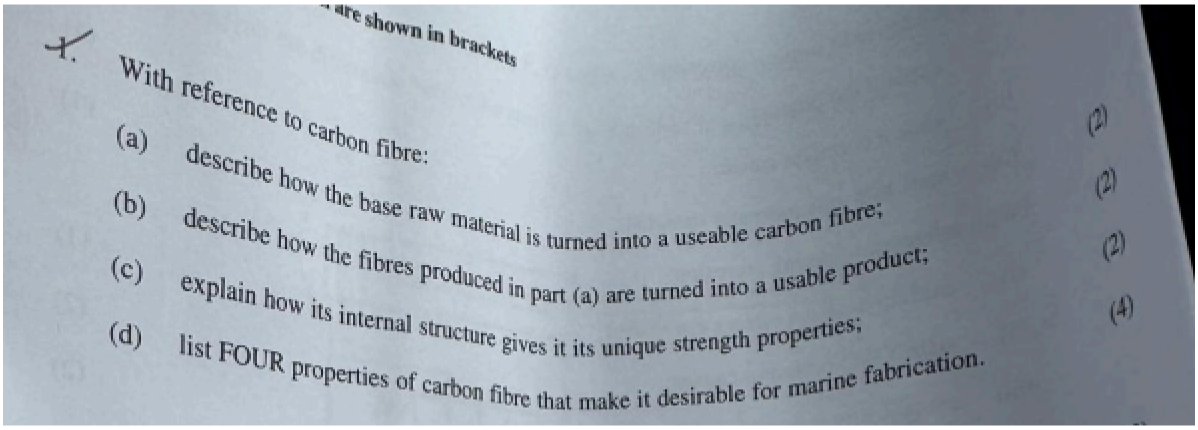

... are shown in brackets

1. With reference to carbon fibre:

(a) describe how the base raw material is turned into a useable carbon fibre; (2)

(b) describe how the fibres produced in part (a) are turned into a usable product; (2)

(c) explain how its internal structure gives it its unique strength properties; (2)

(d) list FOUR properties of carbon fibre that make it desirable for marine fabrication. (4)

With reference to carbon fibre:

(a) Describe how the base raw material is turned into a useable carbon fibre. (2)

- The raw material (usually **polyacrylonitrile (PAN)** or pitch) is spun into fine fibres.
- The fibres are then **stabilised, carbonised, and heat-treated** at high temperatures in an oxygen-free atmosphere to remove non-carbon elements, leaving strong carbon fibres.

(b) Describe how the fibres produced in part (a) are turned into a usable product. (2)

- The carbon fibres are woven into cloths or arranged in layers.
- They are then combined with a **resin matrix** (such as epoxy) and moulded or laminated into the required shape before curing to form a composite product.

(c) Explain how its internal structure gives it its unique strength properties. (4)

- Carbon fibre consists of long chains of carbon atoms bonded together in microscopic crystals.
- The carbon atoms are linked by very strong **covalent bonds**.
- These crystals are aligned mainly along the length of the fibre, giving extremely high tensile strength in that direction.
- The aligned structure also provides high stiffness and a very high strength-to-weight ratio.

(d) List FOUR properties of carbon fibre that make it desirable for marine fabrication. (4)

Any four of:

1. **High strength-to-weight ratio.**
2. **Excellent corrosion resistance** in seawater.
3. **High stiffness (rigidity).**
4. **Low weight**, reducing vessel displacement.
5. **Good fatigue resistance.**
6. **Low thermal expansion.**
7. **High durability and long service life.**
8. **Good vibration damping characteristics.**

Exam-style answer (4 marks)

- High strength-to-weight ratio.
- Excellent corrosion resistance.

- High stiffness.
- Good fatigue resistance.

