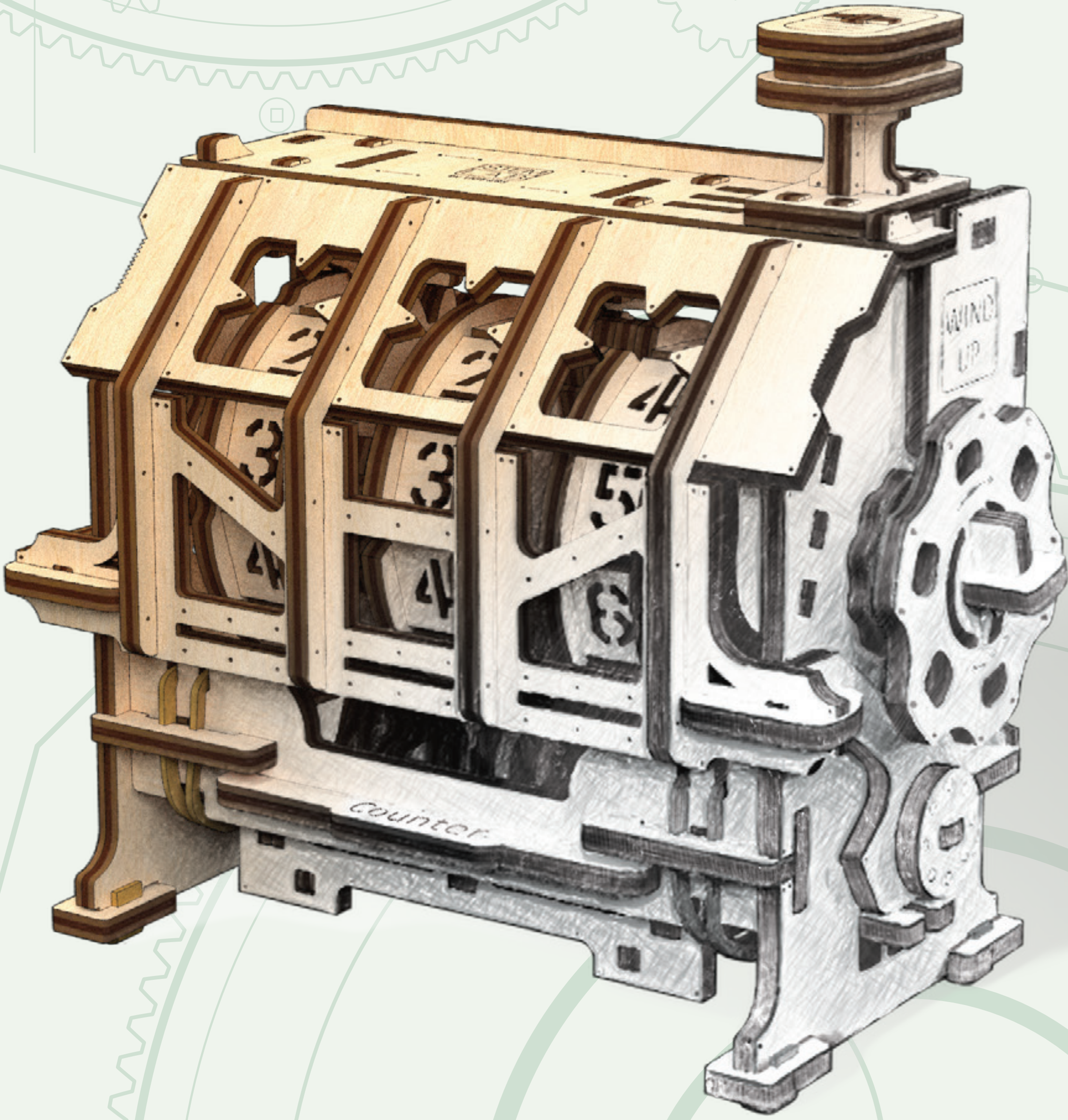
STEM LAB

by UGEARS

MECHANICAL MODEL

# COUNTER



Handbook of A Young Engineer

# §1
## Introduction


**Our brain is wired in such a way that it easily loses count of items or actions over 10 – likely due to the number of fingers of both hands.** Since ancient times, people used all sorts of counting devices, including those that measured the distance between villages – to geo-locate how far away a water source was, to count sacks of grain that have to be transported to the miller, etc.

With industrial and social development, automatic counting became vital – the number of details and operations has to be accounted for, Visitors of exhibitions must be registered, every point professional athletes score must be recorded.

The counter more than covered all these needs! The device seems to be small and simple, but in one form or another it is used in almost all branches of human activity. For instance, when boarding an airplane flight attendants use a miniature counter to calculate the number of passengers keeping it behind their backs.

However, there is one industry where counters have gained a firm foothold and are widely applied — this is an automotive industry.

That's it ... on the dashboard of every car we see figures on the mileage indicator — that's the counter indicator included into the vehicle's odometer system. The name "Odometer" comes from a combination of Greek words, "hodós" – path and "métron" – measure, which gives us a pretty good idea what the device is used for: to measure the path.

The Counter mechanical model we will look at in detail in this study guide can be used to count anything you like up to the number of 999.

