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Ballistic pendulum

11229-00

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Operating instructions

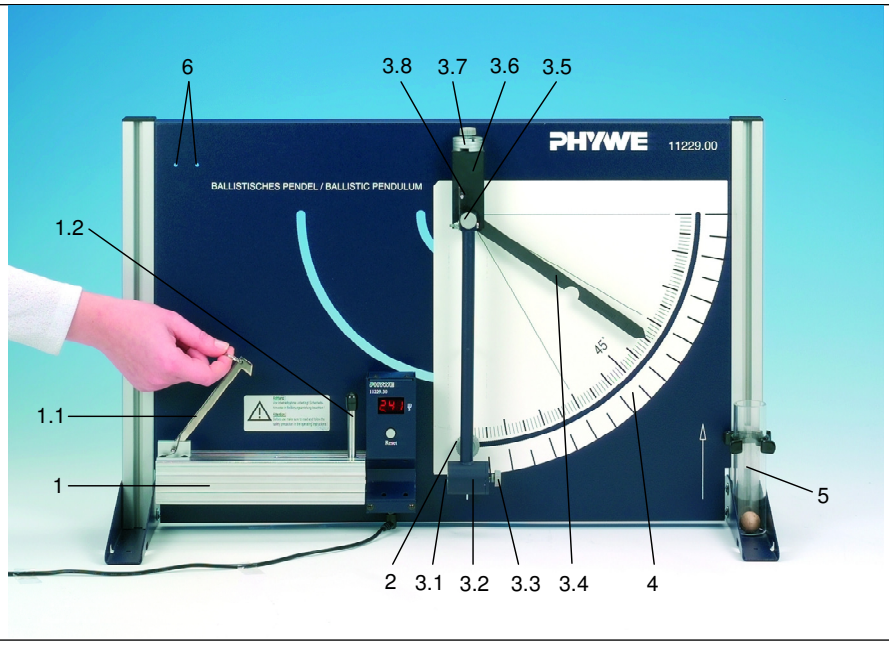

Fig. 1: 11229-00 Ballistic pendulum

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1 SAEFTY PRECAUTIONS

Caution!

- Carefully read these operating instructions before operating this instrument. This is necessary to avoid damage to it, as well as for user-safety.
- Do not start up this instrument in case of visible signs of damage to it.
- Only use the instrument for the purpose for which it was designed.
- Only place projectile at ring magnet of bolt if catapult is not set.
- Never touch the tensed catapult.
- Never put the face in front of the opening of the catapult during and after tensing.
- During experimenting always wear safety goggles.

2 PURPOSE AND CHARACTERISTICS

A three-state spring ballistic unit, whose ejection angle can be continuously varied between 0° (horizontal throw) and 90° (vertical throw), serves as the catapult. At an ejection angle of 45°, throwing ranges of between 2 and 3 meters can be achieved. The striking points of the balls are automatically marked on the recording paper and can be exactly measured.
With just a few deft movements, the ballistic pendulum supplied with the device can be attached in front of the mouth of the ballistic unit in such a manner that the ejected ball remains stuck in the pendulum (inelastic collision). From the deflection of the pendulum, which can be read off the demonstration scale, the velocity of the ball can be calculated.

3 FUNCTIONAL AND OPERATING ELEMENTS

Fig. 1 show the device mounted for measurements with the ballistic pendulum and having the following functional and operating elements.

1 Ballistic untit
It can be removed by unscrewing the two knurled screws on the back of the device in order to be able to attach it to the angle scale *4*, which can be turned, for the ”catapult” operational mode.

1.1 Trigger lever with hole for tying on a pull thread for safe triggering of the shot.

1.2 Tension lever
Before cocking the ballistic unit, the ball is centred on the ring magnets of the bolt; subsequently, the tension lever is pulled to the desired locking position to the left.

2 Knurled screw for attachment of the angle scale *4*, which can be turned, in the desired position.

3 Ballistic pendulum

3.1 Conical entry aperture of the pendulum. If the energy is sufficient (tension level *2* and *3* of the ballistic unit), the ball becomes wedged in the capturing cone (inelastic collision).

3.2 Optionally attached supplementary weights (slotted weights) to change the pendulum’s characteristics (measuring range extension); if not in use, the weights are stored at position *3.7* on the pendulum support.

3.3 Knurled screw for ejecting the captured ball. The screw can also prevent the ball from being caught if it is tightened sufficiently far. In this manner measurements under conditions of an elastic collision can be made.

