Model 4
Cardan shaft

Sometimes the input and output shafts of a transmission are neither aligned nor parallel to each other, but meet at an obtuse angle. In this case, the direction of movement of the shaft must be changed. This can be achieved with a cardan gear, also known as a cross joint or cardan joint.

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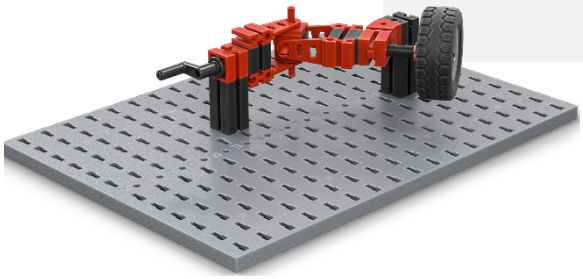


DESIGN TASK

Replicate the universal joint shown in Fig. 1. What is the angle between the drive and output shafts?

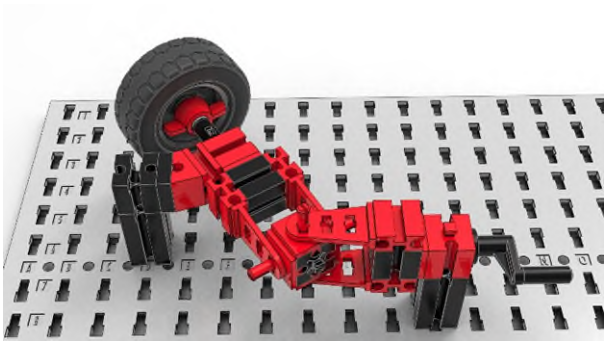
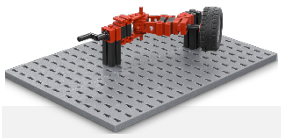


Fig. 1: Cardan joint

When you drive the drive shaft via the crank, you will notice that the movement of the output shaft is not as smooth: it sometimes rotates faster and sometimes slower than the drive shaft. This effect is called "cardan error."

The addition of two protractors to the universal joint allows the angular movements to be measured in two axes. This enables the alignment of the two connected shafts to each other to be analyzed precisely.

THEMATIC TASK



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Instructions for extending the universal joint with angle disc (Fig. 2 or assembly instructions):

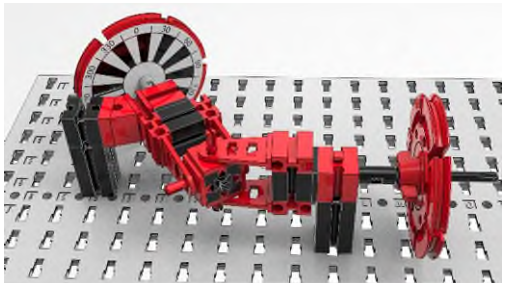


Fig. 2: Extension of the universal joint with two protractors

Extending the drive shaft:

- Attach a detent coupling and insert a detent pin 45 to extend the drive shaft.
- Add a 60 turntable with flat hub so that the hub nut points towards the universal joint.
- Add a second bearing before reattaching the detent crank to the shaft.

Extending the output shaft:

- Install a second turntable 60 with flat hub so that the hub nut points away from the universal joint.

Addition for better readability:

- Extend the bearing of the drive and output shaft with a block 15 on which a 60° angle block is mounted. This makes it easier to read the angle discs.

Cut out the two angle discs (Fig. 3), cut a hole in the middle and slide them onto the two axles in front of the turntables so that they are clamped on the drive axle between the crank and the turntable and on the output axle between the detent clutch and the turntable. You can also attach them to the turntable with transparent adhesive tape.

