AUXILIARY EQUIPMENT PART I

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

1. (a) Sketch a section through a 3-way mixer valve. (8)

   (b) State an application for this type of valve. (2)

2. With reference to centrifugal pumps used for bilge/ballast purposes:

   (a) explain the specific problems which may arise using the pumps for these purposes; (4)

   (b) explain TWO methods used to improve pump performance when used for these purposes. (6)

3. With reference to air compressors:

   (a) state TWO advantages of rotary air compressors; (2)

   (b) state ONE advantage of reciprocating air compressors; (1)

   (c) explain why multistage air compressors are used for starting air purposes. (7)

4. (a) List SIX examples of contaminants that may be found in hydraulic oil. (6)

   (b) State the actions to be taken to reduce or remove the contaminants listed in part (a). (4)

5. Describe, with the aid of a block diagram, the control of an automatic steering system, including auto-pilot and valve operated steering gear. (10)

6. With reference to controllable pitch propellers:

   (a) explain why they should maintain a small amount of pitch when in the neutral position; (3)

   (b) state, with reasons, the failsafe position; (4)

   (c) explain how pitch may be restored should hydraulic system failure occur. (3)

7. Whilst a single screw vessel is on passage it is noticed that an intermediate shaft bearing is running hot.

(a) State FIVE possible causes. (5)

(b) Explain the procedure that should be followed in order to reach port for further investigation if there were no obvious causes. (5)

8. With reference to main propulsion shaft hydraulic sleeve type couplings:

(a) describe, with the aid of a sketch, the removal procedure; (7)

(b) state how it is determined, during reassembly, that the push fit is complete. (3)

(a) Describe, with the aid of a sketch, a cartridge type fuse. (7)

(b) State why a fuse used in a motor circuit differs from a fuse used in a lighting circuit. (3)

Higher 3x load deal with surges

Will blow immediately

Describe TWO methods for detecting earth faults within a distribution system. (10)

insulated

AOA: ~~earth~~ normal

1 earth fault

7. (a) Sketch a section through a 3-way mixer valve. (8)

(b) State an application for this type of valve. (2)

(a) Sketch a section through a 3-way mixer valve (8 marks)

A **3-way mixer valve** has:

- **Two inlets** (e.g. hot water and cold water).
- **One outlet** (delivering mixed fluid at controlled temperature/flow).
- **Valve body** with ports arranged in a “T” or “Y” pattern.
- **Control element** (plug, rotary disc, or sliding spool) which regulates the proportion of each inlet flow.

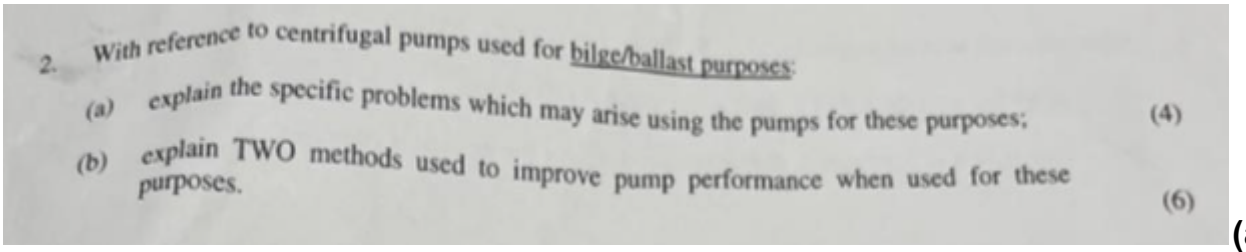
- **Actuator** (manual handle, pneumatic or electric actuator) to position the plug.

✏️ **Exam sketch suggestion:**

- Draw a valve body with two inlet ports at the sides and one outlet at the bottom.
- Show a central plug/spool with openings that can shift or rotate to mix varying amounts of hot and cold water.
- Label **hot inlet, cold inlet, mixed outlet, valve plug, actuator spindle**.

(b) State an application for this type of valve (2 marks)

- **Application:** Control of cooling water temperature to diesel engine jacket or lubricating oil by mixing hot return water with cold sea water.
- **Reason:** Ensures a steady outlet temperature for efficient engine operation and prevents thermal shock.


