AUXILIARY EQUIPMENT PART I

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

1. With reference to thermostatic three-way valves:

   (a) describe how they operate; (4)

   (b) explain how they are tested; (3)

   (c) state THREE examples of their use in the systems of a diesel engine. (3)

2. With reference to positive displacement pumps:

   (a) describe, with the aid of a sketch, the operation of a pulsation damper; (6)

   (b) explain why some positive displacement pump types do not require pulsation dampers. (4)

3. Explain the hazards to personnel with rupture of compressed air lines and fittings. (10)

4. With reference to pneumatic control systems, explain EACH of the following:

   (a) why moisture is undesirable; (4)

   (b) why oil is generally undesirable; (3)

   (c) why oil may be intentionally introduced into parts of the system. (3)

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. (a) Explain how propeller thrust is transmitted to a vessel's hull. (3)

   (b) Describe the mounting arrangements of a thrust block to the hull. (4)

   (c) Explain why the clearance between the thrust block pads and collar is critical. (3)

8. With reference to stern bearings, state the advantages and disadvantages of using EACH of the following:

(a) white metal; (5)

(b) polymer or composite. (5)

9. With reference to the electrical side of an a.c. generator set:

(a) state how it is safely isolated; (3)

(b) outline the routine maintenance that should be carried out. (7)

10. (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. (5)

(b) Explain why EACH device stated is needed. (5)

1. With reference to thermostatic three-way valves:

(a) describe how they operate; (4)

(b) explain how they are tested; (3)

(c) state THREE examples of their use in the systems of a diesel engine. (3)

(a) Describe how they operate (4 marks)

- A thermostatic three-way valve has three ports: **inlet, bypass, and cooler outlet**.
- It contains a **wax-filled or liquid-filled thermostat element** which expands or contracts with temperature changes.
- At **low temperature**, the valve directs flow back through the bypass, avoiding the cooler to allow faster engine warm-up.
- As the fluid temperature rises, the thermostat gradually moves, diverting flow towards the cooler to maintain the correct operating temperature.
- At **normal operating temperature**, flow is proportioned between bypass and cooler to stabilise the system.

(b) Explain how they are tested (3 marks)

- Remove the valve and immerse it in **heated water** while observing the port movement.
- Measure the **temperature at which the valve starts to open** (should match manufacturer's specification).
- Ensure the valve achieves **full travel** at the designated temperature and closes correctly when cooled.
- Check for **smooth operation and absence of sticking**.

(c) State THREE examples of their use in the systems of a diesel engine (3 marks)

1. **Jacket cooling water system** – to maintain engine cooling water at operating temperature.
2. **Lubricating oil cooling system** – to divert oil through a cooler only when required.
3. **Fuel oil pre-heating system** – to maintain fuel at the correct viscosity for injection

2. With reference to positive displacement pumps:

(a) describe, with the aid of a sketch, the operation of a pulsation damper; (6)

(b) explain why some positive displacement pump types do not require pulsation dampers. (4)

(a) Describe, with the aid of a sketch, the operation of a pulsation damper (6 marks)

- **Purpose:** A pulsation damper reduces the pressure pulsations and flow fluctuations produced by reciprocating-type positive displacement pumps (e.g., piston, plunger, diaphragm).
- **Construction:** It usually consists of a chamber fitted close to the pump discharge, containing a flexible **diaphragm** or **bladder** separating the liquid from a pre-charged gas (e.g., nitrogen).
- **Operation:**
  - When pump discharge pressure spikes, liquid enters the chamber, compressing the gas cushion.
  - During low-pressure parts of the stroke, the compressed gas expands, pushing liquid back into the line.
  - This **absorbs pressure surges and evens out flow**, protecting pipelines, valves, and instruments from vibration and shock.
- **Sketch (exam tip):** Draw:
  - Pump discharge line connected to a side chamber.
  - Chamber split into two by diaphragm: liquid below, gas cushion above.
  - Arrows showing liquid pulses being absorbed and released.

(b) Explain why some positive displacement pump types do not require pulsation dampers (4 marks)

- **Rotary positive displacement pumps** (e.g., gear pumps, screw pumps, vane pumps) produce a **nearly continuous flow** with minimal pulsation.
- Their design ensures that multiple pumping chambers overlap, smoothing discharge pressure.
- Because the delivery is steady, **pulsation dampers are unnecessary**, reducing cost and complexity.
- **Example:** Screw pumps are self-balancing and naturally free from flow surges.

