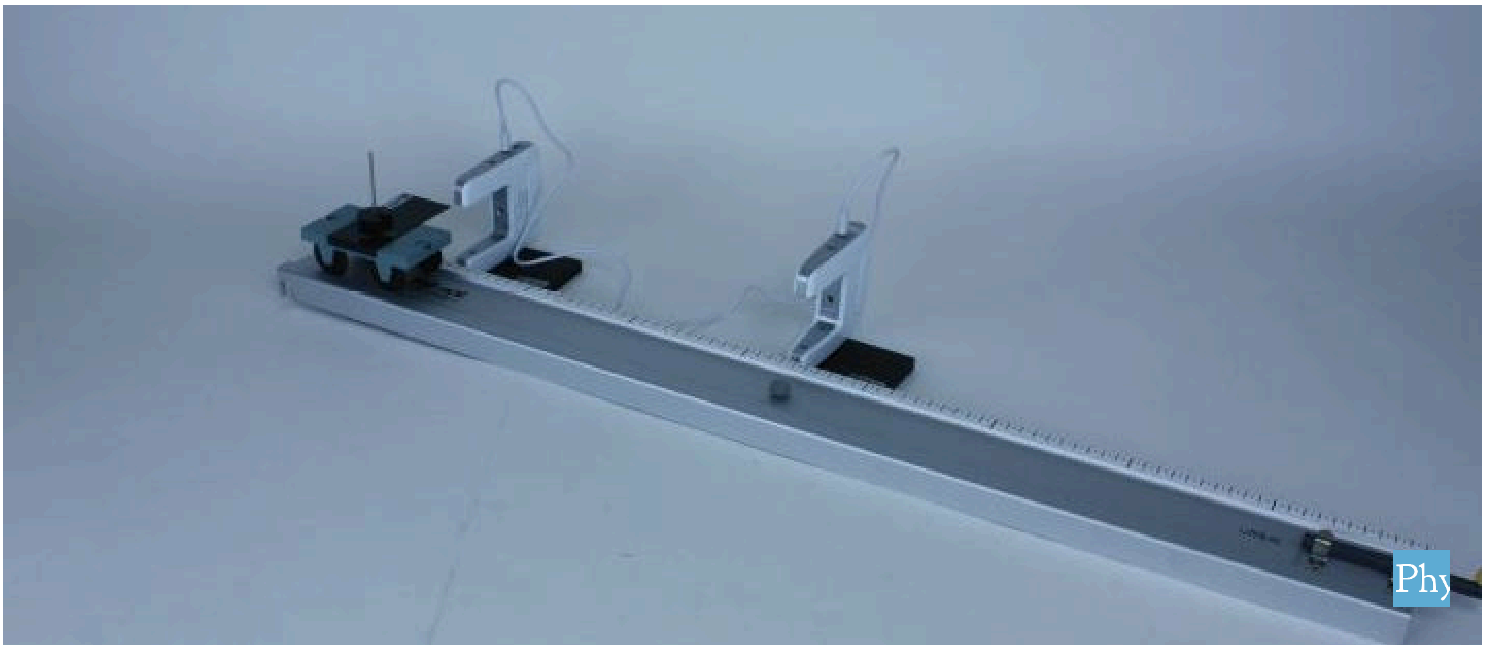
Newton's law: acceleration as a function of mass with Cobra SMARTsense



Physics — Mechanics — Dynamics & Motion

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

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Teacher information

Application

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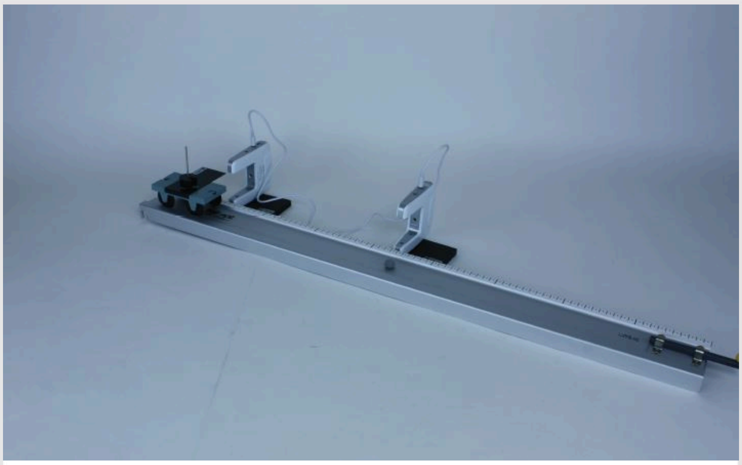

Experiment set-up

The Newtonian equation of motion, also called 2nd Newtonian axiom, 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 the mass m and the acceleration a corresponds to the force F acting on the movement.

$$F = m \cdot a$$

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 terms acceleration, force and speed. They should also be able to mathematically determine the gradient of a straight line and its dimension.

