1. With reference to four stroke engines, explain the effects of EACH of the following:

   (a) advanced fuel injection; (3)

   (b) retarded fuel injection; (4)

   (c) low compression pressure. (3)

(a) Advanced fuel injection (3 marks)

- **Peak pressure occurs earlier** in the cycle (before/near TDC).
- Can lead to **higher maximum cylinder pressure and temperature**.
- Results in **knocking/diesel knock** and increased mechanical stress.

(b) Retarded fuel injection (4 marks)

- **Combustion occurs later** in the expansion stroke.
- Leads to **reduced power output** (less effective pressure on piston).
- Causes **higher exhaust gas temperatures** (incomplete expansion).
- Results in **poor fuel efficiency and possible black smoke** due to incomplete combustion.

(c) Low compression pressure (3 marks)

- **Reduced air temperature** at end of compression.
- Causes **poor ignition or delayed combustion**.
- Leads to **difficult starting, misfiring, and loss of power**.

---

2. (a) Describe the function of a main engine turbocharger. (5)

   (b) Describe how the turbocharger is cooled. (2)

   (c) Describe how the turbocharger is lubricated. (3)

(a) Function of a main engine turbocharger (5 marks)

A turbocharger uses **exhaust gas energy** to drive a turbine, which is connected by a shaft to a compressor. The compressor draws in ambient air, compresses it, and delivers it to the engine cylinders at a higher pressure. This increases the **mass of air available for combustion**, allowing more fuel to be burned efficiently. As a result, the engine produces **greater power output**, improved **thermal efficiency**, and better **scavenging of exhaust gases** (especially in two-stroke engines), without increasing engine size.

(b) How the turbocharger is cooled (2 marks)

- The turbocharger is cooled by **air and/or water cooling systems**.
- The casing is often **water-cooled**, while continuous airflow and exhaust gas flow help remove heat from the turbine and compressor.

(c) How the turbocharger is lubricated (3 marks)

- Lubrication is provided by the **engine's lubricating oil system**.
- Oil is supplied under pressure to the **turbocharger bearings**.
- The oil reduces friction, removes heat, and then **drains back to the sump** for recirculation.

Exam tip:

For full marks:

- (a) mention **turbine + compressor + increased air → more fuel → more power**
- (b) include **water cooling of casing**
- (c) include **pressurised oil supply + return to sump**

3. (a) Sketch a cross section through a four stroke diesel engine piston, labelling the MAIN components. (6)

(b) Describe the transfer of gas force from piston crown through to the crankshaft. (4)

(a) Cross-section of a four-stroke diesel engine piston (6 marks)

```
       Cylinder Liner
     ┌──────────────────┐
     │  Piston Crown    │  ← Combustion space
     │ (Top Land)       │
     │ ──────────────── │
     │ Compression      │
     │    Rings         │
     │ ──────────────── │
     │  Oil Control     │
     │    Ring          │
     │ ──────────────── │
     │  Piston Skirt    │
     │                  │
     │   ┌─────────┐    │
     │   │Gudgeon  │    │
     │   │ (Wrist) │    │
     │   │   Pin   │    │
     │   └─────────┘    │
     └──────────────────┘
            ↓
       Connecting Rod
```

Main components to label:

- Piston crown
- Ring grooves and **compression rings**
- **Oil control ring**
- Piston skirt
- Gudgeon (wrist) pin
- Cylinder liner

(b) Transfer of gas force to the crankshaft (4 marks)

The force generated by combustion acts on the **piston crown**, pushing the piston downward. This force is transmitted through the piston to the **gudgeon (wrist) pin**, which transfers the load to the **connecting rod**. The connecting rod then conveys the force to the **crankpin of the crankshaft**, converting the reciprocating motion of the piston into **rotary motion** of the crankshaft, producing useful work.

4. The daily engine log shows the engine crankcase pressure gauge is indicating a much higher value than the normal reading.

(a) State the implications of this and the immediate actions that should be taken. (2)

(b) Outline the checks and investigations that should be undertaken to ascertain the cause of this increased crankcase pressure. (8)

(a) Implications and immediate actions (2 marks)

Implications:

- Indicates **crankcase overpressure**, likely due to **blow-by** or possible **oil mist formation**, creating a risk of **crankcase explosion**.

