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Operating instructions
Density Determination Set

KERN PBS-A03/A04

Version 1.3
01/2012
GB

PBS-A03/A04-BA-e-1213

English

KERN PBS-A03/A04

GB

Version 1.3 01/2012
Operating instructions
Set for density determination for precision balances
KERN PBJ/PBS

Contents:

1 Introduction

KERN PBS-A03	KERN PBS-A04
• Set for density determination for precision balances of the series **KERN PBJ/PBS** with big weighing plate (180 x 170 mm).	• Set for density determination for precision balances of the series **KERN PBJ/PBS** with small weighing plate (105 x 105 mm).
• When using the density set, the capacity of the balance is reduces by approx. 100 g.	• When using the density set, the capacity of the balance is reduces by approx. 290 g.

- In order to guarantee a safe and trouble-free operation, please read carefully the operating instructions.
- These operating instructions only describe the operation of the density determination set. For further information on how to operate your balance please refer to the operating instructions supplied with each balance.

English

1.1 Scope of supply

Fig. 1: Installed density set **KERN PBS-A04**

1. Weighing tray holder

2. Combination weighing tray

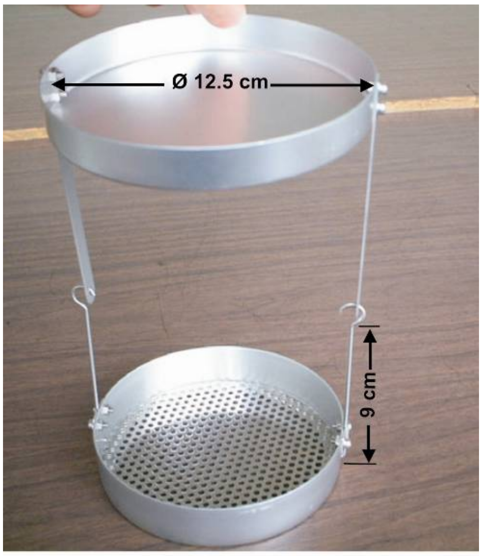
3. Container table

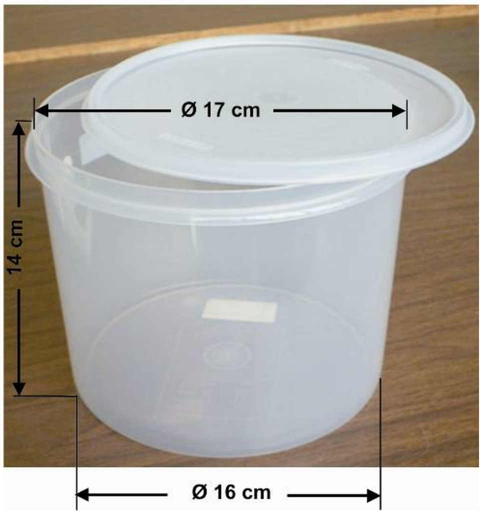
4. Container

5. Weighing tray carrier, 4 items

6. Glass sinker

1.2 Dimensions

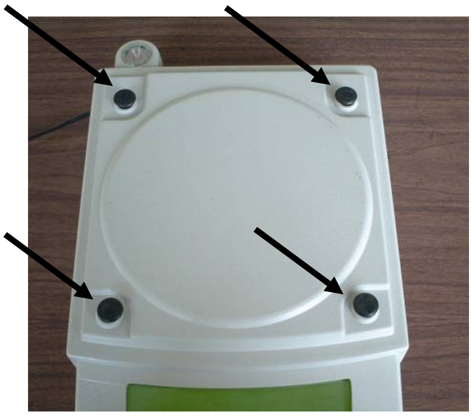




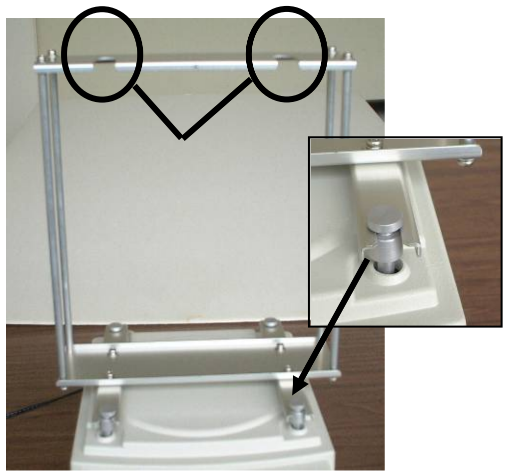
2 Installing the density determination set

