7.8 Fundamental Newtonian Equations – Acceleration as a Function of Force

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interTESS (Version 13.06 B200, Export 2000)

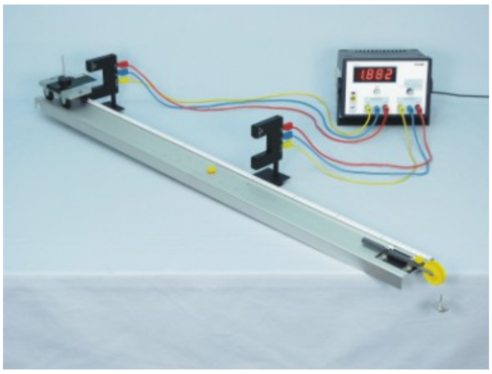
Task

Task

What is the relation between force and acceleration?

After you have examined the general properties of accelerated bodies, now you should find out in what ways the acceleration depends on the accelerating force. For this purpose, the accelerating force will be varied, while the other experimental conditions remain the same.

A weight hangs from a thread connected to a measurement car, passing over a pulley. The weight force of the weight accelerates the car. Examine the acceleration of the car as a function of the amount of weight with the aid of the photoelectric gates and the timer device. The accelerated mass is the mass of the car with the retaining bolt (50 g), the plate (10 g) and the 50 g slotted weight placed on the car, and is referred to as m. The weight on the thread is labelled m_g. It is accelerated as well, but is disregarded as insignificant in comparison to the mass of the car.



Use the space below for your own notes.

Logged in as a teacher you will find a button below for additional information.

Additional Information

In this experiment, pupils should examine acceleration as a function of the accelerating force. The acceleration–force graph should lead the pupils to the formula $F = m \cdot a$.

Note

- The use of "$v = a \cdot t$" (instead of "$s = 1/2\ a\ t^2$") would involve measuring two times in order to measure a – one time for the distance, and a beam interruption time to measure the speed, and is therefore somewhat more involved.

Material

Material from "TESS-Mechanik ME 1" (order nr. 13271.88), "TESS-Mechanik ME 2" (order nr. 13272.88) and "TESS-Mechanik ME 4" (order nr. 13283.88)

Position No.	Material	Order No.	Quantity
1	Measurement/experimental car	11060-00	1
2	Shade plate for the measurement car	11060-10	1
3	Holding pin	03949-00	1
4	Silk thread, 200 m	02412-00	1
5	Weight holder, bronzed, 1 g	02407-00	1
6	Slotted weight, bare, 1 g	03916-00	4
7	Slotted weight, black coloured, 10 g	02205-01	4
8	Slotted weight, black coloured, 50 g	02206-01	3
9	Pulley, movable, d = 40 mm, with hook	03970-00	1
10	Rod for pulley	02263-00	1
11	Timer 2-1, incl. power supply	13607-99	1
12	Compact photoelectric gate	11207-20	2
13	Foot plate for the compact photoelectric gate	11207-22	2
14	Connecting cable, red, 32 A, 1000 mm	07363-01	2
15	Connecting cable, yellow, 32 A, 1000 mm	07363-02	2
16	Connecting cable, blue, 32 A, 1000 mm	07363-04	2
17	Track 1, l = 500 mm	11302-00	1
18	Track 2, l = 500mm	11303-00	1

Material required for the experiment

Setup

Set up the track according to Fig. 1 + Fig. 2.

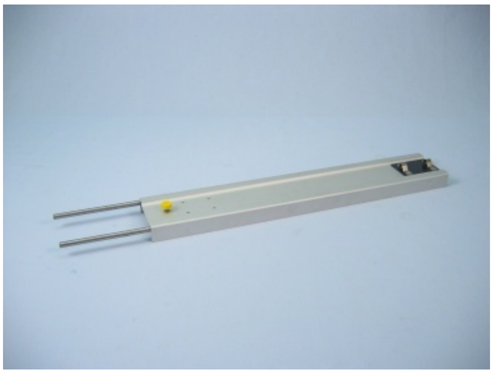


Fig. 1

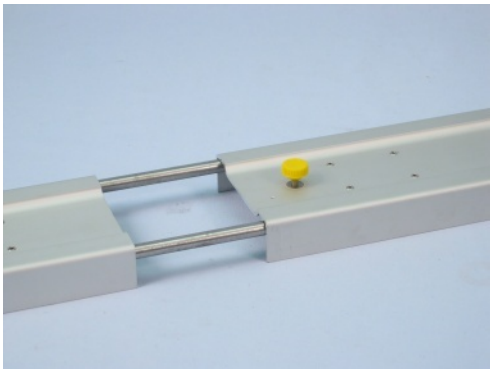


Fig. 2

Place the shade plate and a 50 g weight on the car's retaining bolt (Fig. 3). Set the inclination of the track so that the car continues to roll with a speed which is as continuous as possible once it has been pushed toward the end with the pulley. To do this, place the screw on the other end of the track onto slotted weights and turn its adjustment screw (one 50 g and one 10 g weight should be about right, Fig. 4).


