APPLIED MARINE ENGINEERING

Attempt ALL questions
Marks for each part question are shown in brackets

1. (a) List FIVE different desirable properties of aluminium. (5)

   (b) In modern vessels identify parts that utilises EACH of the properties listed in part (a). (5)

2. With reference to EACH of the following materials, list their percentage composition and a different application for EACH material on board, stating, with reasons, why they are suitable for this application:

   (a) cupro-nickel; (2)

   (b) aluminium bronze; (2)

   (c) admiralty brass; (2)

   (d) duralumin; (2)

   (e) solder. (2)

3. With reference to case hardening steel components:

   (a) describe the changes that occur with this process; (3)

   (b) explain why it may be required; (2)

   (c) describe EACH of the following processes:

      (i) a simple shipboard process; (3)

      (ii) solid pack carburising. (2)

porosity
slag
undercut
underfill
incomplete fusion

4. With reference to fatigue failure of components:

   (a) describe how material fatigue testing is carried out in the laboratory; (2)

   (b) sketch the surface appearance of a fatigue fracture; (2)

   (c) describe the THREE stages of the failure; (3)

   (d) list the methods available on board to limit the possibility of fatigue failure to a propeller shaft. (3)

allignment
rubber coupling

5. Describe, with the aid of sketches, FIVE defects that may be present on a weld produced using the covered electrode welding process. (10)

6. With reference to the cathodic protection of hull fittings:

   (a) explain how sacrificial anodes achieve this; (2)

   (b) state where sacrificial anodes would be fitted and why; (4)

   (c) describe an impressed current system, stating the principle on which it works. (4)

7. Explain EACH of the following terms:

   (a) galvanic corrosion; (2)

   (b) cavitation damage; (2)

   (c) erosion damage; (2)

   (d) stress corrosion; (2)

   (e) atmospheric corrosion. (2)

8. (a) Describe with the aid of a sketch, how Bi-metallic strips are utilised to measure temperature. (8)

   (b) State a typical application for this type of device and its main shortcoming. (2)

9. With reference to engine governors, explain EACH of the following terms:

   (a) sensitivity; (2)

   (b) hunting; (2)

   (c) speed droop; (2)

   (d) stability; (2)

   (e) isochronous governing. (2)

10. (a) State the reasons for fitting a pneumatic process valve with EACH of the following:

(i) a volume booster; (2)

(ii) a feedback positioner. (2)

(b) State, with reasons, the type of actuator fitted to the process valves for EACH of the following systems:

(i) a fuel supply system in which the valve must not move on loss of power to the control system; fail set (3)

(ii) a lubrication oil cooling system in which the valve diverts the oil through a cooler. fail safe. (3)

1. (a) List FIVE different desirable properties of aluminium. (5)

(b) In modern vessels identify parts that utilises EACH of the properties listed in part (a). (5)

(a) Five desirable properties of aluminium (5 marks)

1. **Low density / lightweight** – about one-third the density of steel.
2. **Good corrosion resistance** – natural oxide film resists seawater attack.
3. **High thermal and electrical conductivity.**
4. **Good formability and machinability** – easy to fabricate and shape.
5. **Attractive appearance** – can be polished, anodised, or painted; also non-toxic.

(Other acceptable answers: non-magnetic, high strength-to-weight ratio when alloyed, recyclable.)

(b) Applications of each property on modern vessels (5 marks)

1. **Lightweight** → Superstructure, decks, bulkheads: reduces top-weight, improves stability, increases payload.
2. **Corrosion resistance** → Hull plating, masts, deck fittings exposed to seawater.
3. **High conductivity** → Electrical busbars, cabling, heat exchangers, refrigeration piping.
4. **Good formability/machinability** → Complex fittings, accommodation furniture, ladders, and hatches.
5. **Appearance / non-toxic** → Galley equipment, handrails, decorative trims, interior panels.

2. With reference to EACH of the following materials, list their percentage composition and a different application for EACH material on board, stating, with reasons, why they are suitable for this application:

(a) cupro-nickel; (2)

(b) aluminium bronze; (2)

(c) admiralty brass; (2)

(d) duralumin; (2)

(e) solder. (2)

(a) Cupro-nickel (2)

- **Composition:** ~70–90% copper, 10–30% nickel (often 70/30 or 90/10).
- **Application: Seawater piping, condensers, and heat exchangers.**
- **Reason:** Excellent **corrosion resistance in seawater**, good thermal conductivity, resistant to biofouling.

(b) Aluminium bronze (2)

- **Composition:** ~88–90% copper, 8–11% aluminium, small % of iron/nickel.
- **Application: Propellers and pump components.**
- **Reason:** High **strength and toughness**, very good **corrosion resistance** in seawater, resistant to cavitation/erosion.

