

**APPLIED MARINE ENGINEERING****Attempt ALL questions****Marks for each part question are shown in brackets**

- ① With reference to the manufacture of carbon fibre components:
- (a) describe EACH of the following processes and its advantages:
    - (i) vacuum bagging; (2)
    - (ii) autoclave curing; (2)
    - (iii) resin transfer moulding. (3)
  - (b) list the type of component that EACH process described in part (a) is best suited to. (3)
- ② With reference to case hardening steel components:
- (a) describe the changes that occur with this process; (3)
  - (b) explain why it may be required; (2)
  - (c) describe EACH of the following processes:
    - (i) a simple shipboard process; (3)
    - (ii) solid pack carburising. (2)
- ③
- (a) List FOUR methods for non-destructive crack detection. (4)
  - (b) Describe TWO procedures from the methods listed in part (a). (6)
- ④ Explain EACH of the following engineering terms:
- (a) hardness; (2)
  - (b) proof stress; (2)
  - (c) ultimate tensile strength (UTS); (2)
  - (d) Young's Modulus; (2)
  - (e) yield stress. (2)

5. State, with reasons, a different welding/brazing/soldering process that is best suited to effect EACH of the following situations:

- (a) joining two lengths of aluminium bronze seawater pipe, both pipes having the same diameter; (2)
- (b) attaching a stainless steel handrail to a steel hull; (2)
- (c) re-attach a section of broken flange on a cast iron pump casing; (2)
- (d) attaching a brass flange onto a stainless steel pipe; (2)
- (e) attaching a 1.0 mm steel section to 10 mm thick deckhead plate. (2)

6. With reference to Impressed Current Cathodic Protection of a vessel's hull:

- (a) explain why it may be required; (2)
- (b) describe, with the aid of a sketch, the key points of installation; (5)
- (c) describe its operating principle. (3)

7. With reference to a thermistor:

- (a) state the materials used in their construction, the principle of operation and the reason for their use on vessels; (4)
- (b) state the temperature range over which they are able to operate; (1)
- (c) state, with reasons, FIVE applications where thermistors may be found on board a vessel. (5)

8. State a type of transducer or measuring device suitable for measuring EACH of the following parameters:

- (a) accurate remote reading of a diesel engine exhaust temperature; (1)
- (b) accurate remote reading of the twist of a propeller shaft; (1)
- (c) accurate and remote position of a diesel engine governor or fuel rack; (1)
- (d) the speed of a ship's main propeller shaft in RPM; (1)
- (e) remote reading of a ship's intermediate shaft bearing temperature; (1)
- (f) remote reading of lubricating oil pressure in a diesel engine; (1)
- (g) flow rate of a water maker; (1)
- (h) simple local pressure reading of ships fire-main; (1)
- (i) the position of the steering gear or rudder; (1)
- (j) local reading of jacket cooling water temperature. (1)

9. With reference to pneumatic actuators:

- (a) explain why some applications may be best suited to use a pneumatic powered actuator and others may be more suited to using an electrically powered actuator; (6)
- (b) describe ONE advantage and ONE disadvantage of a pneumatically powered valve; (2)
- (c) describe ONE advantage and ONE disadvantage of an electrically powered valve. (2)

10. (a) Identify components A, B, C, D, E, F, G and H shown in the figure. (8)  
 (b) Explain the difference between a *strainer* and a *filter* in a hydraulic circuit. (2)

