

MARINE DIESEL ENGINEERING

Attempt ALL questions

Marks for each part question are shown in brackets

1. Describe the combustion process of EACH of the following:
 - (a) petrol engine; (5)
 - (b) diesel engine. (5)

2. With reference to engine timing belts or chains:
 - (a) state the cause of loss of timing drive tension; (2)
 - (b) state how this will affect the engine; (6)
 - (c) explain how slight loss of tension can be corrected. (2)

3.
 - (a) Describe the events leading to a crankcase explosion. (4)
 - (b) State the methods of detecting the events of part (a) (2)
 - (c) State how the severity of a crankcase explosion may be limited. (4)

4. With reference to fuel injector needle valves siezing in their bodies during engine operation:
 - (a) explain the effects if the needle has jammed partially open; (3)
 - (b) state the possible causes; (2)
 - (c) state, with reasons, how to minimise this problem. (5)

5. With reference to the properties of fuel oils, explain EACH of the following terms, stating their significance to engine/shipboard operations:
 - (a) specific energy; ~~Ks/Kg~~ Ks/Kg (2)
 - (b) cetane number; (2)
 - (c) residual carbon; (2)
 - (d) sulphur content; (2)
 - (e) relative density (specific gravity). (2)

6. (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)
7. Describe, with the aid of a sketch, the operation of a pre-engage diesel engine electric starting system, labelling the main components. (10)
8. With reference to turbochargers:
- (a) explain the term *surging*; (5)
- (b) describe the indications of *surging*; (2)
- (c) describe the causes of *surging*. (3)
9. With reference to an engine connected to a gearbox via a friction clutch, explain EACH of the following:
- (a) why vibration from the engine should be damped; (7)
- (b) how vibration damping is achieved. (3)
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)
1. Describe the combustion process of EACH of the following:
- (a) petrol engine; (5)
- (b) diesel engine. (5)

(a)

Petrol Engine (Spark-Ignition Engine)

- **Air–fuel mixture preparation:** Fuel is mixed with air (either by carburettor or fuel injection) before entering the cylinder.

- **Compression:** The piston compresses the **air–fuel mixture** to a moderate compression ratio (typically 8:1 – 12:1).
- **Ignition:** Near the end of the compression stroke, an **electric spark plug** ignites the mixture.
- **Combustion:** The mixture burns rapidly in a controlled explosion, producing high-pressure gases.
- **Power stroke:** Expanding gases force the piston down, converting chemical energy to mechanical work.

👉 **Key point:** Petrol engines rely on **spark ignition** of a pre-mixed fuel–air charge.

(b) Diesel Engine (Compression-Ignition Engine)

- **Air induction:** Only air is drawn into the cylinder during the intake stroke.
- **Compression:** The piston compresses the air to a very high compression ratio (typically 14:1 – 22:1), raising its temperature to 600–700 °C.
- **Fuel injection:** Near top dead centre, fuel is injected directly into the hot compressed air by a high-pressure injector.
- **Ignition:** The fuel spontaneously ignites due to the high temperature (no spark required).
- **Combustion:** Combustion occurs progressively as fuel continues to be injected, giving a smoother but higher-pressure rise.
- **Power stroke:** Expanding gases push the piston down, delivering power.

👉 **Key point:** Diesel engines rely on **compression ignition** of fuel injected into hot compressed air.

2. With reference to engine timing belts or chains:

- (a) state the cause of loss of timing drive tension; (2)
- (b) state how this will affect the engine; (6)
- (c) explain how slight loss of tension can be corrected. (2)

(a)

Cause of loss of timing drive tension (2 marks)

- **Wear and stretch** of the timing chain/belt over time.
- **Wear of sprockets or pulleys.**
- **Failure or weakening of the tensioner or guide mechanism.**

(b) Effect on the engine (6 marks)

- Incorrect **valve timing** → poor combustion, reduced efficiency.
 - Incorrect **fuel injection timing** (on engines with camshaft-driven pumps).
 - **Loss of power** and increased fuel consumption.
 - **Rough running, misfiring, or starting problems.**
 - **Valve-to-piston contact** in severe cases → mechanical damage.
 - Possible **engine failure** if the belt/chain slips or breaks.
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(c) How slight loss of tension can be corrected (2 marks)

