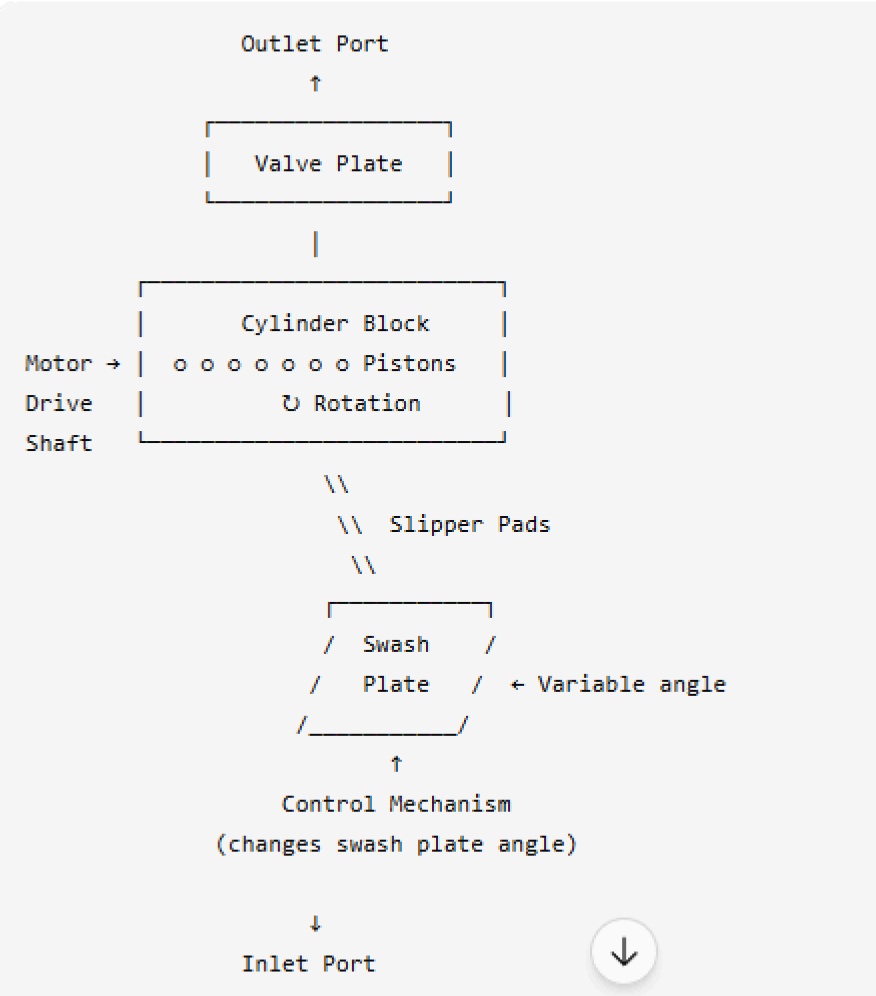
1. Describe, with the aid of a sketch, the operation of a variable delivery axial piston pump.

Variable Delivery Axial Piston Pump (Swash Plate Type)

A variable delivery axial piston pump is a hydraulic pump in which the flow rate can be changed by altering the angle of the swash plate. The pump consists of a number of pistons arranged parallel to the drive shaft within a rotating cylinder block.



Operation

1. Drive Rotation
   - The drive shaft rotates the cylinder block.
   - The cylinder block contains several pistons arranged parallel to the shaft.
2. Piston Movement
   - The piston shoes (slippers) bear against the inclined swash plate.
   - As the cylinder block rotates, the angled swash plate forces the pistons to reciprocate within their bores.
3. Suction Stroke
   - When a piston moves outward from its bore, its chamber volume increases.
   - This creates a vacuum and hydraulic fluid enters through the inlet port in the valve plate.
4. Delivery Stroke
   - As rotation continues, the swash plate pushes the piston back into its bore.
   - The chamber volume decreases, forcing fluid out through the outlet port.
5. Variable Delivery
   - The delivery of the pump depends on the swash plate angle:

- Large angle: Greater piston stroke → higher flow rate.
- Small angle: Shorter piston stroke → lower flow rate.
- Zero angle: No piston reciprocation → no flow, although the shaft continues to rotate.

6. Control of Flow
   - The swash plate angle may be adjusted manually, hydraulically, or by a pressure-compensating mechanism to match system demand.

Advantages

- Flow can be varied without changing pump speed.
- High operating efficiency.
- Rapid response to changes in hydraulic demand.
- Reduced energy losses compared with throttling methods.