- If necessary, carry out necessary adjustment before installation of the density set.
- When the density set is installed, correct adjustment is not possible.
- For reasons of adjustment, take away the density set and place the standard weighing plate.
- The following pictures show the density set **KERN PBS-A03** at a balance with big weighing plate. The density set **KERN PBS-A04** must be installed at the same way.

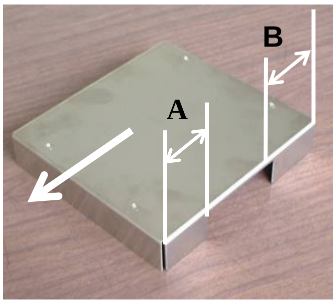
1. Switch off balance and separate it from the power supply.
2. Remove standard weighing plate.
3. Remove carrier of the standard weighing plate and replace by weighing tray carrier of the density set.



4. Put balance tray holder according to fig. into the four balance tray carriers. Thereby observe the right position, the openings on the upper side must point forwards.



5. Place the container table in a way that it does not touch the balance tray holder.



6. Put the containers in the center of the container table

7. Hook up the combination balance tray according to illustration; ensure that it does not touch the container.

English

3 Principle of Density Determination

Three physical magnitudes are the **volume** and the **mass** of bodies as well as the **density** of matter. In density mass and volume are related.

Density [ρ] is the relation of mass [m] to volume [V].

$$\boxed{\rho = \frac{m}{V}}$$

SI-unit of density is kilogram divided by cubic meter (kg/m³). 1 kg/m³ equals the density of a homogenous body that, for a mass of 1 kg, has the volume of 1 m³.
Additional frequently applied units include:

$$1\,\frac{g}{cm^3},\quad 1\,\frac{kg}{m^3},\quad 1\,\frac{g}{l}$$

English

The application of this density determination set in combination with the KERN PBS/PBJ balances provides fast and safe determination of solids and fluids. Our set uses the "**Principle of Archimedes**" to determine density:

BUOYANCY IS A FORCE. IT AFFECTS A BODY THAT IS IMMERSED INTO A FLUID. THE BUOYANCY OF THE BODY EQUALS THE WEIGHT FORCE OF THE DISPLACED FLUID. THE FORCE OF BUOYANCY ACTS VERTICALLY UPWARDS.

Thus, density is calculated according to the formulae below:

Determining density of solid bodies

Our balances enable weighing of solids in air [A] as well as water [B]. If the density of the buoyancy medium is known [ρ_o] the density of the solid [ρ] is calculated as follows:

$$\boxed{\rho = \frac{A}{A-B}\,\rho_o}$$

ρ = density of sample
A = weight of the sample in air
B = weight of sample in measuring fluid
ρ_o = density of measuring fluid

Determining density of liquids

The density of a fluid is determined with the help of a sinker providing a known volume [V]. The sinker is weighed in air [A] as well as in the test fluid [B].

According to the Archimedes' Principle a body immersed in a fluid experiences a force of buoyancy. [G]. This force equals the weight force of the fluid displaced by the volume of the body.