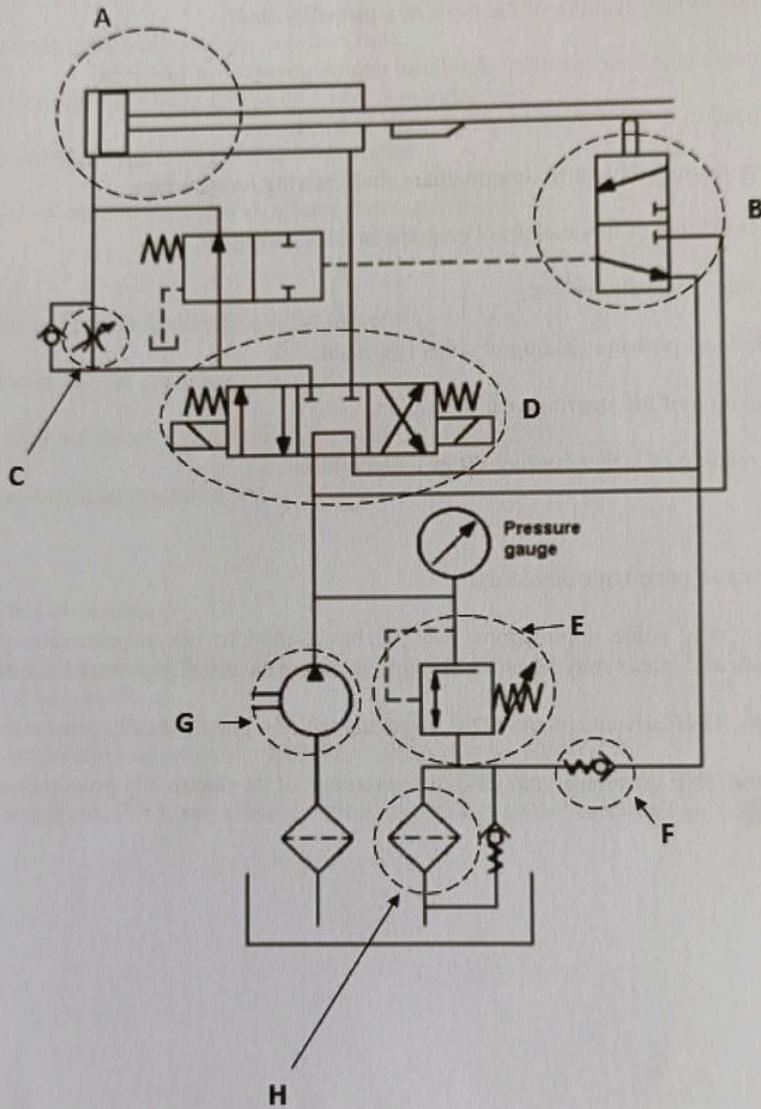


Fig Q10

**1. With reference to the manufacture of carbon fibre components:****(a) describe EACH of the following processes and its advantages:****(i) vacuum bagging; (2)****(ii) autoclave curing; (2)****(iii) resin transfer moulding; (3)****(b) list the type of component that EACH process described in part (a) is best suited to. (3)**

Three different composite fabrication processes: vacuum bagging, autoclave curing, and resin transfer molding (RTM). Each process has its own advantages and disadvantages, and is best suited for different types of components.

Here's a breakdown of each process:

**Vacuum bagging:**

**Process:** A dry fiber preform is placed in a mold, and then covered with a vacuum bag. The air is evacuated from the bag, which applies pressure to the preform and forces the resin to flow through it. The part is then cured under heat.

- **Advantages:**
  - Simple and relatively inexpensive process.
  - Can be used with a wide variety of mold materials and shapes.
  - Good for producing parts with a high fiber volume fraction.
- **Disadvantages:**
  - Limited to parts with simple geometries.
  - Voiding (air pockets) can be an issue.
  - Not suitable for high-performance applications.

**Autoclave curing:**

- **Process:** The vacuum-bagged part is placed in an autoclave, which is a pressure vessel that can be heated and pressurized. The pressure helps to consolidate the laminate and eliminate voids.
- **Advantages:**
  - Produces high-quality parts with excellent surface finish and low void content.
  - Suitable for complex geometries and high-performance applications.
- **Disadvantages:**
  - Expensive process due to the high cost of autoclaves.
  - Limited throughput due to the long cycle times.
  - Not suitable for large parts.

**Resin transfer molding (RTM):**

- **Process:** The dry fiber preform is placed in a closed mold, and then resin is injected into the mold under pressure. The part is then cured under heat.
- **Advantages:**
  - Can produce high-quality parts with good surface finish and low void content.
  - Faster cycle times than autoclave curing.
  - Can be used for larger parts than vacuum bagging.
- **Disadvantages:**
  - More complex process than vacuum bagging.
  - Requires specialized molds and equipment.
  - Not suitable for all geometries.

