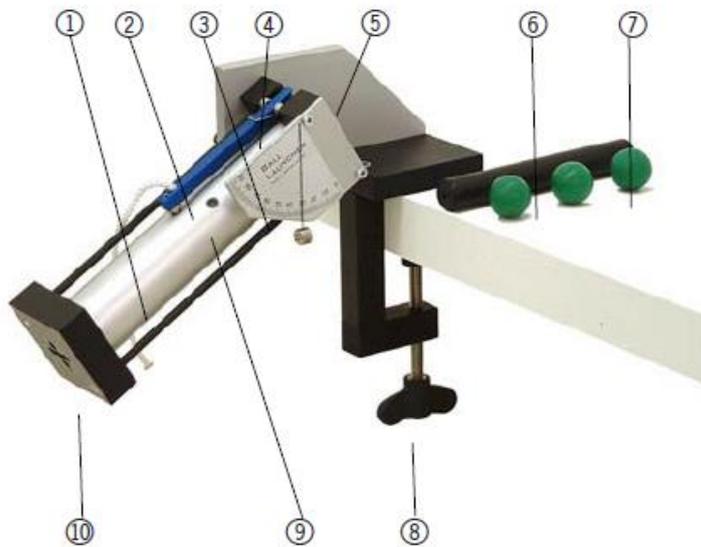


1002654 Projectile Launcher 1002655 Clamp for Projectile Launcher

Instruction sheet

12/15 MH



- 1 Barrel with internal launching mechanism
- 2 Launching lever with cord
- 3 Angle scale
- 4 Aperture
- 5 Holder for projectile launcher1002655
- 6 Ramrod
- 7 Plastic spheres 3x
- 8 Securing screw
- 9 Observation hole 3x
- 10 End cap
- 11 M8x20 knurled screw with pastic disc for securing projectile launcher to holder (not visible)

Fig.1: Components

1. Safety instructions

- To check whether there is a projectile in the launcher and the spring is cocked, the observation holes (9) should be used exclusively. It is forbidden to look through the launch aperture (4) since there is a risk of injury!
- Never aim at people!
- Wear protective goggles when performing experiments.
- Always ensure the spring is not under tension and no projectile is present in the launcher while it is being stored.
- In order to gain an impression of the projectile energy, a hand can be placed over the aperture and a projectile fired at it. The energy is relatively small (usually there is no danger if a plastic sphere is thrown 5 m by hand, either).

2. Description, technical data

The projectile launcher is for experimentally determining ballistic trajectories when a projectile is launched either horizontally or at an angle. Angles between 0° and 90° may be selected. Varying the tension in the spring can also enable 3 different launch velocities to be chosen. The three settings propel the projectile approximately 1.1 m, 2.3 m and 4.5 m when the launch angle is 45° . Clear ratchet points means that the spring tensions are highly reproducible. The standard deviation of the trajectory ranges for a launch angle of 45° is less than 1%. Since the projectile launcher is so secured that the axis about which the barrel is rotated to set the angle coincides with the center of the projectile as it leaves the barrel, the launch height is independent of the launch angle.

3. Operation and maintenance

- The projectile launcher can be mounted on its holder 1002655 or on the ballistic pendulum 1002656. In this case only the holder is described. A separate instruction sheet is available for the ballistic pendulum.
- Holder 1002655 is screwed by means of its clamp to a stable working surface. Then the launcher is attached to the holder as shown in Fig. 1. The launch angle can be adjusted with the help of the angle scale (3).
- Projectiles should always be loaded when the spring is not under tension by placing the sphere in loosely through the front of the plastic cylinder within the device. The sphere is then pushed down inside the barrel using the ramrod until the desired spring tension has been reached. The ramrod should not be removed too quickly, otherwise the suction its removal produces may pull the sphere out with it. The position of the sphere may only be checked using the observation holes. Never look into the barrel!
- Before launching, ensure that no one is in the way of the trajectory. To launch, the cord of the launching lever is given a short pull perpendicular to the lever.
- The projectile launcher requires no maintenance and may not be oiled or otherwise made dirty. It may be cleaned using acetone, ethanol (white spirit) or petroleum ether except in the vicinity of the angle scale. Avoid dipping the equipment in water since this may cause the spring to rust.
- The angle scale can be calibrated, for example, after dismantling the projectile launcher. To do this, the launcher is placed in a vertical position (90°) and it should be observed whether a projectile launched directly upwards like this falls straight back into the aperture of the barrel (in order that the projectile is not damaged by hitting sharp edges, it should be stopped by hand after a short distance). If the sphere does not fall directly back into the barrel, the launch angle should be corrected and another experiment attempted. Once the precise vertical position is found by this means, the securing screws for the scale can be loosened slightly and the scale adjusted so that it shows 90°, then it is secured firmly once again.
- The projectile launcher should be stored with the spring loose and the knurled screw (11) only slightly tightened.

