DEMETER PROJECT

HOW THE ROVER MOVES UNIT

Co-funded by the Erasmus+ Programme of the European Union

UNIT 1. How the rover moves

This unit was carried out jointly by the Physics / Maths teacher and the Mechanical construction teacher.

This will allow students to learn and understand how the rover moves, through experimentation and analysis.

To do this, the students will therefore need to mobilise and combine knowledge and skills from different subjects such as Maths, Physics and mechanics rules.

The first step will be to show to the students the different motions used with the remote control.

Then, they will learn how many motors are used, the revolution direction of each motor for the different motions (forward, turn left…).

They sum up the result on a slide which could be used as a rover used notice.

The second part of the unit will be the understanding of gear principle, transmission ratio, output speed in function of input speed. The student must find the speed wheel tracks.

By experimentation, students will verify or compare speed results.

At least, students will be able to calculate the rover speed, to learn which parameters can change this speed. They can compare this result to real rover speed easily.

Teachers

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Duration

This Unit consists of six lessons.

Objectives and Key competences

- Reporting and communication
- develop the practice of office automation tools
- conducting a mini-project (model on the gearing)

Physics : ● Analyse movements

Maths :

- Situate oneself in a plane and in space
- Develop the practice of spreadsheet software

Mechanical construction :

- Understanding of gear principle, transmission ratio, output speed in function of input speed.
- To find an angular speed or linear speed.
- Develop the practice of CAD software

Material / resources

- word processing software, presentation software, spreadsheet software
- The remote controlled rover
- The 2 rover gearboxes and/or gearbox CAO model on PC.
- For experimentation: tachymeter, timer and a meter to check or to compare the results (rover's speed).
- 3D printer and set of workshop tools

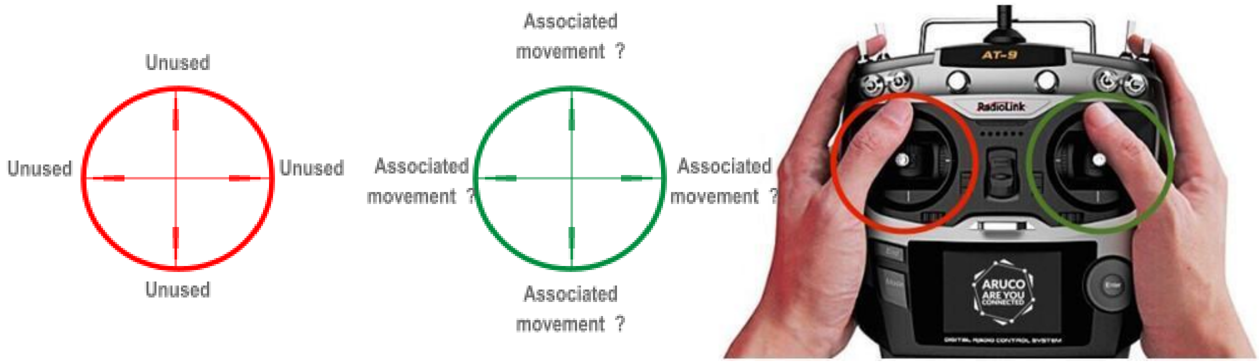
Lesson 1 : Piloting of the different movements

The main objective is to introduce in an enjoyable way the project and to appropriate the technical object that is the rover. It's possible movements, it's structure, it's mode of propulsion

By manipulating the rover made by the last year students and piloting it with the remote control, the students must create a document or a support to present the rover controls to anyone, and the associated action on the motors.

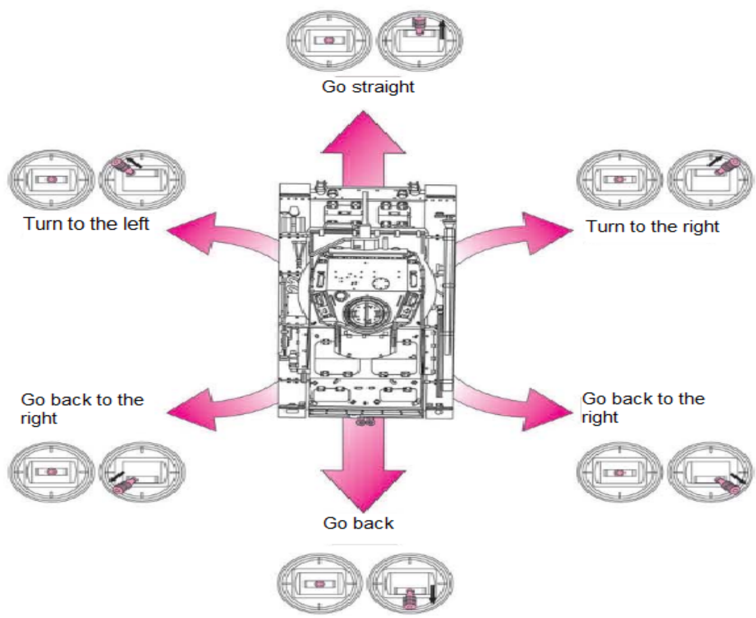
The remote has two joysticks but only the left one is used

The best document will be joint to the rover delivery.



Phase 1 : Analysis

The relationship between the actions on the remote control and the movements must lead them to identify all the possible types of movements and the motor involved.



