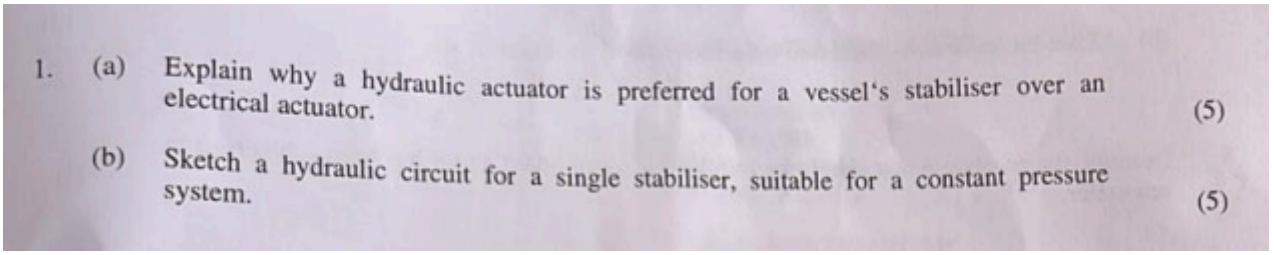


1. (a) Explain why a hydraulic actuator is preferred for a vessel's stabiliser over an electrical actuator. (5)

(b) Sketch a hydraulic circuit for a single stabiliser, suitable for a constant pressure system. (5)

1. (a) Explain why a hydraulic actuator is preferred for a vessel's stabiliser over an electrical actuator. (5 marks)

Hydraulic actuators are generally preferred for operating vessel stabilisers because:

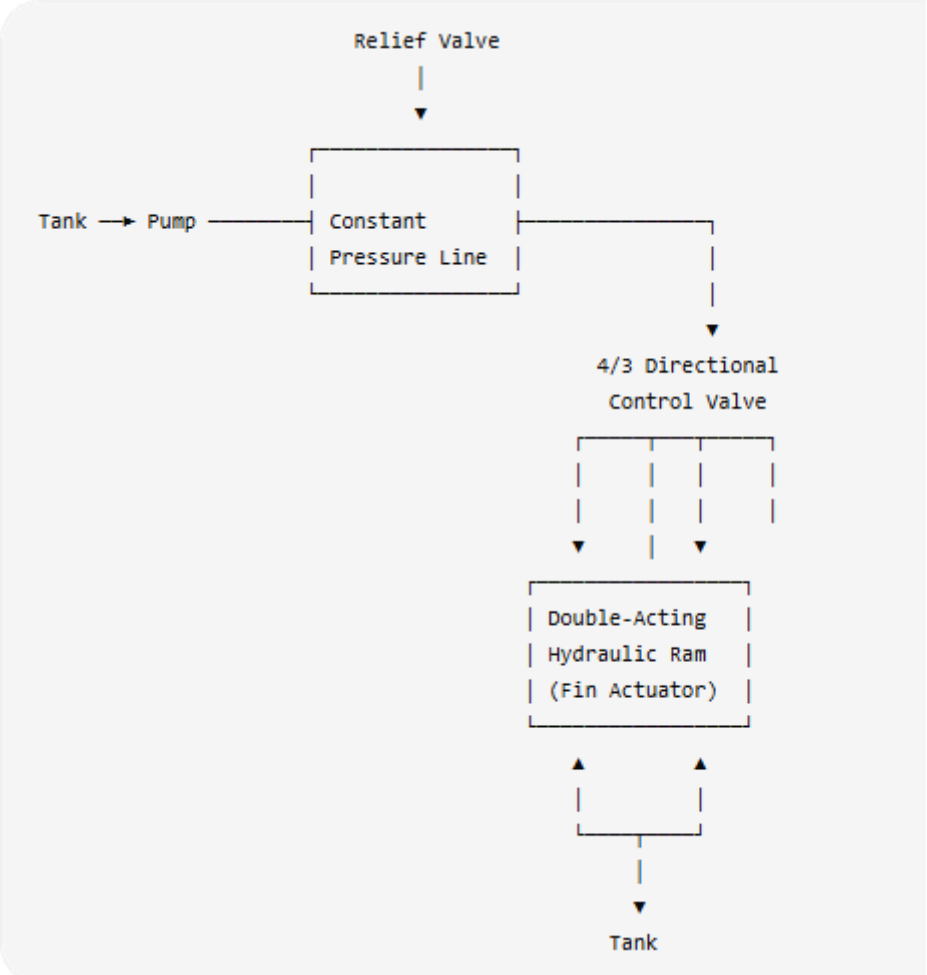
1. **High force output** – Hydraulic systems can produce very large torques and forces from relatively compact actuators, which are required to move stabiliser fins against heavy sea loads.
2. **Fast response** – They can rapidly change the fin angle in response to rolling motions, providing effective stabilisation.
3. **Smooth and precise control** – Hydraulic flow can be accurately controlled, allowing continuous adjustment of fin position.
4. **Ability to withstand shock loads** – Hydraulic systems absorb sudden changes in loading better than electrical drives and are less susceptible to damage from wave-induced forces.
5. **Compact and robust construction** – Hydraulic actuators occupy less space for a given power output and operate reliably in the harsh marine environment.
6. **Simple overload protection** – Relief valves can protect the system from excessive pressures and mechanical damage.

Exam Answer (5 marks)

> Hydraulic actuators are preferred because they provide high torque from a compact unit, respond quickly to changing sea conditions, give smooth and precise fin control, withstand shock loading, and can be protected easily against overload by relief valves.