(c) Admiralty brass (2)

- **Composition:** ~70% copper, 29% zinc, ~1% tin.
- **Application: Condenser and heat exchanger tubes.**
- **Reason:** Tin improves resistance to **dezincification**, good thermal conductivity, resists seawater corrosion.

(d) Duralumin (2)

- **Composition:** ~90–95% aluminium, 4% copper, small amounts of magnesium, manganese.
- **Application: Deckhouse structures, ladders, masts.**
- **Reason:** Lightweight, strong, good machinability – ideal for **reducing topside weight**.

(e) Solder (2)

- **Composition:** Traditionally ~60% tin, 40% lead (now lead-free types: Sn-Cu or Sn-Ag-Cu).
- **Application: Electrical wiring and electronic joints.**
- **Reason:** Low melting point, good wettability, provides strong **electrical and mechanical bond**.

3. With reference to case hardening steel components:

(a) describe the changes that occur with this process; (3)

(b) explain why it may be required; (2)

(c) describe EACH of the following processes:

(i) a simple shipboard process; (3)

(ii) solid pack carburising. (2)

porosity
slag
undercut
underfill
incomplete fusion

(a) Describe the changes that occur with this process (3 marks)

- The **surface layer of the steel is hardened** by adding carbon/nitrogen and then quenching, producing **hard martensite** at the surface.

- The **core remains softer and tougher**, usually ferrite/pearlite, retaining ductility and impact resistance.
- The result is a component with a **hard, wear-resistant surface** and a **tough, shock-resistant core**.

(b) Why it may be required (2 marks)

- To resist **surface wear, abrasion, and fatigue** in service (e.g., gears, cams, shafts).
- While maintaining a **tough, ductile core** to absorb shocks and prevent brittle fracture.

(c) Case hardening processes

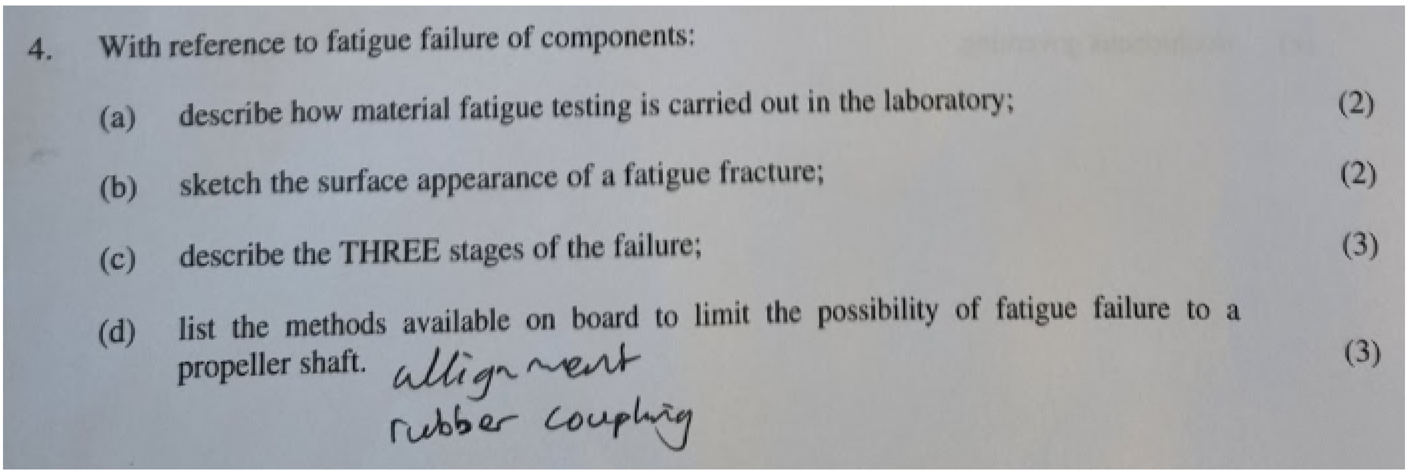
(i) A simple shipboard process (3 marks)

- **Flame hardening**: Heat the steel surface locally using an oxy-acetylene flame, then rapidly quench with water/air spray.
- Produces a thin **hardened surface layer** (martensite), leaving the core unaffected.
- Advantage: Simple, portable, quick for local repairs onboard.

(Alternative acceptable: induction hardening – using a high-frequency coil, then quenching.)

(ii) Solid pack carburising (2 marks)

- Components are packed in a sealed box with a **carbonaceous material** (e.g., charcoal plus barium carbonate as an energiser).
- Heated to around **900 °C** for several hours.
- Carbon diffuses into the steel surface, enriching it. On quenching, the **case becomes hard** while the core stays tough.



