
Gear technique?
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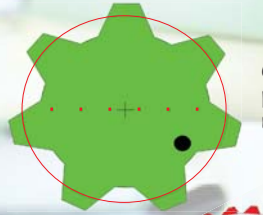
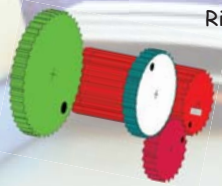
From gear modulus to 9 speed automatic transmission in some simple steps ...



Gear wheel with pitch circle and modulus

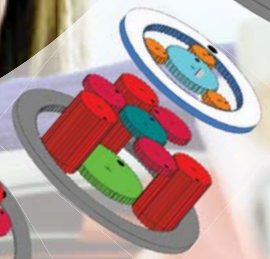
Spur gears



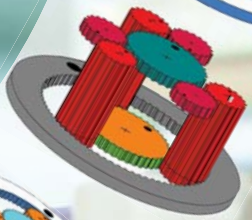
Ring gear

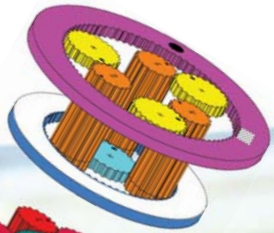
Planetary gear

Ravigneaux gear set



Lepelletier gear set





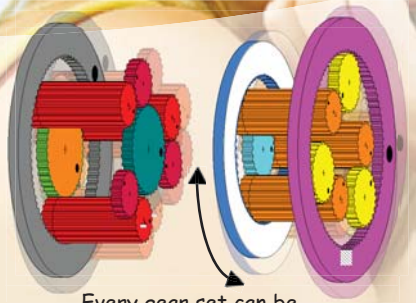
9 speed automatic transmission

...and many features

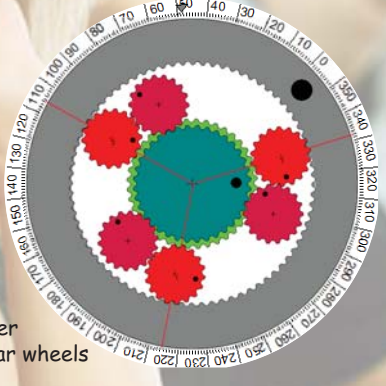
Free setup of teeth numbers of every gear wheel

Ravigneaux gear set

		V	S
Short planet	19	✓	
Internal ring	-75	✓	✓
Small sun	30	✓	✓
Large sun	39	✓	
Long planet	18	✓	



