1. With reference to hydraulic control systems:

(a) explain the functions of the reservoir; (5)

(b) describe, with the aid of a sketch, meter out speed control for a cylinder in a constant pressure system. (5)

1. With reference to hydraulic control systems:

(a) Explain the functions of the reservoir. (5 marks)

The **reservoir (hydraulic tank)** stores and conditions the hydraulic fluid used in the system. Its functions include:

1. Storage of Hydraulic Fluid

- Holds an adequate quantity of oil for system operation.
- Provides a reserve to compensate for leakage and changes in actuator volume.

2. Cooling the Oil

- Dissipates heat generated by pumps, valves, and actuators.
- The large surface area of the tank assists in reducing oil temperature.

3. De-aeration

- Allows entrained air bubbles and foam to separate from the oil before recirculation.
- Prevents cavitation, erratic operation, and oxidation of the oil.

4. Settling of Contaminants

- Dirt, wear particles, and water can settle at the bottom of the reservoir.
- This improves the cleanliness of the circulating oil.

5. Accommodating Volume Changes

- Compensates for expansion and contraction of the oil due to temperature changes.
- Supplies additional oil when cylinders extend and receive returning oil when they retract.

Other Acceptable Functions

- Provides a location for suction and return strainers.
- Allows inspection of oil level through a sight glass.
- Facilitates filling, draining, and maintenance.

Exam-Style Answer

The reservoir stores hydraulic oil, provides a reserve supply, dissipates heat from the system, allows entrained air to separate from the oil, permits contaminants and water to settle out, and accommodates changes in oil volume during operation and temperature fluctuations.

(b) Describe, with the aid of a sketch, meter-out speed control for a cylinder in a constant pressure system. (5 marks)

Sketch

2. With reference to variable speed control of a 3 phase ac induction motors:

(a) explain why EACH of the following is not preferred:

(i) variable voltage, constant frequency; (3)

(ii) variable frequency, constant voltage. (3)

(b) explain why voltage and frequency should both be varied. (4)

```
              Relief Valve
Pump ─────┬──────────┐
          |          |
          |          ▼
          |         Tank
          |
          ▼
     ┌───────────┐
     | 4/3 DCV   |
     └─┬─────┬───┘
       |     |
       |     |
       |     ▼
       |  Flow Control Valve
       | (with check valve)
       |        |
       |        ▼
       |       Tank
       |
       ▼
 ┌─────────────────┐
 | Double-Acting   |
 |    Cylinder     |
 └─────────────────┘
```

More Detailed Arrangement

```
              Extension

Pump → DCV → Cap End of Cylinder

Rod End of Cylinder
          |
          ▼
   Adjustable Flow
    Control Valve
  ┌─────────────┐
  |      ↗      | Check valve
  | Restrictor  |
  └─────────────┘
          |
          ▼
      DCV → Tank
```

Principle of Meter-Out Control

Meter-out control means:

The oil leaving the actuator is restricted to control its speed.

The flow control valve is fitted in the **return line from the cylinder**.

Operation

Cylinder Extension

- The directional control valve directs pressure oil to the cap end of the cylinder.
- Oil displaced from the rod end cannot return freely.
- It must pass through the adjustable flow control valve.
- The restriction meters the exhaust flow and controls the piston speed.

Speed Adjustment

- Closing the valve increases restriction.
- Less oil can leave the cylinder.
- The piston moves more slowly.
- Opening the valve reduces restriction.
- More oil leaves the cylinder.
- The piston speed increases.

Cylinder Retraction

- The integral check valve bypasses the restriction in the opposite direction.
- Oil flows freely into or out of the cylinder depending on the circuit design.
- Retraction can therefore be unrestricted or separately controlled.

Advantages of Meter-Out Control

- Prevents overrunning loads.
- Provides smooth movement of vertically loaded cylinders.
- Prevents the load from running ahead of the pump.
- Reduces shock and cavitation.

Exam-Style Answer

In a meter-out speed control system, the flow control valve is installed in the exhaust line from the cylinder. Pressure oil enters the cylinder normally, while oil leaving the opposite side is restricted by the adjustable valve. The restriction controls the rate at which oil can leave the cylinder and therefore controls piston speed. Meter-out control is particularly suitable for constant-pressure systems and cylinders subjected to overrunning loads, as it prevents the load from accelerating uncontrollably.

