AUXILIARY EQUIPMENT PART I

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

1. (a) State, with reasons, the type of valve that should be used in EACH of the following situations:

    (i) isolating valve within a fire main; (2)

    (ii) main engine stand-by cooling water circulating pump discharge. (2)

   (b) With reference to a fuel service tank outlet valve:

    (i) describe its operation; (4)

    (ii) state the reason for the operation in part (b)(i). (2)

2. (a) State FOUR types of pumps suitable for use in a hydraulic system. (4)

   (b) Explain why the pumps stated in part (a) are suitable for hydraulic systems. (6)

3. With reference to reciprocating air compressors:

   (a) state the meaning of the term *bump clearance*; (2)

   (b) explain the effects on operation if the bump clearance is:

    (i) too large; (3)

    (ii) too small. (3)

   (c) explain how an aftercooler helps remove moisture from the air. (2)

4. With reference to hydraulic systems:

   (a) state FOUR applications for a hydraulic system on board a vessel; (4)

   (b) state the effects and possible causes of EACH of the following:

    (i) air in the system; (2)

    (ii) dirt and foreign particles in the system; (2)

    (iii) separated water in the system. (2)

5. With reference to an electro-hydraulic steering gear, explain EACH of the following:

(a) how steering may be maintained should the telemotor system fail; (5)

(b) how steering may be achieved should there be total failure of the hydraulic system. (5)

6. Describe, with the aid of a sketch, the operation of a transverse thruster that is hydraulically driven. (10)

7. Describe, with the aid of sketches, the fitting of a hydraulically tensioned bolt suitable for main propulsion shaft flanges. (10)

8. With reference to intermediate shaft bearings of the roller type, describe, with the aid of a sketch, EACH of the following:

(a) how some angular misalignment of the shaft is accommodated; (5)

(b) how longitudinal movement of the shaft is accommodated. (5)

9. With reference to electrical maintenance:

(a) explain the procedure for proving a motor circuit is isolated using a multimeter; (5)

(b) explain the procedure for testing the insulation resistance and earth bonding of the motor, giving examples of acceptable readings. (5)

10. (a) Sketch a block diagram of the layout of a vessel electrical distribution system for 440/220 V, including the main and emergency generators. (7)

(b) Describe the MCA recommended procedure for testing the Emergency Alternator. (3)

1. (a) State, with reasons, the type of valve that should be used in EACH of the following situations:

(i) isolating valve within a fire main; (2)

(ii) main engine stand-by cooling water circulating pump discharge. (2)

(b) With reference to a fuel service tank outlet valve:

(i) describe its operation; (4)

(ii) state the reason for the operation in part (b)(i). (2)

Q1 (a) State, with reasons, the type of valve that should be used in EACH of the following situations:

(i) Isolating valve within a fire main (2 marks)

- **Type of valve:** Gate valve.
- **Reason:** Gate valves give a full, unobstructed bore when open (low pressure loss, important in fire-fighting). They also provide tight shut-off when closed, suitable for isolating sections of the fire main.

(ii) Main engine stand-by cooling water circulating pump discharge (2 marks)

- **Type of valve:** Non-return (check) valve.
- **Reason:** Prevents backflow of water into the standby pump when the main pump is running. Ensures automatic operation of the standby pump when started, without manual intervention.

Q1 (b) With reference to a fuel service tank outlet valve:

(i) Describe its operation (4 marks)

- The outlet valve is typically a **quick-closing, remote-operated valve**.
- Operated manually or pneumatically/hydraulically from outside the machinery space.
- In normal operation, it remains open to supply fuel to the system.
- In an emergency (e.g., fire), the valve can be closed rapidly from a safe location to cut off fuel supply.

(ii) State the reason for the operation in part (b)(i) (2 marks)

- To prevent fuel oil feeding a fire in the event of a machinery space fire.

- Ensures rapid isolation of fuel without requiring personnel to enter the fire area, improving safety and fire control.

2. (a) State FOUR types of pumps suitable for use in a hydraulic system. (4)

(b) Explain why the pumps stated in part (a) are suitable for hydraulic systems. (6)

Q2 (a) State FOUR types of pumps suitable for use in a hydraulic system. (4 marks)

1. **Gear pump**
2. **Vane pump**
3. **Axial piston pump**
4. **Radial piston pump**

Q2 (b) Explain why the pumps stated in part (a) are suitable for hydraulic systems. (6 marks)

- **Gear pump**
  - Simple, robust design, relatively low cost.
  - Provides a constant flow at moderate pressures, reliable for many hydraulic applications.
- **Vane pump**
  - Smooth flow with little pulsation.
  - Can handle variable displacements (in some designs), making them useful where flow control is required.
- **Axial piston pump**
  - High efficiency and capable of operating at very high pressures.
  - Variable displacement versions allow precise flow and pressure control in complex hydraulic systems.
- **Radial piston pump**
  - Can generate very high pressures (higher than axial piston pumps).
  - Suitable for applications needing high power density in compact systems.

