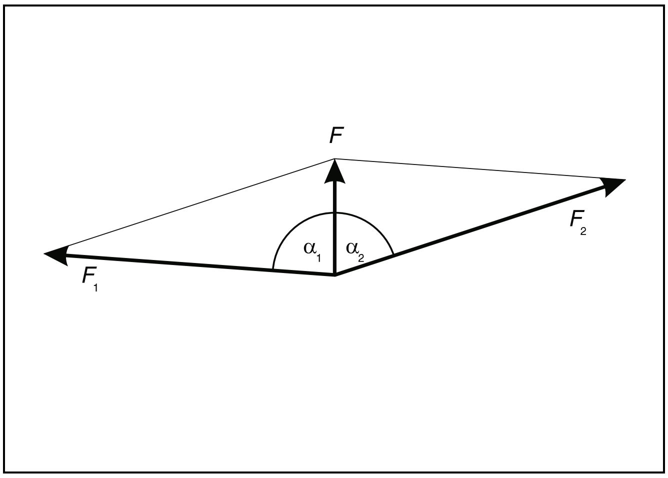
Composition and resolution of forces

Objects of the experiment

- Composition of two non-parallel forces $\mathbf{F}_1$ and $\mathbf{F}_2$ acting on a point to form a force $\mathbf{F}$.
- Resolution of a force $\mathbf{F}$ acting on a point into two non-parallel forces $\mathbf{F}_1$ and $\mathbf{F}_2$.
- Determining the absolute values of the component forces as a function of their directions.



Composition and resolution of forces

Principles

The nature of force as a vectorial quantity can be easily and clearly verified in experiments on the adhesive magnetic board. The point of application of all forces is positioned at the midpoint of the angular scale on the adhesive magnetic board, and all individual forces and the angles between the forces are measured.

In this experiment a given vertical force $\mathbf{F}$ is compensated by the spring forces $\mathbf{F}_1$ and $\mathbf{F}_2$ of two dynamometers which are arranged at an angle of α_1 and α_2 to the vertical, respectively. The absolute values of the component forces F_1 and F_2 are determined as a function of α_1 and α_2.

To illustrate the vectorial composition

$$\mathbf{F}_1 + \mathbf{F}_2 = \mathbf{F} \quad \text{(I)}$$

and the resolution

$$\mathbf{F} = \mathbf{F_1} + \mathbf{F_2} \quad \text{(II)}$$

the underlying parallelogram of forces can be graphically developed. In addition, the experiment also confirms the relationship

$$F = F_1 \cdot \cos\alpha_1 + F_2 \cdot \cos\alpha_2 \quad \text{(III)}$$

for the vertical vector component and the relationship

$$0 = F_1 \cdot \sin\alpha_1 + F_2 \cdot \sin\alpha_2 \quad \text{(IV)}$$

for the horizontal component.

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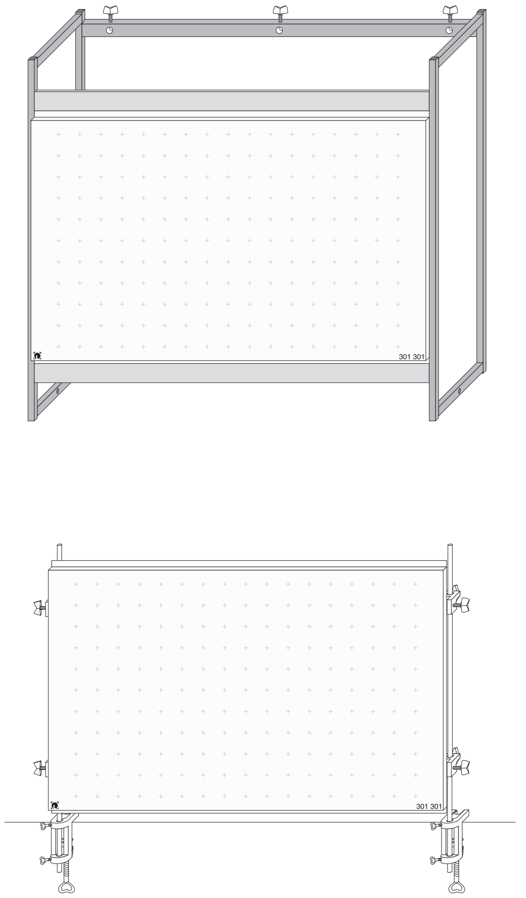
Apparatus

