7.9 Fundamental Newtonian Equations – Acceleration as a Function of Mass

Experiment by: **Phywe**
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interTESS (Version 13.06 B200, Export 2000)

Task

Task

What is the relation between mass and acceleration?

In this experiment you will find out in what ways the acceleration depends on the mass being accelerated, under a constant accelerating force. For this purpose, the mass being accelerated will be varied, while the other experimental conditions remain the same.

A constant 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 the weight of the car with the aid of the photoelectric gates and the timer device. The mass of the car is changed by attaching different slotted weights to the retaining bolt on the car. The car with the retaining bolt weighs 50 g, the plate 10 g. The accelerated mass is the sum of the masses of the car, plate, weights and the weight hanging from the thread, m_g.

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 the pupil should examine acceleration as a function of the accelerated mass, with a constant accelerating mass. The acceleration-mass 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.
- The tendency is to measure the times as being too short, and therefore the acceleration too great, because some time elapses before the first gate's beam is broken, and because the car reaches the first gate already with a starting speed.

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


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Setup

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

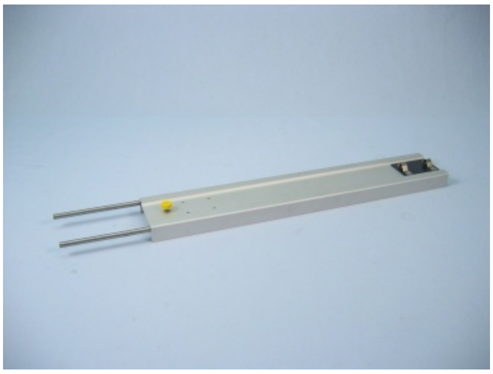


Fig. 1

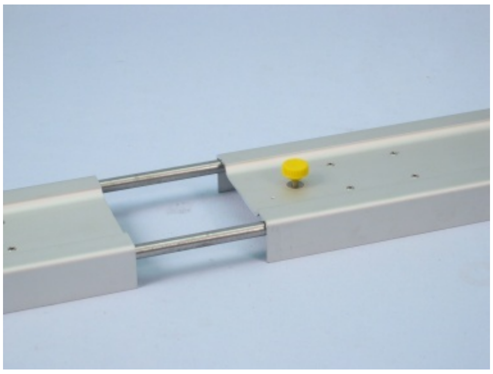


Fig. 2

Place the shade plate and a 50 g weights 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

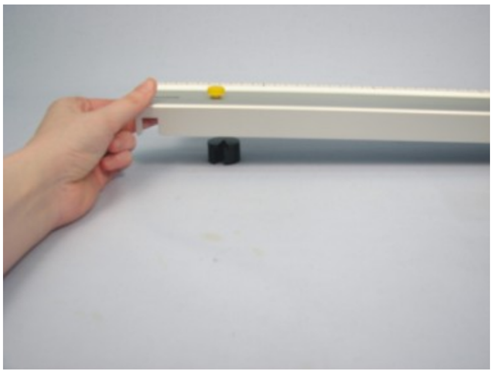


Fig. 4

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).