2. With reference to centrifugal pumps used for bilge/ballast purposes:

(a) explain the specific problems which may arise using the pumps for these purposes; (4)

(b) explain TWO methods used to improve pump performance when used for these purposes. (6)

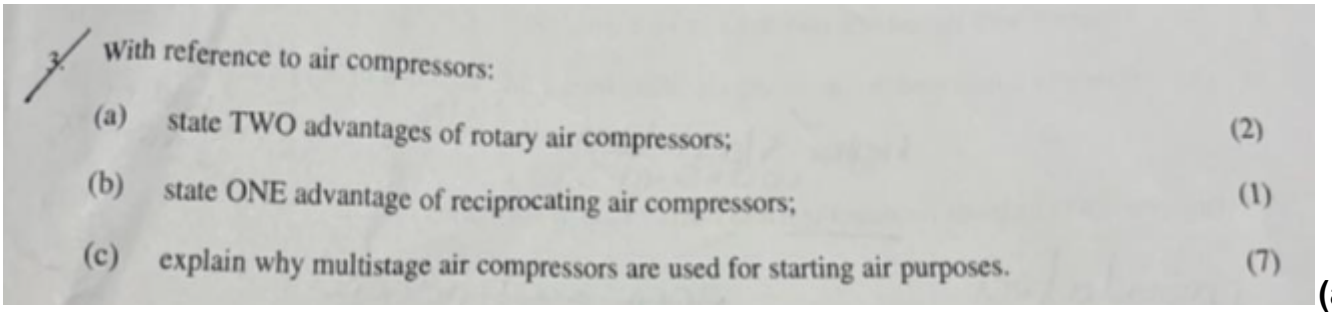
(a) Specific problems which may arise using the pumps for these purposes (4 marks)

1. **Air entrainment / loss of suction** – bilge systems often contain air pockets; centrifugal pumps are not self-priming, so they can lose suction.
2. **Abrasive solids** – bilge water may contain silt, rust, scale, or debris, which can erode impellers and casings.
3. **Corrosive liquids** – bilge and ballast water can be contaminated with oil, chemicals, or seawater, leading to corrosion.
4. **Variable suction conditions** – fluctuating liquid levels may cause cavitation, vibration, and reduced efficiency.

(b) TWO methods used to improve pump performance (6 marks)

1. **Use of a priming system** – e.g. a liquid ring or positive displacement priming pump connected to the centrifugal pump suction, ensuring the pump remains primed and effective.
    - *Benefit:* Prevents air lock and ensures reliable operation even with variable suction.
2. **Fitting strainers and robust materials** – suction strainers filter out solids and debris, while impellers and casings may be made of wear-resistant or corrosion-resistant materials (e.g. bronze, stainless steel).

- *Benefit:* Reduces wear, prevents blockage, and extends pump life.



3. With reference to air compressors:

(a) state TWO advantages of rotary air compressors; (2)

(b) state ONE advantage of reciprocating air compressors; (1)

(c) explain why multistage air compressors are used for starting air purposes. (7)

(a) TWO advantages of rotary air compressors (2 marks)

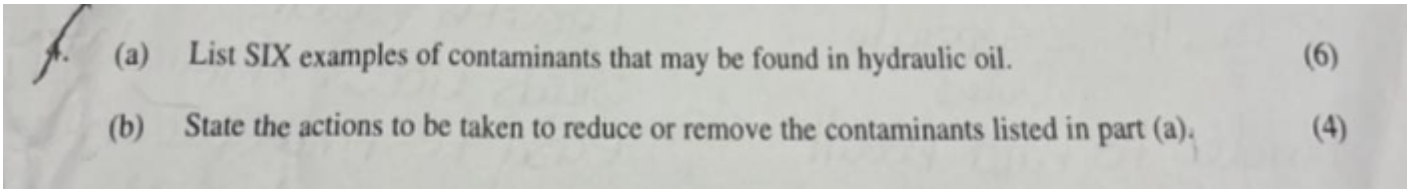
1. Deliver **continuous, pulse-free airflow** (smoother operation compared to reciprocating).
2. **High capacity for size**, compact and lighter with fewer moving parts, so lower vibration and easier maintenance.

(b) ONE advantage of reciprocating air compressors (1 mark)

- Can achieve **very high pressures** (suitable for main engine starting air, up to 30 bar or more).

