

**AUXILIARY EQUIPMENT PART II****Attempt ALL questions****Marks for each part question are shown in brackets**

1. Describe, with the aid of sketches, the operating principle of an axial variable delivery hydraulic pump. (10)
  
2. With reference to a crane operated by a constant pressure hydraulic system incorporating unidirectional, fixed displacement pumps that run continuously, explain EACH of the following:
  - (a) the purpose of the accumulator; (2)
  - (b) how the hydraulic pressure is regulated; (2)
  - (c) how the speed and direction of the hoist motor is varied; (3)
  - (d) how the torque available from the hoist motor can be varied. (3)
  
3. With reference to a 3-phase motor supplied with a six terminal connection without links, describe, with the aid of sketches, how the phase ends can be identified and the motor connected to run in permanent delta mode. (10)
  
4. With reference to paralleling and load sharing of generators, explain EACH of the following:
  - (a) the possible causes of no voltage indication on start up of a stand-by generator; (2)
  - (b) the purpose of the check synchroniser; (2)
  - (c) the reason for the incoming machine to be running slightly faster than the busbar frequency at the instant of closing the incoming breaker; (2)
  - (d) how equal kW load sharing is maintained; (2)
  - (e) why the power factors may be different even though the kW loads are equal. (2)

5. With reference to air conditioning systems, state the meaning of EACH of the following terms:
- (a) heating load; (1)
  - (b) cooling load; (1)
  - (c) sensible heat; (2)
  - (d) latent heat; (2)
  - (e) absolute humidity; (2)
  - (f) specific humidity. (2)
6. Sketch a line diagram of a free standing air conditioning unit, showing the direction of flow, position of safety cut outs, oil separator and charging point. (10)
7. With reference to the visual inspection of lifting gear before use, state the removal from service criteria for EACH of the following when visually inspecting before use:
- (a) shackles; (5)
  - (b) hooks. (5)
7. *Note: They are within inspection dates, are of the correct SWL and clearly labelled.*
8. Describe the safety requirements for the electrical installation in a large locker on deck, designated for the carriage of petrol, or vehicles with fuel in their tanks. (10)

9. With reference to transverse stresses in a vessel's hull:
- (a) state the cause of the stress when the vessel is:
    - (i) floating in still water; (1)
    - (ii) being acted on by waves; (2)
    - (iii) drydocked. (1)
  - (b) state the areas where the stress is a maximum when the vessel is:
    - (i) floating in still water; (1)
    - (ii) drydocked; (1)
  - (c) describe the structure that resists the stress. (4)
10. With reference to surface preparation for the painting of a vessels hull in dry-dock, list the advantages and disadvantages of EACH of the following methods:
- (a) abrasive blasting; (5)
  - (b) hydroblasting. (5)

1. Describe, with the aid of sketches, the operating principle of an axial variable delivery hydraulic pump. (10)

**Q1: Describe, with the aid of sketches, the operating principle of an axial variable delivery hydraulic pump. (10 marks)**

### Description

An axial variable delivery hydraulic pump is a **positive displacement pump** in which pistons are arranged parallel (axially) to the drive shaft. The pump converts mechanical input power into hydraulic energy by pressurising fluid.

The **delivery (flow rate)** can be varied by altering the angle of the swash plate (or tilting block), which changes the piston stroke.

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## Main Components

1. **Drive shaft** – supplies rotary power to the cylinder block.
  2. **Cylinder block** – contains several pistons in axial bores.
  3. **Pistons** – move axially within the cylinder bores, drawing in and discharging oil.
  4. **Swash plate (or tiltable yoke/block)** – determines piston stroke length by its angle.
  5. **Port plate (valve plate)** – provides inlet and outlet passages.
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## Operating Principle

- As the shaft rotates, the pistons are forced to reciprocate due to contact with the angled swash plate.
  - During the **inlet stroke**, pistons move outwards, creating suction, and oil enters the cylinder bore.
  - During the **delivery stroke**, pistons move inward, pressurising the oil and forcing it out through the outlet port.
  - **Variable delivery** is achieved by changing the swash plate angle:
    - Large angle → longer piston stroke → **higher flow**.
    - Small angle → shorter piston stroke → **lower flow**.
    - Neutral ( $0^\circ$  angle) → no stroke → **no delivery**.
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## Sketch (to include in exam)