- **Details of track movements « To go straight »**

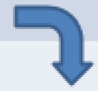
		Tracks speeds	Rover direction
Motor n°1	clockwise	high speed	
Motor n°2	Counter clockwise	high speed	

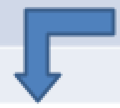
		Tracks speeds	Rover direction
Motor n°		Slow speed	
Moror n°		high speed	

		Tracks speeds	Rover direction
Motor n°		High speed	
Motor n°		Slow speed	

- **Details of track movements « To go back »**

		Tracks speeds	Rover direction
Motor n°1	Counter clockwise	High speed	
Motor n°2	clockwise	High speed	

		Tracks speeds	Rover direction
Motor n°		High speed	
Motor n°		Slow speed	

		Tracks speeds	Rover direction
Motor n°			
Motor n°			

- **Details of track movements « To turn on itself to the left »**

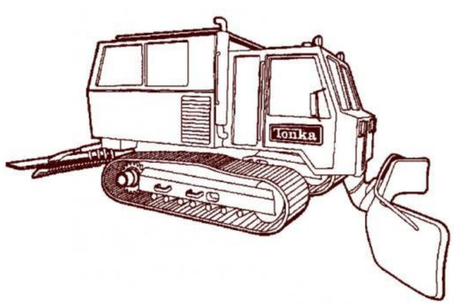
		Tracks speeds	Rover direction
Motor n°1	Counter clockwise	High speed	
Motor n°2	Counter clockwise	High speed	

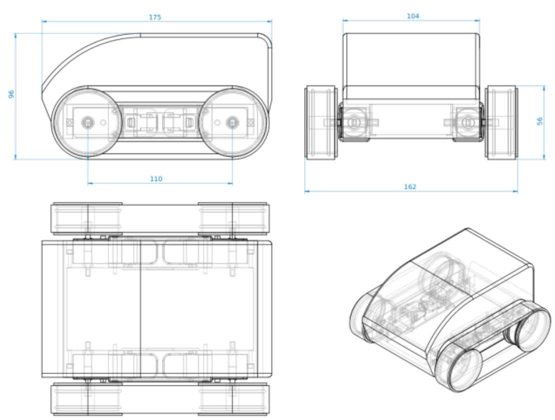
- **Details of track movements « To turn on itself to the right »**

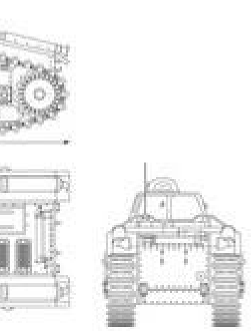
		Tracks speeds	Rover direction
Motor n°1	Clockwise	High speed	
Motor n°2	Clockwise	High speed	

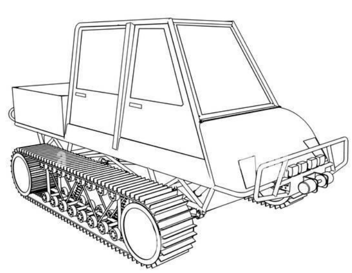
Phase 2 : search of infographics

The students have to search relevant pictures and infographics about tracked vehicles to illustrate their document.







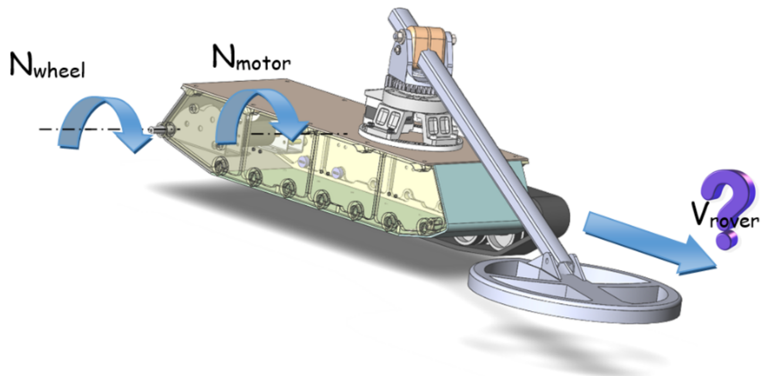


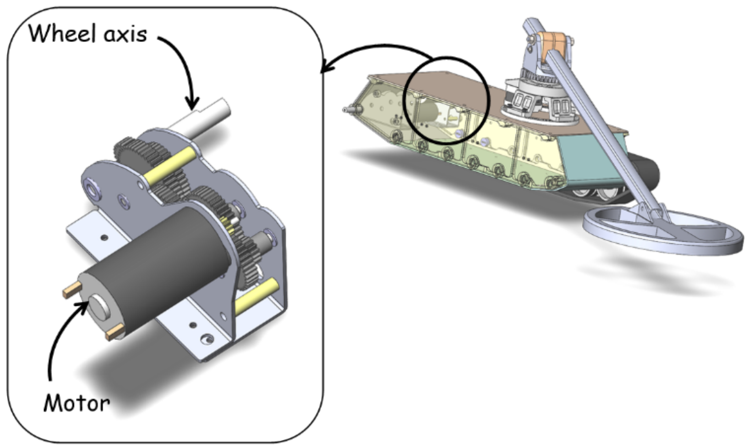
Phase 3 : Write the document

They have to write a clear and concise document : a leaflet or a slide show.

Lesson 2: gearbox function

The rover speed depends on the speed **rotation motor**, the gear box will adapt this speed rotation to the rover wheel tracks speed…how?