Exam-Style Answer

A variable delivery axial piston pump consists of a rotating cylinder block containing several pistons parallel to the drive shaft. The piston slippers run against an inclined swash plate. Rotation of the cylinder block causes the pistons to reciprocate, drawing fluid into the cylinders through the inlet port and discharging it through the outlet port. The pump delivery is varied by changing the swash plate angle. Increasing the angle increases piston stroke and flow, while reducing the angle decreases flow. At zero swash plate angle, no fluid is delivered despite continued shaft rotation.

(10)

2. Explain the operation of the hydraulic system shown in figure.

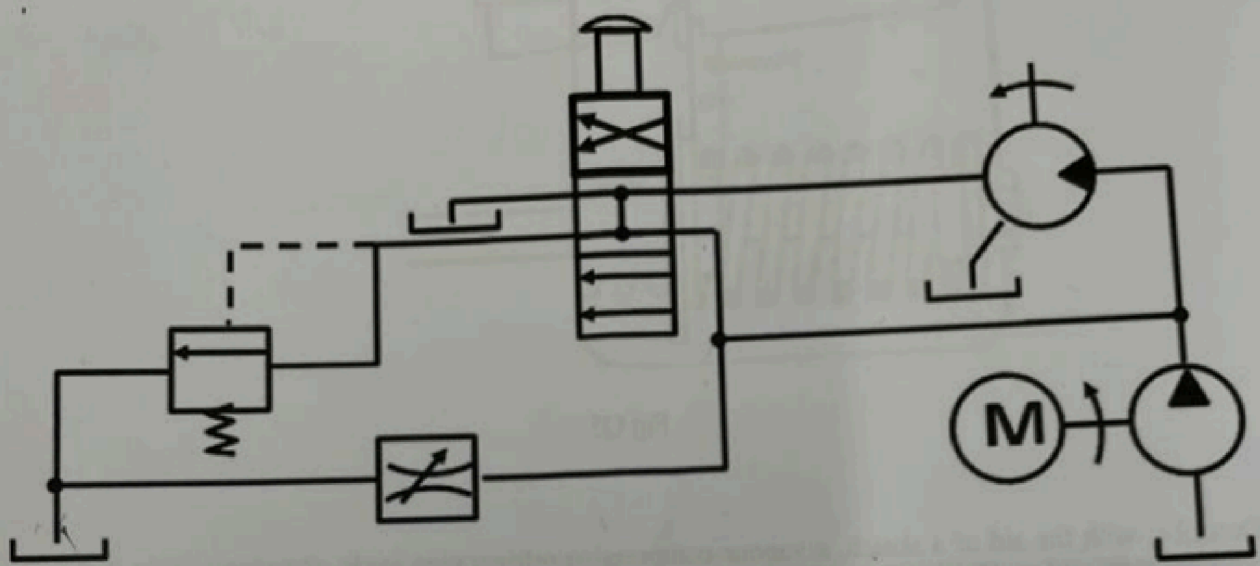


Fig Q2

"The circuit could be used to operate a mooring winch or anchor windlass. The hydraulic motor provides the rotary motion required, the flow control valve allows adjustment of operating speed, the directional valve starts and stops the motor, and the relief valve protects the system against overload."

The key issue is the centre position of the directional control valve.

From the symbol in your figure, the centre position does not appear to block both motor ports completely. Instead, it looks like the motor ports may be interconnected and/or connected in such a way that the motor can freewheel or "float."

If that interpretation is correct, then:

- The motor is not hydraulically locked in the neutral position.
- The motor could be turned by an external load.
- On a winch or windlass, this would allow the load to pay out under control rather than remain stationary.

The adjustable valve in the return line would then act as a brake/throttle, controlling the rate at which the motor turns when driven by the load.

So the operation would be:

Neutral position

- Pump flow is unloaded back to tank.
- The hydraulic motor is not positively driven by the pump.
- Depending on the exact centre-port configuration, the motor may be free to rotate under an external load.
- In a winch application, this allows paying out of the rope or chain.

Lever operated

- Pump flow is directed to the motor.
- The motor rotates in the powered direction.
- The flow control valve regulates the speed.

Overload

- The pilot-operated relief valve opens if pressure exceeds the set value.
- Excess oil returns to tank, protecting the system.

3. With reference to load sharing of a.c. generators:

(a) state the meaning of the term *speed droop*; (3)

(b) explain the effect of running generators in parallel with different speed droop settings for EACH of the following:

(i) when the generators are sharing the load equally; (3)

(ii) when the load suddenly increases. (4)

3. With reference to load sharing of A.C. generators:

(a) State the meaning of the term speed droop. (3 marks)

Speed droop is the intentional reduction in the governor speed setting as generator load increases. It is expressed as the percentage decrease in frequency (or prime mover speed) between the no-load condition and full-load condition.

In other words, as a generator takes more load, its governor allows the engine speed to fall slightly. This enables generators operating in parallel to share load automatically and stably.