Every gear set can be turned automatically or manually in 3D view



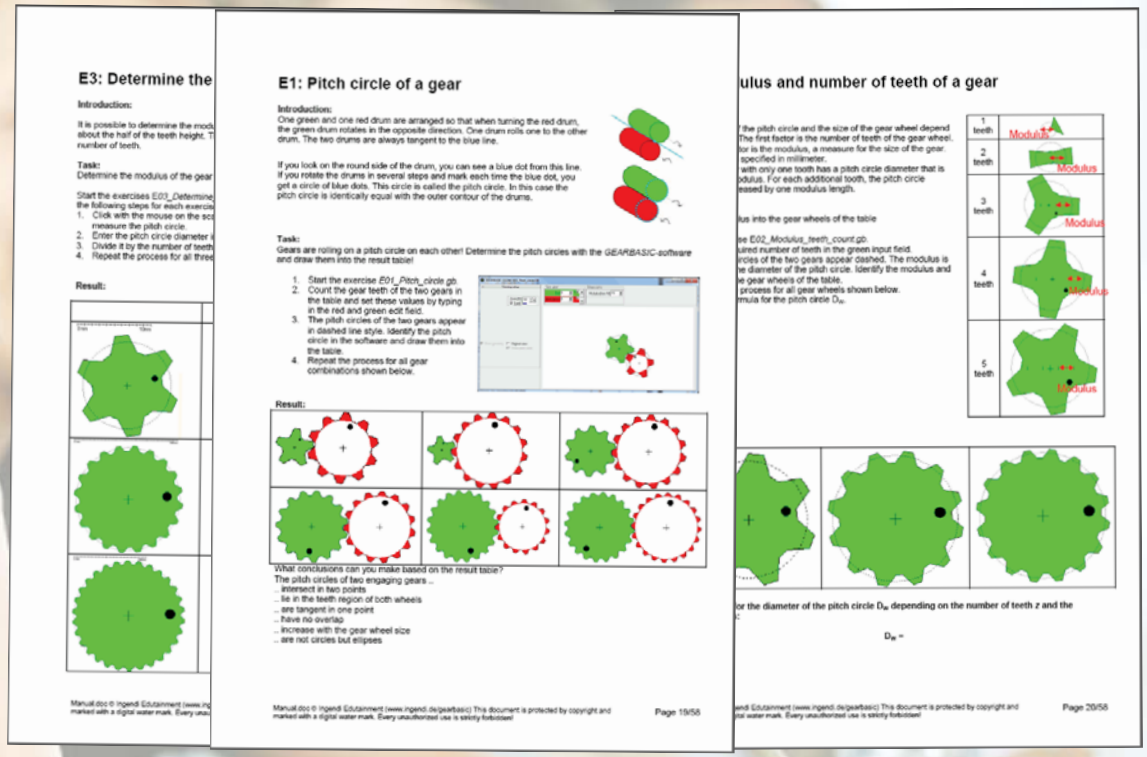
Goniometer for all gear wheels

Gear speed table with switching elements

Gear	●○○	●●○	●●○	(●)	(●)	i
R	X				X	-2.237
N						0
1			X		X	2.742
2			X	X		1.538
3		X	X			1.000
4		X		X		0.691

Predefined exercises / workingsheets with the following contents:

Pitch circle, modulus, axes distance, determination of modulus, gear ratio, spur gear sets with two, three, four gear wheels, planetary gear set, stationary gear set, revolutionary gear set, direct gear, reverse gear, hybrid,
summing planetary gear, carrier division angles, Ravigneaux-set, Lepelletier-set, power flow,
four speed automatic transmission, six speed automatic transmission, seven speed automatic transmission, nine speed automatic transmission, original build-up, brakes and clutches, gear ratio measurement , vehicle speed, gear speed change with one switching element



E4: Distance of rotation axes of two engaging gear wheels

Introduction:

Two gear wheels that engage with each other and drive each other, must have a precisely defined distance between with their rotation axes.

Task:
Determine the distance between the axes of rotation of different gear wheel combinations and find the dependence of the pitch circles.

1. Start the exercise *E04_Axis_distance.gb*
2. Set number of teeth given by the table by typing in the red and green input fields.
3. Move the scale and measure the dimensions of the pitch circles (D_{w1} and D_{w2}) of both gear wheels and the rotation axis distance a and enter all values in the table.
4. Calculate the half of pitch diameters of the gears and enter them into the table.
5. Repeat the process for all gear combinations shown below.
6. Find a formula which describes the dependence of distance a and the two pitch circles D_{w1} and D_{w2}.

Result:

z_1	10	10	20	20
z_2	10	15	15	20
Distance a [mm]				
D_{w1}[mm]				
D_{w2}[mm]				
0,5 * D_{w1}[mm]				
0,5 * D_{w2}[mm]				

The formula for the distance a as a relation depending on D_{w1} and D_{w2} is:

a =

E8: Gear ratio ring gear

Introduction:

A gear is located in the hollow interior of an internal/ ring gear and both gears engage each other. The small gear is called pinion in this build-up. This combination of gear wheels is called ring gear.
The ring gear teeth number has a negative sign. Also, all gear ratio calculations are done with this negative number of teeth.

Task:
Determine the gear ratio.

1. Start the exercise *E08_Gear_ratio_ring_gear.gb*
2. Set number of teeth given by the table by typing in the red and gray input fields.
3. Press [0] button to set the goniometer scales to zero.
4. Click on the red/white gear, hold the mouse button down and turn the red/white gear wheel. The gray gear wheel rotates with it. Turn it until the gray (!) gear is rotated to 100 °. w_2 is now 100 degrees.
5. Enter the current rotation angle of the red gear w_1 in the table.
6. If the red/white gear wheel has a different rotation direction than the gray gear wheel, give the w_2 table value a negative sign.
7. Calculate the gear ratio i by dividing w_1 by w_2. Note the sign!
8. Repeat the procedure, beginning from step 2 for all gear combinations shown below.
9. Find a formula showing the relation of the gear ratio and the two numbers of teeth. Note the sign!