(b) Sketch a hydraulic circuit for a single stabiliser, suitable for a constant pressure system. (5 marks)

A typical constant-pressure circuit is shown below.



Components

- Reservoir (tank)
- Fixed-delivery pump
- Pressure relief valve (maintains constant system pressure)
- 4/3 directional control valve
- Double-acting hydraulic actuator connected to the stabiliser fin
- Return line to tank

Operation

Neutral Position

- The pump continuously supplies oil at constant pressure.
- The relief valve maintains the set pressure by bypassing excess flow back to the tank.
- The directional valve is centred, holding the stabiliser fin in position.

Fin Movement in One Direction

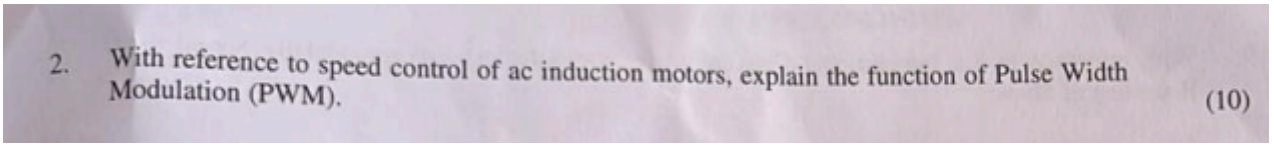
- The directional valve is shifted.
- Pressure oil is directed to one side of the actuator piston.
- Oil from the opposite side returns to the tank.
- The hydraulic ram rotates the stabiliser fin to one angle.

Fin Movement in the Opposite Direction

- The directional valve is moved to the opposite position.
- Flow paths reverse.
- The actuator moves in the opposite direction, rotating the fin the other way.

Exam Answer (5 marks)

A constant-pressure stabiliser circuit consists of a reservoir, fixed-capacity pump, pressure relief valve, 4/3 directional control valve, and a double-acting hydraulic actuator connected to the stabiliser fin. The relief valve maintains constant pressure by returning excess flow to the tank. Operation of the directional valve directs oil to either side of the actuator, causing the fin to rotate in the required direction and counteract vessel roll.


2. With reference to speed control of ac induction motors, explain the function of Pulse Width Modulation (PWM). (10)

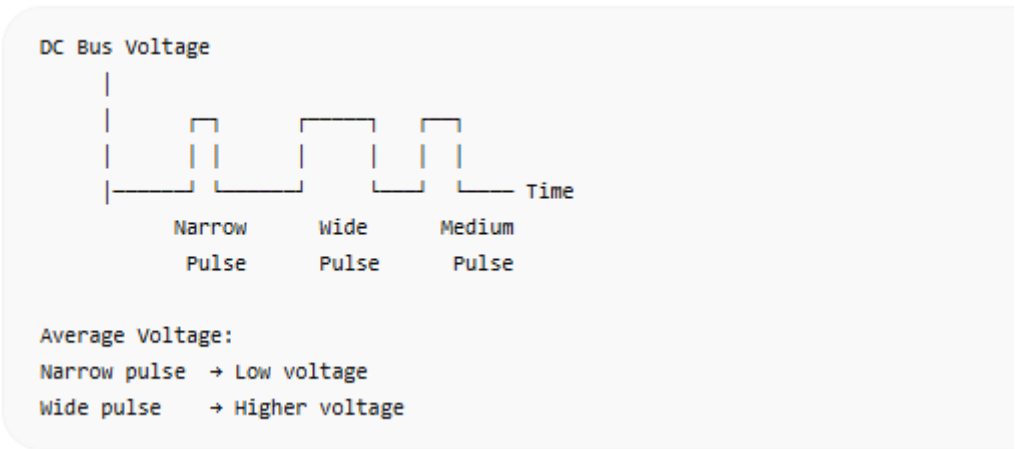
2. With reference to speed control of AC induction motors, explain the function of Pulse Width Modulation (PWM). (10 marks)

Definition

Pulse Width Modulation (PWM) is a technique used in Variable Frequency Drives (VFDs) to control the speed of AC induction motors by converting a fixed DC voltage into an AC output of variable voltage and frequency.

It achieves this by rapidly switching semiconductor devices on and off and varying the width of the voltage pulses supplied to the motor.

Sketch of PWM Principle



The motor effectively responds to the **average value** of these pulses, which approximates a sinusoidal AC waveform.

Operation of PWM in Motor Speed Control

1. Rectification

- The incoming fixed-frequency AC supply is first converted to DC using a **rectifier**.
- AC Supply → Rectifier → DC Link

2. Inversion

- An **inverter** containing power semiconductor switches (IGBTs) converts the DC back into AC.
- The switches turn ON and OFF many times each cycle.
- DC Link → PWM Inverter → Variable AC Output

3. Pulse Width Variation

- The duration for which each switch remains ON is varied.
- **Wider pulses** produce a higher effective voltage.
- **Narrower pulses** produce a lower effective voltage.

---

4. Frequency Control

- By altering the switching pattern, the inverter changes the **output frequency**.
- Since induction motor speed depends on supply frequency, the motor speed changes accordingly.

The synchronous speed is given by:

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

where:

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

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

-

Thus:

- Increasing frequency increases motor speed.
- Decreasing frequency decreases motor speed.