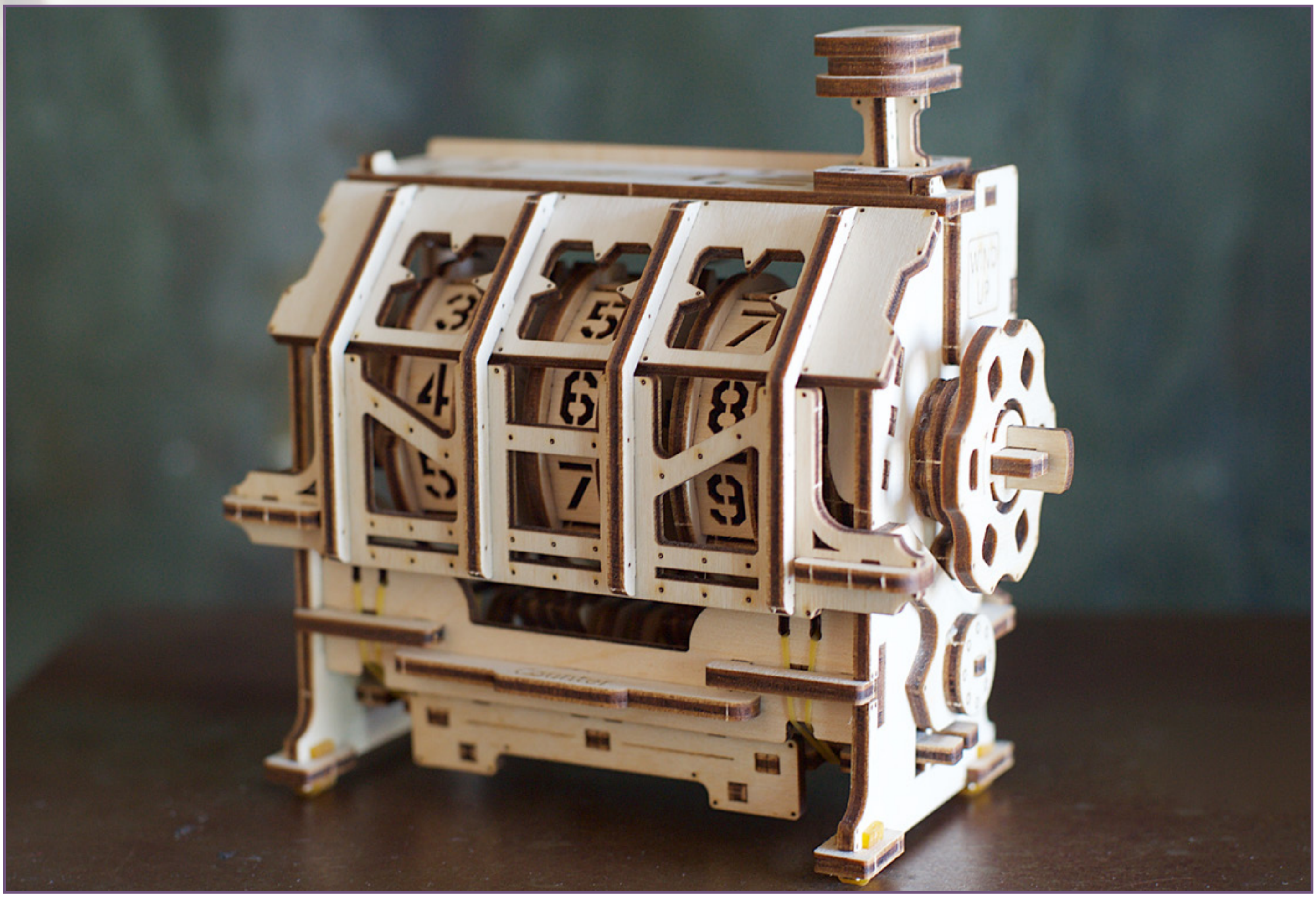
For example, this model will allow you to keep track of moves when playing chess or keep score of goals in ball games, count the number of steps, repeated words per day and much more.

Of course, calculating the car mileage will cause difficulties, however by counting the number of poles outside the car window and multiplying their number by the distance between them, you can get the distance you drove….

As we noted earlier, the counters are most commonly used as part of the odometer.

Let's take this device as an example and consider the history and operation principle of this amazing and seemingly simple mechanism!


Manual mechanical counter



**The Counter from STEM-lab range**
The model is designed to resemble
the constructional element of an industrial machine of the past,
from the times of the industrial revolution.

# §2

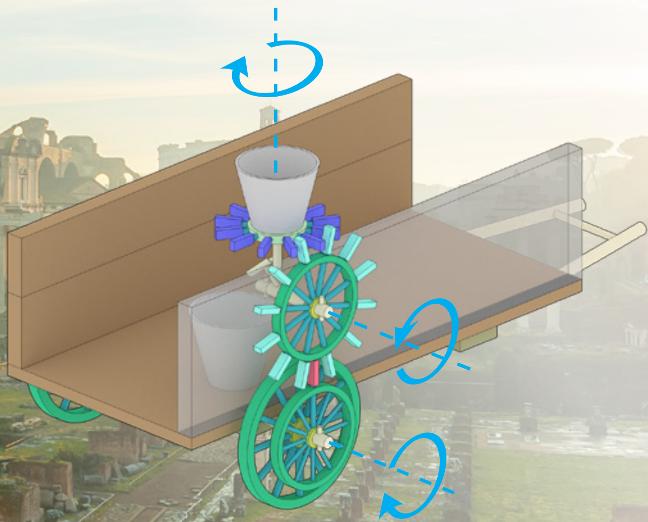
## Historical reference

**The odometer (and its core part – the Counter) has been around for a long while. It's known to have been used almost 2000 years ago to measure the length of roads.** Three historical figures at once claim the credit for its invention: Chinese polymathic scientist Zhang, the famous Greek mathematician Archimedes of Syracuse, and Hero of Alexandria, another engineer from Ancient Greece.

Hero's odometer (picture 1) was a very simple mechanism with two gears and a box with stones, and was found in carriages. With one full revolution of a wheel*, the vertically installed gear turned by one cog. When the vertical gear completed the full circle, it meshed with a horizontally installed gear that had a hole in it. Pushed by a vertical gear, the horizontal one rotated so that a stone fell through the hole. The number of stones would be counted in the end of the way, and knowing the circumference of the wheel, it was easy enough to calculate the distance the carriage covered.

