

AUXILIARY EQUIPMENT PART 1

Attempt ALL questions

Marks for each part question are shown in brackets

1. With reference to ship's side valves:
 - (a) state why grey cast iron is not a suitable material;
 - (b) state, with reasons, TWO suitable materials;
 - (c) state the regular maintenance that the valves should receive, outlining reasons for this maintenance.

2.
 - (a) Describe, with the aid of sketches, the operating principles of a centrifugal pump.
 - (b) State why centrifugal pumps are not self-priming.

3.
 - (a) Explain the circumstances under which EACH of the following devices fitted to an air compressor may operate:
 - (i) fusible plug;
 - (ii) bursting disc.
 - (b) State where EACH device in part (a) may be fitted.

4. With reference to hydraulic systems:
 - (a) state THREE possible contaminations;
 - (b) state possible causes of the contaminations stated in part (a).
 - (c) explain how the contaminants stated in part (a) are prevented from affecting the system.

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

6. With reference to controllable pitch propellers:
 - (a) describe a mechanism that changes the pitch of the blades;
 - (b) explain how the pitch of the blades is indicated.

7. With reference to intermediate shaft bearings of the roller type, describe, with the aid of a sketch, EACH of the following:
- how some angular misalignment of the shaft is accommodated;
 - how longitudinal movement of the shaft is accommodated.
8. Sketch an arrangement for the aft seal of an oil lubricated stern tube bearing.
9. (a) State FIVE devices fitted to a main distribution switchboard in order to protect a.c. generators that can be operated in single or parallel mode.
- (b) Explain why EACH device stated is needed.
10. (a) Explain the term *single phasing*.
- (b) State the effects on a motor of single phasing.
- (c) State how single phasing may be protected against in the motor starter circuit.

1. With reference to ship's side valves:
- state why grey cast iron is not a suitable material;
 - state, with reasons, TWO suitable materials;
 - state the regular maintenance that the valves should receive, outlining reasons for this maintenance.

(a) Why grey cast iron is not suitable (2 marks)

- Grey cast iron is **brittle** and has poor impact resistance.
- Under shock loading (e.g. collision, debris impact, or sudden pressure surges), it may fracture suddenly and dangerously.

- It is also more prone to **corrosion in seawater**, reducing reliability.
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(b) Two suitable materials with reasons (4 marks)

1. Bronze (gunmetal or aluminium bronze)

- Excellent **corrosion resistance** in seawater.
- Good toughness and machinability, making it reliable for prolonged service.

2. Steel (cast steel or stainless steel)

- **High strength and toughness**, less risk of brittle fracture.
 - Can withstand **impact loads** and high pressures.
 - Stainless grades additionally resist seawater corrosion.
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(c) Regular maintenance required (4 marks)

- **Regular operation of valves** to prevent seizure and ensure free movement.
- **Inspection for corrosion, erosion, and wastage** of valve body and seat to maintain sealing integrity.
- **Lubrication of moving parts** where applicable to reduce wear.
- **Testing valve closure tightness** to ensure watertight integrity in emergencies.
- **Cleaning and removal of marine growth** around valves to prevent blockage and ensure full flow.

Reason: These maintenance practices ensure that the ship's side valves remain reliable for **safety, watertight integrity, and operational efficiency**, especially since failure could lead to flooding.

2. (a) Describe, with the aid of sketches, the operating principles of a centrifugal pump.
- (b) State why centrifugal pumps are not self-priming.

(a) Operating principle of a centrifugal pump (with sketches) (6–7 marks)

- A centrifugal pump consists of an **impeller** mounted on a shaft inside a casing.
- **Liquid enters** the pump axially at the centre of the rotating impeller (called the **eye of the impeller**).
- As the impeller rotates, it **imparts velocity (kinetic energy)** to the liquid by centrifugal force, throwing it radially outwards.
- The **volute casing** or diffuser passages then **convert this velocity energy into pressure energy**, producing a steady flow at the pump outlet.

- The continuous movement is maintained by suction at the impeller eye as fluid is discharged, ensuring a steady supply if the suction line remains flooded.