Immediate actions:

- **Reduce engine load immediately**.
- Increase monitoring and **prepare to stop the engine** if condition worsens.

(b) Checks and investigations (8 marks)

1. **Check for blow-by past piston rings**
   - Worn or broken piston rings allowing combustion gases into crankcase.
2. **Inspect cylinder liners**
   - Excessive wear, scoring, or damage.
3. **Check piston condition**
   - Cracked piston crown or damaged ring lands.
4. **Examine crankcase ventilation system**
   - Blocked or restricted breather causing pressure build-up.
5. **Check for overheating components**
   - Hot spots may lead to oil vaporisation and mist formation.
6. **Inspect for oil mist presence**
   - Ensure oil mist detector (if fitted) is functioning correctly.
7. **Check bearing condition**
   - Overheated bearings can generate oil vapour and increase pressure.
8. **Verify correct oil level and condition**
   - Overfilled or contaminated oil may contribute to mist formation.

5. (a) Sketch a scroll type fuel pump, labelling the main components. (6)

(b) Explain how the pump sketched in part (a) may vary the end of delivery. (4)

```
      Fuel Inlet
          ↓
    ┌─────────────┐
    │   Pump Body │
    │             │
    │  Helical    │  ← Scroll (helix) on plunger
    │  Groove     │
    │     |       │
    │   Plunger   │
    │     ↑       │
    │  Barrel     │
    └─────┬───────┘
          ↓
    Spill Port
          ↓
    Fuel Outlet → To Injector

      ↑
 Camshaft & Tappet
      ↑
 Plunger Movement (Up/Down)

  Control Rack → rotates plunger
```

Main components to label:

- Plunger with **helical (scroll) groove**
- Barrel
- Spill port
- Fuel inlet and outlet
- Delivery valve (above outlet)
- Camshaft and tappet (drive mechanism)
- Control rack (for rotation of plunger)

(b) How end of delivery is varied (4 marks)

The end of fuel delivery is controlled by the **rotation of the plunger**, which has a **helical groove (scroll)**. As the plunger rises under cam action, it initially covers the spill port and fuel is pressurised and delivered to the injector. When the helix aligns with the spill port, the high-pressure fuel is released back into the pump, causing a **sudden drop in pressure and termination of injection**. By rotating the plunger using the **control rack**, the position at which the helix uncovers the spill port changes, thereby **varying the end of delivery and the quantity of fuel injected**.

6. (a) Explain what is meant by microbial degradation of a lubricating oil. (4)

(b) State FOUR indications that could be observed if a lubricating oil was suffering from microbial degradation. (4)

(c) Describe TWO actions that should be taken on detecting the early start of microbial degradation of the main engine lubricating oil. (2)

(a) Microbial degradation of lubricating oil (4 marks)

Microbial degradation is the **breakdown of lubricating oil by microorganisms** such as bacteria and fungi, usually in the presence of **water contamination**. These microbes feed on components of the oil, producing **acids, sludge, and biomass**, which deteriorate the oil's properties and can lead to corrosion and system damage.

(b) FOUR indications of microbial degradation (4 marks)

1. **Sludge or slimy deposits** in tanks, filters, or pipework.
2. **Foul or sour odour** from the oil.
3. **Increase in acidity (low pH)** of the oil.
4. **Filter blockage or rapid clogging** due to microbial growth.

(Other acceptable: corrosion, emulsification, discolouration)

(c) TWO actions to take at early detection (2 marks)

1. **Remove water contamination** (drain tanks, improve separation).
2. **Treat oil with biocide** to kill microorganisms.

7. (a) Describe, with the aid of a sketch, a central cooling water system. (8)

(b) State the advantage of the system described in part (a). (2)

```
              CENTRAL COOLING SYSTEM

          Sea Water System
   Sea Chest → SW Pump → Central Cooler → Overboard
                             ↑
                             |
                    Fresh Water (LT circuit)
                             |
        ┌───────────────┬─────────────────┐
        |               |                 |
  Main Engine      Auxiliary       Other Coolers
   (HT circuit)      Engines       (LO, Air, etc.)
        |               |                 |
        └───────→ LT Return Line ←────────┘
                             ↓
                          LT Pump
                             ↓
                    Central Cooler
                             ↓
                         LT Supply

        (HT circuit has its own pump + heater if fitted)
```

Description:

A central cooling system uses **fresh water (usually in two circuits: HT and LT)** to cool engine components, while **seawater is only used in a central cooler**. The **low-temperature (LT) circuit** circulates fresh water through a central cooler, where heat is removed by seawater. This LT water then cools various systems such as lubricating oil coolers and air coolers.