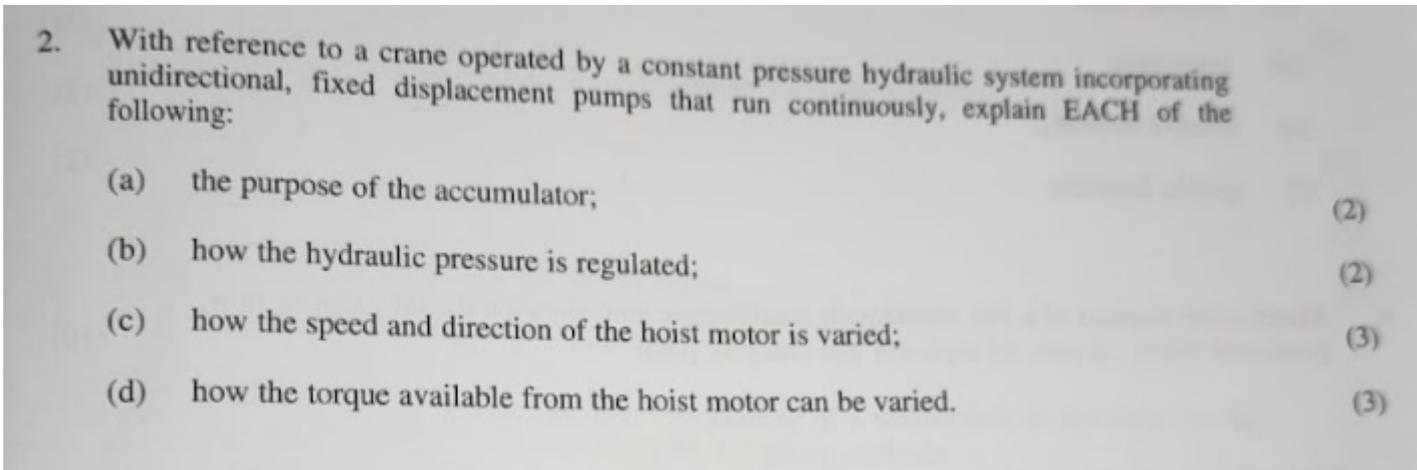
Draw:

- Shaft with cylinder block and pistons.
- Swash plate shown at an angle.
- One piston at suction position, one at delivery.
- Arrows indicating fluid flow (inlet & outlet).

- Show that changing swash plate angle changes piston stroke length.
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### Answer Summary (10 mark points)

1. Positive displacement pump with pistons arranged axially.
2. Driven by a rotating shaft connected to the cylinder block.
3. Pistons move against an angled swash plate.
4. Suction stroke occurs as pistons move outward.
5. Delivery stroke occurs as pistons move inward.
6. Port plate provides inlet and outlet passages.
7. Flow rate depends on piston stroke length.
8. Swash plate angle determines piston stroke.
9. Variable flow achieved by altering swash plate angle.
10. At zero angle, no delivery occurs.

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2. With reference to a crane operated by a constant pressure hydraulic system incorporating unidirectional, fixed displacement pumps that run continuously, explain EACH of the following:
- (a) the purpose of the accumulator; (2)
  - (b) how the hydraulic pressure is regulated; (2)
  - (c) how the speed and direction of the hoist motor is varied; (3)
  - (d) how the torque available from the hoist motor can be varied. (3)

#### (a) The purpose of the accumulator (2 marks)

- Stores hydraulic energy under pressure for immediate use when demand is high.
  - Smooths out pressure fluctuations and absorbs shocks/pulsations in the system.
  - Reduces pump load by supplying oil during peak demand, preventing pressure drops.
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#### (b) How the hydraulic pressure is regulated (2 marks)

- Achieved using a **pressure relief valve** or **pressure regulating valve**.
  - When system pressure reaches a set value, excess flow is diverted back to the tank, keeping pressure constant.
  - Maintains safe operation by preventing over-pressurisation.
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**(c) How the speed and direction of the hoist motor is varied (3 marks)**