2. (a) State the TWO steps occurring in the fracture process of a material. (2)

(b) Explain EACH of the following fracture failures:

(i) highly ductile fracture; (2)

(ii) moderately ductile fracture; (2)

(iii) brittle fracture. (2)

(c) Explain the process of *fatigue failure* and its significance in engineering design. (2)

(a) State the TWO steps occurring in the fracture process of a material. (2)

1. **Crack initiation (nucleation)** – a crack or defect begins to form within the material.
2. **Crack propagation (growth)** – the crack grows and spreads until complete failure occurs.

(b) Explain EACH of the following fracture failures:

(i) Highly ductile fracture (2)

- Occurs after **large plastic deformation** and significant necking.
- The material absorbs a large amount of energy before failure, usually producing a **cup-and-cone** fracture surface.

(ii) Moderately ductile fracture (2)

- Occurs with **some plastic deformation**, but less than in highly ductile fracture.
- Limited necking occurs before the crack propagates and causes failure.

(iii) Brittle fracture (2)

- Occurs with **little or no plastic deformation** before failure.
- The crack propagates rapidly, often suddenly, and the fracture surface is relatively flat and perpendicular to the applied load.

(c) Explain the process of fatigue failure and its significance in engineering design. (2)

Fatigue failure occurs when a material is subjected to **repeated or cyclic stresses**. Small cracks initiate at stress concentrations (such as notches, welds, or surface defects), then grow with each stress cycle until sudden fracture occurs.

Significance in engineering design:

- Components may fail at stresses well below their yield strength.
- Engineers must consider fatigue life, stress concentrations, material selection, and safety factors when designing machinery, ships, aircraft, and structures.

Exam answer (2 marks):

> Fatigue failure is the progressive growth of cracks caused by repeated cyclic loading. It is important in engineering design because components can fail suddenly at stresses below their normal strength, so fatigue life and safety factors must be considered.

3. (a) Explain EACH of the following terms:

(i) plasticity; (2)

(ii) sheer stress; (2)

(iii) Young's modulus; (2)

(iv) safety coefficient (factor of safety). (2)

(b) State TWO factors that may influence the safety coefficient in operation. (2)

3 (a)

Explain EACH of the following terms:

(i) Plasticity (2)

Plasticity is the property of a material that allows it to undergo **permanent deformation** without breaking when subjected to a load. The material does not return to its original shape after the load is removed.

(ii) Shear stress (2)

Shear stress is the force acting **parallel** to a surface divided by the area over which it acts. It tends to cause one part of a material to slide past another.

Shear Stress=Shear ForceArea\text{Shear Stress} = \frac{\text{Shear Force}}{\text{Area}}Shear Stress=AreaShear Force

---

(iii) Young's modulus (2)

Young's modulus is a measure of a material's **stiffness**. It is the ratio of tensile stress to tensile strain within the elastic limit of the material.

E=StressStrainE=\frac{\text{Stress}}{\text{Strain}}E=StrainStress

A high value of Young's modulus indicates a stiff material.

(iv) Safety coefficient (Factor of Safety) (2)

The **factor of safety (FoS)** is the ratio of the material's failure strength (or ultimate strength) to the allowable working stress used in design.

Factor of Safety=Failure StrengthWorking Stress\text{Factor of Safety}=\frac{\text{Failure Strength}}{\text{Working Stress}}Factor of Safety=Working StressFailure Strength

It provides a margin of safety against unexpected loads, defects, or operating conditions.

(b) State TWO factors that may influence the safety coefficient in operation. (2)