4. With reference to fatigue failure of components:

(a) describe how material fatigue testing is carried out in the laboratory; (2)

(b) sketch the surface appearance of a fatigue fracture; (2)

(c) describe the THREE stages of the failure; (3)

(d) list the methods available on board to limit the possibility of fatigue failure to a propeller shaft. (3)

allignment
rubber coupling

(a) How material fatigue testing is carried out in the laboratory (2 marks)

- A specimen is subjected to **cyclic loading** (e.g., rotating bending, axial loading, or torsion) at a known stress level.

- The **number of cycles to failure** is recorded, producing an **S–N curve** (stress vs. number of cycles) which shows fatigue life.

(b) Sketch/surface appearance of a fatigue fracture (2 marks)

(Describe if no sketch possible)

- Surface shows **beach marks or concentric rings** from progressive crack growth.
- A relatively **smooth area** where the crack propagated slowly, ending in a **rough, crystalline final fracture zone** where sudden failure occurred.

(c) The three stages of fatigue failure (3 marks)

1. **Crack initiation** – starts at stress concentrations (surface scratches, keyways, weld defects).
2. **Progressive crack growth** – under repeated cyclic stresses, crack slowly extends; beach marks visible.
3. **Final sudden fracture** – remaining section fails catastrophically once it can no longer sustain the load.

(d) Methods onboard to limit fatigue failure of a propeller shaft (3 marks)

- Ensure **accurate alignment** of shafting and couplings.
- Fit **flexible/rubber couplings** to absorb shocks and misalignment.
- Maintain correct **bearing lubrication and support** to reduce cyclic stresses.
- Avoid sharp corners/keyway stress raisers; keep good surface finish.
- Regular inspections for **cracks or corrosion pitting**.

5. Describe, with the aid of sketches, FIVE defects that may be present on a weld produced using the covered electrode welding process. (10)

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1. Porosity

- Small gas holes trapped in the solidified weld metal.
- Caused by **contaminants, damp electrodes, or insufficient shielding**.
- Weakens weld by reducing cross-sectional area.

2. Slag Inclusions

- Non-metallic particles (flux/slag) trapped in the weld.
- Caused by **poor cleaning between passes** or incorrect electrode angle.
- Reduces strength and can initiate cracks.

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3. Lack of Fusion (Incomplete Fusion)

- Weld metal fails to fuse properly with the parent metal or previous bead.
- Caused by **low heat input, incorrect electrode angle, or poor technique**.
- Creates planes of weakness along the joint.

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4. Undercut

- Groove melted into the parent metal at the toe of the weld that is not filled with weld metal.
- Caused by **excessive current or incorrect travel speed**.
- Acts as a **stress concentration point**, reducing fatigue strength.

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5. Cracking

- Can be **hot cracks** (during solidification) or **cold cracks** (after cooling).
- Causes include **high restraint, hydrogen embrittlement, poor design, or rapid cooling**.
- Severely compromises weld integrity.

Answering with sketches

- Each of the above should ideally be accompanied by a **simple labelled sketch** (e.g., weld bead cross-section showing porosity holes, slag inclusion lines, lack of fusion gap, undercut groove, and a crack line).

6. With reference to the cathodic protection of hull fittings:

(a) explain how sacrificial anodes achieve this; (2)

(b) state where sacrificial anodes would be fitted and why; (4)

(c) describe an impressed current system, stating the principle on which it works. (4)

(a) How sacrificial anodes achieve cathodic protection (2 marks)

- Sacrificial anodes are made from a **more reactive (anodic) metal** such as zinc, aluminium, or magnesium.
- When connected to the steel hull, the anode preferentially **corrodes (sacrifices itself)**, supplying electrons to the hull and making the hull a **cathode** → preventing its corrosion.

(b) Where sacrificial anodes are fitted and why (4 marks)

- **Locations:**
  - Along the ship's **hull**, especially near the stern.
  - Around **sea chests** and **bilge keels**.
  - On or near **rudders, shafts, propellers, and stern gear**.
- **Reasons:**
  - These areas are most exposed to seawater and prone to galvanic corrosion.
  - Ensures **uniform protection** of vulnerable fittings and areas of turbulent flow.

(c) Impressed current system: principle and description (4 marks)

- Uses **inert anodes** (e.g., titanium with mixed metal oxide) fixed to the hull and connected to a **DC power source**.
- The hull is connected to the **negative terminal**, anodes to the **positive terminal**.
- A controlled current flows from the anodes into seawater, making the **hull uniformly cathodic**.
- **Principle:** By **impressing a direct current**, the hull potential is maintained at a protective level (typically −0.85 V vs Ag/AgCl), preventing corrosion.

7. Explain EACH of the following terms:

(a) galvanic corrosion; (2)

(b) cavitation damage; (2)

(c) erosion damage; (2)

(d) stress corrosion; (2)

(e) atmospheric corrosion. (2)

(a) Galvanic corrosion (2)

- Occurs when **two dissimilar metals** are electrically connected in an electrolyte (e.g., seawater).
- The **more anodic metal** corrodes preferentially, protecting the cathodic metal.