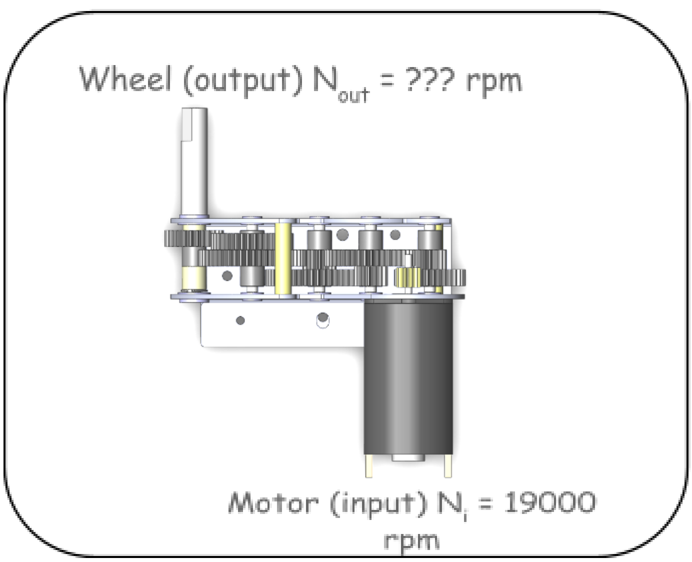


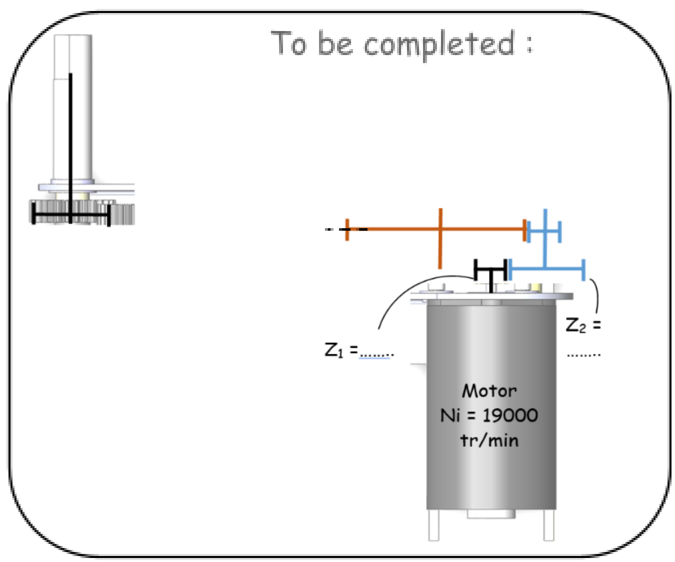


Gearbox (leftside)

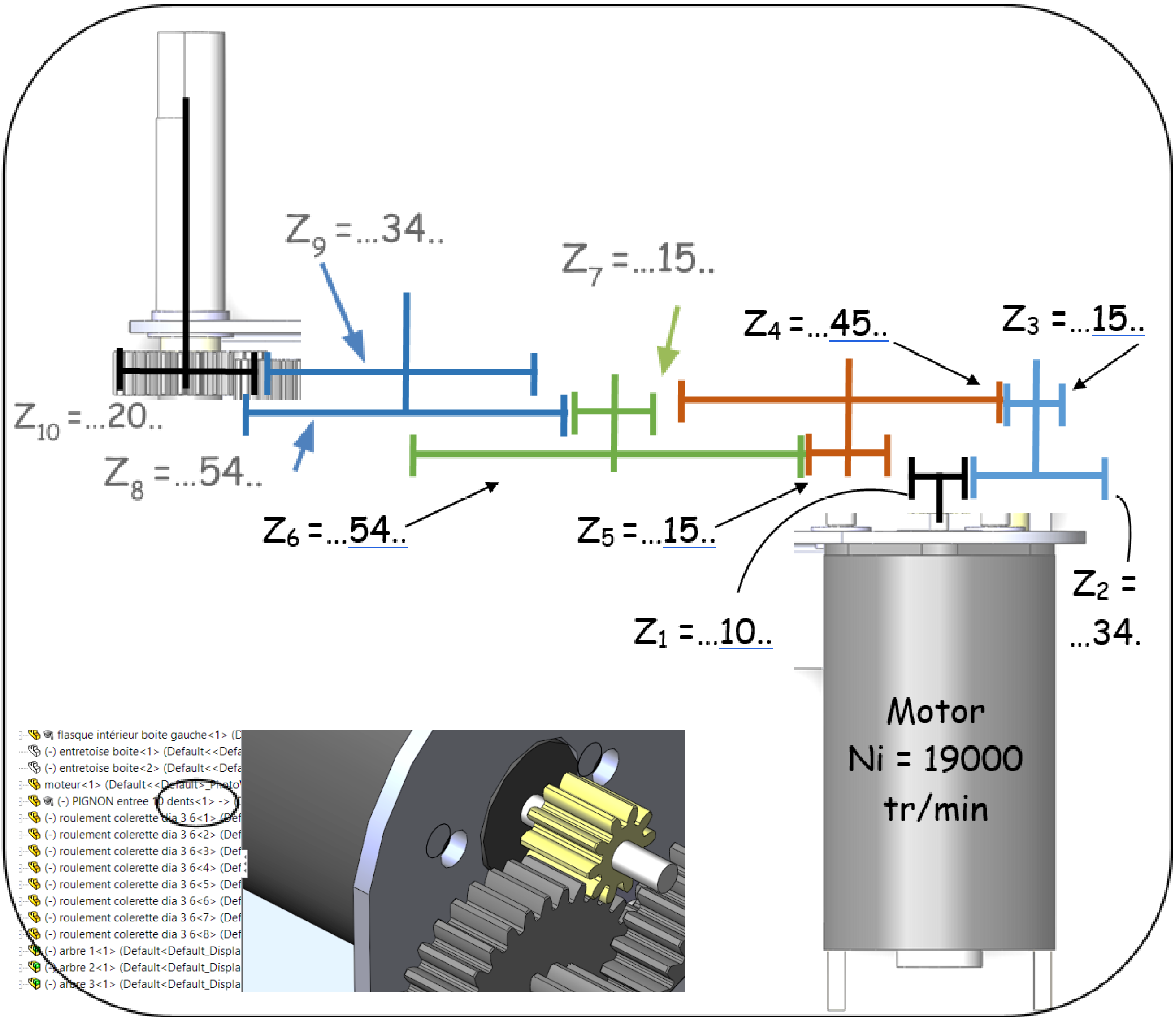
First step : Symbolise the gearbox in order to simplify the real gearbox.