(c) Why multistage air compressors are used for starting air purposes (7 marks)

1. **High final pressure** required (typically 30 bar for starting air) cannot be achieved efficiently in a single stage.
2. **Compression ratio per stage** is reduced → avoids excessive temperature rise in one stage.
3. **Intercooling between stages** reduces air temperature, increases air density, and lowers work input.
4. **Improved efficiency** since less power is required to compress cooled, denser air.
5. **Reduced risk of lubrication breakdown** and fire/explosion because discharge temperatures are lower.
6. **Better mechanical reliability** – lower stresses on pistons, valves, and cylinders.
7. **Dryer, cleaner air** – intercoolers help remove moisture and oil mist, protecting the air start system.



4. (a) List SIX examples of contaminants that may be found in hydraulic oil. (6)

(b) State the actions to be taken to reduce or remove the contaminants listed in part (a). (4)

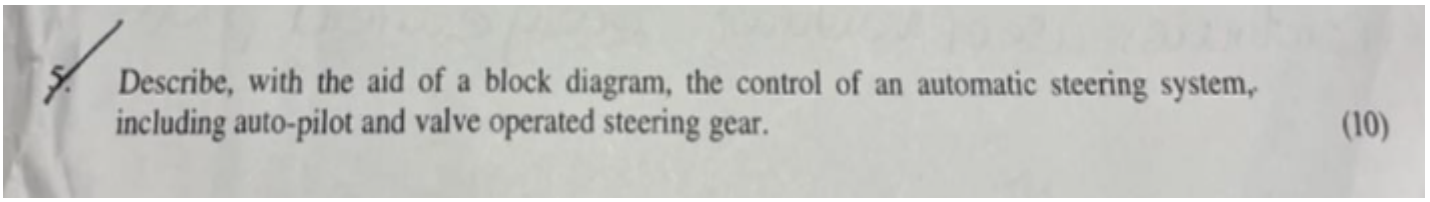
(a) SIX examples of contaminants in hydraulic oil (6 marks)

1. **Water** – from condensation, leaks in coolers, or tank vents.
2. **Air bubbles/entrained air** – from poor sealing or suction leaks.

3. **Dirt and dust particles** – from the environment or poor tank sealing.
4. **Metal particles** – from wear of pumps, valves, or actuators.
5. **Fibres/rubber fragments** – from degraded seals, hoses, or filters.
6. **Oxidation products/sludge/varnish** – from oil breakdown at high temperature.

(b) Actions to reduce/remove contaminants (4 marks)

1. **Filtration** – fine filters and strainers to remove dirt, wear particles, and fibres.
2. **Water separation** – by settling tanks, centrifuges, or water-absorbing filters.
3. **Air removal** – by proper system design, deaeration chambers, and ensuring suction lines are airtight.
4. **Good housekeeping** – clean oil storage, sealed filling equipment, routine sampling, and timely oil replacement.



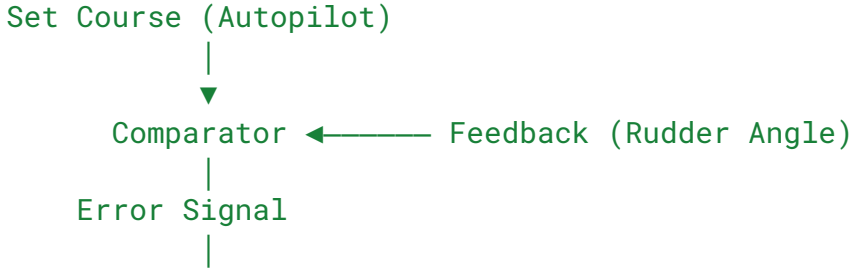
5. Describe, with the aid of a block diagram, the control of an automatic steering system, including auto-pilot and valve operated steering gear. (10)

