AUXILIARY EQUIPMENT PART I

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

1. (a) State THREE reasons that may cause a relief valve to lift in service. (3)

   (b) State THREE reasons that may cause a relief valve to fail to lift should excessive pressure occur. (3)

   (c) Explain how the correct operation of a relief valve is ensured. (4)

2. Describe, with the aid of sketch, a system for priming a centrifugal pump using a priming pump driven from the centrifugal pump. (10)

3. With reference to air compressors, explain EACH of the following:

   (a) why an air filter is important; (4)

   (b) why the compressor should not be allowed to run with a dirty air filter. (6)

4. With reference to a windlass that is hydraulically operated by a variable displacement motor, explain the effect of changing EACH of the following:

   (a) the flow rate of hydraulic oil; (4)

   (b) the displacement of the motor. (6)

5. With reference to a hydraulic steering gear, explain the purpose of EACH of the following:

   (a) shock valve; (3)

   (b) by-pass valve; (3)

   (c) pump isolating valve. (4)

6. Explain, with the aid of a sketch, the securing of a controllable pitch propeller to the tailshaft. (10)

7. Sketch a shaft coupling of the flexible diaphragm type, labelling the MAIN components. (10)

8. Describe the checks carried out during the inspection of a main thrust bearing. (10)

9. (a) State the factor that determines the minimum number of available generators required for a vessel to put to sea. (3)

(b) State SEVEN essential services for the operation of a vessel. (7)

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

(b) State the effects on a motor of single phasing. (6)

(c) State how single phasing protection is achieved in the motor starter circuit. (2)

1. (a) State THREE reasons that may cause a relief valve to lift in service. (3)

(b) State THREE reasons that may cause a relief valve to fail to lift should excessive pressure occur. (3)

(c) Explain how the correct operation of a relief valve is ensured. (4)

(a) State three reasons that may cause a relief valve to lift in service. (3 marks)

1. **Excessive system pressure** – due to pump running against a closed valve or system blockage.
2. **Thermal expansion** of fluid in a closed system (e.g., heating of trapped liquid).
3. **Faulty pressure regulation** or malfunction of control equipment, allowing pressure to exceed safe limits.

(b) State three reasons that may cause a relief valve to fail to lift should excessive pressure occur. (3 marks)

1. **Valve seized or stuck** due to corrosion, dirt, or fouling.
2. **Incorrect spring adjustment or over-tightening** preventing lift at the set pressure.
3. **Blocked discharge line or frozen outlet**, stopping the valve from operating.

(c) Explain how the correct operation of a relief valve is ensured. (4 marks)

- Relief valves are **regularly tested and set** to the correct lift pressure using calibrated test equipment.
- **Periodic in-service testing** (lifting gear or easing gear) is carried out to prove that the valve is free to operate.
- **Regular inspection and maintenance** (cleaning, lapping of seat, checking for corrosion or deposits).
- **Proper installation** ensuring correct orientation, venting, and free discharge to a safe location.

2. Describe, with the aid of sketch, a system for priming a centrifugal pump using a priming pump driven from the centrifugal pump. (10)

Answer

Principle:
A centrifugal pump cannot pump air; it must be filled with liquid (primed) before starting. A small **positive displacement pump** (priming pump) is fitted, driven from the same shaft as the centrifugal pump, to evacuate air and fill the main pump casing with liquid.

Description of System:

1. **Priming Pump:**
   - Usually a liquid ring or reciprocating pump.
   - Connected to the suction side of the centrifugal pump.
   - Removes air from the pump casing and suction line.
2. **Discharge of Priming Pump:**
   - Air is discharged to atmosphere or into a vent line.
   - Once liquid reaches the centrifugal pump casing, the priming pump discharges a small quantity of liquid along with air.
3. **Non-return (check) valves:**
   - Fitted in the priming line to prevent backflow of liquid into the priming pump.
4. **Automatic operation:**
   - Some systems include a float or vacuum-operated device that automatically disengages the priming pump once priming is complete.

Sketch (exam-friendly):

Your sketch should show:

- The **centrifugal pump casing** (impeller inside).

- The **priming pump** (gear or liquid ring) driven from the centrifugal pump shaft.
- The **priming line** connecting suction side of centrifugal pump to priming pump.
- **Check valve** on discharge of priming pump venting to atmosphere or return line.
- Flow arrows showing air being sucked out and liquid filling the centrifugal pump.

Key Points to Mention for Marks:

- Centrifugal pump cannot self-prime.
- Priming pump evacuates air and fills casing with liquid.
- Positive displacement pump is used for priming.
- Non-return valves prevent reverse flow.
- Automatic disengagement prevents wear once primed.

3. With reference to air compressors, explain EACH of the following:

(a) why an air filter is important; (4)

(b) why the compressor should not be allowed to run with a dirty air filter. (6)

3. With reference to air compressors:

(a) Why an air filter is important (4 marks)

1. Prevents dust, dirt, and abrasive particles from entering the compressor cylinder.
2. Protects valves, pistons, and liners from scoring and wear.
3. Ensures clean compressed air for downstream systems and instruments.
4. Improves reliability and service life of the compressor.