---

5. Constant V/f Ratio

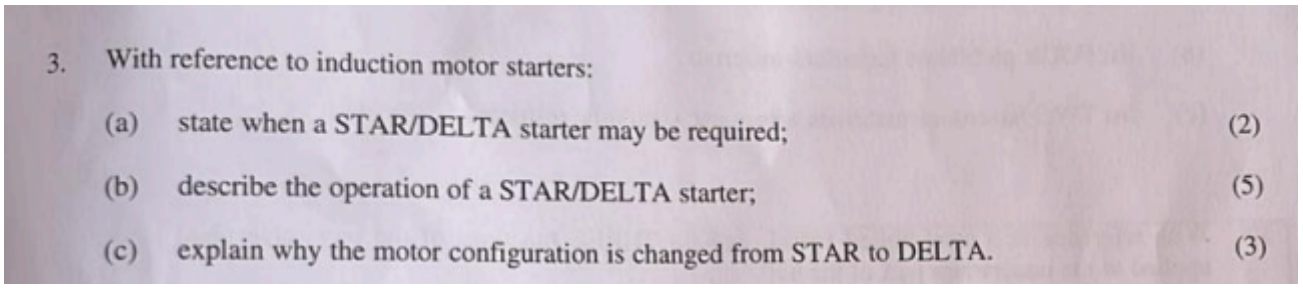
- PWM drives usually maintain an approximately constant **voltage-to-frequency ratio (V/f)**.
- This maintains the motor flux and allows the motor to develop its rated torque over a wide speed range.

Advantages of PWM

- Accurate speed control.
- Smooth acceleration and deceleration.
- High efficiency with low power losses.
- Good torque characteristics at varying speeds.
- Reduced mechanical stress during starting.
- Improved process control and energy savings.

Exam Answer (10 marks)

Pulse Width Modulation (PWM) is a method used in variable frequency drives to control the speed of AC induction motors. The AC supply is first rectified to DC and then inverted back to AC by rapidly switching semiconductor devices. By varying the width of the output pulses, the effective output voltage is controlled, while the switching pattern determines the output frequency. Since the speed of an induction motor depends on supply frequency, PWM provides smooth and efficient speed control. The drive normally maintains a constant voltage-to-frequency ratio to preserve motor torque and performance over a wide operating range.



3. With reference to induction motor starters:

(a) state when a STAR/DELTA starter may be required; (2)

(b) describe the operation of a STAR/DELTA starter; (5)

(c) explain why the motor configuration is changed from STAR to DELTA. (3)

3. With reference to induction motor starters:

(a) State when a STAR/DELTA starter may be required. (2 marks)

A **STAR/DELTA starter** is required when:

- A **three-phase induction motor has a high starting current**, and it is necessary to reduce the current drawn from the supply during starting.
- The motor is **designed to run in DELTA on the normal supply voltage** and has six terminals available to permit STAR/DELTA connection.

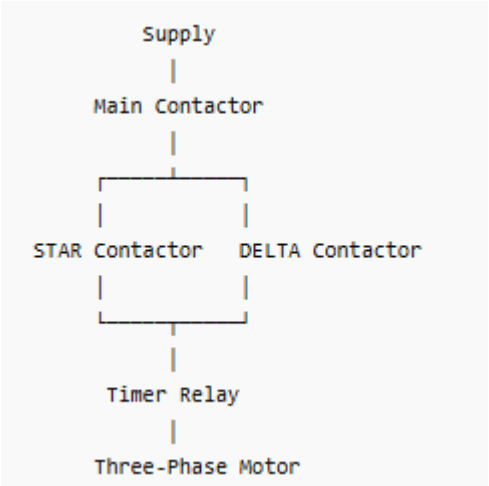
Typical applications include large pumps, compressors, fans, and other machinery where a reduced starting current is desirable.

Exam Answer (2 marks)

A STAR/DELTA starter is used for three-phase induction motors to reduce the high starting current. It is suitable for motors designed to operate in DELTA at the supply voltage and provided with six accessible winding terminals.

(b) Describe the operation of a STAR/DELTA starter. (5 marks)

Sketch



Operation

1. Starting in STAR

- When the START button is pressed, the **main contactor** and **STAR contactor** energise.
- The motor windings are connected in **STAR (Y)**.
- Each winding receives only

$$V_{\text{phase}} = \frac{V_{\text{line}}}{\sqrt{3}}$$

$$V_{phase} = \frac{V_{line}}{\sqrt{3}}$$

- The motor accelerates while drawing a reduced current.

2. Changeover

- After a preset time, a **timer relay** de-energises the STAR contactor.
- There is a brief transition period to prevent overlap.

3. Running in DELTA

- The **DELTA contactor** energises.

- The motor windings are reconnected in **DELTA (Δ)**.
- Each winding now receives the full line voltage.
- The motor continues operating at normal speed and full power.

4. Interlocking

- Electrical and/or mechanical interlocks prevent the STAR and DELTA contactors from closing simultaneously, which would cause a short circuit.

(c) Explain why the motor configuration is changed from STAR to DELTA. (3 marks)

The motor is initially started in **STAR** because:

- The voltage across each winding is reduced to **1/√3 (58%) of the line voltage**.
- This reduces the **starting current to approximately one-third** of the direct-on-line value.
- The starting torque is also reduced to approximately one-third.