Result:

z_1	15	12	10	8
z_2	-45	-48	-60	-80
w_1[°]				
w_2[°]	100	100	100	100
Gear ratio i = w_1 / w_2				

The formula for the gear ratio i as a dependence of the teeth numbers z_1 and z_2 is:

i =

E7: The gear ratio of four gears (spur gears)

Introduction:
Four gear wheels engage each other and transmit a rotation from the first gear wheel (input) into a rotation of a second gear wheel which transmit its rotation to a third gear wheel which transmits its rotation to a forth gear wheel (output).

Task:
Determine the gear ratio as a relation of the teeth count of four gear wheels.

1. Start the exercise *E07_Gear_ratio_four_gears.gb*
2. Set number of teeth given by the table by typing in the red, dark red, green and dark green input fields.
3. Press [0] button to set the goniometer scales to zero.
4. Click the dark green / white gear wheel, hold the mouse button down and turn the dark green / white gear. This also rotates the dark read, red and green gear wheel. Turn until the green (!) gear wheel rotation angle is set to 100 °. w_4 is now 100 degrees.
5. Enter the current angle of the dark green / white gear in the w_1 table cell.
6. When the dark green / white gear wheel has a different rotation direction than the green gear wheel, give the entered value a negative sign.
7. Calculate the gear ratio i by dividing w_1 by w_4. Note the sign!
8. Repeat the procedure from step 2 for all gear combinations shown below.

Result:

z_1	10	10	10	10	20	20	20	20
z_2	10	20	10	20	10	20	10	20
z_3	10	10	10	10	10	10	10	10
z_4	10	10	15	15	15	15	20	20
w_1[°]								
w_4[°]	100	100	100	100	100	100	100	100
Gear ratio i = w_1 / w_4								

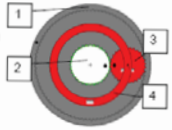
What influence have the second and third gear wheel on gear ratio and rotation direction?

Find a formula showing the relation of gear ratio i and teeth numbers z_1, z_2, z_3 and z_4. Note the sign!

i =

E12: Planetary gear – revolving gear ratio

Introduction:
The stationary gear ratio takes its name from the fact that the planetary gear wheel carrier is held stationary. However, there are also other ways to operate a planetary gear set for example to hold the sun (2) or the ring gear (1) stationary. In both cases the planetary gear wheels are revolving around the sun (2) gear wheel.



For the following exercise the sun gear wheel is (2) fixed and the planetary carrier works as input (4).

Task: Determine the gear ratio.

1. Start the exercise *E12_Planetary_gear_revolving_ratio.gb*.
2. Set number of teeth given by the table by typing in the red, green and gray input fields.
3. Press [3.1] button to set the goniometer scales to zero.
4. Click on the red / white planetary gear wheel carrier, hold the mouse button down and turn it until the gray (1) ring gear wheel is rotated to 100 °. w_{ring} is now 100 degrees.
   Calculate the gear ratio i_{cmea} by dividing the turn angle of the carrier by 100°.
   Enter the result in the i_{cmea} cell of the table.
5. Calculate the stationary gear ratio i_{12} and enter it into the table.
6. Calculate i_{c2} with the formula specified in the table and enter the value in the table also.
7. Repeat the procedure from step 2 for all gear combinations shown below.

Result:

z_{sun}	8	30	70	100
z_{ring}	-104	-150	-140	-110
i_{cmea}				
Stationary gear ratio $i_{12}=-z_{ring}/z_{sun}$				
$i_{c2}=1/(1-1/i_{12})$				

Compare the measured gear ratio values with the calculated gear ratio values!

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E18: Planetary gear - carrier division

The number of planetary gear wheels in a planetary gear set can be selected within wide ranges.
Depending on the number of teeth and the number of planetary gear wheels, it may happen that the planetary gear wheels cannot be placed engaging the other gear wheels while the carrier division angels (β_1 to β_n) are kept equal.

To enable the engaging, the division (β_1 to β_n) angles have to be adapted.


Unequal (corrected) division


Equal division

Task: Check the specified planetary gear for the need of correction.

1. Start the exercise *E18_Planetary_gear_carrier_division.gb*.
2. Set up the required numbers of teeth and planetary gear wheels.
3. Press [3.1] button to set the goniometer scales to zero.
4. Fill in the table "yes" or "no", depending on whether the division angels can be kept equal or not.
5. If there are unequal division angles, use the *carrier correction* division to blend out and to blend in the correction for better identification.