**2. With reference to case hardening steel components:**

- (a) describe the changes that occur with this process; (3)
- (b) explain why it may be required; (2)
- (c) describe EACH of the following processes:
  - (i) a simple shipboard process; (3)
  - (ii) solid pack carburising. (2)

**2. With reference to case hardening steel components:**

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(a) Describe the changes that occur with this process:

(3 marks)

Case hardening changes the outer surface layer (case) of a low-carbon steel component into a hard, wear-resistant layer, while leaving the core (interior) tough and ductile. The process introduces additional carbon or nitrogen atoms into the surface, increasing hardness through heat treatment. This produces a hard martensitic case after quenching, with the core remaining softer and tough.

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(b) Explain why it may be required:

(2 marks)

Case hardening is used when a component must resist wear and surface fatigue (e.g. gears, pins, shafts), but still absorb shock loads without cracking. It is often applied to low-carbon steels to combine surface hardness with core toughness, making the part durable and long-lasting.

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(c) Describe EACH of the following processes:

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(i) A simple shipboard process (3 marks)

A common shipboard case hardening method is flame hardening. In this process, an oxy-acetylene torch rapidly heats the surface of the component to its critical temperature, after which it is immediately quenched in water or oil. This creates a thin hardened surface. It is quick and suitable for repair work or treating small areas (e.g. bearing surfaces, gear teeth) without requiring a furnace.

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(ii) Solid pack carburising (2 marks)

Solid pack carburising involves embedding the steel component in a carbon-rich solid compound (like charcoal mixed with barium carbonate) inside a sealed container. The container is heated in a furnace at 900–950°C for several hours. Carbon atoms diffuse into the surface, and the component is then quenched to form a hard martensitic case. It produces deep case depths and is used for components requiring significant surface hardness.

- 4. (a) List FOUR methods for non-destructive crack detection. (4)
- (b) Describe TWO procedures from the methods listed in part (a). (6)

(a) Four Methods:

1. Visual Inspection: While seemingly simple, trained inspectors can often identify surface cracks and other defects under proper lighting and magnification. This method is quick and accessible but limited to surface flaws.
2. Dye Penetrant Testing (PT): A coloured liquid is applied to the surface and allowed to seep into cracks. After wiping the surface, a developer draws the dye back out, highlighting crack locations. This is effective for surface and near-surface cracks but requires careful cleaning and interpretation.
3. Ultrasonic Testing (UT): High-frequency sound waves are transmitted through the material and reflected back. Cracks disrupt the wave path, generating signals detected by the receiver, indicating their presence and location. This works for internal and surface cracks but requires skilled operators and specialised equipment.
4. Eddy Current Testing (ET): Magnetic fields induced by a coil interact with the material, and cracks affect the resulting electrical currents. This method works best for surface and near-surface cracks in conductive materials like metals and can be automated for rapid inspection.

(b) Two Procedure Descriptions:

1. Ultrasonic Testing (UT):

- Process: A transducer sends short bursts of ultrasound waves into the material at specific angles. These waves propagate and reflect back from interfaces within the material, including cracks. The received signals are analysed to determine the time and intensity of reflections.
- Strengths: Can detect internal and surface cracks, pinpoint crack location and depth, and evaluate crack severity. Works on various materials, including metals, composites, and ceramics.
- Limitations: Requires skilled operators and specialised equipment, interpretation of signals can be complex, and access to both sides of the material may be needed.

2. Eddy Current Testing (ET):

- Process: A coil generates an alternating magnetic field that induces eddy currents in the material. Cracks disrupt the flow of these currents, causing changes in the electromagnetic field detected by the coil. These changes are analysed to identify crack locations and characteristics.
- Strengths: Fast and automated, suitable for surface and near-surface crack detection in conductive materials, can be used for continuous monitoring during operation.
- Limitations: Only works on conductive materials, less effective for deep cracks, and requires careful calibration and interpretation of readings.

These are just two examples, and the choice of method depends on the specific material, crack type, application, and desired level of detail.

3. Explain EACH of the following engineering terms:

- |                                      |     |
|--------------------------------------|-----|
| (a) hardness;                        | (2) |
| (b) proof stress;                    | (2) |
| (c) ultimate tensile strength (UTS); | (2) |
| (d) Young's Modulus;                 | (2) |
| (e) yield stress.                    | (2) |

(a) Hardness:

Hardness quantifies a material's resistance to indentation or scratching. It indicates how easily the surface of the material can be permanently deformed by an external force. Common hardness tests include Brinell, Rockwell, and Vickers. Higher hardness values indicate a more resistant material.