Scientific principle

The measuring carriage on the carriageway is evenly accelerated by the gravitational force by means of the deflection roller and the thread. The concrete value of the acceleration is calculated a from the tractive force F and the accelerated car mass m from Newton's second axiom:

$$a = F/m$$

Other teacher information (2/2)

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Learning objective

In this experiment, the students are to experimentally apply the simplified formulation of the 2nd Newtonian axiom $F = m \cdot a$

Tasks

1. The students accelerate a car of variable mass m on a track by means of a towed constant tractive mass m_z and measure the driving time t that the car will take for a distance s from $50\,cm$. For this purpose, the students increase the total accelerated mass (car mass + load mass) step by step from $65\,g$ up to $185\,g$.
2. They then evaluate the measured data and obtain a linear relationship between acceleration and accelerated mass, 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 notes

A second light barrier can be added to adjust the track inclination (for friction compensation): Push the carriage, measure the shading times of both light barriers. Compare both measured values (shading times) and adjust the track inclination if necessary.

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Student Information

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Motivation

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Rocket Launch

The Newtonian equation of motion, or also called 2nd Newtonian axiom, is a fundamental equation in mechanics, with the help of which mechanical systems in space and time can be described completely.

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

In this experiment you experimentally arrive at Newton's second axiom: $F = m \cdot a$.

Tasks

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1. Let the measuring car accelerate over the track with constant tractive force but with varying total mass and measure the times t which the car has to travel for the specified distance s.
2. values the measured data with the aid of a diagram in which the acceleration a of the carriage depending on the reciprocal value of the accelerated mass $1/m$ and determine the gradient k of the resulting curve and its dimension.

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense - Photogate, 0 ... ∞ s, two pieces (Bluetooth)	12909-00	1
2	Track, l 900 mm	11606-00	1
3	Meter scale, demo. l=500mm, self adhesive	03005-00	2
4	Cart for measurements and experiments	11060-00	1
5	Shutter plate for cart	11060-10	1
6	Holding pin	03949-00	1
7	Adapter plate for Light barrier compact	11207-22	2
8	Silk thread, l = 200 m	02412-00	1
9	Weight holder, silver bronze, 1 g	02407-00	1
10	Slotted weight, black, 50 g	02206-01	3
11	Slotted weight, black, 10 g	02205-01	4
12	Slotted weight, blank, 1 g	03916-00	4
13	Pulley,movable,dia.40mm,w.hook	03970-00	1
14	Rod for pulley	02263-00	1
15	measureAPP - the free measurement software for all devices and operating systems	14581-61	1

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Set-up (1/6)

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The Cobra SMARTsense Photogate and measureAPP are required to carry out the experiment. The app can be downloaded for free from the App Store - QR codes see below. Check whether Bluetooth is activated on your device (tablet, smartphone).

measureAPP for Android operating systems

measureAPP for iOS operating systems

measureAPP for Tablets / PCs with Windows 10

Set-up (2/6)

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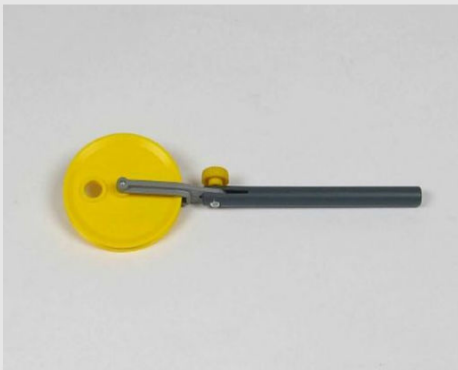
Connect the pulley to the handle and then carefully slide the handle under the retaining clips at the end of the track. To do this, lightly lift the holding clamps with your fingers. Position the track at the end of the table so that the pulley can rotate freely.

Take the measuring car and attach the holding bolt and the shading screen to it.



