# Lego WeDo Centrifugal Speed Governor

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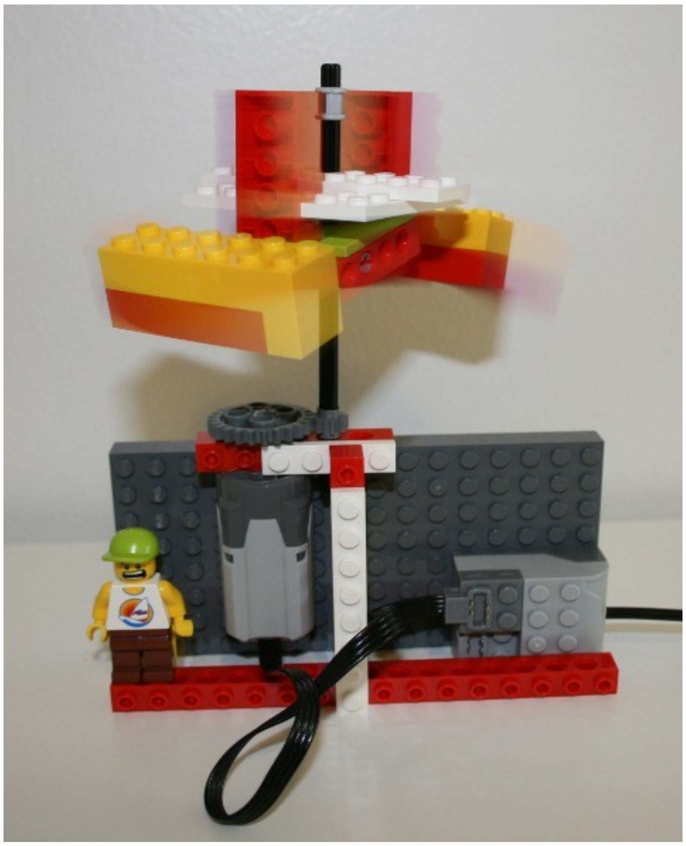
**The centrifugal speed governor is a mechanical device to measure and control the speed of a machine by transforming the rotational speed to a mechanical displacement. A model is built and programmed using Lego WeDo to demonstrate the physics behind it.**



## Description

Two weights (yellow-red Lego blocks) are attached to a rotating axle like a pendulum. The faster the axle spins the bigger the angles between the axle and the attached weights become. Through a mechanism, this angles are transformed to a vertical displacement of the white platform. The faster the rotation, the bigger the angle and the lower the position of the platform.

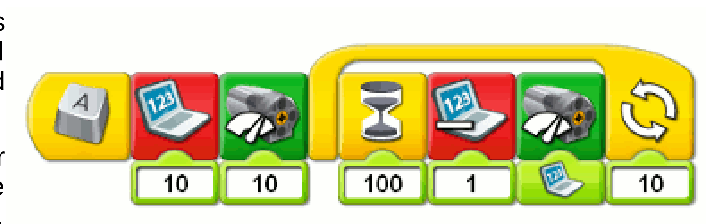
The platform could now be connected to a controlling device, like a valve. Systems like this were used since the 18th century as a mechanical "cruise control" for steam engines with the valve controlling the steam flow to the engine.

To see a video of the speed governor, visit:

http://stefans-robots.net/en/wedo-speed-governor.php

## The WeDo program

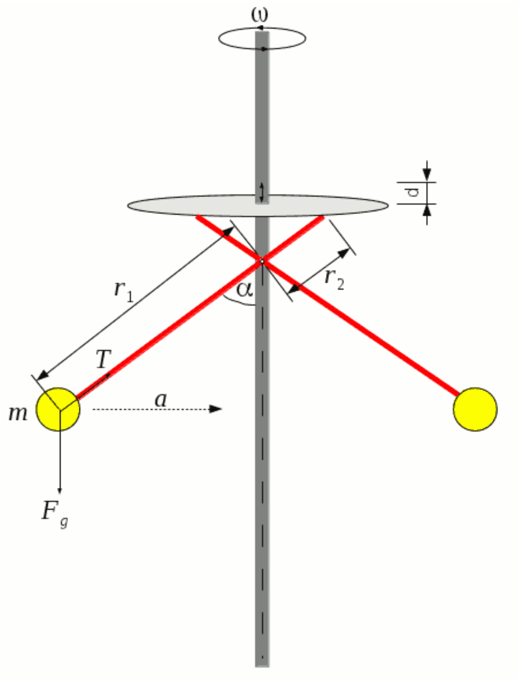
The WeDo program used for the speed governor starts when the "A"-key is pressed. First, the number 10 is stored in the display and the motor set in motion at full speed (10).




Now a 10-times repeating loop starts. At each run, after waiting a time interval of 100, we subtract 1 from the display number and set the result as the new motor speed.

Thus the motor will, over the 10 repetitions, slow down until he comes to a complete standstill.

## The physics of the centrifugal speed governor




From Newtons second law we get in vertical direction

$$T \cdot \cos(\alpha) - m \cdot g = 0 \quad \rightarrow \quad T = \frac{m \cdot g}{\cos(\alpha)}$$ [Eq. 1]

and horizontally:

$$T \cdot \sin(\alpha) = m \cdot a \quad \rightarrow \quad \tan(\alpha) = \frac{a}{g}$$ [Eq. 2]

The centripetal (center seeking) acceleration a of a uniform circular motion is:

$$a = r \cdot \omega^2 \quad \rightarrow \quad a = r_1 \sin(\alpha) \cdot \omega^2$$ [Eq. 3]

Combining the equations 2 and 3 we get:

$$\cos(\alpha) = \frac{g}{r_1 \cdot \omega^2}$$ [Eq. 4]

And finally for the horizontal displacement d:

$$d = r_2 \cdot \cos(\alpha) \quad \rightarrow \quad \boxed{d = \frac{r_2 \cdot g}{r_1 \cdot \omega^2}}$$ [Eq. 5]

As d can only be between 0 and $r_2$ , there is a interesting limitation for equation 5. :

$$\boxed{\omega \geqslant \sqrt{\frac{g}{r_1}}}$$ [Eq. 6]

That limitation actually was present in equation 4: $\cos(\alpha)$ only exists between 0 and 1. Which is only the case if $\omega \geqslant \sqrt{\frac{g}{r_1}}$ .

### The physical meaning of the working range limits of the centrifugal speed governor

The centrifugal force required to keep the weights of the governor at an angle $\alpha$ is: $F_{req} = \tan(\alpha) \cdot g \cdot m$

However the centrifugal force produced by the rotation is $F = \sin(\alpha) \cdot r_1 \cdot \omega^2 \cdot m$ .

For $\omega$ smaller than specified by equation 6. The produced centrifugal force is not high enough to balance out the gravity. The arms of the governor will therefore not be lifted. .

**Building instructions**