(b) Proof Stress:

Proof stress, also known as yield strength in some contexts, is the stress level at which a material begins to deform plastically (permanently). This means that once stress exceeds the proof stress, the material will not return to its original shape after the stress is removed. It defines the practical limit of elastic behaviour for a material.

## (c) Ultimate Tensile Strength (UTS):

UTS is the maximum stress a material can withstand before fracturing or breaking under tension (pulling force). It represents the strongest point the material can reach before ultimate failure. UTS is typically a higher value than yield stress, as it measures the breaking point rather than the point of permanent deformation.

## (d) Young's Modulus:

Young's modulus, also known as elastic modulus, describes the stiffness of a material. It quantifies the relationship between stress and strain within the elastic range (region where deformation is temporary). A higher Young's modulus indicates a stiffer material that requires more force to deform a given amount.

## (e) Yield Stress:

Yield stress, as mentioned earlier, can be used interchangeably with proof stress in some contexts. It refers to the stress level at which plastic deformation begins. However, depending on the material and testing method, there might be slight variations in how these terms are defined and measured.

5. State, with reasons, a different welding/brazing/soldering process that is best suited to effect EACH of the following situations:
- (a) joining two lengths of aluminium bronze seawater pipe, both pipes having the same diameter; (2)
  - (b) attaching a stainless steel handrail to a steel hull; (2)
  - (c) re-attach a section of broken flange on a cast iron pump casing; (2)
  - (d) attaching a brass flange onto a stainless steel pipe; (2)
  - (e) attaching a 1.0 mm steel section to 10 mm thick deckhead plate. (2)

5. State, with reasons, a different welding/brazing/soldering process that is best suited to effect each of the following situations:

(a) Joining two lengths of aluminium bronze seawater pipe, both pipes having the same diameter

Process: TIG (GTAW) welding using suitable filler rod (e.g., aluminium bronze filler).

Reason: TIG welding provides excellent control and produces a high-quality, corrosion-resistant weld suitable for non-ferrous metals like aluminium bronze, which are commonly used in seawater systems.

(b) Attaching a stainless steel handrail to a steel hull

Process: MIG (GMAW) welding with appropriate filler (e.g., stainless steel wire).

Reason: MIG welding allows good fusion between dissimilar steels (carbon and stainless), provides strong mechanical bonding, and is ideal for structural fixtures like handrails where appearance also matters.

(c) Re-attach a section of broken flange on a cast iron pump casing

Process: Oxy-acetylene brazing with a suitable flux.

Reason: Cast iron is brittle and prone to cracking with high heat input; brazing keeps the temperature lower than welding, reducing thermal stress and preserving component integrity.

(d) Attaching a brass flange onto a stainless steel pipe

Process: Silver brazing (hard soldering)

Reason: Silver brazing is ideal for dissimilar metals like brass and stainless steel. It forms a strong, leak-tight joint without melting the base metals, and is commonly used in piping systems.

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(e) Attaching a 1.0 mm steel section to 10 mm thick deckhead plate

Process: MIG welding (with low heat input) or Spot welding

Reason: MIG welding allows for controlled heat input, which is important to avoid burn-through of the thin section. Alternatively, spot welding may be used if the component is flush and access is good.

6. With reference to Impressed Current Cathodic Protection of a vessel's hull:

- (a) explain why it may be required; (2)
- (b) describe, with the aid of a sketch, the key points of installation; (5)
- (c) describe its operating principle. (3)

## 6. With reference to Impressed Current Cathodic Protection (ICCP) of a vessel's hull:

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(a) Explain why it may be required (2 marks)

ICCP is required to **prevent corrosion of the vessel's underwater hull** and fittings due to electrochemical reactions in seawater. Corrosion occurs when the **steel hull acts as an anode** and loses metal to the seawater. ICCP protects the hull by **making it a cathode** in a controlled electrical circuit, thereby **preventing metal loss and extending the vessel's service life**.