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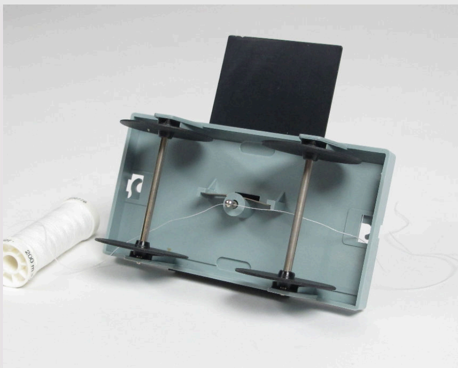
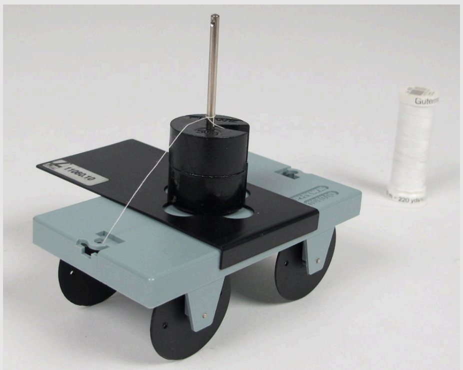
Set-up (3/6)

Tilt the track so that the slightly pushed car continues to roll at a constant speed. To do this, place the set screw at the other end of the track on slotted weights and use it to adjust the inclination. Then guide the end of the sewing silk through the hole of the holding bolt on the bottom of the car, guide it through the back of the car to the top of the car and knot it to the holding bolt.





Set-up (4/6)

Tie the thread end to the weight plate with knots

Knot the other end to the 1-g weight plate and select the thread length so that the weight plate only touches the floor after the car has passed the light barrier positioned further down.

Load the weight plate with a total of four 1 g slotted weights, so that the total pulling mass is 5 g.

Now place the thread connecting the measuring car with the weight plate over the roller. The thread should run above the axis of the car and parallel to the track.

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Set-up (5/6)

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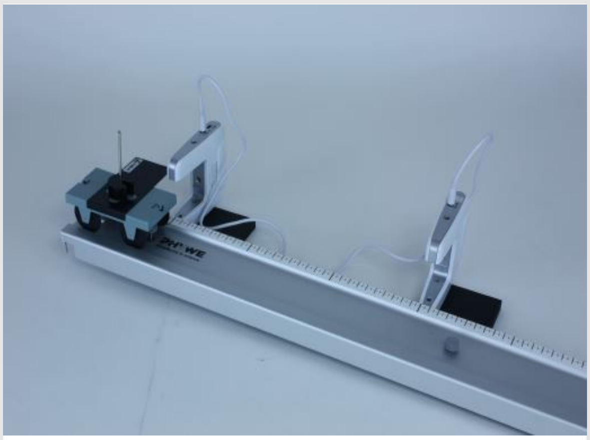

Connect adapter plates with light barriers

Connect the adapter plates (if necessary, each with a spacer bolt) to the light barriers in such a way that they can be set up well beside the track and the screen on the car can pass through the light barriers without colliding with them.

Set the light barrier A approximately at the 8.2 cm mark on the tape measure, measured from the top of the carriageway and position the light barrier B at a distance of 50 cm from the first. When starting, the measuring car should end with the track without interrupting the first light barrier. If necessary, correct the position of the light barriers accordingly.

Set-up (6/6)

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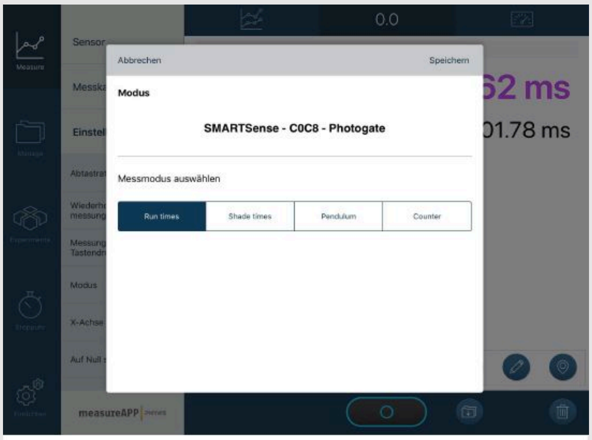

Selection of the measuring mode in measureAPP

Connect both light barriers with the jack cable and switch them on. Select the light barriers in measureAPP under "Sensor" and select "Running times" in the menu which then appears.