With the real gearbox or the CAO model, students count teeth (Z) and drawn each gear.





Second step: using transmission ratio rules, students find the value of this transmission ratio.



Formula : $r = Z_{leading} / Z_{following}$

$$r = Z1 \times Z3 \times Z5 \times Z7 \times Z9 / Z2 \times Z4 \times Z6 \times Z8 \times Z10$$

Result : r = 0.0128

The animation joined (or the real gearbox) allows to verify that the transmission ratio found before is a reducer. The student can deduce the following rule:

☐ **r < 1** : the gearbox is a reducer,	If **r < 1** : the gearbox is multiplier ☐
☐ **r > 1** : the gearbox is multiplier	if **r > 1** : the gearbox is a reducer ☐
☐ **r = 1** : the gearbox doesn't change the speed.	if **r = 1** : the gearbox change the speed ☐

Last step : find the output speed (wheel speed) N_{out}.

By testing and using an example, students try to find the formula for N_{out}. They know that the output speed is lower than N_{in} the input speed (r <1).

Example given:

If r = 0.5 and N_{in} = 100 rpm, then N_{out}. = 200 rpm? Or N_{out}. = 50 rpm? Or N_{out}. = 0.005 rpm?

They try: $N_{out} = N_{in} \times r$ or $N_{out} = N_{in} / r$ or $N_{out} = r / N_{in}$

After many trying, they find: $N_{out} = N_{in} \times r$ $N_{out} = 19000 \times 0.0128$ $N_{out} = 243$rpm

The rule deduces from this example: $\mathbf{r = N_{out}/ N_{in}}$

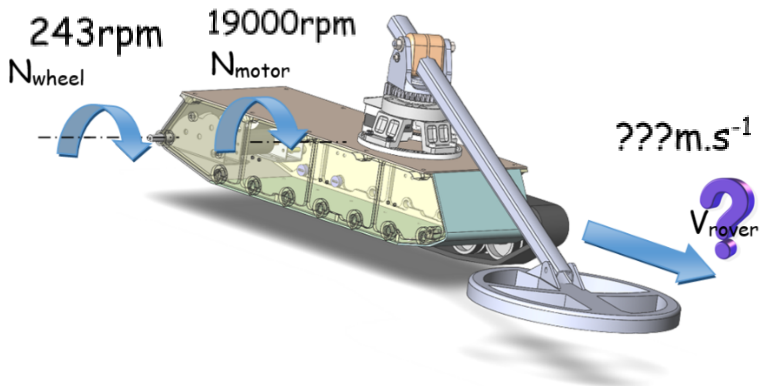
In conclusion :

The motor's speed is 19000 rpm. After the gearbox, the **wheel speed** is N_{out} **= 243rpm**

This result may be compared or verified by testing with tachymeter.