Example

If a generator runs at:

- 60 Hz at no load, and
- 58.2 Hz at full load,

then:

$$\text{Speed droop} = \frac{60 - 58.2}{60} \times 100 = 3\%$$

A typical speed droop setting is **3–5%**.

(b) Explain the effect of running generators in parallel with different speed droop settings.

(i) When the generators are sharing the load equally (3 marks)

If two generators have different speed droop settings, they can still be adjusted to share the load equally by altering their governor speed settings.

However:

- The generator with the smaller droop (flatter characteristic) tends to resist frequency changes and is more sensitive to load changes.
- The generator with the larger droop experiences a greater speed reduction as load increases.
- Equal load sharing is therefore possible only after careful governor adjustment, but the arrangement is less stable than if both generators have identical droop settings.

(ii) When the load suddenly increases (4 marks)

When an additional load is applied:

- The system frequency initially falls.
- The governors of both generators respond to increase fuel supply.
- The generator with the lower speed droop setting increases its output by a greater amount because its governor characteristic is steeper.
- The generator with the higher droop setting takes a smaller share of the additional load.
- Consequently, the generators no longer share the load equally; the low-droop machine becomes more heavily loaded.
- If the difference in droop settings is large, one generator may approach overload while the other remains lightly loaded.

Exam-style answer

(a)

Speed droop is the percentage reduction in generator speed or frequency between no-load and full-load conditions caused by the governor characteristic. It allows stable load sharing between generators operating in parallel.

(b)(i)

Generators with different droop settings may be adjusted to share the existing load equally by altering governor settings, although the sharing is less stable than with identical droop characteristics.

(b)(ii)

Following a sudden increase in load, the generator with the lower droop setting accepts a larger proportion of the additional load, while the generator with the higher droop setting accepts less. The load therefore becomes unequally shared and the low-droop generator may become overloaded.

4. With reference to a 440 Volt, 3-phase motor supplied with six terminal connections in the terminal box:

(a) sketch a Delta connection, showing the relationship between phase and line voltages; (2)

(b) sketch a Star connection, showing the relationship between phase and line voltages; (2)

(c) state the relative speed of both connections; (2)

(d) sketch and label the terminal link connections so the motor will run in permanent Delta mode. (4)

4. With reference to a 440 V, 3-phase motor supplied with six terminal connections in the terminal box:

(a) Sketch a Delta connection, showing the relationship between phase and line voltages. (2 marks)

```
        L1
        •
       / \
      /   \
Vph  /     \ Vph
    /       \
   •---------•
  L3   Vph   L2
```

Each winding is connected end-to-end to form a closed loop.

Voltage Relationship

In a Delta connection: $$V_L = V_{ph}$$

Therefore, for a 440 V supply:

- Line Voltage (VL) = 440 V
- Phase Voltage (Vph) = 440 V

(b) Sketch a Star connection, showing the relationship between phase and line voltages. (2 marks)

Star (Y) Connection

```
        L1
        •
        |
       Vph
        |
        •
       /|\
      / | \
     /  |  \
  Vph   N   Vph
   /         \
  •           •
 L2           L3
```

One end of each winding is joined to form the neutral point.

Voltage Relationship

In a Star connection:

$$V_L = \sqrt{3}V_{ph}$$

or

$$V_{ph} = \frac{V_L}{\sqrt{3}}$$

For a 440 V supply:

$$V_{ph} = \frac{440}{1.732} \approx 254\ V$$

Therefore:

- **Line Voltage (VL) = 440 V**
- **Phase Voltage (Vph) ≈ 254 V**

(c) State the relative speed of both connections. (2 marks)

The **speed of the motor is the same in both Star and Delta connections.**

This is because motor speed depends mainly on:

$$N_s = \frac{120f}{P}$$

$N_s = \frac{120f}{P}$

where:

- N_s = synchronous speed (rpm)
- f = supply frequency (Hz)
- P = number of poles

Since the supply frequency and number of poles do not change, the speed remains essentially unchanged.

> **Relative Speed:**
> Star speed = Delta speed.

(The torque differs, but not the speed.)

(d) Sketch and label the terminal link connections so the motor will run in permanent Delta mode. (4 marks)

Assuming the six terminals are arranged as:

```
U1    V1    W1
U2    V2    W2
```

Permanent Delta Connections

Permanent Delta Connections

```
Supply

L1 ── U1
       |
       | Link
       W2

L2 ── V1
       |
       | Link
       U2

L3 ── W1
       |
       | Link
       V2
```

Terminal Box Layout

```
      U1       V1        W1
L1 ──●         ●────L2  ●────L3
      |        |         |
      |        |         |
      ●        ●         ●
      W2       U2        V2
```

Links fitted:

- **U1 – W2**
- **V1 – U2**
- **W1 – V2**

Exam-Style Answer

- **Delta:** $V_L = V_{ph}$; each winding receives the full 440 V.
- **Star:** $V_L = \sqrt{3}V_{ph}$; each winding receives approximately 254 V from a 440 V supply.
- **Speed:** The motor runs at essentially the **same speed** in both Star and Delta connections.
- **Permanent Delta:** Fit links **U1–W2, V1–U2, and W1–V2**, and connect L1, L2, and L3 to U1, V1, and W1 respectively.