3. With reference to two identical generators operating in parallel supplying a switchboard that automatically shares load equally, explain EACH of the following:

(a) the effect of the excitation of one generator reducing while the load remains constant; (5)

(b) the possible effects of closing the main circuit breaker when frequency and voltage are equal but phases are out of phase. (5)

3. With reference to two identical generators operating in parallel supplying a switchboard that automatically shares load equally, explain EACH of the following:

(a) The effect of the excitation of one generator reducing while the load remains constant. (5 marks)

When two identical AC generators are operating in parallel:

- **Real power (kW)** sharing is controlled by the **governors**.
- **Reactive power (kVAr)** sharing is controlled by the **excitation systems (AVRs)**.

If the **excitation of one generator is reduced** while the total load remains constant:

Effects

1. **The affected generator supplies less reactive power (kVAr).**
    - Its power factor becomes more **lagging** (or less leading).
2. **The other generator automatically supplies more reactive power.**
    - Its excitation effectively becomes relatively higher.
3. **The kW load sharing remains substantially unchanged.**
    - Since the governors have not been altered, each generator continues to carry approximately equal real power.
4. **The armature current of the under-excited generator may increase.**
    - Excessive under-excitation can lead to overheating.
5. **If excitation is reduced excessively:**
    - The generator may become unstable,
    - It may begin to absorb reactive power from the system,
    - Loss of synchronism may eventually occur.

Exam-Style Answer

If the excitation of one generator decreases, that generator supplies less reactive power (kVAr), while the other generator supplies a greater share of the reactive load. The kW load sharing remains substantially unchanged because governor settings are unaffected. Excessive reduction of excitation may cause overheating, instability, or loss of synchronism.

(b) The possible effects of closing the main circuit breaker when frequency and voltage are equal but phases are out of phase. (5 marks)

For correct synchronising, the following conditions must exist:

- Equal voltage,
- Equal frequency,
- Same phase sequence,
- **Zero phase angle difference.**

If the circuit breaker is closed when the generators are **out of phase**, severe consequences may result.

Effects

1. Heavy Circulating Current

- A large current flows immediately between the generators due to the voltage phase difference.
- This current is limited mainly by the generator reactances.

---

2. Severe Mechanical Shock

- Large electromagnetic forces act on the rotor.
- The prime movers experience sudden torque shocks.

---

3. Shaft and Coupling Damage

- Shafts, couplings, keys, and foundations may be subjected to severe twisting forces.
- Mechanical damage may occur.

---

4. Generator Winding Stress

- High transient currents produce intense heating.
- Stator and rotor windings may suffer insulation damage.

---

5. Operation of Protective Devices

- Reverse power,

- Overcurrent,
- Differential protection,

may operate and trip the generator circuit breaker.

---

6. Loss of Synchronism

- The generator may be forced out of step with the system.
- In severe cases, major damage to the alternator and prime mover can occur.

Sketch

Correct Synchronising

```
Generator 1      Generator 2


   /‾\              /‾\
  /   \            /   \
 /     \          /     \
/       \        /       \


Phases coincide
Safe to close breaker
```

Out of Phase Synchronising

```
Generator 1      Generator 2


   /‾\                /‾\
  /   \              /   \
 /     \            /     \
/       \          /       \
        \         /
         \       /
          \_____/


Phase angle difference

DO NOT CLOSE BREAKER
```

Exam-Style Answer

(a)

Reducing the excitation of one generator reduces its kVAr output. The other generator takes a larger share of the reactive load, while kW sharing remains substantially unchanged. Excessive under-excitation may lead to overheating and instability.

(b)

Closing the breaker when the generators are out of phase results in heavy circulating currents and severe mechanical shocks. Shafts, couplings, and windings may be damaged, protective devices may trip, and the generator may lose synchronism with the system.