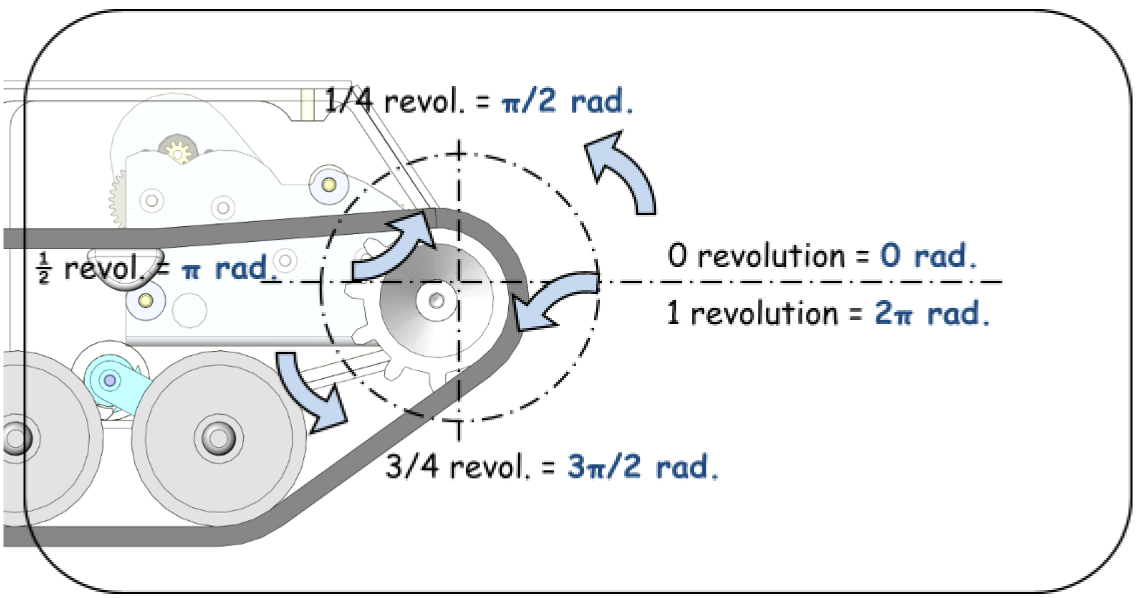
Lesson 3: Rover's speed

The rover wheel tracks speed is found in lesson 2, N_{wheel} = 243 rpm (rotational motion). Another previous lesson, made in science, allows to test track speed with a tachymeter. This lesson 3 is made to find the rover speed (translation motion). This speed is important to regulate the sensor motion.



First step: Recall of the radian unit. Determine the angular speed (ω in $rad.s^{-1}$) instead of the frequency of rotation (N in rpm).

The linear speed in $m.s^{-1}$ depends on angular speed in $rad.s^{-1}$, what is a radian ?



So, the radian is a unit which allows to graduate a circle. It may be compared to the degree unit (180° = π rad., 360° = 2 π rad.) or to revolution.

We will remember that: **1 revolution = 2π rad.**

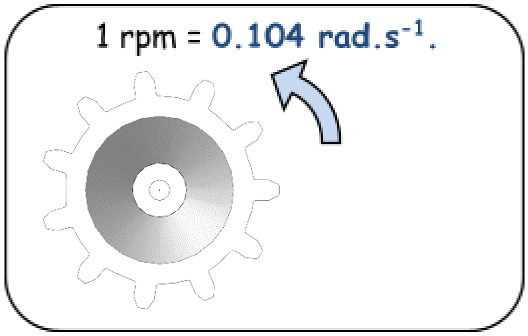
Now, to find the angular speed (ω in rad.s^{-1}) instead of the revolution per minute(N in rpm), students have to convert revolution in radian and minute in seconds (1min = 60s) :

$$\omega = 2\pi \; x \; \frac{N}{60}$$

For example: if the rover wheel turns at 1 revolution per minute, how many radians per seconds is the rover wheel turning?

