Projectile motion

The goal of this experiment is to understand the general laws of projectile motion.

Physics > Mechanics > Dynamics & Motion

Difficulty level	Group size	Preparation time	Execution time
easy	2	45+ minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/606595daf1639a0003d1a783

General information

Application

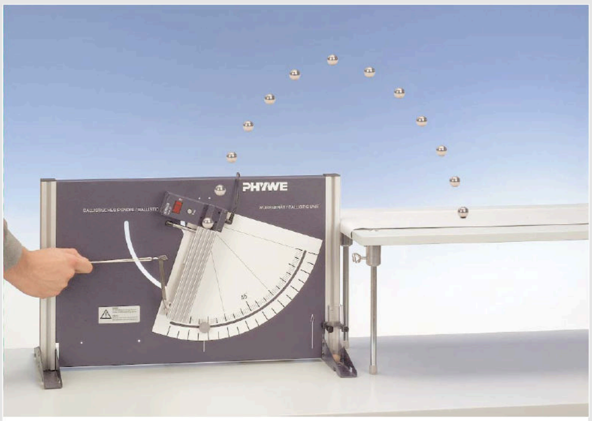

Fig. 1: Experimental setup for measuring the maximum range of a projectile with additional equipment to measure the initial velocity.

An understanding of general projectile motion is very important for fields such as ballistics.

Additionally, such an understanding gives first insights into the laws of gravity.

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Other information (1/2)

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Prior knowledge

There is no prior knowledge necessary.

Main principle

A steel ball is fired by a spring at different velocities and at different angles to the horizontal. The relationships between the range, the height of projection, the angle of inclination, and the firing velocity are determined.

Other information (2/2)

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Learning objective

The goal of this experiment is to understand the general laws of projectile motion.

Tasks

1. To determine the range as a function of the angle of inclination.
2. To determine the maximum height of projection as a function of the angle of inclination.
3. To determine the (maximum) range as a function of the initial velocity.

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Theory (1/2)

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If a body of mass m moves in a constant gravitational field (gravitational force $m\vec{g}$), the motion lies in a plane (see Fig. 2).

If the coordinate system is laid in this plane (x-y-plane, Fig. 2) and the equation of motion:

$m\frac{d^2}{dt^2}\vec{r}(t) = m\vec{g}$

where $\vec{r} = (x, y);\ \vec{g} = (0,\ \ -g)$

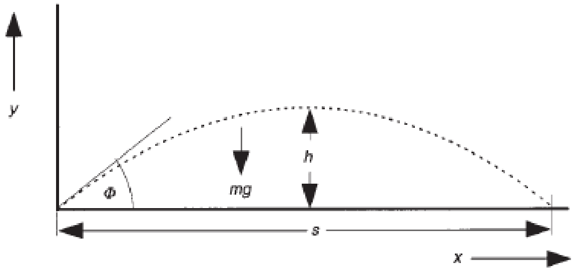

Fig. 2: Movement of a mass point under the effect of gravitational force.

Theory (2/2)

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is solved, then, with the initial conditions

$r(0) = 0$ and $\vec{v}(0) = (v_0 \cos\phi,\ v_0 \sin\phi)$

we obtain the coordinates as a function of time t:

$x(t) = v_0 \cdot \cos\phi \cdot t \qquad y(t) = v_0 \cdot \sin\phi \cdot t - \frac{1}{2}gt^2$

From this, the maximum height of projection h is obtained as a function of the angle of projection ϕ:

$h = \frac{v_0^2}{2g}\sin^2\phi$

and the maximum range is $\quad s = \frac{v_0^2}{g}\sin(2\phi)$

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Equipment

Position	Material	Item No.	Quantity
1	Ballistic Unit	11229-10	1
2	Steel ball, d = 19 mm	02502-01	2
3	Scale, l = 750 mm, on rod	02200-00	1
4	Barrel base expert	02004-00	1
5	Speed measuring attachment	11229-30	1
6	Power supply 5 VDC/4 A, according EN61558-2-16	12651-99	1
7	Recording paper, 1 roll,25 m	11221-01	1
8	Two-tier platform support	02076-03	1

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Setup and Procedure

Setup and procedure (1/2)

The ballistic unit is adjusted. The scale is set to read 90° and a ball is fired upwards (setting 3) and is caught in the hand. The support base adjusting screws are turned until a vertical projection is obtained.

The initial velocities of the ball corresponding to the three tension stages of the firing spring can be determined using the speed measuring attachment, or from the maximum height for a vertical projection from the expression $v_0 = \sqrt{2gh}$. The initial velocities may vary greatly from unit to unit.The 2-tier platform support (02076-01) is used for determining the range.

To mark the points of impact, the recording strip is secured to the bench with adhesive tape. It is best to measure the long ranges before the short ones (secondary impact points!) and to mark the primary impact points with a felt pen.

