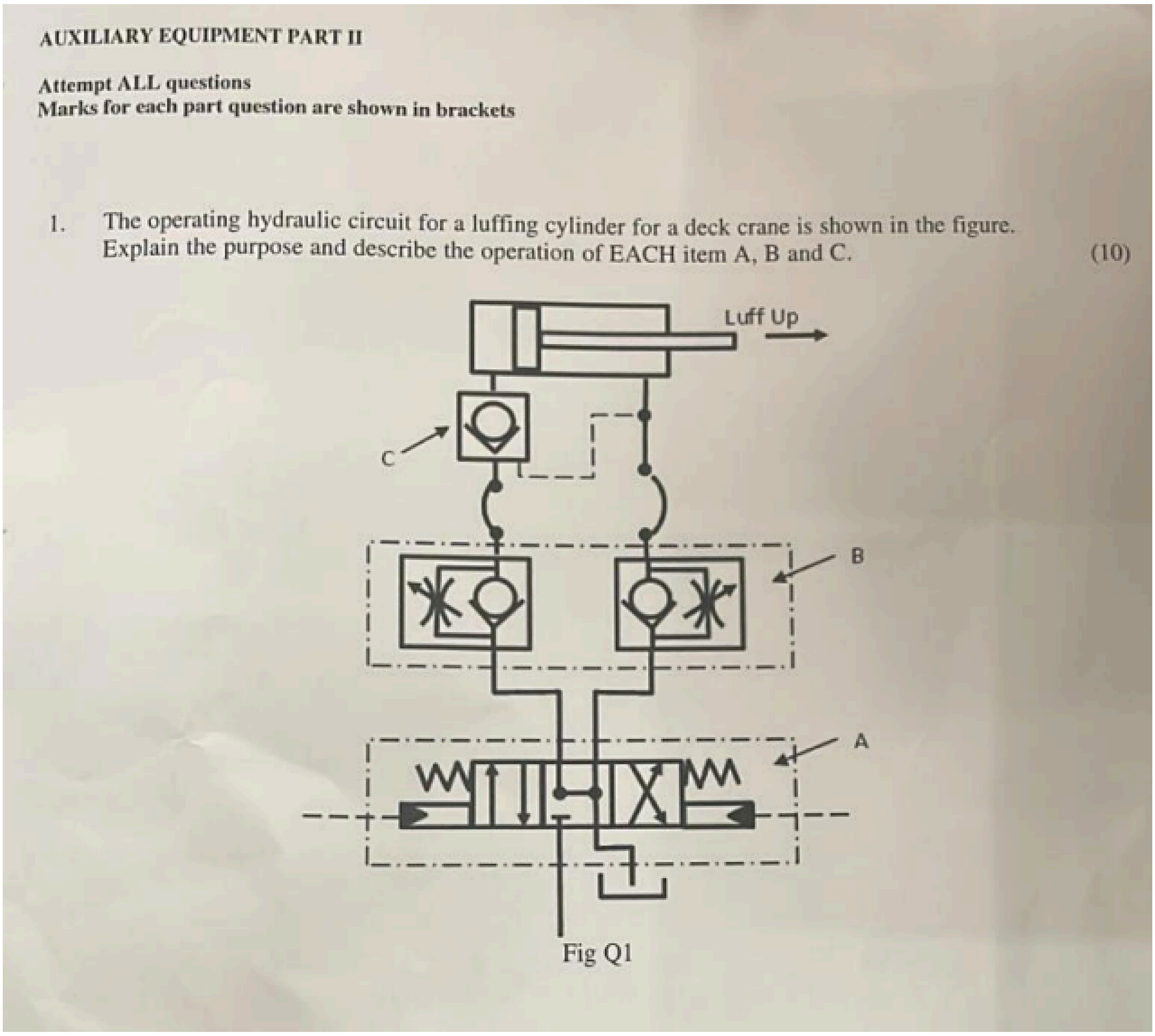


AUXILIARY EQUIPMENT PART II

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

1. The operating hydraulic circuit for a luffing cylinder for a deck crane is shown in the figure. Explain the purpose and describe the operation of EACH item A, B and C. (10)

Fig Q1

1. The operating hydraulic circuit for a luffing cylinder for a deck crane is shown in the figure. Explain the purpose and describe the operation of EACH item A, B and C. (10 marks)

The circuit shown is a **luffing cylinder circuit for a deck crane**. The purpose of the circuit is to safely raise and lower the crane jib while preventing uncontrolled movement of the load.

Identification of Components

A – 4/3 Directional Control Valve

B – Double Overcentre (Counterbalance) Valve Assembly

C – Pilot-Operated Check Valve

A. Directional Control Valve

Purpose

- To control the direction of oil flow to and from the luffing cylinder.
- To determine whether the crane jib is:
  - Raised,
  - Lowered, or
  - Held stationary.

Operation

Neutral Position

- The valve is spring-centred.
- Pump flow is returned to tank (or blocked depending on the centre configuration).
- No pilot pressure is sent to the cylinder.
- The luffing cylinder remains locked by the load-holding valves.

Luff Up

- The valve spool is moved to direct pressure oil to the cylinder cap end.
- The piston extends.
- The crane jib rises.

Luff Down

- The spool is moved in the opposite direction.
- Pressure oil is directed to the rod end.
- Pilot pressure is generated to release the holding valves.
- The cylinder retracts, lowering the jib under control.