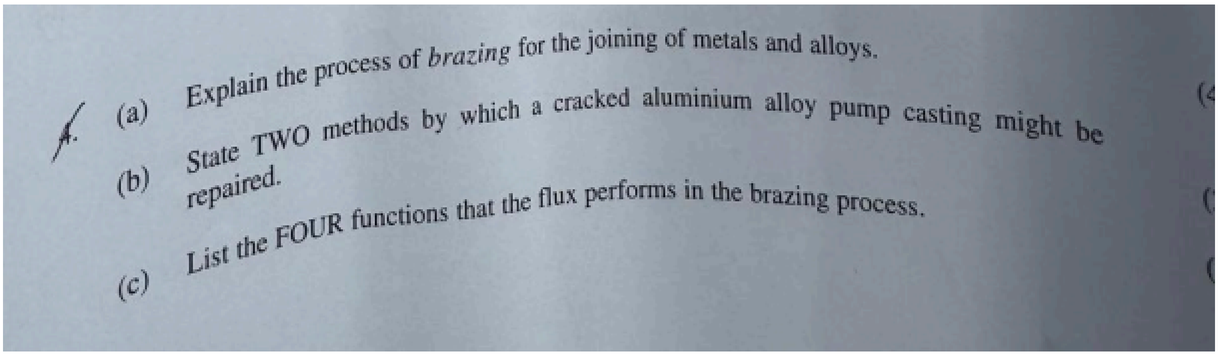
Any two of the following:

1. **Nature of the loading** (steady, fluctuating, shock, or impact loads).
2. **Consequences of failure** (risk to life, environment, or equipment).

3. **Material properties and reliability**.
4. **Operating environment** (corrosion, temperature, wear, vibration).
5. **Quality of manufacture and inspection**.
6. **Uncertainty in applied loads and service conditions**.

Exam answer (2 marks):

- Nature of the loading (static or shock loading).
- Operating conditions such as corrosion, temperature, and vibration.


4. (a) Explain the process of *brazing* for the joining of metals and alloys.

(b) State TWO methods by which a cracked aluminium alloy pump casting might be repaired.

(c) List the FOUR functions that the flux performs in the brazing process.

(a) Explain the process of brazing for the joining of metals and alloys. (4)

Brazing is a metal-joining process in which two or more metal parts are heated and joined by a **filler metal** that has a melting point above 450°C but below that of the parent metals.

1. The joint surfaces are cleaned and prepared.
2. Flux is applied to prevent oxidation.
3. The components are assembled and heated uniformly.
4. The filler metal melts and is drawn into the joint by **capillary action**.
5. On cooling, the filler metal solidifies, producing a strong, leak-tight joint without melting the parent metals.

(b) State TWO methods by which a cracked aluminium alloy pump casting might be repaired. (2)

Any two of:

1. **TIG (GTAW) welding** using a suitable aluminium filler rod.
2. **Brazing** with an appropriate aluminium brazing alloy.
3. **Metal stitching (metal locking)**.
4. **Replacement of the damaged casting section or complete casting.**
5. **Epoxy/metal-filled composite repair** (for non-critical applications).

(c) List the FOUR functions that the flux performs in the brazing process. (4)

1. **Removes existing oxide films** from the metal surfaces.
2. **Prevents further oxidation** during heating.
3. **Promotes wetting and flow** of the molten filler metal.
4. **Protects the heated surfaces** from atmospheric contamination, producing a sound joint.

Exam answer (4 marks)

- Removes oxides from the joint surfaces.
- Prevents oxidation during heating.
- Assists the flow of the filler metal.

- Protects the joint area from contamination.

(a) With reference to fretting corrosion:

(i) explain the process; (3)

(ii) state a common cause; (1)

(iii) state how it is normally detected. (1)

(b) With reference to pitting corrosion:

(i) explain the term *pitting corrosion*; (1)

(ii) state TWO common causes; (2)

(iii) explain why it is considered to be dangerous. (2)

5 (a) With reference to fretting corrosion:

(i) Explain the process. (3)

Fretting corrosion occurs when two metal surfaces in contact are subjected to **small repeated relative movements or vibration**. The movement damages the protective oxide film, producing fine metal particles that oxidise and cause wear and corrosion at the contact surfaces.

(ii) State a common cause. (1)

- **Vibration between tightly fitted components** (e.g. shafts and couplings, bearings, bolted joints, or keyed connections).