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(b) Describe, with the aid of a sketch, the key points of installation (5 marks)

(You can sketch a simplified diagram showing the following elements:)

- **Inert anodes** (e.g. titanium with mixed metal oxide coating) mounted externally on the hull.
- **Reference electrodes** placed near the anodes to monitor hull potential.
- A **DC power supply** (often from a control panel inside the ship).
- **Cabling** from the power supply to the anodes and reference electrodes.
- **Wiring connected to the ship's hull**, completing the circuit.

**Key installation points:**

- Anodes should be **positioned symmetrically** along the hull to ensure even protection.
- **Reference electrodes** must be located where accurate hull potential can be measured.

- Cabling must be **well-insulated** and protected against seawater ingress.
  - Power/control units should be installed in a **dry, accessible location** on board.
  - System must be **earthed correctly** to prevent electrical faults.
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**(c) Describe its operating principle (3 marks)**

ICCP works by **impressing a controlled direct current (DC)** from an external power source. The current flows:

- **From the inert anodes,**
- **Through seawater,**
- **To the steel hull,** which becomes the **cathode.**

This **prevents oxidation** (corrosion) of the hull by **supplying electrons** to it. The **reference electrode continuously monitors** the hull potential, and the control unit adjusts current flow to maintain the desired protective voltage (typically around -850 mV relative to silver/silver chloride reference). Unlike sacrificial anodes, ICCP does not consume the anodes, offering **longer service life and better control.**

7. With reference to a thermistor:

- (a) state the materials used in their construction, the principle of operation and the reason for their use on vessels; (4)
- (b) state the temperature range over which they are able to operate; (1)
- (c) state, with reasons, FIVE applications where thermistors may be found on board a vessel. (5)

**(a) Materials, principle of operation, and reason for use on vessels**

- **Materials used:** Thermistors are usually made from **metal oxides** such as manganese oxide, cobalt oxide, nickel oxide, or copper oxide, which are sintered into a ceramic body. Sometimes polymers are also used for specific designs.
- **Principle of operation:** A thermistor is a **temperature-sensitive resistor**. Its electrical resistance changes significantly with temperature:
  - **NTC (Negative Temperature Coefficient)** thermistors → resistance decreases as temperature increases.
  - **PTC (Positive Temperature Coefficient)** thermistors → resistance increases as temperature increases.

- **Reason for use on vessels:**

- They provide **accurate, sensitive, and rapid response** to temperature changes.
  - They are **compact, robust, and reliable** in harsh marine environments.
  - Useful in **monitoring and protection systems** for machinery where precise temperature measurement is critical.
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## **(b) Temperature range of operation**

- Typical **operating range:  $-50\text{ }^{\circ}\text{C}$  to about  $+250\text{ }^{\circ}\text{C}$**  (depending on design and material).
  - Some specialised thermistors can operate beyond these limits, but for marine use this range is standard.
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## **(c) Five applications on board a vessel (with reasons)**

### **1. Main engine cooling water system monitoring**

- Ensures engine jacket water stays within safe limits. Rapidly detects overheating and triggers alarms or automatic shutdowns.

### **2. Lubricating oil temperature monitoring**

- Prevents low-temperature viscosity problems or high-temperature degradation of oil. Helps protect bearings and moving parts.

### **3. Refrigeration and air-conditioning plants**

- Controls compressor cycling and expansion valve operation by monitoring brine or air temperature.

### **4. Electrical equipment protection (e.g., generator windings, transformers, motors)**

- Embedded thermistors detect overheating in windings to prevent insulation failure and fire risk.

### **5. Cargo temperature monitoring (reefer containers, liquid cargo tanks)**

- Ensures perishable or temperature-sensitive cargo is transported under controlled conditions.

