Automotive Technology
Basic Worksheets

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"Automotive Technology – Basic Worksheets" contains worksheets for the following subject areas: **Service, Repairs, Diagnosis, Conversions and Retrofits.**

The worksheets are designed to form a foundation for operational situations.

- In each subject area, practical situations serve as an introduction to the topical contents. Comprehensive assignments provide the necessary basic technical knowledge. The learning situations found at the beginning of each topic can then be solved with this basic knowledge.

- Clearly outlined assignments can be solved independently in groups or with an instructor with the help of the "Modern Automotive Technology" textbook as well as the reference table.

- Circuit diagrams, maintenance schedules and work plans as well as functional descriptions are chosen such that they can be processed similarly to comparable job-related workflows.

- With the help of the accompanying ESI-Tronic CD, the student can obtain information and work on customised exercises.

- Content on operational organisation, operational communication and quality management can be found in the Service worksheets in the form of practical tasks.

- An example of a vehicle registration certificate, Part I, for registered vehicles in Europe, can be found on the inside back cover. Such documents are required to identify the vehicle during repair work and in locating spare parts in dealerships and auto parts stores.

The following tasks are given in the four subject areas:

1. **Service**
   - Maintaining and inspecting vehicles and systems according to specifications.

2. **Repairs**
   - Checking, disassembling, exchanging and assembling simple components and systems.

3. **Diagnosis**
   - Identify and eliminate malfunctions

4. **Conversions and retrofits**
   - Performing customer-driven conversions

The worksheets, along with other vehicle technology textbooks such as "Modern Automotive Technology", Verlag Europa-Lehrmittel (ISBN 978-3-8085-23025), form a complete unit.

They are intended to help in carrying out practice-orientated lessons.

The Authors

Fall 2015
1 Service
Maintaining and inspecting vehicles and systems according to specifications

Motor vehicle system, Sheets 1 ... 2 ........................................ 5 ... 6
Motor vehicle classifications, Dimensions .................................. 7
Evolution of the motor vehicle .................................................. 8
Four-stroke spark-ignited engine,
  Sheets 1 ... 5 ........................................................................ 9 ... 13
Ignition interval, firing order, Sheets 1 ... 3 ................................. 14 ... 15
PV diagram, Sheets 1 ... 2 ......................................................... 17 ... 18
Four-stroke diesel engine, Sheets 1 ... 2 .................................... 19 ... 20
Signs: prohibition, warning, rules and rescue ................................ 21
Vehicle lifting platform operating instructions, Sheets 1 ... 2 .......... 22 ... 23
Workshop safety regulations, Sheets 1 ... 2 ................................. 24 ... 25
High voltage safety, Sheets 1 ... 2 ............................................. 26 ... 27
Electrical current safety measures ............................................. 28
Fluids and additives, Sheets 1 ... 3 ............................................. 29 ... 31
First aid ................................................................................... 32
Vehicle registration certificate .................................................... 33
Workshop information system, Sheets 1 ... 7 ............................... 34 ... 40
Inspections, Sheets 1 ... 4 ........................................................ 41 ... 44
Cooling system maintenance, Sheets 1 ... 4 ................................. 45 ... 48
Drive belt changes, Sheets 1 ... 2 ............................................. 49 ... 50
Oil and filter changes, Sheets 1 ... 4 .......................................... 51 ... 54
Battery maintenance, Sheets 1 ... 2 .......................................... 55 ... 56
Wheels and tyres, Sheets 1 ... 4 ............................................... 57 ... 60
Brakes, Sheets 1 ... 4 .............................................................. 61 ... 64
Changing brake fluid, Sheets 1 ... 2 .......................................... 65 ... 66
Windscreen wipers, Sheets 1 ... 2 ............................................. 67 ... 68
Vehicle care, Sheets 1 ... 6 ....................................................... 69 ... 74
Work order processing, Sheets 1 ... 4 ....................................... 75 ... 78
Quality management, Sheets 1 ... 2 ......................................... 79 ... 80
Workshop tests, Sheets 1 ... 2 ................................................... 81 ... 82