Sketches to include in your notes:

1. Simple impeller cross-section (showing eye, blades, and radial discharge).
 2. Volute casing showing velocity → pressure energy conversion.
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(b) Why centrifugal pumps are not self-priming (3–4 marks)

- A centrifugal pump requires the impeller passages to be filled with liquid before it can develop suction.
- If filled with air, the impeller cannot impart sufficient velocity or pressure to the air (low density, compressible).
- This means **no vacuum is created at the eye**, so liquid cannot be drawn into the pump from the suction line.
- Therefore, they must either be fitted **below liquid level (flooded suction)** or be primed using a **separate priming pump, ejector, or vacuum system** before operation.

3. (a) Explain the circumstances under which EACH of the following devices fitted to an air compressor may operate;
- (i) fusible plug;
 - (ii) bursting disc.
- (b) State where EACH device in part (a) may be fitted.

(a) Circumstances under which each device may operate

(i) Fusible plug (2 marks)

- The fusible plug contains a low-melting-point alloy (e.g. tin/lead).
- If the **air compressor delivery temperature rises excessively** (e.g. due to lubrication failure, cooling water failure, or overheating from compression), the alloy melts.
- This opens the plug and releases compressed air to atmosphere, preventing fire/explosion caused by oil vapour ignition.

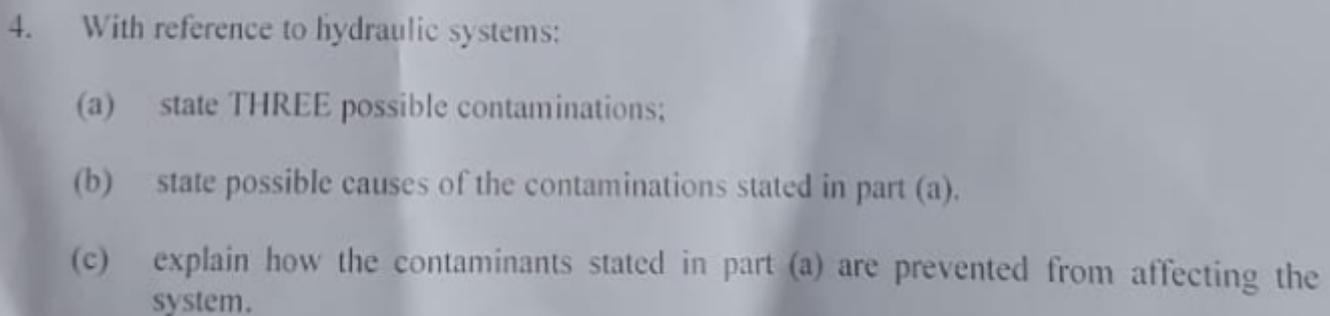
(ii) Bursting disc (2 marks)

- A thin diaphragm designed to rupture at a set safe pressure.

- Operates if the **pressure inside the air compressor or its receiver exceeds the design limit** (e.g. safety valve failure, pressure regulator malfunction).
 - The disc ruptures, venting compressed air safely to atmosphere, thus preventing catastrophic vessel rupture.
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(b) Where each device may be fitted

- **Fusible plug:** fitted in the **compressor delivery line** or **intercooler/discharge line**, where there is a risk of overheating and oil vapour ignition.
- **Bursting disc:** fitted on the **compressor casing, intercoolers, or air receiver**, where sudden pressure rise could cause dangerous rupture.

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4. With reference to hydraulic systems:
- state THREE possible contaminations;
 - state possible causes of the contaminations stated in part (a).
 - explain how the contaminants stated in part (a) are prevented from affecting the system.

(a) State THREE possible contaminations (3 marks)

1. **Solid particles** – e.g. dirt, dust, metal wear debris.
 2. **Water contamination** – from condensation, leaks, or cooling water ingress.
 3. **Air/gas contamination** – entrained air bubbles or dissolved gases.
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(b) State possible causes of the contaminations stated in part (a) (3 marks)

1. **Solid particles** – caused by poor maintenance, wear of pump/valve components, dirty oil filling, or inadequate sealing.
 2. **Water contamination** – condensation in the oil reservoir, leaking heat exchangers, or ingress through faulty seals.
 3. **Air/gas contamination** – poor bleeding of the system, suction leaks on pump inlet lines, or low oil levels causing vortexing.
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(c) Explain how the contaminants are prevented from affecting the system (4 marks)

1. **Filtration systems (filters/strainers)** – remove solid particles before they can damage sensitive components.
2. **Water separators and breathers** – prevent moisture ingress and allow venting while blocking contaminants.
3. **Reservoir design and deaeration devices** – allow entrained air to separate and escape.
4. **Regular maintenance (oil analysis, draining, replacement)** – ensures contamination is detected and removed early.

