

Heat

Thermodynamic cycle

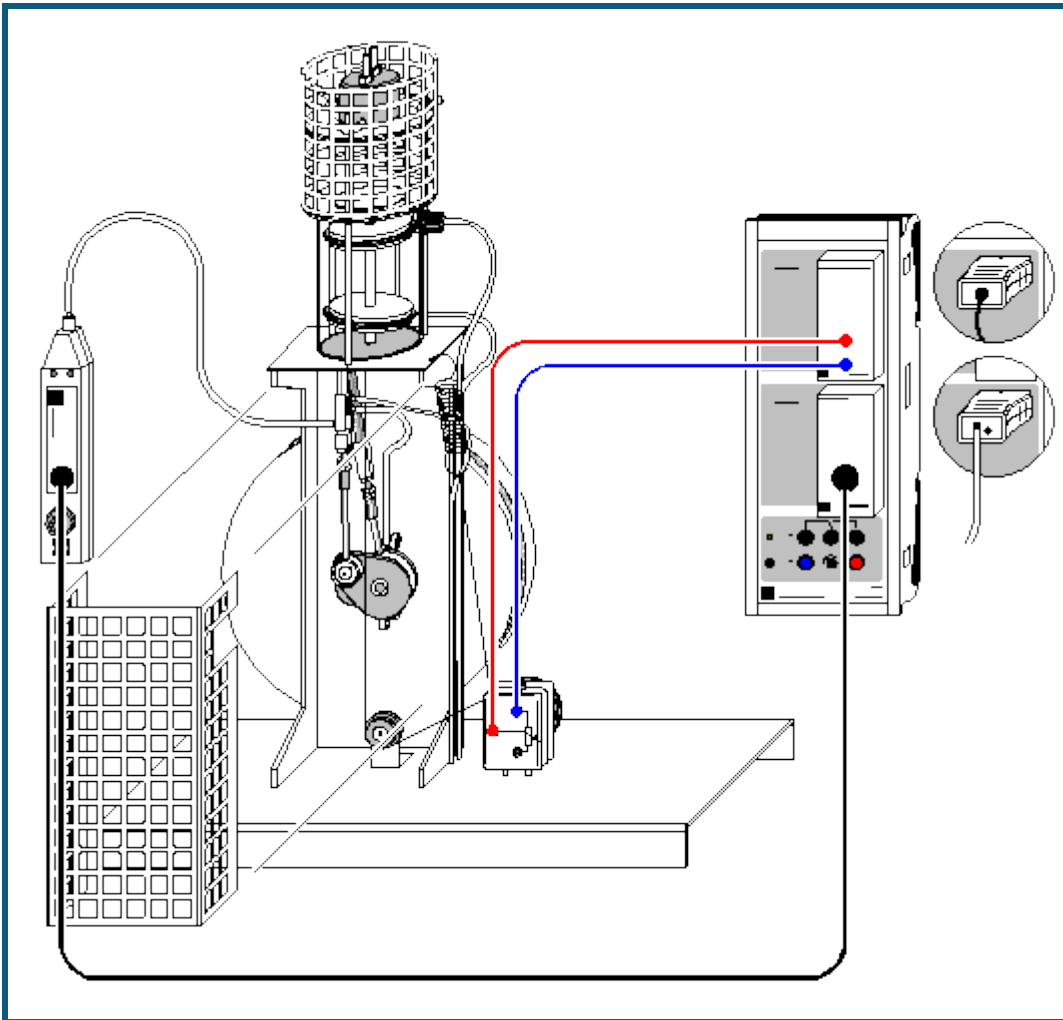
Hot-air engine: quantitative experiments


pV diagram of the hot-air engine as a heat engine -
Recording and evaluating
with CASSY

Description from CASSY Lab 2

For loading examples and settings,
please use the CASSY Lab 2 help.

pV diagram of a hot-air engine



 can also be carried out with [Pocket-CASSY](#)

Safety notes

- Before each experiment, make sure that the hot plate is seated in the notches and the heating filament does not touch the displacement piston.
- The heating head of the hot air engine can become very hot and the connecting rods of the drive and displacement pistons can cause injury when the engine is running. Therefore always use the touch protection covers when the engine is in operation.
- Never use the engine without a cooling water flow. You can connect the engine to tap water or use a circulation pump with reservoir; in this case the use of distilled or boiled (scale-free) water is recommended. If the flow should drop off when using tap water, flush the entire system with a warm scale-removing compound.
- Lubricate the two cylinders of the hot air engine regularly with silicone oil. The easiest way to do this to remove the hot plate, move the displacement piston to bottom dead center and, using a straw, drip silicone oil from a squeeze bottle so that it runs down the wall of the cylinder onto the top piston ring. As the seal is not fully tight, sufficient oil will reach the lower piston ring in a short time.
When lubrication is insufficient the engine becomes loud and only runs at a reduced speed!
- Never connect the mains coil (562 21) without the transformer core.