- **Direction:** Controlled by a **directional control valve (DCV)**, which reverses the flow to the hydraulic motor.
  - **Speed:** Controlled by **throttle valves** or **flow control valves** (orifice restriction) that regulate the rate of oil flow to the motor.
  - Reduced flow → slower motor speed; increased flow → faster motor speed.
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**(d) How the torque available from the hoist motor can be varied (3 marks)**

- Torque depends on **pressure × displacement** of the motor.
  - Torque is varied by:
    1. Adjusting the system pressure (via relief/pressure control valve).
    2. Using a motor with **variable displacement** (if fitted).
    3. Controlling load-sensing hydraulics so that higher pressure is supplied when heavier loads are lifted.
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**Marking Breakdown (10 marks)**

- (a) Accumulator – energy storage + smoothing (2)  
(b) Pressure regulation – relief/regulating valve action (2)  
(c) Speed/direction – DCV for direction, flow control for speed (3)  
(d) Torque – varies with pressure/displacement, regulated via valves/motor design (3)

3. With reference to a 3-phase motor supplied with a six terminal connection without links, describe, with the aid of sketches, how the phase ends can be identified and the motor connected to run in permanent delta mode.

(10)

**Q3: With reference to a 3-phase motor supplied with a six terminal connection without links, describe, with the aid of sketches, how the phase ends can be identified and the motor connected to run in permanent delta mode. (10 marks)**

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### Step 1: Identifying phase ends (U1, V1, W1, U2, V2, W2)

1. A 3-phase motor winding has **three windings** → each with a **start** and **finish**.
  - Phase 1 → U1 (start), U2 (finish)
  - Phase 2 → V1 (start), V2 (finish)
  - Phase 3 → W1 (start), W2 (finish)
2. **Insulation test / continuity test** with a megger or ohmmeter:
  - Find three pairs of terminals that show continuity → these are the three windings.
  - Label them temporarily as A-A', B-B', C-C'.
3. **Polarity test** to distinguish start vs finish:
  - Apply a low DC voltage to one pair (say A-A').
  - Connect a sensitive DC voltmeter across another pair (say B-B').
  - Momentarily connect/disconnect supply.
    - If the voltmeter deflects in the same direction → identified terminals are both “starts” (A and B).
    - If opposite direction → one is a start, the other a finish.
  - Repeat for all pairs → correctly identify U1/U2, V1/V2, W1/W2.

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### Step 2: Delta connection (permanent delta mode)

In delta, **each winding end is connected to the start of the next winding**:

- Connect U1 → W2
- Connect V1 → U2
- Connect W1 → V2

Then connect the **3-phase supply lines (L1, L2, L3)** to **U1, V1, W1** (or equivalent).

### Step 3: Sketch

You should draw:

1. **Six terminals** arranged in two rows of three (top row: U1, V1, W1; bottom row: U2, V2, W2).
2. Delta links:
  - U1 → W2
  - V1 → U2
  - W1 → V2
3. Incoming supply L1 → U1, L2 → V1, L3 → W1.

This shows a closed triangle (delta).

### Marking Breakdown (10 marks)

- Identification of three windings with continuity test (2)
- Polarity test to establish start/finish (2)
- Correct labelling of U1, V1, W1, U2, V2, W2 (2)
- Explanation of delta connection principle (2)
- Correct sketch of delta connection (2)

4. With reference to paralleling and load sharing of generators, explain EACH of the following:
- (a) the possible causes of no voltage indication on start up of a stand-by generator; (2)
  - (b) the purpose of the check synchroniser; (2)
  - (c) the reason for the incoming machine to be running slightly faster than the busbar frequency at the instant of closing the incoming breaker; (2)
  - (d) how equal kW load sharing is maintained; (2)
  - (e) why the power factors may be different even though the kW loads are equal. (2)

**Q4: With reference to paralleling and load sharing of generators, explain EACH of the following:**

**(a) Possible causes of no voltage indication on start-up of a standby generator (2 marks)**

- Residual magnetism in the alternator field has been lost → no voltage build-up.
  - Fault in the excitation system (e.g., AVR failure, exciter fuse blown, or open circuit field winding).
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**(b) The purpose of the check synchroniser (2 marks)**

- It provides an additional safety device to ensure the generator is only connected to the busbar when:
    - **Voltage, frequency, and phase angle** of the incoming machine are within safe limits.
  - It prevents accidental closing of the breaker under out-of-phase conditions, protecting generator and busbar.
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**(c) Reason for the incoming machine to be running slightly faster than the busbar frequency at the instant of closing the incoming breaker (2 marks)**