1 Adhesive magnetic board	301 301
2 Round dynamometers 5 N	314 215
1 Magnetic base with hook	301 331
1 Helical spring, 5 N; 0.25 N/cm	352 08
1 Steel tape measure, 2 m	311 77
1 Set of 12 weights, 50 g each	342 61
1 Demonstration-experiment frame	301 300
or	
4 Leybold multiclamps	301 01
4 Metal plates	200 65 559
2 Stand rods 100 cm	300 44
2 Simple bench clamps	301 07

Additionally recommended:

1 Thread

Fig. 1 Setting up the adhesive magnetic board in the demonstration-experiment frame (top), with stand material (bottom)



Setup

– Set up the adhesive magnetic board either in the demonstration experiment frame or with stand material, as described in the instruction sheet (see Fig. 1).

Carrying out the experiment

a) Composition of forces:

– Mount the magnetic base with hook above the midpoint of the angular scale and hang the helical spring from the hook.
– Mount the two round dynamometers and hang their hooks in the eyelet of the helical spring.
– By moving and turning the round dynamometers, extend the helical spring downward until the eyelet is at the midpoint of the scale. Make sure that the threads of the round dynamometers always run tangential (see Fig. 2).
– Read off and write down the forces F_1 and F_2 of the round dynamometers and angles α_1 and α_2 of the threads from the vertical.
– Remove one round dynamometer and use the other to deflect the spring vertically downward as far as the midpoint of the angular scale once more (see Fig. 3).
– Read off and write down force F_R of the round dynamometer.

Forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$ together give us the “resulting” force $\boldsymbol{F}_R$.

– Repeat the experiment with different angles α_1 and α_2 and forces F_1 and F_2

b) Resolution of forces:

Tie loops in the two ends of one thread.

– Mount a round dynamometer on the adhesive magnetic board, hang one loop in the hook of the dynamometer and suspend five weights from the thread (see Fig. 4).
– Read off the force F_G which corresponds to the gravitational force of the five weights from the dynamometer and write this down.
– Hang the hook of the second round dynamometer in the top loop of the thread.
– Move and turn the two dynamometers so that the top loop is at the midpoint of the angular scale. Make sure that the threads of the round dynamometers run tangentially.
– Read off and write down the forces F_1 and F_2 of the round dynamometers and angles α_1 and α_2 of the threads from the vertical (Fig. 5).
The “gravitational force” $\boldsymbol{F}_G$ can be resolved into the two forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$.
– Repeat the experiment with different angles α_1 and α_2 and forces F_1 and F_2

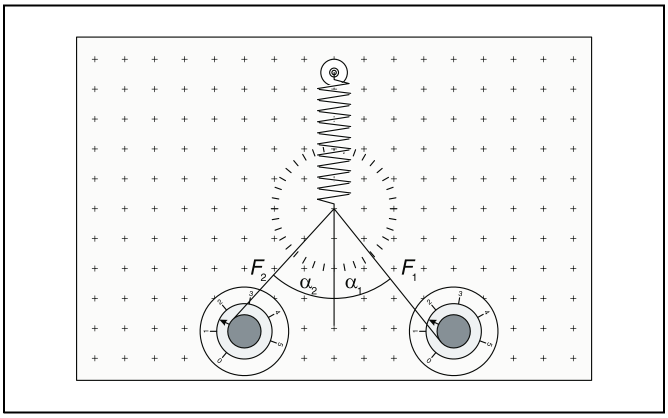
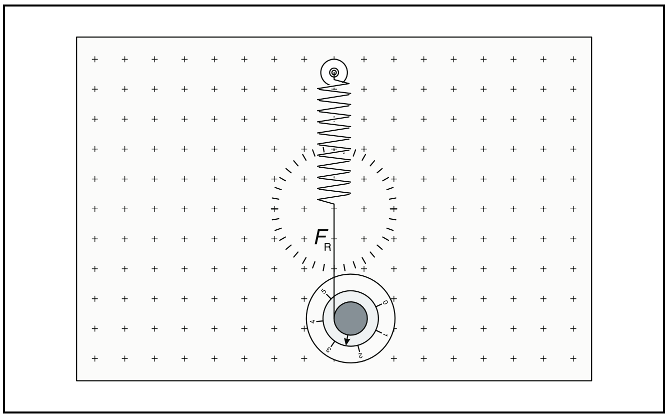