B. Double Overcentre (Counterbalance) Valve Assembly

Purpose

- Prevents the load from running away under gravity.
- Holds the jib securely if a hose fails.
- Provides smooth and controlled lowering.
- Prevents cavitation and shock loading.

Construction

Each valve consists of:

- A check valve.
- A pilot-operated relief valve.
- Cross-pilot connections.

Operation

During Luff Up

- Oil entering the cylinder passes freely through the check valve.
- Oil leaving the opposite side can only escape when pilot pressure opens the opposite counterbalance valve.
- The jib rises smoothly.

During Luff Down

- The weight of the jib tends to force oil out of the cylinder.
- The counterbalance valve remains closed until sufficient pilot pressure is applied.
- Oil is metered out of the cylinder.
- The load lowers at a controlled speed.

Hose Failure

- If a hydraulic hose bursts, pilot pressure is lost.
- The counterbalance valves close automatically.
- The jib is prevented from falling.

C. Pilot-Operated Check Valve

Purpose

- Acts as a load-holding valve.
- Locks the cylinder mechanically by trapping oil.
- Prevents cylinder creep due to leakage.

Operation

Normal Holding

- When control pressure is absent, the check valve closes.
- Oil cannot leave the cylinder chamber.
- The crane jib remains fixed in position.

Cylinder Movement

- Pilot pressure from the opposite line acts on the pilot piston.
- The check valve opens.
- Oil is allowed to flow out of the cylinder.
- The cylinder can extend or retract.

Emergency Condition

- Loss of pilot pressure causes the valve to close immediately.
- The load remains supported safely.

Overall Operation of the Circuit

Luffing Up

1. Directional valve (A) directs pressure oil to the cylinder.
2. Counterbalance valve (B) opens under pilot pressure.
3. Pilot-operated check valve (C) opens.
4. Cylinder extends and raises the crane jib.

Holding Position

1. Directional valve returns to neutral.
2. Pilot pressure is removed.
3. Check valve (C) closes.
4. Counterbalance valves (B) close.
5. The jib remains securely locked.

Luffing Down

1. Directional valve (A) reverses flow.
2. Pilot pressure opens the appropriate counterbalance valve.
3. Oil is metered from the cylinder.
4. The jib lowers smoothly under control.

Exam-Style Answer

> **A** is a spring-centred 4/3 directional control valve used to direct oil to raise, lower, or stop the luffing cylinder. **B** is a double overcentre (counterbalance) valve assembly that prevents runaway loads, controls lowering speed, and protects against hose failure. **C** is a pilot-operated check valve that locks the cylinder in position and prevents drift. During luffing, pilot pressure opens the load-holding valves to permit movement, while in the neutral position the valves close and securely support the crane jib.

2. Describe, with the aid of a sketch, a variable frequency drive for speed control of a three phase motor. (10)

A **Variable Frequency Drive (VFD)** is an electronic device used to control the speed of a three-phase AC motor by varying the **frequency and voltage** supplied to the motor.

The speed of an AC motor is approximately proportional to the supply frequency:

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

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

where:

- NsN_sNs = synchronous speed (rpm)
- fff = supply frequency (Hz)
- PPP = number of poles

Thus, reducing the frequency reduces motor speed, while increasing frequency increases motor speed.

Sketch of a Variable Frequency Drive

```
      3-Phase AC Supply
        L1   L2   L3
         |    |    |
         ▼    ▼    ▼
  ┌─────────────────────┐
  │     RECTIFIER       │
  │ (Diode/SCR Bridge)  │
  └─────────────────────┘
             |
             | DC
             ▼
  ┌─────────────────────┐
  │      DC LINK        │
  │ Capacitors/Choke    │
  │  Filter & Storage   │
  └─────────────────────┘
             |
             | Smoothed DC
             ▼
  ┌─────────────────────┐
  │      INVERTER       │
  │   IGBT Transistors  │
  │ PWM Control         │
  └─────────────────────┘
             |
             | Variable Voltage
             | Variable Frequency
             ▼
     3-Phase AC Motor
```

Operation

1. Rectifier Section

- The incoming fixed-frequency three-phase supply (e.g., 440 V, 60 Hz) enters the rectifier.
- The rectifier converts the AC supply into DC.
- Diodes or controlled rectifiers (SCRs) may be used.

---

2. DC Link Section

- The DC output passes to the DC link.
- Capacitors smooth out voltage ripple.
- Chokes or reactors may reduce harmonics.
- The DC link stores energy and provides a stable DC supply to the inverter.

---

3. Inverter Section

- The inverter uses power electronic switches, usually **IGBTs (Insulated Gate Bipolar Transistors)**.
- The DC supply is switched on and off rapidly using **Pulse Width Modulation (PWM)**.

- This produces a three-phase output with:
  - Variable frequency,
  - Variable voltage.

---

4. Motor Speed Control

- The inverter changes the output frequency to control motor speed.
- The output voltage is varied in proportion to frequency to maintain a nearly constant **V/f ratio**.

Examples:

Frequency	Approximate Motor Speed
60 Hz	100% speed
45 Hz	75% speed
30 Hz	50% speed
15 Hz	25% speed

Advantages of a VFD

- Smooth acceleration and deceleration.
- Accurate speed control.
- Reduced starting current.
- Energy savings at reduced speeds.
- Reduced mechanical stress on equipment.
- Adjustable torque characteristics.
- Reversing can be achieved electronically.