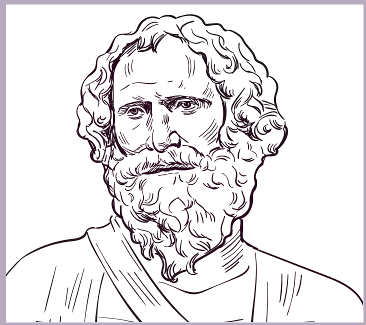
Similar devices were used at about the same period of time both in the Roman and Chinese Empires. Also, in the 3rd century in China, the term "Ji Li Gu Che" emerged describing "a counter that measures a path of a carriage in li". "Li" is a measure of distance that in modern interpretation equals 500 meters or 1640 feet.

The benefits of odometers has been recognised in every country in the world! Over the years, odometers were improved, modified, and adapted according to different measurement units used in different countries – miles, leagues, kilometres. So, as centuries passed, the carts were replaced by carriages and they, in turn, were replaced by modern cars, but one thing remained the same — the desire to know how many miles you've driven. Well, what's so important about understanding the mileage and why does the odometer matter so much? Let's try to figure out.



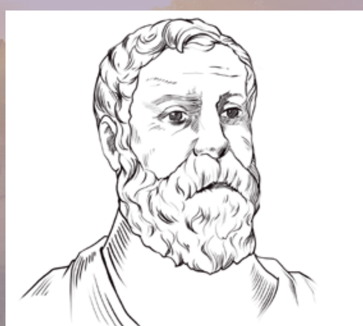
Picture 1

* If you know the length of circumference of a circle (2πR) – e.g. the wheel of your carriage – and the number of revolutions that your counter indicates you can easily calculate the distance.



**Archimedes** is an ancient Greek scientist and engineer. He made many discoveries in geometry. He laid the foundations of mechanics, hydrostatics, and was the author of a number of important inventions.

**Zhang Heng,** adult name was Pingzi, is a Chinese philosopher, encyclopaedic thinker, writer, poet, statesman, and scientist who made world discoveries and inventions in mathematics, astronomy, mechanics, seismology, geography.



**Hero of Alexandria** is a Greek mathematician and mechanical engineer. Details of his life are unknown. Hero is one of the greatest engineers in the history of humankind.

# §3 About the Mechanism and the Range of its use

**Thus, we already know what an odometer is – it's a device that usually records the car mileage (distance travelled) in kilometres or miles.**
Now let's figure out how it works and what types of odometers can be found nowadays!

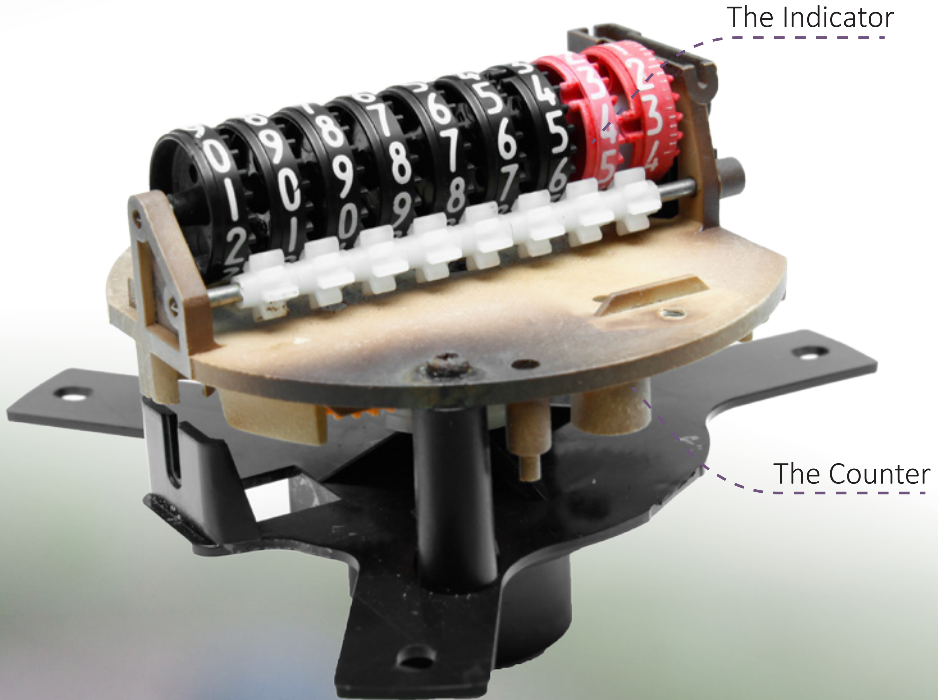
***The odometer is comprised of three key component parts:***

**1. The Detector** — it is the detector that transmits the information to the counter about how many revolutions the wheel of a car has made.

As a rule, detectors are located in the gearbox housing, or in the wheel itself. Following the operation principle we can distinguish mechanical (receive revolutions and transmit them to the counter), electromechanical ones (receive revolutions and convert them into electrical signals).

**2. The Counter** is the most important device! It converts the signal received from the detector and displays it on the indicator. For example, if we are talking about a mechanical odometer, then the detector, through a special flexible cable, physically transmits the rotation to the counter and set the mechanism in motion. However, in the electronic counter nothing is set in motion. The electronic impulses perform the main function, they are processed making the value to be displayed on the indicator.

**3. The Indicator** – in layman's terms is a panel with figures or a display. We look at it and understand how long we drove.




***Based on the foregoing, let's determine what types of odometers we can have:***

**Mechanical odometer** is a mechanical detector + mechanical counter. This is the simplest device, which was arranged on the principle of transmitting rotation through a cable directly to the counter mechanism.

**Hybrid or electromechanical odometer** is a mechanical detector + electronic counter. In this case, the physical rotation of the cable actuated the counter mechanism, but the indicator was digital, which means that the operation of the counter mechanism was digitalised.

**Digital odometer** is an electromechanical detector + electronic counter. It is the most modern of the commercially applied circuits. In this case, the detector receives revolutions, converts them into an electronic impulse (called a Hall sensor), and then the electronic impulse is interpreted in the counter and transmitted to the indicator.