Fig. 2 Determining the forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$

Fig. 3 Determining the “resulting” force F_R.



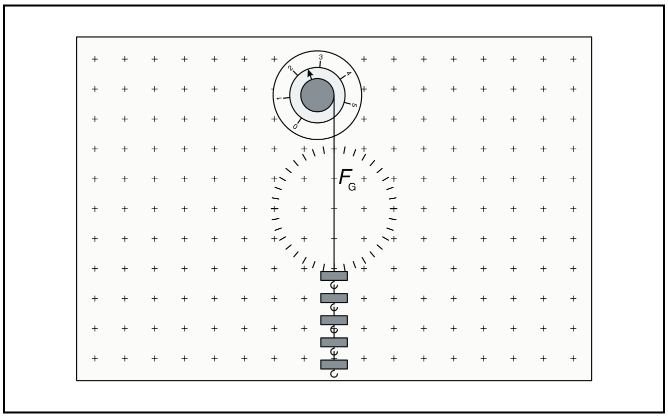
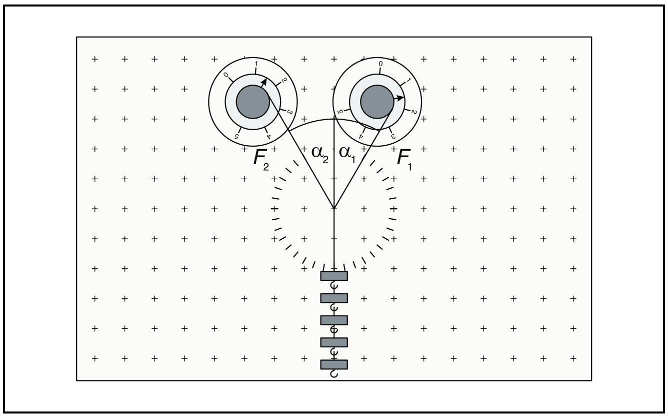


Fig. 4 Determining the “force of gravty” F_G.

Fig. 5 Determining the component forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$



Measuring example

a) Composition of forces:

Table 1: Absolute values F_1, F_2 and angles α_1, α_2 of the component forces and absolute value F_R of the composite force.

$\frac{F_1}{N}$	α_1	$\frac{F_2}{N}$	α_2	$\frac{F_R}{N}$
1.6	–40°	1.6	40°	2.5
2.0	–30°	1.3	52.5°	2.5

b) Resolution of forces:

Table 2: Absolute value F_G of the resolved force and absolute values F_1, F_2 and anlges α_1, α_2 of the component forces.

$\frac{F_G}{N}$	$\frac{F_1}{N}$	α_1	$\frac{F_2}{N}$	α_2
2.5	1.4	–30°	1.4	30°
2.5	1.6	–40°	1.6	40°
2.5	1.9	–50°	1.9	50°
2.5	2.3	–10°	0.4	60°

Evaluation

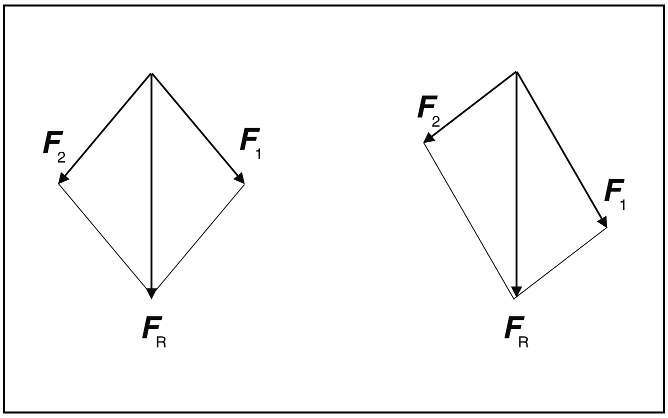
a) Composition of forces:

