Automotive Technology
Basic Worksheets

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Foreword

“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
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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 labels</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.

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

<table>
<thead>
<tr>
<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>Diesel engine</td>
</tr>
<tr>
<td>Spark-ignition engine</td>
<td>Diesel engine</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><img src="image" alt="Nikolaus August Otto" /></td>
<td>1832 – 1891</td>
</tr>
<tr>
<td><img src="image" alt="Carl Benz" /></td>
<td>1844 – 1929</td>
</tr>
<tr>
<td><img src="image" alt="Gottlieb Daimler" /></td>
<td>1834 – 1900</td>
</tr>
<tr>
<td><img src="image" alt="Rudolf Diesel" /></td>
<td>1858 – 1913</td>
</tr>
<tr>
<td><img src="image" alt="Robert Bosch" /></td>
<td>1861 – 1942</td>
</tr>
<tr>
<td><img src="image" alt="Wilhelm Maybach" /></td>
<td>1846 – 1929</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>Displacement in l</th>
<th>Power density in kW/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>88 / 120</td>
<td>2.0</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>4-stroke spark-ignition engine</th>
<th>4-stroke spark-ignition engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>Com-</td>
<td>Categorisation according to type of...</td>
</tr>
<tr>
<td></td>
<td>bustion engine categ</td>
<td>ural to type of...</td>
</tr>
<tr>
<td></td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>process</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>cylinder motion</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>ignition</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>cooling</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>compressed medium</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>injection</td>
<td>direct</td>
<td>twin-rotor engine</td>
</tr>
<tr>
<td>carburetion</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>cylinder arrangement</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
<tr>
<td>power control</td>
<td>4-stroke</td>
<td>4-stroke</td>
</tr>
</tbody>
</table>
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><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
<td><img src="image3.png" alt="Image 3" /></td>
<td><img src="image4.png" alt="Image 4" /></td>
<td><img src="image5.png" alt="Image 5" /></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><img src="image6.png" alt="Image 6" /></td>
<td><img src="image7.png" alt="Image 7" /></td>
<td><img src="image8.png" alt="Image 8" /></td>
<td><img src="image9.png" alt="Image 9" /></td>
<td><img src="image10.png" alt="Image 10" /></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.

<table>
<thead>
<tr>
<th>Engine case</th>
<th>Crankshaft drive</th>
<th>Engine control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

17 Speed sensor
18 Spark plug
19 Intake manifold
20 Oil-pump strainer/oil pump
21 Fuel injector
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...

\[
\begin{array}{|c|c|c|}
\hline
\text{strokes} & \text{crank angle} \\ \hline
\hline
\text{camshaft rotation} & \text{cam angle} \\ \hline
\text{crankshaft rotations} & \text{opening and closing of the inlet and exhaust valves} \\ \hline
\end{array}
\]

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>( \odot-IV )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \odot-EV )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \odot-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.
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

<table>
<thead>
<tr>
<th>Cyl.</th>
<th>Intake valve opens</th>
<th>Exhaust valve opens</th>
<th>Intake valve closes</th>
<th>Exhaust valve closes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6° before TDC</td>
<td>40° before BDC</td>
<td>44° after BDC</td>
<td>10° after TDC</td>
</tr>
</tbody>
</table>

Firing order 1 – 2 – 4 – 5 – 3

Ignition interval =

<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>
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>Curve</th>
<th>Ignition point</th>
<th>Effect on combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</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</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>
Situation: You are to carry out work on the engine pictured below.

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 =

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</td>
<td>kW / 1/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. torque / speed</td>
<td>Nm / 1/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ emissions</td>
<td>g/km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>l/100 km</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>Cylinder pressure</td>
<td>Cylinder pressure</td>
<td>Cylinder pressure</td>
<td>Cylinder pressure</td>
</tr>
<tr>
<td>Cylinder temperature</td>
<td>Cylinder temperature</td>
<td>Cylinder temperature</td>
<td>Cylinder temperature</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
      - 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?