TP #2

Technical pamphlets

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The Physics of putting

Rolling of the ball - friction

Why the ball rolls

The ball rolls on the effect of friction and the friction is produced by the effect of gravity .

The friction can be defined as "mutual resistance to the motion of the body A and of the body B that is opposite from the forces with which the two bodies interact in the area of contact".

The forces that oppose slippage are called "static friction" when the bodies A and B are no properties to each other, and "dynamic friction" if one of the two bodies is in motion. The friction that counteracts the rolling is called "rolling friction" .

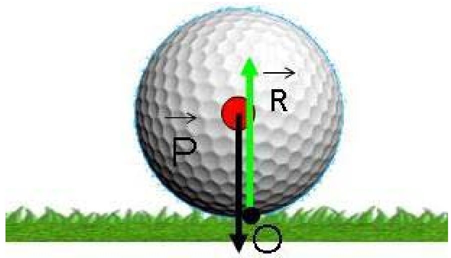
When the ball comes to rest on the green the force acting is the static friction, if a force act, the putter in our case, that sets it in motion, friction consists of a horizontal force acting on the ball impeding the movement .

In the case of the ball that moves, not the perfect elasticity of the bodies, in particular of green, has as a consequence that the distribution of the pressures on both surfaces in contact (ball and grass) is not symmetrical : in front of the ball there is more pressure than behind the ball and, therefore, the ball starts to roll and then to slow down.

But as the forces acting on the ball.

Let's start with the example of a ball on the green in the condition of static friction (stopped): action of two equal and opposite forces represented by the weight of the ball P→ (vector) and the reaction constraint R→ (vector) or pressing force (gravity terrestrial), both passing through the centre C indicated by the red circle (fig. 1).

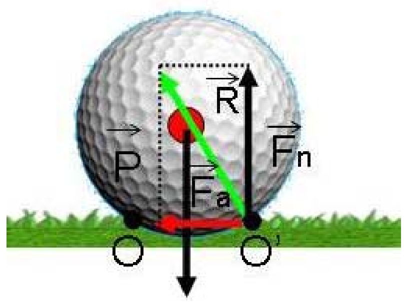
Figure 1 ball in conditions is static friction



To set in motion the ball an external force, must be applied or the surface must be inclined.

The figure 2 illustrates a driving force F→ applied to the ball that rolls and that locally deforms the surface on which the ball rests, in fact in Fig. 1 the support base is punctual (O) due to P→, while the application of the driving force increases the support base (fig.2) , so that the reaction goes to R→O' , becomes tilted and it has currently not zero instantaneous axis of rotation passing through O.

Figure 2 : decomposition forces Fn→ and F → and local deformation of the surface



Decomposing the resultant R → in two forces (fig.3), a horizontal Fa→ = -F→ (remembering that with → indicate vector quantities, while the others are scalars) and a vertical Fn→ =-P→, are got two pairs of forces: the first F→ and Fa→ , the second Fn→ and P→.

The first pair F→ and Fa→ has an arm approximately equal to the radius of the ball (r) and tends to impart a clockwise rotation, the second pair Fn→ and P→ has an arm equal to OO' and tends to impart a counterclockwise rotation .

The moments of the vector 2 couples and their modules are:

M1→ = CO'→ x Fa→ e M2→ = OO'→ x Fn→

M1 = r x Fa M2 = OO' x Fn

For the equilibrium with respect to O, the sum of the moments M1→ + M2→ + must be zero, then:

CO'→ x Fa→ + OO'→ x Fn→ = 0

The moments of the 2 couples have the same direction, but the verses are opposites (one clockwise and the other counterclockwise), so it can be in balance only if the modules are the same:

rxFa = OO'xFn which corresponds to write:

Fa = (OO'x Fn)/r

The distance OO' takes the name of rolling friction coefficient (μ_v) and depends on the nature of the bodies, and in our case, fixed constant the nature of the ball, depends on the nature of the green, for which the experimental law leads to write:

Fa = μ_v x Fn/r

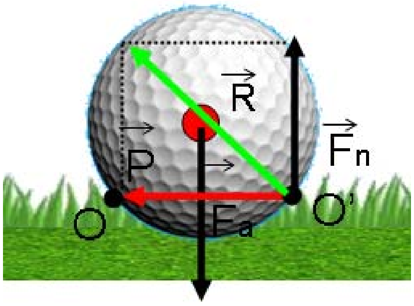
From all this discussion you get to understand that:

"Given a constant radius of the golf ball , and given a constant driving force exerted on the ball, the ball rolling depends on the coefficient of friction of the green that can be equated to the height of the cut grass (if desired also the type of grass and the ground surface that is covered with grass)".

