

Physics

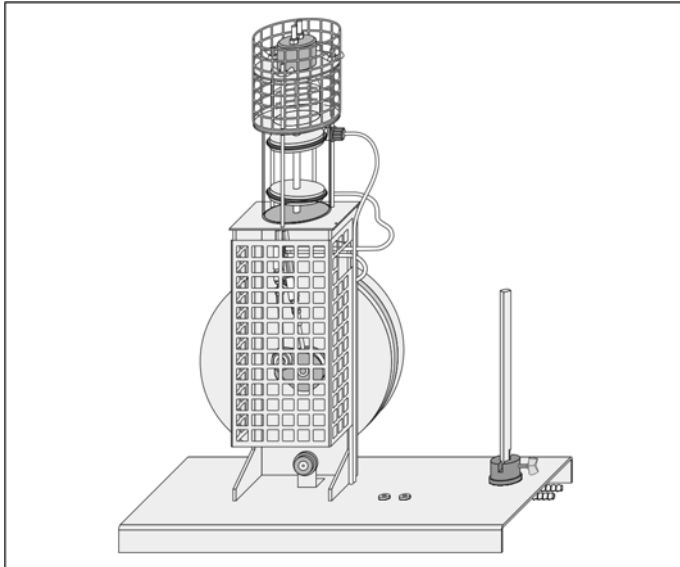
Chemistry · Biology

Technology



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06/05-Hke/Sel



Instruction sheet 388 182

Hot-air engine (388 182)

1 Description

The hot-air engine is a reproduction of the Stirling engine optimized for educational purposes. Its cylinder and the displacement piston are made of glass. The hot-air engine may be used to study thermodynamic cycles qualitatively and quantitatively. It can be operated as a heat engine or as a heat pump and refrigerating machine.

2 Scope of supply

- 1 hot-air engine
- 1 cylinder-head cap with heating coil
- 1 protective pipe, for heating coil
- 1 cylinder-head cap with screw gasket
- 1 set of 10 test tubes
- 1 demonstration cord (as friction band)
- 1 driving belt
- 1 handle
- 1 square stand rod
- 1 flask of silicone oil, 20 ml (388 21)

Safety notes

The glass components of the hot-air engine must not be exposed to excess thermal load.

- Do not operate the hot-air engine without cooling water. Make sure that the circulation of the cooling water is flawless.
- Do not allow the temperature of the cooling water to exceed 30 °C when the water enters the cooling circuit.
- Heat the heating coil up to high temperatures (yellow heat) only when the machine runs fast, and do not maintain high temperatures in continuous operation.

When the hot-air engine is operated as a heat engine, it is not self-starting. The machine will stop after a power failure, for example. Blocking the piston rods and the bearings can also cause the unit to stall. If this happens, the heat supplied to the cylinder head will not be adequately dissipated.

- Do not heat the cylinder head continuously when the machine is at a standstill.
- Do not leave the hot-air engine unsupervised.
- Switch the electric heating off immediately if the engine stalls.

- Protect the piston rods and the bearings against unauthorized access by attaching the grille.

The glass components, piston rods and bearings can be damaged if the hot-air engine is moved without due care.

- When moving the engine always support it at the base.