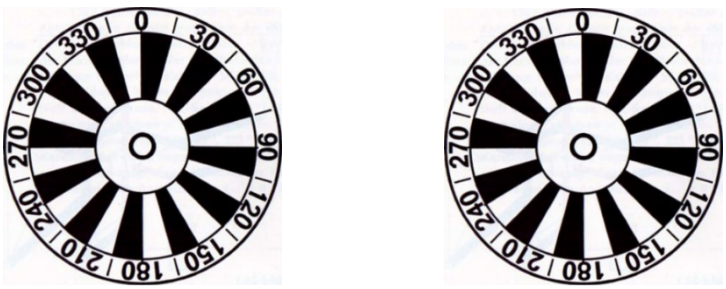
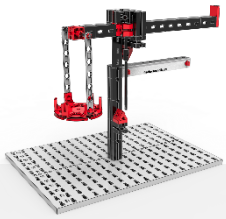


Fig. 3 Discs with degree markings as protractors



Place the universal joint in the same position as shown in Fig. 2 and align the two protractors so that the tip of the red angle stone is "flush" with the 0° mark. Now turn the crank in 15° increments from 0° to 180° and note the angle value displayed on the second protractor on the output shaft.

Enter the measurement results and the respective deviation of the output shaft from the drive shaft ("delta") in the following table.

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Drive rotation angle	**Output rotation angle**	**Δ**	**Drive rotation angle**	**Output rotation angle**	**Δ**
0°	0°	0°	90°	90°	0°
15°			105°		
30°			120°		
45°			135°		
60°			150°		
75°			165°		
90°	90°	0°	**180°**	180°	0°

EXPERIMENT

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As you have seen, the cardan error of a cardan joint can be significant. The greater the angle by which the shaft is deflected, the greater the error.

But here's an interesting thing: if we connect two cardan joints to form a cardan shaft so that the drive shaft and output shaft are parallel, the cardan errors of the two cardan joints cancel each other out. That's why cardan joints are usually only used in practice for uniform drives with low deflection or in pairs in the form of a cardan shaft.

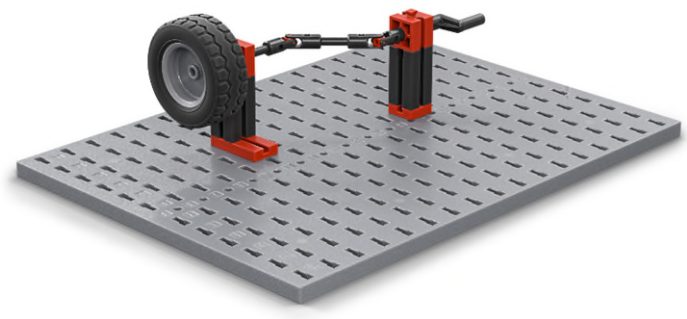

Fig. 4: Cardan shaft with two cardan joints

Fig. 4 shows such a cardan shaft. Construct it and use it to solve the following tasks:

1. What is the maximum angle at which the two cardan joints can still rotate "cleanly"?

2. Mount the two protractors on the drive and output shafts of the cardan shaft and check whether the cardan error has actually been eliminated.

3. What other transmissions can you think of that can achieve an axle offset from drive to output shaft corresponding to that of a cardan shaft?

What are their advantages or disadvantages compared to a cardan shaft?

3. What other types of transmission can you think of that can achieve an axle offset from drive to output similar to that of a cardan shaft?

   What are their advantages and disadvantages compared to a cardan shaft?

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Additional task

Expand the cardan shaft shown in Fig. 4 with a motor and test the model.

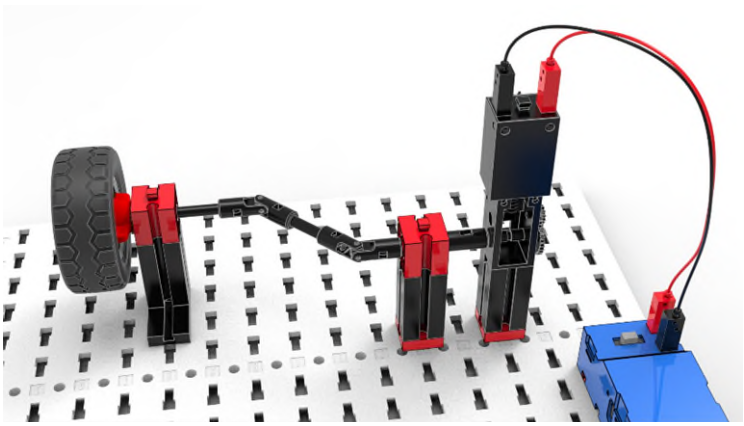

Fig. 4: Cardan shaft with motor