***Thus, what's so important about knowing how long we drove?***

In practice, the odometer helps to determine the length of the path, such as the mileage of a car to let the driver know when the next service is due. When you reset your odometer (or mark the numbers) before your trip, you can figure out the distance from your initial point to your final destination. Or you can, for example, figure out the distance your car can make on one full tank.

In addition, when buying or selling a car, the car remaining lifetime is often determined by miles driven, and this affects its price.

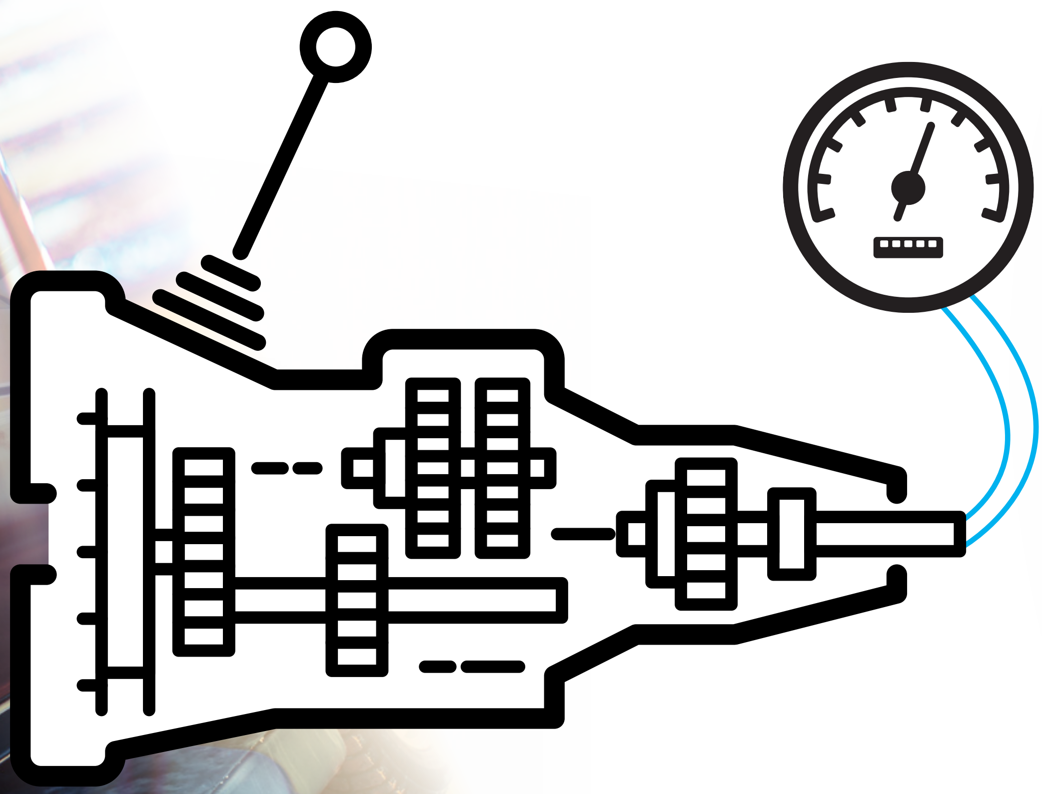
Mileage determines taxi fare, etc.

Normally, for the driver's convenience, the odometer in a car is placed next to the speedometer, another mechanism that determines car speed.

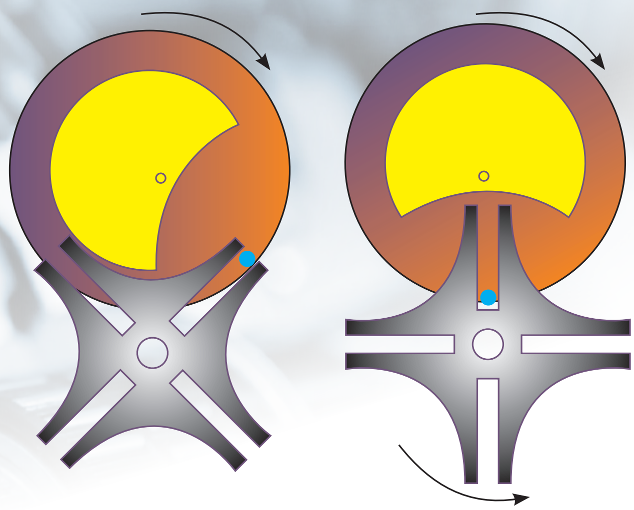
If our counter were a part of the odometer system, then it would be a mechanical odometer.

Let's take a closer look at what happens inside the mechanical counter when the detector starts to work.

**Let us take a closer look at the mechanical automobile odometer.** The principal of its working is based on counting the number of revolutions of the wheel that remains the same for each kilometer the car makes. Knowing the number of revolutions made during the trip, it is easy to calculate the distance the vehicle covered.



**Geneva Drive** is an intermittent gear, that converts uniform rotary motion into intermittent rotary motion.



We started the car and drove. As we said, the detectors are most often placed in the gearbox. Nevertheless, where exactly? Why in the gearbox and not on the wheel itself? The answer is simple. It's convenient! A good thing there's a spot in the gearbox that can give us a sense of how fast we're driving right now, which means how fast the wheels are rotating.

The gearbox converts the revolutions from the engine shaft and, depending on the gear selected, reduces, increases or reverses them (in the case of reverse gear). We can get these revolutions if we connect our detector to the output shaft of the gearbox. After all, that's wherefrom the revolutions go further to the wheels. The rotation of the shaft is transmitted to the detector mechanism, which in turn transmits them to a flexible cable connected to the counter.

Within the counter, the cable transmits the rotation to the input shaft of the worm gears system (we will not consider them yet). Next, the gear of the last worm gear activates the first indicator cylinder (the same cylinders that we see in the car). Cylinder-1 begins to rotate and count the first mileage value — hundredths of kilometres (every 10 metres). Having counted up to 10 positions (i.e. we have travelled 100 metres), it makes one turn of the next cylinder-2, which denotes a tenth of a kilometre (every 100 metres), and continues to rotate further. When the second cylinder reaches the value of 10, it makes one turn of cylinder-3, showing the kilometres travelled and so on.