But equal quality of the green, the driving force impressed will act undoubtedly also because the coefficient of friction to the impact will be different according to the distance OO' ; see a specific case.

A ball lying on the collar of the green will be more sunk compared to the green, and thus the distance OO' will be greater with the consequence of a greater rolling friction coefficient and, being μ_v in numerator, Fa will increase , and this is intuitive and obvious.

Figure 3



If, however, we think that the driving force is transmitted to the ball with the putter having a dynamic loft negative, we get that, due to the gravitational P→ is added pressure due to compression of the green grass and the soil , so that the distance OO' increases, so that , being worth as reported above

Fa = (OO'x Fn)/r, Fa will also increases,

and set Fa = μ_v x Fn/r , μ_v too.

In other words, to make the same distance to the ball reached with a zero loft putt or positive, the driving force must be increased on the ball if it is hit with a negative loft .

From the point of view of the ball

Always considering the effect that is obtained on the translational motion of the ball as a function of the type of swing, the way of hitting the ball, the speed and rhythm of the swing, etc ... , but rarely from the point of view of the ball.

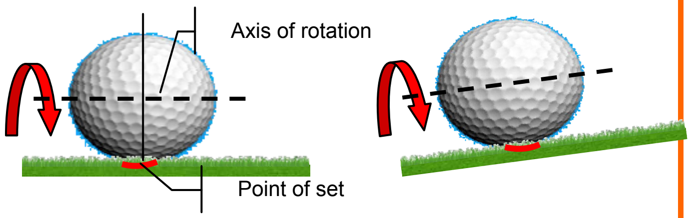
We try to consider it carefully, regardless of the type of swing or attack angle of the face of the putter .

The golf ball is spherical, diameter of 42.67 mm , the surface of which is more or less studded with dimples, circular, hexagonal etc ..A perfect form that allows the rolling on the supporting surface, tilting the axis of rotation continues to roll, unlike that of the wheel, changing the angle of rotation, yields to heeling and falls.

Note 1: The moments are vector quantities, the modules are scalar quantities

On the green the ball rotates on the axis parallel to the ground even when running on a green inclined transversely and the axis of rotation is tilted, but the point of support of the ball remains unchanged , since at least so that the speed is sufficient.

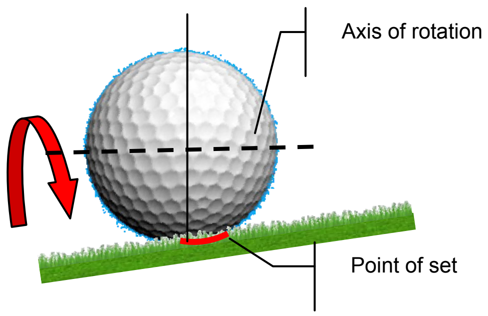
Figure 4



Then, it is good mentioning that, unlike what happens in the long shots, the gyroscopic effect of the rotation of the ball is completely absent, since the speed of rotation is identical to the linear translation speed . What shots "that make the ball fly" , also said "rivolurent", the gyroscopic effect, coupled with the presence of dimples, produces a significant effect, known by the name of "Magnus effect", can produce deviations of trajectory .

If the gyroscopic effect was actual, the condition of the ball would be that illustrated in the following figure, namely the support base would shift , while the axis of rotation remains parallel to the ground, making sure that the ball does not tell the slope and continues in straight line.

Figure 5

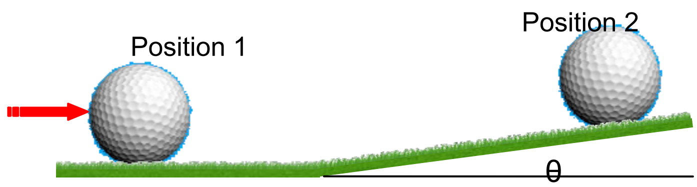


Already in the previous sheets has been talked about friction , but now we will discuss it under a slightly different profile, that is how the ball behaves as a function of the surface on which he runs.

We have seen that the distance traveled by the ball in the roto-translation is, for the same energy transmitted, in relationship to the coefficient of friction of the green.