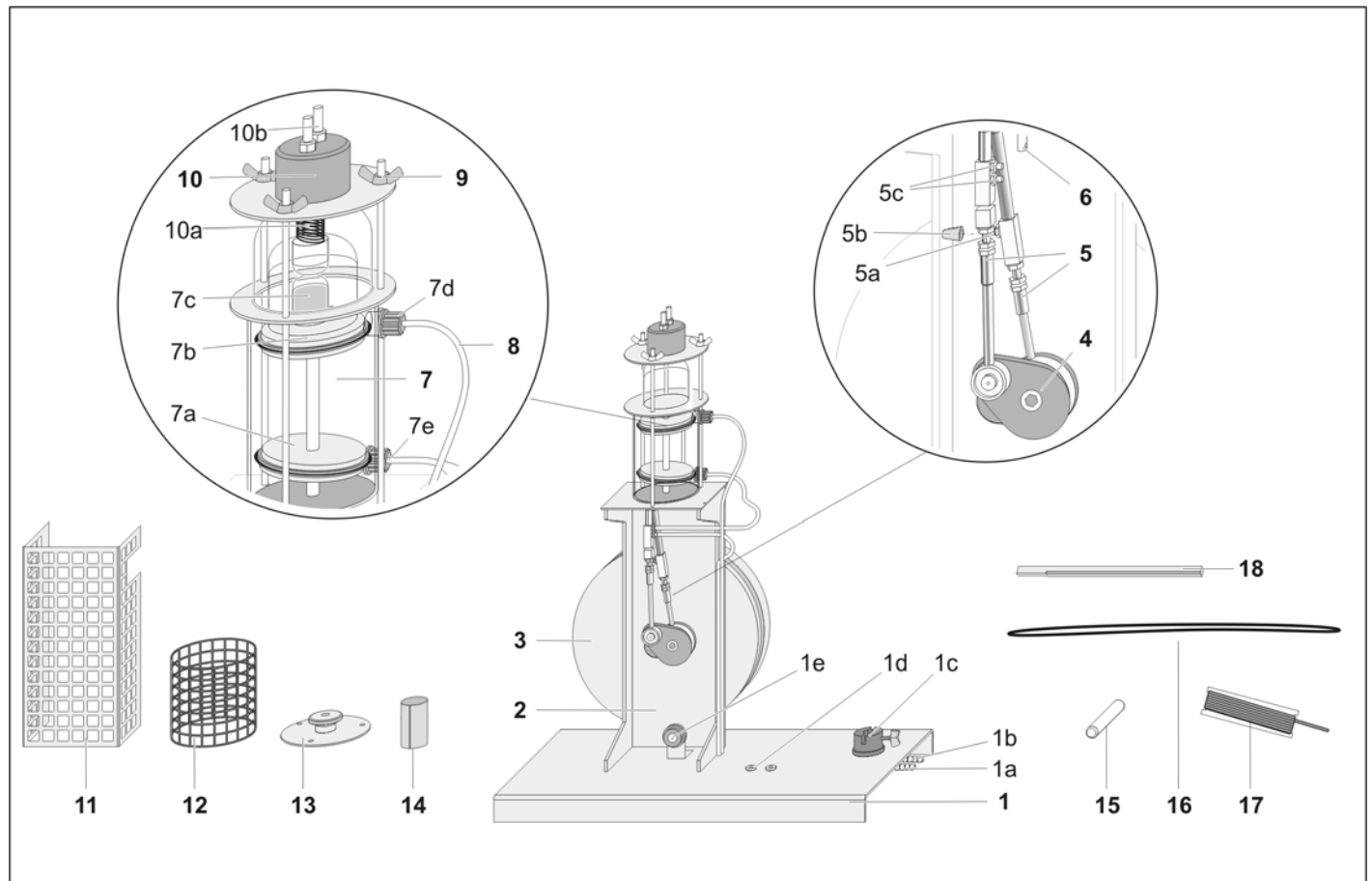
Both pistons of the hot-air engine must be regularly greased and sealed against the cylinder wall with silicone oil. If the engine is inadequately greased, it will become noisy and run only at a reduced rotational speed.

- Grease the hot-air engine particularly when it is first put into service and whenever it has not been used for a long time.

Attention: the cylinder head and the connector sockets become very hot when the engine is operated for long periods at maximum calorific power.

- Attach the grille of the cylinder.
- Allow the hot-air engine to cool down before removing the connecting cables or exchanging the cylinder-head cap.

3 Components



- 1 Base**
cooling-water outlet (1a), cooling-water inlet (1b), clamp (1c), 4-mm bores (1d), pulley block (1e)
- 2 Holder**
- 3 Flywheel**
- 4 Crankshaft**
- 5 Piston rods**
tubing shaft (5a), stopper (5b), tubing shafts for cooling water (5c)
- 6 Pin with eye**, connected to the working piston
- 7 Cylinder**
working piston (7a), displacement piston (7b), copper wool (7c), cooling-water outlet (7d), cooling-water inlet (7e)
- 8 Cooling-water tubing**, with GL14-boltings
- 9 Threaded rods**, with butterfly nuts
- 10 Cylinder-head cap**
with heating coil (10a), connector sockets (10b)
- 11 Grille for the holder**
- 12 Grille for the cylinder**
- 13 Cylinder-head cap** with screw gasket
- 14 Protective pipe**, for heating coil
- 15 Handle**
- 16 Driving belt**
- 17 Demonstration cord**
- 18 Square stand rod**