Marine Applications

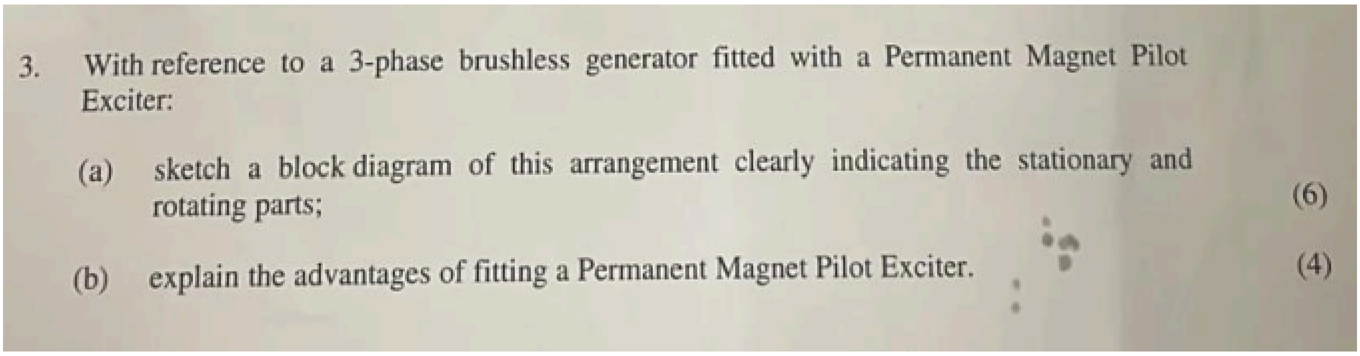
Variable Frequency Drives are commonly used for:

- Engine room ventilation fans,
- Pumps,
- Refrigeration compressors,

- Cargo pumps,
- Bow thrusters,
- Steering gear auxiliaries,
- Crane and winch drives.

Exam-Style Answer

A variable frequency drive controls the speed of a three-phase motor by varying the frequency of the electrical supply. The incoming AC supply is converted to DC by a rectifier. The DC is smoothed in a DC link using capacitors and reactors. An inverter employing IGBTs and PWM techniques converts the DC back into a three-phase AC supply of variable frequency and voltage. Since motor speed is proportional to supply frequency, varying the output frequency changes the motor speed. The voltage is adjusted in proportion to the frequency to maintain the correct V/f ratio, ensuring efficient motor operation and good torque characteristics.



3. With reference to a 3-phase brushless generator fitted with a Permanent Magnet Pilot Exciter:

(a) sketch a block diagram of this arrangement clearly indicating the stationary and rotating parts; (6)

(b) explain the advantages of fitting a Permanent Magnet Pilot Exciter. (4)

3. With reference to a 3-phase brushless generator fitted with a Permanent Magnet Pilot Exciter:

(a) Sketch a block diagram of this arrangement clearly indicating the stationary and rotating parts. (6 marks)

Block Diagram

```
                    STATIONARY PARTS
  ┌──────────────────────────────────────────────────┐
  │                                                  │
  │  Automatic Voltage Regulator (AVR)               │
  │            ▲                                     │
  │            │ Voltage sensing from main generator │
  │            │                                     │
  │  PMG Stator ─────────────▶ AVR ────────▶ Exciter │
  │                                   Field Winding│
  └──────────────────────────────────────────────────┘
                  │
                  │
                  │ Magnetic field
                  ▼

                    ROTATING PARTS
  ┌──────────────────────────────────────────────────┐
  │                                                  │
  │ PMG Rotor                                        │
  │     │                                            │
  │     ▼                                            │
  │ Exciter Armature (3-phase AC output)             │
  │     │                                            │
  │     ▼                                            │
  │ Rotating Rectifier Assembly                      │
  │ (Diode Wheel)                                    │
  │     │ DC                                         │
  │     ▼                                            │
  │ Main Generator Rotor Field                       │
  │     │                                            │
  │     ▼                                            │
  │ Main Generator Rotor                             │
  └──────────────────────────────────────────────────┘
                  │
                  │
                  ▼

               STATIONARY PARTS

            Main Generator Stator
           (3-phase Output to Load)
```

Arrangement Explained

A brushless generator with a Permanent Magnet Pilot Exciter (PMG) consists of:

Stationary Components

- PMG stator
- Automatic Voltage Regulator (AVR)
- Exciter field winding
- Main generator stator

Rotating Components

- PMG rotor (permanent magnets)
- Exciter armature
- Rotating rectifier assembly (diode wheel)
- Main generator rotor field

Operation

1. Permanent Magnet Pilot Exciter (PMG)

- Permanent magnets mounted on the rotor rotate inside the PMG stator.
- A three-phase AC supply is generated in the PMG stator.
- This supply is independent of the main generator output.

---

2. Automatic Voltage Regulator (AVR)

- The AVR receives power from the PMG.
- It senses the main generator terminal voltage.
- It controls the DC supplied to the stationary exciter field winding.

---

3. Exciter Generator

- The exciter field is stationary.
- The exciter armature rotates with the shaft.
- Three-phase AC is induced in the rotating exciter armature.