5. (a) State THREE reasons for the operation of a *High Pressure Cut-out* in a vapour compression refrigeration system. (3)

(b) Describe the operation of the High Pressure Cut-Out, employed in a vapour compression refrigeration system shown in the figure. (7)

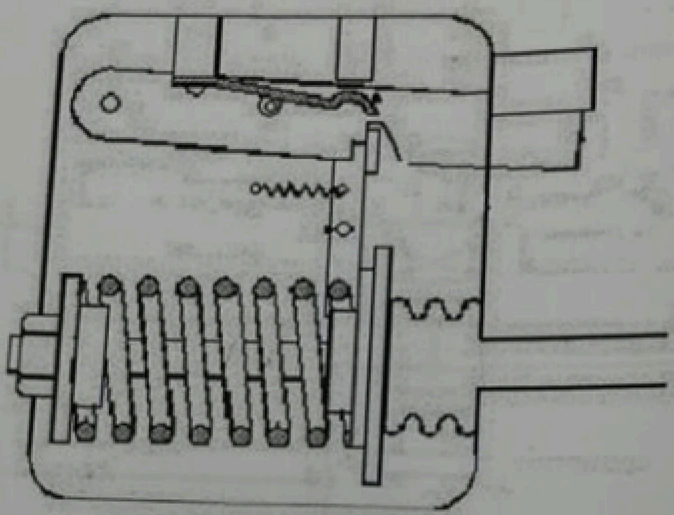


Fig Q5

5. (a) State THREE reasons for the operation of a High Pressure Cut-out in a vapour compression refrigeration system. (3 marks)

A High Pressure Cut-out (HPCO) protects the refrigeration compressor by stopping it when the discharge (condensing) pressure becomes excessive.

Three reasons why the high pressure cut-out may operate are:

1. Insufficient cooling water flow through the condenser
   - Sea water pump failure.
   - Condenser inlet valve closed.
   - Blocked cooling water passages.
2. Fouling or scaling of the condenser
   - Dirty condenser tubes reduce heat transfer.
   - The refrigerant cannot condense efficiently, causing discharge pressure to rise.

3. Air or non-condensable gases in the system
    - Air occupies space in the condenser.
    - This increases the condensing pressure and compressor discharge pressure.

Other acceptable answers include:

- Cooling water temperature too high.
- Overcharge of refrigerant.
- Condenser fan failure (air-cooled systems).
- Restricted discharge line.

(b) Describe the operation of the High Pressure Cut-out shown in the figure. (7 marks)

The figure shows a manual reset bellows-operated high pressure cut-out switch.

Construction

The device consists of:

- A bellows connected to the compressor discharge line.
- An adjustable spring opposing the bellows movement.
- A lever and latch mechanism.
- A set of electrical contacts.
- A manual reset button.

Operation

Normal Operation

- High-pressure refrigerant from the compressor discharge line acts on the bellows.
- The force exerted by the bellows is balanced by the opposing spring force.
- Under normal operating pressure, the contacts remain closed.
- The compressor control circuit is complete, allowing the compressor to run.

High Pressure Condition

- If the discharge pressure rises above the preset cut-out value:
    - The increased pressure causes the bellows to expand.
    - The bellows movement overcomes the spring force.
    - The movement operates the lever mechanism.
    - The latch trips and the electrical contacts open.
    - The compressor motor contactor is de-energised.
    - The compressor stops, preventing damage to the system.

Manual Reset

- After the cause of the high pressure has been identified and corrected:
  - The system pressure falls.
  - The operator presses the manual reset button.
  - The latch re-engages.
  - The contacts close again.
  - The compressor can then be restarted.

Exam-Style Answer

> The high pressure cut-out is a safety device fitted to the compressor discharge side. Under normal pressure conditions, refrigerant pressure acting on the bellows is balanced by an adjustable spring and the electrical contacts remain closed. If the discharge pressure exceeds the preset value, the bellows expands and operates a lever and latch mechanism, causing the contacts to open and stopping the compressor. After the fault causing the high pressure has been rectified and the pressure has reduced, the device must be manually reset before the compressor can be restarted.

