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1. Describe the working principle of the four stroke cycle. (10)

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2. With reference to large medium speed diesel engine turbo chargers:

   (a) explain why a thrust bearing is needed; (4)

   (b) state where the thrust bearing is fitted; (2)

   (c) describe how the thrust bearing is lubricated. (4)

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3. (a) Show, using sketches, the THREE clearances necessary for efficient piston ring functioning. (3)

   (b) Explain why piston rings are necessary. (2)

   (c) Explain why the clearances sketched in part (a) are necessary. (5)

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4. (a) Describe the operation and purpose of a diesel engine fuel nozzle. (6)

   (b) State the defects diesel engine fuel nozzles may encounter during service. (4)

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5. With reference to distillate fuel, explain the potential problem for EACH of the following, stating how they may be avoided:

   (a) flash point; (3)

   (b) wax; (3)

   (c) microbes. (4)

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6. (a) Describe possible reasons for fluctuations in the oil level of a main engine sump. (8)

(b) State how spurious sump level alarms can be avoided. (2)

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7. Sketch a typical diesel engine cooling water system, describing the purpose of EACH component. (10)

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8. Describe the checks and maintenance required for a main engine starting system that uses an air motor. (10)

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9. (a) State TWO possible causes for EACH of the following exhaust emissions:

(i) black smoke; (2)

(ii) blue smoke; (2)

(iii) white smoke. (2)

(b) State ONE remedy for EACH of the emissions in part (a). (3)

(c) State how combustion defects may be diagnosed. (1)

October 2019 MDE

10. (a) Describe a gearbox inspection. (6)

(b) State, with reasons, TWO gear tooth faults. (4)

October 2019 MDE

1. Describe the working principle of the four stroke cycle. (10)

The four-stroke cycle is the operating principle behind most internal combustion engines, including gasoline and diesel engines. It utilizes four distinct strokes of the piston within the cylinder to achieve combustion and produce power. Here's a breakdown of the four strokes:

1. Intake Stroke (Suction):

- The piston moves downward from Top Dead Center (TDC) towards Bottom Dead Center (BDC).
- The intake valve opens, allowing an air-fuel mixture (gasoline engines) or fresh air (diesel engines) to be drawn into the cylinder by the increasing volume created by the descending piston.
- The exhaust valve remains closed throughout the intake stroke.

2. Compression Stroke:

- The piston moves upward from BDC towards TDC.
- Both the intake and exhaust valves are closed.
- The trapped air-fuel mixture (or air in diesel engines) is compressed by the rising piston, significantly increasing its pressure and temperature.

3. Combustion Stroke (Power Stroke):

- Shortly before TDC on the compression stroke, a spark plug ignites the compressed air-fuel mixture in gasoline engines. In diesel engines, the high pressure and temperature cause the injected fuel to spontaneously combust.
- The combustion process rapidly expands the hot gases, forcing the piston down with significant force, creating the power output of the engine.
- Both the intake and exhaust valves remain closed throughout the combustion stroke.

4. Exhaust Stroke:

- The piston moves upward from BDC towards TDC.
- The exhaust valve opens.
- The burned exhaust gases are pushed out of the cylinder by the rising piston.
- The intake valve remains closed throughout the exhaust stroke.

Repeating Cycle:

- Once the exhaust stroke is complete, the piston reaches TDC again, and the cycle repeats, continuously drawing in fresh air/fuel mixture, compressing it, combusting it for power generation, and expelling the exhaust gases.

Key Points:

- The crankshaft is connected to the piston by a connecting rod and converts the reciprocating motion of the piston into rotary motion for driving the wheels or other applications.
- The four strokes occur in two complete revolutions of the crankshaft.
- Precise timing of valve opening and closing is crucial for efficient engine operation and is controlled by a camshaft or other valve actuation mechanisms.

