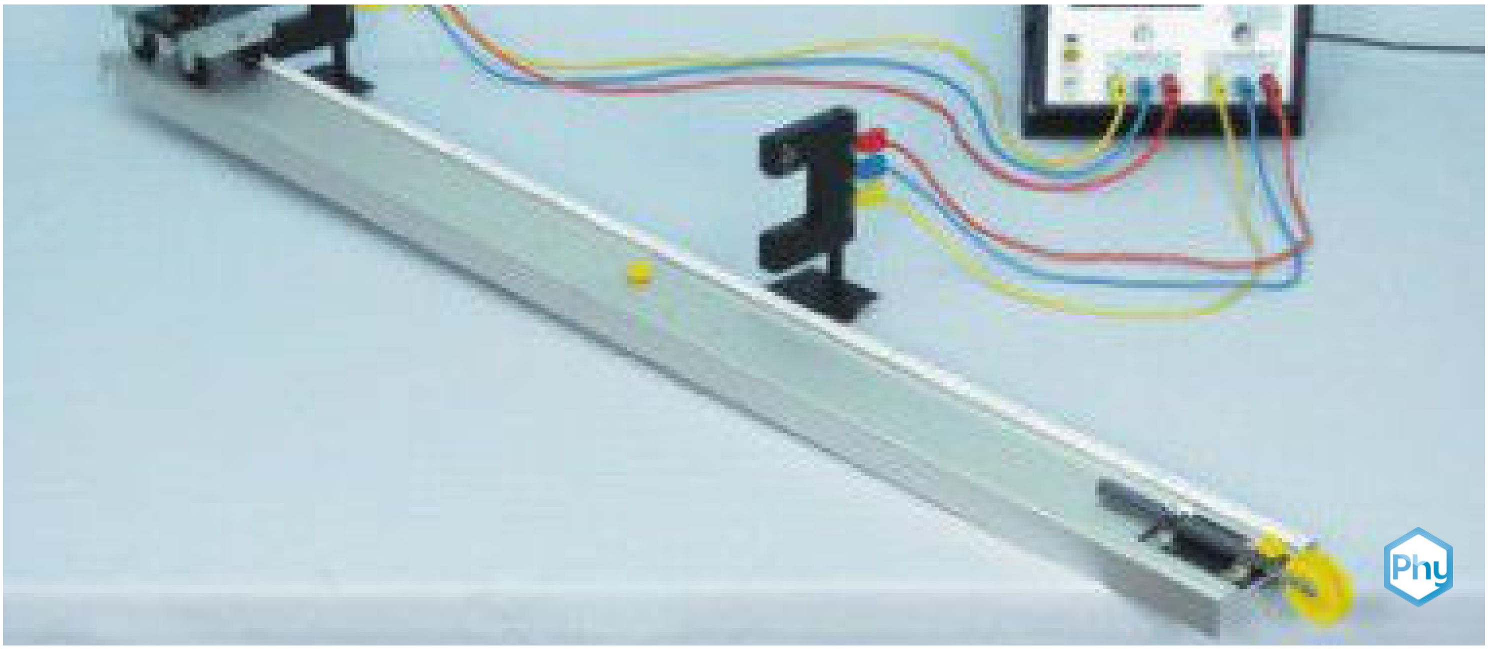
Newton's law: acceleration as a function of force with the 2-1 timer



Physics	Mechanics	Energy conservation & impulse

Difficulty level	Group size	Preparation time	Execution time
hard	2	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/5fdbb8f85098f00003f1edf5