3. Explain the hazards to personnel with rupture of compressed air lines and fittings. (10)

Q3. Explain the hazards to personnel with rupture of compressed air lines and fittings. (10 marks)

Hazards:

1. **Blast of compressed air** – sudden release produces a high-velocity jet which can throw debris or fittings, causing serious injury.
2. **Flying fragments** – pipework, connectors, or tools may become projectiles.
3. **Hearing damage** – very loud explosive noise can cause temporary or permanent hearing loss.
4. **Eye injury** – airborne particles, rust, or oil carried by the jet may strike the eyes.
5. **Skin penetration** – high-pressure air can penetrate the skin, leading to embolism or tissue damage.
6. **Respiratory hazard** – atomised oil mist, scale, or dust may be blown into the atmosphere and inhaled.
7. **Burns / frostbite** – rapid expansion of compressed air causes a sharp temperature drop (Joule-Thomson effect), leading to cold burns on exposed skin.
8. **Disorientation / loss of balance** – a sudden blast may knock a person off balance, particularly in confined spaces.
9. **Fire hazard** – oil-contaminated air discharged at high velocity may ignite on hot surfaces.
10. **Psychological shock / panic** – sudden rupture can startle personnel, leading to accidents or mistakes.

4. With reference to pneumatic control systems, explain EACH of the following:

(a) why moisture is undesirable; (4)

(b) why oil is generally undesirable; (3)

(c) why oil may be intentionally introduced into parts of the system. (3)

Q4. With reference to pneumatic control systems, explain EACH of the following:

(a) Why moisture is undesirable (4 marks):

1. Moisture can freeze at low temperatures, blocking small orifices and lines.
2. It causes corrosion of metallic components in the system.
3. Leads to sticking or malfunction of sensitive instruments and valves.
4. Reduces efficiency and reliability of pneumatic controls.

(b) Why oil is generally undesirable (3 marks):

1. Oil vapour or droplets can clog and contaminate fine passages, nozzles, and filters.
2. It may form sticky deposits, causing sluggish response of control valves.
3. Oil can degrade flexible diaphragms, seals, and other non-metallic parts.

(c) Why oil may be intentionally introduced into parts of the system (3 marks):

1. To lubricate moving mechanical parts such as cylinders and rotary actuators.
2. To reduce wear and extend service life of sliding or rotating components.
3. To provide smoother operation and reduce frictional losses.

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):

1. Local control can be taken at the steering gear compartment using the **trick wheel** or **local lever** operating the control valves.
2. The **electrical follow-up system** can be used to bypass the failed telemotor, giving direct electrical control of the servo valves.
3. Manual operation of the servo valves is possible in an emergency to direct oil to the hydraulic rams.
4. Bridge orders may be relayed to the steering flat via sound-powered telephone or engine-room telegraph if automatic control is lost.
5. Standby telemotor or duplicated system (if fitted) can be brought into service.

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

1. Use of **emergency steering gear** (usually a smaller independent hydraulic pump and motor).
2. Operation of the **emergency tiller**, fitted directly to the rudder head and actuated manually or with mechanical assistance.
3. Use of **differential engine thrust** (e.g., on twin-screw vessels) to provide directional control.
4. Use of **bow thruster** or stern thruster (if fitted) at low speeds for limited maneuvering.
5. Vessel's speed may be reduced to maintain steerage with minimal corrective action, assisting emergency procedures.

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)

Answer:

Description of Operation:

- A transverse thruster (commonly a bow thruster) is mounted in a tunnel through the ship's hull, allowing thrust to be developed at right angles to the vessel's main axis.
- The thruster is powered by a **hydraulic motor**, which is supplied with pressurised hydraulic oil from a pump driven by the ship's main engines or electric motor.
- The **directional control valve** regulates the flow of hydraulic oil:
  - Oil flow in one direction rotates the hydraulic motor (and propeller) clockwise, producing thrust to port.
  - Reversing the oil flow makes the motor rotate in the opposite direction, producing thrust to starboard.
- The **speed (and hence thrust magnitude)** is controlled by varying the hydraulic oil flow rate using a flow control valve or variable-displacement pump.
- Hydraulic oil is returned to the reservoir via filters and coolers to maintain oil quality and temperature.
- Relief valves protect the system against overpressure.

Sketch (exam style, simplified):

Your sketch should include:

- A **tunnel** through the ship's bow with a propeller inside.
- A **hydraulic motor** connected to the propeller shaft.
- A **hydraulic pump** (driven by electric motor or engine).
- **Directional control valve** showing oil flow paths for port and starboard thrust.
- **Reservoir, filters, cooler, and return line**.
- Arrows indicating oil flow and thrust direction.