(iii) State how it is normally detected. (1)

- By the presence of **reddish-brown or black powder/debris** at the contact surfaces during inspection.
- Also indicated by wear marks or pitting at the mating surfaces.

(b) With reference to pitting corrosion:

(i) Explain the term pitting corrosion. (1)

Pitting corrosion is a highly localised form of corrosion that produces small holes or pits in a metal surface due to the breakdown of the protective film.

(ii) State TWO common causes. (2)

1. **Breakdown of the protective oxide coating**, often due to chloride ions (salt water).
2. **Stagnant water deposits or differential aeration cells** on the metal surface.

(Other acceptable answers include damaged coatings, poor maintenance, or contamination.)

(iii) Explain why it is considered to be dangerous. (2)

- Pitting can cause **deep penetration with very little overall metal loss**, making the damage difficult to detect.
- The pits act as **stress concentration points**, which can lead to cracking, leakage, or sudden structural failure.

Exam-style answers

Fretting corrosion:

- Caused by small oscillatory movement between contacting surfaces.
- Common cause: vibration.
- Detected by reddish-brown/black powder and wear marks.

Pitting corrosion:

- Localised attack forming pits in the metal surface.
- Causes: chloride contamination and stagnant conditions.
- Dangerous because it is difficult to detect and can cause sudden failure despite little visible corrosion.

6. With reference to root whitening in GRP hull construction:

(a) explain the term *root whitening*, stating where it is most likely to occur; (2)

(b) explain TWO possible reasons why this may happen; (4)

(c) state TWO possible actions that could be taken if it is discovered. (4)

6.

With reference to root whitening in GRP hull construction:

(a) Explain the term root whitening, stating where it is most likely to occur. (2)

Root whitening is the appearance of white lines or whitening in the resin at the base (root) of a fibreglass laminate. It is caused by the separation of fibres from the resin or the formation of microscopic cracks due to excessive stress.

It is most likely to occur:

- At **corners, radii, and sharp changes in section**.
- Around **stiffeners, bulkheads, frames, and other highly stressed areas** of a GRP hull.

(b) Explain TWO possible reasons why this may happen. (4)

1. Excessive loading or impact

- Heavy wave action, grounding, collision, or repeated flexing can overstress the laminate.
- The resin cracks or separates from the glass fibres, causing the characteristic white appearance.

2. Poor construction or design

- Sharp internal corners with insufficient radius create stress concentrations.
- Inadequate resin impregnation, poor bonding, or insufficient laminate thickness can lead to localised stress and root whitening.

(Other acceptable reasons include fatigue loading, incorrect curing, or over-tightening of fittings.)

(c) State TWO possible actions that could be taken if it is discovered. (4)

1. Inspect and assess the damage

- Determine the extent of the whitening by visual inspection and, if necessary, non-destructive testing.
- Check for delamination, cracking, or structural weakening.

2. Repair and reinforce the affected area

- Grind out damaged laminate if necessary.
- Re-laminate with new glass fibre and resin, ensuring proper bonding and adequate reinforcement.
- Correct any design or support issues that caused the problem.

Exam-style answer

(a) Root whitening is the whitening of resin caused by fibre/resin separation or micro-cracking. It commonly occurs at corners, stiffeners, and highly stressed areas.

(b) Causes:

1. Excessive loading, impact, or flexing.
2. Poor laminate design/construction causing stress concentrations.

(c) Actions:

1. Inspect to determine the extent of damage.
2. Repair and reinforce the laminate by re-laminating the affected area.

7. Describe, with the aid of a sketch, a floatation device that produces an output signal to remotely control the liquid level in a tank. (10)

7. Describe, with the aid of a sketch, a floatation device that produces an output signal to remotely control the liquid level in a tank. (10)

A common device is a **float-operated level transmitter**.

