

# Ceiling Rails and the Pendulum Effect

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## 2. Pendulum Effect and Ceiling Rails

When it comes to robotic camera systems, the pendulum effect is mostly associated with ceiling rails that use long hanging columns. Ceiling rail stability is reasonably guaranteed by securely mounting the track to the ceiling. However, a more secure and rigid solution is to connect to a truss that has suitable frame supports, and ideally a dual set of rails for added rigidity. No track has a perfectly machined straight profile, hence it may not be possible for the dolly to travel at the maximum specified speed or the lowest specified speed with the lens totally in telephoto position while remaining in contact with the rails. One solution to maintain rail contact is to use a three-wheeled dolly. Such an approach could remove all emphasis related to the rail being level while ensuring that all wheels are constantly in contact with the rails beneath them. Another factor to consider is the size of the wheelbase and width of the track – a longer and wider track dolly will enhance the stability and performance to reduce the pendulum effect.

Experienced directors know to expect the characteristic pendulum sway that is associated with ceiling-mounted cameras and ask their camera operators to creatively work within these limits. Experienced camera operators will seek to create movements with increased dampening or will decrease speed during manual movement. It is important to always bear in mind that the track is suspended and requires finesse to ease the pendulum effect.

The pendulum effect can also be seen on floor rail solutions and on pedestal systems, which are by definition inverted pendulums. If there is a column between the head and the dolly, telescopic or not, the pendulum effect will be present. The effect is exacerbated by two different forces generated by the horizontal acceleration: acceleration on the rail and centrifugal acceleration.

## 3. Acceleration on the Rail (Start and Stop)

To avoid the pendulum effect, the motor drive of the dolly must be as smooth as possible. A sudden change in acceleration along the track will create unwanted levels of jerk within the motion that is amplified through the column. In simplest terms, if the dolly suddenly speeds up, there will be a delay in the velocity of the camera at the bottom of the column as it takes time to respond to the force of the dolly. Similarly, if the dolly stops abruptly, the camera will continue at a higher velocity and will not stop immediately. In each case, the disconnection between the dolly and the camera position will contribute to a pendulum effect.

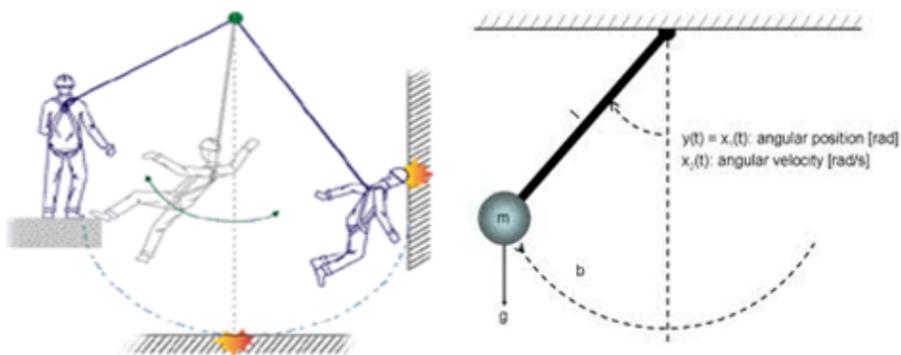
A sudden change in velocity can cause an increase in acceleration, and this produces a higher force acting on the center of gravity. Additional force at the center of gravity will try to “rotate” the system, and this will emphasize the pendulum effect. Having the center of gravity point closer to the rails/tracks will reduce this effect.

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### 1. Definition - What is the Pendulum Effect?

The Pendulum Effect is a movement in one direction that causes an equal movement in another direction. It is a natural law discovered by Galileo Galilei and can be applied in various domains, including politics, sociology and psychology. Additionally, it describes the continuous swinging motion of a pendulum on a physical object that is created by acquired momentum and the action of gravity. The pendulum effect relies on two factors: gravitational force and length of the pendulum. The pendulum effect is activated when the mass is displaced, and as gravitational force remains constant at any place, the effect fully depends on the pendulum’s length.