3.4 Maximum (trailing) pointer to indicate the maximum deflection of the ballistic pendulum.

3.5 Knurled screw. The pendulum rod can be removed after this screw has been unscrewed. This is necessary to determine the mass and the distance of the centre of gravity from the pivot point for the Evaluation section.

3.6 Pendulum support. It can be removed after loosening two knurled screws on the back of the device. This is necessary in order to use the ”catapult” operating mode. For storage, the pendulum can be attached to the back of the mounting plate using the holes provided *6*.

3.7 Storage location for slotted weights which are not in use.

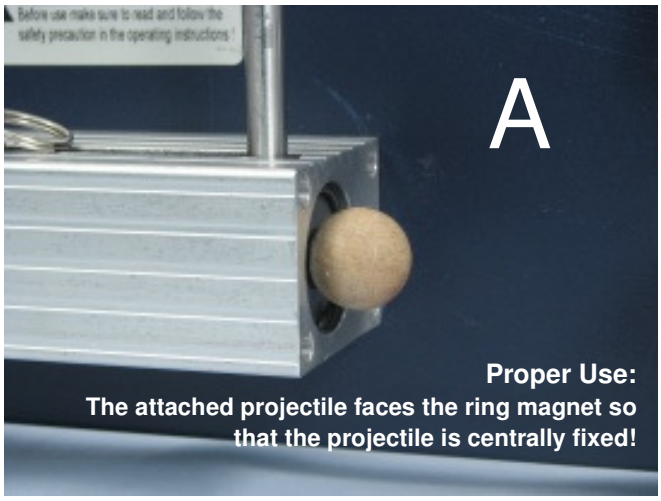
3.8 Spring to dampen the back swing of the pendulum against the ballistic unit. To measure the pendulum’s oscillation period, the spring can be temporarily turned toward the front until the movement is no longer blocked by the pin which serves as the block. Caution: After completion of the measurement of the oscillation period immediately bring the spring back into its original position; without an effective damping spring the backswinging pendulum can cause damage.

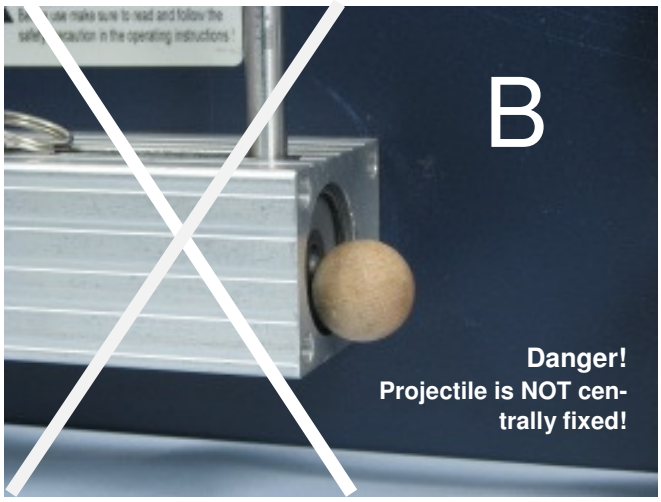
4 Angle scale for reading off the maximum deflection of the ballistic pendulum. In the ”catapult” operating mode, the ballistic unit is attached to two holes in the scale with its knurled screws (in Fig. 1 the holes are covered by the pendulum). By turning the scale after loosening the clamping screw *2*, the ejection angle can be set to between 0° and 90° by turning the scale.

5 Tube for storing the balls. To release them pull the tube upwards (arrow).

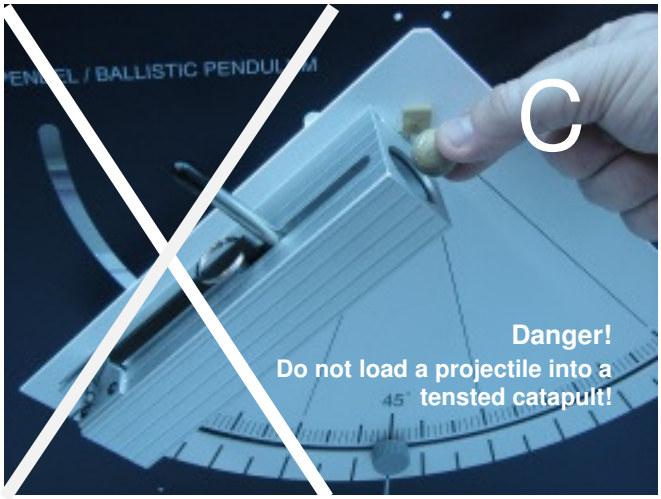
6 Holes for attaching the pendulum to the back when not needed.