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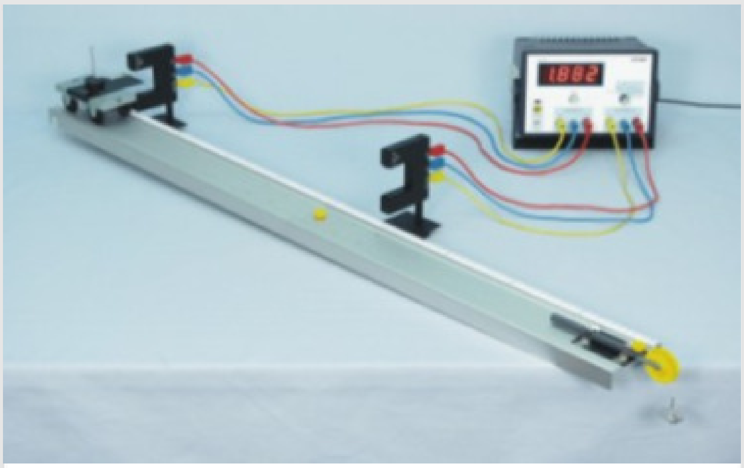
Teacher information

Application



Experiment set-up

Newton's equation of motion, or Newton's 2nd law, represents a fundamental equation in mechanics. With the help of this equation, systems of mechanics can be completely described in space and time.

It states that the product of a mass m and acceleration a corresponds to the required force F.

$$F = m \cdot a$$

It is used wherever forces act on bodies with masses.

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Other teacher information (1/2)

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Prior knowledge

Students should be familiar with the concepts of acceleration, force, and velocity. In addition, students should be able to mathematically determine the slope of a straight line and its dimension.

Scientific principle

The cart on the roadway is accelerated uniformly by the gravitational force with the aid of the deflection pulley and the thread. The concrete value of the acceleration is calculated as a from traction F and the accelerated mass of the wagon m from Newton's second law:

$$a = F/m$$

Other teacher information (2/2)

PHYWE

Learning objective

In this experiment, students should experimentally respond to the simplified formulation of Newton's 2nd law $F = m \cdot a$.

Tasks

1. The students accelerate a car of known mass on a track with the help of an attached mass and measure the travel time t that the car needs to cover a distance s of $50\ cm$. In the process, the tensile weight is increased step by step.
2. They then evaluate the measurement data and obtain a linear relationship between force and acceleration, from which they determine the slope and its dimension.

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Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

General information

A second light barrier can be added to adjust the path inclination (for friction compensation): push the car, measure the shading time of the first light barrier. Reset the measured value before the car arrives at the second light barrier, measure the second shading time. Compare with the first time.

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Student Information

Motivation

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Rocket launch

Newton's equation of motion, or Newton's 2nd Law, is a fundamental equation in mechanics that can be used to completely describe mechanical systems in space and time.

It states that the product of a mass m and acceleration a is the required force F and is used wherever forces act on bodies with masses. If, for example, a rocket is to be launched, the engine must be used to generate such a large force effect that it permanently overcomes the acceleration due to gravity many times over.

In this experiment, you experimentally arrive at Newton's 2nd law: $F = m \cdot a$.

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Equipment

Position	Material	Item No.	Quantity
1	Cart for measurements and experiments	11060-00	1
2	Shutter plate for cart	11060-10	1
3	Holding pin	03949-00	1
4	Silk thread, l = 200 m	02412-00	1
5	Weight holder, silver bronze, 1 g	02407-00	1
6	Slotted weight, blank, 1 g	03916-00	4
7	Slotted weight, black, 10 g	02205-01	4
8	Slotted weight, black, 50 g	02206-01	3
9	Pulley,movable,dia.40mm,w.hook	03970-00	1
10	Rod for pulley	02263-00	1
11	PHYWE Timer 2-1	13607-99	1
12	Light barrier, compact	11207-20	2
13	Adapter plate for Light barrier compact	11207-22	2
14	Connecting cord, 32 A, 1000 mm, red	07363-01	2
15	Connecting cord, 32 A, 1000 mm, yellow	07363-02	2
16	Connecting cord, 32 A, 1000 mm, blue	07363-04	2
17	Track, l 900 mm	11606-00	1

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11	PHYWE Timer 2-1	13607-99	1
12	Light barrier, compact	11207-20	2