How does it happen so that, having reached 10, the cylinder rotates the adjacent one by one cog and continues to rotate further? The answer lies in **Geneva Drive.**

The operation principle of this mechanism is also laid down in the model "Gearbox" of the STEM-lab series. **Having assembled this model, you will understand how this simple mechanism works.**

The principle has remained the same since Ancient Rome only replacing stones with numbers indicated on the cylinder gears with the number of kilometres and metres travelled.

The mechanical counter uses worm gears.

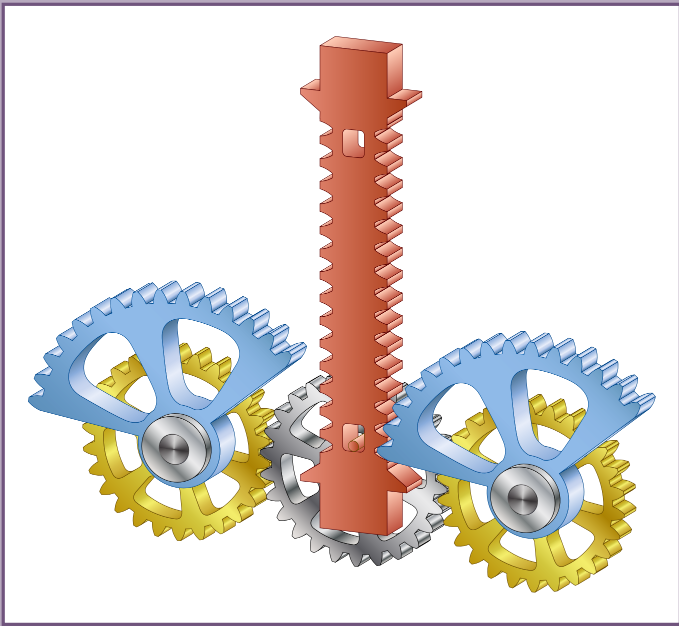
To ensure the precision of indication, drivers/users calibrate their odometers, for example, when the diameter of the wheel is changed, etc

**The worm gear (crossed helical gear)** — is a type of a mechanical gear arrangement in which a worm (put simply, a screw) meshes with a worm gear (gear wheel).

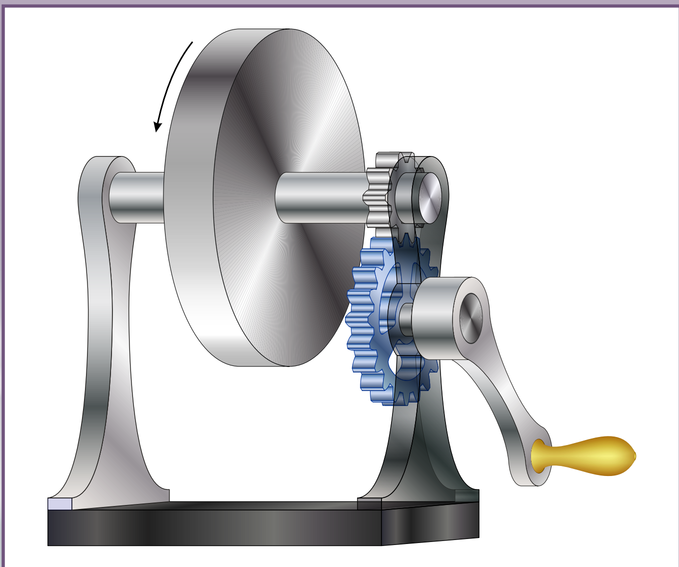
Now, when we know what the odometer is, let us examine its work in practice – using our newly assembled mechanical puzzle. Your model is a combination of a counter and an indicator. And the detector is the one who is pressing the click-button or turning the handle on the right side of the model – yourself!

The Counter model has three cylinder gears with numbers from 0 to 9, a turn handle to quickly scroll through the indicator values performing a **rotating motion,** a click-button for data registering, performing **reciprocating motion,** a flap to “zero out” the results.

The counter operation is based on the Geneva Drive!