When making quantitative measurements, use the steel ball only. The wooden ball can also be attached to the bolt of the ballistic unit with the aid of its iron core. This ball is used to illustrate the influence of a smaller ball mass in a qualitative manner.





Note: Photograph A and B show the catapult in released state. Only C shows a tensed catapult.



Required Loading Sequence of the Catapult

1st step: Loading of the projectile into the Catapult. The projectile has to be placed centrally to the piston so it is fixed by the ring magnet of the piston. In case the wooden sphere as projectile (329066) is used, face the iron inset to the ring magnet. As a result, the wooden projectile is centered and fixed to the piston, independly to the ejection angle!

Caution: In case a projectile is not centered and fixed to the piston, the projectile may get seized so that the catapult may get damaged (Photograph-B)!

2nd step: Tense the catapult. After loading the projectile, the catapult is tensed.

Caution: Never load a projectile when the catapult has been tensed before (Photograph-C)!

4 HANDLING

4.1 Assembly

For better packaging, the device is delivered in a partially disassembled state. We recommend first assembling the device according to Fig. 1. When not in use, it should also be stored in this manner, as in this condition all parts are assembled and cannot be lost. To begin with, mount the two square profile sections laterally on the base plate and then screw on the feet. A suitable Allen wrench is included with the device. Knot a thread in the form of a loop in the hole on the trigger lever. Now, the device is ready for operation as a ballistic pendulum.

4.2 Velocity measurements with the ballistic pendulum

For experiments, the device should always be attached to the table with two C-clamps to avoid measurement errors due to slipping. To begin with, make sure that the knurled screw *3.3* has been loosened sufficiently to firmly hold the ball in the pendulum aperture. To do this, press the ball into the aperture *3.1* applying moderate force with your hand; in the process the ball must not fall out when the aperture is pointing downward. To remove the ball, deflect the pendulum by approximately 45° and tighten the screw until the ball falls out. Then loosen the screw again by approximately two turns.

Before tensioning the spring on the ballistic unit, fix the steel ball on the holding magnet of the bolt. Then pull the bolt back to the second or third locking position. (The first locking position is generally not suitable, because the energy imparted on the ball is too low to securely wedge it into the pendulum.)

Now, without touching the pendulum's pulling pin, ensure that the pendulum is at rest and that the maximum pointer is set approximately to zero. After these preparations, trigger the shot by pulling the retention (trigger) lever. The amplitude of the pendulums oscillation can be read off the maximum indicator *3.4*.

Note: Due to the maximum pointer's friction, which is inherent in the design, the amplitude measured may be somewhat too low. It is therefore advisable, to shoot a second and a third shot at the resting pendulum with the same spring tension without zeroing the maximum pointer. If the maximum pointer does not move any further, one can assume that the indicated angle has not been misrepresented. If this is not the case, additional shots are required. One achieves more rapid results, if one sets the maximum pointer to 90° for the first shooting trail and estimates the deflection. For the following measurement, one sets the pointer to an angle that is slightly smaller as the observed deflection, so that the maximum pointer is just barely reached.

If the deflection φ greater than 90°, the measuring range is to extended by moving the slotted weights (4 x 10 g) from their storage location *3.7* to the lower end of the Pendulum *3.2*.

For the evaluation, one requires the following values in addition to the deflection φ:

1. m = Mass of the ball
2. M = Mass of the oscillating part of the pendulum including the captured ball
3. r = Distance between the axis of rotation and the centre of gravity of the pendulum with the captured ball
4. r_b = 0,240 m = 0.240 m = Distance between the axis of rotation and the centre of the captured ball
5. g = Acceleration of gravity
6. T =Oscillation period of the pendulum with captured ball

To determine the mass M of the pendulum, remove the knurled screw *3.5*, take off the pendulum rod and weigh it. Subsequently, determine the centre of gravity by suspending the pendulum rod in a loop of thread and shifting the rod's position until it is nearly balanced. The distance between this suspension point and the axis of the bearing's bore is *r*.