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

Q5. Automatic Steering System (with block diagram)

Description of Operation

1. **Course Setting (Autopilot input):**
 - The helmsman sets the desired course on the **autopilot unit**.
 - The autopilot compares the ship's actual heading (from the **gyrocompass**) with the set course.
2. **Error Signal Generation:**
 - Any difference between the desired heading and actual heading is calculated.
 - This produces an **error signal** proportional to the course deviation.
3. **Amplification & Control:**
 - The error signal is sent to the **amplifier/controller**, which boosts and conditions it.
 - The controller determines the size and direction of rudder movement needed to correct the error.
4. **Electro-Hydraulic Interface:**
 - The amplified signal operates a **solenoid-controlled follow-up valve** (or servo valve).
 - This valve directs **hydraulic oil** to the steering gear actuator (hydraulic rams or rotary vane motor).
5. **Rudder Movement:**
 - Hydraulic power moves the rudder to the required angle.
 - The **rudder angle transmitter** sends feedback to the autopilot system.
6. **Feedback Loop:**
 - Once the rudder has corrected the heading error, the feedback cancels out the error signal.

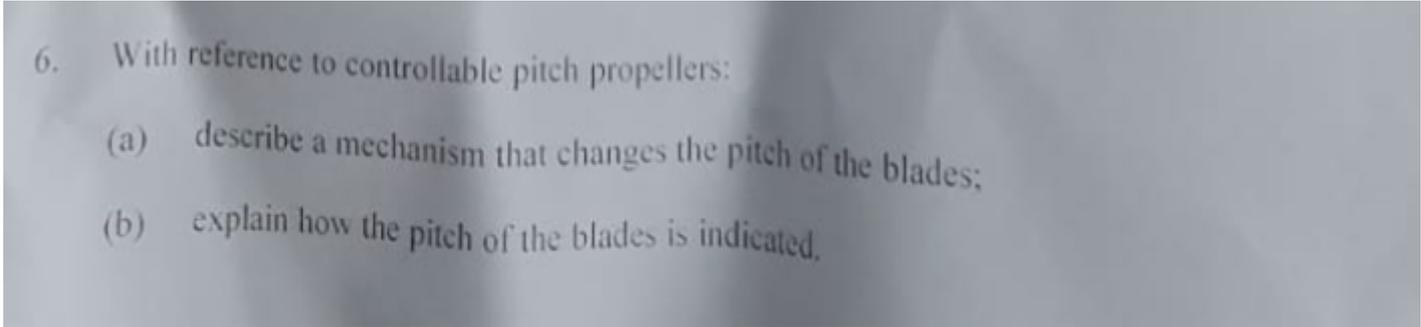
- The rudder is then returned to neutral, preventing oversteer (hunting).

Gyrocompass (heading sensor) → Autopilot Comparator (set vs actual course)

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Error Signal → Amplifier/Controller → Solenoid Valve (servo control)

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Hydraulic Steering Gear (rams/vane motor) → Rudder

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Rudder Angle Transmitter (feedback) → Autopilot Comparator

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6. With reference to controllable pitch propellers:
- (a) describe a mechanism that changes the pitch of the blades;
 - (b) explain how the pitch of the blades is indicated.

(a) Describe a mechanism that changes the pitch of the blades (6 marks)

- CPP blades are mounted on trunnions in the hub, allowing them to rotate about their own axes.
- A **hydraulic servo piston**, located inside the hub, is used to move the blades.
- Hydraulic oil is supplied through a **hollow propeller shaft** from a hydraulic pump system.
- The piston is connected to each blade root via **crankpins and links**; movement of the piston rotates the blades simultaneously, altering pitch.
- The hydraulic system is controlled by a **governor or remote control unit**, which regulates oil pressure and direction to achieve ahead, astern, or variable thrust.
- Mechanical stops and feedback mechanisms prevent over-travel and ensure safe operation.