Labelled Components from Fig Q5

- Bellows (pressure sensing element)
- Adjustable spring
- Lever mechanism
- Electrical contacts
- Latch/trip mechanism
- Manual reset button
- Connection to compressor discharge line

This type of manual-reset HPCO is commonly fitted on marine refrigeration plants because it prevents automatic restarting after a potentially dangerous high-pressure fault.

6. Describe, with the aid of a sketch, a vapour-compression refrigeration cycle, showing clearly the physical state and condition of the refrigerant in the system. (10)

6. Describe, with the aid of a sketch, a vapour-compression refrigeration cycle, showing clearly the physical state and condition of the refrigerant in the system. (10 marks)

Sketch of a Vapour-Compression Refrigeration Cycle

```
        HIGH PRESSURE SIDE

    ┌──────────────────────────────┐
    |                              |
    |       CONDENSER              |
    |   Heat rejected to           |
    |   seawater/air               |
    └──────────────────────────────┘
               |
               |
               | High-pressure liquid
               | (subcooled liquid)
               ▼
     EXPANSION VALVE
   (throttling device)
               |
               | Low-pressure liquid/
               | vapour mixture
               ▼
    ┌──────────────────────────────┐
    |                              |
    |         EVAPORATOR           |
    | Heat absorbed from           |
    | refrigerated space           |
    └──────────────────────────────┘
               |
               |
               | Low-pressure
               | dry saturated or
               | slightly superheated vapour
               ▼
         COMPRESSOR
               |
               | High-pressure,
               | high-temperature
               | superheated vapour
               ▼
            Back to
            CONDENSER
```

Description of the Cycle

The vapour-compression refrigeration cycle consists of four main components:

1. Compressor
2. Condenser
3. Expansion valve
4. Evaporator

The refrigerant undergoes changes in pressure, temperature, and physical state as it circulates through the system.

---

1. Evaporator

Refrigerant Condition Entering

- Low pressure
- Low temperature
- Mixture of liquid and vapour

Process

- The refrigerant absorbs heat from the refrigerated space.
- The remaining liquid boils and evaporates.

Refrigerant Condition Leaving

- Low-pressure dry saturated vapour
- Often slightly superheated vapour to ensure no liquid enters the compressor.

---

2. Compressor

Refrigerant Condition Entering

- Low-pressure dry or slightly superheated vapour.

Process

- The compressor draws in the refrigerant vapour and compresses it.
- Compression increases both pressure and temperature.

Refrigerant Condition Leaving

- High-pressure
- High-temperature
- Superheated vapour

---

3. Condenser

Refrigerant Condition Entering

- High-pressure superheated vapour.

Process

The refrigerant first loses its superheat and then condenses:

1. Desuperheating
   - Superheated vapour cools to the saturation temperature.
2. Condensation
   - Latent heat is rejected to the cooling medium.

    - Vapour changes into liquid.
3. Subcooling
    - The liquid may be cooled below its saturation temperature.

Refrigerant Condition Leaving

- High-pressure liquid
- Usually subcooled liquid

---

4. Expansion Valve (Thermostatic Expansion Valve)

Refrigerant Condition Entering

- High-pressure liquid refrigerant.

Process

- The refrigerant passes through a restriction.
- Pressure drops suddenly.
- No external work is done.
- Some of the liquid flashes into vapour.

Refrigerant Condition Leaving

- Low-pressure
- Low-temperature
- Liquid and vapour mixture

This mixture then returns to the evaporator to repeat the cycle.

Physical State of the Refrigerant Throughout the Cycle

Component	Pressure	Temperature	Physical State
Evaporator inlet	Low	Low	Liquid/vapour mixture
Evaporator outlet	Low	Low	Dry saturated or slightly superheated vapour
Compressor outlet	High	High	Superheated vapour

Condenser outlet	High	Moderate	Saturated or subcooled liquid
Expansion valve outlet	Low	Low	Liquid/vapour mixture

Exam-Style Answer

In a vapour-compression refrigeration cycle, low-pressure liquid refrigerant from the expansion valve enters the evaporator as a liquid/vapour mixture and absorbs heat from the refrigerated space, leaving as a dry saturated or slightly superheated vapour. The compressor raises the pressure and temperature of the vapour, producing a high-pressure superheated vapour. In the condenser, heat is rejected to the cooling medium and the refrigerant condenses to a high-pressure liquid, often becoming subcooled. The liquid then passes through the expansion valve, where its pressure and temperature are reduced, producing a low-pressure liquid/vapour mixture that returns to the evaporator to repeat the cycle. This continuous process transfers heat from the refrigerated space to the surroundings.