This four-stroke cycle efficiently converts chemical energy stored in the fuel into mechanical work that can be used to power vehicles, generators, and other machinery

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2. With reference to large medium speed diesel engine turbo chargers:

(a) explain why a thrust bearing is needed; (4)

(b) state where the thrust bearing is fitted; (2)

(c) describe how the thrust bearing is lubricated. (4)

Thrust Bearing in Large Medium Speed Diesel Engine Turbochargers:

(a) Why a Thrust Bearing is Needed:

A thrust bearing is a crucial component within a large medium-speed diesel engine turbocharger for managing axial forces acting on the shaft. Here's why it's necessary:

- **Opposing Axial Forces:** During operation, the turbine and compressor blades in the turbocharger generate opposing axial forces along the shaft.
  - **Turbine:** The exhaust gas pushing on the turbine blades creates a force trying to push the shaft towards the exhaust side.
  - **Compressor:** The compressed air pushing on the compressor blades creates a force trying to push the shaft in the opposite direction.
- **Axial Force Management:** The thrust bearing absorbs these opposing axial forces, ensuring the shaft remains properly positioned within the housing. This prevents excessive axial movement that could lead to:
  - **Inefficient Operation:** Misalignment due to uncontrolled axial movement could hinder proper operation of the turbine and compressor wheels.
  - **Increased Friction Losses:** Excessive axial movement might cause the shaft to rub against the housing, increasing friction and reducing efficiency.
  - **Potential Damage:** Uncontrolled axial movement could lead to contact and wear between the shaft and housing, potentially damaging the turbocharger.

(b) Where the Thrust Bearing is Fitted:

The thrust bearing is typically located on the **compressor side** of the turbocharger shaft within the housing. This placement allows it to effectively counter the axial force generated by the turbine on the opposite end. The exact location may vary slightly depending on the specific turbocharger design.

(c) How the Thrust Bearing is Lubricated:

The thrust bearing relies on the engine's pressurized lubrication system for proper operation:

- **Engine Oil Supply:** Engine oil is continuously circulated through dedicated passages within the turbocharger housing.
- **Oil Reaches Bearing:** Channels within the housing deliver oil to the thrust bearing surfaces.
- **Hydrodynamic Lubrication:** The pressurized oil creates a thin film between the bearing surfaces, separating the shaft from the housing. This film minimizes friction and allows for smooth, low-friction rotation of the shaft while absorbing the axial forces.
- **Oil Return:** Used oil from the thrust bearing drains back to the engine's crankcase through a return line, where it re-enters the lubrication system for filtration and further cooling.

Maintaining a healthy engine oil system with clean oil and proper oil pressure is crucial for optimal lubrication of the thrust bearing and overall turbocharger health.

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3. (a) Show, using sketches, the THREE clearances necessary for efficient piston ring functioning. (3)

(b) Explain why piston rings are necessary. (2)

(c) Explain why the clearances sketched in part (a) are necessary. (5)

Piston Ring Clearances and Their Importance:

(a) Three Essential Piston Ring Clearances:

1. **Top Ring Land Clearance:** This refers to the gap between the top compression ring and its groove in the piston. This clearance allows for thermal expansion of the ring and piston, preventing seizing and maintaining proper ring-to-cylinder wall contact for effective sealing.
2. **Second Ring Land Clearance:** This is the gap between the second compression ring and its groove in the piston. It's typically larger than the top ring land clearance, allowing for better oil control while still maintaining adequate gas sealing.
3. **Piston Ring End Clearance (Gap):** This refers to the space between the ends of a piston ring when placed inside its groove. This clearance is crucial for:
    - **Thermal Expansion:** As the ring and cylinder wall heat up, they expand. The gap allows for this expansion and prevents seizing.
    - **Oil Control:** Excess oil needs to return to the crankcase. The gap allows for scraped oil to pass through.
    - **Sealing Efficiency:** A small amount of gas leakage is inevitable. The gap allows for controlled leakage, preventing pressure buildup behind the rings.

(b) Necessity of Piston Rings:

Piston rings play a vital role in ensuring efficient and smooth operation of a diesel engine. They perform several critical functions:

- **Sealing:** Piston rings create a tight seal between the piston and the cylinder wall. This prevents combustion gasses from leaking past the piston into the crankcase, which would reduce engine power and efficiency. It also prevents excessive oil from entering the combustion chamber, which could lead to oil burning and increased emissions.
- **Oil Control:** Piston rings scrape excess oil from the cylinder wall on the downward stroke, preventing excessive oil from entering the combustion chamber. This helps maintain proper lubrication while minimizing oil consumption and emissions.
- **Heat Transfer:** Piston rings aid in heat transfer from the piston to the cylinder wall. This heat is then transferred to the engine coolant, helping to regulate engine temperature.