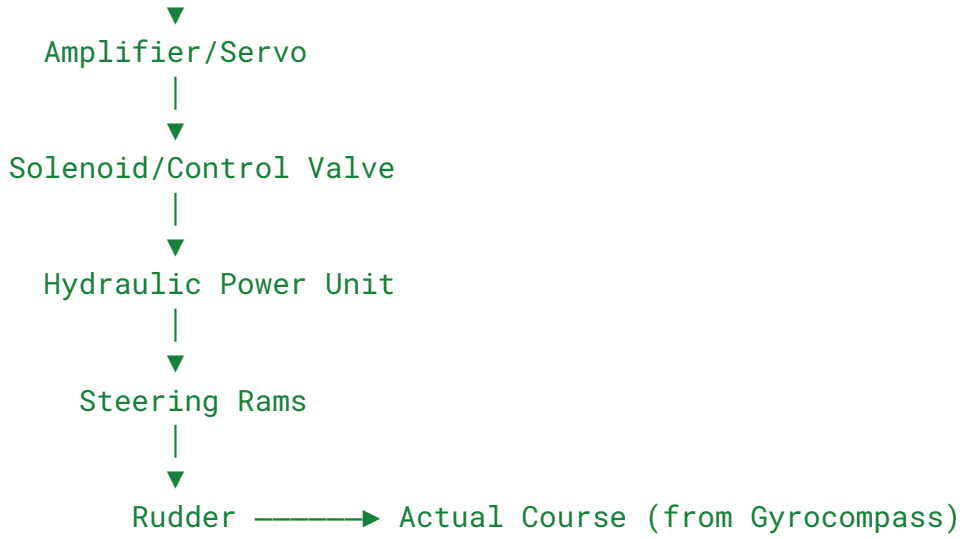
(a) Description (with autopilot and valve-operated steering gear)

- The **autopilot (controller)** compares the **set course** (desired heading) with the **actual course** (from the gyrocompass).
- Any **error signal** (difference between set course and actual course) is amplified and sent to the **servo amplifier**.
- The **servo amplifier** operates a **solenoid or follow-up valve** in the steering gear system.
- The **valve** directs pressurised hydraulic oil from the pump to either side of the **steering gear ram**.
- The **ram moves**, turning the rudder until the vessel's heading matches the set course.
- A **feedback signal** from the rudder angle indicator is fed back into the system to cancel the error and prevent overshoot/hunting.

This forms a **closed-loop control system** with proportional and follow-up action.

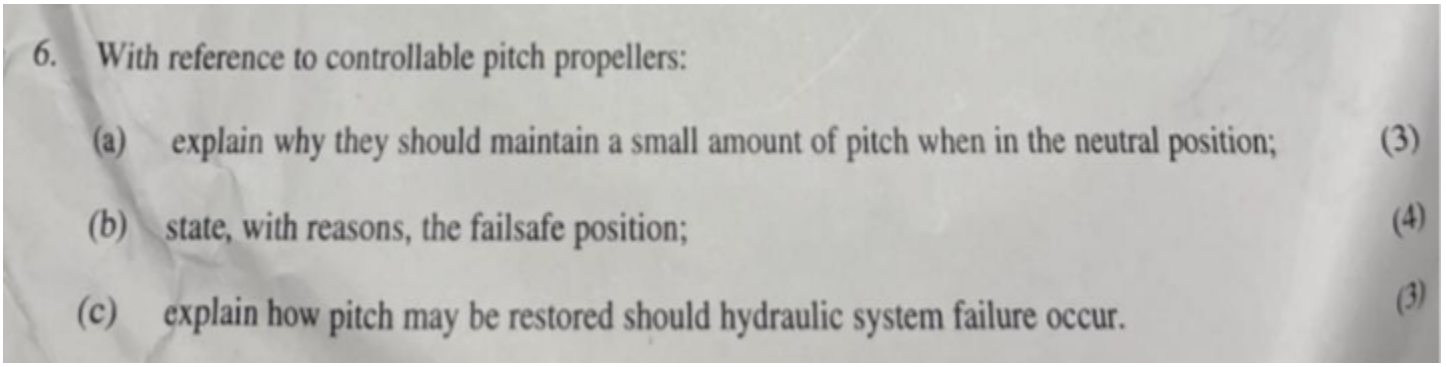
(b) Block diagram (simplified)





(c) Key Points for Marks

1. Autopilot sets course.
2. Comparator compares with gyrocompass heading.
3. Error amplified and used to operate valve.
4. Valve directs hydraulic oil to steering gear.
5. Ram/rudder moves to correct course.
6. Feedback signal (rudder angle transmitter).
7. Closed-loop ensures accuracy.
8. Hydraulic power provides force.
9. Valve-operated system prevents overshoot.
10. Safety: can be switched to manual control if autopilot fails.



