AUXILIARY EQUIPMENT PART I

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

1. (a) Sketch a section through a direct emergency bilge suction valve. (8)
   (b) Describe how the valve sketched in part (a) is tested. (2)

2. With reference to a centrifugal pump used for ballast/emergency bilge purposes, explain EACH of the following:
   (a) the purpose of the volute; (3)
   (b) the purpose of the wear rings and why the clearance is critical; (5)
   (c) the need for a priming device. (2)

3. Sketch a system that is capable of supplying compressed air suitable for use in pneumatic control equipment. (10)

4. With reference to hydraulic systems:
   (a) describe how the system is checked for water contamination, after an extended period of shut down; (8)
   (b) state TWO sources of water contamination. (2)

5. With reference to steering gears, explain the meaning of EACH of the following:
   (a) 100% redundancy; (5)
   (b) single failure criteria. (5)

6. Describe the advantages of using water jets instead of conventional propellers for vessel propulsion. (10)

7. Sketch an arrangement for the aft seal of an oil lubricated stern tube bearing. (10

8. With reference to propulsion shaft intermediate bearings of the plain bearing type, explain EACH of the following:

(a) how change of alignment due to vessel condition is allowed for; (2)

(b) why the shaft must be able to move longitudinally; (4)

(c) why the aftmost bearing requires a complete bush but other bearings may have the bush only in the lower half. (4)

9. With reference to a.c. generators:

(a) state why direct current is used for excitation; (2)

(b) state THREE factors that determine the output voltage; (3)

(c) explain how the output voltage is controlled and adjusted. (5)

10. Outline the necessary precautions, as stated in the Code of Safe Working Practices for Merchant Seamen, for working near live electrical equipment, when it is essential for the safety of the ship or for testing purposes. (10)

1. (a) Sketch a section through a direct emergency bilge suction valve. (8)

(b) Describe how the valve sketched in part (a) is tested. (2)

(a) Sketch and description (8 marks)

A direct emergency bilge suction valve allows the main engine circulating pump to be used for pumping out bilges in case of flooding, bypassing the normal bilge pumping system.

Features of the section sketch (what to show and label):

- Main engine sea water circulating pump suction line.
- Branch connection leading to bilge suction.
- Emergency bilge suction valve (non-return or screw-down type).
- Bilge suction pipe leading to bilge well/strum box.
- Non-return valve (to prevent backflow from sea chest).
- Valve spindle with handwheel, normally sealed shut (only used in emergency).

Operation:

- In normal running, the pump draws seawater via the sea chest.
- In emergency, the emergency bilge suction valve is opened, allowing the circulating pump to draw directly from the bilge well to pump water overboard.
- Non-return valves prevent mixing between bilge and seawater systems.

(b) Testing the valve (2 marks)

- The valve is **periodically operated locally** (open/close) to ensure free movement.
- Testing is done by opening the emergency suction valve while the circulating pump is running and verifying flow (with sea suction temporarily shut).
- Often carried out during port stays or drills to confirm readiness.
- After testing, the valve is **resealed in the closed position** to prevent accidental use.

(2)

2. With reference to a centrifugal pump used for ballast/emergency bilge purposes, explain EACH of the following:

(a) the purpose of the volute; (3)

(b) the purpose of the wear rings and why the clearance is critical; (5)

(c) the need for a priming device. (2)

(a) The purpose of the volute (3 marks)

- The volute is the spiral-shaped casing around the impeller.
- It gradually increases in cross-sectional area, which **reduces the velocity** of the liquid and **converts kinetic energy into pressure energy** (according to Bernoulli's principle).
- It also helps to **collect and direct the flow** efficiently to the pump discharge, reducing losses and maintaining smooth flow.