4 Technical data

Heat engine:

Power:	approx. 10 W
Calorific power:	approx. 300 W
Connection voltage:	6-20 V

Heat pump and refrigerating machine:

Maximum temperature:	approx. 100 °C
Minimum temperature:	approx. - 30°C

Cylinder:

Internal diameter:	60 mm
Minimum gas volume:	approx. 200 cm ³
Maximum gas volume:	approx. 350 cm ³
Displacement:	approx. 150 cm ³
Compression:	approx. 1:2.1

Flywheel:

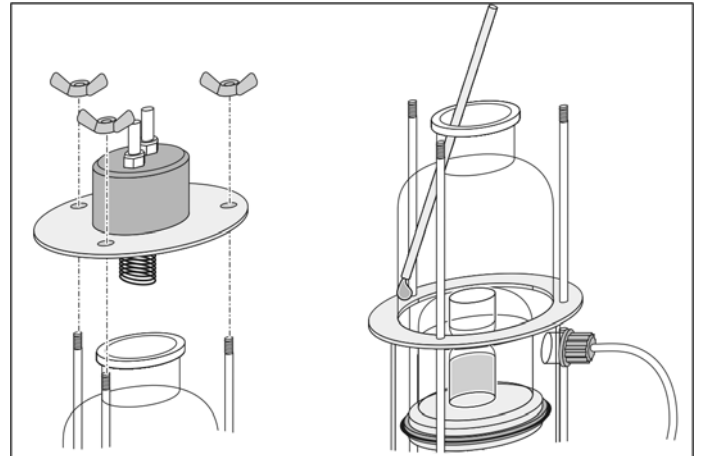
External diameter:	25 cm
Diameter of the shaft:	2.5 cm
Mass:	4.25 kg
Moment of inertia:	0.043 kg m ²

General data:

Cooling-water circulation:	0.1-1 l min ⁻¹
Dimensions:	50 cm × 25 cm × 65 cm
Weight:	15 kg

5 Initial operation

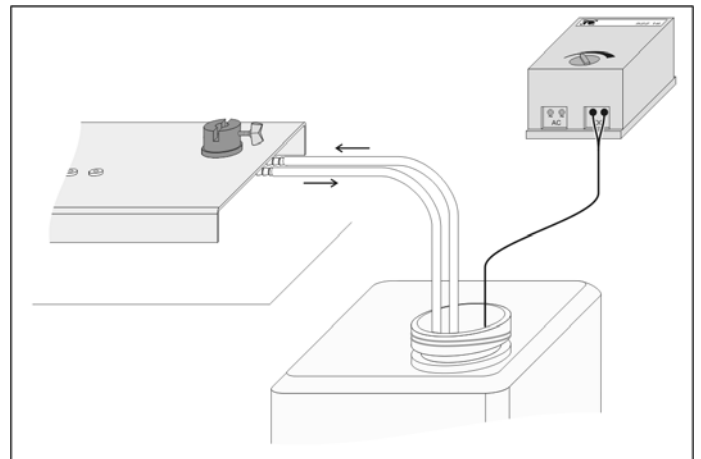
5.1 Lubrication



Both pistons of the hot-air engine must be regularly greased with silicone oil. If the engine is inadequately greased, it will become noisy and run only at a reduced rotational speed. The hot-air engine should be lubricated particularly when it is first put into service and whenever it has not been used for a long time.

- Remove the butterfly nuts of the threaded rods and the cylinder-head cap.
- Move the displacement piston to its lower dead centre position by turning the flywheel.
- Take a drop of silicone oil (supplied with the hot-air engine) from the flask using a drinking straw.
- Insert the silicone oil into the cylinder and spread it on the inside wall so that it runs down onto the upper packing ring. Since the packing is not perfect, the oil reaches the lower packing ring too after some time.