---

4. Rotating Rectifier Assembly

- The AC output from the rotating exciter armature passes through the rotating diode bridge.
- The diodes rectify the AC into DC.

---

5. Main Generator Field

- The DC from the rotating rectifiers energises the main generator rotor field winding.
- This creates the magnetic field required for generation.

---

6. Main Generator Output

- The rotating magnetic field cuts the stationary main stator windings.
- Three-phase AC power is induced in the stator and supplied to the ship's electrical system.

(b) Explain the advantages of fitting a Permanent Magnet Pilot Exciter. (4 marks)

1. Independent Excitation Supply

- The AVR receives its power from the PMG rather than from the main generator terminals.
- Excitation is maintained even during severe voltage dips.

---

2. Improved Fault Performance

- During short circuits, the PMG continues supplying the AVR.
- The AVR can provide maximum excitation current.
- This improves fault current capability and assists protective devices to operate correctly.

---

3. Better Voltage Regulation

- The excitation system is unaffected by load disturbances on the main generator.
- Faster response to sudden load changes results in improved voltage stability.

---

4. Increased Reliability

- No brushes or slip rings are required.
- Reduced maintenance and less wear.
- Eliminates brush sparking and associated problems.

Exam-Style Answer

(a)

In a brushless generator fitted with a PMG, the PMG supplies power to the AVR, which controls the stationary exciter field. The rotating exciter armature generates three-phase AC that is rectified by rotating diodes to provide DC excitation to the main generator rotor field. The rotating field induces three-phase AC in the stationary main stator windings, which supply the electrical load.

(b)

The advantages of a PMG are that it provides an independent supply to the AVR, maintains excitation during faults and voltage collapse, improves voltage regulation and transient response, and eliminates the need for brushes and slip rings, thereby reducing maintenance and increasing reliability.

4. Explain, with the aid of a sketch, the procedure for *vapour* re-charging of a refrigeration plant. (10)

4. Explain, with the aid of a sketch, the procedure for vapour re-charging of a refrigeration plant. (10 marks)

Vapour re-charging is the process of introducing refrigerant into a refrigeration system in its **gaseous state**, usually through the **compressor suction side**. This method is used to top up the refrigerant charge safely without risking liquid slugging of the compressor.

```
   Refrigerant Cylinder
  (upright position)
          |
          | Vapour
          ▼
  Charging Valve
          |
          | Flexible Hose
          ▼
Suction Charging Point
          |
          ▼
    Compressor
          |
          ▼
    Condenser
          |
          ▼
Expansion Valve
          |
          ▼
    Evaporator
          |
          └───────────────┐
                          |
                       Back to
                     Compressor
```

Procedure for Vapour Re-Charging

1. Identify the Need for Charging

Indications of low refrigerant charge include:

- Low suction pressure.
- Bubbles in the sight glass.
- Reduced cooling effect.
- Low evaporator pressure.

- Increased superheat.
- Frequent compressor cycling.

---

2. Check for Leaks

Before adding refrigerant:

- Inspect the system for leaks.
- Use:
  - Electronic leak detector,
  - Halide detector (older systems),
  - Soap solution.

The leak should be repaired before recharging.

---

3. Connect the Charging Equipment

- Stop the compressor.
- Connect the manifold gauge set:
  - Low-pressure hose to the compressor suction service valve.
  - Centre hose to the refrigerant cylinder.
- Ensure all connections are tight.

---

4. Purge Air from the Charging Hose

- Slightly crack open the cylinder valve.
- Loosen the hose connection briefly.
- Allow a small amount of refrigerant vapour to escape.

This removes air and moisture from the hose.

Never introduce air into the refrigeration system.

---

5. Position the Refrigerant Cylinder

- Keep the cylinder **upright**.

This ensures that **vapour only** enters the system.

```
Correct:            Incorrect:

   ┌──┐                ┌──┐
   │  │                │  │
   │  │                │  │
   └──┘               ────
 Upright             Inverted
 Vapour              Liquid
 Charging            Charging
```

6. Start the Compressor

- Open the suction service valve as required.
- Start the compressor.
- The compressor draws refrigerant vapour into the system.

---

7. Charge Slowly

- Open the cylinder valve slowly.
- Open the manifold low-side valve slightly.
- Allow vapour refrigerant to be drawn into the suction side gradually.

Monitor:

- Suction pressure,
- Discharge pressure,
- Sight glass condition,
- Evaporator temperature,
- Compressor current.

---

8. Determine Correct Charge

Charging should continue until:

- The sight glass is clear.
- Suction pressure returns to normal.
- Correct superheat is obtained.
- Cooling performance is restored.
- Operating conditions match manufacturer's recommendations.

 Avoid overcharging.

---

9. Isolate and Disconnect

- Close the manifold valve.
- Close the refrigerant cylinder valve.
- Allow the compressor to clear refrigerant from the charging hose.
- Close service valves if necessary.
- Disconnect hoses and replace caps.

---

10. Final Checks

Check and record:

- Suction pressure.
- Discharge pressure.
- Compressor amperage.
- Evaporator temperature.
- Condenser cooling conditions.
- Any remaining signs of leakage.

Precautions

- Wear goggles and gloves.
- Do not vent refrigerant unnecessarily to atmosphere.
- Keep cylinders upright during vapour charging.
- Charge slowly to avoid compressor damage.
- Never admit air into the system.
- Ensure the correct refrigerant type is used.