The volume [V] of the immersed body equals the volume of the displaced fluid.

$$\boxed{\rho = \frac{G}{V}}$$

G = buoyancy of sinker

Buoyancy of sinker =
Weight of the sinker in air [A] - weight sinker in test liquid [B]

From this follows:

$$\boxed{\rho = \frac{A-B}{V} + \rho_L}$$

ρ = Density of test liquid
A = weight of sinker in air
B = weight of sinker in sample fluid
V = volume of sinker*
ρ_L = Air density (0.0012 g/cm³)

* If the volume of the sinker is unknown, this can be determined e.g. in water and be calculated as follows, see chap. 5.1.

$$\boxed{V = \frac{A-B}{\rho_w}}$$

V = volume of sinker
A = weight of sinker in air
B = weight of sinker in water
ρ_W = density of water

3.1 Influencing magnitudes and error sources

⇨ Air pressure
⇨ temperature
⇨ Volume deviance of the sinker ($\pm$ 0,005 cm^3)
⇨ Surface tension of the liquid
⇨ Air bubbles
⇨ Immersion depth of the sample dish of sinker
⇨ Porosity of the solid

English

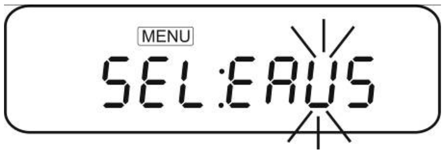
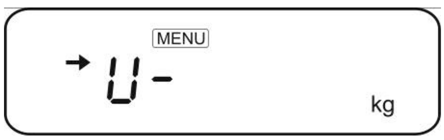
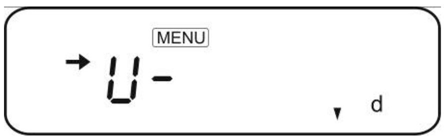
4 Density determination of solids

For the density determination of solid material, the solid is weighed first in air and then in the measuring liquid. From the weight difference results the buoyancy from where the software calculates the density.

⇨ Prepare balance as described in chapter 2 "Installation of density determination set".

⇨ Fill measuring liquid into the container. Filling height should be approx. ¾ of the capacity. Heat measuring liquid until temperature is constant.

4.1 Activate function

⇨ Switch on balance	
In weighing mode press repeatedly CAL/MENU until „**U**“ flashes.	
⇨ Press TARE / →0← ↵	
⇨ Press repeatedly CAL/MENU until „**U-▼d**“ is displayed. From now on the balance is in density determining mode for solids.	

English

4.2 Input „Density measuring liquid“

⇨ Press TARE / →0← ↵, the density saved as last of the measuring liquid is displayed. When changing by the arrow keys, enter first the numeric value of the density considering the current temperature (see chap. 7), then set the decimal place.

Use UNIT ↑ to increase the numeric value of the flashing cipher.

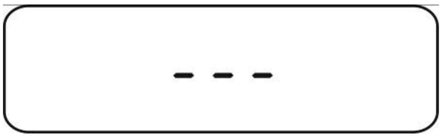
Use PRINT → to move the number selection to the right, the respective active position flashes.

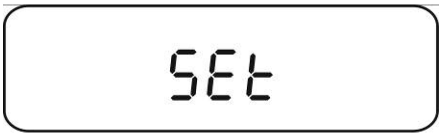
⇨ Set decimal place

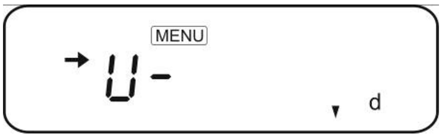
Take the last place using PRINT →, when this place dot is flashing, press PRINT → anew . The decimal place represented as „▼“ appears.

Use UNIT ↑ to define the position of the decimal place.

⇨ Acknowledge with TARE / →0← ↵.
Observe that the stability mark is displayed, if not, the entry has not been accepted.







⇨ Press ON/OFF ESC repeatedly or keep pressed for 3 sec until the gram display will appear.

English

4.3 Measurement „Density solid material“

<table>
<tr>
<td>

1. Repeatedly press UNIT ↑ until the balance is in density determination mode for solids. May be that „dSP pL“ can be displayed, but in that step this isn’t any error message and can be ignored.