(c) Importance of Piston Ring Clearances:

The clearances mentioned in part (a) are essential for optimal piston ring function for the following reasons:

- **Minimizing Friction:** Excessive clearance can increase friction between the rings and the cylinder wall, leading to power losses and wear.
- **Maintaining Sealing:** Too little clearance, particularly for the top ring land clearance and piston ring end gap, can cause the rings to seize or bind in their grooves. This can damage the rings and cylinder wall, compromising sealing and leading to blow-by (gas leakage) and increased oil consumption.
- **Effective Oil Control:** The second ring land clearance needs to be large enough to allow scraped oil to return to the crankcase. However, it can't be too large, or it could compromise gas sealing.

These clearances are carefully engineered based on engine design, materials used, and operating conditions. Maintaining them within the specified range is crucial for optimal engine performance, efficiency, and longevity.

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4. (a) Describe the operation and purpose of a diesel engine fuel nozzle. (6)

(b) State the defects diesel engine fuel nozzles may encounter during service. (4)

(a) Operation and Purpose of a Diesel Engine Fuel Nozzle:

A diesel engine fuel nozzle plays a critical role in the efficient combustion process. Here's a breakdown of its operation and purpose:

Purpose:

The primary purpose of a diesel engine fuel nozzle is to deliver a precisely **metered**, **atomized**, and **timed** spray of fuel into the engine cylinder at the appropriate moment during the compression stroke.

Operation:

1. **Fuel Injection Pressure:** High-pressure fuel from the injection pump reaches the nozzle through an inlet passage.
2. **Needle Valve:** The fuel pressure acts on a spring-loaded needle valve within the nozzle. When the pressure overcomes the spring force, the valve lifts, allowing fuel to flow through.
3. **Atomization:** The fuel exiting the nozzle passes through tiny orifices at the tip, breaking it up into a fine mist (atomization). This increases the surface area of the fuel for better mixing with air within the cylinder.
4. **Spray Pattern:** The design of the nozzle tip and orifices determines the spray pattern of the atomized fuel. This pattern ensures proper distribution of fuel within the cylinder for optimal combustion.
5. **Injection Timing:** The timing of the injection process is crucial. The injection pump controls the timing by electronically actuating the opening and closing of the nozzle's needle valve. Fuel is ideally injected shortly before the top dead center (TDC) of the compression stroke for optimal performance.

By delivering a precisely controlled spray of atomized fuel at the right time, the nozzle promotes efficient combustion, leading to:

- **Increased Power Output:** Better fuel-air mixing leads to more complete combustion, resulting in higher engine power output.
- **Improved Efficiency:** Efficient fuel combustion reduces fuel consumption and improves engine efficiency.
- **Reduced Emissions:** Proper atomization and combustion contribute to lower emissions of pollutants like soot and NOx.

(b) Defects a Diesel Engine Fuel Nozzle May Encounter During Service:

During operation, several issues can develop with diesel engine fuel nozzles, affecting performance and potentially leading to engine problems:

- **Sticking or Leaking Injector Needle Valve:** Wear or deposits on the needle valve can cause it to stick partially open or leak, leading to poor fuel metering and potentially causing excessive smoke or incomplete combustion.
- **Blocked or Worn Nozzle Orifices:** Deposits from the fuel or wear on the orifices can reduce fuel flow and disrupt the spray pattern, hindering proper atomization and combustion.
- **Internal Leakage:** Worn seals or internal components within the nozzle can lead to internal leakage, bypassing the metering process and affecting fuel delivery.
- **Faulty Solenoid Valve (if applicable):** In electronically controlled nozzles, a faulty solenoid valve might not properly actuate the needle valve, leading to incorrect injection timing or even injector failure.