Experiment description

Thermodynamic cycles are often described as a closed curve in a pV diagram (p: pressure, V: volume). The work added to or withdrawn from the system (depending on the direction of rotation) corresponds to the area enclosed by the curve.

This experiment records the pV diagram of a hot air engine operated as a heat engine. The pressure sensor measures the pressure p in the cylinder and a displacement sensor measures the position s, from which the volume

is calculated, as a function of the time t . The measured values are displayed on the screen directly in a pV diagram. In the further evaluation, the mechanical work performed as piston friction per cycle

$$W = -\int p \cdot dV$$

is calculated.

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	Current source box	524 031
	with Displacement transducer and	529 031
	Pair of cables, 100 cm, red and blue	501 46
	or	
1	Rotary motion sensor S	524 082
1	B box	524 038
	with Pressure sensor and	529 038
	Multi-core cable, 6-pole	501 16
	or	
1	Pressure sensor S, ± 2000 hPa	524 064
1	Hot air engine	388 182
1	Fishing line	from 309 48ET2
1	Helical spring	from 352 08ET2
1	U-core with yoke	562 11
1	Clamping device with spring clip	562 121
1	Mains coil, 500 turns	562 21
1	Low-voltage coil, 50 turns	562 18
2	PVC tubings, \varnothing 8 mm	307 70
1	Immersion pump 12 V	388 181
1	Low-voltage power supply	521 231
1	Can	604 307
2	Connecting leads, 100 cm, black	501 33
1	Water reservoir 10 l	
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)


Set up the demountable transformer and clamp the yoke onto it.

Set up the hot plate as described in the experiment setup and connect the heater to the two outermost sockets of the low-voltage coil using the two connecting leads.

Connect the hose of the pressure sensor to the pressure fitting of the working-piston connecting rod. The pressure sensor is connected to the B box at input B of Sensor-CASSY. Attach the displacement transducer to the base plate with two coupling plugs and connect it to input A via the current source box; wind a cord as shown in the diagram. The working piston is provided with a pin with eyelet at the bottom end for attaching the cord. Hang the restoring spring in the hole on the frame head. This must be under tension when the cylinder is at bottom dead center. Wind the cord two times around the pulley of the displacement transducer to prevent slip! Set the potentiometer so that a volume of approx. 50 cm^3 is indicated when the working cylinder is at top dead center.

Carrying out the experiment

■ Load settings

- Test the displacement transducer to ensure that it is working properly: turn the motor once by hand and observe whether the volume display is within the measuring range. If it is not, loosen the cord slightly and turn the wheel of the displacement transducer until the displayed value is correct.
- Turn on the heating using the switch at the mains coil. When starting the first time, you should wait approx. 1 minute before pushing the motor, until the gas is hot enough for easy starting. In subsequent experiments you can start the motor when the heating coil begins to glow.
- Start the measurement with . The software automatically records and displays the predefined number of measuring points; the measurement is set to run for just a few cycles to simplify the subsequent integration.

Evaluation

Determination of volume (already conducted in example): the inside diameter of the working cylinder is 60 mm, which gives us a piston surface area of 28.3 cm^2 . Together with the path s_{A1} , we obtain the formula for the volume with the corresponding measuring instrument.

The work per cycle is determined from the enclosed area. We obtain this as follows: select [Calculate Integral \(Peak Area\)](#) in the Evaluations menu (click the right mouse button in the diagram) and mark one cycle (click on the starting point, hold down the left mouse button and drag the pointer along the cycle). The measuring points used for integration are highlighted. It is usually not possible to capture all measuring points of a cycle; however, it has no effect on the calculation of the area if one or two measuring points are substituted by a straight line. When you release the mouse button, the area is filled in and the corresponding value is displayed in the [status line](#).

In this example, we obtain a value for work $W = 18,900 \text{ hPa} \cdot \text{cm}^3 = 1.89 \text{ Nm}$.

Remark

The power of the motor is $P = W \cdot f$ with the f being the no-load frequency or speed.

You can determine the frequency f using a light barrier and a counter. Another way is to use the **Frequency Spectrum** display (click on this tab with the mouse). However, better frequency resolution requires more measured values than recorded in the example (increase the number from 125 to e.g. 2000 in the [Measuring Parameters dialog](#)).