</td>
<td>

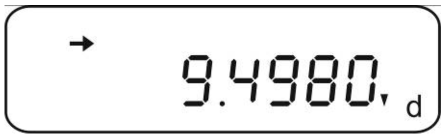
⇩

</td>
</tr>
<tr>
<td>

2. Press TARE / →0← ↵ (no change of the display).
3. Place sample in the upper sample dish.
4. Wait for stability display, then press CAL MENU.

   May be that „dSP pL“ can be displayed, but in that step this isn’t any error message and can be ignored.
5. Place sample in the lower sample dish.
6. The density of the sample is shown.

</td>
<td>



</td>
</tr>
<tr>
<td colspan="2">To start the next measurement press CAL MENU, before the current sample is removed from the lower sample dish. For the new measurement start at step 2.</td>
</tr>
<tr>
<td colspan="2">When using an other measuring liquid, start at the entry „Density measuring liquid“, see chapter 4.2.</td>
</tr>
<tr>
<td colspan="2">Using UNIT ↑ the balance returns into the weighing mode.</td>
</tr>
</table>

English

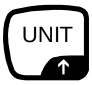
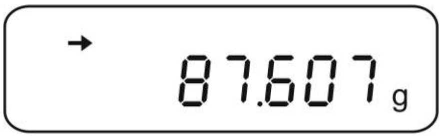
5 Determining density of liquids

5.1 Volume determination of the sinker

⇨ Prepare balance as described in chapter 2 "Installation of density determination set".

⇨ Fill water into the container. Filling height should be approx. ¾ of the capacity. Heat sample liquid until temperature is constant.

⇨ Keep the sinker ready

⇨ Switch-on balance, repeatedly press the  key until the balance is in weighing mode..	
⇨ Place sinker in the upper sample dish. Wait for stability display to appear; write down the displayed weighing value.	
⇨ Place sinker in the lower sample dish. Wait for stability display to appear; write down the displayed weighing value.	

The volume of the sinker is computed by applying the following formula.

$$V = \frac{A - B}{\rho_W}$$

V = volume of sinker
A = weight of the sinker in air = 99.998 g
B = weight of the sinker in water = 87.607 g
ρ_W = density of water (see chap. 7) at 20°C = 0.9982 g/cm³

English

$$V = \frac{99.998g - 87.607\ g}{0.9982\ g/cm^3} = 12.413\ cm^3$$

5.2 Density determination at known volume of the sinker

⇨ Prepare balance as described in chapter 2 "Installation of density determination set".

⇨ Fill test liquid in the container. Filling height should be approx. ¾ of the capacity. Heat sample liquid until temperature is constant.

⇨ Keep the sinker ready

⇨ Switch-on balance, repeatedly press the UNIT key until the balance is in weighing mode..	→ 0.000 g
⇨ Place sinker in the upper sample dish. Wait for stability display to appear; write down the displayed weighing value.	→ 99.998 g
⇨ Place sinker in the lower sample dish. Wait for stability display to appear; write down the displayed weighing value.	→ 90.068 g

The density of the test liquid is computed by applying the following formula.

$$\rho = \frac{G}{V}$$

G = buoyancy of sinker

Buoyancy of sinker =
Weight of the sinker in air [A] - weight sinker in test liquid [B]

From this follows:

$$\rho = \frac{A\text{-}B}{V}$$

ρ = density of sample fluid
A = weight of sinker in air
B = weight of the sinkers in test liquid
V = volume of sinker

$$\rho = \frac{99.998\,g - 90.068\,g}{12.413\ cm^3} = 0.799\ g/cm^3$$

6 Preconditions for Precise Measurements

There are numerous error possibilities during density determination.
Accurate knowledge and caution are required to achieve precise results when applying this density set in combination with the balance.

6.1 Calculation of Results

The balance displays results for density determination by giving four decimal places. However, this does not mean that the results are accurate down to the last decimal place as this would be the case for a calculated value. Therefore all weighing results used for calculations have to be examined closely.