These defects can manifest in various symptoms, such as:

- **Reduced Engine Power:** Poor fuel atomization and delivery can lead to a noticeable decrease in engine power output.
- **Increased Fuel Consumption:** Incomplete combustion due to injector issues can result in higher fuel consumption.
- **Black Smoke Emission:** Improper fuel-air mixing or incomplete combustion can cause excessive black smoke emission from the exhaust.
- **Rough Engine Running:** Uneven fuel delivery due to faulty injectors can lead to rough engine operation and vibrations.

Regular maintenance practices, including cleaning or replacing nozzles as per manufacturer's recommendations, are crucial to prevent these issues and ensure optimal engine performance.

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5. With reference to distillate fuel, explain the potential problem for EACH of the following, stating how they may be avoided:

(a) flash point; (3)

(b) wax; (3)

(c) microbes. (4)

(a) Flash Point:

- **Problem:** Distillate fuel oil has a flash point, the minimum temperature at which it can vaporize and ignite. If the fuel oil temperature reaches or exceeds the flash point in the presence of an ignition source, a fire can occur.
- **How to Avoid:**
  - **Storage:** Store fuel oil in designated, cool, and well-ventilated areas away from heat sources and ignition sources like open flames or sparks.
  - **Handling:** Implement proper handling procedures to minimize the risk of spills and ensure safe transfer during refueling.
  - **Fuel Selection:** In some cases, depending on the application and climate, you might consider using a distillate fuel with a higher flash point for increased safety margins.

(b) Wax:

- **Problem:** Distillate fuel oil contains paraffin waxes, which can solidify at low temperatures. This can cause problems like:
  - **Filter Plugging:** Wax crystals can clog fuel filters, restricting fuel flow to the engine and potentially leading to engine stalling or power loss.
  - **Poor Flow:** Wax formation can thicken the fuel, hindering proper fuel flow within the fuel system.
- **How to Avoid:**
  - **Fuel Selection:** When operating in cold weather conditions, using a distillate fuel with a lower cloud point (temperature at which wax crystals begin to form) is crucial. This ensures the fuel remains liquid at the expected operating temperatures.
  - **Fuel Additives:** Specific cold flow improver additives can be used to lower the cloud point of the fuel and prevent wax crystal formation at moderate cold temperatures.
  - **Proper Storage:** Avoid storing fuel oil for extended periods in extremely cold conditions, as this can promote wax separation and solidification.

(c) Microbes:

- **Problem:** Microbial growth (bacteria, fungi) can occur in distillate fuel oil, especially if there is water contamination. Microbes can cause several issues:
  - **Blocked Filters:** Microbial colonies can clog fuel filters, restricting fuel flow.
  - **Corrosion:** Microbial activity can produce byproducts that contribute to fuel system corrosion.

- **Degraded Fuel Quality:** Microbial activity can break down fuel components, reducing its energy content and hindering combustion efficiency.

- **How to Avoid:**
  - **Minimize Water Ingress:** Maintain a water-tight storage system and regularly drain any accumulated water from the fuel tank.
  - **Proper Storage Practices:** Store fuel in clean, sealed containers and avoid prolonged storage times, especially in warm and humid conditions.
  - **Biocide Additives:** Consider using biocide fuel additives as a preventative measure to inhibit microbial growth within the fuel.
  - **Regular Fuel Testing:** Periodically test fuel samples for signs of microbial contamination.

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6. (a) Describe possible reasons for fluctuations in the oil level of a main engine sump. (8)

(b) State how spurious sump level alarms can be avoided. (2)

(a) Reasons for Fluctuations in Main Engine Oil Level:

Fluctuations in the main engine sump oil level can occur due to several reasons. Here are some possible causes:

- **Consumption:** Diesel engines naturally consume a small amount of oil during operation. This oil is burned along with the fuel or accumulates in the blow-by past the piston rings. Oil consumption can increase with wear on piston rings, cylinder liners, or valve guides.
- **Air Ingestion:** Air leaks in the engine's intake system can cause air to enter the crankcase, creating foam in the oil. This foam can temporarily increase the displayed oil level reading.
- **Fuel Dilution:** In some cases, unburned fuel can leak past worn injector seals or piston rings and dilute the engine oil. This can lead to a false high reading on the oil level gauge.
- **Temperature Changes:** Engine oil expands as it heats up and contracts as it cools. Significant temperature swings can cause slight variations in the displayed oil level reading on the gauge.
- **Improper Dipstick Reading:** If the dipstick is not inserted fully or wiped clean before reinserting, the oil level reading might be inaccurate. Ensure proper dipstick reading procedures are followed.
- **External Leaks:** Leaks from the engine oil system, such as around the sump gasket, oil filter, or other connections, can cause a genuine decrease in the oil level.