There was , however, told under what conditions the ball in motion will begin to translate with sliding friction and rolling friction which with . Figure 6

Let's start with a little exercise .



Consider a portion of green that starts flat, then uphill.

The variation of angular velocity (ω) , and not the speed of linear translation speed , is produced by the force of static friction , that is memories acts parallel to the support surface , and , while in the flat portion does not act at all, in the stretch in uphill acts in the same direction , which means that in the ascent static friction counteracts the rolling motion slowing the angular velocity ($\omega = v / r$) . On the basis of this it follows that in the uphill stretch the sliding friction force makes less rapid slowing of the center of the ball , ie in the presence of sliding friction the ball reaches higher that in the absence of friction.

With a force of static friction A → 0 , θ the angle formed by green inclined upward and the plane , m is the mass of the ball, to the acceleration . g the acceleration of gravity , the speed of the center of the ball will be C :

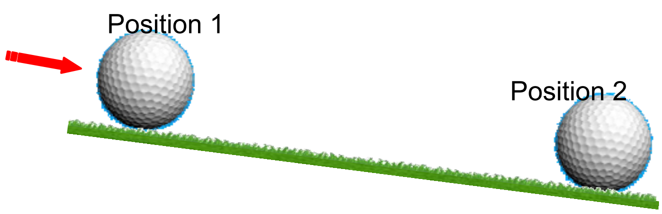
$$v = v_0 + at$$

$$a = -g \times sen(\theta) + \frac{a}{m}$$

In the case in which the same coefficient of friction of the green and equal energy transferred to the motion, the ball rolling to achieve a far greater distance than a ball that moves without rolling.

In the reverse case, with a green downhill, acts in the opposite direction to the velocity of the center of the sphere, then, in the downhill section the sliding friction produces rolling.

Figure 7



From these assessments , pointing out that this applies only for pure rolling of the ball , it follows that :

in a blow uphill the sliding friction counteracts the rolling motion and the smaller the portion of translation in the absence of rolling and the greater the distance traveled by the ball ;

in plan is entirely irrelevant ;

downhill sliding friction produces rolling.

Therefore it follows that : " equal friction and static equal energy transferred to the motion , a ball will start rolling downhill before a ball hit in plan and even more so the ball hit uphill ."

The sliding friction serves to counteract the " creep " of the ball on the green.

An example: If a ball hit perfectly at the equator , with the sliding friction that counteracts the motion of sliding , begins to roll gradually losing speed, and when the travel speed and the rolling speed is such as to satisfy :

$\omega = v / r$,

pure rolling begins .

What has been described above it is observed often in the game , especially on a green very "fast" .

We observe balls that seem still in a green slightly downhill and then resume rolling , downhill if the static friction does not produce rolling, the ball would not move because in the absence of rolling would not have enough energy to start moving again . We observe the same phenomenon when, in an uphill shot , the ball goes into the hole from the back , the hole is exceeded and even a modest slope rolls the ball back .

If a green plan in effect is irrelevant, we analyze the uphill and downhill .

The ball goes where the gravity of the door

A body or pushed in from above or fall down on an inclined plane will always move in the direction on which acts the force of gravity , when this exceeds the energy exerted on the body.

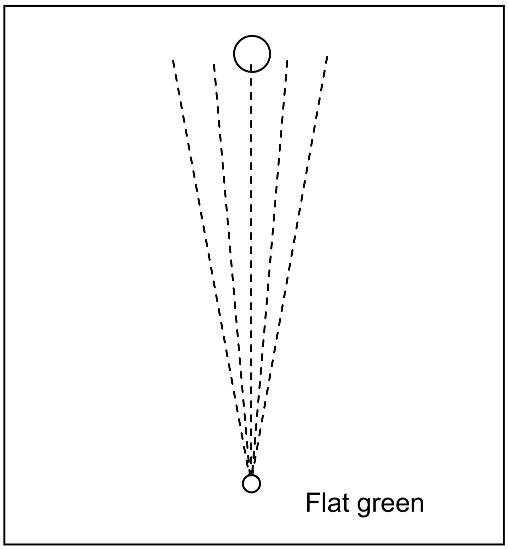
In the study of the direction of the putter rarely we take into account this fact, which at first glance may seem wrong , but I assure you that this is so : " a ball that moves downhill is more likely to be pocketed that a ball uphill ."