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Setup and procedure (2/2)

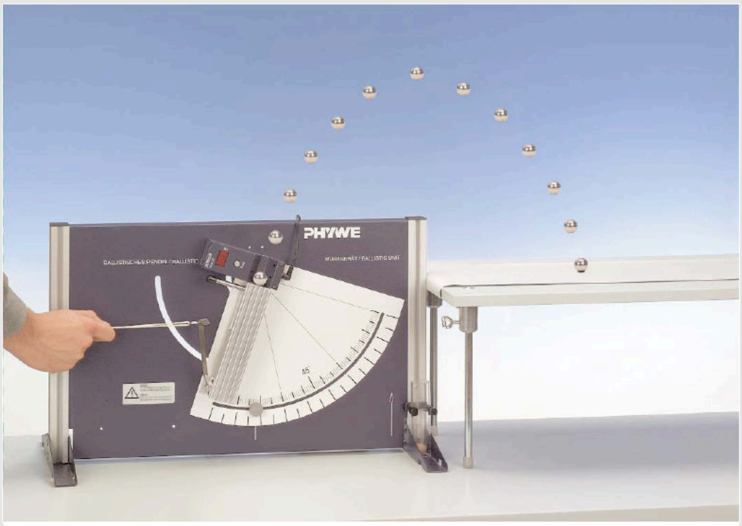

Fig. 3: Experimental setup

The distance from the ballistic unit is frequently checked with the meter scale during the test. An empty box can be placed behind the bench to catch the balls.

To measure the height of projection the meter scale is clamped in the barrel base and moved parallel to the plane of projection. The empty box is again used to catch the balls. The heights

Evaluation

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Evaluation (1/3)

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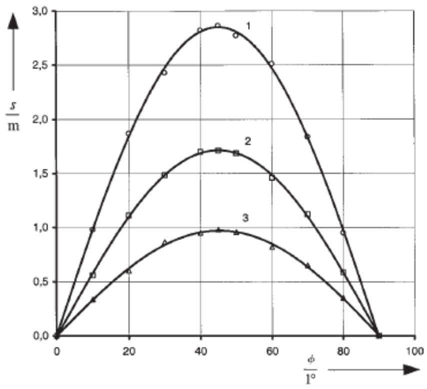

Fig. 3: Maximum range s as a function of the angle of inclination ϕ for different initial velocity v_0: curve 1: $v_0 = 5.3\,\mathrm{m/s}$; curve 2: $v_0 = 4.1\,\mathrm{m/s}$; curve 3: $v_0 = 3.1\,\mathrm{m/s}$.

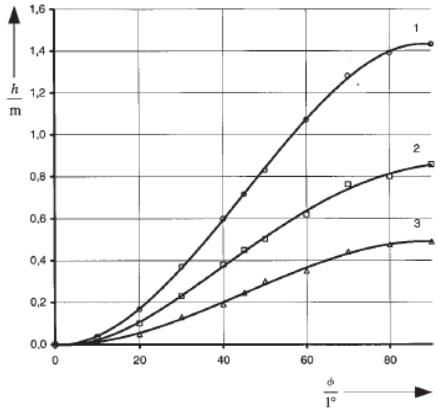

Fig. 4: Maximum height of projection h as a function of the angle of inclination ϕ for the initial velocities as in Fig. 1.

Evaluation (2/3)

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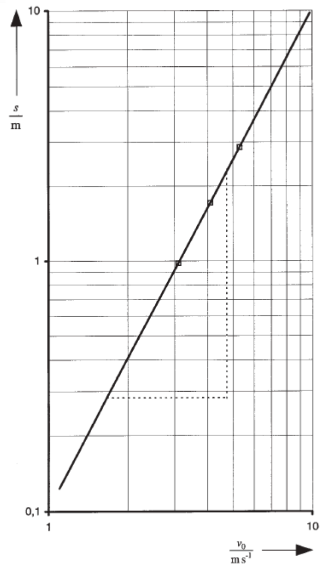
The maximum range s is reached at an inclination angle of 45° for every initial velocity. Fig. 5 shows the range s for an angle of 45° plotted against different initial velocities v_0.

By choosing a logarithmic scale, a regression line can be applied to the measured data and used to determine the maximum range for arbitrary initial velocities.

Fig. 5: Maximum range s as a function of the initial velocity v_0 with a fixed angle of inclination $\phi = 45°$.



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Evaluation (3/3)

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To ensure an accurate determination of the initial velocity, the time taken for the ball to cover the measuring distance must be taken into account. Depending on the angle of inclination, the ball already leaves the light barrier with a reduced velocity. If v_{exp} is the experimentally determined initial velocity we obtain as actual initial velocity

$$v_0 = \sqrt{v_{\text{exp}}^2 + gd\sin\phi}$$

where d is the distance between the striker and the centre between the light barriers.

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