

Related topics

Velocity, acceleration, force, acceleration due to gravity.

Principle and task

The distance-time law, the velocity-time law, and the relationship between mass, acceleration and force are determined with the aid of the air track rail for uniformly accelerated motion in a straight line.

Equipment

Air track rail	11202.17	1
Blower	13770.93	1
Pressure tube, l = 1.5 m	11205.01	1
Glider f. air track	11202.02	1
Screen with plug, l = 100 mm	11202.03	1
Hook with plug	11202.07	1
Starter system	11202.13	1
Magnet w. plug f. starter system	11202.14	1
Precision pulley	11201.02	1
Stop, adjustable	11202.19	1
Fork with plug	11202.08	1
Endholder for air track rail	11202.15	1
Light barrier, compact	11207.20	4
Timer 4-4	13605.99	1
Slotted weight, 10 g, black	02205.01	8
Slotted weight, 50 g, black	02206.01	4
Weight holder 1 g	02407.00	1
Silk thread, 200 m	02412.00	1
Slotted weight, 1 g, natur.colour	03916.00	20
Portable balance Mod. LS2000	46002.93	1
Barrel base	02006.10	4
Support rod -PASS-, square, l = 400 mm	02026.55	4

Right angle clamp -PASS-	02040.55	4
Connecting cord, 1000 mm, red	07363.01	4
Connecting cord, 1000 mm, yellow	07363.02	4
Connecting cord, 1000 mm, blue	07363.04	4
Connecting cord, 2000 mm, yellow	07365.02	4
Connecting cord, 2000 mm, black	07365.05	4

Problems

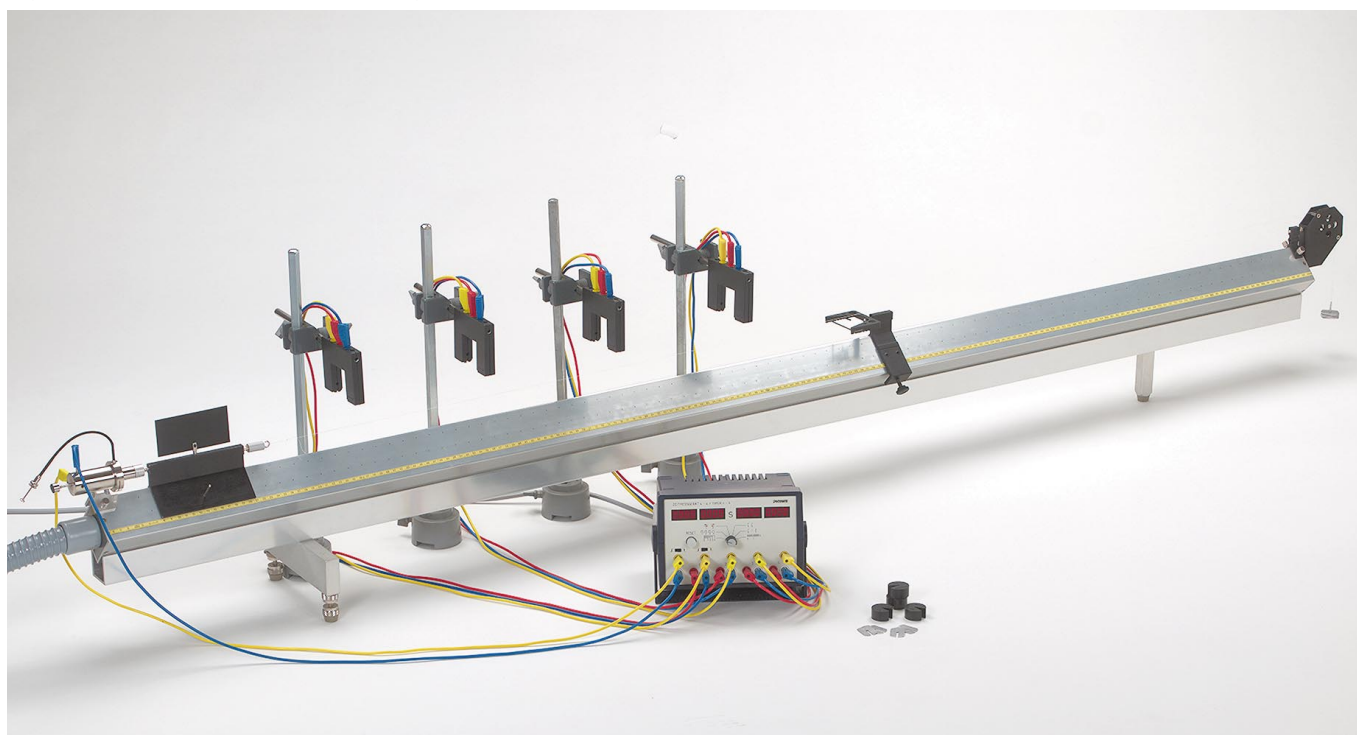
Determine the following for uniformly accelerated motion in a straight line:

1. Distance travelled as function of time
2. Velocity as a function of time
3. Acceleration as a function of the accelerated mass
4. Acceleration as a function of force.

Set-up and procedure

The experimental set-up is shown in Fig. 1. The starting device is mounted in such a manner that triggering unit releases the glider without giving it an initial impulse when triggered. It is connected with the two "Start" jacks on the timer; when connecting it, ensure that the polarity is correct. The red jack on the starting device is connected with the yellow jack of the timer. The four light barriers are connected in sequence from left to right with the control input jacks "1" to "4" on the timer. Connect jacks having the same colour when doing so. The mass of the glider can be altered by adding slotted weights. Always place weights having the same mass on the glider's weight-bearing pins, as optimum gliding properties are provided only with symmetrically loading. The accelerating force acting on the glider can be varied by changing the num-

Fig. 1. Experimental set-up for investigation of uniformly accelerated motion.



ber of weights (on the weight holder) acting via the silk thread and the precision pulley. Determine the mass of the glider without the supplementary slotted weights by weighing it. Position the four light barriers in a manner such that they divide the measuring distance into approximately equal segments. Place the last light barrier such that the glider with screen passes through it before the accelerating weight touches the floor. Position the adjustable stop with the fork and plug on the track in such a manner that the glider is gently braked by the rubber band just before the accelerating weight touches the floor. Measure the distances travelled $s_1 \dots s_4$ between the front edge of the screen from the starting position to the respective light barriers exactly for the evaluation. Perform all subsequent measurements without changing the light barriers' positions.

After measuring the times $t_1 \dots t_4$ required for the four distances travelled $s_1 \dots s_4$ with the timer in the "s(t)" operating mode (see operating instructions), determine the corresponding velocities with the "v(t)" operating mode. While doing so, the shading times $\Delta t_1 \dots \Delta t_4$ of the four light barriers are measured; from them the mean values of the velocity for the corresponding distance travelled are determined with reference to the screen's length. These mean velocities correspond to the instantaneous velocities represented by the times $t'_1 \dots t'_4$ in accordance with the following:

$$t'_n = t_n + \frac{\Delta t_n}{2}$$

To determine the acceleration as a function of the mass, increase the mass of the glider progressively by 20 g increments (10 g on each side), and measure the instantaneous velocity at a predetermined position.

In determining the acceleration as a function of force, the total mass remains constant. Successively transfer 2 g (1 g from each side) from the glider to the weight holder and measure the instantaneous velocity at a fixed position. The accelerated mass must not exceed 20 g.

Before beginning with the measurements, it is advisable to check the track's adjustment.

Theory and evaluation

Newton's equation of motion for a mass point of mass m to which a force \vec{F} is applied is given by the following:

$$m \cdot \vec{a} = \vec{F},$$

where

$$\vec{a} = \frac{d^2 \vec{r}}{dt^2}$$

is the acceleration.