(b) Explain how the pitch of the blades is indicated (4 marks)

- Pitch indication is normally obtained by **feedback linkage or electronic transducer** connected to the servo piston.
- As the piston moves, its position corresponds directly to blade angle, which is transmitted to a **bridge control pitch indicator**.
- Modern systems use **linear variable differential transformers (LVDTs)** or potentiometers to give continuous electrical signals to display pitch digitally.
- Thus, the ship's control room and bridge can always monitor the exact propeller pitch.

7. With reference to intermediate shaft bearings of the roller type, describe, with the aid of a sketch, EACH of the following:
- how some angular misalignment of the shaft is accommodated;
 - how longitudinal movement of the shaft is accommodated.

(a) How some angular misalignment of the shaft is accommodated (5 marks)

- **Spherical roller bearings** or **self-aligning roller bearings** are used.
 - These bearings have two rows of barrel-shaped rollers running in an **outer raceway that is spherical**.
 - This spherical profile allows the inner ring (connected to the shaft) to tilt slightly inside the outer ring.
 - Hence, small angular misalignments of the shaft due to hull deflection, thermal expansion, or installation tolerances are accommodated without overloading the rollers.
 - This reduces stress concentrations and prevents premature bearing failure.
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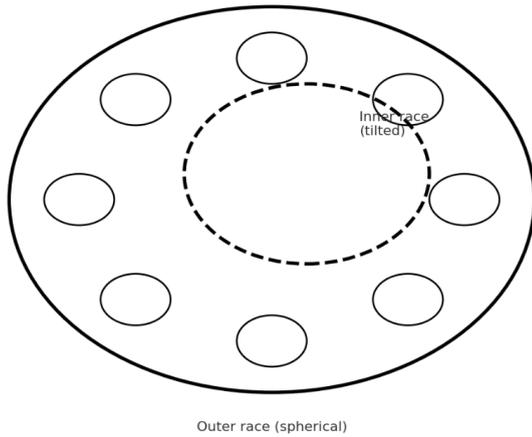
(b) How longitudinal movement of the shaft is accommodated (5 marks)

- One bearing (the **fixed bearing**) is designed to locate the shaft axially.
 - The other bearings (the **floating bearings**) allow axial movement.
 - This is achieved using **cylindrical roller bearings** or **spherical roller bearings** with specially designed inner raceways that allow the rollers to slide along the shaft axis.
 - This design accommodates **thermal expansion/contraction** of the long intermediate shaft without imposing axial stresses.
 - By fixing only one bearing and allowing the rest to float, smooth transmission and alignment are maintained.
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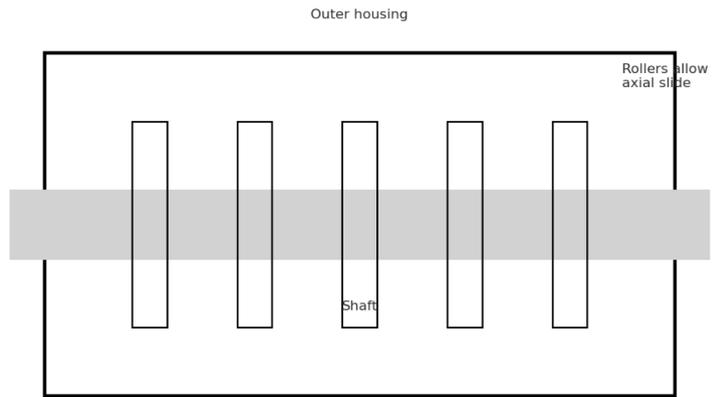
✓ Exam tip:

- Draw two sketches:
 1. **Self-aligning spherical roller bearing** → showing spherical outer race and two rows of rollers, with tilted inner ring.
 2. **Floating bearing arrangement** → showing rollers permitting axial shaft displacement relative to the housing.