In this measurement setting, the light barrier measures the time required for the car to pass the light barriers after the start of the measurement.

Then set the digital measured value display.

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Procedure (1/2)

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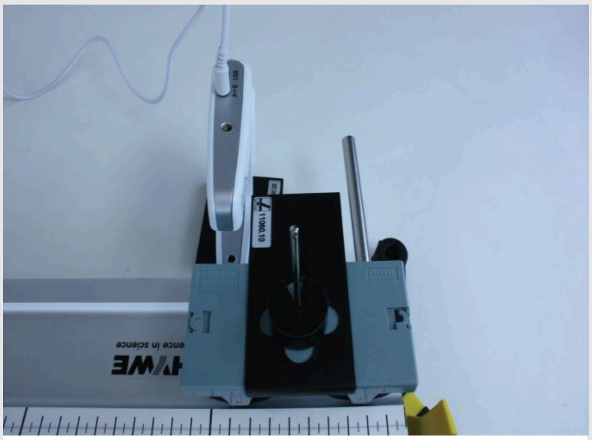

car at the beginning of the track

- Push the measuring cart to the upper end of the track. The cart should end with the end of the track seen from above.
- Make sure that the light barrier is not yet interrupted.
- Check whether the yarn really runs over the deflection roller and that it can rotate freely.
- Press Start measurement in the app.
- Now release the car without hitting it and catch it behind the second light barrier.

Procedure (2/2)

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Test set-up with carriage at the upper end of the carriageway

- Finish the measurement and calculate the travel time by plotting the difference between the two measured times of the light barriers and note the value in Table 1 in the Results.
- Increase the mass m (wagon mass + load mass), which is accelerated from 65 g (wagon without weights + load mass) to 85 g, 115 g, 135 g, 165 g, 185 g in succession using the 10 g and 50 g slotted weights.
- Before each start, check whether the yarn runs over the roller and make sure that the start light barrier is only interrupted after the measuring cart has been released.

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Report

Table 1

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Enter your measured driving times t and their quadratic values t^2 into the table.

Calculate both the reciprocal value of mass $1/m$ as well as the acceleration a of the car. For the latter, use the formula of uniform acceleration $s = \frac{1}{2} \cdot a \cdot t^2$:

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

m $[g]$	$t\,[s]$	$t^2\,[s^2]$	$1/m\,[1/kg]$	$a\,[m/s^2]$
65				
85				
115				
135				
165				
185				

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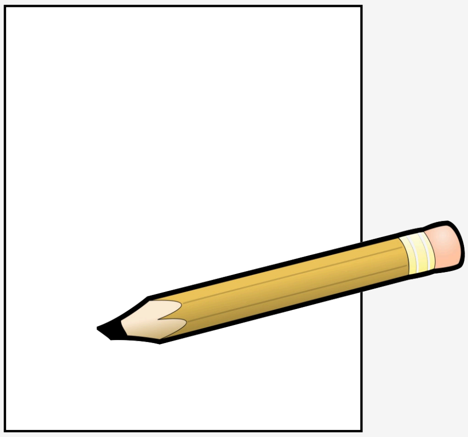
Task 1

Now take a piece of paper and create a diagram on it. In this diagram you set the acceleration a (y-axis) depending on the reciprocal value of the mass $1/m$ (x-axis).



Task 2

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In the diagram the acceleration a against the reciprocal value of the accelerated mass $1/m$ applied. Which statements can be taken from the diagram?

- ☐ At a (theoretically) infinite mass, acceleration would be zero.
- ☐ The acceleration is proportional to the accelerated mass.
- ☐ The smaller the accelerated mass, the greater the acceleration.
- ☐ Acceleration and reciprocal value of mass are proportional to each other.
- ☐ The larger the accelerated mass, the stronger the acceleration.