Exam-Style Answer

> Vapour re-charging is carried out by connecting a refrigerant cylinder in the upright position to the compressor suction charging point through a manifold gauge set. After checking for leaks and purging air from the charging hose, the compressor is started and refrigerant vapour is admitted slowly into the suction side. System pressures, sight glass condition, superheat, and cooling performance are monitored until the correct charge is obtained. The charging valves are then closed, the equipment disconnected, and final operating checks carried out. This method prevents liquid refrigerant entering the compressor and causing damage.

5. (a) Explain EACH of the following refrigeration terms:

(i) superheated; (2)

(ii) saturation temperature; (2)

(iii) sub-cooled. (2)

(b) Sketch a basic vapour compression refrigeration system, showing the refrigerants condition as explained in part (a). (4)

5. (a) Explain EACH of the following refrigeration terms:

(i) Superheated (2 marks)

Superheated vapour is refrigerant vapour that has been heated to a temperature **above its saturation temperature at that pressure**.

In other words:

> It is a vapour that contains **no liquid droplets**, and additional heat has been added after all the liquid has evaporated.

Example

If refrigerant at a particular pressure has a saturation temperature of **−10°C**, but its actual temperature is **−5°C**, then it is **5°C superheated**.

Importance

- Ensures only vapour enters the compressor.
- Prevents liquid slugging and compressor damage.

(ii) Saturation Temperature (2 marks)

The **saturation temperature** is:

> The temperature at which a refrigerant changes state between liquid and vapour at a given pressure.

At this temperature:

- Liquid and vapour coexist.
- Heat added causes evaporation without a rise in temperature.

- Heat removed causes condensation without a fall in temperature.

Example

R134a at a particular pressure may boil and condense at **5°C**. Therefore, **5°C is its saturation temperature at that pressure**.

(iii) Sub-cooled (2 marks)

Sub-cooled liquid is liquid refrigerant that has been cooled to a temperature **below its saturation temperature at that pressure**.

In other words:

> Additional heat has been removed after condensation has been completed.

Example

If the saturation temperature is **40°C**, but the liquid temperature is **35°C**, the refrigerant is **5°C sub-cooled**.

Importance

- Prevents flash gas forming before the expansion valve.
- Improves refrigeration efficiency.

(b) Sketch a basic vapour compression refrigeration system, showing the refrigerant conditions as explained in part (a). (4 marks)

Sketch

```
        COMPRESSOR
    ┌────────────────┐
    │                │
    └────────────────┘
            │
            │ High-pressure
            │ SUPERHEATED
            │ vapour
            ▼
     ┌─────────────┐
     │ CONDENSER   │
     └─────────────┘
            │
            │ High-pressure
            │ SUB-COOLED
            │ liquid
            ▼
    ┌────────────────┐
    │ EXPANSION      │
    │    VALVE       │
    └────────────────┘
            │
            │ Low-pressure
            │ liquid/vapour
            │ mixture
            ▼
     ┌─────────────┐
     │ EVAPORATOR  │
     └─────────────┘
            │
            │ Low-pressure
            │ dry saturated
            │ or slightly
            │ SUPERHEATED
            │ vapour
            ▼
       COMPRESSOR
```

Refrigerant Conditions Around the Cycle

Location	Refrigerant Condition
Compressor suction	Dry saturated or slightly superheated vapour
Compressor discharge	High-pressure superheated vapour

Condenser outlet	High-pressure sub-cooled liquid
Expansion valve outlet	Low-pressure liquid/vapour mixture
Evaporator outlet	Dry saturated or slightly superheated vapour

---

Exam-Style Answer

(a)

Superheated: Refrigerant vapour at a temperature above its saturation temperature at the prevailing pressure.

Saturation temperature: The temperature at which a refrigerant changes state between liquid and vapour at a given pressure.

Sub-cooled: Liquid refrigerant cooled below its saturation temperature at the prevailing pressure.

(b)

In a basic vapour compression system, the refrigerant leaves the evaporator as a dry saturated or slightly superheated vapour, is compressed to a high-pressure superheated vapour, condensed to a high-pressure liquid which is often sub-cooled, expanded through the expansion valve to a low-pressure liquid/vapour mixture, and returns to the evaporator to repeat the cycle.

6. (a) Describe TWO possible sources of contamination of compressed air used for breathing. (4)

(b) State THREE contaminants that may be found in compressed air, outlining the effect of the contaminant on the user when the compressed air is used for diving (SCUBA) purposes. (6)

6. (a) Describe TWO possible sources of contamination of compressed air used for breathing. (4 marks)

Breathing air used for diving must be free from harmful contaminants. Two possible sources of contamination are:

1. Compressor Lubricating Oil

- Oil from the compressor may pass into the compressed air due to:
  - Worn piston rings,
  - Faulty oil separators,
  - Excessive lubrication,
  - Poor maintenance.
- Oil vapour can be carried into the breathing air supply and may decompose under high temperatures to form toxic substances.

---

2. Contaminated Compressor Intake Air

- The compressor intake may draw in polluted air if it is located near:
  - Engine exhaust outlets,
  - Boiler uptakes,
  - Vehicle exhaust fumes,
  - Paint fumes or solvents,
  - Fuel handling areas.
- This can introduce contaminants such as carbon monoxide and other toxic gases into the breathing air system.