Carrier division correction: 130 %

6. Repeat the procedure from step 2 for all table columns.
7. Calculate the missing entries in the table, accurate to three decimals.

Result:

Teeth number sun z_{sun}	8	8	8	8	8	8	9	9	9	9	9	9	9	9
Teeth number ring z_{ring}	-22	-22	-22	-24	-24	-24	-27	-27	-27	-28	-28	-28	-28	-28
Number planetary gear wheels p	4	3	2	4	3	2	4	3	2	4	3	2	1	
Division angles need correction yes/no														
$z_{sun} + z_{ring}$ / p														

Can you find a rule that describe if the division angles can be equal?

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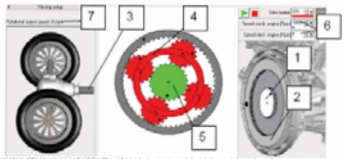
E16: Summing gear - hybrid

A summing gear allows the merging of two power inputs into one power output.
The example can be found in the Toyota Prius and shows the output of a combustion engine (1) and the output of an electrical engine (2). Both engines drive (3) the same output shaft.



To do this the combustion engine (1) is connected to the planetary gear carrier (4) and the electrical engine (2) is connected to the sun gear wheel (5) of a planetary gear set. The rotational speeds of the engines can be set separately for both engines via input fields (6). The merged output speed is indicated in a display (7).

Task: Determine the merged output speed.

1. Start the exercise *E16_Summing_gear_hybrid.gb*.
2. Calculate i_{12} and i_2 and enter the results into the table.
3. Set the required rotational speeds for electrical and combustion engine.
4. Read the output speed and enter it into the table.
5. Repeat the procedure beginning from step three for all speed combinations.
6. Calculate the missing entries in the table.

Result:

	z_{sun}	23	z_{ring}	-57
	stationary gear ratio i_{12}		revolutionary gear ratio $i_2=1/(1-1/i_{12})$	
n_1 rotational speed combustion engine [Rev/min]	1000	0	1000	1000
n_2 rotational speed electrical engine [Rev /min]	0	1000	1000	-1000
n_{sun} [Rev /min]				
n_1 / i_{12} [Rev /min]				
n_2 / i_2 [Rev /min]				
$n_1 / i_{12} + n_2 / i_2$ [Rev /min]				

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E21: Four speed automatic transmission - original build-up

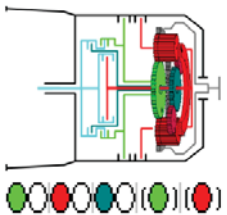
Introduction:

The figure shows the gear view of the GEARBASIC software extended with clutches and brakes placed in a transmission bell housing.
Additional another component must be added, which ensures that the different speeds and torques between the engine and output shaft during gear speed change or starting are slowly equalized. This component is called torque converter and has the right shown symbol.

Task:
Complete the figure:

1. Assign the switching elements ◯◯◯◯◯◯◯ to their correspondences in the figure with connecting lines.
2. Draw the torque converter in the figure.
3. Identify the input and output.
4. Sketch the power flow of the first gear speed in the figure.

Result:

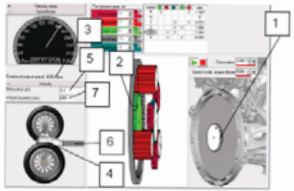


E24: Four speed automatic – vehicle speed

Introduction:
The previous examinations of the gear ratios are always related to the speed of the engine crankshaft (1) and the output speed (3) of the gear output (2) the ring gear wheel.

To calculate the speed of a vehicle two additional factors have to be considered.

The transmission is not directly connected to the wheels, it is connected via the differential gear (4). The differential gear (4) distributes the gear rotation to the two driving wheels.



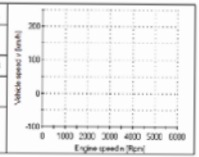
The differential gear is also a gear set, so it has its own gear ratio that has to taken into account. To do this, input a gear ratio into the corresponding input field (5). Now, the speed of the wheel drive shaft (6) and the wheel can be calculated. To get the vehicle speed it is necessary to calcuate the travel distance of one wheel revolution. This travel distance depends on the wheel diameter (7) which also can be set.