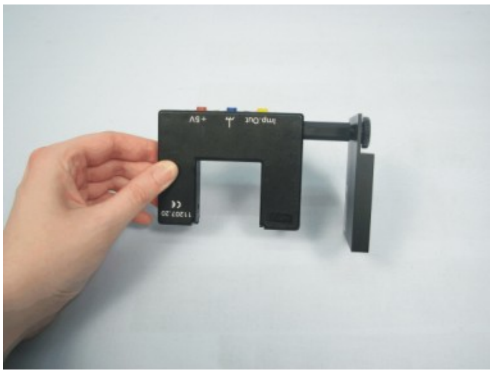


Fig. 5

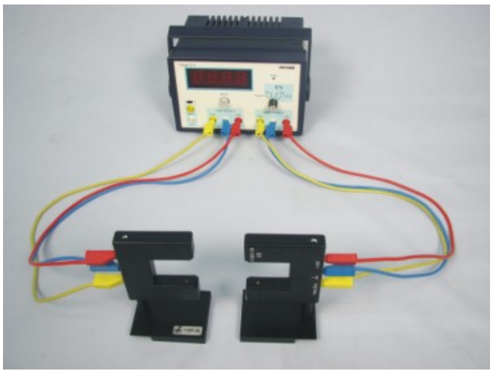


Fig. 6

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 "" 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 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. Tie the opposite end to the 1 g weight holder (Fig. 8), 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. 9).

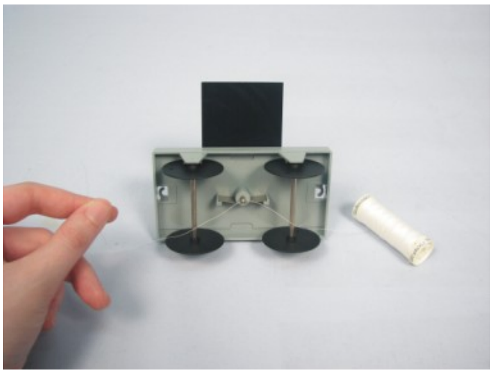


Fig. 7

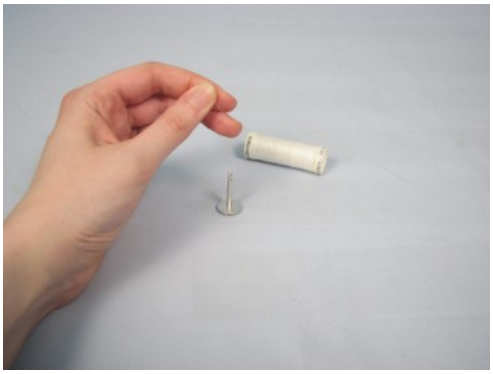


Fig. 8

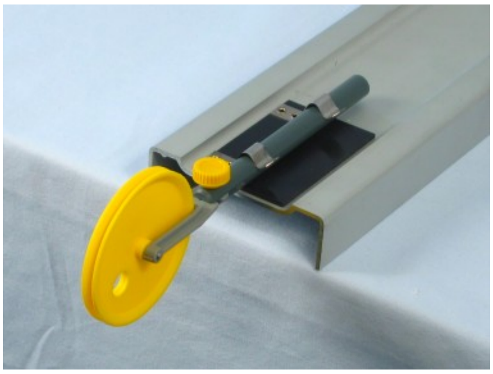


Fig. 9

Procedure

Press the reset button on the timer before every measurement.

Place four 1 g slotted weights on the weight holder. The weight m_g is then, together with the holder, 5 g (Fig. 10).

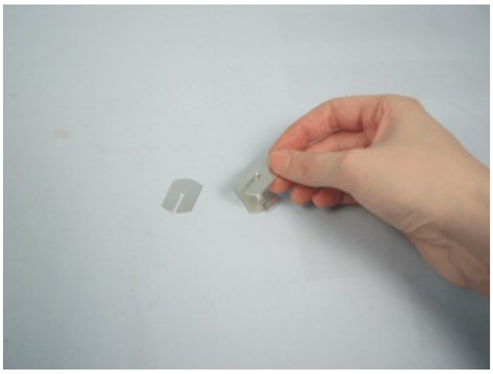


Fig. 10

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).

Fig. 11

Let go of the car and catch it after it has gone 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.

Combine two 10 g and two 50 g slotted weights on the car to get the mass values, m_g, given in the table for the total weight of the car plus retaining bolt, plate, weights on the car and accelerating weight and repeat the experiment (Fig. 12).