- To ensure the generator will **take up load immediately** after being paralleled.
  - If it were slower, it would absorb load (act as a motor), which could damage the prime mover.
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**(d) How equal kW load sharing is maintained (2 marks)**

- By adjusting the **governor settings** (speed/load control) of each generator.
  - In droop-governed systems, each generator reduces speed slightly as load increases → ensuring proportional load sharing.
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**(e) Why the power factors may be different even though the kW loads are equal (2 marks)**

- Because **kVAr (reactive power) sharing** depends on excitation control (AVR settings).
- Two generators can share the same active (kW) load, but if their excitation is unequal, one may supply more reactive power (leading to a higher or lower power factor).

5. With reference to air conditioning systems, state the meaning of EACH of the following terms:
- |                        |     |
|------------------------|-----|
| (a) heating load;      | (1) |
| (b) cooling load;      | (1) |
| (c) sensible heat;     | (2) |
| (d) latent heat;       | (2) |
| (e) absolute humidity; | (2) |
| (f) specific humidity. | (2) |

**Q5: With reference to air conditioning systems, state the meaning of EACH of the following terms:**

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**(a) Heating load (1 mark)**

- The total amount of heat energy that must be **added** to a space to maintain the desired indoor temperature when external conditions are cooler.
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**(b) Cooling load (1 mark)**

- The total amount of heat energy that must be **removed** from a space to maintain the desired indoor temperature when external conditions or internal heat gains increase the temperature.
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**(c) Sensible heat (2 marks)**

- Heat that causes a **change in temperature** of a substance (e.g., air) without a change in its phase (state).
  - Example: heating air from 20 °C to 25 °C.
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**(d) Latent heat (2 marks)**

- Heat absorbed or released by a substance during a **phase change** without a change in temperature.
  - Example: condensation or evaporation of water vapour in air.
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**(e) Absolute humidity (2 marks)**

- The **actual mass of water vapour** present in a given volume of air.
  - Usually expressed in grams of water vapour per cubic metre of air ( $\text{g/m}^3$ ).
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**(f) Specific humidity (2 marks)**

- The **mass of water vapour per unit mass of dry air** in an air–water vapour mixture.
- Usually expressed as grams of water vapour per kilogram of dry air ( $\text{g/kg}$ ).

6. Sketch a line diagram of a free standing air conditioning unit, showing the direction of flow, position of safety cut outs, oil separator and charging point.

(10)

**Q6: Sketch a line diagram of a free-standing air conditioning unit**

**Key components and flow (with direction):**

**1. Compressor**

- Draw at the start.
- Arrow out = **high-pressure, high-temperature vapour**.
- **Oil separator** fitted at discharge side.

**2. Discharge line → Condenser**

- Heat rejected to ambient (air-cooled or water-cooled).
- Vapour condenses to **high-pressure liquid**.

**3. Liquid line → Receiver**

- Stores liquid refrigerant.
- **Charging point** usually provided here (liquid charging).

**4. Filter-drier & Sight glass**

- In liquid line before expansion valve.
- Removes moisture/particles, allows observation of refrigerant condition.

**5. Expansion valve (TXV / capillary)**

- Pressure-reducing device.
- Liquid becomes **low-pressure mixture**.

6. **Evaporator**

- Absorbs heat from conditioned space.
- Refrigerant becomes **low-pressure vapour**.

