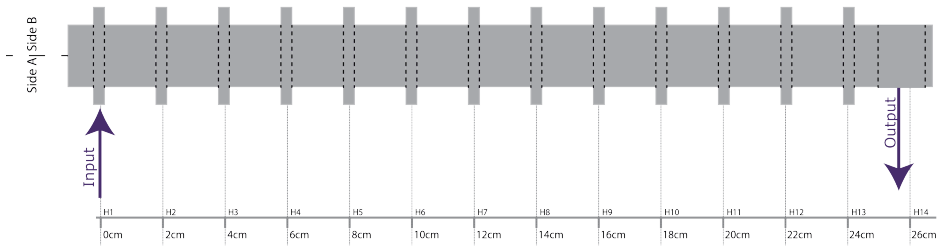
Synthesis Challenge 2

In this challenge you must design another gear train! You will learn to use gears in more sophisticated ways to achieve higher reduction ratios in less space.

Your gear train will use the frame shown below. There are 14 holes positioned along the same straight line. The hole centers are spaced 2 cm apart. Differing from Synthesis Challenge 1, you can now choose to place gears on both sides of the frame if you wish. These are referred to as Side A and Side B as shown in the diagram.

To specify your gear train you must decide how many rotating shafts you are going to use, which of the 14 holes they will go in, and the radii of the gears to be fixed to either end of the shaft. Each shaft can have either one or two gears fixed to it, with a maximum of one gear per side of the frame.



Your gear train must transmit power from the input shaft (leftmost hole) to the output shaft (rightmost hole). **For 2023 your aim is to produce a 12:1 speed reduction ratio**, which means that 12 turns of the input shaft must result in 1 turn of the output shaft, in the same direction! Speed ratios that are up to 1% higher or lower than 12:1 will also be acceptable, more specifically, any ratio in the range 11.88:1 up to 12.12:1 will be acceptable.

- You can specify gear shafts to be placed in any of the holes.
- You can specify up to 14 rotating shafts, and there can be either one or two gears (maximum one per side) fixed to each shaft.
- Imagine the gears to be circles—a pair of gears mesh properly when they are on the same side of the frame and the circles just touch each other. Gears on opposite sides of the frame cannot mesh!
- Gears on the same side of the frame will be considered to mesh if their respective circles are within 0.01 cm of intersecting one another. If a pair of gears are further apart than this, they are considered not to mesh. If a pair of gears overlaps by more than this amount, they are considered to interfere.
- **For** 2023, the gears can be of any radii between 1 cm and 8 cm.
- The rightmost hole (hence the output shaft) can be moved to the left or right of its preferred position, as far as needed to make the gears mesh.

Design objectives

More than one design could satisfy the requirements stated above! But some designs will be better than others. Your aim is to maximise (1) the efficiency of the transmission, done by reducing the number of meshing gear pairs and to minimise (2) the total area of the circles representing the gears, which indicates cost, and (3) the distance the output shaft has to be repositioned from its preferred location, 26 cm from the input shaft.

Submission

You must submit your solution using the Canvas Quiz by the specified date and time. The quiz provides 14 answer boxes for each side (i.e. Side A and Side B) to represent the 14 holes in the same sequence. If your design calls for a gear shaft to go in a particular hole, enter the radius of the gear(s) that go onto that shaft into the corresponding box(es). If your design does not call for a shaft in a particular hole, leave that text box blank.

For example, if your design calls for one gear with of radius 5 cm to be placed on Side A in hole 1, and one gear with radius 6 cm to be placed on Side B in hole 14, enter 5 in the first text box of Side A (r1A) and 6 in the last text box of Side B (r14B), leaving the others empty.

Please make sure to use the right dimension (this submission is in cm) and ONLY TO PUT NUMERIC VALUES in these answer boxes. Carefully check your solution and carefully check it is entered correctly with no typing errors, before submitting it. Just like a test, we will not accept any request to change your solution after the submission closes.

As part of your submission you are also asked to write a short and honest reflection on the synthesis challenges and what you have learned. Prepare honest answers to the following two questions (minimum 100 words each, no upper word limit) and be ready to paste them into the Canvas quiz when doing your submission:

- What have you learned about the interplay between synthesis (creating and adjusting a design) and analysis (checking and calculating) while working on the two synthesis challenges?
- How did your experience with the first challenge influence your approach to the second challenge?

There are no right or wrong answers to these questions. The intention is to demonstrate that you have reflected on your design experience and used this to develop your skills.

Assessment

This challenge is worth 2 points and you should allow a few hours to complete it. 0.5 marks will be for your written reflection. 0.75 marks will be gained by submitting a design that satisfies the requirements. The remaining 0.75 marks will be determined by how well your design performs in comparison with the rest of the class. The performance of your design, P, will be calculated as:

$$P = A\frac{1}{0.9^N} + B\sum_{i=1}^{n} r_i^2 + Cd^3$$

- $A = 25.0$, $B = 0.2$, $C = 4.5$.
- $N =$ the total number of meshing gear pairs used in your design. (the first term indicates the objective to maximise transmission efficiency of your design)
- $n =$ the total number of gears used in your design.
- $r_i =$ radius of gear i, in cm (the second term indicates the objective to minimise cost of your design)

- d = distance the output gear must be repositioned from its preferred location which is 26 cm away from the input shaft, in cm.

It is essential to remember that a lower value of P is better.

We have provided a doodling template to help you develop your ideas. Hint: You might not find a solution using algebra. You might need to iterate between synthesis and analysis, proposing ideas, checking how good they are, and iterating to improve them. Remember, this is the essence of design! It will help to be systematic and keep track of what you have tried.

A little bit of theory

You will need to employ a compound gear train in your design. Watch the videos for a worked example!

- Remember that two gears fixed to the same shaft will rotate at the same speed, and in the same direction.
- Be sure to check for interference of gears on both sides, and be sure that your gears mesh as intended.
- Be sure that your input shaft and output shaft have exactly ONE gear each. Also check that every gear in your design meshes with at least one other gear.
- To understand how to assess the number of meshing gear pairs N in your design, it may help to refer to the example given in the second video of this Synthesis Challenge. In that case, r1B and r4B mesh, as well as r4A and r7A. Therefore there are 2 meshing gear pairs and $N = 2$. Note that there are more gears than meshing gear pairs!

Teamwork

This is an individual assignment. You can discuss the challenge with your friends but if you share a solution, or use someone else's solution, you will be CHEATING.