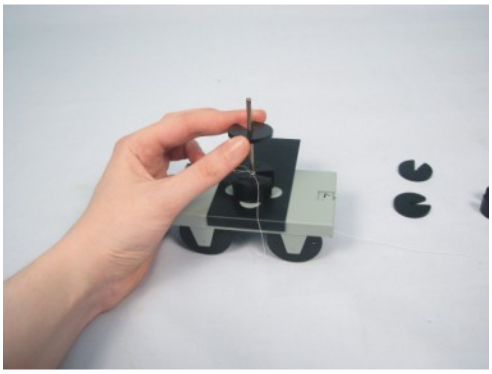


Fig. 12

Results

Table 1

m_g in kg	t in s	$1/m$ in 1/kg	t^2 in s^2	$a = 2s / t^2$ in m / s^2	$m = F / a$ in kg
0.065					
0.085					
0.115					
0.135					
0.165					
0.185					

Table 1

m_g in kg	t in s	$1/m$ in 1/kg	t^2 in s^2	$a = 2s / t^2$ in m / s^2	$m = F / a$ in kg
0.065	1.1	15.4	1.2	0.83	0.059
0.085	1.3	11.8	1.7	0.59	0.083
0.115	1.5	8.7	2.3	0.43	0.11
0.135	1.6	7.4	2.6	0.38	0.13
0.165	1.8	6.1	3.2	0.31	0.16
0.185	1.9	5.4	3.6	0.28	0.18

Evalutation

Question 1

Calculate the inverse of the accelerated mass *m*: 1/*m*. Complete table 1.

See table 1.

Question 2

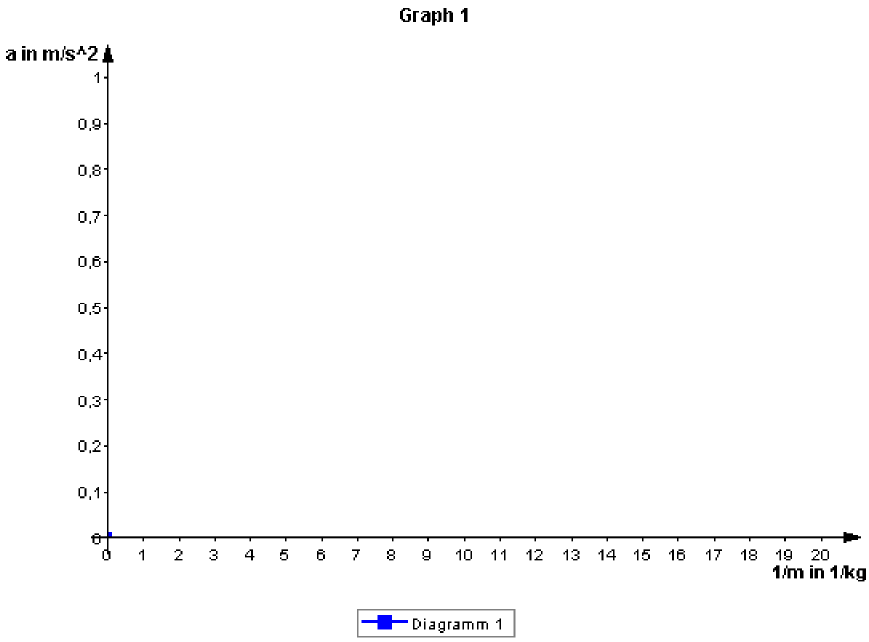
Calculate the square of the *t* values and complete the t^2 column in table 1. The time was measured accurately to two significant figures (one before and one after the decimal point). Therefore the calculated values must be reported with two significant figures.