- By **adjusting or resetting the tensioner mechanism** (automatic or manual).
- In some designs, **repositioning the tensioner pulley** or **replacing a worn tensioner spring.**

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|----|-----|---|-----|
| 3. | (a) | Describe the events leading to a crankcase explosion. | (4) |
| | (b) | State the methods of detecting the events of part (a) | (2) |
| | (c) | State how the severity of a crankcase explosion may be limited. | (4) |

(a)**Events leading to a crankcase explosion (4 marks)**

1. Oil mist or vapour forms in the crankcase due to **overheated bearings or hot spots.**
 2. The oil mist becomes **suspended in air**, forming an explosive mixture.
 3. A **hot surface** (such as a overheated bearing, piston rod, or friction surface) reaches auto-ignition temperature.
 4. Ignition of the mist occurs → leading to a **primary explosion**, which may trigger a more violent **secondary explosion** if more oil mist is present.
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(b) Methods of detecting the events in part (a) (2 marks)

- **Oil Mist Detectors (OMD)** fitted to crankcase spaces.

- **Bearing temperature monitoring** (thermistors, RTDs).
(Other acceptable: regular inspection, alarm systems for high temperature/low LO pressure.)
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(c) How severity of a crankcase explosion may be limited (4 marks)

- **Crankcase relief valves** fitted to release excess pressure safely.
- Relief valves fitted with **flame arrestors** to prevent flame spread.
- Use of **oil mist detectors and alarms** to warn crew early.
- Strict **maintenance and cleanliness** of crankcase (remove sludge, avoid hot spots).
- **Good lubrication practices** to prevent overheating of bearings.

4. With reference to fuel injector needle valves siezing in their bodies during engine operation:
- (a) explain the effects if the needle has jammed partially open; (3)
 - (b) state the possible causes; (2)
 - (c) state, with reasons, how to minimise this problem. (5)

(a)

Effects if the needle has jammed partially open (3 marks)

- Continuous dribbling of fuel into the cylinder.
 - Poor atomisation → incomplete combustion.
 - Results: black smoke, knocking, high exhaust temperatures, fouling of piston crown/liner, risk of scavenge fire.
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(b) Possible causes (2 marks)

1. Poor fuel quality (contaminants, water, catalytic fines, low lubricity).
 2. Overheating of injector → fuel coking and carbon deposits around needle.
(Also acceptable: corrosion, inadequate lubrication, poor maintenance, incorrect cooling of injector.)
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(c) How to minimise the problem (with reasons) (5 marks)

- **Use properly treated and filtered fuel** → removes abrasive particles/cat fines.

- **Maintain correct fuel temperature** → prevents overheating and carbonisation.
- **Regular cleaning and overhauling of injectors** → removes deposits before seizure.
- **Correct cooling arrangements** (if fitted with cooling jackets) → avoids local overheating.
- **Ensure proper lubrication and clearance tolerances** during overhaul → smooth needle movement.

5. With reference to the properties of fuel oils, explain EACH of the following terms, stating their significance to engine/shipboard operations:

- (a) specific energy; ~~kJ/kg~~ Kj/kg (2)
- (b) cetane number; (2)
- (c) residual carbon; (2)
- (d) sulphur content; (2)
- (e) relative density (specific gravity). (2)

(a)

Specific energy (kJ/kg) (2 marks)

- **Definition:** The amount of heat energy released per unit mass of fuel when completely burned (kJ/kg).
- **Significance:** Determines the **power output and efficiency** of the engine for a given fuel consumption; fuels with higher specific energy produce more power for the same mass burned.

(b) Cetane number (2 marks)

- **Definition:** A measure of the **ignition quality** of diesel fuel, based on its delay between injection and ignition.
- **Significance:** Higher cetane number = shorter ignition delay = smoother combustion, less knocking, better cold starting. Important for reliable operation.

(c) Residual carbon (2 marks)

- **Definition:** The percentage of carbon left as solid residue after the fuel is burned in a controlled test.
- **Significance:** Indicates tendency to form **deposits in combustion chambers, exhaust valves, turbochargers**. High residual carbon = fouling and maintenance problems.