Once the motor has accelerated and the starting period has passed, it is changed to **DELTA** because:

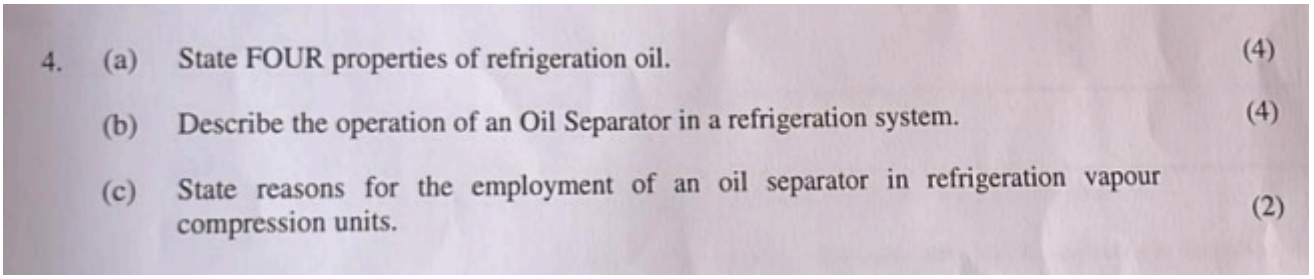
- Full line voltage is then applied to each winding.
- The motor can develop its **rated torque and power output**.
- Normal operating performance and efficiency are achieved.

Exam Answer (10 marks)

(a) A STAR/DELTA starter is used to reduce the starting current of a three-phase induction motor designed to run in DELTA and having six winding terminals.

(b) On starting, the main and STAR contactors energise, connecting the motor windings in STAR. After a timed interval, the STAR contactor opens and the DELTA contactor closes, reconnecting the windings in DELTA for normal running. Interlocks prevent both contactors from operating together.

(c) The motor is started in STAR to reduce the voltage applied to each winding, thereby reducing starting current and torque. It is then changed to DELTA so that full line voltage is applied, allowing the motor to produce its rated torque and operate normally.



4. (a) State FOUR properties of refrigeration oil. (4)

(b) Describe the operation of an Oil Separator in a refrigeration system. (4)

(c) State reasons for the employment of an oil separator in refrigeration vapour compression units. (2)

4.

(a) State FOUR properties of refrigeration oil. (4 marks)

A good refrigeration oil should possess the following properties (any four):

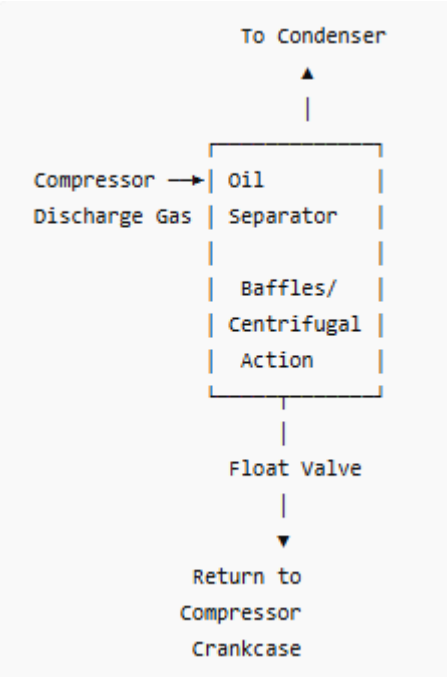
1. **Suitable viscosity** to provide effective lubrication over the operating temperature range.
2. **Low pour point**, so that the oil remains fluid at low evaporator temperatures.
3. **High flash point** to minimise the risk of fire and excessive vapour formation.
4. **Chemical stability**, so that it does not decompose or react with refrigerant, moisture, or system materials.
5. **Good dielectric strength** when used in hermetic compressors with electric motors.
6. **Freedom from moisture and impurities** to prevent corrosion and ice formation.
7. **Low carbon-forming tendency** to avoid deposits on valves and compressor parts.
8. **Compatibility with the refrigerant** used in the system.

Exam Answer (4 marks)

> Refrigeration oil should have suitable viscosity, a low pour point, a high flash point, and good chemical stability. It should also be free from moisture and compatible with the refrigerant.

(b) Describe the operation of an Oil Separator in a refrigeration system. (4 marks)

Sketch



Operation

- The oil separator is installed in the **compressor discharge line** between the compressor and condenser.
- The hot refrigerant vapour carrying entrained oil enters the separator.
- The velocity of the vapour is reduced and the flow is directed through **baffles or a centrifugal chamber**.
- Due to the change in direction and reduced velocity, the heavier oil droplets separate from the refrigerant vapour and collect at the bottom of the separator.
- The separated oil is returned automatically to the compressor crankcase through a **float-operated needle valve** or other controlled return arrangement.
- The refrigerant vapour, substantially free of oil, continues to the condenser.

Exam Answer (4 marks)

> Discharge gas from the compressor enters the oil separator where its velocity is reduced and its direction changed by baffles or centrifugal action. Oil droplets separate from the refrigerant vapour and collect in the bottom of the separator. The oil is returned automatically to the compressor crankcase by a float valve, while the refrigerant vapour passes to the condenser.

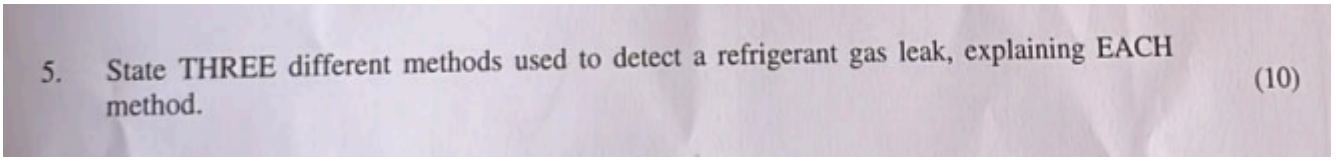
(c) State reasons for the employment of an oil separator in refrigeration vapour compression units. (2 marks)

The oil separator is fitted to:

1. **Ensure adequate lubrication of the compressor** by returning oil to the crankcase.
2. **Prevent oil from circulating through the refrigeration system**, where it could coat heat-transfer surfaces and reduce efficiency.
3. **Avoid oil accumulation in evaporators and condensers**, which can impair system performance.
4. **Reduce refrigerant and oil losses**, improving reliability and reducing maintenance.