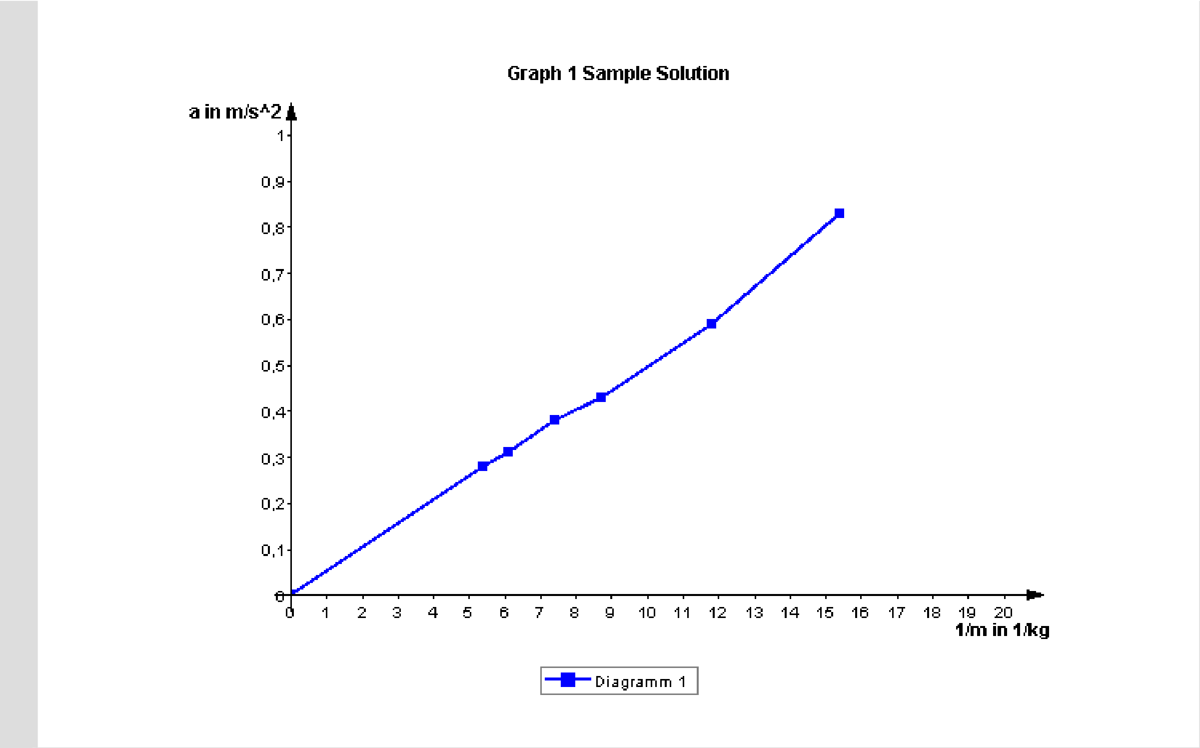
See table 1.

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.


Graph 1
a in m/s^2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1/m in 1/kg
Diagramm 1



Question 4

In graph 1, you plotted *a* against *1/m*. How large does *a* become, when *1/m* approaches 0, that is, as the accelerated mass becomes infinitely large, while it is pulled with the same force? What is the relation between *a* and *1/m* shown in graph 1?

See graph 1. The greater the mass, the smaller the acceleration. As the mass approaches infinity, the acceleration approaches zero. The image shows a straight line through the origin. The acceleration, *a*, is therefore inversely proportional to the mass.

Question 5

Determine the slope of the curve from graph 1: $k = \Delta a / \Delta(1/m)$. Compare it with the accelerating force F = 0,0049 N. What do you notice?

The slope of the curve in graph 1 is: $k = \Delta a / \Delta(1/m)$ = 0,054 N. At this level of accuracy, this corresponds to the accelerating force F = 0,049 N.

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Question 6

Articulate in words the relation between mass, *m*, force, *f*, and acceleration, *a*, which has been determined here, for example in a sentence of the form "the more/less...the...".

Under a constant force, *F*, the greater is the mass *m,* the smaller is the acceleration, *a*. The product of *m* and *a* is constant.

Question 7

From $F = m\,a$ follows $m = F/a$. Calculate mass values from the measurement data, complete the last column in table 1, and compare with the values for the car mass, m.

See table 1. At this level of accuracy, the values agree.