Spherical Roller Bearing
(Self-aligning)

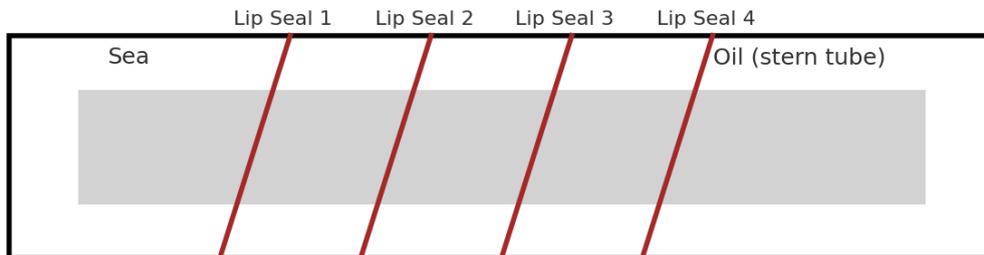


Floating Bearing
(Axial Movement)



8. Sketch an arrangement for the aft seal of an oil lubricated stern tube bearing.

Aft Seal Arrangement - Oil Lubricated Stern Tube Bearing



Here's a **sketch of the aft seal arrangement** for an oil-lubricated stern tube bearing:

- The **propeller shaft** runs through the stern tube.
- Multiple **lip seals (usually 3–4)** are arranged in series:
 - The forward-most seals retain **lubricating oil** inside the stern tube.
 - The aft-most seals prevent **sea water ingress**.
- The space between seals may be filled with oil or grease and is often monitored for leaks.
- A **seal housing** holds the sealing rings in position.

👉 In an exam, you would sketch:

- Shaft running through the centre.
- Housing around the shaft.
- Four lip seals angled alternately.
- Labels for **Sea side**, **Oil side**, and **sealing rings**.

9. (a) State FIVE devices fitted to a main distribution switchboard in order to protect a.c. generators that can be operated in single or parallel mode.
- (b) Explain why EACH device stated is needed.

Q9. (a) State FIVE devices fitted to a main distribution switchboard in order to protect A.C. generators that can be operated in single or parallel mode.

(b) Explain why EACH device stated is needed.

(a) Devices:

1. **Circuit Breaker / Overcurrent Protection**
 2. **Reverse Power Relay**
 3. **Under-Voltage / Over-Voltage Relay**
 4. **Under-Frequency / Over-Frequency Relay**
 5. **Earth Fault Protection**
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(b) Explanation of Each Device:

1. **Circuit Breaker / Overcurrent Protection**
 - Trips if current exceeds rated value (short circuit or overload).
 - Protects generator windings and cables from overheating and damage.
2. **Reverse Power Relay**
 - Prevents a generator in parallel from becoming a motor and driving the prime mover if it fails.
 - Protects against damage to the prime mover (e.g. diesel engine or turbine).
3. **Under-Voltage / Over-Voltage Relay**
 - Trips if the generator voltage deviates excessively from normal.
 - Prevents damage to sensitive equipment and ensures safe synchronisation.

4. Under-Frequency / Over-Frequency Relay

- Trips if the generator speed (hence frequency) is too low or too high.
- Protects equipment and maintains stability when operating in parallel.

5. Earth Fault Protection

- Detects leakage of current to earth due to insulation failure.
- Prevents fire, electric shock risk, and damage to generator windings.

10. (a) Explain the term *single phasing*.
- (b) State the effects on a motor of single phasing.
- (c) State how single phasing may be protected against in the motor starter circuit.

(a) Explain the term *single phasing*. (2 marks)

Single phasing occurs when **one phase of a three-phase supply fails** (open circuit in line, blown fuse, loose connection, or cable fault). As a result, the motor continues to run on the remaining two phases, but with unbalanced currents and reduced torque.

(b) State the effects on a motor of single phasing. (4 marks)

- Motor draws **excessive current** in the remaining two phases → overheating and possible winding damage.
 - **Loss of torque**, so the motor may not start under load, or if already running, it may slow or stall.
 - **Vibration and noise** due to unbalanced magnetic forces.
 - **Insulation failure risk** and possible burning of the windings if protection is not provided.
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(c) State how single phasing may be protected against in the motor starter circuit. (4 marks)

- **Phase failure relays (single-phasing relays)**: Detect imbalance or loss of a phase and trip the motor.
- **Overload relays (thermal or electronic)**: Sense overcurrent in the remaining phases and disconnect the supply.
- **Phase sequence/phase monitoring relays**: Monitor all three phases for correct supply conditions and disconnect if one is missing.