4. Describe, with the aid of a sketch, the operation of the FOUR main components in a simple vapour compression cycle for a refrigeration system, making reference to the physical state and condition of the refrigerant. (10)

4. Describe, with the aid of a sketch, the operation of the FOUR main components in a simple vapour compression cycle for a refrigeration system, making reference to the physical state and condition of the refrigerant. (10 marks)

A simple vapour compression refrigeration system consists of four main components:

1. **Compressor**
2. **Condenser**
3. **Expansion Valve**
4. **Evaporator**

The refrigerant circulates continuously through these components, changing its **pressure, temperature, and physical state**.

```
              High Pressure Side

        ┌─────────────────┐
        │   COMPRESSOR    │
        └────────┬────────┘
                 │
                 │ High-pressure,
                 │ high-temperature
                 │ SUPERHEATED VAPOUR
                 ▼
        ┌─────────────────┐
        │   CONDENSER     │
        └────────┬────────┘
                 │
                 │ High-pressure
                 │ SUB-COOLED LIQUID
                 ▼
        ┌─────────────────┐
        │ EXPANSION VALVE │
        └────────┬────────┘
                 │
                 │ Low-pressure,
                 │ low-temperature
                 │ LIQUID/VAPOUR MIXTURE
                 ▼
        ┌─────────────────┐
        │   EVAPORATOR    │
        └────────┬────────┘
                 │
                 │ Low-pressure
                 │ DRY SATURATED or
                 │ SLIGHTLY SUPERHEATED
                 │ VAPOUR
                 ▼
            COMPRESSOR

              Low Pressure Side
```

1. Evaporator

Operation

- Low-pressure refrigerant enters the evaporator as a **cold liquid/vapour mixture**.
- The refrigerant absorbs heat from the refrigerated space.
- The remaining liquid boils and evaporates.

Refrigerant Condition

Entering:

- Low pressure
- Low temperature

- Liquid/vapour mixture

Leaving:

- Low-pressure **dry saturated vapour**
- Usually **slightly superheated vapour**

Purpose

To absorb heat from the space being cooled.

---

2. Compressor

Operation

- The compressor draws vapour from the evaporator.
- It compresses the refrigerant to a higher pressure.
- Compression raises both the pressure and temperature.

Refrigerant Condition

Entering:

- Low-pressure dry saturated or slightly superheated vapour

Leaving:

- High-pressure
- High-temperature
- **Superheated vapour**

Purpose

To circulate the refrigerant and raise its pressure so that it can condense.

---

3. Condenser

Operation

The condenser rejects heat to seawater or air.

The refrigerant undergoes three stages:

(i) Desuperheating

- The superheated vapour cools to saturation temperature.

(ii) Condensation

- Latent heat is removed.
- Vapour changes into liquid.

(iii) Subcooling

- Additional heat is removed from the liquid.

Refrigerant Condition

Entering:

- High-pressure superheated vapour

Leaving:

- High-pressure **sub-cooled liquid**

Purpose

To reject heat from the refrigerant and convert vapour into liquid.

---

4. Expansion Valve

Operation

- The high-pressure liquid passes through a restriction.
- The pressure drops suddenly.
- Some of the liquid flashes into vapour.
- The temperature decreases significantly.

Refrigerant Condition

Entering:

- High-pressure sub-cooled liquid

Leaving:

- Low-pressure
- Low-temperature
- **Liquid/vapour mixture**

Purpose

To reduce the pressure and temperature of the refrigerant before it enters the evaporator.

Summary of Refrigerant Conditions

Component	Refrigerant Entering	Refrigerant Leaving
Evaporator	Low-pressure liquid/vapour mixture	Low-pressure dry saturated or slightly superheated vapour
Compressor	Low-pressure vapour	High-pressure superheated vapour
Condenser	High-pressure superheated vapour	High-pressure sub-cooled liquid
Expansion Valve	High-pressure sub-cooled liquid	Low-pressure liquid/vapour mixture

---

Exam-Style Answer

> In a simple vapour compression refrigeration cycle, low-pressure liquid/vapour refrigerant enters the evaporator where it absorbs heat and leaves as a dry saturated or slightly superheated vapour. The compressor draws in this vapour and compresses it to a high-pressure, high-temperature superheated vapour. In the condenser, heat is rejected and the refrigerant first desuperheats, then condenses to a liquid and is often sub-cooled. The high-pressure 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.