(b) Why the compressor should not be allowed to run with a dirty air filter (6 marks)

1. A dirty filter restricts air intake, reducing compressor volumetric efficiency and capacity.
2. Causes increased suction vacuum, leading to overheating of the compressor.
3. Higher power consumption due to the compressor working harder to draw air.
4. Possible oil carryover due to poor sealing caused by pressure imbalance.
5. Risk of filter collapse or bypass, allowing unfiltered air to enter and damage internals.
6. Ultimately shortens compressor life and increases maintenance costs.

4. With reference to a windlass that is hydraulically operated by a variable displacement motor, explain the effect of changing EACH of the following:

(a) the flow rate of hydraulic oil; (4)

(b) the displacement of the motor. (6)

4. With reference to a windlass that is hydraulically operated by a variable displacement motor:

(a) Effect of changing the flow rate of hydraulic oil (4 marks)

- Increasing flow rate → increases motor speed → windlass rotates faster, allowing quicker raising or lowering of the anchor.
- Decreasing flow rate → reduces motor speed → slower windlass operation.
- Flow rate affects **speed only**, not torque (as torque depends mainly on pressure and displacement).
- Too high a flow rate may cause shock loading or overheating of the system.

(b) Effect of changing the displacement of the motor (6 marks)

- Displacement refers to the volume of oil required for one revolution of the motor.
- Increasing displacement → higher torque output at a given pressure (useful for heavy anchor loads), but lower rotational speed.
- Decreasing displacement → lower torque output, but higher speed for the same oil flow.
- Allows the motor to adapt between **high torque/low speed** (for breaking anchor out of seabed) and **low torque/high speed** (for retrieving chain quickly).
- Variable displacement therefore gives flexibility and efficiency in windlass operation.
- Prevents the need for oversizing pumps or using multiple motors.

5. With reference to a hydraulic steering gear, explain the purpose of EACH of the following:

(a) shock valve; (3)

(b) by-pass valve; (3)

(c) pump isolating valve. (4)

5. With reference to a hydraulic steering gear, explain the purpose of EACH of the following:

(a) Shock valve (3 marks)

- Protects the system from excessive pressure surges caused by sudden rudder movements or external forces (e.g. heavy seas striking the rudder).
- Opens automatically to relieve excess pressure back to the return line.
- Prevents damage to pipes, cylinders, and pumps.

(b) By-pass valve (3 marks)

- Connects the two sides of the steering gear cylinders together.
- Allows manual movement of the rudder when pumps are stopped or under maintenance.
- Provides a safety feature in emergencies by enabling rudder operation using emergency/manual gear.

(c) Pump isolating valve (4 marks)

- Fitted in the suction and discharge lines of each steering gear pump.
- Used to isolate one pump for maintenance while the other remains in operation (complying with SOLAS redundancy requirements).
- Prevents backflow of oil and ensures safe working conditions.
- Essential for systems with duplicated pumps to ensure continuous steering availability.

6. Explain, with the aid of a sketch, the securing of a controllable pitch propeller to the tailshaft. (10)

6. Explain, with the aid of a sketch, the securing of a controllable pitch propeller (CPP) to the tailshaft. (10 marks)

Explanation:

- The CPP boss (hub) is mounted onto the tapered end of the tailshaft.
- A **tapered shrink fit** ensures a tight mechanical connection between the shaft and the propeller hub.
- The propeller is held in position by a **key** (parallel or sometimes spline arrangement) that transmits torque from the shaft to the hub.
- A **propeller nut** and **locking device** (e.g., a castellated nut with split pin, or a nut with a locking ring) secure the assembly against axial movement.
- A **forward thrust collar** transfers thrust from the blades through the hub into the shaft.
- A **sealing arrangement** (aft seal) prevents seawater ingress and oil leakage from the hub, since the CPP hub contains a hydraulic mechanism for blade pitch adjustment.
- Hydraulic oil from the tailshaft passes through a **hollow bored shaft** to the hub, where a servo piston alters the pitch of the blades.

✅ **Key features to show in a sketch:**

1. Tailshaft taper.
2. Key or spline connection.
3. Propeller hub (CPP boss).
4. Propeller securing nut and locking arrangement.
5. Thrust collar.
6. Oil passages for blade pitch control.
7. Aft seal to prevent oil leakage/seawater ingress.

7. Sketch a shaft coupling of the flexible diaphragm type, labelling the MAIN components. (10)

7. Sketch a shaft coupling of the flexible diaphragm type, labelling the MAIN components. (10 marks)

Description (to go with the sketch):

- A **flexible diaphragm coupling** connects two shafts (e.g. engine to gearbox or gearbox to propeller shaft).
- It allows **slight axial, radial, and angular misalignment** while still transmitting torque.
- The diaphragm is a **thin metallic disc or pack of laminated discs** that flex under misalignment, but remain stiff in torsion.
- Torque is transmitted from the driving shaft flange → through bolts → diaphragm pack → through bolts → driven shaft flange.
- The design eliminates backlash, needs no lubrication, and reduces vibration transmission.