Fig. 6 shows the vector arrows of the component forces $\boldsymbol{F}_1$ und $\boldsymbol{F}_2$ drawn to scale and supplemented to complete the parallelogram. The diagonal of the parallelogram agrees (in close approximation) with the vector arrow of force $\boldsymbol{F}_R$. Table 3 shows the vertical and horizontal component forces calculated with (III) and (IV).

Table 3: Absolute values F_1, F_2 and angles α_1, α_2 of the component forces and absolute value F_R of the composite force.

$\frac{F_1 \cos\alpha_1 + F_2 \cos\alpha_2}{N}$	$\frac{F_R}{N}$	$\frac{F_1 \sin\alpha_1 + F_2 \sin\alpha_2}{N}$
2.45	2.5	0
2.52	2.5	0.03

Fig. 6 Graphical representation of the composition of the component forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$ to produce the force $\boldsymbol{F}_R$.



b) Resolution of forces:

Fig. 7 is a graphical representation of the resolution of the "force of gravity" F_G into the component forces F_1 and F_2. The diagonal of the parallelogram agrees (in close approximation) with the vector arrow of force $\boldsymbol{F}_G$. Table 4 shows the vertical and horizontal component forces calculated with (III) and (IV).

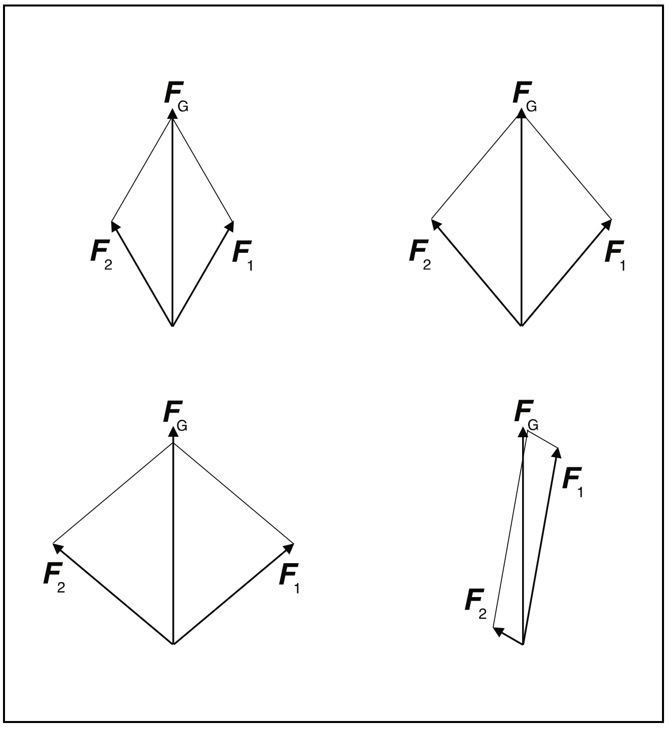


Fig. 7 Graphical representation of the resolution of force $\boldsymbol{F}_G$ into the component forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$.

Table 4: Absolute value F_G of the resolved force and absolute values F_1, F_2 and angles α_1, α_2 of the component forces.

$\frac{F_G}{N}$	$\frac{F_1 \cos\alpha_1 + F_2 \cos\alpha_2}{N}$	$\frac{F_1 \sin\alpha_1 + F_2 \sin\alpha_2}{N}$
2.5	2.42	0
2.5	2.45	0
2.5	2.44	0
2.5	2.47	–0.05

Results

Any two arbitrary non-parallel forces $\boldsymbol{F}_1$ und $\boldsymbol{F}_2$ acting on a point can be expressed as a single, equivalent force $\boldsymbol{F}$. Any arbitrary force $\boldsymbol{F}$ can be resolved into two non-parallel forces $\boldsymbol{F}_1$ and $\boldsymbol{F}_2$ acting on a point.