Check

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Task 3

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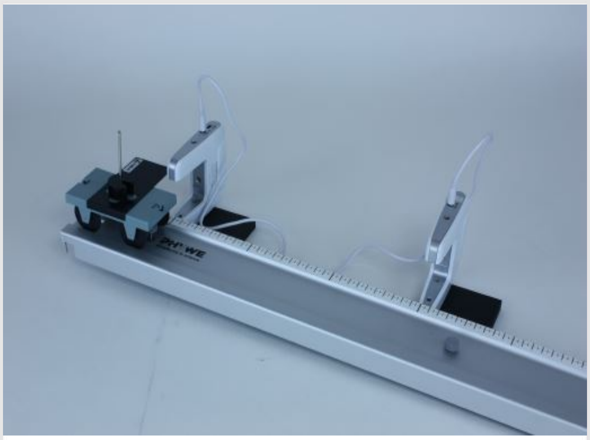

Experiment set-up

Determine the gradient k the straight line from the diagram and determine its dimension.

$k =$ [ ] [ ]

Task 4

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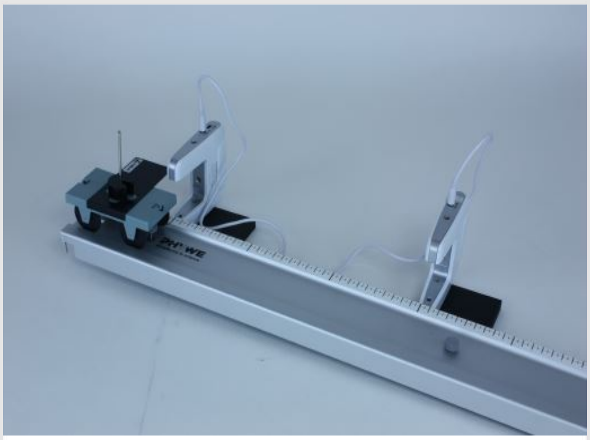

Experiment set-up

Determine the dimension of the gradient k of the linear course from the diagram and select the correct unit!

- $[k] = kg$
- $[k] = N/m^2 = Pa$
- $[k] = kg \cdot m/s^2 = N$
- $[k] = kg \cdot m^2/s^2 = Nm$

Check

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Task 5

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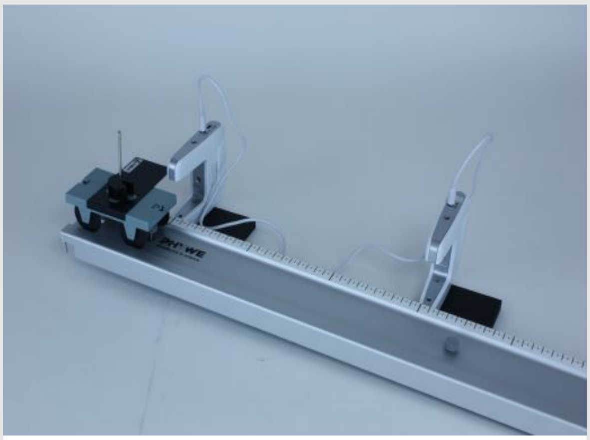

Experiment set-up

Compare the slope found k with the traction $F = 5g \cdot 9,81m/s^2 = 0,049N$. What can you determine?

- $k \ll F$
- $k = 2 \cdot F$
- $k \gg F$
- $k = F$

Check

Task 6

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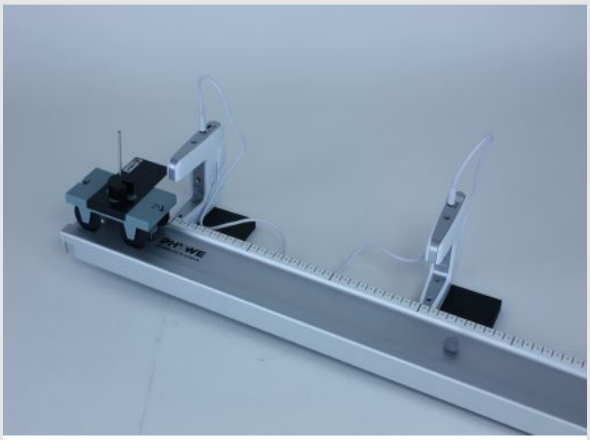

Experiment set-up

Which of the following equations results from the diagram with the found proportionality factor k taking into consideration the previous question?

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

Check

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Slide	Score / Total
Slide 21: relation between \(a\) and \(1/m\)	0/3
Slide 23: unit of \(k\)	0/1
Slide 24: settlement of \(k\) and \(F\)	0/1
Slide 25: Equation	0/1

Total amount 0/6

Solutions Repeat Exporting text

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