7. With reference to the Code of Safe Working Practices for Merchant Seamen and maintenance of lifting equipment:

(a) outline FIVE maintenance procedures to be carried out on lifting equipment (excluding loose gear); (5)

(b) state who should carry out the examination of the lifting equipment, the interval between examinations and the defects that may be found. (5)

7. With reference to the Code of Safe Working Practices for Merchant Seamen and maintenance of lifting equipment:

(a) Outline FIVE maintenance procedures to be carried out on lifting equipment (excluding loose gear). (5 marks)

Lifting equipment includes cranes, derricks, winches, hoists, and associated fixed fittings. The following maintenance procedures should be carried out:

1. Inspect Wire Ropes

- Check for broken wires, kinks, crushing, corrosion, bird-caging, and reduction in diameter.

- Ensure ropes are correctly reeved on drums and sheaves.

2. Lubricate Moving Parts

- Lubricate bearings, sheaves, pivot pins, gears, and wire ropes as recommended by the manufacturer.
- Ensure suitable lubricants are used to reduce wear and corrosion.

3. Examine Brakes and Clutches

- Check brake linings and drums for wear.
- Test that brakes hold the load effectively.
- Inspect clutch mechanisms for correct operation and adjustment.

4. Inspect Structural Components

- Examine booms, derricks, crane jibs, foundations, and welds for cracks, deformation, corrosion, and loose fastenings.
- Check securing bolts and supporting structures.

5. Check Safety Devices and Controls

- Test limit switches, overload protection devices, emergency stops, indicators, and control systems.
- Ensure all operating controls function correctly and are clearly marked.

Other acceptable procedures include inspection of hydraulic systems for leaks, checking electrical connections, and verifying that guards and protective covers are in place.

(b) State who should carry out the examination of the lifting equipment, the interval between examinations, and the defects that may be found. (5 marks)

Who Should Carry Out the Examination?

The examination should be carried out by a:

> Competent person, that is, a person with the necessary knowledge, experience, qualifications, and independence to assess the condition of the lifting equipment.

This may be:

- A classification society surveyor,
- A manufacturer's representative,
- A suitably qualified marine engineer or inspector authorised for the task.

Interval Between Examinations

Under the Code of Safe Working Practices:

- Lifting appliances should be thoroughly examined at least once every 12 months.
- They should also be examined:
    - After any substantial alteration or repair,
    - After an accident or exceptional occurrence,
    - Whenever there is reason to doubt their continued safety.

Defects That May Be Found

Examples include:

- Cracked or distorted structural members.
- Corrosion or excessive wear.
- Broken, worn, or distorted wire ropes.
- Defective brakes or clutches.
- Worn bearings or sheaves.
- Hydraulic leaks.
- Loose or missing securing bolts.
- Faulty limit switches or overload protection devices.
- Defective controls or emergency stops.

Exam-Style Answer

(a)

Maintenance procedures include inspecting wire ropes, lubricating moving parts, examining brakes and clutches, inspecting structural members for cracks and corrosion, and testing safety devices and controls.

(b)

Thorough examinations should be carried out by a competent person at intervals not exceeding 12 months, and additionally after repairs, alterations, or accidents. Defects that may be found include cracked structures, corrosion, worn wire ropes, defective brakes, hydraulic leaks, faulty safety devices, and loose fastenings.

8. Explain the requirements for the stowage and operation of LPG cylinders. (10)

8. Explain the requirements for the stowage and operation of LPG cylinders. (10 marks)

LPG (Liquefied Petroleum Gas) cylinders contain highly flammable gases such as propane and butane. The **Code of Safe Working Practices for Merchant Seamen** requires strict precautions for their storage and use.

(a) Stowage Requirements

1. Store in a Dedicated Locker

- Cylinders should be kept in a **separate LPG storage locker** designed specifically for gas bottles.
- The locker should be clearly marked:

"LPG – HIGHLY FLAMMABLE – NO SMOKING OR NAKED LIGHTS."

2. Adequate Ventilation

- The locker must be **well ventilated to the open air**, preferably at both high and low levels.
- Since LPG is **heavier than air**, low-level ventilation is particularly important to prevent gas accumulation.

3. Location of Locker

- The locker should be situated:
  - On an open deck or in a safe external position.
  - Away from accommodation spaces, machinery spaces, and sources of ignition.
  - Away from air intakes and openings leading into the ship.

4. Cylinders Secured Upright

- Cylinders must always be stored **upright**.
- They should be properly secured to prevent movement, falling, or damage in heavy weather.

5. Protection from Heat

- Cylinders should be protected from direct sunlight and excessive heat.
- They must not be exposed to temperatures that could increase internal pressure.

6. Valve Protection

- Cylinder valves should be closed when not in use.
- Protective valve caps or guards should be fitted where provided.

7. Separation of Full and Empty Cylinders

- Full and empty cylinders should be clearly identified and stowed separately to avoid confusion.