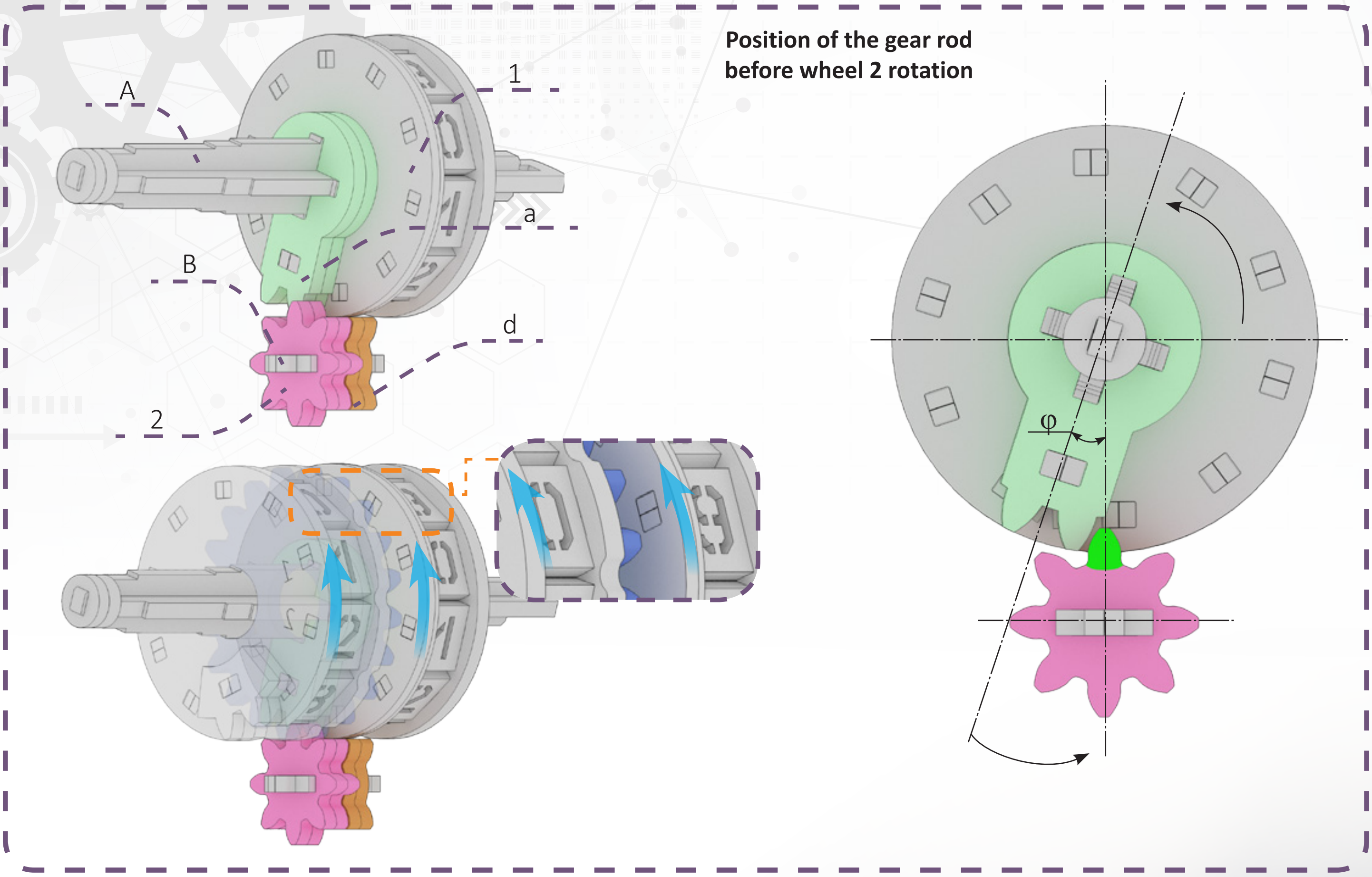
**Reciprocating motion** is a repeated linear upward-downward or forward-backward movement. This principle applies to a wide range of mechanisms, including piston engines

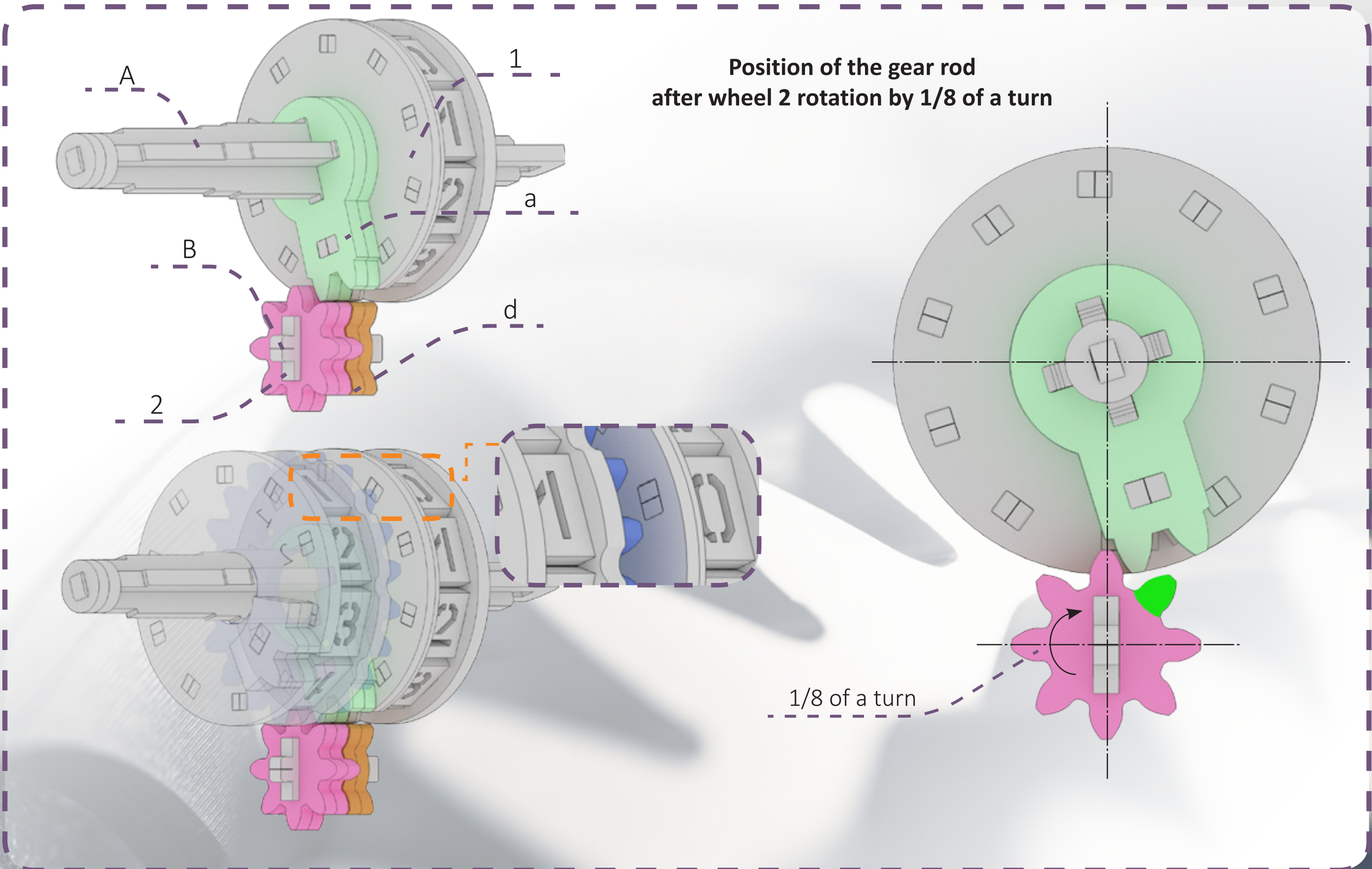


**Rotating motion i**s a type of mechanical motion. When rotating, the material point (a very small point on the rotating object) describes a circle