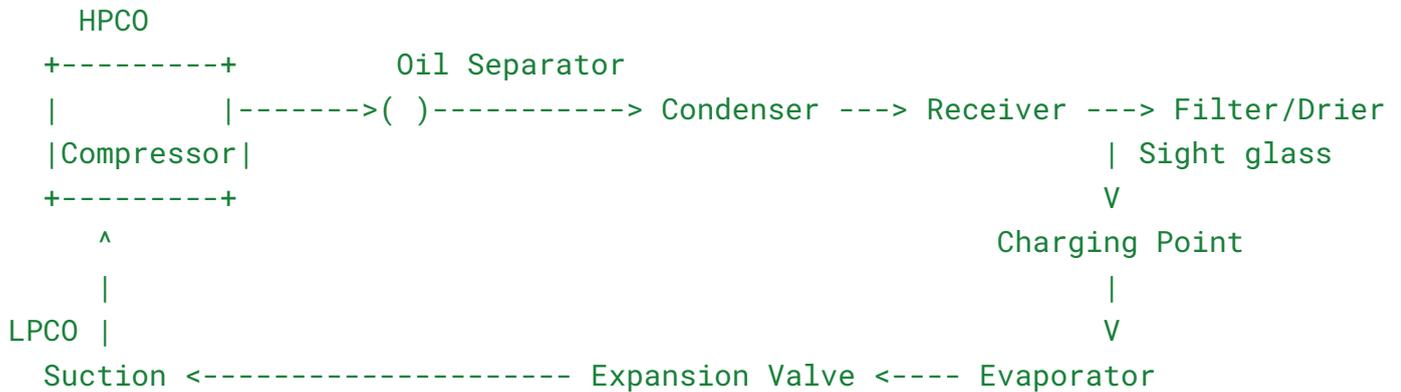
7. **Suction line → Compressor**

- Includes **low-pressure cut-out (LPCO)** for protection.

**Safety cut-outs**

- **High-pressure cut-out (HPCO)**: on discharge line after compressor.
- **Low-pressure cut-out (LPCO)**: on suction line before compressor.
- **Oil pressure cut-out**: linked to compressor lubrication system.

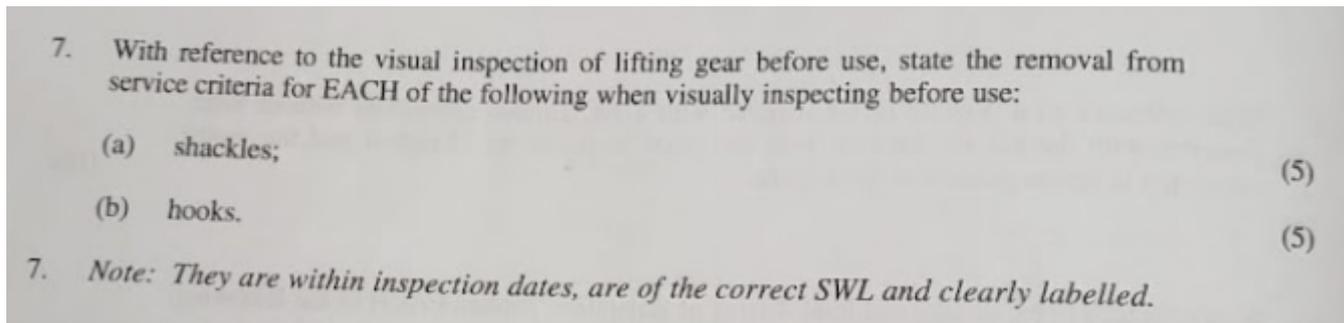
**Diagram layout (in words for sketching)**



**Marking scheme (10 marks likely split):**

- Compressor, condenser, evaporator, expansion valve (4 marks)
- Oil separator shown in discharge line (1 mark)
- Charging point correctly placed (1 mark)
- High & low pressure cut-outs shown (2 marks)

- Flow arrows in correct direction (1 mark)
- General correctness and neatness of line diagram (1 mark)



### Q7: With reference to the visual inspection of lifting gear before use

#### (a) Shackles (5 marks) – Remove from service if:

1. **Bent, distorted or cracked body/pin** – any deformation compromises strength.
  2. **Excessive wear** (usually >10% of original diameter).
  3. **Corrosion or pitting** that reduces section strength.
  4. **Thread damage** on pin or eye, preventing secure fastening.
  5. **Improper pin fitment** – e.g., wrong type of pin, missing split pin or securing device.
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#### (b) Hooks (5 marks) – Remove from service if:

1. **Throat opening enlarged** beyond permissible limits (sign of overload).
  2. **Twist or bending** of the hook shank or body.
  3. **Cracks or sharp nicks** visible, especially at the hook's saddle or eye.
  4. **Excessive wear** at load-bearing points (tip, saddle, or latch area).
  5. **Safety latch missing, bent or inoperative** – essential for preventing slippage.
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✓ **Key Note:** As the question states, we assume that the gear is already:

- **Within inspection dates**
- **Correct SWL (Safe Working Load)**
- **Clearly labelled**

So the focus is purely on **physical condition checks** during a pre-use inspection.