The velocity v obtained by application of a constant force is given as a function of the time t by the expression

$$\vec{v}(t) = \frac{\vec{F}}{m} t$$

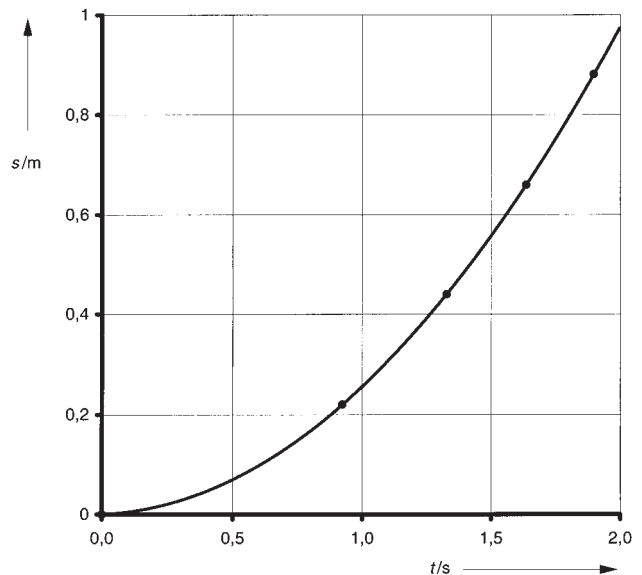
for

$$\vec{v}(0) = 0.$$

Assuming that

$$\vec{v}(0) = 0; \quad \vec{r}(0) = 0$$

Fig. 2. The distance travelled s plotted as a function of the time t ; $m_1 = 10$ g, $m_2 = 201$ g.



the position of \vec{r} of the mass point is

$$\vec{r}(t) = \frac{1}{2} \frac{\vec{F}}{m} \cdot t^2. \quad (0)$$

In the present case the motion is unidimensional and the force produce by a weight of m_1 is

$$|\vec{F}| = m_1 \cdot |\vec{g}| \equiv m_1 \cdot g$$

where g is the acceleration of gravity. If the total mass of the glider is m_2 the equation of motion is given by

$$(m_2 + m_1) \cdot |\vec{a}| = m_1 \cdot g; \quad (1)$$

The velocity is

$$|\vec{v}(t)| \equiv v = \frac{m_1 \cdot g}{m_1 + m_2} \cdot t \quad (2)$$

and the position is

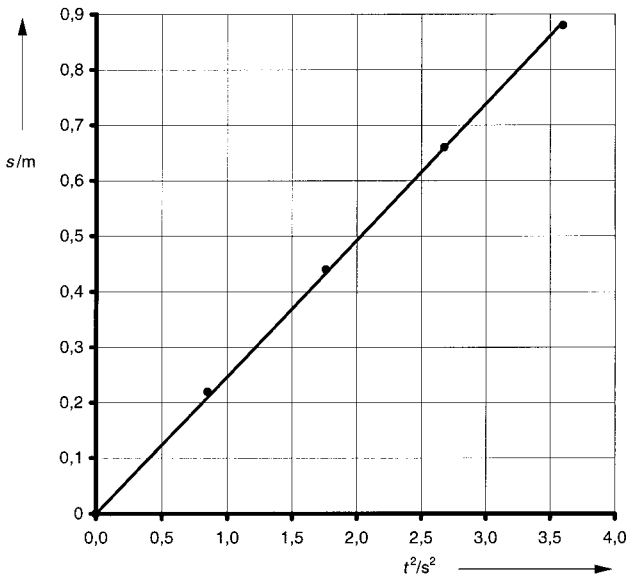
$$|\vec{r}(t)| \equiv s(t) = \frac{1}{2} \frac{m_1 \cdot g}{m_1 + m_2} \cdot t^2. \quad (3)$$

The evaluation is now illustrated by the following sample measurements. For all the measurements the distances of the four light barriers from the starting point were 22 cm, 44 cm, 66 cm and 88 cm, respectively. The mass of the glider including the screen, hooks and support magnet was 201 g.

