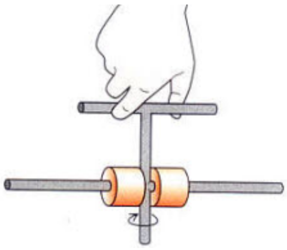
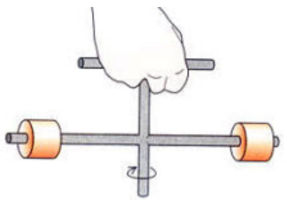
FORELEG MOTION AND MOMENT OF INERTIA



We will give the levers a rest for a while and look at another physical process involved in the motion of the foreleg. This is the concept of M**oment of Inertia.**
Essentially moment of inertia relates to the rotation of a body around the centre of rotation. The two diagrams at the side have come from my old physics text book. The top configuration with the weights close to the centre of rotation requires little effort to get the apparatus rotating.

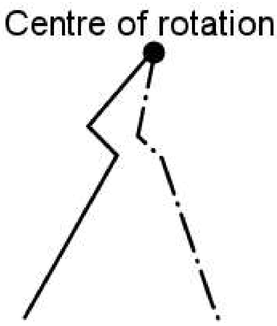


The second configuration with the weights at a distance from the centre of rotation requires much more effort to get it rotating.
Conversely it is easier to stop the rotation of the top arrangement than the bottom with the weights away from the centre of rotation.

The formula for moment of inertia for those interested is

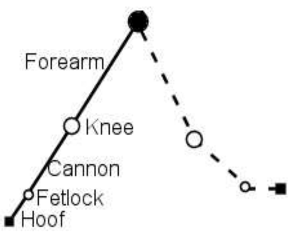
$$I = m_1 r_1^2 + m_2 r_2^2 + \cdots = \sum_i m_i r_i^2$$

What this means is that the total moment of inertia (***I***) is the sum of all the little masses times the square of their distance from the centre of rotation. You might ask what this has to do with the motion of the foreleg of a horse.



In the previous articles we have only looked at the motion in terms of what affects the length of stride. What we are interested in here is how much energy is required to get the leg to make that stride.
The diagram at the left represents the position of the leg at maximum extension (solid line). To complete the stride the leg must rotate about the top of the shoulder to reach the position as shown by the dashed line and this requires energy. A light hoof and pastern would require less energy than a heavy hoof and pastern.

If only it were that simple. The horse’s leg is not like a plank, there are several articulated joints such as the shoulder/humerus, humerus/forearm, forearm/cannon, cannon/pastern and so on. So let’s simplify the situation. We will disregard the shoulder and humerus as these are close to the centre of rotation and do not influence the moment of inertia as much as the more distant components of the leg.



Our new diagram on the left represents the top of the forearm as the centre of rotation for the cannon, pastern and hoof from the maximum extension to the the completion of the stride.
The muscles rotate the forearm as well as the cannon,fetlock and hoof in a backward motion. Because the latter units are some distance from the top of the forearm and have considerable mass they have a sizable moment of inertia. They will tend to lag behind the forearm as a result of the articulation of the knee joint. This is not an ideal situation as can be seen from the following images.

Figure 1

Figure 2

Figure 3

In figure 1 we have the horse at maximum extension of the foreleg. Note that the hoof lines up vertically under the nose which was a good point mentioned in the first article on length of rein. You will also notice there is a very slight lag of the cannon behind the forearm. Likewise the hoof itself lags behind the pastern. These lags in forward motion are due to the moments of inertia of those sections of the leg, the heavy hoof being the main influence because of its weight and also its distance from the main centre of rotation, the humerus/forearm joint.

In figure 2 the forearm has now rotated in its backward motion. Because of the large moment of inertia of the hoof and cannon, they have been left behind because of the articulation of the knee joint. The whole limb takes on the appearance of "back at the knee". This movement places undue pressure on the carpal bones which increases the danger of carpal chip or carpal slab fracture. A short cannon, a short pastern and a light hoof will seriously reduce the moment of inertia of these bodies at the knee joint.

In figure 3 the off fore hoof is firmly planted on the track while the rest of the horse rotates around the leg as mentioned in an earlier article. You will notice that there is still an angle between the forearm and the cannon. In this case the hoof is stationary on the ground while the forearm is still moving backwards. This will quickly change as the flexor apparatus takes charge and pulls the hoof back. You will also notice there is no sign of the hoof. As the hoof hits the ground the pastern deflects so that the fetlock is almost touching the ground in a shock absorber action. The track was a heavy 8 when these pictures were taken.

In summary, how does moment of inertia affect a horse's performance? A large moment of inertia shortens the stride as the cannon and hoof are pulled back by the retreating forearm before they have reached their full extension. It also decreases the number of strides per minute as a heavy hoof is harder to get moving, for example a smaller horse can get more strides per minute, but shorter, as the leg has a smaller moment of inertia. The way to limit the moment of inertia is to have a short cannon and pastern and a light hoof. However the hoof should be large enough to stand up to the pressures placed on it. By the same token a lightly boned horse will have a lower moment of inertia but may be subject to damage.

So we get back to balance mentioned in the previous Length of Rein article . Bone mass not too heavy but adequate for the job, leg length for a good stride but not too long to cause moment of inertia problems and a hoof large enough to spread the load but no larger.

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