(b) The purpose of the wear rings and why clearance is critical (5 marks)

- **Purpose:**
  - Wear rings are fitted between the impeller and the casing to act as **replaceable sacrificial surfaces**.
  - They **minimise leakage** of liquid from the high-pressure side of the impeller back to the low-pressure suction side.
  - They protect the more expensive impeller and casing from wear.
- **Importance of clearance:**
  - If clearance is **too large**, excessive recirculation occurs, reducing pump efficiency and causing cavitation/erosion.
  - If clearance is **too small**, there is a risk of contact between impeller and wear rings due to thermal expansion or shaft deflection, leading to seizure and damage.
  - Hence, correct clearance ensures **efficiency, reliability, and longevity**.

(c) The need for a priming device (2 marks)

- A centrifugal pump **cannot handle air** and must have its casing filled with liquid before operation (it is **not self-priming**).
- A priming device (e.g., vacuum pump, priming ejector, or hand primer) removes air from the suction line and pump casing, allowing liquid to flow into the impeller and pumping to commence.

3. Sketch a system that is capable of supplying compressed air suitable for use in pneumatic control equipment. (10)

Key points to include in your sketch:

- **Air Compressor** → produces compressed air.
- **Aftercooler** → cools air, removes bulk moisture.
- **Moisture Separator/Trap** → collects and drains condensed water.
- **Air Receiver** → stores compressed air, smooths pulsations.
- **Filters** → remove dust, oil mist, and fine contaminants.
- **Air Dryer** (refrigerated or desiccant type) → removes remaining moisture.
- **Pressure Regulator** → reduces and stabilises air to required working pressure (often 6–8 bar for control equipment).
- **Final Line Filter** → ensures very clean, dry air supplied to sensitive control devices.
- **Pneumatic Control Equipment** (actuators, controllers, instruments).

Written description (to back up sketch):

1. Air is compressed by the **compressor**.
2. It passes through an **aftercooler and separator** to remove bulk water.
3. The **air receiver** stores compressed air and allows some cooling/settling.
4. **Filters and dryers** further remove oil, dirt, and moisture.
5. A **pressure regulating valve** ensures stable supply pressure.
6. **Final polishing filter** ensures only clean, dry air reaches the control system.

4. With reference to hydraulic systems:

(a) describe how the system is checked for water contamination, after an extended period of shut down; (8)

(b) state TWO sources of water contamination. (2)

(a) How the system is checked for water contamination after an extended shutdown (8 marks)

1. **Visual inspection** of oil in sight glasses, sample bottles, or reservoirs – water contamination shows as cloudy/milky oil (emulsification).

2. **Bottom drain sampling** – draw off a small amount of fluid from the lowest point of the reservoir; water, being heavier, will collect at the bottom.

3. **Crackle test** – place a drop of oil on a hot plate (~150°C). If water is present, it will vaporise violently ("crackling").

4. **Laboratory analysis** – Karl Fischer titration or moisture meters can accurately measure water content in ppm.

5. **Check filters and strainers** – water contamination can cause swelling of filter media or rust deposits.

6. **Check system components** – signs of corrosion, rusting, or pitting in valves, pumps, and actuators indicate water ingress.

7. **Reservoir inspection** – condensation on tank walls or water pooling at the bottom may be seen.

8. **Compare with manufacturer's limits** – ensure measured water levels are within acceptable limits for that fluid type.

(b) Two sources of water contamination (2 marks)

1. **Condensation** inside the hydraulic reservoir during cooling/shutdown.

2. **Leakage ingress** from faulty heat exchangers (sea water/fresh water coolers) or from seals and fittings.

5. With reference to steering gears, explain the meaning of EACH of the following:

(a) 100% redundancy; (5)

(b) single failure criteria. (5)

(a) 100% redundancy (5 marks)

- Means the steering system must be capable of operating the rudder fully even if **one complete system fails**.

- SOLAS requires that vessels ≥10,000 GT have **two independent steering systems**, each capable of meeting performance requirements.

- Practically, this is achieved by fitting **two power units (hydraulic pumps/motors), two control systems, and duplicated power supplies**.

- If one unit is under maintenance or fails (e.g., pump failure, motor burnt out, electrical failure), the second system can take over **without loss of steering capability**.

- This ensures that at any time, there is always **100% steering capacity available**.

