laser beam welding process in the context of its characteristics features, capabilities and its applications. **(SUMMER 2026, 7 Marks OR)**

Answer:

Laser Beam Welding (LBW):

- Uses a highly focused, coherent monochromatic light beam to melt and join metals.
- Can be operated in conduction mode (shallow) or keyhole mode (deep penetration).

Characteristics Features:

- Very high energy density; narrow HAZ.
- Precise control; no electrode contact; no filler required.
- Can weld dissimilar metals; automation-friendly.

Capabilities:

- Deep penetration (up to 20 mm in keyhole mode).
- High welding speed; low distortion.
- Welds thin foils to thick sections.

Applications:

- Automotive (body panels, transmission parts).
- Electronics (micro-welding, sensors).
- Aerospace and medical devices.

Diagram Description: Laser source with focusing lens directing beam onto workpiece; keyhole formation in deep penetration mode; narrow weld bead.