Description

- A **float** rests on the surface of the liquid in the tank.
- As the liquid level rises or falls, the float moves vertically with the liquid surface.
- The float is connected by a lever, cable, or magnetic linkage to a **transducer** (such as a potentiometer, LVDT, reed switch assembly, or pneumatic transmitter).
- The movement of the float is converted into an **electrical or pneumatic signal** proportional to the liquid level.
- This signal is transmitted to a **remote indicator, controller, or control valve**.
- When the level changes, the controller can automatically operate pumps or valves to maintain the desired tank level.
- The system provides continuous monitoring and remote control without direct access to the tank.

```
        Remote Indicator/
        Level Controller
               |
        Electrical Signal
               |
      ┌────────┴────────┐
      |  Transmitter    |
      └────────┬────────┘
               |
            Lever
               |
               O   Float
~~~~~~~~~~~~~~~~~|~~~~~~~~~~ Liquid Level
               |
               |
               |
      ┌─────────────────┐
      |      Tank       |
      |                 |
      └─────────────────┘
```

Operation

1. Liquid level rises.
2. Float rises with the liquid surface.
3. Float movement operates the transmitter.
4. Transmitter produces a proportional output signal (e.g., 4–20 mA).
5. Signal is sent to a remote controller.
6. Controller adjusts a valve or pump to maintain the required level.

Exam Answer (10 Marks)

A float-operated level transmitter consists of a float that follows the liquid level in a tank. The float is mechanically or magnetically connected to a transmitter that converts the float movement into an electrical or pneumatic signal. This signal is sent to a remote indicator or controller, which may operate pumps or valves to maintain the required liquid level. As the level rises or falls, the output signal changes proportionally, providing continuous remote level measurement and control. Include a labelled sketch showing the float, transmitter, signal line, and remote controller.

8. (a) Describe, with the aid of a sketch, the principle and operation of a potentiometer. (6)

(b) Explain how a potentiometer can be used to measure rotary movement. (4)

8

(a) Describe, with the aid of a sketch, the principle and operation of a potentiometer. (6)

A **potentiometer** is a variable resistor used to measure displacement or position by converting mechanical movement into a proportional electrical voltage signal.

Principle

- A uniform resistance element is connected across a DC voltage supply.
- A movable contact called a **wiper** slides along the resistance element.
- As the wiper moves, the resistance on either side changes.
- The output voltage taken from the wiper is proportional to its position along the resistor.

Sketch

```
     +V Supply
         |
         |
   A o--------------------o B
     Resistance Element
              ↑
            Wiper
              |
              |
         Output Voltage
              |
             0V
```

Operation

1. A constant voltage is applied across the resistance element.
2. The wiper is mechanically connected to the moving component.
3. Movement of the wiper changes the resistance ratio.
4. The output voltage varies proportionally with the wiper position.
5. The output signal can be used for indication, measurement, or control purposes.

(b) Explain how a potentiometer can be used to measure rotary movement. (4)

- In a **rotary potentiometer**, the wiper is attached to a rotating shaft.
- As the shaft rotates, the wiper moves around a circular resistance track.
- The output voltage changes in proportion to the angle of rotation.
- By calibrating the output voltage against shaft angle, the amount and direction of rotary movement can be measured remotely.

Sketch of Rotary Potentiometer

Sketch of Rotary Potentiometer

```
            Shaft
              |
              ▼
          ┌───────┐
          |   ↑   |  Wiper
          |  /    |
          | /     |
          └───────┘
       Circular Resistance
            Track

  Output Voltage ∝ Angle of Rotation
```

Exam-style Answer

(a) A potentiometer consists of a resistance element and a movable wiper supplied by a constant voltage. As the wiper moves, the voltage at the wiper changes proportionally to its position, producing an electrical signal corresponding to displacement.

(b) In a rotary potentiometer, the wiper is connected to a rotating shaft. Rotation moves the wiper around a circular resistance track, producing an output voltage proportional to the angular position of the shaft, allowing rotary movement to be measured.

9. With reference to a main engine lubricating oil system, explain, with the aid of a sketch, the principle of a *closed loop* temperature control system. (10)

9. With reference to a main engine lubricating oil system, explain, with the aid of a sketch, the principle of a closed-loop temperature control system. (10)

A **closed-loop temperature control system** continuously measures the lubricating oil temperature, compares it with a desired set value, and automatically adjusts the cooling water flow through the lubricating oil cooler to maintain the correct oil temperature.