(b) Operational Requirements

1. Leak Testing

- Before use, connections, hoses, regulators, and valves should be checked for leaks.
- A **soap solution** should be used.
- **A naked flame must never be used to detect leaks.**

2. Correct Regulators and Fittings

- Only approved regulators, hoses, and fittings suitable for LPG service should be used.
- Improvised connections are prohibited.

3. Open Valves Slowly

- Cylinder valves should be opened slowly to avoid sudden pressure surges.

4. Shut Off Supply After Use

- The cylinder valve should be closed whenever the equipment is not in operation.
- The appliance control valve should then be closed after the gas in the line has been consumed.

5. No Smoking or Naked Lights

- Smoking, welding, grinding, or other ignition sources must be prohibited near LPG cylinders.

6. Regular Inspection

- Hoses should be inspected for cracks, wear, or deterioration.
- Regulators and connections should be maintained in good condition.

7. Action in the Event of a Leak

If a leak is suspected:

- Close the cylinder valve immediately.
- Extinguish all naked flames.
- Isolate electrical equipment if safe to do so.
- Ventilate the area thoroughly.
- Report the defect and do not use the equipment until repaired.

Exam-Style Answer

> LPG cylinders should be stored upright in a dedicated, well-ventilated locker located on open deck and away from accommodation spaces and sources of ignition. Cylinders must be secured against movement, protected from heat, clearly labelled, and have valves closed when not in use. During operation, only approved regulators and hoses should be used, leak tests should be carried out using soapy water, valves should be opened slowly, and smoking or naked lights prohibited. In the event of a leak, the gas supply should be isolated, the area ventilated, and the fault rectified before further use.

Key Points Examiners Look For

✓ Dedicated ventilated locker
✓ Upright and securely fastened cylinders
✓ Away from ignition sources and accommodation
✓ Valves closed and protected
✓ Leak testing with soapy water only
✓ Approved fittings and regulators
✓ No smoking or naked flames
✓ Correct action in the event of a leak

9. Explain, with the aid of sketches, the dynamic stresses encountered by a vessel in a seaway as a wave moves along the length of the hull.

(10)

9. Explain, with the aid of sketches, the dynamic stresses encountered by a vessel in a seaway as a wave moves along the length of the hull. (10 marks)

As a vessel travels through a seaway, the distribution of buoyancy changes continuously as waves pass along the hull. This causes the hull girder to be subjected to **dynamic longitudinal stresses**, principally **hogging** and **sagging**. In addition, local dynamic stresses such as panting, pounding, and torsion may occur.

(a) Hogging

Condition

Hogging occurs when:

- The **wave crest is amidships**, or
- The **bow and stern are in wave troughs**.

The centre of the ship is supported more than the ends.

Sketch

```
          Wave Crest Amidships
                 /\
                /  \
~~~~~~~~~~~~~~~~\/~~~~~~~~~~~~~~~~

      Bow               Stern
       \                 /
        \_______________/
               ↑
           Hull bends

            HOGGING
```

Stresses Produced

- **Deck:** Tension (stretched)
- **Bottom plating/keel:** Compression (squeezed)

```
    Deck      ← Tension

 ┌─────────────────┐
 │                 │
 └─────────────────┘

    Keel      ← Compression
```

Explanation

The middle of the vessel tends to rise relative to the ends, causing the ship to bend upward like an arch.

(b) Sagging

Condition

Sagging occurs when:

- The **wave trough is amidships**, or
- The **bow and stern are supported by wave crests**.

The ends are supported more than the centre.

Sketch

Sketch

```
~~~~~~~~~~~~~~/\~~~~~~~~~~~~~~/\~~~~~~~
              \              /
               \____________/
                     \/
              Wave Trough

               SAGGING
```

Stresses Produced

- **Deck:** Compression
- **Bottom plating/keel:** Tension

```
    Deck      ← Compression

  ┌──────────────────┐
  │                  │
  └──────────────────┘

    Keel      ← Tension
```

Explanation

The centre of the vessel tends to droop below the ends, causing the hull to bend downward.

(c) Panting

Description

Panting is the **in-and-out movement of the shell plating at the bow and stern** due to alternating water pressure as the vessel pitches in heavy seas.

Effects

- Flexing of shell plating.
- Stress concentration around frames.
- Possible cracking if severe.

Prevention

- Panting beams.
- Stringers.
- Closely spaced framing in the forepeak.

(d) Pounding (Slamming)

Description

Pounding occurs when:

- The bow emerges from the water during pitching.
- It then falls heavily onto the next wave surface.

Effects

- High impact loads on the forward bottom structure.
- Damage to shell plating and frames.
- Possible deformation and cracking.

Prevention

- Increased plate thickness forward.
- Closer frame spacing.
- Additional strengthening.

(e) Torsion

Description

Torsional stresses occur when waves act unevenly along the ship, causing the hull to twist about its longitudinal axis.