(a) State THREE types of fire damper that may be used to control the airflow in an air conditioning system. (3 marks)

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

1. **Fusible link fire damper** – closes automatically when the fusible link melts at a predetermined temperature.
2. **Motor-operated (electrically actuated) fire damper** – closes on receipt of a signal from the fire detection system.
3. **Pneumatically operated fire damper** – uses air pressure to operate the damper during a fire condition.
4. **Spring-loaded fire damper** – held open during normal operation and snaps shut when released.
5. **Gravity (drop) fire damper** – closes under its own weight when the retaining mechanism is released.

---

5 (b) Describe, with the aid of a sketch, an automatic fire damper installed in a vertical air duct or in those that pass through bulkheads designated as fire boundaries. (7 marks)

A common arrangement is the **fusible-link automatic fire damper**.

Sketch

```
          AIR FLOW
             ↑
     ┌──────────────────┐
     |   Vertical       |
     |     Duct         |
     |                  |
     |   ┌─────────┐    |
     |   | Damper  |    |
     |   | Blade   |    |
     |   └─────────┘    |
     |      \ /         |
     |   Fusible Link   |
     |        |           |
     |     Spring         |
     └──────────────────┘
        Bulkhead/Deck
     (Fire Boundary)
```

Description

- The fire damper is fitted where the ventilation duct passes through a **fire-resisting bulkhead or deck**.
- Under normal conditions, the **damper blade is held in the open position** by a **fusible link**.
- The fusible link is designed to melt at a specified temperature, typically around **68–74°C**.
- If a fire occurs, the rise in temperature causes the **fusible link to melt**.
- Once released, a **spring mechanism or gravity action closes the damper automatically**.
- The closed damper prevents the **spread of flames, smoke, and hot gases** through the ventilation system, thereby maintaining the integrity of the fire boundary.
- Many installations also provide a **manual reset or remote indication** to show whether the damper is open or closed.

Exam Answer (7 marks)

An automatic fire damper is installed where air ducts penetrate fire boundaries. The damper blade is normally held open by a fusible link. In the event of a fire, the increased temperature melts the fusible link, releasing the spring- or gravity-operated blade, which closes the duct automatically. This prevents the passage of fire, smoke, and hot gases through the ventilation system and preserves the fire integrity of the bulkhead or deck.

6. With reference to a reciprocating air compressor:

(a) define the term *Volumetric Efficiency*; (4)

(b) explain how the operation of the suction and delivery valves affect the volumetric efficiency of the compressor. (6)

6. With reference to a reciprocating air compressor:

(a) Define the term *Volumetric Efficiency*. (4 marks)

Volumetric efficiency is the ratio of the actual volume of free air drawn into the compressor cylinder during the suction stroke to the swept volume of the cylinder.

It is usually expressed as a percentage.

$$\text{Volumetric Efficiency} = \frac{\text{Actual volume of air inducted}}{\text{Swept volume of cylinder}} \times 100$$

$\eta_v = \frac{\text{Actual volume of air inducted}}{\text{Swept volume of cylinder}} \times 100\%$

Exam definition:

> Volumetric efficiency is the percentage ratio of the actual quantity of free air taken into the compressor cylinder to the piston displacement (swept volume) of the cylinder.

(b) Explain how the operation of the suction and delivery valves affect the volumetric efficiency of the compressor. (6 marks)

The operation and condition of the suction and delivery valves have a significant effect on volumetric efficiency.

Suction Valve

- The suction valve should open promptly at the beginning of the suction stroke.
- If it opens late due to weak springs, carbon deposits, sticking, or mechanical defects, less air enters the cylinder.
- Restrictions through dirty or damaged valves increase pressure losses.
- The reduced quantity of air admitted lowers the volumetric efficiency.

Delivery Valve

- The delivery valve should close quickly at the end of the discharge stroke.
- If it leaks or does not seat properly, compressed air flows back into the cylinder during the suction stroke.
- This raises the pressure of the residual air trapped in the clearance volume.
- The piston must then expand this trapped air for a longer period before fresh air can enter, reducing the amount of new air inducted.
- Consequently, the volumetric efficiency decreases.

General Effects

- Carbon deposits, worn valve seats, broken springs, sticking valves, and excessive pressure losses all reduce the efficiency of the valves.
- Efficient, leak-free valves with rapid opening and closing maximise the amount of fresh air admitted and therefore improve volumetric efficiency.