This statement can generate disbelief , but the same Dave Pelz has long been supported and physical evidence prove , despite having to say that in practice it is reversed , but because of the player and not the physical .

Let's see why .

Imagining hitting the ball on a green perfectly level , in which case even if the ball was addressed at a divergent angle from the center of the hole , its path would still have straight from the start to the stop.

Figure 8

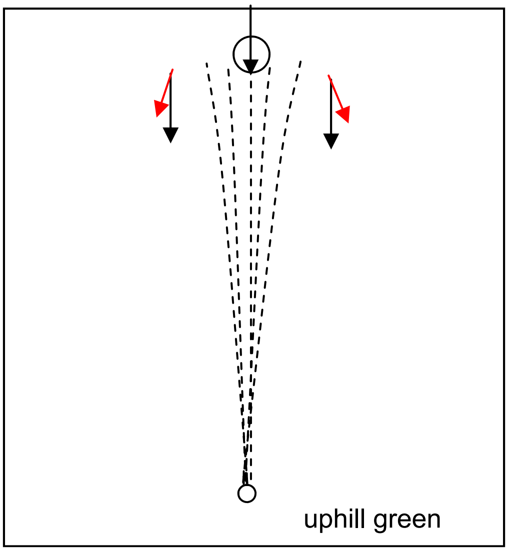


The force of gravity acts orthogonally (vertically) to the rolling surface of the ball so the ball is not affected due to divergent angle of the hole . (figure 8)

In the case of a blow uphill , with a single slope opposite to the direction of shooting , the force of gravity acts both orthogonally , as if it were in the green plane , both obliquely in the direction opposite to that of rolling , with an angle equal to that the slope of the green . (black arrows in Figure 9) .

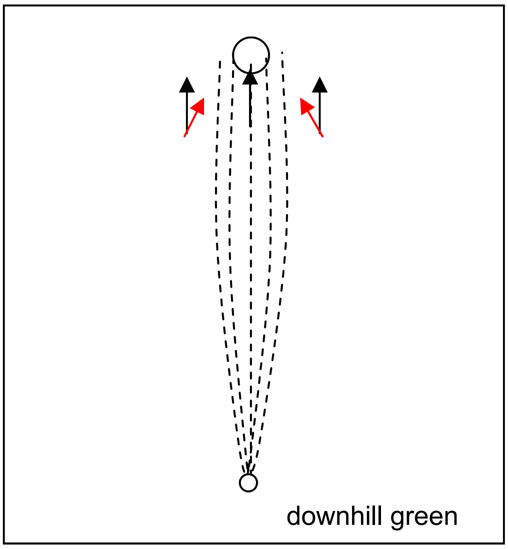
In the case in which the pulling direction diverges from the central line, the gravitational force is charged with a new component that operates tangentially (red arrow) with respect to the ideal line of fire, so that, bring the ball to diverge even more than to the target line already diverging from the ideal.

Figure 9



In the opposite case, ie a green downhill, the tangential component of the gravitational force, diverges from the ideal line, but with a direction of the internal moment (red arrow of Figure 10), so that the ball, while addressed on a line divergent from that ideal, will tend to be reported to the hole.

Figure 10



This aspect can be very useful in the practice of putting, whereas, and always say we have a surface of a green appropriate to increase the chances you will have to mail:

for a shot uphill ensure the overcoming of the hole with sufficient energy to ensure that the tangential component of the force of gravity are not felt by the ball;

for a downward stroke to ensure a modest energy by ensuring that the tangential component of the gravity force is felt by the ball;

In other words you want to say that the blows uphill, you must "attack the hole", while for the downhill shots is better to "leave it to gravity."

What has been described is the point of view of the system ball-green, but in the game there is a third player, the player, who must properly modulate the energy of the shot so that in one case the physical does not intervene (uphill), and in 'another case to intervene as much as possible (downhill).

To describe mathematically, we can indicate that the tangential component t is:

where:

f is the coefficient of friction

I is the moment of inertia

θ is the angle of the gradient orthogonal to the firing line

$$t = \frac{f \times cos\theta \times cos\alpha \times cos\beta - I \times cos\theta \times sen\alpha}{(1+I) \times cos\varphi} \times mg$$

α is the angle of slope of the line of fire

φ is the angle of action of the force of gravity

β is the angle of divergent delivering the ball

m is the mass of the ball

g is the force of acceleration gravitazioneale

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