Set-up (1/5)

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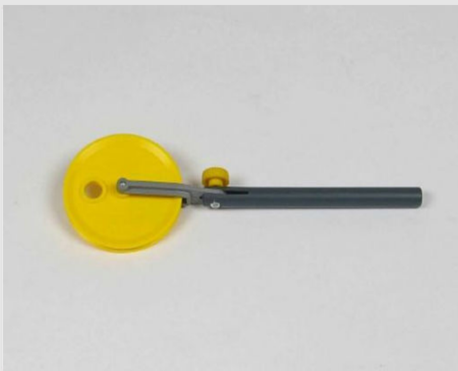
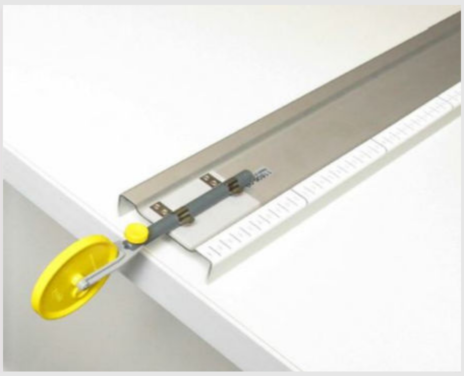
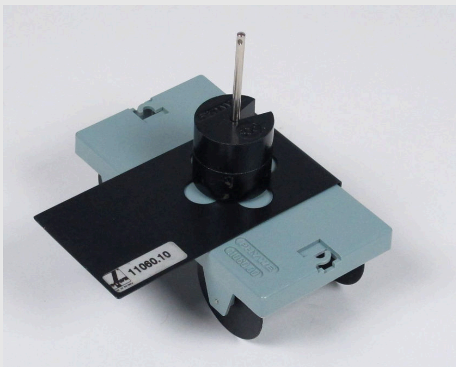
Connect the pulley to the handle and then carefully slide the handle under the brackets at the end of the track. To do this, lift the retaining clips slightly with your fingers. Position the track at the end of the table so that the pulley can rotate freely.

Take the cart, attach the holding pin, the shading screen and two 50 g masses to it.







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Set-up (2/5)

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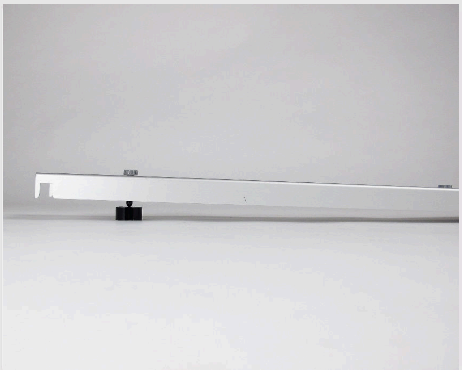
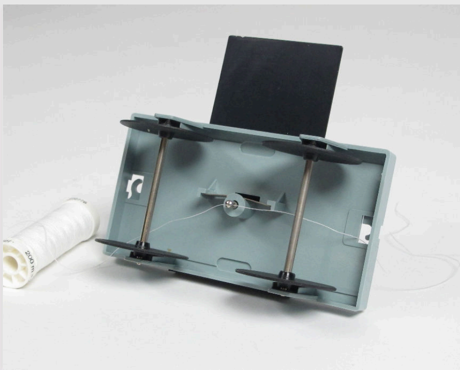
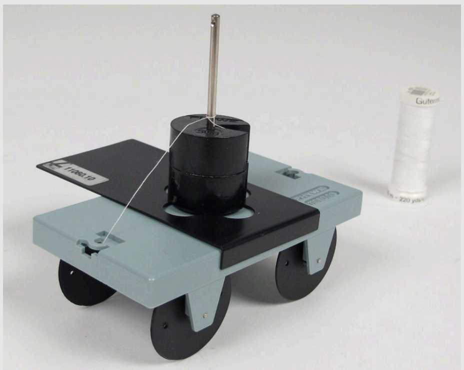
Tilt the track so that when the car is lightly pushed, it rolls at as constant a speed as possible. To do this, set the set screw at the other end of the track to slot weights and use it to adjust the incline. Then feed the end of the sewing silk through the hole of the holding bolt at the bottom of the cart, feed it through to the back of the top of the cart and knot it to the holding pin.