2 Repairs
Checking, disassembling, exchanging and assembling simple components and systems

Checking and measuring, Sheets 1 ... 2 ..................................... 83 ... 84
Drilling and threading, Sheets 1 ... 10 ........................................ 85 ... 94
Thread repair ............................................................................. 95
Torque, Sheets 1 ... 3 .............................................................. 96 ... 98
Making brake lines, Sheets 1 ... 3 ............................................ 99 ... 101
Section repair, Sheets 1 ... 5 ..................................................... 102 ... 106
Adhesives .................................................................................. 107
Inner door assembly, Sheets 1 ... 3 .......................................... 108 ... 110
Materials overview ................................................................. 111
Materials, Sheets 1 ... 4 ........................................................ 112 ... 115
Non-ferrous metals ................................................................. 116
Chassis, corrosion protection, Sheets 1 ... 2 .............................. 117 ... 118
Motor vehicle plastics ............................................................. 119
Material properties ............................................................... 120

3 Diagnosis
Identify and eliminate malfunctions

Motor vehicle electrical components ........................................ 121
Electrical loads ........................................................................ 122
Electrical voltage, Sheets 1 ... 3 .............................................. 123 ... 125
Electrical current, Sheets 1 ... 2 .............................................. 126 ... 127
Electrical power ....................................................................... 128
Electrical resistance, Sheets 1 ... 2 ......................................... 129 ... 130
Ohm’s Law ............................................................................. 131
Electrical resistor circuits ....................................................... 132
Electrical circuits, Sheets 1 ... 5 .............................................. 133 ... 137
Ignition switch, Sheets 1 ... 2 .................................................. 138 ... 139
Battery safety terminal ........................................................... 140
Electromagnetism, Sheets 1 ... 2 ............................................. 141 ... 142
Induction, Sheets 1 ... 2 ........................................................ 143 ... 144
Troubleshooting, Sheets 1 ... 4 ............................................. 145 ... 148
Light test, Sheets 1 ... 2 .......................................................... 149 ... 150
Troubleshooting lighting equipment, Sheets 1 ... 2 ..................... 151 ... 152
Fundamentals of electronics, Sheets 1 ... 6 .............................. 153 ... 158
Electronics troubleshooting, Sheets 1 ... 2 .............................. 159 ... 160
Oscilloscope, Sheets 1 ... 2 ..................................................... 161 ... 162
Fundamentals of controls, Sheets 1 ... 3 ................................. 163 ... 165
Cruise control equipment, Sheets 1 ... 2 ................................. 166 ... 167
Fundamentals of pneumatics and hydraulics, Sheets 1 ... 3 ........ 168 ... 170
Cylinder control, Sheets 1 ... 2 .............................................. 171 ... 172
Bus door control, Sheets 1 ... 3 .............................................. 173 ... 175
Loading platform, Sheets 1 ... 4 ............................................. 176 ... 179

4 Conversions and retrofits
Performing customer-driven conversions

Wheel and tyre conversions, Sheets 1 ... 6 .............................. 181 ... 186
Parking assistance, Sheets 1 ... 4 .......................................... 187 ... 190
Fog lights, Sheets 1 ... 4 ........................................................ 191 ... 194
Trailer equipment, Sheets 1 ... 4 .......................................... 195 ... 198
Trailer coupling, Sheets 1 ... 2 .............................................. 199 ... 200
The use of technical terms is required in on- and off-the-job communication.

1. Identify the parts and component groups.

2. Fill in the table with the correct part and its function.

<table>
<thead>
<tr>
<th>Component-group</th>
<th>Part</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Springs, dampers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting-equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brakes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Identify the numbered drivetrain subsystems in the table and fill in their functions.