8. Describe the safety requirements for the electrical installation in a large locker on deck, designated for the carriage of petrol, or vehicles with fuel in their tanks.

(10)

**Q8:**

### **Safety requirements for the electrical installation in a large locker on deck (for petrol or vehicles with fuel in tanks)**

#### **1. Explosion-Proof Equipment**

- All electrical fittings (lights, switches, junction boxes, motors, etc.) must be of **flameproof/explosion-proof design** (Ex-rated).
- Certified for use in areas where flammable vapours may be present (hazardous area classification Zone 1 or Zone 2).

#### **2. Ingress Protection (IP Rating)**

- Enclosures must be at least **IP 55 or higher** to prevent entry of petrol vapour and moisture.

#### **3. Cabling Requirements**

- Use **armoured, gas-tight, or flame-retardant cables** resistant to hydrocarbons.
- Cable glands must be **flameproof type** and sealed to prevent vapour ingress.

#### **4. Overcurrent Protection**

- All circuits must be fitted with fuses/circuit breakers located **outside the locker** to prevent sparks inside.

#### **5. Switchgear Location**

- No switching devices inside the locker – all control switches should be **outside** the hazardous space.

#### **6. Earthing and Bonding**

- All metallic parts (enclosures, conduits, fittings) must be properly **earthed** to prevent static charge build-up.

#### **7. Lighting**

- If lighting is required inside, it must be of **intrinsically safe or flameproof type** with reinforced glass covers.

#### **8. Ventilation Interlock**

- Electrical systems should only be energised if **adequate mechanical/natural ventilation** is provided to remove vapours.

### 9. No Portable Electrical Equipment

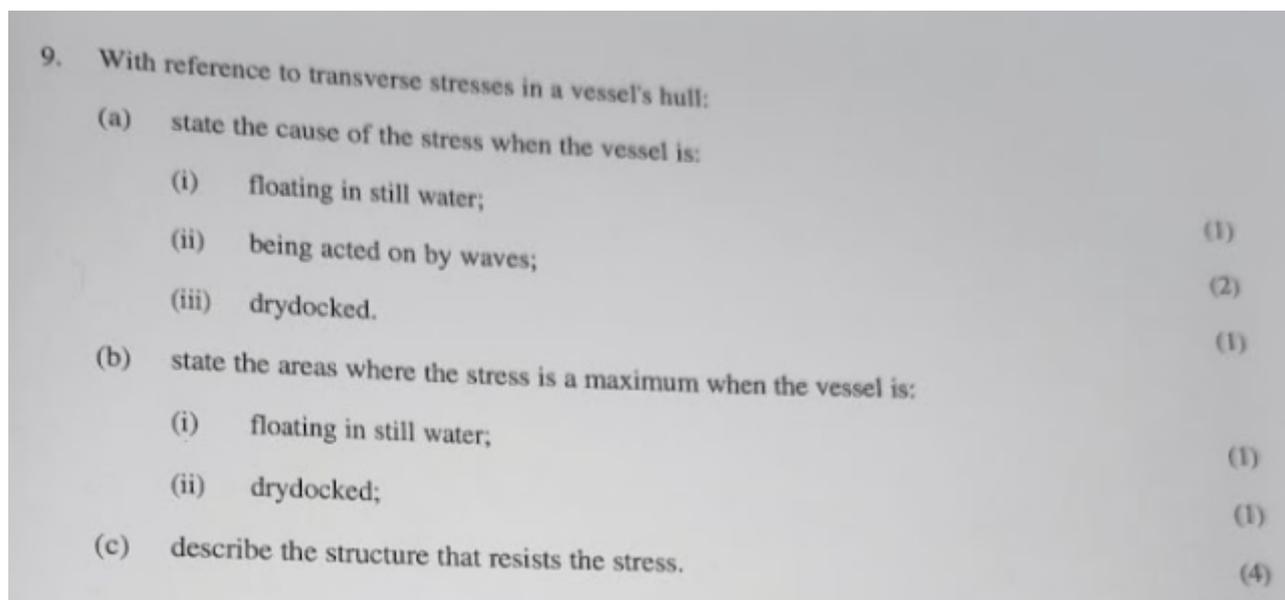
- Portable lamps, tools, or extension leads are strictly prohibited unless certified for use in hazardous areas.