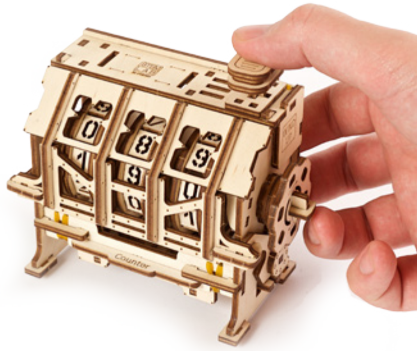
## Geneva Drive using a counter:

Cylinder 1 rotating around axis A has a gear rod a, which periodically engages with teeth d of wheel 2 rotating around axis B. When wheel 1 is rotated (Fig. 2.1) by angle φ, wheel 2 is rotating by 1/8 of a turn (Fig. 2.2).



# §4
## Technical design and principles of working

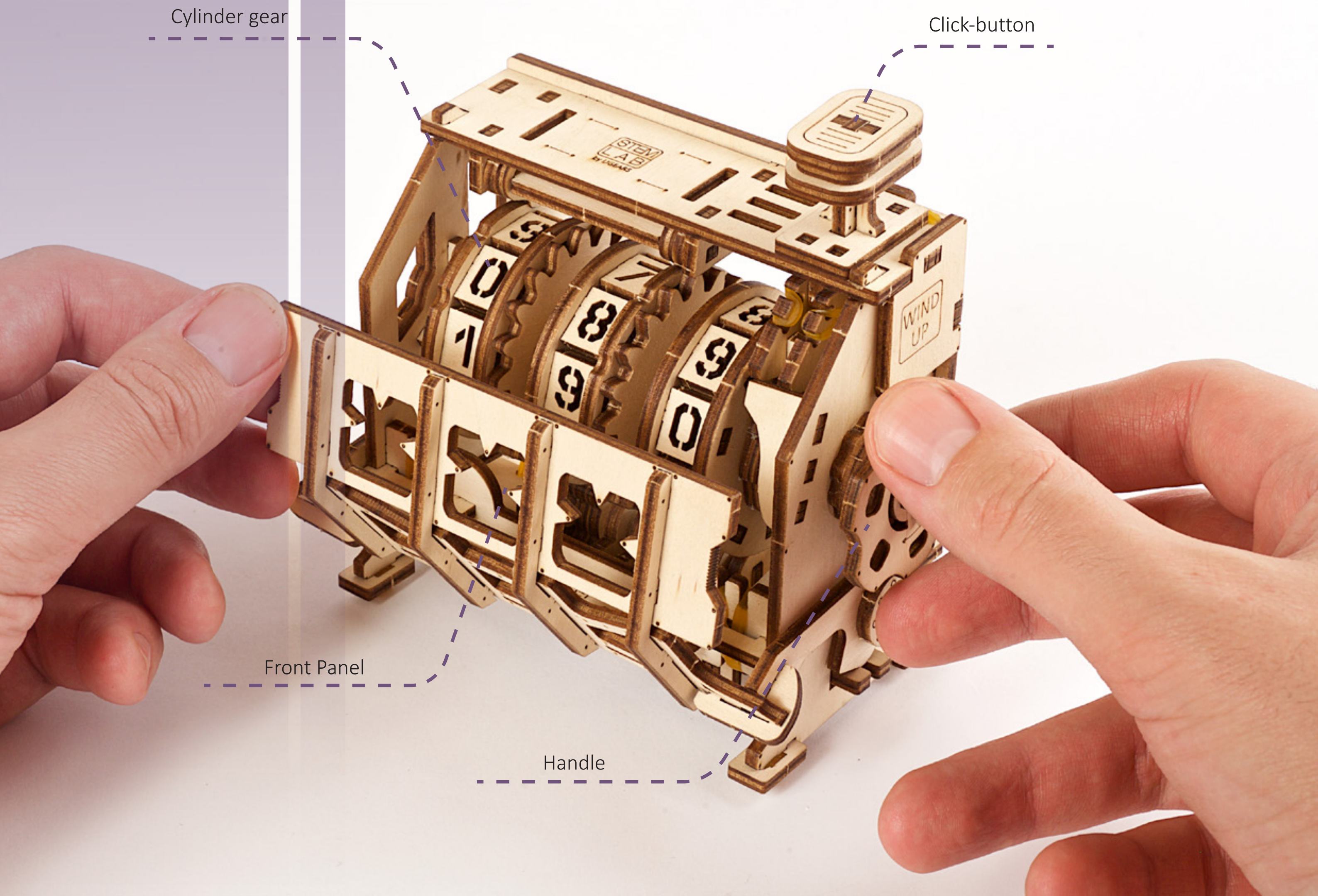


### How it works

Pressing the click-button makes the Counter shift by one place (turning the handle, in 1 full revolution the value of the first registering cylinder will change by 10 values and the second registering cylinder will rotate by 1 value). When the count passes 9, the Geneva Drive catches the next register cylinder and adds it to the count (the mechanism switches the next cylinder by one place when the previous cylinder is fully rotated and the value of the next register is changed, etc. until the second cylinder comes to the value of 10. Then the Geneva Drive of the third register is engaged). Altogether, the three-digit display of the Counter can register values from 1 to 999.

The ratchet gears keep the mechanism from counting down or resetting when the cover is closed ensuring that the counting goes in correct succession.

**To reset the counter manually,** you need to open the panel and rotate the cylinders down to zero.



# §5 Formative hands-on tasks

## To solve the tasks you will need:

**Formula 1.** The formula for calculating length of circumference of a circle

$$C = 2\pi R \ (\text{м})$$

**Where:**
C – length of circumference, meters (m);
R- circle radius, meters (m);
π – the mathematical constant that expresses the ratio of the circumference of a circle to its diameter, π is approximately equal 3.14.