Task: Determine the maximum speeds for each gear speed of the automatic transmission!

1. Start the exercise *E24_Four_speed_automatic_transmission_vehicle_speed.gb*
2. Enter the differential gear ratio 4.1 and the wheel diameter 600mm.
3. Set an engine speed of 6000 rev/min.
4. Select the required gear speed by click on the gear speed table.
5. Read the speedometer and enter the value in v_{max}.
6. Sketch a point with the coordinate n_{max} / v_{max} in the diagram.
7. Sketch a line through the origin and this point
8. Repeat from step 4 for each gear speed.

Result:

	R-Gear	1st Gear	2nd Gear	3rd Gear	4th Gear
Maximum engine speed n_{max} [Rev/min]	6000	6000	6000	6000	6000
Gear ratio	-1.927	2.833	1.558	1	0.658
Maximum output speed N_{output} [Rev/min]					
Vehicle speed v_{max} [km/h]					



Read from the diagram the vehicle speeds that can be reached with an engine idle speed of 800 rev / min in the first, second and reverse gear speed?

E22: Ravigneaux gear set - carrier division

In exercise E18 we learned that it is necessary to correct carrier division angels (β_1 to β_3) to engange all gear wheels.

The Ravigneaux gear set makes this problem more complex. The already known problem from the planetary gear set exists here too.

Unequal (corrected) division

Equal division

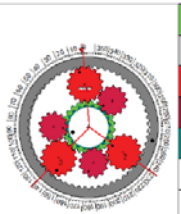
But even if this problem is solved, there is no guarantee that the short and long planet gear wheels are correctly engaged. To bring them into the engagement, the carrier division angels (β_1 to β_3) have to be changed. This can result in significant differences in the carrier division angles.

Task: Change the carrier division angles until all gear wheels are angaged

1. Start the exercise *E22_Ravigneaux-carrier_division.gb*.
2. Enter the required numbers of teeth and planetary gear wheels.
3. Press [-2.0] button to set the goniometer scale zero.
4. Use the *teeth ofs.* input field for each planetary gear wheel to change the corresponding carrier division angle.
5. Use the input field planetary division to hide and show the changed carrier division angles.

6. Repeat the procedure from step 2 for all table columns.

Result:



teeth number large sun $Z_{Large\ sun}$	24	24	24	22
teeth number ring Z_{Ring}	-56	-56	-58	-50
Teeth number long planet $Z_{Long\ planet}$	16	16	17	14
Teeth number short planet $Z_{Short\ planet}$	14	13	14	14
teeth number small sun $Z_{Small\ sun}$	19	19	19	18
Number of planetary gear wheels p	3	3	3	3
Planetary gear wheel 2 teeth offset				
Planetary gear wheel 2 teeth offset				

E31: Seven speed automatic transmission - original build-up

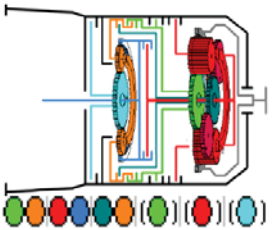
Introduction:

The figure shows the gear view of the GEARBASIC software extended with clutches and brakes placed in a transmission bell housing.
Additional another component must be added, which ensures that the different speeds and torques between the engine and output shaft during gear speed change or starting are slowly equalized. This component is called torque converter and has the right shown symbol.

Task:
Compiete the figure:

1. Assign the switching elements  to their correspondences in the figure with connecting lines.
2. Draw the torque converter in the figure.
3. Identify the input and output.
4. Sketch the power flow of the first gear speed in the figure.

Result:



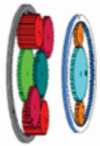
speed							
R	X					X	X
N							
1				X		X	X
2				X	X		X
3	X			X			X
4		X	X				X
5	X	X	X				
6	X	X					X
7		X			X		X

E30: Seven speed automatic transmission (Lepelletier set) - gear ratio

Introduction:
This automatic transmission consists of six-speed automatic transmission with an additional switchable brake and has seven forward gears and one reverse gear. The gear ratios are ideal for use in a motor vehicle. The output is performed in any gear by the ring gear wheel of the Ravigneaux gear set.