3. With reference to reciprocating air compressors:

(a) state the meaning of the term *bump clearance*; (2)

(b) explain the effects on operation if the bump clearance is:

(i) too large; (3)

(ii) too small. (3)

(c) explain how an aftercooler helps remove moisture from the air. (2)

Q3 (a) State the meaning of the term *bump clearance*. (2 marks)

- Bump clearance is the **minimum distance between the piston crown and the cylinder head (or valve plate)** when the piston is at Top Dead Centre (TDC).
- It ensures no mechanical contact occurs and allows for proper clearance with thermal expansion.

Q3 (b) Explain the effects on operation if the bump clearance is:

(i) Too large (3 marks)

- Reduced volumetric efficiency (more clearance volume, more re-expansion of compressed air).
- Lower overall compressor efficiency.
- Reduced delivery pressure and increased power consumption per unit of delivered air.

(ii) Too small (3 marks)

- Risk of mechanical contact between piston and cylinder head at TDC (damage to piston, valves, or head).
- Increased mechanical stress due to insufficient clearance for expansion.
- Possible overheating and knocking, leading to serious compressor damage.

Q3 (c) Explain how an aftercooler helps remove moisture from the air. (2 marks)

- The aftercooler **cools the compressed air**, reducing its temperature.
- As the air cools, its capacity to hold water vapour decreases, causing moisture to **condense into liquid water**, which is then collected and drained through a moisture trap.

4. With reference to hydraulic systems:

(a) state FOUR applications for a hydraulic system on board a vessel; (4)

(b) state the effects and possible causes of EACH of the following:

(i) air in the system; (2)

(ii) dirt and foreign particles in the system; (2)

(iii) separated water in the system. (2)

Q4 (a) State FOUR applications for a hydraulic system on board a vessel. (4 marks)

1. **Steering gear operation** – precise control of the rudder.
2. **Controllable pitch propeller (CPP) actuation** – adjustment of propeller blade angle.
3. **Windlass and mooring winches** – anchor handling and mooring line control.
4. **Stabiliser fin actuation** – roll reduction at sea.
   (Other acceptable examples: hatch covers, cranes, cargo winches, ramps/lifts).

Q4 (b) State the effects and possible causes of EACH of the following:

(i) Air in the system (2 marks)

- *Effects*: Spongy/erratic operation, loss of control accuracy, cavitation, increased wear due to aeration.
- *Causes*: Poor bleeding during filling, leaks on suction side, low oil levels allowing vortex formation.

(ii) Dirt and foreign particles in the system (2 marks)

- *Effects*: Scoring of pump/valve surfaces, sticking of control valves, accelerated wear of seals and components.
- *Causes*: Poor filtration, dirty oil during topping-up, ingress through faulty seals or breathers.

(iii) Separated water in the system (2 marks)

- *Effects*: Corrosion of components, reduced lubrication, risk of cavitation and microbial growth.
- *Causes*: Condensation from humid air, leaking coolers, ingress through tank vents or seals.

5. With reference to an electro-hydraulic steering gear, explain EACH of the following:

(a) how steering may be maintained should the telemotor system fail; (5)

(b) how steering may be achieved should there be total failure of the hydraulic system. (5)

Q5. With reference to an electro-hydraulic steering gear:

(a) How steering may be maintained should the telemotor system fail (5 marks)

- The telemotor system transmits control signals (helm order) to the steering gear.
- If it fails, steering can be maintained by:
    1. **Local control**: Using the local trick wheel or control lever in the steering gear room to operate the hydraulic control valves directly.
    2. **Electrical follow-up system**: If fitted, switch to electric manual control from bridge emergency steering panel.
    3. **Manual operation of servo valves**: Operating the hydraulic control valves directly bypassing the telemotor.
    4. **Engine room personnel**: Receive helm orders by telephone/voice pipe/bridge-engine room communication system.
    5. **Standby telemotor (duplicated system)**: Many vessels have a second telemotor that can be brought into service.

(b) How steering may be achieved should there be total failure of the hydraulic system (5 marks)

- If **hydraulic power is lost**, the main steering gear rams cannot operate. Steering may then be maintained by:
    1. **Use of emergency/auxiliary steering gear**: A completely independent system (e.g. hand-operated mechanical gear, chain and sprocket system).
    2. **Emergency tiller**: Fitted directly to the rudder head, allows manual movement of rudder using tackles or jacks.
    3. **Differential engine thrust**: Use of main engine(s) or controllable pitch propeller to steer vessel by varying thrust (for twin screw or azimuth units).
    4. **Bow thrusters or stern thrusters** (if fitted) for manoeuvring at low speed.
    5. **Reduce vessel speed**: To maintain control and minimise risk while alternative steering arrangements are used.