<table>
<thead>
<tr>
<th>Number</th>
<th>Subsystem</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Converts stored chemical energy into mechanical propulsion.</td>
</tr>
<tr>
<td>2</td>
<td>Clutch</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Distributes torque to the front and rear axles in all-wheel-drive vehicles.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Collect sensor data, calculate control device parameters, control actuators.</td>
</tr>
</tbody>
</table>

4. In the picture, fill in the vehicle material flow for air, fuel and exhaust and the energy flow.

4. In the picture, fill in the vehicle material flow for air, fuel and exhaust and the energy flow.

5. How much fuel energy reaches the wheel? How high are the losses? Fill in the table.

<table>
<thead>
<tr>
<th></th>
<th>Exhaust, cooling, radiation losses in %</th>
<th>Driving power at the wheel in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spark-ignition engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spark-ignition engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel engine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Motor vehicles are divided into the following classifications.

2. Fill in the dimensions in the table and add mm or degrees.

<table>
<thead>
<tr>
<th>Vehicle length</th>
<th>Rear seat height</th>
<th>1648 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle height</td>
<td>2915 mm</td>
<td>Approach angle</td>
</tr>
</tbody>
</table>

3. Identify the vehicles below and indicate their special features.

4. Which drivetrains are built into today's vehicles?
1. Which important machines did these individuals invent?

<table>
<thead>
<tr>
<th>Portrait</th>
<th>Invention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nikolaus August Otto 1832 – 1891</td>
<td><img src="image1" alt="Image" /></td>
</tr>
<tr>
<td>Carl Benz 1844 – 1929</td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>Gottlieb Daimler 1834 – 1900</td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td>Rudolf Diesel 1858 – 1913</td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>Robert Bosch 1861 – 1942</td>
<td><img src="image5" alt="Image" /></td>
</tr>
<tr>
<td>Wilhelm Maybach 1846 – 1929</td>
<td><img src="image6" alt="Image" /></td>
</tr>
</tbody>
</table>

2. Use the reference book to determine power, displacement and power density for the pictured vehicles.

<table>
<thead>
<tr>
<th>Power in kW / HP</th>
<th><img src="image7" alt="Image" /></th>
<th><img src="image8" alt="Image" /></th>
<th><img src="image9" alt="Image" /></th>
<th><img src="image10" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement in l</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power density in kW/l</td>
<td>77.5</td>
<td></td>
<td></td>
<td>146.67</td>
</tr>
</tbody>
</table>
Different engine concepts are used for vehicles. Combustion engines can be categorised according to various characteristics.

1. Fill in the table.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Engine</th>
<th>4-stroke spark-ignition engine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4-stroke</td>
</tr>
</tbody>
</table>

- **Vehicle**: Various types of vehicles are shown.
- **Engine**: Various engine components are represented.
- **Combustion engine categorisation according to type of…**: Various characteristics are listed, including:
  - Process
  - Cylinder motion
  - Ignition
  - Cooling
  - Compressed medium
  - Injection
  - Carburetion
  - Cylinder arrangement
  - Power control

The table is structured with the vehicle images in the left column and the engine images in the right column, with corresponding columns for the characteristics.
2. The cylinder arrangements pictured below are common in 4-stroke piston engines.
   a. Match the engine picture to its construction with an arrow.
   b. Fill in the engine designation and give an example of an application (vehicle).

<table>
<thead>
<tr>
<th>Figure</th>
<th>Matching</th>
<th>Construction</th>
<th>Description</th>
<th>Example-application</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Engine 1]</td>
<td>![Arrow]</td>
<td>![Diagram 1]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>![Engine 2]</td>
<td>![Arrow]</td>
<td>![Diagram 2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>![Engine 3]</td>
<td>![Arrow]</td>
<td>![Diagram 3]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>![Engine 4]</td>
<td>![Arrow]</td>
<td>![Diagram 4]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Other cylinder arrangements are illustrated in the table below. These were or are seldom built.