Fig. 2 shows the distance travelled s as a function of the time t ($m_1 = 10$ g, $m_2 = 201$ g). In Fig. 3 the distance travelled is illustrated as a function of t^2 for the same measured values. A linear correlation results, as was expected from the theory. The slope is 0.246 m/s^2 and the following is thus obtained from Equation (0):

$$F = 2 \cdot (m_1 + m_2) \cdot 0.246 \text{ ms}^{-2} = 0.104 \text{ N}.$$

Fig. 3. The same measurement as in Fig. 2 plotted against t^2 .



As a good approximation, this corresponds to the weight force of the mass m_1 (0.010 kg); $F = m_1g = 0.0981$ N.

Under the same experimental conditions, the correlation $v(t)$ presented in Fig. 4 is obtained by measuring the shading time of the four light barriers due to the screen, which has a length of 10 cm. The slope of the compensation line drawn through the origin correspond to the acceleration a in this case. For the presented sample measurement $a = 0.473$ ms^{-2} . We expect a to be equal to

$$a = \frac{m_1g}{m_1 + m_2} = 0.465 \frac{m}{s^2},$$

This value agrees with the acceleration determined using Fig. 4. very well.

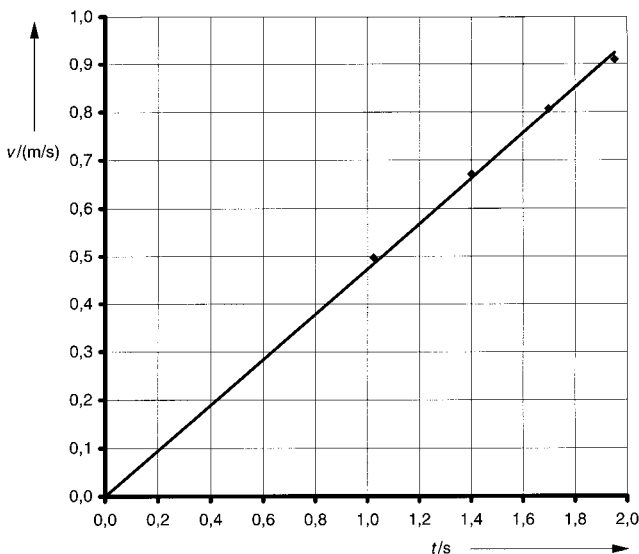
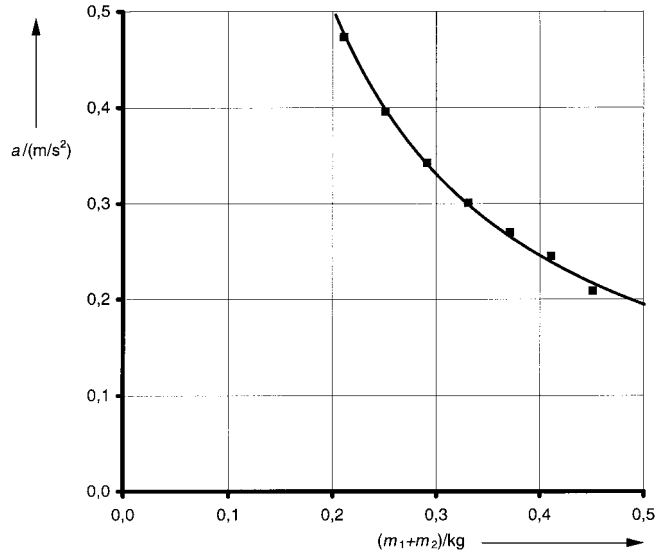


Fig. 4. The velocity v plotted as a function of the time t ; $m_1 = 10$ g, $m_2 = 201$ g.

