

## Inclined plane: force along the plane and force normal to the plane

### Objects of the experiment

- Measuring the force  $F_1$  along the plane and the force  $F_2$  normal to the plane of a body on an inclined plane as a function of the angle of inclination  $\alpha$ .
- Comparing the measured forces  $F_1$  and  $F_2$  with the forces calculated through vectorial resolution of the force of gravity  $G$ .

### Principles

The motion of a body on an inclined plane can be described most easily when the force exerted by the weight  $G$  (force of gravity) on the body is vectorially resolved into a force  $F_1$  along the plane and a force  $F_2$  normal to the plane. The force along the plane acts parallel to a plane inclined at an angle  $\alpha$ , and the force normal to the plane acts perpendicular to the plane (see Fig. 1). For the absolute values of the forces, we can say

$$F_1 = G \cdot \sin \alpha \quad (I)$$

and

$$F_2 = G \cdot \cos \alpha \quad (II)$$

The experiment verifies this resolution. Here, the two forces  $F_1$  and  $F_2$  are measured for various angles of inclination  $\alpha$  using precision dynamometers. We can vary the angle of inclination  $\alpha$  by moving a support with the height  $h = 5$  cm to various distances  $s$  between the pivot of the inclined plane and the support point (see Fig. 1). We can say

$$\sin \alpha = \frac{h}{s} \quad (III)$$

and

$$\cos \alpha = \sqrt{1 - \left(\frac{h}{s}\right)^2} \quad (IV)$$

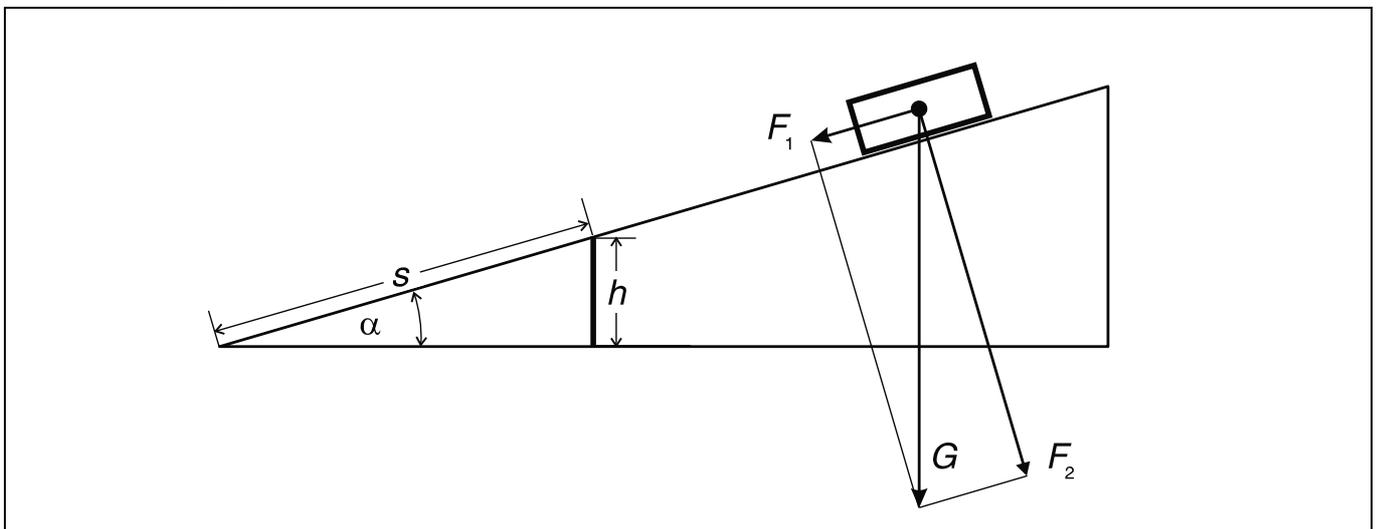
(I) and (III) give us the force along the plane

$$F_1 = G \cdot \frac{h}{s} \quad (V)$$

and (II) and (IV) give us the force normal to the plane

$$F_2 = G \cdot \sqrt{1 - \left(\frac{h}{s}\right)^2} \quad (VI)$$

Fig. 1 Vectorial resolution of the force of gravity  $G$  into the force  $F_1$  along the plane and the force  $F_2$  normal to the plane on an inclined plane



**Apparatus**

- 1 Inclined plane with trolley and screw model . . . . . 341 21
- 1 Precision dynamometer, 1.0 N . . . . . 314 141

**Measuring example**

$h = 5 \text{ cm}$   
 $G = 1.07 \text{ N}$

Table 1: Position  $s$  of ramp support and forces  $F_1$  and  $F_2$  on the inclined plane

$\frac{s}{\text{cm}}$	$\frac{F_1}{\text{N}}$	$\frac{F_2}{\text{N}}$
50	0.10	1.01
40	0.12	0.98
30	0.18	0.97
20	0.27	0.97
15	0.35	0.95
10	0.59	0.81

**Setup and carrying out the experiment**

**a) Correcting the zero point of the dynamometer**

- Lay out dynamometer  $F_1$  horizontally and correct the zero point.
- Hold dynamometer  $F_2$  vertically downward and correct the zero point.