6. With reference to controllable pitch propellers:

(a) explain why they should maintain a small amount of pitch when in the neutral position; (3)

(b) state, with reasons, the failsafe position; (4)

(c) explain how pitch may be restored should hydraulic system failure occur. (3)

(a) Explain why they should maintain a small amount of pitch when in the neutral position. (3 marks)

- If blades are set to exactly zero pitch, **vibration and hunting** can occur due to fluctuating forces on the blades.

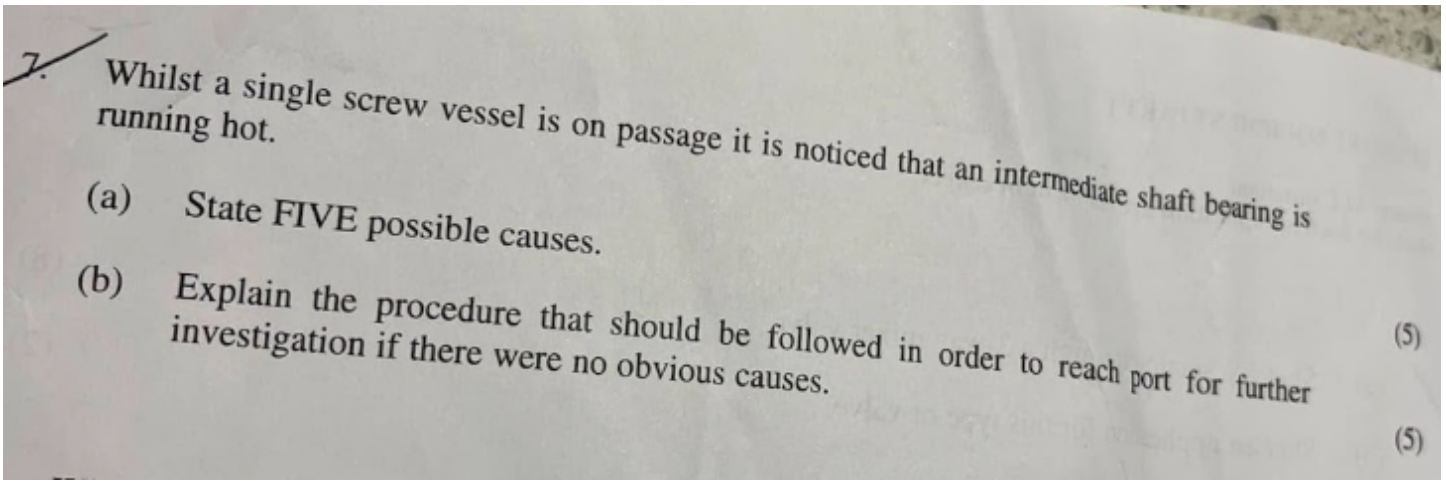
- A small positive pitch ensures **smooth water flow** over the blades, preventing cavitation and reducing mechanical stress.
- It also avoids the risk of **shaft resonance** and allows easier transition into ahead or astern operation.

(b) State, with reasons, the failsafe position. (4 marks)

- The failsafe position is usually set to **"Full Astern" or "Zero Thrust"** depending on vessel type and safety philosophy.
- **Full Astern**: On some ships, this is chosen to quickly stop the vessel in case of control failure.
- **Zero Thrust (small ahead pitch)**: On others, to avoid uncontrolled astern movement and keep the shaft rotating smoothly for lubrication and cooling of bearings.
- The chosen failsafe ensures the vessel remains **under control** and prevents damage to shaft bearings and propulsion machinery.

(c) Explain how pitch may be restored should hydraulic system failure occur. (3 marks)

- A **mechanical/manual hand pump** is usually fitted to supply oil pressure to the servo system in case of main hydraulic pump failure.
- Some systems use **accumulators** that store hydraulic pressure to move the blades to a safe pitch setting.
- Emergency pitch can also be set by **local manual control at the hub or control stand**, bypassing the automatic control system.



7. Whilst a single screw vessel is on passage it is noticed that an intermediate shaft bearing is running hot.

(a) State FIVE possible causes.