(b) State THREE contaminants that may be found in compressed air, outlining the effect of the contaminant on the user when the compressed air is used for diving (SCUBA) purposes. (6 marks)

1. Carbon Monoxide (CO)

Source

- Exhaust gases drawn into the compressor intake.
- Overheating and decomposition of compressor oil.

Effect on Diver

- Carbon monoxide combines with haemoglobin approximately **200–250 times more readily than oxygen**.
- Reduces the blood's oxygen-carrying capacity.

Symptoms

- Headache,
- Dizziness,
- Nausea,
- Confusion,
- Loss of consciousness,
- Death in severe cases.

---

2. Oil Vapour or Oil Mist

Source

- Compressor lubricating oil carry-over.

Effect on Diver

- Irritation of the respiratory system.
- Lung inflammation.
- Nausea and breathing difficulties.
- Some decomposed oil products can be toxic.

Symptoms

- Coughing,
- Chest irritation,
- Shortness of breath.

---

3. Water Vapour (Moisture)

Source

- Inadequate drying of compressed air.

Effect on Diver

- Can cause corrosion within cylinders and regulators.
- May freeze in regulators at depth, causing malfunction.
- Promotes microbial growth in equipment.

Symptoms/Consequences

- Regulator icing and failure.
- Potential interruption of the air supply.

Other Acceptable Contaminants

Examiners may also accept:

Carbon Dioxide (CO_2)

- Causes increased breathing effort.
- Headache and panic.
- Drowsiness and unconsciousness at high concentrations.

Particulate Matter (Rust, Dust)

- Irritates the respiratory tract.
- Can damage valves and regulators.

Exam-Style Answer

(a)

Two possible sources of contamination are:

1. Lubricating oil entering the air from the compressor due to poor maintenance or worn components.
2. Polluted intake air being drawn into the compressor from engine exhausts or other contaminated areas.

(b)

Three contaminants that may be found in compressed breathing air are:

- **Carbon monoxide**, which reduces the blood's ability to carry oxygen and may cause headache, unconsciousness, and death.
- **Oil vapour or oil mist**, which irritates the lungs and respiratory tract and may be toxic.
- **Water vapour**, which can cause regulator icing and equipment corrosion, potentially leading to interruption of the diver's air supply.

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

(a) state the interval between testing and who should carry out the testing; (2)

(b) state the name of the document where details of the vessel's lifting gear is kept; (1)

(c) state the meaning of SWL; (1)

(d) state the possible reasons for needing to take a piece of lifting equipment out of service, explaining the measures to be taken before it can be returned to service. (6)

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

(a) State the interval between testing and who should carry out the testing. (2 marks)

Interval Between Testing

Under the **Code of Safe Working Practices for Merchant Seamen**:

- Lifting appliances should be **thoroughly examined and tested at intervals not exceeding 12 months**.
- Additional testing/examination should be carried out:
  - After substantial repair or alteration,
  - Following an accident,
  - Whenever there is reason to suspect that the equipment is unsafe.

Who Should Carry Out the Testing?

> The testing and thorough examination must be carried out by a **competent person**.

A competent person may be:

- A classification society surveyor,
- A certified lifting gear inspector,
- A manufacturer's representative,
- Another suitably qualified person authorised to conduct such examinations.

(b) State the name of the document where details of the vessel's lifting gear are kept. (1 mark)

The details are recorded in the **Register of Lifting Appliances and Cargo Handling Gear**.

This register contains:

- Certificates of test and examination,
- Safe Working Loads,
- Dates of inspections and tests,
- Details of repairs and renewals.

(c) State the meaning of SWL. (1 mark)

SWL means **Safe Working Load**.

It is:

The maximum load that a lifting appliance or item of lifting gear may safely lift under specified operating conditions.

The SWL must be clearly marked on the equipment.

(d) State the possible reasons for needing to take a piece of lifting equipment out of service, explaining the measures to be taken before it can be returned to service. (6 marks)

Reasons for Taking Equipment Out of Service

Lifting equipment should be removed from service if defects such as the following are found:

1. **Cracks in structural members or welds.**
2. **Excessive corrosion or wastage.**
3. **Distortion, bending, or deformation of components.**
4. **Broken, kinked, bird-caged, or excessively worn wire ropes.**
5. **Defective brakes, clutches, limit switches, or safety devices.**
6. **Hydraulic leaks or malfunction of hydraulic systems.**
7. **Loose or missing securing bolts and fasteners.**
8. **Damage following an overload incident or accident.**

Measures Before Returning to Service

Before the equipment is used again:

- The defective equipment must be **clearly marked and isolated from use**.
- Necessary **repairs or replacement of defective parts** must be carried out.
- Repairs should be completed by **competent personnel** using approved procedures.
- The appliance should undergo a **thorough examination and, where required, a proof load test** by a competent person.
- The results should be **entered in the Register of Lifting Appliances and Cargo Handling Gear**.

- Only after certification that it is safe should the equipment be returned to service.

Exam-Style Answer

(a)

Lifting appliances should be thoroughly examined and tested at intervals not exceeding **12 months** by a **competent person**.

(b)

Details of the vessel's lifting gear are kept in the **Register of Lifting Appliances and Cargo Handling Gear**.

(c)

SWL means **Safe Working Load**, being the maximum load that may be safely lifted.