✅ **Main components to label in the sketch:**

1. **Driving shaft flange** (bolted to one shaft).
2. **Driven shaft flange** (bolted to the other shaft).
3. **Flexible diaphragm (disc pack)** between the flanges.
4. **Bolts and spacers** securing the diaphragm to both flanges.
5. (Optional but good for extra marks) – **hub taper/keys** securing each flange to its shaft.

8. Describe the checks carried out during the inspection of a main thrust bearing. (10)

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Checks during inspection:

1. **Cleanliness and general condition**
   - Ensure all oil, dirt, and debris are removed before inspection.
   - Look for signs of overheating, discolouration, or scoring.
2. **Bearing pads (thrust shoes/segments)**
   - Check for uniform wear across the pads.
   - Inspect for pitting, cracks, scoring, or fatigue.
   - Ensure pad surface is smooth and free from wiping.
3. **Thrust collar (or thrust block collar on shaft)**
   - Inspect for scoring, fretting, overheating marks, or cracks.
   - Check the contact surface between collar and pads.
4. **Clearances and contact pattern**
   - Measure axial clearance using feeler gauges or dial indicators.
   - Check that pad contact is even (using engineers' blue if needed).
   - Ensure alignment is correct, preventing uneven loading.
5. **Lubrication system**
   - Verify oil supply holes and grooves are clean and free of blockage.
   - Check oil film formation evidence (no signs of dry running).
   - Inspect oil jets/spray pipes for cleanliness and alignment.
6. **Fastenings and support structure**
   - Inspect holding-down bolts, studs, and nuts for tightness.
   - Check for cracks or fretting in the bearing housing.
   - Ensure pads and pivots (if tilting pad type) are secure.
7. **Temperature monitoring devices**
   - Inspect thermocouples or RTDs for correct placement and functioning.
   - Check wiring and connections.

8. **Wear down measurement**
    - Compare pad thickness with maker's limits.
    - Record measurements for trend monitoring.

9. (a) State the factor that determines the minimum number of available generators required for a vessel to put to sea. (3)

(b) State SEVEN essential services for the operation of a vessel. (7)

9 (a) Factor determining the minimum number of available generators required for a vessel to put to sea:

- The **total electrical load demand** of the vessel at sea, including essential and emergency services, determines the minimum number of generators required.
- Classification Society and Flag State regulations stipulate that there must always be sufficient generator capacity to safely operate essential ship services, even if one generator is out of service.
- Therefore, enough generators must be available to cover the **maximum continuous load** plus a **spare margin** for safety and redundancy.

Answer point: The factor is the **maximum sea-going load demand of essential services in compliance with Classification Society and statutory requirements**. ✅

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9 (b) Seven essential services for the operation of a vessel:

1. **Main propulsion auxiliaries** (lubrication oil pumps, fuel pumps, cooling water pumps) – essential to keep the main engine operating.
2. **Steering gear system** – must always be powered for navigation and manoeuvring.
3. **Navigation equipment** (gyro, radar, communications, autopilot, GPS) – essential for safe navigation.
4. **Bilge and ballast pumps** – necessary for stability and seaworthiness.
5. **Fire-fighting systems** (fire pumps, emergency lighting, alarms) – essential for safety compliance.
6. **Refrigeration and ventilation systems** (for provisions and machinery spaces).
7. **Emergency lighting and alarms** – must remain operational to meet SOLAS requirements.

(Other acceptable answers may include sewage treatment plant, air compressors, fresh water production, cargo pumps – depending on vessel type.)

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

(b) State the effects on a motor of single phasing. (6)

(c) State how single phasing protection is achieved in the motor starter circuit. (2)

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

- **Definition**: Single phasing occurs when one phase of a three-phase supply to an induction motor is lost due to a blown fuse, broken conductor, or faulty contactor.
- **Effect on supply**: The motor continues to run on only two phases, creating unbalanced conditions.

(b) State the effects on a motor of single phasing (6 marks)

1. **Excessive current** flows in the remaining two phases → overheating of windings.
2. **Reduced torque output** → motor cannot drive load efficiently.
3. **Severe vibration and noise** due to unbalanced magnetic field.
4. **Overheating and possible burning** of motor windings.
5. **Possible stalling** if the load demand is high.
6. **Reduced motor life** due to insulation damage and thermal stress.

(c) State how single phasing protection is achieved in the motor starter circuit (2 marks)

- **Protection devices** such as **phase failure relays** or **current unbalance relays** are fitted in the starter circuit.
- These devices detect phase loss or current imbalance and **trip the motor circuit breaker/contactor** to disconnect supply, preventing damage.