6. Describe, with the aid of a sketch, the operation of a transverse thruster that is hydraulically driven. (10)

Q6. Describe, with the aid of a sketch, the operation of a transverse thruster that is hydraulically driven.
(10 marks)

Description:

- A **transverse thruster** (commonly called a bow thruster or stern thruster) is fitted in a tunnel across the vessel's hull near the bow or stern.
- It provides **side thrust** to improve manoeuvrability in confined waters, docking, or undocking without tug assistance.
- In a **hydraulically driven system**:
    - Hydraulic oil is supplied under pressure from pumps (often driven by electric motors or main engines).
    - The hydraulic power drives a **hydraulic motor** located close to the tunnel thruster.
    - The motor rotates a propeller (sometimes two contra-rotating) within the tunnel.
    - By controlling the **direction of oil flow** using a directional control valve, the motor can rotate in either direction, producing thrust to port or starboard.
    - The **flow rate of oil** determines motor speed and hence the magnitude of thrust.
- The hydraulic system includes:
    - **Reservoir and filters** (to provide clean oil).
    - **Relief valves** (to protect against overload).
    - **Control valves** (for direction and thrust magnitude).
    - **Coolers** (to dissipate heat).

Operation sequence:

1. Operator selects **thrust direction** at the bridge control panel.
2. Electrical signal energises a **solenoid-operated hydraulic control valve**.
3. Hydraulic oil is directed to the motor in the chosen direction.
4. Motor drives the thruster propeller, creating lateral thrust.
5. **Feedback sensors** (oil pressure, motor speed, tunnel flow) ensure correct operation.

Sketch (exam style):

Your sketch should show:

- A **transverse tunnel** through the bow of the vessel.
- A **hydraulic motor** mounted on the tunnel, connected to the propeller shaft.
- **Hydraulic supply lines** (pressure and return) from a pump/reservoir system.

- A **directional control valve** and relief valve in the circuit.
- Arrows showing **oil flow direction** and **thrust direction** (port or starboard).

Key points for full marks:

- Identify it as a bow/stern thruster.
- State that it is hydraulically driven (hydraulic motor in tunnel).
- Explain how direction of oil flow controls thrust direction.
- State that flow rate controls magnitude of thrust.
- Mention safety/auxiliary equipment (filters, relief valves, coolers).
- Include a **clear labelled sketch**.

7. Describe, with the aid of sketches, the fitting of a hydraulically tensioned bolt suitable for main propulsion shaft flanges. (10)

Q7. Describe, with the aid of sketches, the fitting of a hydraulically tensioned bolt suitable for main propulsion shaft flanges. (10)

Answer:

Description:

- Hydraulic bolt tensioning is used to achieve accurate and uniform preload in heavily loaded flange connections such as propulsion shaft flanges.
- Instead of applying torque (which introduces frictional error), hydraulic pressure directly stretches the bolt to the required tension.

Fitting Procedure:

1. **Positioning the bolt:** The hydraulic tensioning bolt is inserted through the flange holes, with its nut loosely fitted.
2. **Mounting the hydraulic jack:** A hydraulic tensioning tool (jack) is placed over the bolt end and engages the bolt's puller thread.
3. **Applying hydraulic pressure:** Hydraulic oil is pumped into the jack, which applies an axial tensile force to stretch the bolt elastically.
4. **Nut tightening:** While the bolt is elongated, the nut is run down to the flange face using minimal torque.
5. **Pressure release:** Hydraulic pressure is released, allowing the bolt to contract and place the nut under high clamping load.

6. **Completion:** The jack is removed, and the process is repeated for all bolts in sequence to ensure even loading.

Advantages:

- Achieves very accurate preload.
- Minimises thread and flange surface damage (low torque required).
- Ensures uniform distribution of stresses.
- Safe and efficient for large-diameter bolts.

Sketch (exam-style):

A clear cross-section would show:

- Flange faces.
- Bolt passing through flange.
- Nut on bolt.
- Hydraulic tensioning jack on bolt end.
- Arrows showing *hydraulic pressure applied* and *bolt elongation*.

8. With reference to intermediate shaft bearings of the roller type, describe, with the aid of a sketch, EACH of the following:

(a) how some angular misalignment of the shaft is accommodated; (5)

(b) how longitudinal movement of the shaft is accommodated. (5)

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

- **Self-aligning spherical roller bearings** are commonly used.
- These have **spherical outer raceways** which allow the inner ring to tilt slightly relative to the outer ring.
- This feature compensates for **small angular misalignments** in the shaft caused by hull deflection, elastic deformation, or slight installation inaccuracies.
- Misalignment is taken up without creating excessive stress on rollers or races.
- This ensures smooth load transfer, reduces localized stress, and prevents premature failure.