Fig. 3

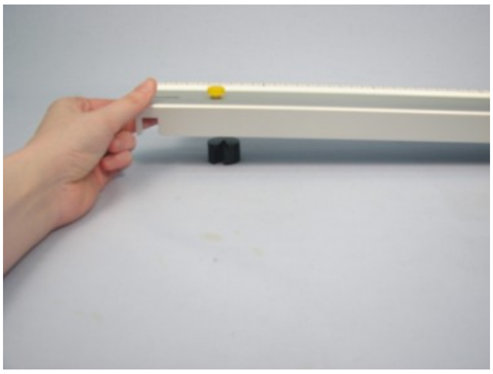


Fig. 4

Screw a separator bolt and a foot plate onto the photoelectric gates, so that the plate on the car goes through the gate where the latter is placed (Fig. 5) and connect the gates to the timer (Fig. 6).

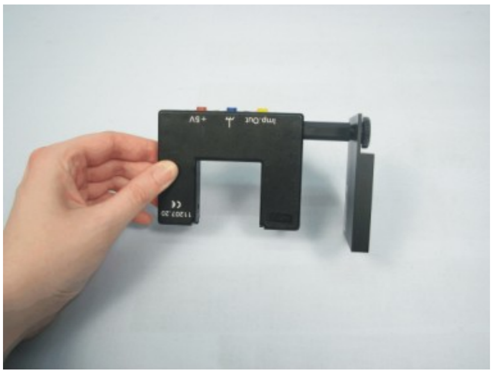


Fig. 5

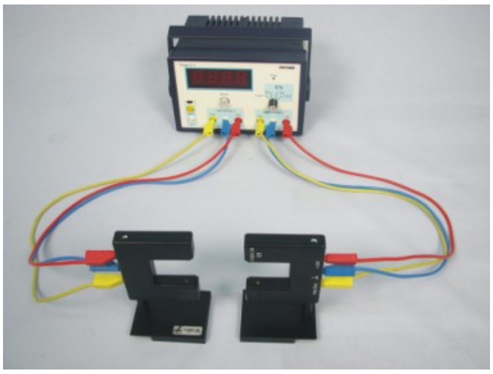


Fig. 6

Place the gate 8.2 cm away from the upper track end, so that its beam is immediately broken by the plate as the car starts from the end of the track.

Place the second gate 50 cm away from the first.

Set the slide switch, which is over the "Start" label on the timer, to the position to the right (↴).

Set the rotary switch on the timer to the "ʃ⊔ʃ" position, the third from the left. This way, the device shows the time between the interruption of the light beam at the first gate and second.

Put a the end of a length of thread through the hole of the retaining bolt on the underside of the car (Fig. 7), run it under the car, through and onto the upper side and tie it to the retaining bolt (Fig. 8). Tie the opposite end to the 1 g weight holder (Fig. 9), with a length of thread such that the weight holder touches the ground after the car has passed the second gate. The thread should run over the car's axles and parallel to the track, over the wheels (Fig. 10).