To change gear speed, three clutches and three brakes are needed.

speed							
R	X					X	X
N							
1				X		X	X
2				X	X		X
3	X			X			X
4		X	X				X
5	X	X	X				
6	X	X					X
7		X			X		X



Task:
Determine gear ratios for all gear speeds of a seven speed automatic transmission:

1. Start the exercise *E30_Seven_speed_automatic_transmission_lepelletier_gear_ratio.gb*.
2. Select the required gear speed by click on the gear speed table.
3. Press ⊡0⊡ button to set the goniometer scales zero.
4. Turn the white input gear wheel with the mouse until the output gear wheel has rotated by 100 °.
5. Enter the rotation angle of the input gear w_{input} into the table.
6. If the input gear wheel has a different rotation direction than the output gear wheel, give w_{input} a negative sign.
7. Calculate the ratio by dividing w_{input} by w_{output}.
8. Repeat the procedure from step 2 for all gear speeds.

Result:

	 *R*-Gear	1st gear	2nd gear	3rd gear	4th gear	5th gear	6th gear	7.Gang
w_{input}[°]								
w_{output}[°]	100	100	100	100	100	100	100	100
Gear ratio i								

Does the seven speed automatic transmission have a direct gear speed in which all gears are blocked and a gear ratio of one results?
Is it possible to decouple the seven speed automatic transmission from the engine completely with the existing switching elements?

E25: Six speed automatic transmission (Lepelletier set) - power flow

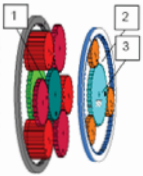
Introduction:
To implement a six-speed automatic transmission, it is an easy way to extend the Ravigneaux gear set (1) with a simple planetary gear set (2). This build-up is called a Lepelletier gear set.

The sun gear of the simple planetary gear set (3) is fixed and cannot rotate.

The Lepelletier six speed automatic transmission has similar to the Ravigneaux gear set also five switching elements.

Typically, three planetary gears are used. For a better view, only two are shown here.

speed							
R	X					X	
N							
1				X		X	
2				X	X		
3	X			X			
4		X	X				
5	X	X					
6		X		X			

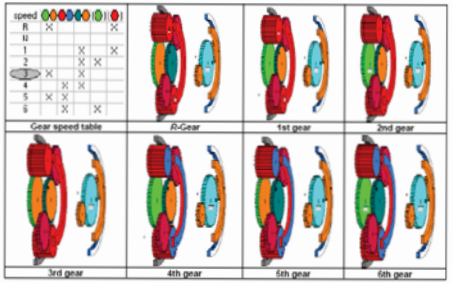


Task: Determine the power flow for each gear speed and draw it into the figure. Further information regarding power flows can be found in *E15 planetary gear power flow*.

1. Start the exercise *E25_Six_speed_automatic_transmission_lepelletier_power_flow.gb*.
2. Select the required gear speed by click on the gear speed table.
3. Turn with the mouse the white input gear wheel, identify the power flow and draw it into the gear view.
4. Repeat the procedure from step 2 for all gear speeds.

Result:

speed							
R	X					X	
N							
1			X			X	
2			X	X			
3	X		X				
4		X	X				
5	X	X					
6		X		X			



E36: Nine speed automatic gear changes with a switching element

To activate an individual gear speed, the switching elements (brakes and clutches) must be activated or disabled. Fast and economical gear changing can be performed if only one switching element is disabled and only one other switching element is activated. These gear speed changes uses only one switching element.

The gear change matrix with one switching element clearly shows the possible gear speed changes with only one switching element. We demonstrate this with a fictive three gear automatic transmission.

1		
	2	
		3

For each gear speed one row and one column is required. With three gear speed a table is created with three columns and three rows.
On the diagonal from top left to bottom right are the names of all gear speeds.

Now we iterate the diagonal:
We start with the first gear speed in the first field.
The green fields, right of the diagonal represent the gear speed change into a higher gear, the red boxes on the left of the diagonal, represent a gear speed shift into a lower gear. The following table lists the meaning of each field and specifies the number of switching elements that have to be changed for the corresponding gear speed change.
If the gear change of the corresponding table field is supported with only one switching element, we insert the name of the destination gear speed. If it's not possible, we left the field empty.