(b) Avoiding Spurious Sump Level Alarms:

Spurious sump level alarms can be a nuisance and potentially mask real issues. Here are some ways to avoid them:

- **Routine Checks:** Perform regular visual inspections of the engine for external oil leaks. This helps identify and address leaks promptly, preventing a genuine oil level drop that could trigger an alarm.
- **Dipstick Verification:** Don't rely solely on the electronic oil level gauge. Regularly checking the oil level using the dipstick provides a physical confirmation and helps identify potential discrepancies with the gauge reading.
- **Alarm Settings:** If possible, some engine control systems allow adjusting the sump level alarm thresholds. Setting the alarm to trigger only for significant oil level drops can help minimize false alarms caused by minor fluctuations.
- **Investigate Root Cause:** If spurious sump level alarms persist, investigate the potential causes mentioned in part (a). Addressing the root cause, such as worn piston rings or air leaks, can prevent future false alarms.
- **System Calibration:** In some cases, the electronic oil level sensor or gauge might require calibration to ensure accurate readings. Consult the manufacturer's recommendations for proper calibration procedures.

By implementing these practices, you can minimize the occurrence of spurious sump level alarms and ensure the system effectively alerts crew members to genuine oil level problems requiring attention.

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7. Sketch a typical diesel engine cooling water system, describing the purpose of EACH component. (10)

A typical diesel engine cooling water system utilizes a closed-loop design to regulate engine temperature and prevent overheating. Here's a breakdown of the main components and their functions:

Components:

1. **Engine Block and Cylinder Head:** These are the primary heat sources within the system. Coolant absorbs heat generated by combustion within the engine block and cylinder head.
2. **Water Jacket:** Passages within the engine block and cylinder head that allow coolant to circulate and absorb heat directly from these hot engine components.
3. **Cooling System Pump (Water Pump):** This pump, typically driven by the engine crankshaft via belt, gears, or an electric motor, circulates the coolant throughout the closed loop.
4. **Thermostat:** This temperature-controlled valve regulates coolant flow. When the coolant reaches a set operating temperature, the thermostat opens, allowing coolant to flow through the radiator for cooling. When the coolant temperature drops below the set point, the thermostat closes, restricting flow to the radiator and allowing the engine to reach its optimal operating temperature faster.
5. **Radiator:** This heat exchanger is the primary cooling component. Hot coolant flows through tubes within the radiator, while air flows across the tubes. The large surface area of the radiator fins promotes heat transfer from the coolant to the surrounding air. A fan may be positioned in front of the radiator to draw air through the fins for more effective heat dissipation, especially at low engine speeds.

6. **Bypass Line:** A pipe that allows coolant to circulate around the radiator when the thermostat is closed. This helps the engine reach operating temperature quickly during startup.
7. **Expansion Tank:** This pressurized tank accommodates the volume changes of the coolant due to temperature fluctuations. As the coolant heats up, it expands, and the excess coolant is stored in the tank. When the coolant cools down and contracts, coolant is drawn back from the tank into the system.
8. **Temperature Sensor:** Monitors the coolant temperature and sends a signal to the engine control unit (ECU) or an indicator gauge on the dashboard.
9. **Hoses and Pipes:** Connect the various components within the system and provide a closed-loop path for coolant circulation.

Purpose of Each Component:

- **Engine Block and Cylinder Head:** Transfer heat to the coolant.
- **Water Jacket:** Provides a passage for coolant to circulate around the hottest areas of the engine.
- **Cooling System Pump:** Maintains continuous coolant circulation.
- **Thermostat:** Regulates coolant flow to maintain optimal engine operating temperature.
- **Radiator:** Transfers heat from the coolant to the surrounding air.
- **Bypass Line:** Allows the engine to warm up quickly.
- **Expansion Tank:** Accommodates coolant volume changes due to temperature variations.
- **Temperature Sensor:** Monitors coolant temperature for control and information purposes.
- **Hoses and Pipes:** Connect the components and provide a closed path for coolant flow.