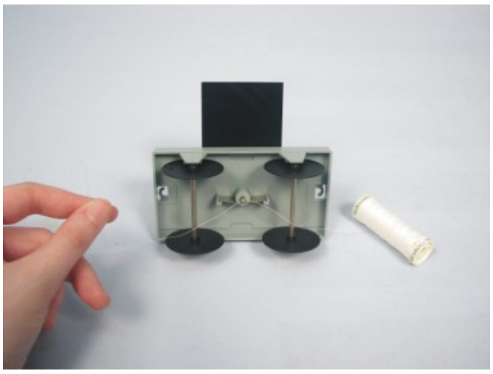


Fig. 7

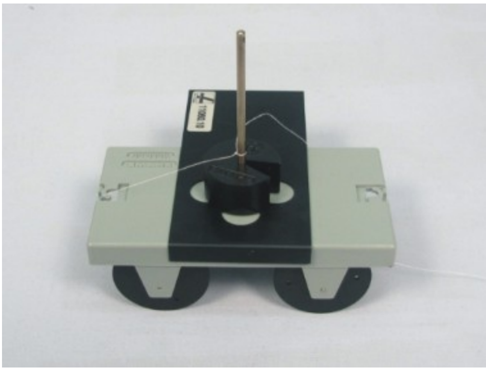


Fig. 8

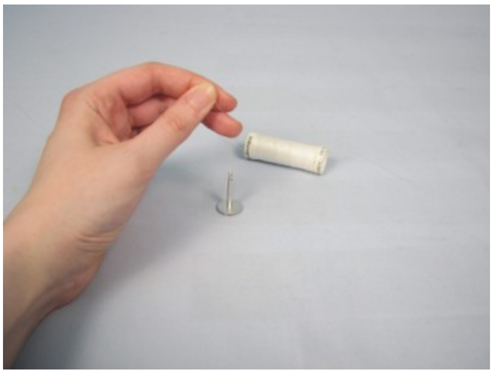


Fig. 9

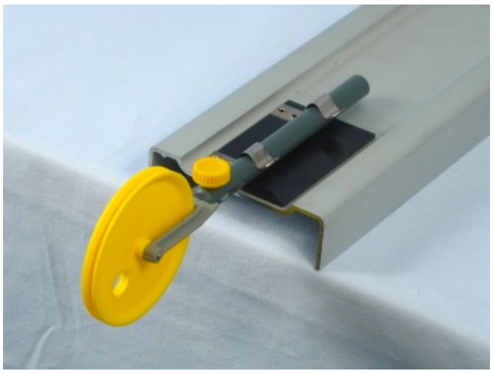


Fig. 10

Procedure

Press the reset button on the timer before every measurement.

At first, do not place a weight onto the weight holder, the weight is then 1 g.

Start the car always exactly from the same point at the beginning of the track, so that the edge of the car coincides with the edge of the car, as seen from the top. Start the car by letting go of it, without pushing.

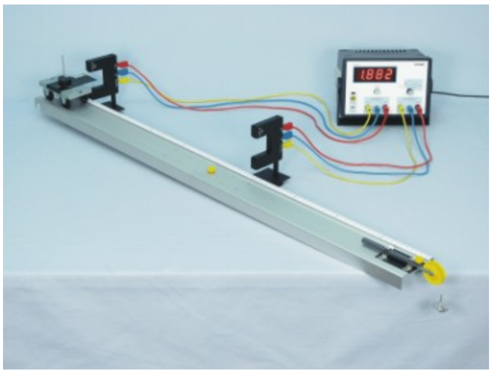


Fig. 11

Let go of the car and catch it after it has gon throught the second gate. Record the time, *t*, shown by the timer, on table 1. Round off the reading to one decimal. This is the time needed by the car to cover the distance s = 50 cm.

Increase the weight on the weight holder by adding one 1 g slotted weight.

Results

Table 1

m_g in kg	t in s	t^2 in s^2	$F = m_g \cdot g$ in N	$a = 2s / t^2$ in m/s^2	$m = F/a$ in kg
0.001					
0.002					
0.003					
0.004					
0.005					

Table 1

m_g in kg	t in s	t^2 in s^2	$F = m_g \cdot g$ in N	$a = 2s / t^2$ in m/s^2	$m = F/a$ in kg
0.001	3,1	9,6	0,010	0,10	0,10
0.002	2,3	5,3	0,020	0,19	0,11
0.003	1,9	3,6	0,029	0,28	0,10
0.004	1,7	2,9	0,039	0,35	0,11
0.005	1,5	2,3	0,049	0,44	0,11

Evaluation

Question 1

Calculate the square of the *t*–values and complete the t^2 column in table 1. The time was measured to two significant digits (one before, one after, the decimal point). Therefore all calculated values are to be indicated with two significant digits.

See table 1.

Question 2

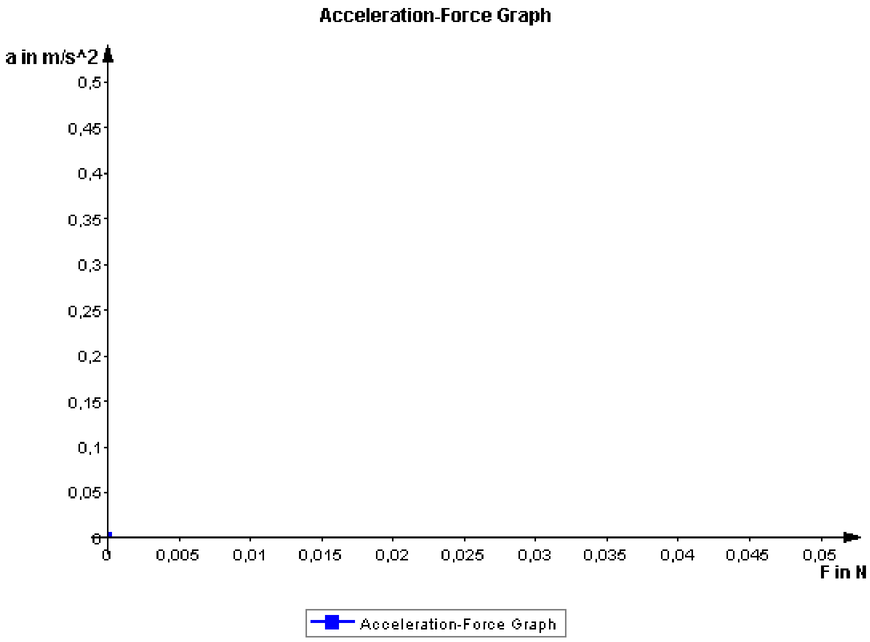
Calculate the force of gravity *F*, which is the source of the acceleration: $F = m_g\ g$, where m_g is the mass of the weight hanging from the thread and where $g = 9{,}81$ m / s^2 is the gravitational acceleration of the earth. Complete table 1.