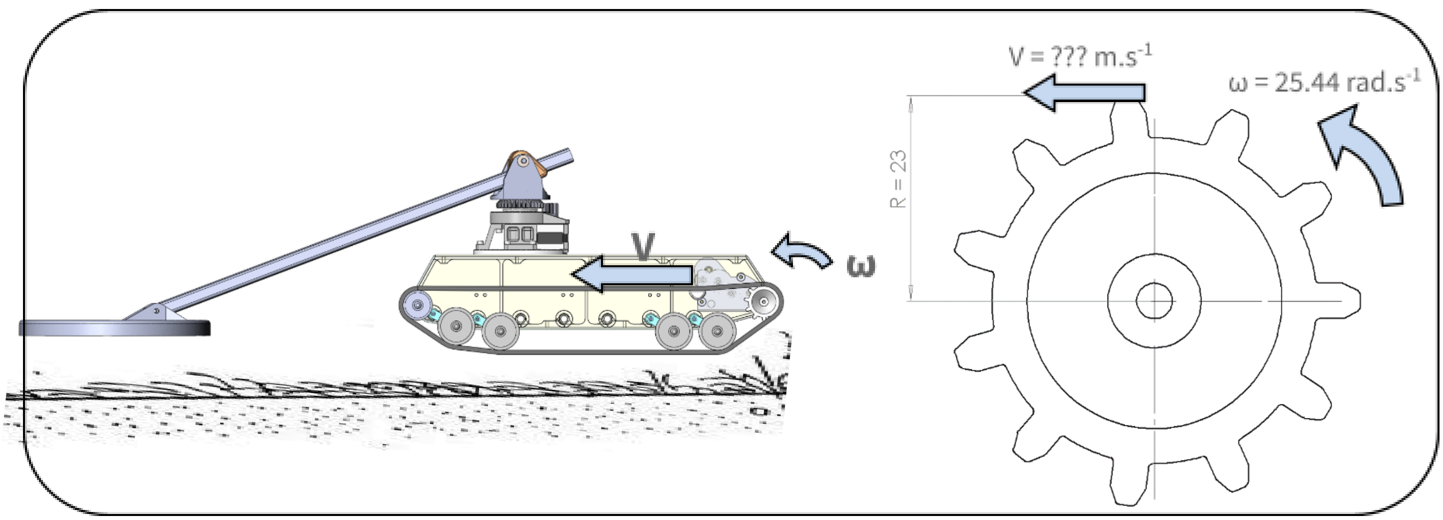
$$\omega = 2\pi \; x \; \frac{N}{60}$$

$$\omega = 2\pi \; x \; \frac{1}{60} \qquad \omega = 0.104 rad.s^{-1}$$



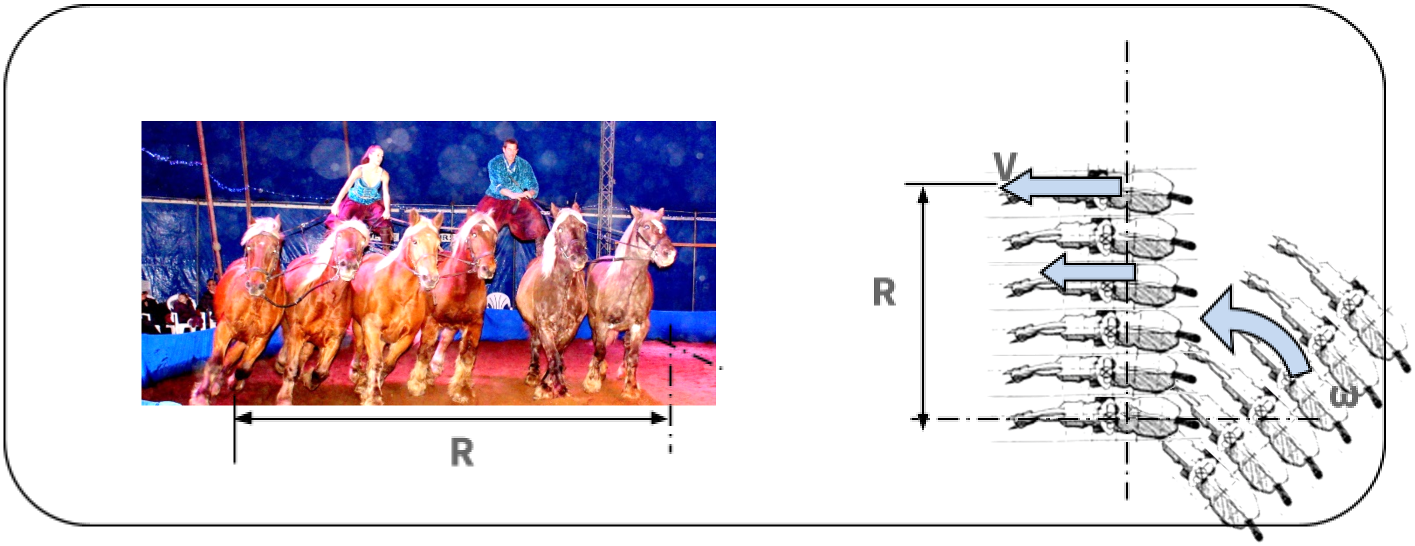
This result may be compared or verified with the speed found in science lessons.

Second step : Find the linear speed **V** of the rover. Use and understand the formula V = ω x R



Students have to think about the different parameters used in the formula. An easy example below:

Which is the horse running fastest? Why?



Using the previous example, the data and the formula, students calculate the linear speed **V** of the rover:

(Be careful of distance R unit: in m)

$V = \omega \times R$

$V = 25.44 \times 0.023$

$V = 0.59\ m.s^{-1}$

<u>Conclusion</u>:

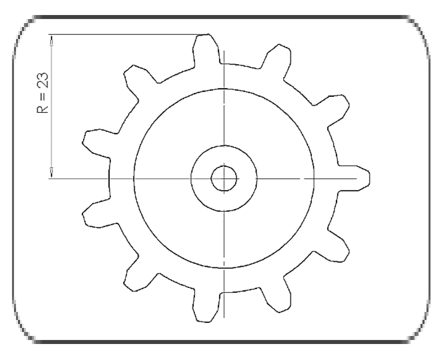
The rover move forward at the speed of 0.59 $m.s^{-1}$ (about 2.1 $km.h^{-1}$)

This result may be compared or verified in timing the rover on few meters.

Another activity could be treated by students on this subject:

If we would like to increase the rover speed, the radius R of the wheel should be increased or decreased?

To increase V: ☐ should be increase ☐should be decrease



To be able to detect mines, the rover must move forward at a maximum speed of 2 $km.h^{-1}$ (= 0.55$m.s^{-1}$), calculate the new radius of the wheel.

V = 2 $km.h^{-1}$ = 0.55m $m.s^{-1}$

V = ω x R and R = V / ω

New radius : → R = 21

R = 0.55 / 25.44

R = 0.021 m = 21mm

Lesson 4 : Speed of rotating parts

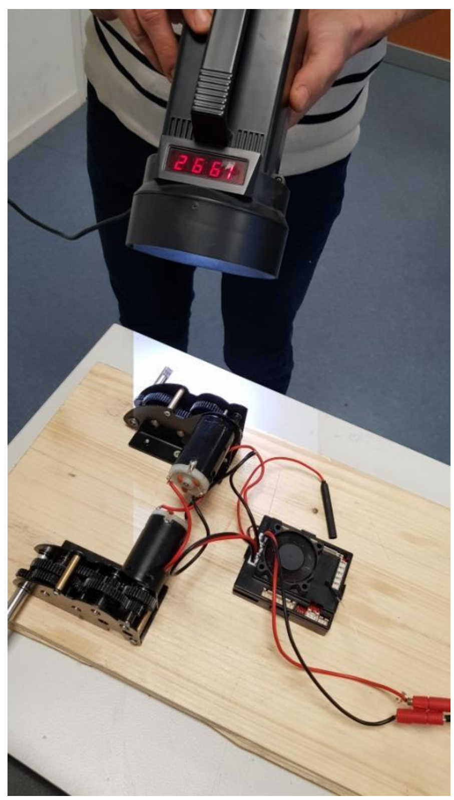
The main objective is to illustrate with various concrete measurements the theoretical notions developed in the physics and mechanics courses.