Set-up (3/5)

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Knot end of thread to weight plate

Tie the other end to the 1 g weight plate, choosing the length of the thread so that the weight plate only touches the floor after the trolley has passed the light barrier set up further down.

Now place the thread that connects the cart to the weight plate over the roller. The thread should run above the axis of the carriage and parallel to the track.

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Set-up (4/5)

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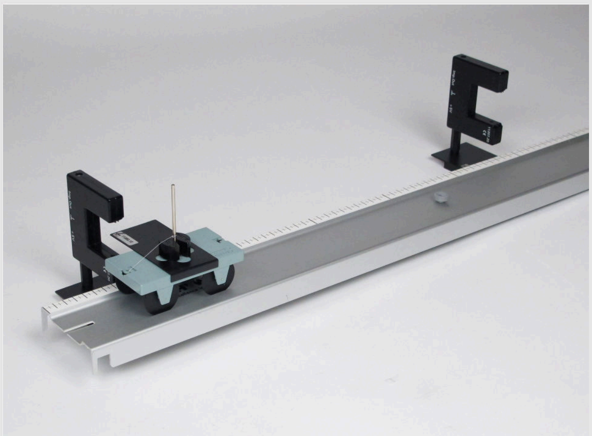

Connecting adapter plates with light barriers

Connect the adapter plates (if necessary, each with a spacer bolt) to the forked light barriers in such a way that they can be easily set up next to the carriageway and the screen on the cart can pass through the light barriers without hitting them.

Set up the first light barrier at about the 8.2 cm mark on the measuring tape, measured from the top end of the carriageway, and position the second light barrier at a distance of 50 cm from the first. When starting, the car should be flush with the road surface without interrupting the first light barrier. If necessary, correct the position of the light barriers accordingly.

Set-up (5/5)

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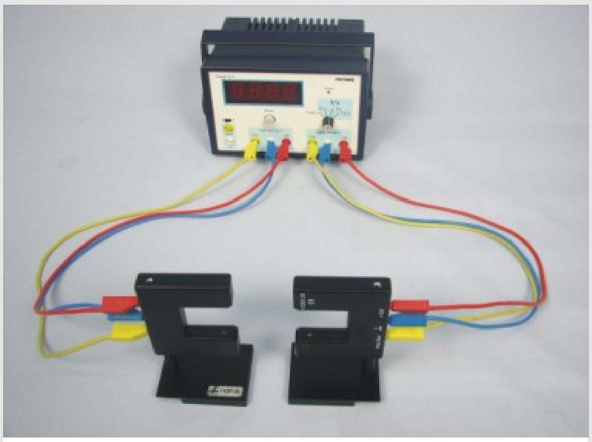

Connect the light barriers to the timing device

Connect both light barriers to the timing device.

Set the slide switch above the "Start" field on the timing device to the right position.

Set the rotary switch on the timing device to the third position from the left. Then the device displays the time that has elapsed between the interruption of the first and the second light barrier.