(b) Explain the procedure that should be followed in order to reach port for further investigation if there were no obvious causes. (5)

(5)

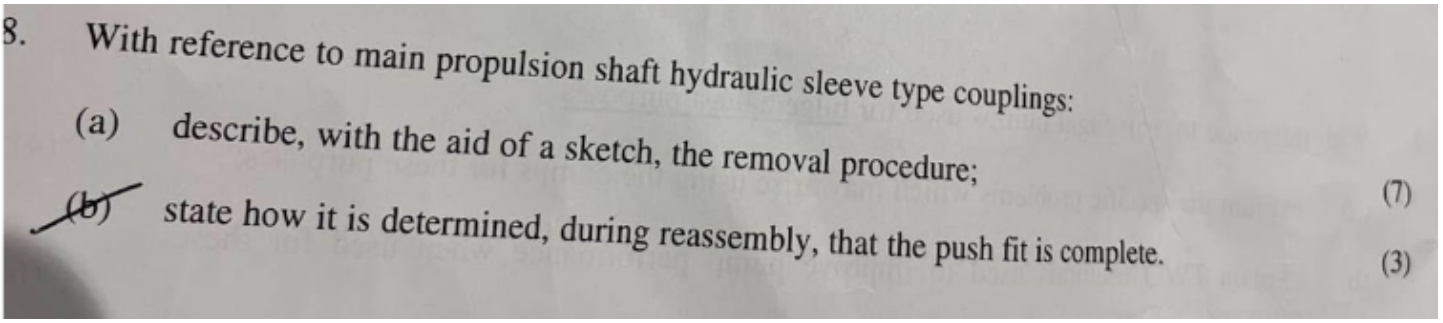
(a) Five possible causes of an intermediate shaft bearing running hot (5 marks)

1. **Insufficient lubrication** – low oil level, pump failure, or blocked oil supply line.
2. **Contaminated lubricant** – dirt, salt, or water ingress reducing lubrication effectiveness.
3. **Excessive bearing load or misalignment** – hull deflection, improper alignment, or worn foundation.

4. **Excessive shaft vibration** – imbalance, whirling, or propeller damage transmitting vibration.
5. **Bearing wear or damage** – scoring, pitting, or reduced clearance causing metal-to-metal contact.

(b) Procedure to be followed to reach port safely if no obvious causes are found (5 marks)

1. **Reduce engine load / speed** – lowers bearing load and heat generation.
2. **Increase lubrication rate (if possible)** – ensure maximum cooling and lubrication.
3. **Monitor temperature continuously** – use thermometers or alarms to track condition.
4. **Regular inspection during passage** – frequent checks of vibration, sound, and lubricant condition.
5. **Prepare for emergency action** – be ready to further reduce speed, stop, or transfer propulsion to emergency means if bearing temperature rises uncontrollably.



8. With reference to main propulsion shaft hydraulic sleeve type couplings:

(a) describe, with the aid of a sketch, the removal procedure; (7)

(b) state how it is determined, during reassembly, that the push fit is complete. (3)

(a) Describe, with the aid of a sketch, the removal procedure (7 marks)

Procedure:

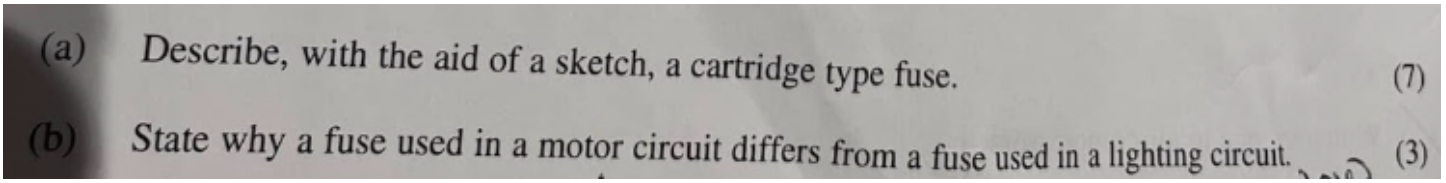
1. **Preparation:** Remove coupling bolts, fit oil injection equipment to the hydraulic ports on the coupling sleeve.
2. **Oil Injection:** High-pressure oil (typically 700–1000 bar) is pumped into the annular space between the shaft and the coupling sleeve.
3. **Hydraulic Expansion:** The oil film reduces friction and slightly expands the sleeve, breaking the interference fit between the shaft and coupling.
4. **Axial Movement:** With friction eliminated, the coupling can be withdrawn by using jacking bolts, a hydraulic jack, or manual winch gear.
5. **Safety Precautions:** Maintain hydraulic pressure until the sleeve is fully moved, then safely depressurise the system and remove equipment.
6. **Final Step:** Withdraw the shaft or coupling completely for inspection/maintenance.