Effects

- Particularly significant in container ships and vessels with large deck openings.
- Produces shear stresses and twisting loads.

Summary Table

Dynamic Stress	Cause	Main Effect
Hogging	Wave crest amidships	Deck in tension, keel in compression
Sagging	Wave trough amidships	Deck in compression, keel in tension

Panting	Alternating bow/stern water pressure	In-and-out shell plating movement
Pounding (Slamming)	Bow striking the sea surface	Heavy impact stresses forward
Torsion	Uneven wave support	Twisting of hull girder

Exam-Style Answer

As waves move along the length of a vessel, varying buoyancy forces produce dynamic stresses in the hull girder. When a wave crest is amidships, the vessel experiences **hogging**, causing the deck to be in tension and the keel in compression. When a wave trough is amidships, **sagging** occurs, producing compression in the deck and tension in the keel. Other dynamic stresses include **panting**, caused by fluctuating water pressure at the bow and stern; **pounding (slamming)**, resulting from the bow striking the sea surface during pitching; and **torsion**, caused by uneven wave action twisting the hull. Ships are structurally reinforced to withstand these repeated dynamic loads.

10. With reference to stresses and strain in vessels, describe, with the aid of a sketch, EACH of the following:

(a) panting; (2)

(b) pounding; (2)

(c) racking; (2)

(d) hogging; (2)

(e) sagging; (2)

10. With reference to stresses and strain in vessels, describe, with the aid of a sketch, EACH of the following:

(a) Panting (2 marks)

Description

Panting is the **inward and outward flexing of the shell plating at the bow and stern** caused by alternating water pressures as the vessel pitches in heavy seas.

Sketch

```
     Heavy Sea

  Water pressure
        ↓
 →  /‾‾‾‾\  ←
    |     |
    | Bow |   Shell plating
 ←  \_____/  →
     In and out movement

       PANTING
```

Prevention

- Panting beams
- Panting stringers
- Closely spaced frames

(b) Pounding (2 marks)

Description

Pounding (or slamming) occurs when the **bow lifts clear of the water and then falls heavily onto the next wave**, causing severe impact stresses on the forward bottom structure.

Sketch

```
       Ship pitches upward


            _______
           /       \
~~~~~~~~~~~/         \~~~~~~

                ↓ Impact

~~~~~~~~~~~~~~~/\~~~~~~~~~~

           POUNDING
```

Prevention

- Increased shell plate thickness
- Closer frame spacing
- Additional strengthening forward

(c) Racking (2 marks)

Description

Racking is the **distortion of the ship's transverse structure caused by rolling motions in a seaway**. The originally rectangular framework tends to become diamond-shaped.

Sketch

```
Normal Frame          Racked Frame

┌────────┐           /────────\
│        │          /          \
│        │   →     \            /
│        │           \────────/
└────────┘

       RACKING
```

Effects

- Stress in side frames and bulkheads.
- Particularly significant in ships with large openings.

(d) Hogging (2 marks)

Description

Hogging occurs when a **wave crest is amidships**, causing the middle of the vessel to rise relative to the bow and stern.

Sketch

```
        Wave Crest

~~~~~~~~~~~~~/\~~~~~~~~~~~~~

      \_____________/
           ↑

        HOGGING
```

Stresses

- Deck: **Tension**
- Keel: **Compression**

(e) Sagging (2 marks)

Description

Sagging occurs when a **wave trough is amidships**, causing the centre of the vessel to droop below the bow and stern.

Sketch

```
~~~~~~~~/\~~~~~~/\~~~~~~~

        /‾‾‾‾‾‾‾\
            ↓

          SAGGING
```

Exam-Style Answers

(a) Panting

> Panting is the in-and-out movement of shell plating at the bow and stern due to fluctuating water pressure in heavy seas.

(b) Pounding

> Pounding is the impact stress caused when the bow slams heavily onto the sea surface after emerging from the water during pitching.

(c) Racking

> Racking is the distortion of the ship's transverse structure due to rolling, causing rectangular sections to become diamond-shaped.

(d) Hogging

> Hogging occurs when a wave crest is amidships, placing the deck in tension and the keel in compression.

(e) Sagging

> Sagging occurs when a wave trough is amidships, placing the deck in compression and the keel in tension.

Quick Memory Aid

Stress	Cause	Deck	Keel
Panting	Pressure changes at bow/stern	–	–
Pounding	Bow slamming on waves	Impact stress	Impact stress
Racking	Rolling motion	Transverse distortion	Transverse distortion
Hogging	Crest amidships	Tension	Compression
Sagging	Trough amidships	Compression	Tension

Memory tip:

- **Hogging = hump in the middle** (like a hog's back).
- **Sagging = sinking in the middle.**