Fill in the table.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Matching</th>
<th>Construction</th>
<th>Description</th>
<th>Example-application</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Double Piston Engine]</td>
<td></td>
<td>![Diagram 5]</td>
<td>Double piston engine with fork connecting rod</td>
<td>Triumph; Puch; Java Motorcycle engines</td>
</tr>
<tr>
<td>![Junkers Marine Engine]</td>
<td></td>
<td>![Diagram 6]</td>
<td></td>
<td>Junkers marine, stationary and aircraft engines</td>
</tr>
<tr>
<td>![Aircraft Engine]</td>
<td></td>
<td>![Diagram 7]</td>
<td></td>
<td>Aircraft engines</td>
</tr>
<tr>
<td>![Sports Car Engine]</td>
<td></td>
<td>![Diagram 8]</td>
<td></td>
<td>Sports cars</td>
</tr>
</tbody>
</table>
As a part of communication within the workshop, it is necessary to be able to identify engine component groups and parts in vehicle engine care and maintenance.

1. Identify the component groups in the exploded views.

2. In the simplified cross-section of a 4-stroke spark-ignition engine, identify the numbered parts and fill in the missing number for the parts given.

3. Mark the crankshaft drive and engine control parts in different colours.

**Engine case**

1. 
2. 
3. 
4. 
5. 

**Crankshaft drive**

6. 
7. 
8. 
9. 
10. 

**Engine control**

11. 
12. 
13. 
14. 
15. 
16.
Situation: You read the following in the magazine "Motor Sport": "...the new turbocharged 4-cylinder 4-stroke engine is a classic short-stroke engine with a 92 mm bore and 60.3 mm stroke. The 1596 cc engine has an 85 kW power output and produces 250 Nm of torque. The compression ratio is 12 to 1. The average fuel economy is 6.1 litres to 100 km..." 

1. Define the following engine-related terminology found in the text and include the respective notation:

   Stroke:
   Dead centre:
   Displacement:
   Compression space:
   Crank angle:
   Compression ratio:

2. Fill in the values corresponding to the terms below that are associated with a 4-stroke engine. An operating cycle consisting of...

   
   strokes | crank angle
   camshaft rotation | cam angle
   crankshaft rotations | opening and closing of the inlet and exhaust valves

3. a) Identify the parameters in the table and enter them in the illustration.
b) With the part dimensions from the illustration (scale 1:4), calculate \( V_h \).

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( s )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_h )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_c )</td>
<td></td>
<td>26 cm(^2)</td>
</tr>
<tr>
<td>( \bigcirc-IV )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \bigcirc-EV )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \bigcirc-Cc )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDC</td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>BDC</td>
<td></td>
<td>–</td>
</tr>
</tbody>
</table>
4. Identify the individual strokes.
5. Mark the cylinders and the crank circles with TDC and BDC.
6. Mark the direction of cylinder movement with an arrow.
7. Sketch in the connecting rod and crankshaft according to the cylinder's position.
8. Sketch in the valves for each stroke.
9. For each stroke, enter into the table
   - whether the inlet and exhaust valves are open or closed
   - at what crank angle the inlet and exhaust valves open or close
   - the max. temperature in the cylinder
   - the max. pressure in the cylinder
   Use a reference table.
10. Enter the open and close positions Io, Ic, Eo, Ec in the crank circle of the corresponding stroke.
    Use values from an engine in the reference table.
    Fill the cylinder above the piston with a different colour for each stroke.