(d) Sulphur content (2 marks)

- **Definition:** Percentage of sulphur by mass in the fuel oil.
 - **Significance:** On combustion forms **SO_x gases**, which are corrosive and harmful to the environment. Requires use of low-sulphur fuels in **Emission Control Areas (ECAs)** and affects **lubricant alkalinity (BN)** selection to neutralise acids.
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(e) Relative density (specific gravity) (2 marks)

- **Definition:** Ratio of the mass of a given volume of fuel at 15 °C to the mass of an equal volume of water at 15 °C.
- **Significance:** Affects **fuel handling, purification (centrifuges)**, and combustion. High density fuels may be difficult to burn efficiently and may contain more impurities.

6. (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)

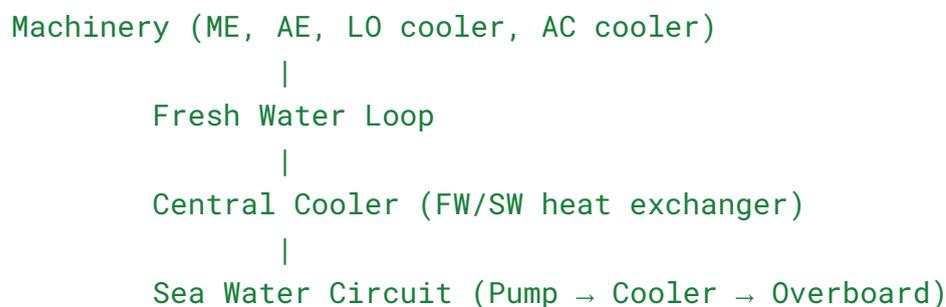
(a) Describe, with the aid of a sketch, a central cooling water system (8 marks)**Description:**

- A **closed loop system** is used where fresh water (FW) circulates through all engine and auxiliary machinery as the **primary coolant**.
- The fresh water absorbs heat from:
 - Main engine jacket water, pistons, turbochargers
 - Auxiliary engines
 - Lubricating oil coolers
 - Other heat exchangers (e.g., air coolers).
- This heated fresh water is then cooled in **central coolers**, which are **sea water (SW) cooled heat exchangers**.
- Thus, sea water does not circulate through machinery directly — it only enters the central cooler, minimising corrosion/contamination risks.
- Pumps:
 - **FW circulating pumps** keep the freshwater circuit flowing.

- **SW pumps** supply seawater to central coolers.
- Temperature is regulated by **3-way control valves** to maintain stable engine operating temperatures.

Sketch (exam style):

(you'd draw this simple block diagram with arrows)



Label: **FW circuit, SW circuit, heat loads, cooler, pumps, 3-way valve.**

(b) Advantage of a central cooling water system (2 marks)

1. **Sea water is kept out of the machinery** → reduces corrosion, scaling, and contamination.
2. **Stable engine operating temperatures** are maintained with controlled fresh water circulation.
3. **Simplifies pipework**: only central coolers need SW connections, reducing maintenance.

(Examiner usually expects any 2 of the above.)

7. Describe, with the aid of a sketch, the operation of a pre-engage diesel engine electric starting system, labelling the main components. (10)

Description of Operation

- The system uses an **electric starter motor** to crank the engine until it fires.
- Called *pre-engage* because the **pinion gear is fully engaged with the flywheel ring gear before the starter motor armature begins to rotate.**
- Main components:
 1. **Starter motor** (DC motor).
 2. **Solenoid/relay** – engages pinion gear and closes main contacts.
 3. **Pinion gear & sliding shaft (Bendix drive)** – engages with flywheel.

4. **Flywheel ring gear** – connected to engine crankshaft.
5. **Battery** – supplies electrical power.
6. **Ignition/start switch** – initiates operation.

Operation sequence:

1. When the start switch is closed, current energises the **solenoid coil**.
2. Solenoid action moves a **plunger** which pushes the **pinion gear** along a helical spline into mesh with the flywheel ring gear.
3. At the end of travel, the solenoid also closes the **main electrical contacts**, supplying heavy current to the starter motor.
4. The motor turns, driving the flywheel and cranking the engine.
5. When the engine starts and the switch is released, the solenoid de-energises, disconnecting the motor and withdrawing the pinion from the flywheel.
6. An overrunning clutch in the drive prevents the engine from driving the starter if it remains engaged momentarily.