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Procedure (1/2)

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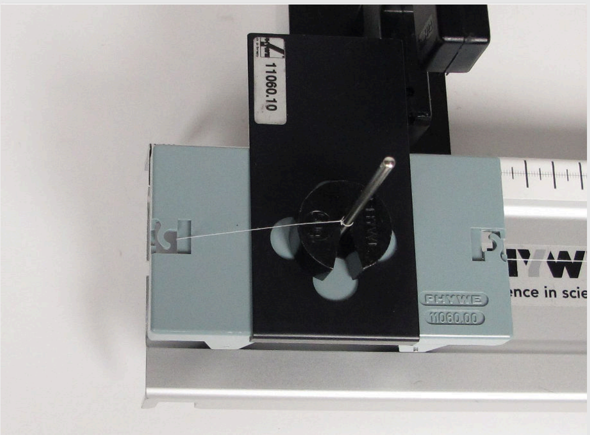

Cart at the top of the carriageway

- Push the cart to the upper end of the lane. The cart should be flush with the end of the carriageway as seen from above.
- Make sure that the light barrier is not yet interrupted.
- Check whether the thread really runs over the deflection pulley and whether it can be turned freely.
- Press the "Reset" button on the timer 2-1 before each measurement. button on Timer 2-1.
- Now let go of the car without bumping it and catch it behind the second light barrier.

Procedure (2/2)

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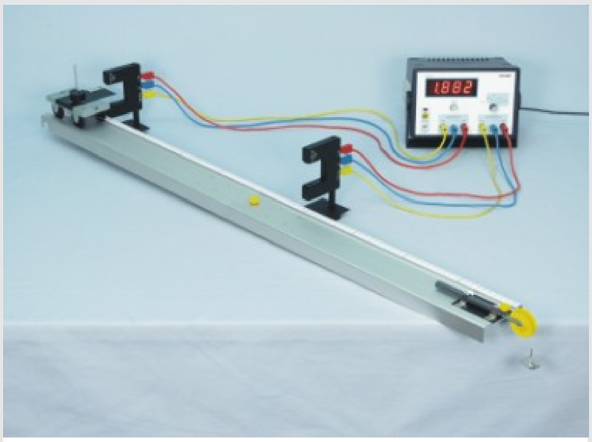

Test setup with cart at the upper end of the lane

- Read the driving time t and note the value in Table 1 in the report.
- Increase the pull weight by placing another 1 g slotted weight on the weight plate for each additional pass until all four weights are finally on the plate, bringing the total mass to 5 g.
- Before each start, check whether the yarn runs over the roller and make sure that the start light barrier is only interrupted after the cart has been released.

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Report

Table 1

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Enter your measured travel times t and their squared values t^2 in the table.

Calculate both the weight force $F_G\,[N]$ the acceleration mass m_G as well as the acceleration a of the car. Use for the latter the formula of uniform acceleration $s = \frac{1}{2} \cdot a \cdot t^2$:

$$F_G = m_G \cdot g$$

$$a = \frac{2 \cdot s}{t^2}$$

	$m\ [g]$	$t\,[s]$	$t^2\,[s^2]$	$F_G\,[N]$	$a\,[m/s^2]$
1					
2					
3					
4					
5					

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Task 1

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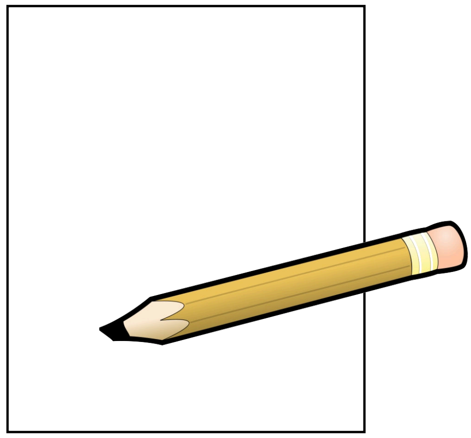
Now take a sheet of paper and draw a diagram on it. In this diagram you place the acceleration a (y-axis) as a function of the tensile force F_G ($x$axis).



Task 2

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Determine the total mass m_W of the cart with weight and record the value in kilograms on $10\ g$ rounded into the window.

The masses required for this are: Empty cart $42\ g$, shadow hood $10\ g$ holding pin $7\ g$.

$m_W =$ ___ g

Determine the slope k of the straight lines from the diagram and determine their dimension.

Additionally determine the reciprocal $1/k$.