Sketch (for exam):

- Show **shaft**, **hydraulic sleeve coupling**, **oil injection point**, **HP pump line**, and **jacking bolts**.
- Arrows to indicate **oil injection** and **axial withdrawal direction**.

(b) State how it is determined, during reassembly, that the push fit is complete (3 marks)

1. **Correct axial position:** The coupling hub face aligns with the scribed reference marks made before removal.
2. **Hydraulic pressure drop:** A sudden fall in injection pressure indicates metal-to-metal contact and proper seating.
3. **No further axial movement:** Even when hydraulic pressure is maintained, the coupling does not move further onto the shaft.


(a) Describe, with the aid of a sketch, a cartridge type fuse. (7)

(b) State why a fuse used in a motor circuit differs from a fuse used in a lighting circuit. (3)

(a) Describe, with the aid of a sketch, a cartridge type fuse. (7 marks)

Description:

- A cartridge fuse is a protective device designed to protect electrical circuits from overcurrent.
- It consists of a cylindrical body, usually made of **ceramic or glass**, filled with arc-quenching material such as **silica sand**.
- Inside the body, there is a **fuse element (wire/strip)** of specific cross-section that melts when the current exceeds its rated capacity.
- **Metal end caps** are fitted on both ends, allowing the fuse to be inserted into a holder for good electrical contact.
- When excessive current flows, the element heats up and melts, breaking the circuit safely.

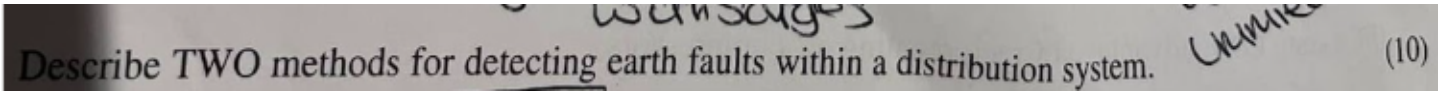
Sketch (exam style to include labels):

- Cylindrical body (ceramic/glass)
- Fuse element (wire/strip inside)
- Silica filling (arc suppression)
- End caps (for circuit connection)

(b) State why a fuse used in a motor circuit differs from a fuse used in a lighting circuit. (3 marks)

- **Motor circuits** experience **high inrush (starting) current**, often several times the rated running current, which lasts a short time.

- Therefore, **motor fuses** are designed with a **time delay (slow-blow characteristic)** to withstand this surge without blowing.
- **Lighting circuits**, however, have no high inrush current and therefore use **fast-acting fuses** that blow immediately on overcurrent to protect delicate wiring.


Describe TWO methods for detecting earth faults within a distribution system. (10)

Q: Describe TWO methods for detecting earth faults within a distribution system. (10 marks)

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1. Earth Fault Lamps (Lamp Balance System):

- Three lamps are connected in star across the three phases with the neutral point connected to earth.
- Under normal balanced conditions, the lamps glow dimly or remain off, as the potential across each is equal.
- If an earth fault occurs on one phase, the balance is disturbed:
  - The lamp in the faulty phase will extinguish.
  - The other two lamps will glow brightly.
- This provides a **visual indication** of which phase is earthed.

(Marks: diagram of three lamps in star, explanation of balance and fault behaviour).

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2. Earth Fault Relays (Current or Voltage Detection):

- Protective relays are fitted to detect earth leakage current or imbalance in the system.
- **Zero-sequence current transformer (CT):** All three phase conductors pass through a common CT. Under healthy conditions, the vector sum of the currents is zero.
- If an earth fault occurs, the imbalance produces a residual current in the CT, which energises a relay.
- The relay can activate an alarm and/or trip the circuit breaker to isolate the faulty circuit.

(Marks: explanation of residual current principle + mention of relay action).

✅ **Exam Tip:**

- Include a simple sketch for both methods:
  - **Earth fault lamp circuit** (star-connected lamps with earth).
  - **Earth fault relay with CT** showing three phases through a toroidal CT connected to a relay.
- Writing **principle + indication + action** ensures full marks.