Exam Answer (10 marks)

(a) Volumetric efficiency is the ratio of the actual volume of free air drawn into the compressor cylinder to the swept volume of the cylinder, expressed as a percentage.

(b) The suction valve must open freely and with minimum resistance to admit the maximum quantity of air. Delayed opening, sticking, or restrictions reduce the amount of air inducted and lower volumetric efficiency. The delivery valve must close tightly to prevent compressed air leaking back into the cylinder. Leakage or delayed closing increases the effect of the clearance volume, delaying the entry of fresh air and reducing the quantity of air taken in. Therefore, faulty suction or delivery valves decrease the volumetric efficiency of the compressor.

7. Explain, with the aid of a sketch, the operation of a hydraulic Pilot Operated Pressure Maintaining Valve. (10)

7. Explain, with the aid of a sketch, the operation of a hydraulic Pilot Operated Pressure Maintaining Valve. (10 marks)

A **pilot operated pressure maintaining valve** is used to maintain a predetermined pressure in a section of a hydraulic system. It ensures that the upstream circuit pressure does not fall below a set value before allowing flow to the downstream circuit.

Sketch

```
                  To secondary circuit
                          |
                          ▼
                  ┌────────────┐
                  | Main Valve |
                  |   Poppet   |
                  └─────┬──────┘
                        ▲
                   Main Spring
                        |
          ┌─────────────┘
          |
Inlet ────┴──────────────────────────► Outlet
Pressure  |
          |
          └──► Pilot Passage ──► Pilot Valve
                                     |
                              Adjusting Screw
                                     |
                               Pilot Spring
                                     |
                               Drain / Tank
```

Construction

The valve consists of:

- A **main valve (poppet or spool)** carrying the main system flow.
- A **main spring** that tends to keep the valve closed.
- A **pilot valve** which senses the inlet pressure.
- An **adjustable pilot spring** used to set the desired pressure.
- Internal pilot passages and a drain connection.

Operation

1. Pressure Below the Set Value

- Hydraulic fluid enters the valve inlet.
- The pilot valve remains **closed** because the inlet pressure is insufficient to overcome the pilot spring force.
- Pressure is maintained above the main valve, assisting the main spring in keeping the main valve shut.
- Consequently, little or no flow reaches the secondary circuit.
- The primary circuit pressure therefore rises and is maintained at the required level.

---

2. Pressure Reaches the Set Value

- As inlet pressure increases, it eventually overcomes the force of the **pilot spring**.
- The pilot valve opens.
- Oil trapped above the main valve is allowed to drain away through the pilot passage.
- The pressure acting on top of the main valve decreases.

---

3. Main Valve Opens

- The higher inlet pressure acting beneath the main valve now exceeds the combined force of the main spring and the reduced pressure above it.
- The main valve lifts from its seat.
- Fluid flows to the outlet and supplies the secondary circuit.

---

4. Pressure Regulation

- If the inlet pressure falls below the preset value, the pilot valve closes again.
- Pressure above the main valve builds up.
- The main valve moves towards the closed position.
- The valve continually modulates to maintain the selected upstream pressure.

Purpose of the Valve

A pilot operated pressure maintaining valve is used to:

- Maintain a **minimum pressure** in a primary hydraulic circuit.
- Ensure that **essential services operate first** before supplying secondary circuits.
- Provide stable pressure control with greater accuracy than a direct-acting valve.
- Handle **large flow rates** with relatively small operating forces.

Exam Answer (10 marks)

> A hydraulic pilot operated pressure maintaining valve consists of a main valve controlled by a smaller pilot valve. The pilot spring is adjusted to the desired pressure setting. While the inlet pressure is below this value, the pilot valve remains closed and pressure above the main valve keeps it shut, maintaining pressure in the primary circuit. When the inlet pressure reaches the preset value, the pilot valve opens and relieves the pressure acting on top of the main valve. The main valve then opens and allows flow to the secondary circuit. If pressure falls below the set value, the pilot valve closes and the main valve returns towards its closed position. The valve therefore maintains a predetermined pressure in the upstream circuit before supplying downstream services.