Sketch: show a spherical roller bearing with spherical outer race and rollers arranged in two rows; inner race tilted slightly to illustrate misalignment accommodation.

(b) How longitudinal movement of the shaft is accommodated (5 marks)

- In a shafting system, **thermal expansion or contraction** causes axial movement.
- To allow for this, **one bearing is fixed**, and others are designed as **floating bearings**.
- A floating bearing uses **cylindrical roller bearings** or special raceways which allow the rollers/inner race to **slide axially** relative to the outer race.
- This design permits free shaft expansion without imposing axial stress on the shaft or bearing.
- It ensures correct alignment and avoids damage to couplings, bearings, and connected machinery.

Sketch: show a cylindrical roller bearing with straight raceways, indicating how rollers allow axial sliding of shaft within the bearing.

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9. With reference to electrical maintenance:

(a) explain the procedure for proving a motor circuit is isolated using a multimeter; (5)

(b) explain the procedure for testing the insulation resistance and earth bonding of the motor, giving examples of acceptable readings. (5)

Q9. With reference to electrical maintenance:

(a) Explain the procedure for proving a motor circuit is isolated using a multimeter. (5)

1. **Identify and isolate the circuit** – Switch off the motor supply at the distribution board and apply lock-out/tag-out.
2. **Select correct meter function** – Set the multimeter to measure **AC voltage** in the correct range (typically > 400 V).
3. **Prove the meter** – Test the multimeter on a known live supply first to ensure it is working.
4. **Test the motor circuit** – Measure between:
   - All three phases (L1–L2, L2–L3, L1–L3).
   - Each phase to neutral (if present).
   - Each phase to earth.
     A correct isolation will show **0 V (or negligible voltage)** in all cases.
5. **Prove the meter again** – Re-test on a known live supply to confirm the multimeter is still operational.

👉 This proves both the circuit is dead and that the measuring instrument was functional.

(b) Explain the procedure for testing the insulation resistance and earth bonding of the motor, giving examples of acceptable readings. (5)

1. **Insulation Resistance Test (IR):**

- Disconnect motor windings from supply and discharge any capacitors.
- Use an **insulation resistance tester (Megger)** set typically at 500 V DC.
- Measure between:
  - Each phase to earth.
  - Between each pair of phases.
- **Acceptable readings:** Generally **>1 MΩ**, with good insulation often >5–10 MΩ.
- If readings are low (<1 MΩ), the motor insulation may be damp, dirty, or deteriorated.

2. **Earth Bonding Test:**
   - Use a **low-resistance ohmmeter** or continuity tester.
   - Measure resistance between the motor frame and the ship's earth/earth bus.
   - **Acceptable reading:** Very low resistance, typically **<0.5 Ω**, proving good metallic bonding.

👉 These tests ensure the motor is safe to operate, preventing shock hazards and insulation breakdown.

10. (a) Sketch a block diagram of the layout of a vessel electrical distribution system for 440/220 V, including the main and emergency generators. (7)

(b) Describe the MCA recommended procedure for testing the Emergency Alternator. (3)

(a) Block diagram of vessel electrical distribution system (440/220 V)

A typical layout should include:

- **Main Generators (440 V, 3-phase A.C.)** → feeding → **Main Switchboard**.
- From the **Main Switchboard**:
  - **Essential Services** (e.g. propulsion auxiliaries, pumps, steering gear, etc.).
  - **Transformers/Distribution Boards** → supplying **220 V services** (lighting, sockets, control circuits).
- **Emergency Generator (440 V)** → feeding → **Emergency Switchboard**.
- **Emergency Switchboard** → directly supplies essential/emergency services (emergency lighting, fire pump, steering gear, communication equipment).
- An **Automatic Changeover System** ensures that, on failure of the main supply, the emergency generator starts and supplies the emergency switchboard.

👉 In the exam, sketch boxes for each block and arrows showing power flow:

- **Main Generators → Main Switchboard → 440 V services + 220 V step-down**.
- **Emergency Generator → Emergency Switchboard → Emergency services**.

(b) MCA recommended procedure for testing the Emergency Alternator

1. **Automatic Starting Test** – Simulate a blackout (isolate main switchboard supply). The emergency generator should automatically start within 45 seconds and pick up the emergency switchboard load.

2. **Manual Starting Test** – Verify that manual start arrangements work (e.g. battery start or hydraulic start).

3. **Load Test** – Check that essential loads (emergency lighting, fire pumps, steering gear, communication, alarms) operate correctly from the emergency switchboard.

4. **Weekly Routine** – MCA requires weekly testing of the emergency generator under load, with results recorded in the logbook.