<table>
<thead>
<tr>
<th>1st stroke</th>
<th>2nd stroke</th>
<th>3rd stroke</th>
<th>4th stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet valve</td>
<td>Inlet valve</td>
<td>Inlet valve</td>
<td>Inlet valve</td>
</tr>
<tr>
<td>Exhaust valve</td>
<td>Exhaust valve</td>
<td>Exhaust valve</td>
<td>Exhaust valve</td>
</tr>
<tr>
<td>Temperature in cylinder</td>
<td>Temperature in cylinder</td>
<td>Temperature in cylinder</td>
<td>Temperature in cylinder</td>
</tr>
<tr>
<td>Pressure in cylinder</td>
<td>Pressure in cylinder</td>
<td>Pressure in cylinder</td>
<td>Pressure in cylinder at Eo</td>
</tr>
</tbody>
</table>
Situation: In the course of servicing a VW Lupo, ignition cables have to be replaced.

1. The new ignition cables are provided with the numbers 1 to 3. What do these numbers mean?

2. The cylinder's numbering and the direction the cylinders are counted are DIN-specified.
   a) Define cylinder 1 according to the standards.

   b) The engine rotates clockwise. What does this mean?

3. a) Fill in the cylinder numbering, rotational direction (clockwise) and the construction type of the engine concepts shown according to the DIN Standard.
   b) Indicate the corresponding firing order.

4. What does "firing order" mean?

5. Calculate the number of power cycles per minute with an engine speed of 3000 1/min for a 3-cylinder engine and for a 6-cylinder engine.

Given:
6. Describe the term ignition interval and calculate it for a 3-cylinder engine.

\[ \text{Ignition interval} = \frac{720°}{z} \]

7. The crankshaft is cranked according to the ignition interval (figure). For clarity, the crankshaft is depicted in side and frontal (star diagram) views. The stroke order is shown.

a) Calculate the ignition interval and indicate the firing order.

b) Construct the position of the crank pins (star diagram). Transfer the cylinder numbering to the corresponding crank pin on the star diagram.

Note: Begin with the 1st cylinder. Construct the position of the next crank pin according to the firing order against the direction of rotation by the number of degrees of the ignition interval.

c) Construct the crankshaft side view from the star diagram (with the help of lines).

d) Label the individual stroke of each cylinder.
8. The following illustration is a schematic diagram of the crankshaft mechanism for a five-cylinder four-stroke engine.
   a) Determine and fill in the firing order.
   b) Draw the crank arms for cylinders 2 to 5 onto the crank circle; number the crank pins according to the firing order.
   c) Fill in the crankshaft for cylinders 2 to 5; draw the corresponding piston and connecting rod positions.
   d) Indicate each piston's direction of movement with arrows.
   e) Complete the table with each cylinder's work cycle; indicate the strokes with corresponding colours.
   f) Draw the intake and exhaust values in the correct position (the valves should be shown as clearly closed or open).

Timing
- Intake valve opens 6° before TDC
- Exhaust valve opens 40° before BDC
- Intake valve closes 44° after BDC
- Exhaust valve closes 10° after TDC

Firing order 1 – 2 – 4 – 5 – 3

<table>
<thead>
<tr>
<th>Cyl.</th>
<th>Strokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Combustion</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Ignition interval =
**Situation:** A spark-ignition engine was optimised on a test stand. Several ignition points were set and the pressure profile recorded. Engine characteristics: Bore x Stroke = 89.9 mm x 70 mm, ε = 10.

1. Evaluate the ignition point in the table with "right", "too late" or "too early". Give the ignition point in crankshaft angle. Describe the effect on the combustion process with "knocking", "adverse", or "optimal".

<table>
<thead>
<tr>
<th>Ignition point in °CA</th>
<th>Curve A</th>
<th>Curve B</th>
<th>Curve C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Indicate the maximum piston pressure on the curve at which the engine properly operates.