8. State a type of transducer or measuring device suitable for measuring EACH of the following parameters:
- (a) accurate remote reading of a diesel engine exhaust temperature; (1)
  - (b) accurate remote reading of the twist of a propeller shaft; (1)
  - (c) accurate and remote position of a diesel engine governor or fuel rack; (1)
  - (d) the speed of a ship's main propeller shaft in RPM; (1)
  - (e) remote reading of a ship's intermediate shaft bearing temperature; (1)
  - (f) remote reading of lubricating oil pressure in a diesel engine; (1)
  - (g) flow rate of a water maker; (1)
  - (h) simple local pressure reading of ships fire-main; (1)
  - (i) the position of the steering gear or rudder; (1)
  - (j) local reading of jacket cooling water temperature. (1)

**(a) Accurate remote reading of a diesel engine exhaust temperature**

**Thermocouple** – robust, accurate for high-temperature measurements, widely used for exhaust gases.

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**(b) Accurate remote reading of the twist of a propeller shaft**

**Strain gauge (torsion meter)** – detects strain/twist in the shaft and converts it into an electrical signal.

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**(c) Accurate and remote position of a diesel engine governor or fuel rack**

**Linear variable differential transformer (LVDT) / position transducer** – gives precise position feedback for governor or rack displacement.

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**(d) The speed of a ship's main propeller shaft in RPM**

**Tachometer (magnetic/electromagnetic pickup)** – counts shaft revolutions per unit time.

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**(e) Remote reading of a ship's intermediate shaft bearing temperature**

**Resistance temperature detector (RTD) or thermistor** – accurate and stable for bearing temperature monitoring.

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**(f) Remote reading of lubricating oil pressure in a diesel engine**

**Pressure transducer (strain gauge type) or Bourdon tube with electrical transmitter** – converts oil pressure into an electrical signal.

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**(g) Flow rate of a water maker**

**Flowmeter** – typically an **orifice plate with differential pressure transmitter**, or a **turbine flowmeter** for direct readings.

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**(h) Simple local pressure reading of ship's fire main**

**Bourdon tube pressure gauge** – simple, direct-reading, mechanical gauge.

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**(i) The position of the steering gear or rudder**

**Rudder angle transmitter / potentiometer / synchro transmitter** – converts rudder angle into a remote electrical signal.

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**(j) Local reading of jacket cooling water temperature**

**Mercury-in-glass thermometer or bimetallic thermometer** – direct local reading, simple and robust.

9. With reference to pneumatic actuators:

- (a) explain why some applications may be best suited to use a pneumatic powered actuator and others may be more suited to using an electrically powered actuator; (6)
- (b) describe ONE advantage and ONE disadvantage of a pneumatically powered valve; (2)
- (c) describe ONE advantage and ONE disadvantage of an electrically powered valve. (2)

**(a) Why some applications are better suited to pneumatic vs. electrical actuators (6 marks)**

- **Pneumatic actuators**

- Well-suited where **quick, powerful linear or rotary movement** is required (e.g., valve operation).
- Safer in **hazardous or flammable atmospheres** since they do not generate sparks.
- Generally more **robust, simple, and reliable** in harsh marine conditions.

- Air supply is often readily available on ships (for control systems).

- **Electrical actuators**

- Preferred where **precise positioning** or fine control is required.
  - Useful where compressed air is not available or not practical.
  - Easier to interface with modern **digital/electronic control systems** (automation, monitoring).
  - Typically better for applications needing **slow, controlled movement** with feedback.
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**(b) One advantage and one disadvantage of a pneumatically powered valve (2 marks)**

- **Advantage:**

- Rapid response and high force for size.
- Safe in hazardous/explosive environments.

- **Disadvantage:**

- Requires continuous air supply and good maintenance (leaks reduce efficiency).
  - Less precise positioning compared with electric.
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**(c) One advantage and one disadvantage of an electrically powered valve (2 marks)**

- **Advantage:**

- High accuracy and precise positioning.
- Easy integration with electronic control and monitoring systems.

- **Disadvantage:**

- Potential spark hazard in flammable environments.
- Slower operation, may not deliver as much force as pneumatic systems.

10. (a) Identify components A, B, C, D, E, F, G and H shown in the figure. (8)  
 (b) Explain the difference between a *strainer* and a *filter* in a hydraulic circuit. (2)