This is a basic layout, and some systems might incorporate additional components like heaters for cold weather operation, pressure relief valves, or low-level coolant sensors to provide warnings or automatic shutdowns in case of coolant system issues.

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8. Describe the checks and maintenance required for a main engine starting system that uses an air motor. (10)

While air motor starting systems are generally considered low-maintenance, there are still some crucial checks and maintenance tasks to ensure reliable operation:

Air Filtration:

- Regularly inspect and replace the air filters according to the manufacturer's recommendations. Dirty filters restrict airflow, reducing the air motor's performance and potentially causing damage.

Air Quality:

- Ensure the compressed air supply is clean and dry. Moisture can cause corrosion inside the air motor and reduce its lifespan.

Lubrication:

- Depending on the specific air motor design, it might require lubrication. If so, follow the manufacturer's instructions for lubricant type and frequency of application (usually for gearboxes).

Vanes:

- These are internal components that convert compressed air into rotational motion. They experience wear over time. The inspection interval for vanes depends on the usage and typically falls between 1,000 to 2,000 hours of operation. Worn vanes will reduce the starting torque.

General Checks:

- Regularly perform visual inspections for any leaks, loose connections, or signs of external damage.
- Listen for any unusual noises during operation.

Manufacturer's Recommendations:

- Always refer to the specific air motor and starting system's manual for detailed maintenance procedures and recommended service intervals.

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9. (a) State TWO possible causes for EACH of the following exhaust emissions:

(i) black smoke; (2)

(ii) blue smoke; (2)

(iii) white smoke. (2)

(b) State ONE remedy for EACH of the emissions in part (a). (3)

(c) State how combustion defects may be diagnosed. (1)

Exhaust Emissions and Causes (a):

(i) Black Smoke:

1. **Incomplete Combustion:** When fuel doesn't burn completely due to insufficient air intake, rich fuel mixture, or low combustion chamber temperature, it produces unburnt soot particles that appear as black smoke in the exhaust.
2. **Over-fueling:** Excessive fuel injection or a faulty injector can deliver more fuel than the available air can support, leading to incomplete combustion and black smoke.

(ii) Blue Smoke:

1. **Oil Burning:** Worn piston rings, valve seals, or cylinder liner can allow engine oil to enter the combustion chamber and burn with the fuel, resulting in blue smoke.
2. **Turbocharger Seal Failure:** A faulty seal in the turbocharger can allow engine oil to leak into the compressed air intake, leading to blue smoke upon burning.

(iii) White Smoke:

1. **Coolant Leak:** A leak in the engine's coolant system can allow coolant to enter the combustion chamber and be expelled as white steamy exhaust, especially during engine startup.
2. **Water Ingestion:** In rare cases, water ingestion (e.g., through a faulty air intake or a problem with the head gasket) can cause white smoke upon vaporization.

Remedies for Emissions (b):

(i) Black Smoke:

- **Air Filter Cleaning/Replacement:** Ensure a clean air filter allows proper air intake for efficient combustion.
- **Fuel Injection System Inspection/Repair:** Check for faulty injectors or incorrect fuel delivery settings to address over-fueling.

(ii) Blue Smoke:

- **Engine Rebuild/Replacement of Worn Components:** Depending on the severity, worn piston rings, valve seals, or cylinder liners might need replacement to prevent oil burning.
- **Turbocharger Seal Repair/Replacement:** A faulty turbocharger seal needs repair or replacement to stop oil from entering the air intake.

(iii) White Smoke:

- **Coolant System Leak Repair:** Locate and repair the leak in the coolant system to prevent coolant from entering the combustion chamber.
- **Head Gasket Inspection/Replacement (severe cases):** A blown head gasket can cause coolant leaks. If severe, the head gasket might need replacement.