```
                  Set Temperature
                         |
                         ▼
                  ┌────────────┐
                  | Controller |
                  └─────┬──────┘
                        | Output Signal
                        ▼
                 ┌──────────────┐
Cooling Water -->| Control Valve|---->
                 └──────┬───────┘
                        |
                        ▼
              ┌──────────────────┐
 LO from ME ->| L.O. Cooler      |-> To Engine
              └─────────┬────────┘
                        |
                        ▼
              Temperature Sensor
                        |
                 Feedback Signal
                        |
                        └─────────────► Controller
```

Principle of Operation

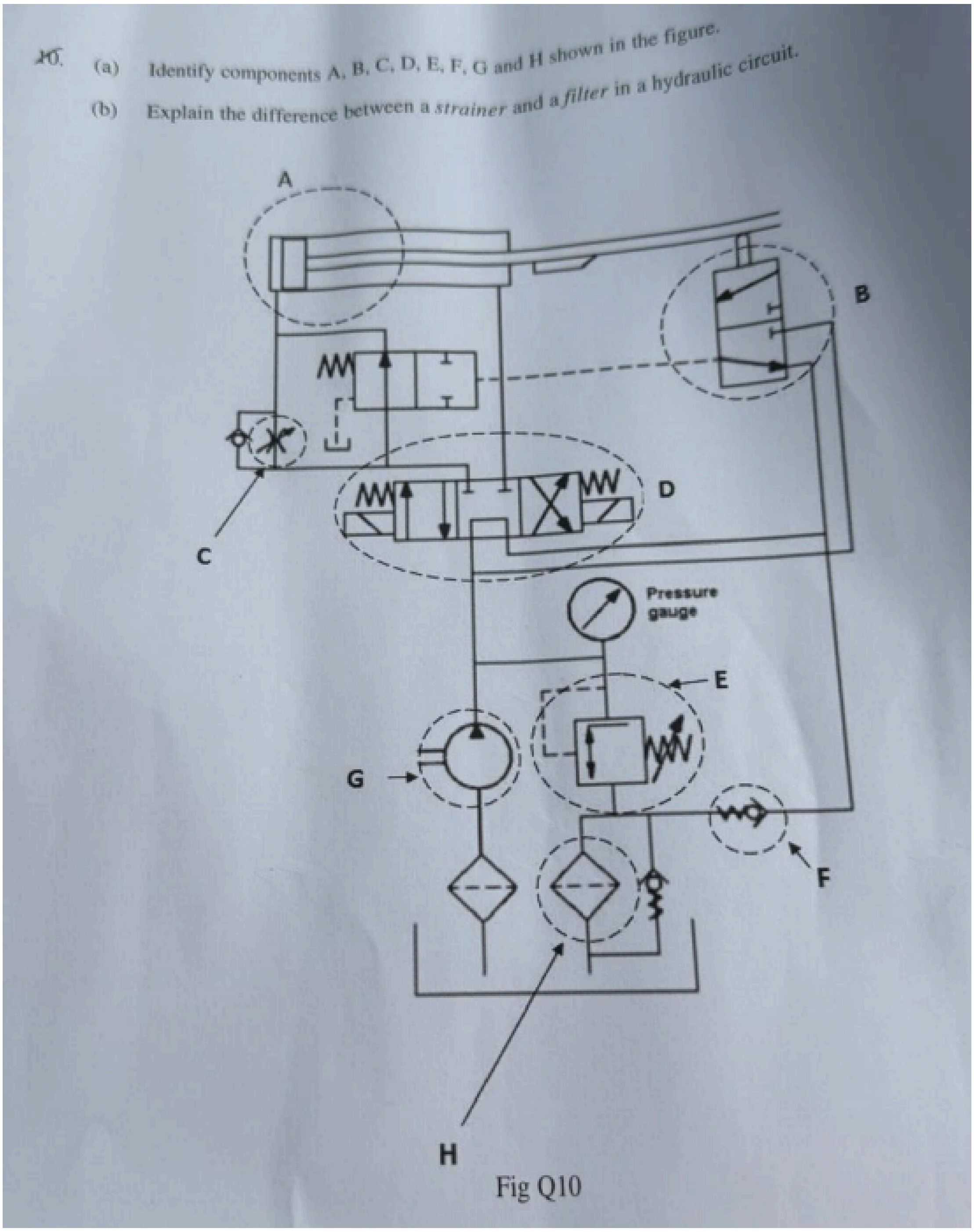
1. Lubricating oil leaving the engine passes through the **lubricating oil cooler**.
2. A **temperature sensor** located at the cooler outlet measures the oil temperature.
3. The sensor sends a **feedback signal** to the temperature controller.
4. The controller compares the measured temperature with the **set point** (desired temperature).
5. Any difference between the actual temperature and set point is called the **error**.
6. The controller processes the error and sends a signal to the control valve.
7. The control valve adjusts the amount of cooling water flowing through the cooler.
8. If the oil temperature rises above the set point, the valve opens further to increase cooling.
9. If the oil temperature falls below the set point, the valve closes slightly to reduce cooling.
10. The sensor continuously measures the resulting temperature and feeds it back to the controller, forming a **closed loop**.

Why it is called a Closed-Loop System

The system is called **closed-loop** because the output variable (lubricating oil temperature) is continuously measured and fed back to the controller. The controller uses this feedback to automatically correct any deviation from the desired temperature.

Exam Answer (10 Marks)