3. Explain the process "knocking combustion".

4. What factors cause knocking?

5. What is shown in a PV diagram for a combustion engine?

6. Cylinder pressure relative to the piston stroke can be carried over for the power cycle of a four-stroke engine into a PV diagram.
   a) Divide the axes according to the given scaling and label them. The cylinder pressure should be on the y-axis and piston stroke on the x-axis.
   Scaling: Pressure scale 0.4 bar = 1 mm; Stroke scale 1 mm = 0.5 mm piston stroke.
   b) Fill in the missing table values for normal combustion and enter the respective points on the curve. The missing values can be found in Figure 1. Draw the PV diagram for a spark-ignited engine. Indicate the effective work with hatch marks.
   c) Mark the valve opening points in the diagram: IVo mm before TDC, IVc 20 mm after BDC, EVo 10 mm before BDC, EVc 6 mm after TDC.
   d) Mark the curves of the 4 strokes in different colours and give the respective stroke names.
e) Mark the ignition point in the diagram with an arrow.
f) Draw the curves for compression and combustion in retarded (late) ignition.

<table>
<thead>
<tr>
<th>Piston stroke in mm</th>
<th>0 (TDC)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>65</th>
<th>70 (BDC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Induction 0°…180° $p_e$ in bar</td>
<td>0</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>Compression 180°…360° $p_e$ in bar</td>
<td>28.0</td>
<td>9.2</td>
<td>5.0</td>
<td>2.4</td>
<td>1.2</td>
<td>0.6</td>
<td>0.0</td>
<td>-0.1</td>
<td>-0.3</td>
<td></td>
</tr>
<tr>
<td>Combustion 360°…450° $p_e$ in bar</td>
<td>40.0</td>
<td>16.0</td>
<td>7.0</td>
<td>4.0</td>
<td>1.0</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhaust 540°…720° $p_e$ in bar</td>
<td>0</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

7. Calculate the missing values for the engine in the table. In the diagram, draw the combustion type with the corresponding ignition point.

**Note:** The middle indexed pressure is the average of all pressures within the work cycle.

<table>
<thead>
<tr>
<th></th>
<th>Middle pressure in bar</th>
<th>Piston force in N</th>
<th>Indexed work in J/kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal ignition</td>
<td>18.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late ignition</td>
<td>10.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. How can you tell that it is a diesel engine?

2. a) Match the numbers on the pictures to their respective part names.

   — Rail — Air flowmeter — pressure pump — injector

b) Components that send information to the control unit are called sensors. Components that receive commands from the control unit are called actuators. To which component group do the red and green marked components belong?

   red =  
   green =

Situation: You are to carry out work on the engine pictured below.

3. a) Fill in the missing vehicle data with help from a reference table.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Smart cdi 0.6</th>
<th>VW Golf 1.9 TDI</th>
<th>Audi Q7 3.0 TDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective power / Nominal speed kW / 1/min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. torque / speed Nm / 1/min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ emissions g/km</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel consumption l/100 km</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Diesel vehicles are hugely popular. Today, 50% of registered new vehicles are diesel. Give reasons for this development.
4. a) In line 1 of the table, name the individual strokes for a turbocharged diesel engine.
   b) Fill the cylinder space above the piston in a different colour for each stroke.
   c) Enter the max. cylinder pressure and temperature for each stroke.
   d) In line 5 of the table, fill in the essential processes for each stroke.

<table>
<thead>
<tr>
<th>1st stroke</th>
<th>2nd stroke</th>
<th>3rd stroke</th>
<th>4th stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cylinder pressure</th>
<th>Cylinder pressure</th>
<th>Cylinder pressure</th>
<th>Cylinder pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cylinder temperature</th>
<th>Cylinder temperature</th>
<th>Cylinder temperature</th>
<th>Cylinder temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

5. The pressure profile during the 4 strokes of a work cycle in a running engine is recorded with a pressure sensor.
   a) The curves were recorded for a spark-ignited engine and a diesel engine, both at full load. Match each process to its respective pressure profile.
   b) Mark the 4 strokes:
      - Induction
      - Compression
      - Combustion
      - Exhaust
   c) In the diagram, mark the ignition point for the spark-ignited engine and the injection process start for the diesel engine.
   d) In the illustration, the pressure profile of a naturally aspirated diesel engine is shown. How would the PV diagram differ with a turbocharged engine?