						Required switching elements
1	Shifting from	1st	in	2nd	Course	1
2	Shifting from	1st	in	3rd	Course	2
3	Shifting from	2nd	in	3rd	Course	1
4	Shifting from	2nd	in	1st	Course	1
5	Shifting from	3rd	in	1st	Course	2
6	Shifting from	3rd	in	2nd	Course	1

1	2	
1	2	3
	2	3

Gear change matrix for example three speed automatic transmission

Task:

Complete the gear change matrix for all forward gear speeds of a Ravigneaux gear set:

speed	R2	R	N	1	2	3	4	5	6	7	8	9
R2	X						X					
R	X						X		X			
N												
1				X		X						X
2				X		X	X		X			
3				X	X		X					
4	X			X			X					
5		X		X			X					
6	X	X		X								
7	X	X					X					
8	X	X										X
9		X			X		X					

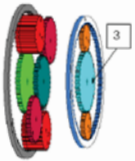
1								
	2							
		3						
			4					
				5				
					6			
						7		
							8	
								9

E29: Seven speed automatic transmission (Lepelletier set) - power flow

Introduction:
For the realization of a seven-speed automatic transmission, it is sufficient to equip the fixed sun gear (6) of the six-speed automatic transmission with a switchable brake.

Typically, a seven speed automatic transmission uses three planetary gears are used. For a better view, only two are shown here.

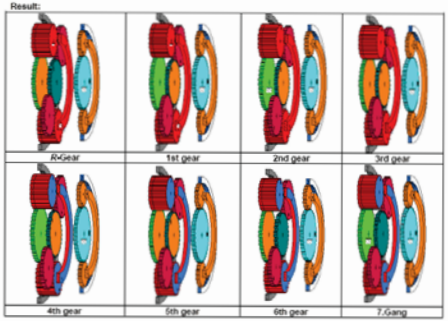
speed						
R	X				X	X
N						
1			X		X	X
2			X	X		X
3	X		X			X
4		X	X			X
5	X	X	X			
6	X	X				X
7		X		X		X



Task: Determine the power flow for each gear speed and draw it into the figure. Further information regarding power flows can be found in E15 *planetary gear power flow*.

1. Start the exercise *E29_Seven_speed_automatic_transmission_lepelletier_power_flow.gb*.
2. Select the required gear speed by click on the gear speed table.
3. Turn with the mouse the white input gear wheel, identify the power flow and draw it into the gear view.
4. Repeat the procedure from step 2 for all gear speeds.

Result:



E35: Nine speed automatic transmission, original construction

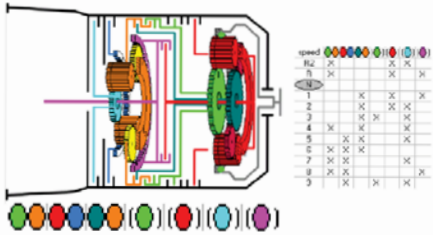
Introduction:

The figure shows the gear view of the GEARBASIC software extended with clutches and brakes placed in a transmission bell housing.
Additional another component must be added, which ensures that the different speeds and torques between the engine and output shaft during gear speed change or starting are slowly equalized. This component is called torque converter and has the right shown symbol.

Task:
Complete the figure:

1. Assign the switching elements  to their correspondences in the figure with connecting lines.
2. Draw the torque converter in the figure.
3. Identify the input and output.
4. Sketch the power flow of the first gear speed in the figure.

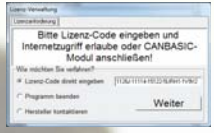
Result:



speed	R2	R	N	1	2	3	4	5	6	7	8	9
R2	X				X	X						
R	X				X		X					
N												
1		X		X		X						X
2		X		X	X							
3		X	X		X							
4	X			X								
5		X	X		X							
6	X	X	X									
7	X	X			X							
8	X	X		X								X
9		X		X		X						

Quickstart of full version:

1. Insert CD
2. Autostart or start "start.exe"
3. Select language
4. Select GEARBASIC
5. Start multimedia presentation or instruction manual
6. Start GEARBASIC-Software from CD
7. Activate Internet access (WithoutInternet access you cannot start the GEARBASIC und you need a license dongle)
8. Enter license code



9. Confirm license information

10. Select desired exercise from folder "exercises-workingsheets"

11. To edit exercises/workingsheets, hold <Ctrl> and <Shift> and click with right mouse button on the gear view

License code:

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