**Formula 2.** Formula for calculating the length of a given interval (l):

$$l = \frac{S}{N}$$

**Where:**
S – the total length of the path you walked/distance covered, meters (m);
N – the number of identical intervals, pieces (pcs.)

**Formula 3.** The formula for calculating the average speed of motion:

$$\upsilon = \frac{S}{t} \ (\text{m/s})$$

**Where:**
S – the length of the path you walked/travelled, meters (m);
t – time you spent for overcoming path, seconds (s).

**Formula 4.** The formula for calculating the length of the path you walked/traveled depending on the length of circumference of a circle and number of turns.

$$S = C \cdot N \ (\text{m})$$

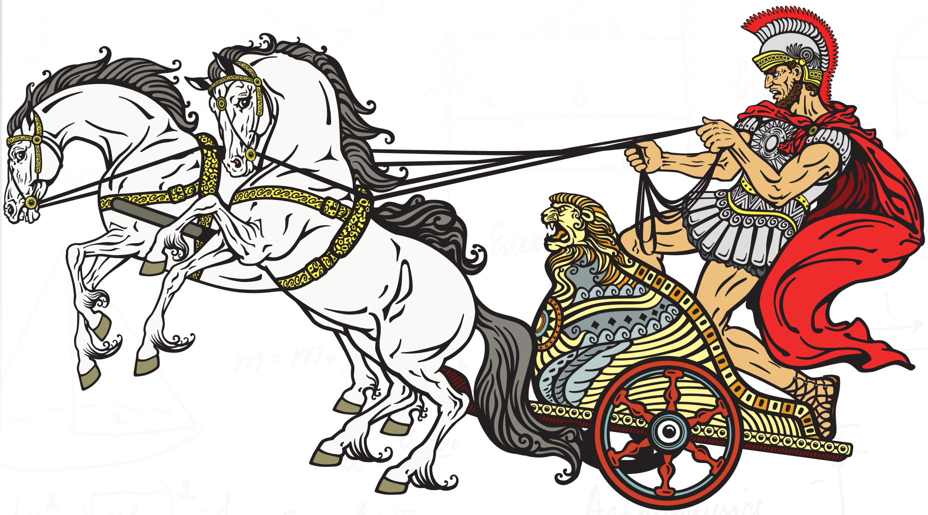
**Where:**
C - the length of circumference of a circle (m – meters);
Nv - number of full turns made by a circumference (e.g. a wheel).

### *Task 1.* «Silk Road»

Given that the caravan was in transit for 6 hours. The wheel of the carriage was making 1800 full turns per hour. The diameter of the wheel is 1.5 m.
Calculate length of the path of a caravan moving along the Silk road using Formula 1 and Formula 4.

### *Task 2.* «The Coliseum»

The Roman legate made 4 rounds around the Coliseum in a chariot and won. The circumference of the Coliseum is 500 passus (Passus - is a historical Roman measure of length, the so-called double step, two steps and it is approximately equal 1.48 m). The diameter of the wheel is 1 m.How many turns did the wheel of a Roman chariot make during a race in Ancient Rome? Use Formula 1 and Formula 4 for calculating..



***Task 3.* “The Length of Your Step”**

Calculate the average length of your step.

Walk 10-20 steps (N) in a room. Use the Counter to register the number of steps. Use a measuring tape to measure the distance you walked – S = __________________ meters (use Si units to write down your data). Use your data – the number of steps and the distance – to calculate the average length of your steps by the following formula 2. For a more precise result, repeat the experiment several times and find the average of your results.

***Task 4.* “Average Speed of Your Motion”**

Finding average speed of motion using Formula 3. Choose your route, for example from home to a park.

Use the Counter to register the number of steps you make to travel the chosen route. Write the number as N = __________________. Note the time the walk took. Measure the time – t – with a stop-watch, in seconds. t = __________________. Use the results you obtained in first exercise for the average length of your step, and the number of steps you’ve registered to calculate the length of your route using the formula 2. And finally find your average speed using Formula 3.

***Exercise 1***

Let’s count the number of cars passing by. To make sure you don’t lose count of, for example, blue cars passing by, use the Counter. During 10 minutes, count the number of passing blue cars. In 10 minutes mark the number and reset the Counter. For the next 10 minutes count white cars. Which number is bigger – the blue cars or white cars?

***Exercise 2***

**Option 1.** Count how many steps there are between your house and a stadium/shop/school and back. Use your Counter to register the number of steps of a one way trip. Mark the number and reset your Counter when you arrive at your destination. Now, repeat your actions for your return trip. Compare the numbers. Are they the same?

**Option 2.** Take a different route back and compare the number of steps of both trips. Are they the same or one way is shorter/longer than the other?

## ASSESSMENT TASK

**1. The device for measuring distance is called…**

☐ a) speedometer
☐ b) tachometer
☐ c) Odometer

**2. Archimedes is believed to improve the power and accuracy of a catapult as well as an invention of…**

☐ a) a propeller
☐ b) aircraft
☐ c) Odometer

**3. Is it true that the original odometer is described as a box with stones that dropped a stone through the hole in a gear every mile?**

☐ a) no
☐ b) this is not a proven fact
☐ c) Yes

**4. How many cylinder gears does the Counter model have?**

☐ a) five
☐ b) seven
☐ c) Three

**5. What types of odometers are there?**

☐ a) mechanical
☐ b) digital
☐ c) all-wheel-drive

**6. Which detail prevents counting down when the panel of the Odometer is closed?**

☐ a) gear
☐ b) shaft
☐ c) ratchet gear

**7. What does a person's average speed depend on?**

☐ a) distance
☐ b) strength
☐ c) length of the step

**8. In uniform motion, the length of the step…**

☐ a) increases
☐ b) decreases
☐ c) remains the same

**Congratulations! You made it!**

Thank you for being with us in this adventure, we hope you had fun and learned a thing or two!