5.2 Cooling-water supply:

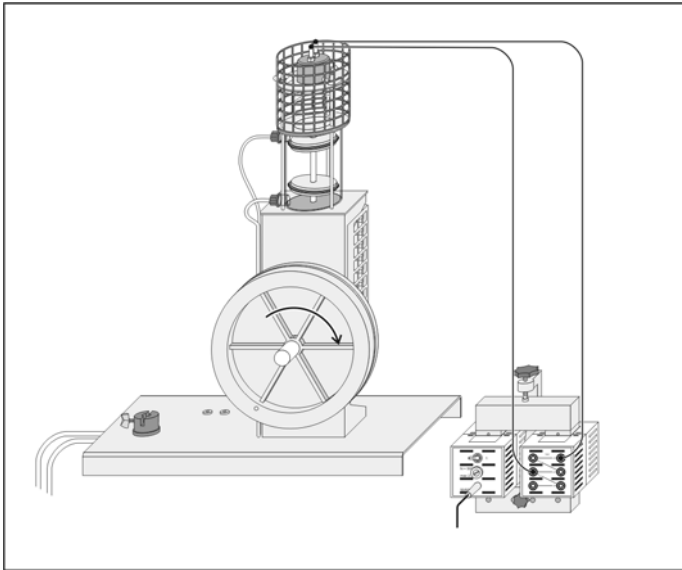


Additional items required:

1 submersible pump 12 V	388 181
1 low-voltage power supply, 3,6,9,12 V	522 16
2 lengths silicone tubings, 1m	667 194
1 water container (at least 10 l)	
or	
a tap with running water and access to a drain.	

6 The hot-air engine as a heat engine

6.1 Operation as heat engine:



Additional items required:

1 U-core with yoke	562 11
1 clamping device	562 12
1 mains coil with 500 turns for 230 V	562 21
1 extra-low-voltage coil, 50 turns	562 18

- Mount the cylinder-head cap with the heating coil; mind the mark.
- Turn the flywheel and check the packing of the hot-air engine; if necessary close the pressure sensor tubing shaft with a stopper.
- Connect the 12-V output of the demountable transformer to the 4-mm sockets of the cylinder-head cap.
- Switch the mains coil on and observe the heating coil.

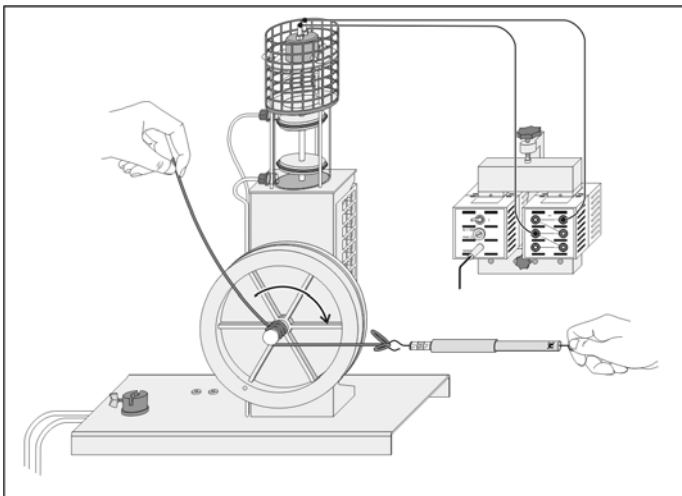
As soon as the cylinder-head cap heating coil is red-hot:

- Start the hot-air engine up by turning the flywheel clockwise.

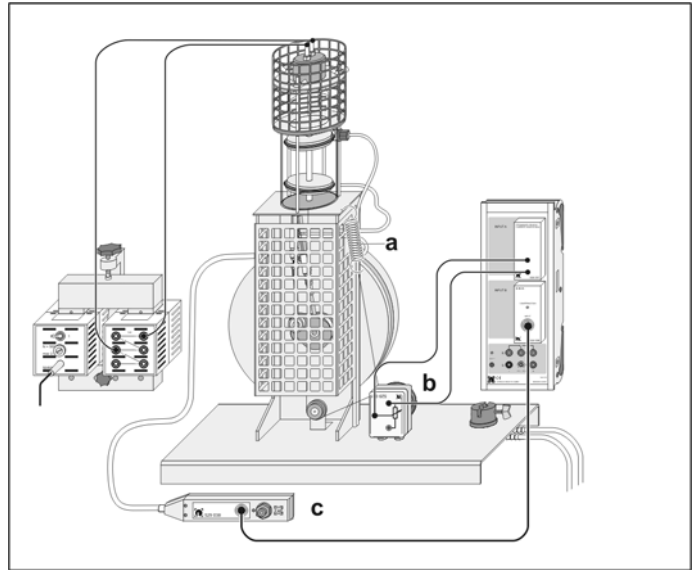
If the hot-air engine does not start after several attempts:

- Switch off the mains coil and check the setup.