Exam Answer (2 marks)

> Oil separators are used to return lubricating oil to the compressor and to prevent oil from entering and accumulating in the refrigeration circuit, thereby maintaining efficient heat transfer and reliable operation.



5. State THREE different methods used to detect a refrigerant gas leak, explaining EACH method. (10 marks)

Several methods may be used to detect refrigerant leaks in a refrigeration system. Any **three** of the following are acceptable.

1. Soap Solution (Bubble Test)

Method

- A soap solution or proprietary leak detection fluid is applied to suspected joints, flanges, valves, and pipe connections.
- The refrigeration system is kept under pressure.
- Escaping refrigerant gas forms **bubbles** in the soap film at the point of leakage.

Advantages

- Simple and inexpensive.
- Easy to use.
- Useful for locating leaks in accessible areas.

Limitations

- Only suitable for relatively large leaks.
- Difficult to use on inaccessible components.

Exam Answer

> Soap solution is brushed or sprayed onto suspected leak points. Escaping refrigerant forms bubbles, indicating the exact location of the leak.

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2. Electronic Leak Detector ("Sniffer")

Method

- An electronic sensing probe is moved slowly around suspected areas of the system.
- The detector senses refrigerant vapour in the surrounding air.
- When refrigerant is detected, the instrument gives an **audible alarm, visual indication, or both**.

Advantages

- Very sensitive.
- Can detect very small leaks.
- Suitable for most modern refrigerants.

Limitations

- Requires calibration and battery power.
- False indications may occur if contaminants are present.

Exam Answer

An electronic detector is passed around joints and components. The presence of refrigerant vapour causes the instrument to activate an audible or visual alarm, enabling small leaks to be identified.

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3. Halide Torch (for halogenated refrigerants)

Method

- Air from around the suspected leak is drawn through a flame containing a heated copper element.
- If halogen refrigerants such as older CFCs or HCFCs are present, the flame changes colour.

Typical colour changes include:

- Blue/green flame indicating refrigerant leakage.

Advantages

- Fairly sensitive.
- Gives a clear indication of leakage.

Limitations

- Only suitable for halogenated refrigerants.
- Uses an open flame and therefore presents a fire hazard.
- Not suitable for modern flammable refrigerants.

Exam Answer

In a halide torch, refrigerant vapour is drawn through the flame. The flame changes colour when halogen refrigerants are present, indicating a leak.

Other acceptable methods

You may also receive credit for describing:

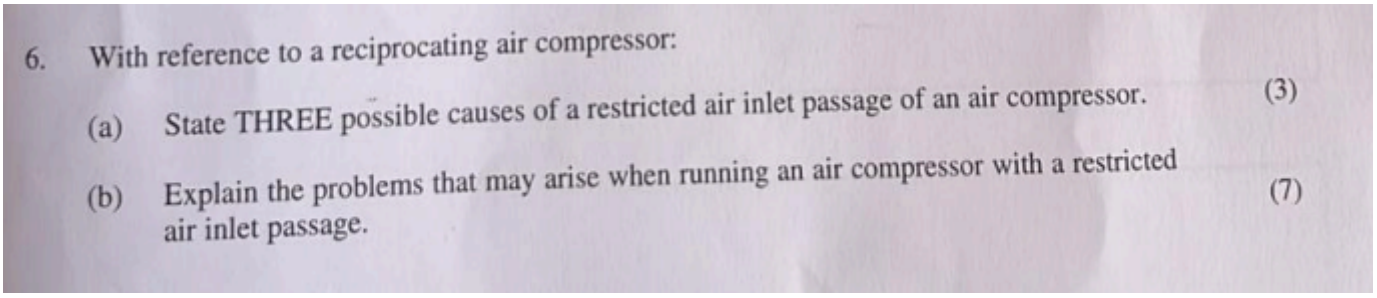
- **Ultraviolet fluorescent dye detection** – dye is added to the system and leaks are located using a UV lamp.
- **Pressure testing with dry nitrogen** – pressure loss indicates leakage, followed by soap testing to pinpoint the leak.
- **Vacuum hold test** – inability to maintain vacuum suggests leakage.
- **Ultrasonic leak detector** – detects the high-frequency sound produced by escaping gas.

Exam Answer (10 marks)

Three methods of detecting refrigerant leaks are:

1. **Soap solution testing**, where bubbles form at the leak site.
2. **Electronic leak detection**, in which a sensing probe detects refrigerant vapour and activates an alarm.
3. **Halide torch testing**, where refrigerant vapour causes a colour change in the flame, indicating the presence of a leak.

Each method enables the location of refrigerant leakage so that repairs can be carried out and refrigerant losses minimised.


6. With reference to a reciprocating air compressor:

(a) State THREE possible causes of a restricted air inlet passage of an air compressor. (3)

(b) Explain the problems that may arise when running an air compressor with a restricted air inlet passage. (7)

6. With reference to a reciprocating air compressor:

(a) State THREE possible causes of a restricted air inlet passage of an air compressor. (3 marks)

Any **three** of the following are acceptable:

1. **Dirty or clogged air intake filter** due to the accumulation of dust, oil, or dirt.
2. **Obstruction in the suction pipework**, such as foreign material, collapsed ducting, or carbon deposits.
3. **Defective or sticking suction valve**, preventing the free flow of air into the cylinder.
4. Damaged or partially closed inlet isolating valve.
5. Ice formation or contamination in the intake system (where applicable).