8. State the safety requirements for small lockers on open deck storing petrol and other highly flammable liquids in hand portable containers. (10)

8. State the safety requirements for small lockers on open deck storing petrol and other highly flammable liquids in hand portable containers. (10 marks)

The following safety requirements should be met:

1. **The locker should be located on the open deck**, away from accommodation spaces, machinery spaces, and sources of ignition.
2. **It should be constructed of steel or other non-combustible material** to provide fire resistance.
3. **The locker should be clearly marked** with warning notices such as:
    - **"HIGHLY FLAMMABLE"**
    - **"NO SMOKING"**
    - **"NO NAKED LIGHTS"**
4. **Adequate natural ventilation should be provided**, with ventilation openings arranged to prevent the accumulation of flammable vapours.
5. **The ventilation outlets should discharge directly to the open atmosphere** and not into enclosed spaces.
6. **Only approved hand-portable containers should be used**, designed and certified for carrying petrol or other flammable liquids.
7. **The quantity stored should be kept to the minimum necessary** for operational requirements.
8. **The locker should be fitted with secure doors and suitable means of fastening** to prevent unauthorised access and movement of containers in heavy weather.
9. **Electrical equipment and fittings within the locker should be avoided**; if fitted, they must be of an approved flameproof or intrinsically safe type.
10. **Suitable fire-fighting equipment should be provided nearby**, such as portable dry powder or foam extinguishers appropriate for Class B fires.
11. **Containers should be kept tightly closed and inspected regularly** for leaks, corrosion, or damage.
12. **Absorbent materials or spill containment arrangements should be available** to deal with accidental spillages safely.

Exam Answer (10 marks)

Small lockers for storing petrol and other highly flammable liquids should be situated on the open deck and constructed of non-combustible material. They should be adequately ventilated to the open atmosphere, clearly marked with warning notices, and located away from sources of ignition. Only approved portable containers should be used, and the quantity stored should be kept to a minimum. The locker should be secured against unauthorised access, any electrical equipment should be flameproof, suitable fire extinguishers should be available nearby, and containers should be maintained in good condition with provisions for dealing with spillages.

9. With reference to the application of protective coatings to a vessel's hull:

(a) state the functions that the coating should perform; (3)

(b) state the legislation that applies to certain coatings and what certification is required to comply with it; (2)

(c) outline the process for re-coating the hull of a vessel in drydock. (5)

9. With reference to the application of protective coatings to a vessel's hull:

(a) State the functions that the coating should perform. (3 marks)

The protective coating applied to a vessel's hull should:

1. **Prevent corrosion** by isolating the steel surface from seawater, oxygen, and other corrosive agents.
2. **Provide anti-fouling protection** by preventing or reducing the attachment and growth of marine organisms such as barnacles, algae, and weed.
3. **Maintain a smooth hull surface**, reducing frictional resistance through the water and improving fuel efficiency and vessel performance.

Other acceptable functions include:

- Increasing the service life of the hull structure.
- Reducing maintenance and dry-docking costs.
- Improving the vessel's appearance.

(b) State the legislation that applies to certain coatings and what certification is required to comply with it. (2 marks)

Legislation

The relevant legislation is the:

> **International Convention on the Control of Harmful Anti-Fouling Systems on Ships (AFS Convention), 2001**, adopted by the IMO.

This convention prohibits or restricts the use of harmful anti-fouling substances, particularly coatings containing **organotin compounds such as tributyltin (TBT).**

Certification Required

Ships subject to the Convention are required to carry either:

- an **International Anti-Fouling System Certificate (IAFS Certificate)**, or

- an **Anti-Fouling System Declaration**, depending on the vessel's size and type.

(c) Outline the process for re-coating the hull of a vessel in drydock. (5 marks)

The typical procedure is:

1. Dry-docking and Cleaning

- The vessel is placed in drydock and the dock is pumped dry.
- Marine growth, dirt, salts, and loose material are removed using high-pressure fresh-water washing.

2. Surface Preparation

- Existing defective coatings, rust, and scale are removed.
- The hull is abrasive blast-cleaned (grit blasting) to the specified standard (e.g., Sa 2½).
- The surface is inspected for cleanliness and profile.

3. Repairs and Inspection

- Areas of pitting, corrosion, or steel damage are repaired.
- Welds and steel renewals are completed as necessary.
- Classification Society and owner's representatives inspect the prepared surface.