Key Points to Mention (for full marks):

1. Thruster located in tunnel, used for low-speed manoeuvring.
2. Hydraulic motor drives propeller, powered by pressurised oil.
3. Direction controlled by reversing oil flow.
4. Speed/thrust controlled by varying flow rate.
5. Protection by relief valves, cooling, and filtering of oil.

7. (a) Explain how propeller thrust is transmitted to a vessel's hull. (3)

(b) Describe the mounting arrangements of a thrust block to the hull. (4)

(c) Explain why the clearance between the thrust block pads and collar is critical. (3)

(a) Explain how propeller thrust is transmitted to a vessel's hull. (3 marks)

- The propeller produces axial thrust which is transmitted along the tailshaft and intermediate shafts.
- This thrust is taken up by the thrust block (thrust bearing), where pads press against the thrust collar on the shaft.
- The reaction force is then transmitted through the thrust block housing to the ship's structure and finally to the hull, propelling the vessel forward.

(b) Describe the mounting arrangements of a thrust block to the hull. (4 marks)

- The thrust block is usually mounted on a strong foundation built into the ship's structure.
- It is securely bolted down to the seating, often with fitted bolts to prevent movement.
- Chocks, resin pads, or liners are used under the base to ensure full and even support.
- The arrangement ensures proper alignment with the shafting and allows the reaction forces to be evenly transmitted into the hull structure.

(c) Explain why the clearance between the thrust block pads and collar is critical. (3 marks)

- Correct clearance ensures an oil film forms between the pads and the thrust collar, preventing metal-to-metal contact.
- Too little clearance may squeeze out oil, causing overheating, excessive wear, and possible seizure.
- Too much clearance leads to uneven load distribution, vibration, and possible damage to pads or collar.

8. With reference to stern bearings, state the advantages and disadvantages of using EACH of the following:

(a) white metal; (5)

(b) polymer or composite. (5)

(a) White Metal Stern Bearings

Advantages:

1. Good conformability and embeddability – can accommodate slight shaft misalignment and embed small dirt particles without scoring.
2. Excellent load-carrying capacity under hydrodynamic lubrication.
3. Low coefficient of friction when fully lubricated.

Disadvantages:

1. Sensitive to lubrication failure – prone to wiping and seizure if oil film breaks down.
2. Limited operating temperature range – white metal softens at higher temperatures, reducing service life.

(b) Polymer or Composite Stern Bearings

Advantages:

1. Can operate with water lubrication (environmentally friendly – no oil pollution risk).
2. High resistance to corrosion, erosion, and abrasive wear from silt or sand.
3. Lower friction under boundary lubrication compared to metal bearings.

Disadvantages:

1. Higher initial cost compared with white metal bearings.
2. Lower load-carrying capacity – may not be suitable for very large, heavily loaded propeller shafts.

9. With reference to the electrical side of an a.c. generator set:

(a) state how it is safely isolated; (3)

(b) outline the routine maintenance that should be carried out. (7)

(a) How it is safely isolated (3 marks)

1. **Open the circuit breaker** connecting the generator to the main switchboard to disconnect it from the system.
2. **Open and lock off the generator's local isolating switch** (lock-out/tag-out procedure applied).
3. **Test with an approved voltage tester** to ensure the circuit is dead before touching equipment.

(b) Routine maintenance that should be carried out (7 marks)

1. **Clean and inspect windings** – check for dust, oil, or salt contamination; ensure insulation is intact.

2. **Check insulation resistance** regularly using a Megger to detect deterioration.
3. **Inspect slip rings and brushes** (if fitted) for wear, pitting, or burning; clean or replace as necessary.
4. **Check cooling system** – fans, ducts, and filters kept clean and free from obstructions.
5. **Examine terminals and connections** for tightness, overheating, or corrosion.
6. **Check protective devices** (circuit breakers, relays, earth fault protection) are in working order.
7. **Lubricate bearings** and check for abnormal vibration or noise.

10. (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. (5)

(b) Explain why EACH device stated is needed. (5)

(a) Five devices fitted to a main distribution switchboard (5 marks)

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

(b) Why each device is needed (5 marks)

1. **Circuit breaker / Overcurrent protection** – trips the generator offline if load exceeds safe limits, preventing overheating and damage.
2. **Reverse power relay** – prevents the generator from motoring (running as a motor) and driving the prime mover if there is a fault or synchronisation error.
3. **Under-voltage / Over-voltage relay** – ensures generator voltage stays within safe limits, protecting equipment from damage due to overvoltage or loss of supply.
4. **Under-frequency / Over-frequency relay** – protects against abnormal engine speed (governor failure or load imbalance), which would affect power quality and damage machinery.
5. **Earth fault protection** – detects leakage current due to insulation failure, preventing fire risk and ensuring personnel safety.