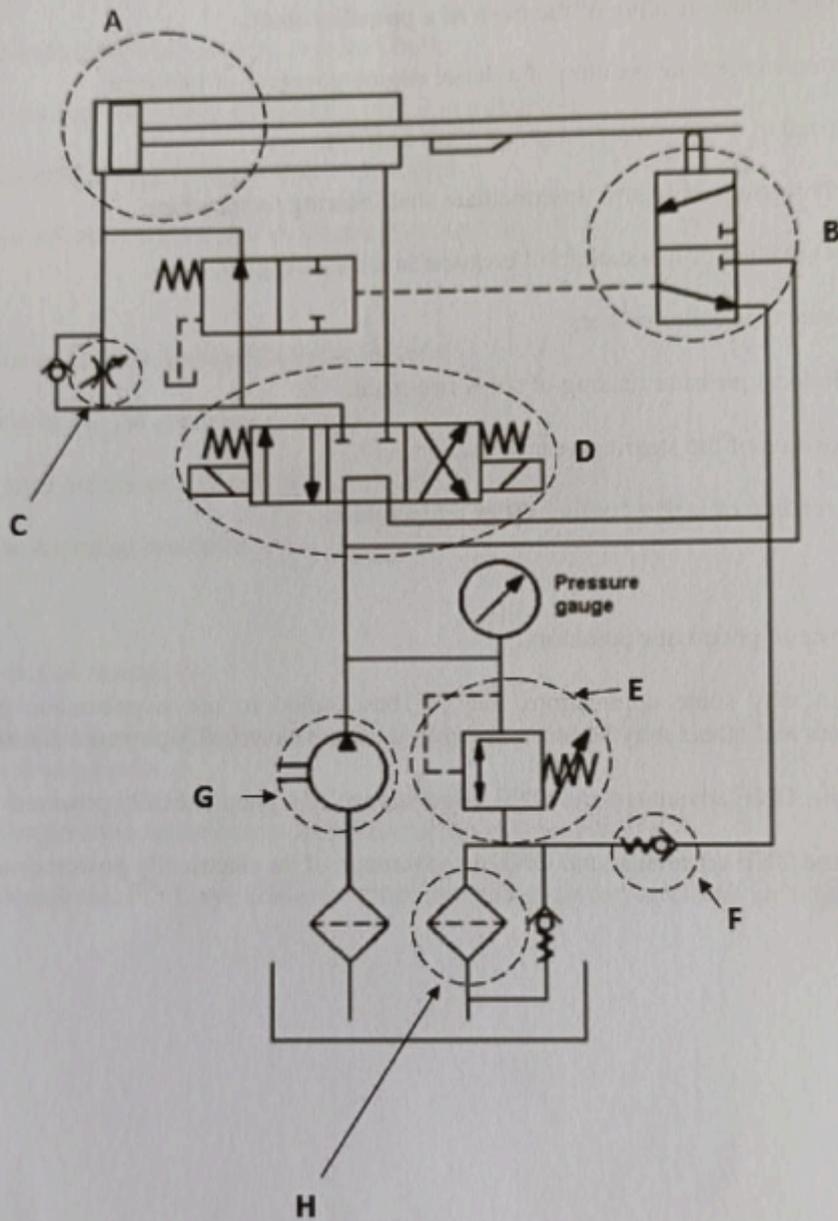


Fig Q10

Here's a

clean identification and the short theory you need for Q10.

**(a) Name the components A–H**

- **A** – Double-acting hydraulic **cylinder** (with cushioning).
- **B** – **Adjustable cushion / meter-out restrictor** built into the cylinder end cap (lets the rod decelerate smoothly near end-stroke).
- **C** – **Pilot-operated check (load-holding) valve** on the cap-end line.
- **D** – **4/3-way directional control valve** (spring-centred) for extend/neutral/retract of the cylinder.

- **E – Pressure-relief valve** on the pump delivery (with **pressure gauge** tapping).
- **F – Check (non-return) valve** in the return line.
- **G – Hydraulic pump** driven by an **electric motor** (the two adjacent circles).
- **H – Reservoir (tank) / power unit** with suction strainer and return-line filter shown on the lines entering the tank.

(8 marks)

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### (b) Strainer vs Filter (hydraulics)

- **Strainer:** a **coarse screen** (typically ~60–250  $\mu\text{m}$ ) used on the **suction side** to stop large debris from entering the pump. Low pressure drop; usually **cleanable/reusable**.
- **Filter:** a **fine, micron-rated element** (e.g., 3–25  $\mu\text{m}$  or as specified) placed in the **pressure or return line** to remove small contaminants; higher efficiency (beta-ratio specified), often **replaceable** and may include a **differential-pressure indicator/bypass**.

(2 marks)