Example for density determination of solids:
To ensure high-grade results, numerators as well as common denominators of the formula below must show the desired accuracy. If either of them is instable or flawed, the result, too, will be instable or flawed.

$$\boxed{\rho = \frac{A}{A-B}\,\rho_o}$$

ρ = density of sample
A = weight of the sample in air
B = weight of sample in measuring fluid
ρ_o = density of measuring fluid

The use of a heavy sample contributes to the accuracy of a result. this increases the numerical value. The use of a light-weight sample, too, contributes to the accuracy of a result because this increases buoyancy (A-B). As a consequence, the result of the common denominator increases. Bear also in mind that the accuracy of the density of the measuring fluid ρ_o enters into the common denominator and, thus, has considerable influence on the accuracy of the result.
The result for the density of the sample cannot be more accurate than the least accurate of the aforementioned individual entities.

6.2 Influence Factors for Measurement Errors

6.2.1 Air bubbles

A small bubble of, for example, 1mm^3 will have a considerable influence on the measurement if the sample is small. Buoyancy will be increased by approximately 1mg resulting immediately in an error of 2 digits. Hence, it has to be ensured that no air bubbles cling to the solid immersed in the fluid. The same applies to the sinker that is immersed in the test fluid.
Take great care when removing air bubbles by swirling, to prevent the fluid from spurting out and splashing onto the sifting bowl or from water splashing. Moisture on the suspension bracket of the sifting bowl results in increased weight.
Do not touch the solid sample or sinker with bare fingers. An oily surface causes air bubbles when immersing the specimen in fluids.
Do not place solid samples (in particular flat objects) in the sifting bowls outside the liquid as this would result in air bubbles when immersed together. For this reason examine the bottom of the sifting bowl for air bubbles after the specimen had been immersed in fluid.

English

6.2.2 Solid body sample

A sample possessing too great a volume that is immersed in fluid will result in an increase in fluid level inside the glass pitcher. As a result, part of the suspension bracket of the sifting bowl will also be immersed causing buoyancy to increase. As a consequence the weight of the specimen in the fluid will drop.
Samples that change the volume or assimilate fluid are unsuitable for measurement.

6.2.3 Liquids

Water temperature is another factor to be taken into consideration. The density of water changes by c. 0.01% per degree Celsius. A temperature measurement showing an error of 1 degree Celsius results in an inaccurate fourth decimal place.

6.2.4 Surface

The suspension bracket of the sifting bowl penetrates the surface of the fluid. This state undergoes continuous change. If the sample or the sinker is relatively small, the surface tension will impair repeatability. The addition of a small amount of detergent makes the surface tension negligible and increases repeatability.

6.2.5 Sinker for liquid density measurement

To save precious specimen liquid, a small beaker and a sinker that fits such a beaker are usually used to measure liquid density. However, note that a larger sinker will bring higher accuracy.
Both the buoyancy and the sinker volume are desired to have as many significant figures as possible for precise results. Because they are the numerator and denominator of the expression to compute the liquid. Seeking accurate volume of the sinker is also important.

English

6.3 General information

6.3.1 Density / Relative Density

Relative density follows from the weight of a specimen divided by the weight of water (at 4° Celsius) of the same volume. For this reason relative density does not have a unit.
Density equals mass divided by volume.
The application of the relative density instead of the density of a fluid in a formula produces an incorrect result. In the case of fluids only their density is physically meaningful.

6.3.2 Drift of Balance Display

The drifting of a balance does not influence the final result of the density determination although the shown weight of weighing in air is affected. Accurate values are merely required if the density of fluids is determined by means of a sinker.
When changing the ambient temperature or location, an adjustment of the balance is necessary. For this purpose remove the density set and carry out adjustment using the standard weighing tray (see operating instructions supplied with the balance).