#### 4. Centrifugal Acceleration (Negotiating Curves)

If the track has curves, additional forces are added when the dolly is moving: centripetal and centrifugal force. The inward centripetal force is created by the movement of the dolly on the rail as the motor pulls the dolly around the curve. Centrifugal force is an apparent force that appears to exert an outward force on the center of gravity of the dolly as it goes around the curve – the same feeling that children experience on a merry-go-round. This force can alter the position of the camera, creating a pendulum effect which is amplified once again by an elevation column.

There are 3 factors affecting the centrifugal force: radius, mass and speed. In a track solution the mass is constant, so the variables are the radius and speed. The tighter the curve or the higher the speed, the greater the acceleration. This principle is similar to the way that roller coasters operate.

If the radius is continuous and more than 5m and the dolly is moving at a speed of less 1 m/s, this is normally not an issue, assuming the profile of the rail is perfect. The critical situation occurs if the rail starts straight and moves on to a curved section with a radius of less than 5m. In this case, the centrifugal force appears abruptly. As the dolly pushes out of the curve, this effect can be seen as a tilt shaking of the picture.

As the centrifugal force also acts on the center of gravity (just like acceleration and deceleration forces as described above), it is also important to keep the center of gravity as close as possible to the rotation point, which is where the wheels touch the rails.

#### 5. Telescopic column construction

If and when the column is telescopic, it is very important to have the most rigid structure available. There are two fundamental variables to consider when ensuring rigidity:

1. The joining sections must be as few as possible, to reduce vibrations and 'jumps'.
2. The connection and alignment between the column sections should be implemented by a bearing system with zero backlash.

Between the sections of vertical telescopic gas pedestal columns, there are preloaded bearings to eliminate backlash or play. However, a ceiling telescopic column is often longer than a gas floor pedestal or strut type floor pedestal, as its stroke is dependent on the ceiling height and how low it needs to extend for the shooting conditions.

One commonly suggested technology for ceiling columns is the telescopic tower. There are already some companies on the market that build equipment to raise antennas and technical equipment for weather forecasts, so why not for cameras? The simple answer is that towers are built with sections that slip into each other with sliding and not rolling bearings, so they need backlash to work. When combining many sections with backlash, it's normal to have not just a "pendulum effect" but a "snake effect" as well.

A much more suitable solution is a column designed using linear guides. This provides the most rigid and efficient ceiling column available, as it can support itself and the payload. The use of linear guides ensures the column deploys straight with no snake effect and maintains the alignment over the lifespan of the product.

Another horizontal force that can cause instability is the relationship between the center of gravity of the camera/prompter/head mass and the pan rotation axes. This can be minimized by raising the center of mass closer to the pivot point. The ideal solution is to use a stabilized head or lens, but this is not possible in virtual and augmented reality applications.

#### 7. Conclusion

The pendulum effect can impact all track and pedestal systems but is particularly associated with ceiling tracks because longer hanging columns amplify the effect, while floor moving solutions are legally limited for height and payload to comply with topple tests.

On ceiling-mounted tracks, the installation is one of the most important factors, as stiffer solutions allow for improved control of the camera mass, and this reduces the pendulum effect.

The foundations for a successful track installation are:

- a solid rigid ceiling structure to mount the track to
- a secure and reliable mounting of the track rail to the ceiling
- a smooth motor drive of the dolly
- a track width suitable for the speed and stroke required
- a robust, stiff column with zero backlash bearings

Virtual tracking and augmented reality require stable images, as any movement, particularly the pendulum effect, will be emphasized in the virtual application. For these applications, it is important to seek out manufacturers that allow tracking data to be easily taken from the track without extensive measurements and calculations.

Consideration of these points will all aid in sufficiently minimizing the pendulum effect so that the track solution is able to provide the innovative on-shot movement for which it is specified.