(b) Single failure criteria (5 marks)

- Means that a **single failure** in any component (power unit, control system, pipework, or power supply) must **not result in total loss of steering**.
- For example:
  - If one hydraulic pump seizes, the second must still operate the rudder.
  - If one power circuit fails, the other must be able to take over.
  - If one control line fails, backup local control or secondary telemotor is available.
- The design must ensure that the steering gear continues to function **safely and reliably after one failure**.
- This is a **safety principle** used in classification society rules to guarantee that no single fault can disable steering, which is critical for ship safety.

6. Describe the advantages of using water jets instead of conventional propellers for vessel propulsion. (10)

Q6: Describe the advantages of using water jets instead of conventional propellers for vessel propulsion. (10 marks)

Advantages of water jets:

1. **High manoeuvrability** – Water jets allow thrust to be directed in any direction, enabling excellent control, including sideways movement and rapid stopping (known as “crash stop”).
2. **Shallow draught operation** – Since the propulsion unit is fully contained within the hull, vessels can operate in shallow waters without risk of propeller strike or grounding damage.
3. **Reduced cavitation** – At high speeds, water jets suffer less from cavitation compared to propellers, maintaining efficiency and reducing vibration.
4. **High speed efficiency** – Water jets are more efficient than propellers at speeds above ~30 knots, making them suitable for fast craft such as ferries, patrol boats, and naval vessels.
5. **Improved safety** – No exposed rotating propellers reduces risk to swimmers, divers, and marine life, and eliminates hazards when docking.
6. **Reduced noise and vibration** – Water jets generally produce less underwater radiated noise and less vibration, improving passenger comfort and reducing marine environmental impact.
7. **Compact arrangement** – The system can be installed within the hull, freeing stern space and simplifying vessel layout.
8. **Quick response to control** – Water jets can reverse thrust almost instantaneously, unlike propellers which rely on shaft reversal or controllable pitch mechanisms.
9. **Less risk of fouling** – With no protruding blades, there is lower risk of damage from floating debris, ropes, or nets.
10. **Low maintenance in service** – With fewer moving parts exposed to seawater, the system tends to have lower in-service maintenance compared to propellers and shafting.

✓7. Sketch an arrangement for the aft seal of an oil lubricated stern tube bearing. (10

Key Features of the Aft Seal Arrangement

- **Propeller shaft** passing through the stern tube.
- **Stern tube bearing** oil-lubricated (aft end shown).
- **Seal housing** bolted to the stern frame.
- **Multiple lip seals (usually 3–4)** fitted inside the housing:
  - One or two **seawater exclusion seals** (to prevent ingress).
  - One or two **oil retention seals** (to prevent egress).
- **Drain/vent pipes** between seals to monitor leakage.
- **Grease injection system** sometimes fitted between sea and oil seals for extra protection.
- **Seal liner/sleeve** shrunk onto shaft to provide smooth running surface for the seals.

How to Sketch It (cross-sectional view along the shaft line)

1. Draw the **shaft** running horizontally.
2. Show a **seal housing** around it.
3. Inside housing, draw **three or four lip seals** angled alternately:
   - First (outboard side) faces outward (keeps seawater out).
   - Next ones face inward (retain oil).
4. Indicate **oil side** (inboard, connected to stern tube bearing).
5. Indicate **sea side** (outboard, near propeller).
6. Add **drain/monitoring pipes** between seals (label them).
7. Label **grease injection point** if shown.
8. Show **sleeve/liner** fitted on shaft for sealing surface.

8. With reference to propulsion shaft intermediate bearings of the plain bearing type, explain EACH of the following:

(a) how change of alignment due to vessel condition is allowed for; (2)

(b) why the shaft must be able to move longitudinally; (4)

(c) why the aftmost bearing requires a complete bush but other bearings may have the bush only in the lower half. (4)

Q8. With reference to propulsion shaft intermediate bearings of the plain bearing type, explain EACH of the following:

(a) How change of alignment due to vessel condition is allowed for (2 marks):

- The bearing is lined with **white metal (Babbitt)**, which is relatively soft and can accommodate small angular misalignments.
- The oil film between the shaft and the bearing surface provides a **hydrodynamic cushion**, allowing the shaft to run without metal-to-metal contact even if the hull flexes or hogs/sags, altering alignment.