Diagnosing Combustion Defects (c):

Combustion defects can be diagnosed using various methods:

- **Visual Inspection:** Mechanics can visually inspect spark plugs (gasoline engines) or glow plugs (diesel engines) for signs of excessive wear, deposits, or fouling that can indicate combustion issues.
- **Compression Test:** This test measures the pressure buildup in each engine cylinder, helping identify weak cylinders with potential combustion problems.
- **Leakdown Test:** A leakdown test pressurizes the cylinder and monitors pressure loss, revealing leaks in valves, piston rings, or the head gasket.
- **Exhaust Gas Analysis:** Analyzing the exhaust gas composition can reveal imbalances in air-fuel ratio and identify incomplete combustion or other combustion defects.

By combining these diagnostic methods, mechanics can pinpoint the root cause of abnormal exhaust emissions and address the underlying combustion defects.

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10. (a) Describe a gearbox inspection. (6)

(b) State, with reasons, TWO gear tooth faults. (4)

Gearbox Inspection (a):

A gearbox inspection is a crucial step in diagnosing potential problems and ensuring the continued smooth operation of a vehicle's drivetrain. Here's a breakdown of a typical gearbox inspection:

External Inspection:

1. **Visual Inspection:** The mechanic will first visually inspect the gearbox housing for any cracks, leaks, or signs of external damage. This might involve removing any underbody panels for better access.
2. **Gearshift Linkage:** The condition of the gearshift linkage and its components (cables, rods, bushings) will be checked for wear, looseness, or damage which could cause shifting difficulties.

Internal Inspection (Requires Gearbox Removal and Disassembly):

1. **Gear Oil Inspection:** The drained gearbox oil will be examined for its color, consistency, and presence of metallic particles. Dark, burnt-smelling oil, or presence of metal shavings could indicate internal wear or damage.
2. **Gear and Bearing Inspection:** Each gear and bearing will be thoroughly cleaned and inspected for:
    - **Pitting:** Small indentations or craters on the gear tooth surfaces, indicating wear and potential for future breakage.
    - **Scoring:** Scratches or grooves on the gear teeth, often caused by debris contamination or misalignment.
    - **Spalling:** Flaking or breaking away of gear tooth material, a more severe form of wear.
    - **Cracks:** Any cracks in gear teeth or bearing races can lead to catastrophic gearbox failure.
    - **Bearing Wear:** Signs of wear or damage on bearing surfaces like pitting, discoloration, or roughness.
3. **Synchro Rings and Dog Teeth:** These components responsible for smooth gear changes will be inspected for wear, chipping, or rounding of the teeth which can cause difficulty engaging gears.
4. **Shift Forks and Selector Rods:** These components will be checked for wear or bending that could hinder proper gear selection.

Measurements:

- Gear clearances between meshing teeth might be measured to ensure they are within specifications. Excessive wear can increase clearances and lead to noisy operation.
- Bearing tolerances might also be checked to ensure proper fit and function.

Reassembly:

After a thorough inspection and replacement of any worn or damaged components, the gearbox will be reassembled using new gaskets and seals. The correct type and amount of gearbox oil will be refilled.

(b) Gear Tooth Faults (2):

1. **Pitting:** This is a common fault where small indentations or craters appear on the gear tooth surfaces. Causes:
    - **Overload:** Excessive torque or load on the gears can cause pitting due to high contact pressure.
    - **Contamination:** Dirt, debris, or worn-out metal particles in the gearbox oil can act as abrasive elements and contribute to pitting.
    - **Improper Lubrication:** Insufficient or low-quality gearbox oil can lead to increased friction and pitting.
2. **Reason for Concern:** Pitting weakens the gear teeth and can eventually lead to tooth breakage if left unchecked. Early detection and replacement of affected gears is crucial.
3. **Spalling:** This is a more severe form of wear where pieces of gear tooth material break away or flake off. Causes: Similar to pitting, overload, contamination, and improper lubrication can lead to spalling. Additionally, factors like:
    - **Fatigue:** Repeated stress cycles on the gear teeth can cause metal fatigue and eventual spalling.
4. **Reason for Concern:** Spalling signifies significant wear and damage. The affected gear might need immediate replacement to prevent complete tooth fracture and potential gearbox failure.