The velocity of the ball is calculated according to the following equation (derivation see Section 6, Experimental Literature).

$$v = \frac{m+M}{m} \cdot \frac{r}{r_b} \cdot \frac{g \cdot T}{2\pi} \cdot \sqrt{2 \cdot (1 - \cos\varphi)}$$

4.3 Elastic collision of the ball and the pendulum
If screw *3.3* is not turned back to its initial position after the ball has been ejected, the ball will be elastically reflected by the screw at the next shot. In this context, the question is whether the deflection of the pendulum will be greater or smaller as in the case of an inelastic collision. The experiment exhibits a greater deflection for an elastic collision. Explanation: The total impulse must be exactly the same in both collision types. In an elastic collision the ball is reflected with a negative impulse, which must be compensated by a larger positive impulse of the pendulum. Additionally, the deflection of the pendulum is increased, because its mass is smaller by the quantity *m* than in an inelastic collision.

4.4 Conversion of the catapult (Fig. 3)
Initially, unscrew the ballistic unit from the base plate by loosening the two knurled screws on the back of the base plate. Next, also remove the pendulum support *3.6* by loosening its two knurled screws. After removing the pendulum, two holes in the angular scale *4* which had previously been covered by the covered by the pendulum rod are exposed. Screw the ballistic unit's attachment screws into these holes; the ballistic unit opening faces upwards. After loosening the clamping screw *2*, the ejection angle can be varied between 0° and 90°. The pendulum, which is no longer needed, can be secured to the back of the base plate by means of holes *6* and stored there.

Fig. 3: Conversion to the catapult mode.

4.5 Measurement of throwing ranges with the ballistic unit
For these measurements it is absolutely necessary that the feet of the device are fixed to the table's surface with C-clamps, because the device would otherwise slip during cocking and shooting. Select an area for experiments with the ballistic unit where no one can be struck and nothing can be damaged by the balls, which can travel as far as 3 meters. Also take into consideration that the ball can bounce off a surface and travel further.
Loading and cocking the ballistic unit as well as triggering a shot is comprehensively described in Section 3.2. Ensure that the trigger is pulled out quickly in order to achieve a good reproducibility of the throwing ranges. Fix a piece of the recording paper to the target area (e.g. with transparent tape) to mark the striking point of the ball. If one ensures that the launch point and the target plane are at the same height, the following formula for the throwing range *s* as a function of the ejection angle Φ:

$$s = \frac{v_0^2}{g} \cdot \sin 2\Phi$$

If one selects Φ = 45° for the largest throwing range, one can calculate the initial velocity v_0 of the ball for this angle from the measured throwing range.

$$v_0 = \sqrt{s \cdot g}$$

The lower platform of the table with two demonstration levels is appropriate as a target plane.

4.6 Maintenance

When necessary, lubricate the pendulum bearing win an appropriate lubricant. The same lubricant, which also acts as protection against corrosion, should occasionally be sprayed in the ballistic unit.

5 LIST OF EQUIPMENT

The device is comprised of the following components, which can also be ordered separately:

Ballistic unit	11229-10
Ballistic pendulum, ballistic unit accessory	11229-20

Included accessories:

Steel ball, *d* = 19 mm	02502-01
Wooden ball with iron core	

The following experimental material is recommended for measurements with the device:

Recording paper, 1 roll, 25 m	11221-01
C-clamps (2)	02014-00
Table with two demonstration levels	02076-03
Balance to 200 g	

For direct measurement of the initial ball velocities:

Velocity measurement attachment	11229-30
Power supply 5V DC	13900-99

6 TECHNICAL DATA

Ballistic unit	**11229-10**
Ejection angle	0… 90°
Projectile ranges	max. 3 m
Dimensions (mm)	600 x 385
Weight	approx. 6 kg

Ballistic Pendulum, for Ballistic Unit	**11229-20**
Pendulum length	250 mm
Weight	approx. 0.3 kg

Due to the geometry of the velocity measurement attachment errors of measurement within the usual statistical error range may occur.

7 NOTES ON THE GUARANTEE

We guarantee the instrument supplied by us for a period of 24 months within the EU, or for 12 months outside of the EU. Excepted from the guarantee are damages that result from disregarding the Operating Instructions, from improper handling of the instrument or from natural wear.

The manufacturer can only be held responsible for the function and technical safety characteristics of the instrument, when maintenance, repairs and alterations to the instrument are only carried out by the manufacturer or by personnel who have been explicitly authorized by him to do so.

8 WASTE DISPOSAL

The packaging consists predominately of environmentally compatible materials that can be passed on for disposal by the local recycling service.

Should you no longer require this product, do not dispose of it with the household refuse.

Please return it to the address below for proper waste disposal.

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