See table 1.

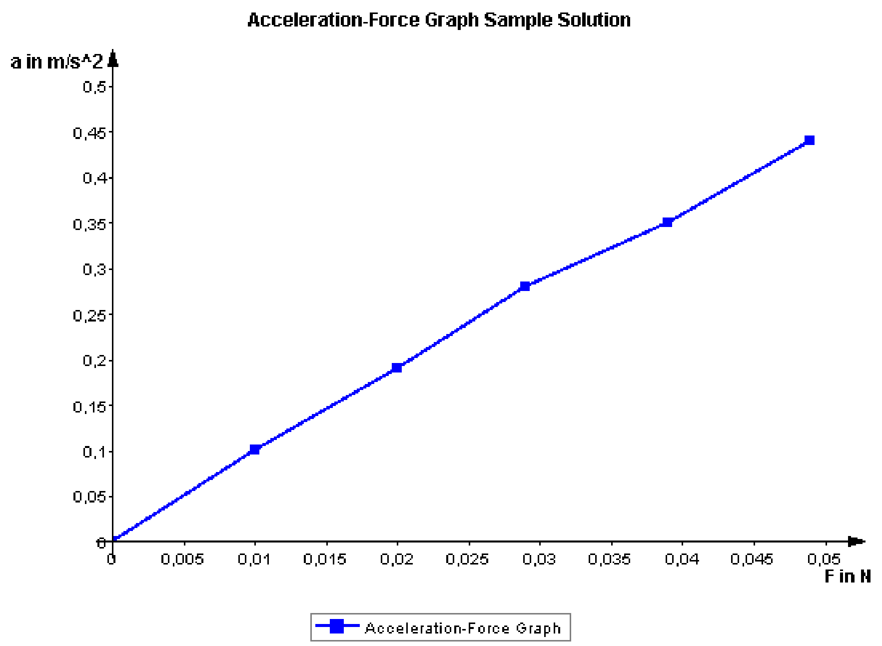
Question 3

Calculate the acceleration, *a*. Given $s = 1/2\ a\ t^2$ it follows that $a = 2\ s/\ t^2$. Complete table 1.

See table 1.



Acceleration-Force Graph
a in m/s^2
0,5
0,45
0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
0
0,005
0,01
0,015
0,02
0,025
0,03
0,035
0,04
0,045
0,05
F in N
Acceleration-Force Graph



Question 4

In the Acceleration–Force graph, you plotted *a* against *F*. How large is *a*, when $F = 0$? What kind of relation between *a* and *F* does the Acceleration–Force Graph show?

See the Acceleration-Force graph. The image is a straight line which goes through the origin. Then, a is proportional to F.

Question 5

Determine the slope of the curve of the Acceleration-Force graph: $k = \Delta a / \Delta F$. Calculate the inverse of the slope, $1/k$, and compare it with the accelerated mass of the car, m = 0,11 kg. What do you notice?

The slope of the curve in the Acceleration-Force graph is the proportionality factor k = 8,9 m/Ns^2 = 8,9 kg^{-1}. The inverse of this factor is $1/k$ = 0,11 kg and coincides with the car's mass of m = 0,11 kg at this level of accuracy. The units also match.

Question 6

Express the correlation between mass m, force F and acceleration a in words.

The larger the force, the larger the acceleration is. The acceleration is proportional to the force and the accelerated mass is the proportionality factor.

Question 7

From *F* = *a* folllows *m* = *F*/*a*. Calculate mass values from the measurement data, complete the last column in table 1 and compare with the car mass, *m* = 0,11 kg.

See table 1. At this level of accuracy, the mass measured matches that of the car.