(d)

Equipment should be taken out of service if defects such as cracks, corrosion, distorted components, defective wire ropes, faulty brakes, or damaged safety devices are discovered. The equipment should be isolated, repaired by competent personnel, thoroughly re-examined and tested if necessary, recorded in the register, and recertified before being returned to service.

8. With reference to Open Flame Gas Installation, describe the safety requirements for the installation of EACH of the following:

(a) cylinders and attachments; (5)

(b) fittings and pipework. (5)

8. With reference to Open Flame Gas Installation, describe the safety requirements for the installation of EACH of the following:

(a) Cylinders and Attachments (5 marks)

The Code of Safe Working Practices lays down strict requirements for the installation and storage of LPG cylinders used for open flame equipment.

1. Dedicated Cylinder Locker

- Cylinders must be stowed in a **dedicated gas locker** used solely for LPG cylinders.
- The locker should be clearly marked:

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

2. Locker Location and Ventilation

- The locker should be located on an **open deck** or in an external position.
- It must be **gas-tight to the ship's interior**.
- Ventilation should discharge directly to the open air.
- As LPG is heavier than air, ventilation openings should be provided at **low level**.

3. Securing of Cylinders

- Cylinders must be kept **upright at all times**.
- They should be firmly secured with straps or chains to prevent movement in heavy weather.

4. Cylinder Valves and Regulators

- Each cylinder should be fitted with:
  - An approved pressure regulator,
  - A manual shut-off valve.
- Valves should be closed when the installation is not in use.
- Protective caps or guards should be fitted where provided.

5. Spare Cylinders

- Spare cylinders should be stored in the same approved locker.
- Full and empty cylinders should be clearly identified and segregated.

(b) Fittings and Pipework (5 marks)

1. Approved Materials

- Pipework and fittings must be of **approved type and suitable for LPG service**.
- Copper or corrosion-resistant metallic pipework is generally used for fixed installations.

2. Pipe Routing

- Pipework should be run in positions where it is:
  - Protected from mechanical damage,

  - Easily accessible for inspection,
  - Kept away from heat sources and electrical equipment.

3. Flexible Hoses

- Flexible hoses should be:
  - Of approved gas-resistant material,
  - Kept as short as practicable,
  - Protected against chafing and heat damage,
  - Regularly inspected and replaced when deteriorated.

4. Isolation Valves

- A readily accessible shut-off valve should be fitted:
  - At the cylinder,
  - Near the appliance.
- This enables the gas supply to be quickly isolated in an emergency.

5. Leak Testing

- All joints and connections should be tested for leaks after installation and maintenance.
- A soap solution should be used.
- **Naked flames must never be used for leak detection.**

Exam-Style Answer

(a) Cylinders and attachments

> LPG cylinders should be stored upright in a dedicated, well-ventilated locker located on open deck and gas-tight to the ship's interior. They should be securely fastened, fitted with approved regulators and shut-off valves, clearly labelled, and have their valves closed when not in use. Spare cylinders should be similarly secured and segregated.

(b) Fittings and pipework

> Pipework and fittings should be of approved materials suitable for LPG service and routed to avoid damage and heat sources. Flexible hoses should be kept short and regularly inspected. Isolation valves should be fitted at the cylinder and appliance, and all joints should be leak-tested using a soap solution, never a naked flame.

Key Points Examiners Look For

✓ Dedicated ventilated gas locker
✓ Cylinders upright and secured
✓ Approved regulators and shut-off valves
✓ Approved metallic pipework and suitable hoses

✓ Isolation valves fitted
✓ Pipework protected from damage
✓ Leak testing with soapy water only
✓ No naked flames or ignition sources during testing

9. Explain the cause and effect of propeller induced vibration on a vessel. (10)

9. Explain the cause and effect of propeller induced vibration on a vessel. (10 marks)

Propeller-induced vibration is vibration transmitted through the hull and machinery as a result of **fluctuating forces generated by the rotating propeller**. These vibrations are among the most common causes of vibration problems on ships.

Causes of Propeller-Induced Vibration

1. Non-Uniform Wake Flow

- Water approaching the propeller does not flow uniformly.
- The hull shape causes the propeller blades to pass through regions of varying water velocity and pressure.
- As each blade enters the wake behind the hull, the load on the blade changes.

Result

- Periodic thrust fluctuations occur.
- These fluctuating forces are transmitted to the shaft and hull.

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2. Blade Passing Frequency

- Each propeller blade produces a pressure pulse as it passes close to the hull.
- The frequency of excitation is:

$$\text{Blade Frequency} = \text{Number of Blades} \times \text{Propeller RPM}$$

$$f = \text{Number of blades} \times \text{Propeller rotational frequency}$$

Example

A four-bladed propeller rotating at 120 rpm:

$$f = 4 \times \frac{120}{60} = 8 \text{ Hz}$$

If this frequency coincides with a natural frequency of the ship structure, resonance may occur.

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3. Cavitation

- Local pressure on the propeller blade may fall below the vapour pressure of water.
- Vapour bubbles form and collapse violently.

Result

- Additional pressure pulses and vibration.
- Increased noise and structural excitation.

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4. Propeller Defects

Examples include:

- Damaged blades,
- Unequal blade pitch,
- Blade imbalance,
- Fouling of the propeller.

Result

- Uneven thrust generation.
- Increased vibration levels.