Exam Answer (3 marks)

Possible causes of a restricted air inlet passage include a blocked air filter, obstructions in the suction pipework, and sticking or defective suction valves.

(b) Explain the problems that may arise when running an air compressor with a restricted air inlet passage. (7 marks)

A restricted air inlet reduces the quantity of air entering the compressor and can lead to several operational problems:

1. Reduced Volumetric Efficiency

- Less air is admitted during the suction stroke.
- The compressor delivers less free air than its rated capacity.

2. Lower Air Output

- Air receivers take longer to reach working pressure.
- Pneumatic systems may suffer from inadequate air supply.

3. Increased Power Consumption

- The compressor must work harder to maintain the required delivery pressure.
- Efficiency decreases and energy consumption rises.

4. Increased Operating Temperature

- Restricted airflow causes a higher compression ratio and increased heat generation.
- Discharge temperatures may rise excessively.

5. Carbon Formation and Oil Degradation

- High temperatures can cause lubricating oil to deteriorate and form carbon deposits on valves and piston rings.

6. Valve Damage

- Excessive temperatures and abnormal pressure conditions may lead to burning, distortion, or premature wear of suction and delivery valves.

7. Increased Mechanical Wear

- Pistons, rings, cylinder liners, and bearings may experience accelerated wear due to overheating and prolonged running periods.

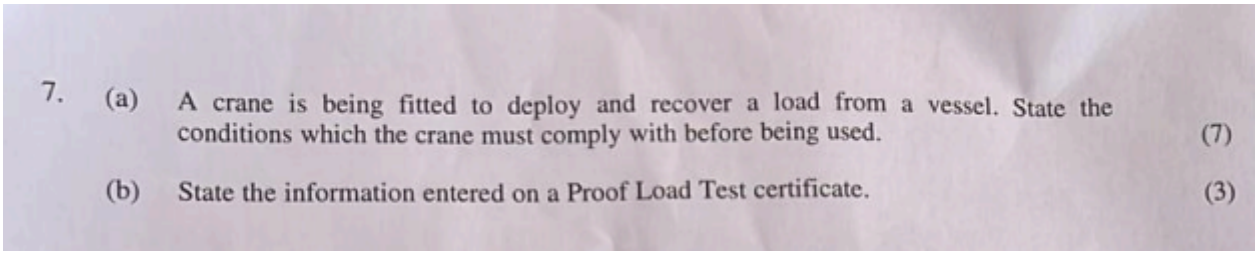
8. Possible Automatic Shutdown

- High-temperature or overload protection devices may trip, taking the compressor out of service.

Exam Answer (10 marks)

(a) Causes of a restricted air inlet passage include a blocked intake filter, obstructions in the suction line, and sticking or defective suction valves.

(b) A restricted inlet reduces volumetric efficiency and compressor capacity, resulting in slower receiver charging. The compressor may consume more power and operate at higher temperatures, causing lubricating oil deterioration, carbon deposits, increased valve and component wear, and possible activation of protective shutdown devices.



7. (a) A crane is being fitted to deploy and recover a load from a vessel. State the conditions which the crane must comply with before being used. (7)

(b) State the information entered on a Proof Load Test certificate. (3)

7.

(a) A crane is being fitted to deploy and recover a load from a vessel. State the conditions which the crane must comply with before being used. (7 marks)

Before a crane is placed into service, it must satisfy the following conditions:

1. Proof Load Tested

- The crane must have been subjected to a **proof load test** in accordance with statutory requirements.
- The test load is generally greater than the Safe Working Load (SWL) to demonstrate structural integrity.

2. Thorough Examination

- It must have undergone a **thorough examination by a competent person** to confirm that it is safe for use.

3. Certification Available

- Valid **test and examination certificates** must be provided and retained on board.

4. Safe Working Load Marked

- The **Safe Working Load (SWL)** must be clearly and permanently marked on the crane.

5. Safety Devices Operational

- All safety devices must be fitted and functioning correctly, such as:
  - overload protection,
  - limit switches,
  - emergency stops,
  - brakes,
  - load indicators.

6. Associated Lifting Gear Certified

- Hooks, blocks, shackles, slings, wire ropes and other lifting accessories must be of approved type and possess valid certificates.

7. Crane in Good Condition

- The structure, foundations, slew bearings, wire ropes, hydraulic systems, and controls must be inspected and found free from defects.

8. Operating Instructions Available

- Operating instructions and procedures should be available, and personnel using the crane should be suitably trained.

Exam Answer (7 marks)

Before being used, a crane must be proof load tested, thoroughly examined by a competent person, and possess valid certificates. Its SWL must be clearly marked, all safety devices must function correctly, associated lifting gear must be certified, and the crane and its foundations must be in a safe condition for operation.