Measurements of the rotation frequencies

The students must measure the input and output rotation speeds thanks to the tachometer or the stroboscope.

measuring the output

with a stroboscope

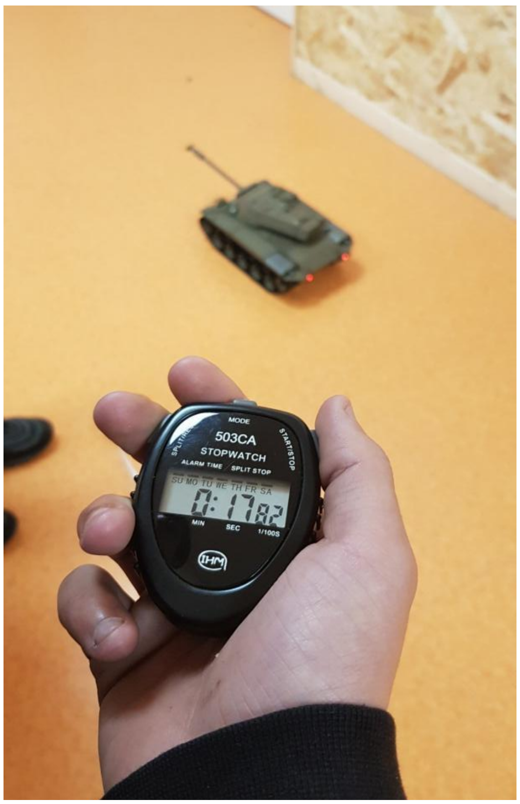


speed with a tachometer
measuring the input speed

Measurements of the average linear speed

They must calculate the average speed from a measured distance and a timed duration

$$v = \frac{d}{t} = \frac{20}{38} = 0,53\; m.s^{-1}$$



measuring the travelling time t=38s
measuring the distance travelled d=20m

We do not have any measuring device at school to measure the instantaneous speed but we can make chronophotographs of the rover's movement and calculate average speeds over shorter periods.

Measurements of the linear speed from the rotation speed of the driving wheel

From a measured rotational frequency and the radius of the driving wheel the students must calculate the tangential speed.

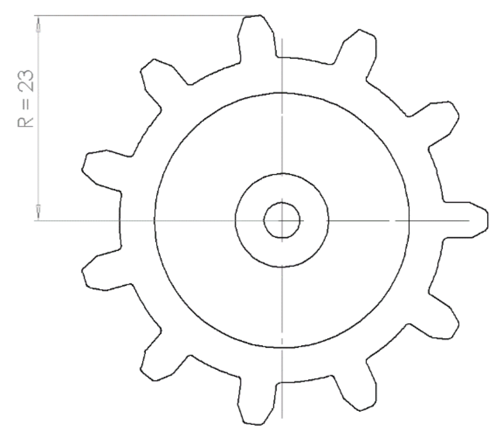
They must first convert the rpm to rps, to use the previously studied formula :

$$As: \ 250\, r.min^{-1} = \frac{250}{60} r.s^{-1} \qquad v = 2\pi \times 0,023 \times \frac{250}{60} = 0,6\, ms^{-1}$$

It is interesting to make them think about the link between the tangential speed of the driving wheel and the linear speed of the rover.

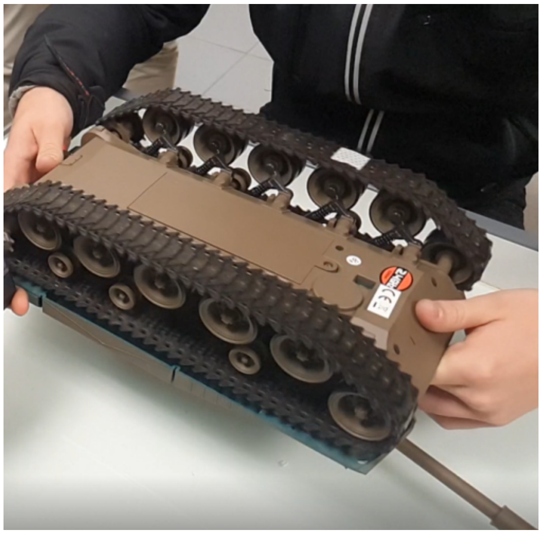
This should lead them to the conclusion that they are identical.

measurement of the rotation frequency of the driving wheel N= 250 $r.min^{-1}$



Measurement of the linear speed from the tracks dimension

From a certain number of revolutions of the track, its length and the timed duration they must calculate the rover speed.



Tracks length = 90 cm

Number of turns = 29

Duration = 49 s

$$v = \frac{29 \times 0{,}90}{49} = 0{,}53\ m.s^{-1}$$

Counting the number of turns by means of a marker on a track n = 29 turns

Lesson 5 : Speeds summary chart

Students must programme a table using a spreadsheet that summarises the speeds of the different stages of the gearbox.