4. Application of Coatings

- The specified **primer coat** is applied promptly to prevent flash rusting.
- Intermediate coats are applied to achieve the required film thickness.
- Anti-corrosive and anti-fouling coats are then applied according to the manufacturer's instructions.

5. Final Inspection and Curing

- Dry film thickness is checked using approved gauges.
- The coating is inspected for defects, holidays, and complete coverage.
- Adequate curing time is allowed before flooding the dock and returning the vessel to service.

Exam Answer (10 marks)

(a) Hull coatings should protect the steel from corrosion, prevent marine fouling, and provide a smooth surface to reduce resistance and improve efficiency.

(b) The applicable legislation is the IMO International Convention on the Control of Harmful Anti-Fouling Systems on Ships (AFS Convention). Compliance requires an International Anti-Fouling System Certificate or an Anti-Fouling System Declaration, as appropriate.

(c) During drydocking, the hull is cleaned and pressure washed, defective coatings and rust are removed by blasting, repairs are carried out, primer and subsequent coating systems are applied to the specified thickness, and the completed work is inspected before the vessel is returned to service.

10. With reference to a vessel's motion control:

(a) outline the SIX degrees of freedom; (3)

(b) explain the term *damping;* (4)

(c) state THREE considerations to be made, before the installation of a motion reduction system. (3)

10. With reference to a vessel's motion control:

(a) Outline the SIX degrees of freedom. (3 marks)

A vessel can move in **six degrees of freedom**, consisting of three translational motions and three rotational motions.

Motion Type	Direction	Description
Surge	Fore and aft	Longitudinal movement forward and backward
Sway	Port and starboard	Sideways transverse movement
Heave	Up and down	Vertical movement
Roll	About the longitudinal axis	Side-to-side tilting motion
Pitch	About the transverse axis	Bow and stern rising and falling
Yaw	About the vertical axis	Turning movement to port or starboard

Sketch

```
                 Heave ↑↓
                   |
                   |
      Sway ◄──────── Ship ────────► Sway
                   |
                   |
               Surge ⇄

Roll  : Rotation about the fore-and-aft axis
Pitch : Rotation about the transverse axis
Yaw   : Rotation about the vertical axis
```

(b) Explain the term *damping*. (4 marks)

Damping is the process by which the amplitude of a vessel's motion is reduced by dissipating the energy causing that motion.

In simple terms, it is the resistance that opposes oscillatory movement and prevents the vessel from continuing to roll, pitch, or yaw excessively.

Sources of damping include:

- **Hydrodynamic damping** caused by the resistance of the surrounding water.
- **Bilge keel damping**, where bilge keels increase water resistance during rolling.
- **Active damping systems**, such as fin stabilisers and anti-roll tanks.
- **Internal friction and eddy losses** within the water moving around the hull.

The effect of damping is to:

- Reduce the magnitude of oscillations.
- Improve passenger comfort.
- Reduce cargo movement and structural stresses.
- Improve vessel safety and operability.

(c) State THREE considerations to be made before the installation of a motion reduction system. (3 marks)

Before fitting a motion reduction system, consideration should be given to:

1. Space and Structural Requirements

- Whether sufficient space is available for the equipment.
- The strength of the hull structure to support the installation and withstand the loads imposed.

2. Vessel Operating Profile

- The vessel's size, type, speed, and service conditions.
- Whether the system will be effective for the routes and sea states encountered.

3. Cost and Power Requirements

- Initial installation costs.
- Maintenance requirements and operating expenses.
- Availability of electrical or hydraulic power needed to operate the system.

Other acceptable considerations include:

- Effects on stability and trim.
- Additional weight introduced by the system.
- Dry-docking requirements for installation.
- Reliability and ease of maintenance.

Exam Answer (10 marks)

(a) The six degrees of freedom are surge, sway, heave, roll, pitch, and yaw.

(b) Damping is the reduction of the amplitude of a vessel's oscillations by dissipating the energy causing the motion. It reduces excessive movement and improves safety and comfort.

(c) Before installing a motion reduction system, consideration should be given to the available space and structural strength, the vessel's operating conditions and suitability of the system, and the cost, maintenance, and power requirements of the installation.