6.3 Slowing down the engine:



6.2 Recording the pV-diagram:



Additional items required:

1 sensor CASSY	524 010
1 CASSY Lab	524 200
1 current supply box	524 031
1 B box	524 038
1 displacement sensor	529 031
1 pressure sensor	529 038
1 multicore cable, 6-pole, 1.5 m long	501 16
1 cord, 10 m	309 48
1 helical spring, 5 N, 0.25 N/cm	352 08

- Remove the stopper and slip on the pressure sensor tubing (**c**) so that it is well fixed.
- Suspend the helical spring (**a**) from the eye of the holder, and mount the displacement sensor (**b**).
- Fasten the cord firmly to the pin with eye, guide it around the pulley block, and fasten the other end firmly to the helical spring.
- Connect the displacement sensor to the current supply box and to the B Box of the sensor CASSY.

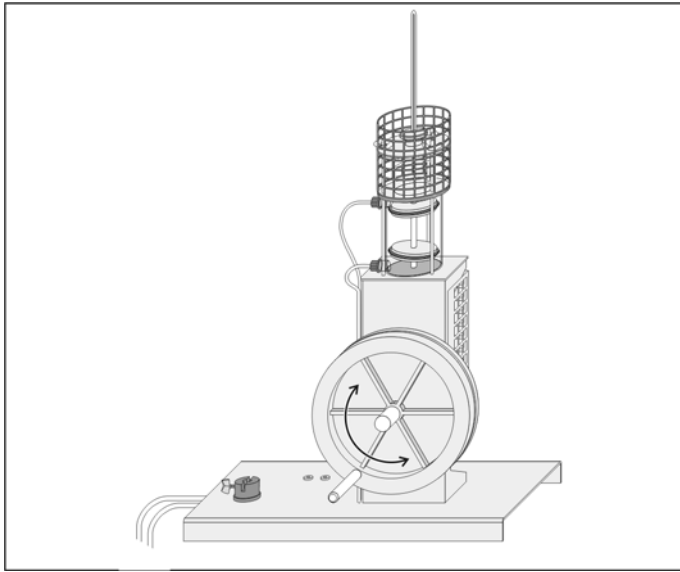
Additional items required:

1 precision dynamometer, 20 N	314 181
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- As friction band, cut off a cord approx. 1.5 m long, wind one end to an eye and hang in the precision dynamometer.
- Hold the dynamometer with the right hand and with the left hand wind the cord from below three times around the crankshaft in sense of rotation.
- Slow the engine down to half the idling speed, read the force F required and estimate the resulting torque of the heat engine.

7 The hot-air engine as a heat pump and refrigerating machine

7.1 Driving with a manual crank:



Additional items required:

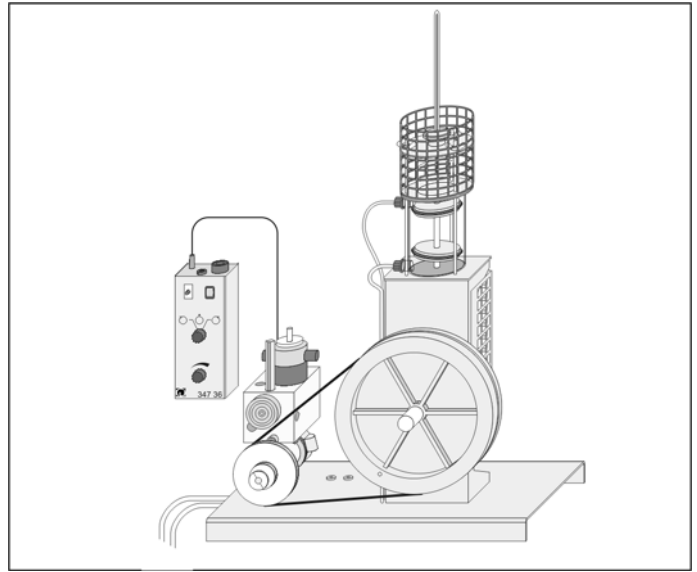
1 thermometer, -50°C to 120°C	388 19
or	
1 digital thermometer	666 190
1 temperature sensor NiCr-Ni	666 193