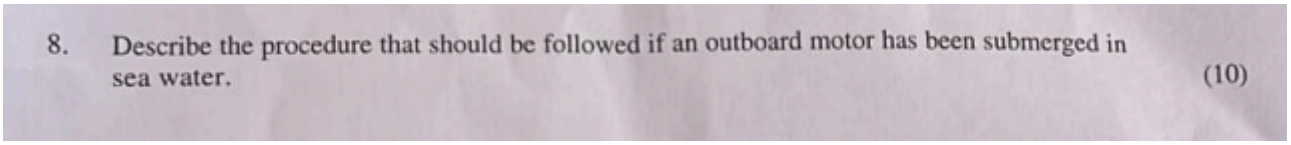
(b) State the information entered on a Proof Load Test Certificate. (3 marks)

A Proof Load Test Certificate normally contains the following information:

1. **Identification details of the crane**
   - Manufacturer
   - Serial number or identification number
   - Description and location of the crane.
2. **Test details**
   - Date and place of the proof load test.
   - The actual proof load applied.
   - The method of testing.
3. **Rated capacity**
   - The crane's **Safe Working Load (SWL)**.
4. **Results of the examination**
   - Confirmation that the crane satisfactorily passed the test and examination.
5. **Certification details**
   - Name, signature, and qualifications of the competent person or authorised surveyor.
   - Name of the testing authority or organisation issuing the certificate.

Exam Answer (3 marks)

A proof load test certificate records the crane identification details, the date and place of testing, the proof load applied, the crane's SWL, the results of the examination confirming satisfactory performance, and the name and signature of the competent person or authorised body issuing the certificate.


8. Describe the procedure that should be followed if an outboard motor has been submerged in sea water. (10)

8. Describe the procedure that should be followed if an outboard motor has been submerged in sea water. (10 marks)

If an outboard motor has been immersed in seawater, immediate action is necessary to minimise corrosion and prevent permanent damage.

Procedure

1. Recover the Motor Quickly

- Remove the outboard motor from the seawater as soon as possible.
- The longer it remains submerged, the greater the corrosion damage.

2. Do Not Attempt to Start It

- **Do not operate the starter or attempt to run the engine.**
- Starting the engine may cause severe internal damage or hydraulic lock.

3. Flush with Fresh Water

- Thoroughly wash the entire motor externally with **fresh water** to remove salt deposits.
- If possible, flush cooling passages and accessible internal areas.

4. Remove the Spark Plugs

- Remove all spark plugs to relieve compression and gain access to the cylinders.

5. Drain Water from Cylinders

- Turn the flywheel or crankshaft by hand to expel seawater from the cylinders through the spark plug holes.
- Continue until no further water is discharged.

6. Lubricate Internal Components

- Spray fogging oil, light lubricating oil, or water-displacing oil into the cylinders, carburettor/intake, and moving parts.
- Rotate the engine several times to distribute the oil and prevent corrosion.

7. Drain and Renew Lubricants

- Drain contaminated lubricating oil from the crankcase (for four-stroke engines).
- Drain and renew gearbox oil, as seawater may have entered through the seals.
- Refill with the correct grade of fresh oil.

8. Clean the Fuel System

- Drain contaminated fuel from the fuel tank, carburettor, and fuel lines if seawater ingress is suspected.
- Replace fuel filters where necessary.

9. Inspect Electrical Components

- Dry and clean the ignition system, starter motor, alternator, switches, and wiring connections.
- Apply suitable moisture-displacing spray to electrical terminals.

10. Reassemble and Test Run

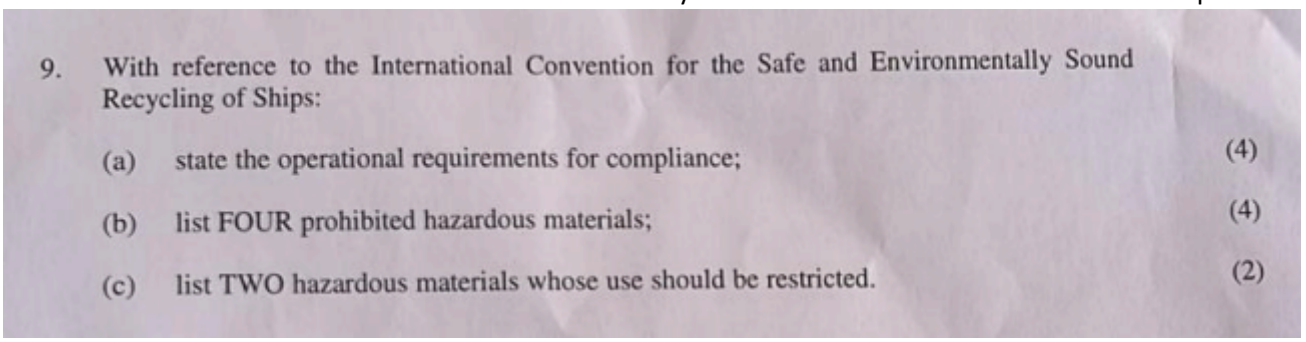
- Refit the spark plugs.
- Connect a supply of cooling water.
- Start the engine and allow it to run while checking:
    - cooling water discharge,
    - smooth operation,
    - unusual noises,
    - oil condition,
    - gearbox operation.

11. Service and Inspection

- Carry out a complete inspection after running.
- Replace damaged seals, bearings, filters, or electrical components as necessary.

Exam Answer (10 marks)

If an outboard motor is submerged in seawater, it should be recovered immediately and not started. The motor should be flushed with fresh water, spark plugs removed, and seawater expelled from the cylinders by turning the engine over by hand. Internal components should be lubricated with water-displacing oil, contaminated lubricating and gearbox oils renewed, and the fuel and electrical systems cleaned and dried. The engine should then be reassembled, supplied with cooling water, test run, and inspected for any further defects or corrosion damage.