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7 Density Table for Fluids

Temperature [°C]	Density p [g/cm³]		
	Water	Ethyl alcohol	Methyl alcohol
10	0.9997	0.7978	0.8009
11	0.9996	0.7969	0.8000
12	0.9995	0.7961	0.7991
13	0.9994	0.7953	0.7982
14	0.9993	0.7944	0.7972
15	0.9991	0.7935	0.7963
16	0.9990	0.7927	0.7954
17	0.9988	0.7918	0.7945
18	0.9986	0.7909	0.7935
19	0.9984	0.7901	0.7926
20	0.9982	0.7893	0.7917
21	0.9980	0.7884	0.7907
22	0.9978	0.7876	0.7898
23	0.9976	0.7867	0.7880
24	0.9973	0.7859	0.7870
25	0.9971	0.7851	0.7870
26	0.9968	0.7842	0.7861
27	0.9965	0.7833	0.7852
28	0.9963	0.7824	0.7842
29	0.9960	0.7816	0.7833
30	0.9957	0.7808	0.7824
31	0.9954	0.7800	0.7814
32	0.9951	0.7791	0.7805
33	0.9947	0.7783	0.7896
34	0.9944	0.7774	0.7886
35	0.9941	0.7766	0.7877

English

8 Uncertainty of Measurement for Density Determination of Solids

This table shows the approximate readability of the balance in connection with the density set. Observe that these values have only been determined by calculation and that influent parameters such as described in chapter 6 have not been taken into consideration.

Approximate display at density measurements (when using a balance with a readability of 0.01g*)									
Weight of sample (g) / Density of sample [g/cm^3]	1	10	50	100	500	1000	2000	3000	4000
1	0.1	0.01	0.003	0.002	0.0005	0.0003	0.0003	0.0002	0.0002
3	0.4	0.04	0.01	0.005	0.001	0.001	0.0005	0.0004	0.0004
5	0.7	0.07	0.01	0.008	0.002	0.001	0.001	0.001	0.0006
8	1.2	0.1	0.02	0.01	0.003	0.002	0.001	0.001	0.001
10	1.5	0.1	0.03	0.02	0.004	0.002	0.001	0.001	0.001
12	1.7	0.2	0.04	0.02	0.004	0.002	0.002	0.001	0.001
20	2.9	0.3	0.06	0.03	0.01	0.004	0.003	0.002	0.002

*when using a balance with a readability of 0.1 g, the numbers in this table have to be multiplied with 10. When using a balance with a readability of 0.001 g, divide the numbers through 10.

Reading example for table:
In a balance with a resolution of 0.001 g and a sample with a weight of 10 g, whose density is 5 g/cm^3, the display graduation is at 0.007 g/cm^3.

9 User Instructions

- To form a reproducible mean value several density measurement are necessary
- Remove fat from solvent-resistant sample / sinker /beaker.
- Regularly clean sample dishes/ sinker/beaker, do not touch immersed part with your hands
- Dry sample/ sinker/pincers after each measurement.
- Adjust sample size to sample dish (ideal sample size > 5 g).
- Only use distilled water.
- When immersing for the first time, lightly shake sample dishes and sinker, in order to Dissolve air bubbles.
- Always ensure that, when re-immersing into the liquid no additional bubbles adhere; it is better to use pincers to place the sample.
- Remove firmly adherent air bubbles with a fine brush or a similar tool.
- To avoid adherent air bubbles smoothen samples with rough surface.
- Take care that no water drips onto the upper sample dish when weighing with the help of tweezers.
- In order to reduce the surface tension of water and the friction of the liquid on the wire, add three drops of a common detergent (washing-up liquid) to the measuring liquid (density modification of distilled water occurring due to the addition of tensides can be ignored).
- Oval samples can be held more easily with pincers when you cut grooves into them.
- The density of porous solids may only be determined approximately. Buoyancy errors occur when not all the air is eliminated from the pores during immersion in the measuring fluid.
- To avoid great vibrations of the balance, place sample carefully.
- Avoid static charge, e. g. dry sinker with cotton cloth only.
- If the density of your solid body just deviates slightly from that of distilled water, ethanol may be used as measuring liquid. However, check beforehand whether the sample is solvent-proof. In addition you must observe the applicable safety regulations when working with ethanol.