Effects of Propeller-Induced Vibration

1. Structural Fatigue

- Repeated cyclic stresses may cause:
  - Cracks in welds,
  - Cracking of foundations,
  - Failure of brackets and supports.

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2. Machinery Damage

- Loosening of holding-down bolts.
- Wear of bearings.
- Misalignment of shafting.
- Damage to pipe supports and fittings.

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3. Discomfort to Personnel

- Excessive vibration causes:
  - Fatigue,
  - Difficulty sleeping,
  - Reduced efficiency of crew and passengers.

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4. Noise

- Increased underwater and onboard noise levels.
- May interfere with communication and passenger comfort.

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5. Instrument and Equipment Problems

- Sensitive instruments may malfunction.
- Electrical connections may loosen.
- Electronic equipment reliability may be reduced.

Methods of Reducing Propeller-Induced Vibration

- Optimise hull form to improve wake distribution.
- Use propellers with suitable blade numbers and geometry.
- Maintain correct shaft alignment.

- Repair damaged or fouled propellers.
- Avoid prolonged operation at critical speeds.
- Improve structural stiffening where necessary.
- Minimise cavitation through proper propeller design.

Exam-Style Answer

Propeller-induced vibration is caused by fluctuating thrust and pressure forces generated as the propeller rotates. The principal causes are non-uniform wake flow, blade passing pressure pulses, cavitation, and propeller defects such as imbalance or damaged blades. These periodic forces are transmitted through the shafting and hull structure and may excite the natural frequencies of the vessel. The effects include structural fatigue, loosening of machinery and fittings, bearing wear, shaft misalignment, increased noise, malfunction of instruments, and discomfort to personnel. Vibration may be reduced by good propeller and hull design, correct maintenance, avoiding critical speeds, and ensuring proper shaft alignment.

10. (a) Describe, with the aid of a sketch, the securing arrangement for a pipe passing through a watertight bulkhead. (5)

(b) Sketch an arrangement for a watertight electric cable gland labelling ALL components. (5)

10. (a) Describe, with the aid of a sketch, the securing arrangement for a pipe passing through a watertight bulkhead. (5 marks)

When a pipe passes through a watertight bulkhead, it must maintain the **watertight integrity** of the bulkhead while allowing for the pipe to be securely supported.

Sketch

```
        Pipe
  ──────────────────────────
             |
             |
      ┌──────┴──────┐
      | Stuffing    |
      | Box/Gland   |
══════╪═════════════╪═══════
      | Watertight  |
      | Bulkhead    |
══════╪═════════════╪═══════
      | Packing     |
      | Rings       |
      |             |
      | Gland       |
      | Follower    |
      └─┬─────────┬─┘
      Bolts    Bolts
```

Description

The arrangement consists of:

1. Sleeve or Gland Body

- Welded securely into the watertight bulkhead.
- Forms the housing through which the pipe passes.

2. Packing Material

- Several rings of approved packing material are fitted around the pipe.
- The packing provides the watertight seal.

3. Gland Follower

- Compresses the packing against the pipe.
- Maintains the watertight integrity.

4. Studs and Nuts/Bolts

- Tighten the gland follower.
- Permit adjustment as the packing wears.

5. Pipe Support

- Pipe clips or hangers should be fitted close to the bulkhead to prevent movement and reduce stress on the gland.

Operation

The pipe passes through a sleeve fitted into the bulkhead. Packing rings around the pipe are compressed by a gland follower tightened by bolts. This forms a watertight seal while allowing minor adjustment and maintenance of the packing.

(b) Sketch an arrangement for a watertight electric cable gland labelling ALL components. (5 marks)

Sketch

```
            Electric Cable
─────────────────────────────────
        |
        | Outer Sheath
        ▼

     Compression Nut
     ┌───────────────┐
     |               |
     └──────┬────────┘
            |
     Gland Cone
       /────\
      /      \
     / Armour  \      ← Cable Armour
    / Clamp     \
   /_____________\
           |
    Sealing Ring
           |
═══════════╪══════════════
           |
     Watertight
     Bulkhead
═══════════╪══════════════
           |
     Gland Body
           |
      Locknut
           |
       Cable
```

Components to Label

1. Electric cable.
2. Outer cable sheath.
3. Compression nut.

4. Armour clamping cone.
5. Cable armour.
6. Sealing ring (rubber/neoprene packing).
7. Gland body.
8. Watertight bulkhead.
9. Locknut.

Description

- The **gland body** is fitted into the bulkhead.
- The **compression nut** tightens the gland assembly.
- The **sealing ring** is compressed around the cable sheath to prevent water ingress.
- The **armour clamp** secures the cable armour and provides mechanical support and earth continuity.
- The **locknut** secures the gland to the bulkhead.

Exam-Style Answer

(a)

A pipe passing through a watertight bulkhead is fitted with a stuffing box or gland arrangement. Packing rings around the pipe are compressed by a gland follower tightened by bolts, producing a watertight seal. The gland body is welded into the bulkhead and the pipe is adequately supported to prevent movement.

(b)

A watertight cable gland consists of a gland body fitted to the bulkhead, a compression nut, sealing ring, armour clamping arrangement, locknut, and cable. Tightening the gland compresses the seal around the cable and secures the armour, maintaining the watertight integrity of the bulkhead while supporting the cable mechanically.