9. With reference to the International Convention for the Safe and Environmentally Sound Recycling of Ships:

(a) state the operational requirements for compliance; (4)

(b) list FOUR prohibited hazardous materials; (4)

(c) list TWO hazardous materials whose use should be restricted. (2)

9. With reference to the International Convention for the Safe and Environmentally Sound Recycling of Ships:

This Convention is commonly known as the **Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009 (Hong Kong Convention).**

(a) State the operational requirements for compliance. (4 marks)

To comply with the Convention, ships are required to:

1. Maintain an Inventory of Hazardous Materials (IHM)

- The ship must carry an up-to-date **Inventory of Hazardous Materials** identifying hazardous materials present in the ship's structure and equipment.

2. Undergo Surveys

- The ship must be subject to:
  - an **Initial Survey**,
  - **Renewal Surveys**,
  - **Additional Surveys** when significant changes affecting the IHM occur.

3. Carry a Valid Certificate

- Ships must possess a valid **International Certificate on Inventory of Hazardous Materials (ICIHM)** issued by or on behalf of the Administration.

4. Be Recycled Only at Approved Facilities

- At the end of its operational life, the ship must be recycled only at an **authorised ship recycling facility** operating in accordance with the Convention.

5. Prepare a Ship-Specific Recycling Plan

- Before recycling commences, a **Ship Recycling Plan (SRP)** specific to that vessel must be developed and approved.

Exam Answer (4 marks)

Compliance requires ships to maintain an Inventory of Hazardous Materials, undergo the prescribed surveys, carry a valid International Certificate on Inventory of Hazardous Materials, and be recycled only at authorised facilities using an approved Ship Recycling Plan.

(b) List FOUR prohibited hazardous materials. (4 marks)

The Convention prohibits the installation or use of certain hazardous materials, including:

1. **Asbestos**
2. **Polychlorinated Biphenyls (PCBs)**
3. **Ozone-Depleting Substances (ODS)**
4. **Organotin compounds that act as biocides** (such as tributyltin-based anti-fouling systems)

Exam Answer (4 marks)

Four prohibited hazardous materials are asbestos, polychlorinated biphenyls (PCBs), ozone-depleting substances, and organotin compounds used as biocides.

(c) List TWO hazardous materials whose use should be restricted. (2 marks)

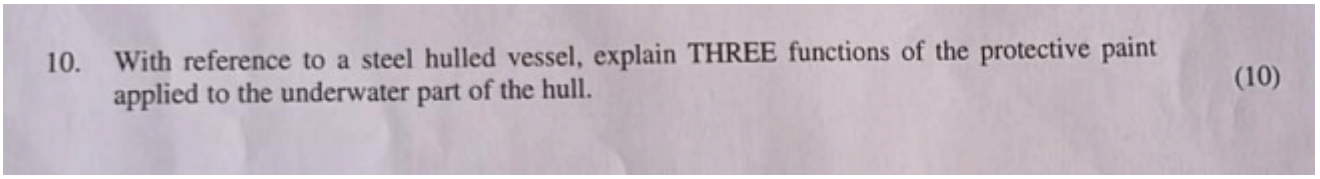
The Convention requires restrictions on the use of:

1. **Cadmium and cadmium compounds**
2. **Hexavalent chromium and hexavalent chromium compounds**
3. **Lead and lead compounds**
4. **Mercury and mercury compounds**

(Any **two** gain full marks.)

Exam Answer (2 marks)

Hazardous materials whose use should be restricted include **lead and lead compounds**, **mercury and mercury compounds**, **cadmium and cadmium compounds**, and **hexavalent chromium compounds**. Any two are acceptable.


10. With reference to a steel hulled vessel, explain THREE functions of the protective paint applied to the underwater part of the hull. (10)

10. With reference to a steel hulled vessel, explain THREE functions of the protective paint applied to the underwater part of the hull. (10 marks)

The protective paint system applied below the waterline performs several important functions. Three principal functions are:

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1. Corrosion Protection

- The paint forms a **barrier between the steel hull and seawater**.
- It prevents seawater, oxygen, and salts from coming into direct contact with the steel surface.
- This reduces or prevents **electrochemical corrosion (rusting)** and prolongs the life of the hull structure.
- By limiting corrosion, the need for steel renewals and repairs is reduced.

Exam Point

> Protective coatings isolate the steel from seawater and oxygen, preventing corrosion and extending hull life.

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2. Anti-Fouling Protection

- Special anti-fouling paints discourage the attachment and growth of marine organisms such as:
  - barnacles,
  - algae,
  - weed,
  - tube worms,
  - molluscs.
- Fouling increases hull roughness and weight.
- By reducing marine growth, the vessel maintains better performance and requires less cleaning during dry-docking.

Exam Point

> Anti-fouling coatings prevent or minimise marine growth on the underwater hull.

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3. Reduction of Frictional Resistance

- A smooth painted surface reduces the friction between the hull and the surrounding water.
- Reduced hull resistance allows the vessel to:
    - maintain service speed more easily,
    - consume less fuel,
    - improve propulsion efficiency,
    - reduce emissions and operating costs.

Exam Point

> A smooth coating reduces drag through the water, improving efficiency and lowering fuel consumption.

Other Acceptable Functions

You may also gain credit for mentioning that protective paints:

- Improve the appearance of the hull.
- Extend dry-docking intervals.
- Reduce maintenance costs.
- Protect against minor abrasion and erosion.

Exam Answer (10 marks)

> The protective paint applied to the underwater hull protects the steel against corrosion by preventing contact with seawater and oxygen. It also provides anti-fouling protection by reducing the attachment of marine organisms such as barnacles and algae. In addition, it provides a smooth hull surface which reduces frictional resistance, improving vessel speed, fuel economy, and overall operating efficiency.