(b) Why the shaft must be able to move longitudinally (4 marks):

- Propeller shafts expand and contract due to **temperature changes** (engine load, sea temperature).
- If the shaft were rigidly fixed, thermal expansion would induce **excessive axial stress**, risking shaft distortion or bearing failure.
- Bearings therefore allow a degree of **axial movement** (sliding on the oil film), with thrust being taken only at the **thrust block**.
- This ensures **smooth operation** and prevents overloading of bearings along the shaft line.

(c) Why the aftmost bearing requires a complete bush but other bearings may have the bush only in the lower half (4 marks):

- The **aftmost bearing** supports the shaft just ahead of the propeller, where **propeller weight and hydrodynamic forces** act continuously in all directions. Therefore, it requires a **full 360° bearing bush** for complete support.
- Intermediate bearings along the shaft mainly support the weight of the shaft itself (which always rests downwards). Hence, only the **lower half of the bush** is needed for support, reducing cost, simplifying maintenance, and easing removal of the shaft for inspection.

✓9. With reference to a.c. generators:

✓(a) state why direct current is used for excitation; (2)

(b) state THREE factors that determine the output voltage; (3)

(c) explain how the output voltage is controlled and adjusted. (5)

(a) Why direct current is used for excitation (2 marks)

- Direct current provides a **steady magnetic field** in the rotor, which is essential for inducing a stable alternating voltage in the stator.
- If a.c. were used, the field would continuously reverse, causing unstable and fluctuating output.

(b) THREE factors that determine the output voltage (3 marks)

1. **Field current (strength of excitation)** – higher d.c. excitation increases magnetic flux and therefore raises output voltage.
2. **Speed of rotation of the rotor** – higher speed increases the rate of flux cutting and induced EMF.
3. **Number of turns in the stator winding / machine design** – more turns or better winding design produces higher induced voltage.

(c) How the output voltage is controlled and adjusted (5 marks)

- The output voltage is controlled by **varying the field excitation current** using an **Automatic Voltage Regulator (AVR)**.
- If load increases → terminal voltage tends to fall → AVR increases excitation to restore voltage.
- If load decreases → terminal voltage tends to rise → AVR reduces excitation.
- The AVR uses feedback from the generator's output to automatically maintain constant voltage under varying load conditions.
- Manual adjustment of excitation is also possible via field rheostats for fine-tuning.

✓10. Outline the necessary precautions, as stated in the Code of Safe Working Practices for Merchant Seamen, for working near live electrical equipment, when it is essential for the safety of the ship or for testing purposes. (10)

Q10: Precautions for working near live electrical equipment (10 marks)

Precautions to be taken:

1. **Work only if essential** – Work on or near live equipment must only be done when absolutely necessary (safety of ship or testing purposes).

2. **Permit-to-work system** – A formal written permit must be issued by a responsible officer before starting work.

3. **Risk assessment** – Hazards must be identified and a safe method of working agreed before starting.

4. **Competent personnel only** – Work must only be carried out by qualified and experienced electricians or engineers.

5. **Insulated tools and protective equipment** – Use tools with insulated handles, wear insulating gloves, boots, and use rubber mats where appropriate.

6. **Remove metal objects** – Rings, watches, or other conductive jewellery must be removed to avoid accidental contact.

7. **Barriers and warning notices** – Barriers should be placed to prevent accidental contact by others, and warning notices displayed.

8. **Adequate lighting and dry conditions** – Ensure good illumination and that the floor/equipment is dry to reduce shock risk.

9. **Emergency arrangements** – A second person must be present, trained in resuscitation and ready to disconnect the supply in an emergency.

10. **Use one hand where possible** – When testing, use one hand to avoid current passing across the chest.