Sketch (exam style)

(Draw a simple block diagram — marks are for clarity, not artistry)

[Battery] → [Starter Switch] → [Solenoid Coil]

↓

[Solenoid Plunger + Main Contacts]

↓

[Starter Motor Armature]

↓

[Pinion Gear + Clutch]

↓

[Flywheel Ring Gear]

↓

[Engine Crankshaft]

8. With reference to turbochargers:
- (a) explain the term *surging*; (5)
 - (b) describe the indications of *surging*; (2)
 - (c) describe the causes of *surging*. (3)

(a) Explain the term *surging* (5 marks)

- Surging is a condition of **unstable airflow** in a turbocharger's compressor.
 - It occurs when the compressor is unable to overcome the pressure in the scavenge/air receiver, leading to **reversal of airflow**.
 - The flow through the compressor repeatedly **breaks down and reverses**, causing **violent oscillations** in pressure and airflow.
 - This produces **vibration, noise, and high stresses** on the turbocharger components.
 - Prolonged surging can cause **bearing failure, blade damage, or complete turbocharger breakdown**.
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(b) Indications of surging (2 marks)

1. **Loud "chuffing" or banging noise** from the turbocharger.
 2. **Fluctuating turbocharger speed, scavenge pressure, and exhaust temperatures.**
(Other acceptable: excessive vibration, smoky exhaust, rapid load fluctuations.)
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(c) Causes of surging (3 marks)

1. **Low engine load** → insufficient exhaust gas energy to drive compressor.
2. **Dirty air filters or fouled turbine/compressor blades** → restricted air flow.
3. **Malfunctioning scavenge/charge air cooler** (choked, high resistance to flow).
(Other possible: excessive back pressure in exhaust, wrong matching of turbocharger to engine.)

9. With reference to an engine connected to a gearbox via a friction clutch, explain EACH of the following:
- (a) why vibration from the engine should be damped; (7)
 - (b) how vibration damping is achieved. (3)

(a) Why vibration from the engine should be damped (7 marks)

1. **Engines produce cyclic torque fluctuations** due to combustion strokes → torsional vibrations in the crankshaft.
2. If not damped, these vibrations are transmitted through the **clutch and shafting** to the gearbox.
3. Can cause **gear rattle**, uneven load distribution, and excessive wear of gear teeth.
4. Leads to **fatigue failure** of shafts, keys, couplings, and clutch components.
5. Excessive vibration causes **noise and discomfort** for crew.
6. Vibrations reduce **operational efficiency** by causing power losses.
7. In severe cases, resonance conditions may occur → catastrophic failure of shafting or gearbox.

(b) How vibration damping is achieved (3 marks)

1. By fitting a **torsional vibration damper** (e.g., viscous or rubber type) to the crankshaft, which absorbs and dissipates vibration energy.
2. Using a **damped friction clutch plate** with springs/rubber inserts to absorb shock loads before transmitting torque to the gearbox.
3. Proper **alignment, balancing, and flexible couplings** also reduce vibration transmission.

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 **continuous lubrication** to heavily loaded gear teeth and bearings.
 - To act as a **coolant**, carrying away frictional heat generated during operation.
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(b) Four possible causes of excessive lubricating oil temperature at normal operating speeds (4 marks)

1. **Inadequate cooling** – cooler malfunction, fouling, or insufficient seawater flow.
2. **Low oil level** – insufficient circulation, poor heat transfer.
3. **Incorrect oil viscosity** – too high viscosity increases frictional heating.
4. **Overloaded gearbox or misalignment** – excessive friction and heat generation.

(Other acceptable: dirty filters restricting flow, pump failure, worn bearings/gears.)

(c) Remedies for each cause (4 marks)

1. **Inadequate cooling** → Clean/repair cooler, restore seawater flow.
2. **Low oil level** → Top up oil to correct level, check for leaks.
3. **Incorrect viscosity** → Use correct grade of lubricating oil as specified.
4. **Overloaded gearbox/misalignment** → Reduce load, realign shafts, inspect gears/bearings.