4. Experiment procedure and evaluation

4.1 Experiment setup

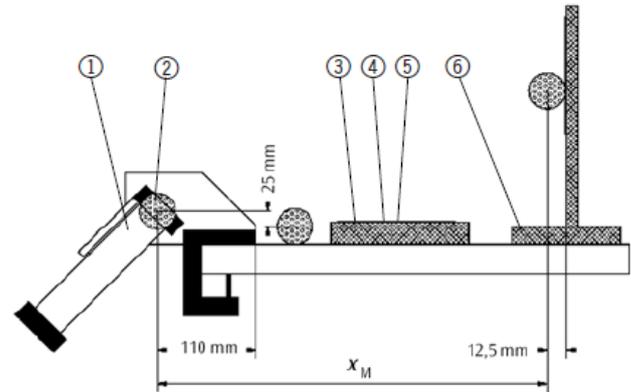


Fig. 2: Experiment setup, key: (1) Projectile launcher, (2) Launch position of projectile, (3) Book or board etc. 25 mm high, (4) Paper, (5) Carbon, paper (6) e.g. Easel with whiteboard

- One possible experiment setup is shown schematically in Fig. 2 (not to scale). If the projectile is to land directly on the board (or book), it should be noted that the launch height is $y_0 = 2.5$ cm.
- When launching against a vertical wall the radius of the projectile sphere (1.25 cm) should be subtracted from the horizontal distance from the “launch point to the wall” to obtain the distance measurement x_M . The height measurement y_M is derived from the distance of the “point of impact on the wall to the table top” minus 3.75 cm (2.5 + 1.25).

4.2 Experiment procedure

- It is practical when performing experiments to note the experiment number, the spring tension (1, 2 or 3), the launch angle and the values x_M and y_M . Example:

No.	Spring tension	Launch angle φ	Projectile distance x_M in cm	Target height y_M in cm
1	1	45°	0.2	0.166
2	1	45°	0.4	0.262
3	1	45°	0.6	0.293
4	1	45°	0.7	0.274
5	1	45°	0.8	0.244
6	1	45°	1.09	0.126
7	1	45°	1.14	0
8	2	45°	2.34	0
9	3	45°	4.60	0

4.3 Experimental evaluation

- It is practical to select the origin of the coordinate system to coincide with the mid-point of the projectile as it exits the barrel. Then:

$$v_x = v_0 \cos \varphi \quad (1)$$

$$v_y = v_0 \sin \varphi \quad (2)$$

$$y = v_y t - \frac{1}{2} g t^2 \quad (3)$$

$$x = v_x t \quad (4)$$

- From Eq. 4 it follows that $t = x / v_x$, where time can be canceled out using Eq. 3.
- If the values v_x and v_y are eliminated from the resulting equation using Eqs. 1 and 2 then

$$y = x \tan \varphi - x^2 \frac{g}{2v_0^2 \cos^2 \varphi} \quad (5)$$

emerges as the equation for the trajectory of the projectile. In this equation, only the initial launch velocity v_0 is unknown, since distances x and y have been measured during the course of the experiments. If v_0 is calculated for each of the experiments, the results are as follows:

No.	v_0 in m/s
1	3.38
2	3.37
3	3.39
4	3.36
5	3.36
6	3.35
7	3.36
8	4.80

- The launch velocity for the lowest spring tension is therefore approximately 3.37 m/s. This means the trajectory can be calculated using Eq. 5 and the individual measurements plotted against one another. The result is shown in Fig. 3.

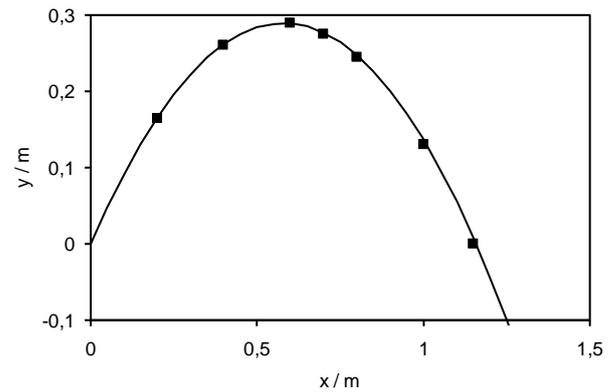


Fig. 3 Comparison of measurements and calculated curve, x = horizontal projectile distance, y = vertical height, symbols = measured values, line = Equation 5