A closed-loop temperature control system for a main engine lubricating oil system consists of a temperature sensor, controller, control valve, and lubricating oil cooler. The sensor measures the oil temperature and sends a feedback signal to the controller. The controller compares this value with the set point and produces an output signal to the cooling water control valve. The valve regulates cooling water flow through the lubricating oil cooler. If the oil temperature rises, cooling water flow is increased; if it falls, cooling water flow is reduced. Continuous feedback of the measured temperature allows automatic correction of errors and maintains the lubricating oil temperature at the desired value.



10 (a) Identify components A, B, C, D, E, F, G and H shown in the figure.

This is a typical **hydraulic cylinder control circuit**.

Label	Component
A	Double-acting hydraulic cylinder (ram)
B	Mechanical limit switch / roller-operated directional control valve
C	Adjustable flow control valve (needle valve with check valve)
D	4/3-way directional control valve, spring-centred

E Pressure relief valve

F Non-return (check) valve

G Hydraulic pump

H Hydraulic reservoir (tank) with suction filter/strainer

---

10 (b) Explain the difference between a strainer and a filter in a hydraulic circuit. (4)

Strainer

- Usually fitted in the **pump suction line**.
- Removes **large particles and debris**.
- Has a relatively **coarse mesh**.
- Protects the pump from damage caused by large contaminants.

Filter

- Usually fitted in the **pressure line, return line, or bypass line**.
- Removes **much finer particles** than a strainer.
- Uses a fine filtering element (paper, fibre, metal, etc.).
- Protects valves, actuators, and other precision hydraulic components from wear and contamination.

Exam Answer

Strainer: A coarse screening device used mainly on the pump suction side to remove large contaminants and prevent pump damage.

Filter: A fine filtration device used in pressure or return lines to remove small particles and maintain hydraulic fluid cleanliness, protecting sensitive hydraulic components.