### 10. Periodic Inspection and Maintenance

- Regular inspection of all installations to ensure gas-tight seals, insulation integrity, and compliance with IMO and IEC standards.

### ✔ Summary:

The locker is treated as a **hazardous area (flammable vapour zone)** → therefore all electrical installations must be **flameproof, gas-tight, outside-controlled, properly earthed, and regularly inspected**.



### Q9: With reference to transverse stresses in a vessel's hull

(a) State the cause of the stress when the vessel is:

i. Floating in still water –

- Unequal distribution of **hydrostatic pressure of water** on the ship's sides and bottom compared with internal weight distribution of cargo, machinery, and structure.

ii. Being acted on by waves –

- **Wave pressure on the sides** of the hull causes alternating stresses (rolling, pitching, and pounding).
- Dynamic loads due to **slamming of waves**, uneven buoyancy when supported by crests and troughs.

- **Concentrated support** at keel blocks while the sides of the vessel are unsupported.
  - Causes transverse stresses due to the weight of ship acting downwards versus local support upwards.
- 

**(b) State the areas where the stress is a maximum when the vessel is:**

i. **Floating in still water** –

- **Midship side shell plating** near the bilges and bottom plating, where hydrostatic pressure is greatest.

ii. **Drydocked** –

- **Bilge area and keel region**, since the weight is carried mainly by the keel blocks and the bilges tend to sag outward.
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**(c) Describe the structure that resists the stress.**

- **Transverse framing system** resists these stresses:
    - **Transverse frames/rings**: provide support across the breadth of the vessel.
    - **Floors and side frames**: strengthen the bottom and side shell against hydrostatic pressure.
    - **Beam knees and deck beams**: tie the side frames together at the deck, resisting outward/inward forces.
    - **Web frames and transverse bulkheads**: add rigidity and distribute stresses.
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✓ **Summary:**

Transverse stresses arise from water pressure, waves, or dock block support, with maximum stress at bilges, sides, and keel. They are resisted by the **transverse framing system** (floors, frames, beams, bulkheads).

10. With reference to surface preparation for the painting of a vessels hull in dry-dock, list the advantages and disadvantages of EACH of the following methods:

- (a) abrasive blasting; (5)
- (b) hydroblasting. (5)

**Q10: With reference to surface preparation for painting of a vessel's hull in dry-dock, list the advantages and disadvantages of:**

**(a) Abrasive blasting (e.g. grit or sand blasting):****✓ Advantages:**

- Produces a **very high standard of surface preparation** (near-white metal finish possible).
- Provides a **good mechanical key** for paint adhesion.
- Removes **rust, mill scale, old paint** effectively.
- Can clean **large areas quickly**.
- Surface roughness profile improves coating durability.

**✗ Disadvantages:**

- Creates a large amount of **dust** (health hazard, requires PPE and environmental controls).
  - Requires **containment and waste disposal** of abrasive material.
  - Noisy and potentially damaging to nearby equipment.
  - Expensive due to need for **special equipment and skilled operators**.
  - Can cause **surface deformation or embed abrasive** in softer steels if poorly controlled.
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**(b) Hydroblasting (high-pressure water jetting):****✓ Advantages:**

- No abrasive waste; more **environmentally friendly**.
- Removes **salts, loose rust, scale, coatings, oil and grease** without dust production.
- Lower health risk compared to abrasive blasting (no inhalation of grit).
- Does not damage the steel surface (no embedding of material).
- Can be used on **confined or sensitive areas**.

**✗ Disadvantages:**

- Does not create a **surface roughness profile** as good as abrasive blasting (weaker paint adhesion in some cases).
- Flash rusting can occur quickly if surface not dried and coated promptly.

- Less effective against **heavily adhered scale or coatings** compared to abrasive blasting.
  - Requires **high-pressure pumps** and large amounts of water.
  - Water run-off management is needed (pollution risk in dock).
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✓ **Summary:**

- **Abrasive blasting** → best adhesion, but dusty, messy, expensive.
- **Hydroblasting** → cleaner, safer, eco-friendly, but less effective against heavy rust/scale and prone to flash rusting.