Fig. 5. The acceleration a as a function of the inert mass $m_1 + m_2$ measured at a constant accelerating (weight) force due to the mass $m_1 = 10$ g.



In the same manner as shown in the example in Fig. 4, the accelerations are measured in two measuring series as a function of the inert mass $m_1 + m_2$ ($F = \text{constant}$) and as a function of the force ($m_1 + m_2 = \text{constant}$). In the process, one can make the evaluation work much easier by using a computer with a spreadsheet program (e.g. Microsoft Excel®).

Fig. 5 shows the acceleration due to the mass $m_1 = 10$ g as a function of the inert mass. If the acceleration is plotted against the reciprocal of the inert mass using the same measured values, a linear correlation results, as expected (Fig. 6). The slope of the straight lines should be equal to the accelerating force,

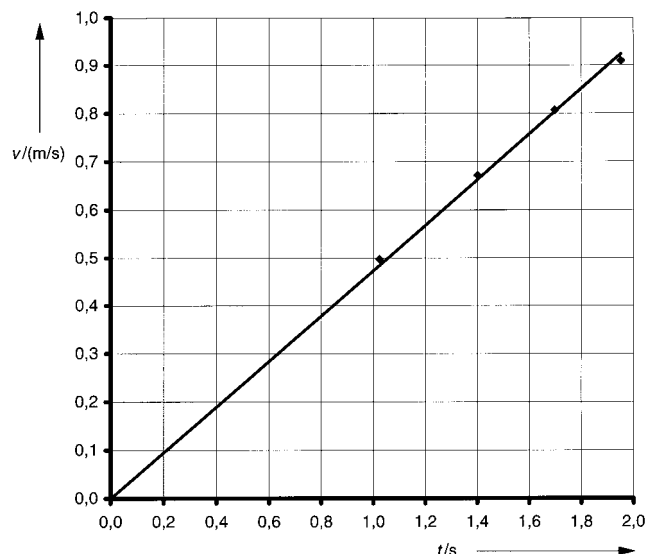
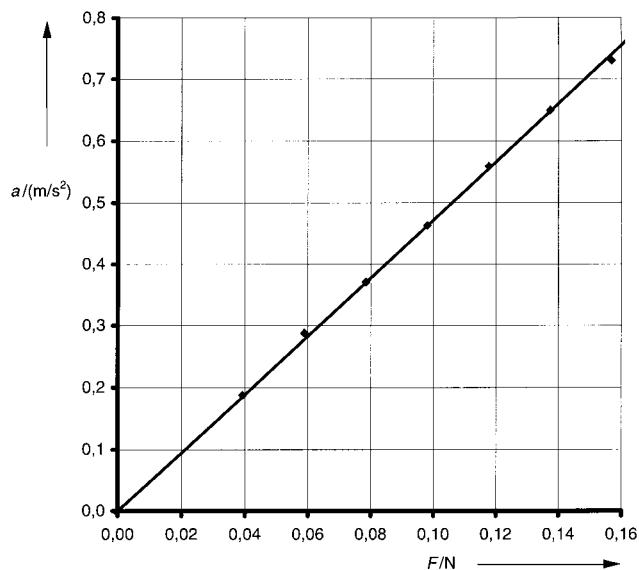


Fig. 6. The same measurement as in Fig. 5 plotted against the reciprocal inert mass.

Fig. 7. The acceleration a as a function of the force F for constant inert mass $m_1 + m_1 = 217$ g.



$m_1 g = 0.981$ N. The evaluation of the present example in Fig. 6. results in a slope of $0.999 \text{ kg} \cdot \text{m} \cdot \text{s}^{-2} = 0.999$ N.

In conclusion, Fig. 7 shows the dependence of the acceleration on the accelerating force F . One sees the linear proportionality between the two parameters. The reciprocal slope is 0.213 kg and corresponds well to the inert mass $m_1 + m_2 = 0.217$ kg.