- Mount the cylinder-head cap with screw closure, and unscrew the screw closure.
- Insert the thermometer through the screw closure and the packing ring,
- or
- Insert the gasket with bore, and put the temperature sensor through the screw closure and the bore.
- Move the displacement piston to upper dead centre by turning the flywheel, and check whether the copper wool in the displacement piston touches the thermometer or the temperature sensor.
- Clamp the thermometer or the gasket with the temperature sensor by fastening the screw closure.

During operation of the hot-air engine an excess pressure is generated and parts may be catapulted upwards.

- Turn the flywheel and check the packing of the hot-air engine; if necessary, close the pressure sensor tubing shaft with a stopper.
- Attach the manual crank to the flywheel, and operate the hot-air engine as a refrigerating machine by turning the fly wheel to the right, or as a heat pump by turning the flywheel to the left.

7.2 Driving with the experiment motor:

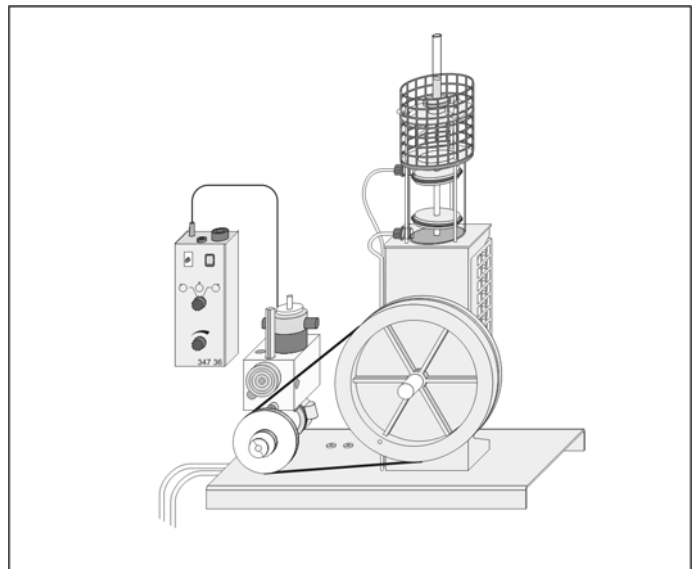


Additional items required for driving:

1 experiment motor	347 35
1 control unit for experiment motor	347 36

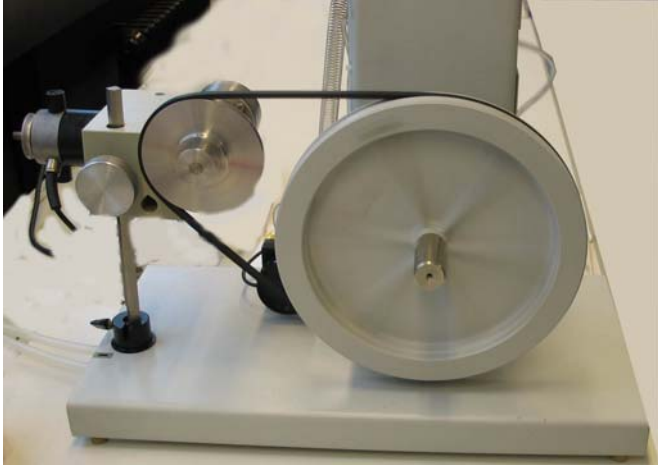
- Insert the „short end“ of the square stand rod into the clamp.
- Mount the electric motor at the square stand rod and tighten the drive belt around the flywheel. Use the control unit to turn the hot-air engine to the right or to the left.

7.3 Cooling and heating water:



- Replace the thermometer in the cylinder-head cap with a test tube (supplied with the hot-air engine).
 - Fill the test tube with 0.5-1.0 cm³ distilled water.
- Water can be cooled below freezing point and heated beyond boiling point.

7.4 Using the experiment motor with a short belt



When a short belt is used, the experiment motor needs to be mounted differently, see picture.