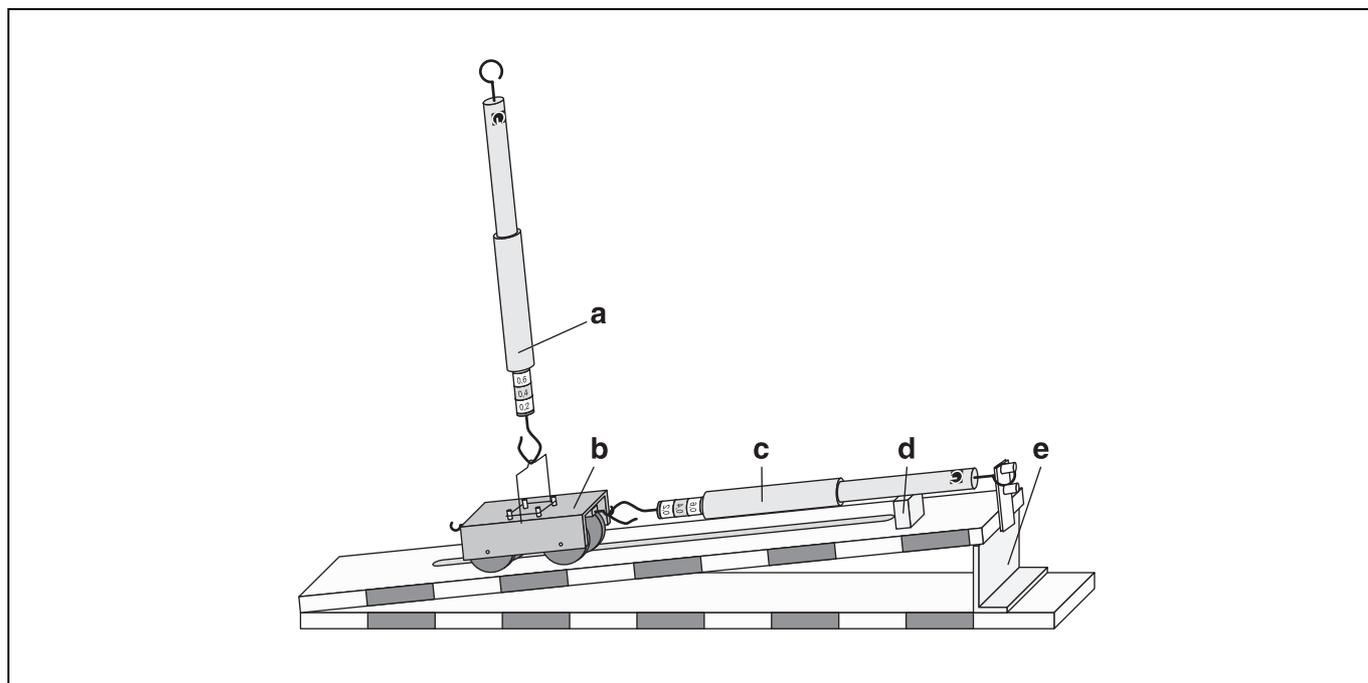
**b) Determining the force of gravity**

- Suspend the trolley freely from dynamometer  $F_2$  using the folding metal hook and determine the weight  $G$  of the trolley.

**c) Determining the force along the plane and the force normal to the plane**

- Set up the inclined plane and position the support (e) at  $s = 50 \text{ cm}$ .
- Place the trolley (b) on the inclined plane and hook it to dynamometer  $F_1$  (c); support the dynamometer with block (d).
- Carefully arrange dynamometer  $F_2$  (a) as nearly perpendicular as possible to the inclined plane and lift the trolley until it is just barely touching the plane surface.
- Read off and write down forces  $F_1$  and  $F_2$ .
- Move the ramp support (b) to the positions  $s = 40, 30, 20, 15$  and  $10 \text{ cm}$  one after another; each time arrange the dynamometer perpendicular to the inclined plane and read off and write down forces  $F_1$  and  $F_2$ .

Fig. 2 Experiment setup for determining the force along the plane and force to the plane



## Evaluation and results

Tables 2 and 3 enable a comparison of the measured forces and those calculated using (V) and (VI). Fig. 3 shows the results plotted in a graph.

For the force normal to the plane we see a systematic deviation between the measured and calculated values. This is due to the fact that the trolley is still partially supported when the force is measured.

Table 2: Measured and calculated force  $F_1$  along the plane

$\frac{s}{\text{cm}}$	$\frac{F_1}{\text{N}}$ measured	$\frac{F_2}{\text{N}}$ calculated
50	0.09	0.107
40	0.12	0.134
30	0.18	0.178
20	0.27	0.268
15	0.33	0.357
10	0.53	0.535

Table 3: Measured and calculated force  $F_2$  normal to the plane

$\frac{s}{\text{cm}}$	$\frac{F_1}{\text{N}}$ measured	$\frac{F_2}{\text{N}}$ calculated
50	1.01	1.065
40	0.98	1.062
30	0.97	1.055
20	0.97	1.036
15	0.95	1.009
10	0.81	0.927

Fig. 3 Measured (solid line) and calculated (points) values for the force  $F_1$  along the plane and the force  $F_2$  normal to the plane