The **high-temperature (HT) circuit** circulates water through the main engine jackets and cylinder heads, maintaining optimal engine temperature. Heat from the HT system is transferred to the LT system via a heat exchanger. Pumps ensure continuous circulation, and temperature control valves regulate flow to maintain correct operating temperatures.

(b) Advantage of the system (2 marks)

- **Reduced corrosion and fouling** since seawater is confined to the central cooler only.
- **Improved temperature control and efficiency** of the cooling system.

8. (a) Explain, with the aid of a diagram, the operation of a solenoid operated, battery powered electric starting system for an internal combustion engine. (6)

(b) Explain the term pre-engaged starter. (4)

```
     Battery
        |
   Ignition Switch
        |
     Solenoid Coil
        |
  ┌─────────────┐
  │  Solenoid   │
  │  (Plunger)  │
  └─────────────┘
        |
        |
 Shift Lever → Engages Pinion
        |
 Starter Motor ───→ Pinion Gear → Flywheel Ring Gear
```

Operation:

When the ignition switch is turned to the start position, current flows from the **battery** to the **solenoid coil**, creating a magnetic field. This pulls in the **solenoid plunger**, which performs two functions:

1. **Mechanically** moves the **shift lever**, engaging the starter pinion with the flywheel ring gear.
2. **Electrically** closes heavy-duty contacts within the solenoid, allowing high current to flow to the **starter motor**.

The starter motor then rotates, turning the engine crankshaft to initiate combustion. Once the engine starts and the switch is released, the solenoid is de-energised, the pinion disengages, and the motor stops.

(b) Pre-engaged starter (4 marks)

A pre-engaged starter is a type of starting system in which the **starter pinion gear is fully engaged with the flywheel ring gear before the starter motor begins to rotate**. This is achieved by the solenoid mechanism, ensuring smooth and reliable engagement, reducing gear wear, and preventing damage caused by gear clash.

9. (a) List FIVE possible causes why a diesel engine may overheat. (5)

(b) State a remedy for EACH of the causes listed in part (a). (5)

(a) FIVE causes of diesel engine overheating (5 marks)

1. **Insufficient cooling water flow**
2. **Blocked or fouled cooler/heat exchanger**
3. **Low cooling water level**
4. **Faulty thermostat or temperature control valve**
5. **Overloading of the engine**

(b) Remedy for EACH cause (5 marks)

1. **Insufficient cooling water flow**
   → Check and repair pumps, clear blockages, ensure valves are open.
2. **Blocked or fouled cooler**
   → Clean/descale the heat exchanger or cooler.
3. **Low cooling water level**
   → Top up system and check for leaks.
4. **Faulty thermostat/control valve**
   → Repair or replace the defective component.
5. **Engine overload**
   → Reduce load and operate within safe limits.

10. With reference to a gearbox:

(a) explain why large quantities of lubricating oil are used; (2)

(b) state FOUR possible causes of excessive lubricating oil temperature when at normal operating speeds; (4)

(c) state how EACH cause stated in part (b) may be remedied. (4)

(a) Why large quantities of lubricating oil are used (2 marks)

- To provide **adequate cooling**, as gearbox oil removes heat generated by gear meshing.
- To ensure a **continuous and effective lubricating film** over all gear teeth and bearings.

(b) FOUR causes of excessive lubricating oil temperature (4 marks)

1. **Insufficient oil flow** (pump fault or blockage).
2. **Fouled or ineffective oil cooler**.
3. **Low oil level**.
4. **Excessive load or misalignment of gears**.

(c) Remedy for EACH cause (4 marks)

1. **Insufficient oil flow**
   → Check pump operation, clear blockages, ensure valves are open.
2. **Fouled oil cooler**
   → Clean or service the cooler.
3. **Low oil level**
   → Top up oil and check for leaks.
4. **Excessive load or misalignment**
   → Reduce load and inspect/realign gears as necessary.