(b) Cavitation damage (2)

- Caused by the **formation and collapse of vapour bubbles** in a liquid, typically near propellers or pump impellers.
- The collapsing bubbles produce **shock waves and micro-jets**, leading to **pitting and surface erosion**.

(c) Erosion damage (2)

- Mechanical removal of material by the **impingement of solid particles or high-velocity fluids**.
- Common in **pipe bends, valves, and pump casings** where turbulence is high.

(d) Stress corrosion (2)

- The **combined effect of tensile stress and a corrosive environment** causes cracking.
- Occurs even at stress levels below the material's yield strength (e.g., in stainless steel exposed to chlorides).

(e) Atmospheric corrosion (2)

- Corrosion due to exposure to **moisture, oxygen, and pollutants** in the air.
- Common in **deck structures, superstructures, and above-waterline hull plating**.

8. (a) Describe with the aid of a sketch, how Bi-metallic strips are utilised to measure temperature. (8)

(b) State a typical application for this type of device and its main shortcoming. (2)

(a) How bimetallic strips are used to measure temperature (8 marks)

- A **bimetallic strip** is made by bonding together **two dissimilar metals** with different coefficients of thermal expansion (e.g., brass and steel).
- When the strip is heated, one metal expands **more than the other**, causing the strip to **bend or curve**.
- The amount of curvature is **proportional to the temperature change**.
- This deflection can be used to:
    - Move a **pointer across a calibrated scale** (for temperature indication).
    - Make or break **electrical contacts** (for alarms, thermostats, or control circuits).
- **Sketch description** (if drawing in exam):
    - Show a bonded strip fixed at one end, free to bend at the other.
    - Arrow indicating deflection with temperature rise.
    - Pointer linkage to scale for temperature reading.

(b) Typical application and shortcoming (2 marks)

- **Application:**
    - Thermometers, thermostats (refrigeration plants, HVAC), engine room thermometers, simple temperature alarms.
- **Shortcoming:**
    - Relatively **slow response** due to thermal mass.
    - Limited **accuracy and sensitivity** compared with electronic devices.
    - Subject to **mechanical fatigue** after long-term use.

9. With reference to engine governors, explain EACH of the following terms:

(a) sensitivity; (2)

(b) hunting; (2)

(c) speed droop; (2)

(d) stability; (2)

(e) isochronous governing. (2)

(a) Sensitivity (2)

- The ability of a governor to **detect and respond to small changes in engine speed**.
- A highly sensitive governor will make fine corrections with minimal speed variation.

(b) Hunting (2)

- Continuous, **oscillatory variation of engine speed** around the set point due to over-correction by the governor.
- Indicates poor damping or excessive sensitivity.

(c) Speed droop (2)

- The **percentage reduction in engine speed** between **no load and full load** at a fixed governor setting.
- Introduced intentionally to allow **stable load sharing** between parallel-running engines.

(d) Stability (2)

- The ability of a governor to **maintain a steady speed** at a given load without oscillations or hunting.
- Achieved through correct balance of sensitivity and damping.

(e) Isochronous governing (2)

- A condition where the governor maintains the **same speed at all loads (zero droop)**.
- No steady-state error, but can lead to **instability when load sharing** between multiple engines.

10. (a) State the reasons for fitting a pneumatic process valve with EACH of the following:

(i) a volume booster; (2)

(ii) a feedback positioner. (2)

(b) State, with reasons, the type of actuator fitted to the process valves for EACH of the following systems:

(i) a fuel supply system in which the valve must <u>not move</u> on loss of power to the control system; fail set (3)

(ii) a lubrication oil cooling system in which the valve <u>diverts the oil through</u> a cooler. fail safe. (3)

(a) Reasons for fitting auxiliaries to pneumatic process valves

(i) Volume booster (2)

- Ensures **rapid response and movement** of large actuators by increasing the rate of air flow.
- Needed when the actuator volume is large and normal instrument air flow would be too slow.

(ii) Feedback positioner (2)

- Provides **accurate positioning of the valve** by feeding back stem position to the controller.
- Overcomes problems of **friction, hysteresis, and varying air supply pressure**, ensuring the valve reaches the demanded position.

(b) Type of actuator for specific systems

(i) Fuel supply system (valve must not move on loss of control power) (3)

- Use a **double-acting actuator with fail-in-place (fail-set) positioner**.
- Ensures valve **remains in last commanded position** if signal/power is lost → avoids unplanned fuel cut-off or flooding of fuel.

(ii) Lubricating oil cooling system (valve diverts oil through cooler, must be fail-safe) (3)

- Use a **spring-return actuator** designed to fail in the **safe position** (valve diverts oil through cooler) if power/control air is lost.
- Protects bearings and machinery by ensuring continued cooling → prevents overheating and damage.