Depending on the level of programming acquired in maths by the students, the complexity of the table can be adapted according to, :

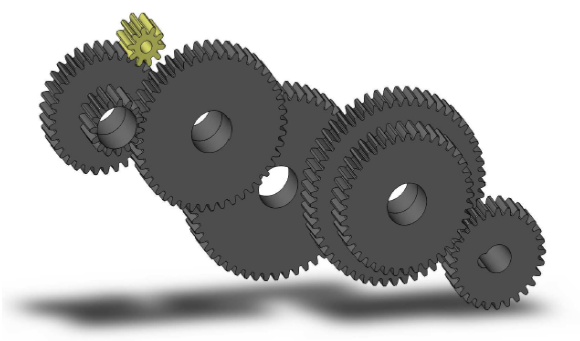
- The input rotation frequency can be within a given range
- The number of sprocket teeth can be fixed or variable
- The driving wheel radius can be fixed or variable

And so on…

Number of sprocket teeth	
Z_1=	10
Z_2=	34
Z_3=	15
Z_4=	45
Z_5=	15
Z_6=	53
Z_7=	15
Z_8=	53
Z_9=	40
Z_{10}=	28

Motor rotation frequency N1 (r/min)	Stage 1 rotation frequency (r/min)	Stage 2 rotation frequency (r/min)	Stage 3 rotation frequency (r/min)	Stage 4 rotation frequency (r/min)	Drive wheel rotation frequency (r/min)	Rover speed (m/s)
5000	1471	490	139	39	56	0,15
6000	1765	588	166	47	67	0,18
7000	2059	686	194	55	79	0,21
8000	2353	784	222	63	90	0,23
9000	2647	882	250	71	101	0,26
10000	2941	980	277	79	112	0,29
11000	3235	1078	305	86	123	0,32
12000	3529	1176	333	94	135	0,35
13000	3824	1275	361	102	146	0,38
14000	4118	1373	388	110	157	0,41
15000	4412	1471	416	118	168	0,44
16000	4706	1569	444	126	179	0,47
17000	5000	1667	472	133	191	0,50
18000	5294	1765	499	141	202	0,53
19000	5588	1863	527	149	213	0,56
20000	5882	1961	555	157	224	0,59

Lesson



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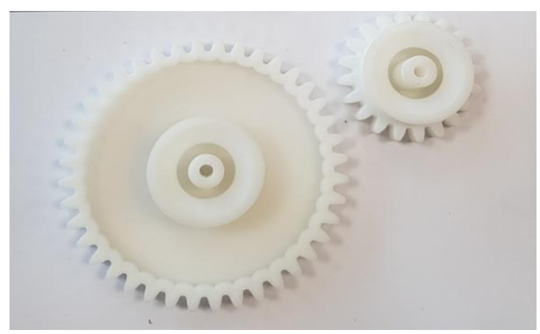


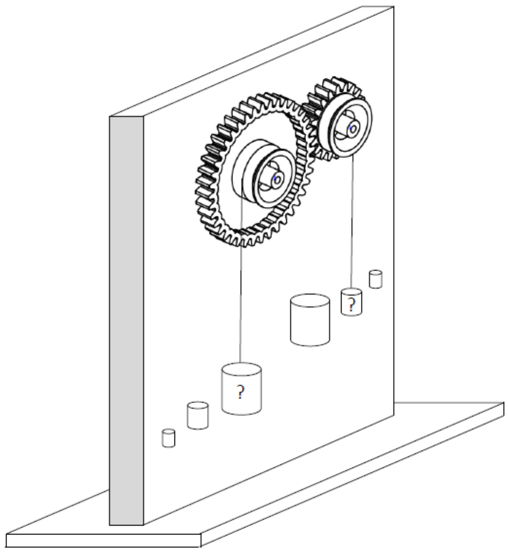
Experimental model on the gearing

3D model of the entire gearbox

3D printing made by students

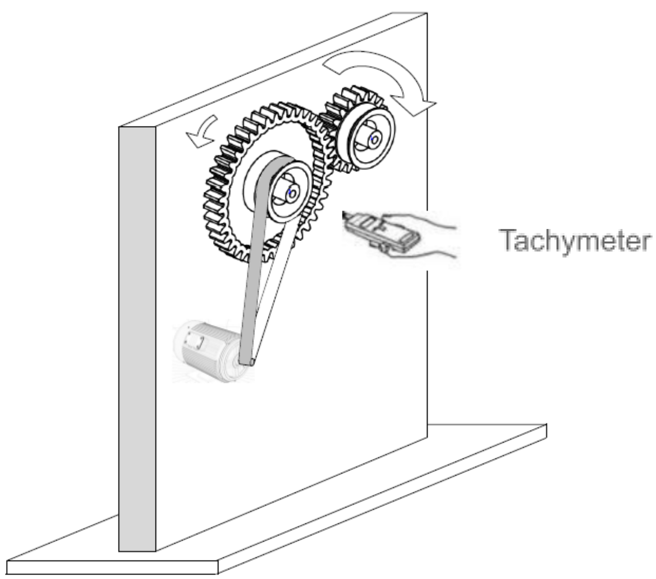
In order to study the gearbox, students can be asked to think about the design of an experimental model to explain the principle of the gears by isolating 2 wheels.

The model would be based on the principle of force reduction.



The goal could be highlighting the ratio of forces on each wheel by achieving the balance.

The model would also make it possible to study the principle of speed reduction.



In this configuration, the goal could be highlighting the ratio of rotation speeds.