$k =$ ___ ___

$1/k =$ ___ ___

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Task 3

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In the diagram for Table 1, the acceleration a as a function of the tractive force F_G shown. Drag the words to the right places.

The greater the force F_G the ______ the acceleration a at constant mass. The acceleration a is to the tractive force F_G ______.

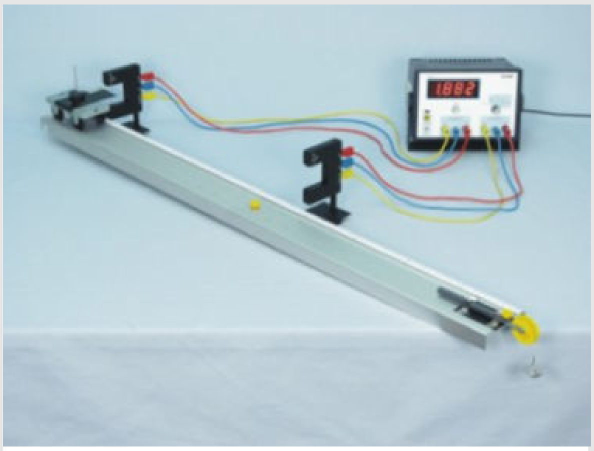
\Not needed: ______

- smaller
- greater
- proportional

Check

Task 4

PHYWE



Experiment set-up

What unit does the slope k of the straight line of the acceleration-force diagram have?

- $[k] = m/s$
- $[k] = 1/kg$
- $[k] = kg$
- $[k] = kg/m$

Check

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Task 5

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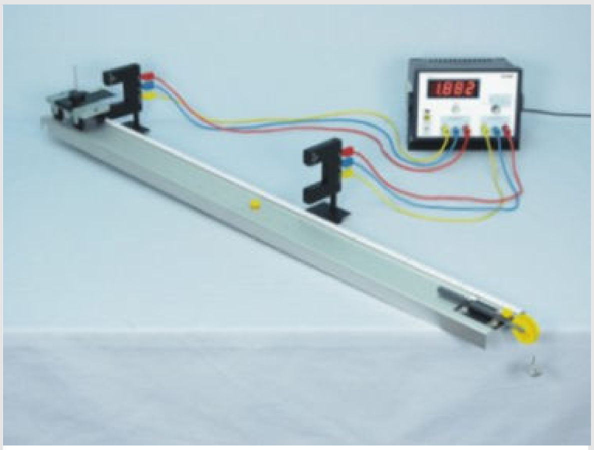


Experiment set-up

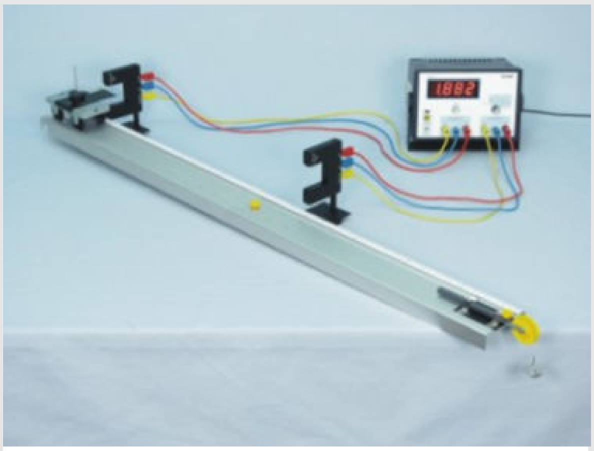
What unit does the reciprocal $1/k$ the slope of the straight line from the diagram have?

- $1/k = [kg]$.
- $1/k = [m^2]$.
- $1/k = [m/N]$.
- $1/k = [1/kg]$.

Check

Task 6

PHYWE



Experiment set-up

Which of the following equations results from the diagram with the proportionality factor k and the knowledge gained from the previous question?

- $F = m \cdot a^2$
- $F = m/a$
- $F = m \cdot a$

Check

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