GOLF BIODYNAMICS
swing excellence through 3D technology
www.golfbiodynamics.com

Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com

Ball Impacts

Many sports rely on the skill of humans to make contact with a ball using some sort of stick. In some of these sports the ball is moving when you hit it (e.g., baseball, tennis and cricket) whilst in others, the ball is stationary (e.g., golf or snooker). The most skillful players have the ability to control the distance and direction that the ball leaves the club, bat or racquet. As teachers or instructors, it is critical that we understand the basic mechanics of impact.

There are two governing equations for any impact, including every golf shot! These two equations relate to momentum (conservation of momentum) and energy. Let's start from basics. Newton determined that during collisions momentum (**p**) in the system is conserved (these types of situations are described as conservative systems). Thus, the momentum prior to impact is exactly equal to the momentum after impact. We will now look at a few examples, remembering that momentum is just the product of mass and velocity.

Background

If you hit a golf ball squarely with a flat surface (golf club), the momentum of the system prior to impact will be exactly equal to the momentum after impact. In mathematical terms, $\mathbf{p}_{\mathbf{initial}} = \mathbf{p}_{\mathbf{final}}$. Since both the club and the ball are involved, and momentum is the product of mass and velocity, we need an easy way of differentiating each of the bodies involved. Thus, each variable that is subscripted with a "b" relates to the ball and similarly for the club with a "c". The simplest way of representing the situation mathematically is as described below:

$$\textbf{System momentum before impact} = \textbf{System momentum after impact}$$

$$\mathbf{p}_{\mathbf{initial}} = \mathbf{p}_{\mathbf{after}}$$

$$m_c\mathbf{u}_c + m_b\mathbf{u}_b = m_c\mathbf{v}_c + m_b\mathbf{v}_b$$

where,

m_c = mass of the club

m_b = mass of the ball

$\mathbf{u}_c$ = v*elocity* of the club before impact

$\mathbf{v}_c$ = v*elocity* of the club after impact

$\mathbf{u}_b$ = v*elocity* of the ball before impact

$\mathbf{v}_b$ = v*elocity* of the ball after impact

In golf ball impacts,

$$m_c\mathbf{u}_c + 0 = m_c\mathbf{v}_c + m_b\mathbf{v}_b \quad \text{(since the inital ball velocity} = 0)$$

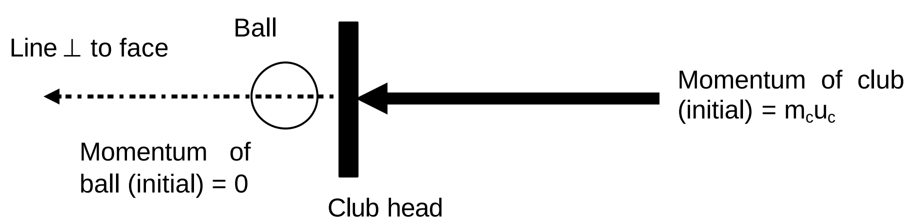
GOLF BIODYNAMICS
swing excellence through 3D technology
www.golfbiodynamics.com
Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com

That is, if you add up the momentum of the ball and the club before impact it must equal their respective momenta after impact. Since momentum is a vector quantity (i.e., it has both magnitude and direction – speed and direction in this case), when the addition is done, direction **MUST** be considered

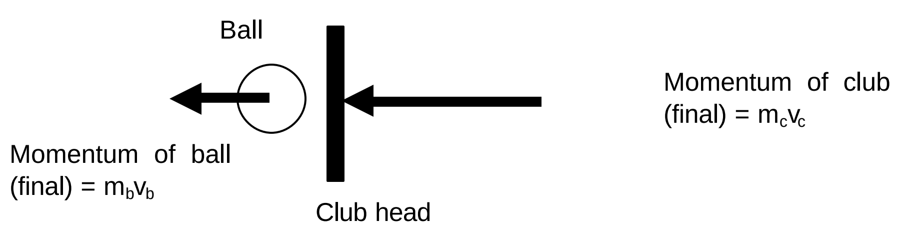
Example 1

The simplest case is when you only have to consider momentum in one direction. Let's go through the case where the path of the club and the line perpendicular to the clubface are collinear. The resulting ball flight of such an impact is straight (only backspin is imparted to the ball due to the loft of the club at impact). Remember, the path of the club is defined as the direction of the velocity vector at the instant prior to impact. For simplicity, we will only consider the movement in the horizontal plane (i.e., the view from above). This definition is critical since the club head is moving on an arc and its instantaneous velocity changes direction throughout the entire swing. The diagram below describes this simple situation:

Before impact



After impact



Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com

Notice that the total momentum of the system before and after impact is the same (what the club loses, the ball picks up!). The momentum of both the ball and the club is in exactly the **same** direction after impact as the club was before impact.

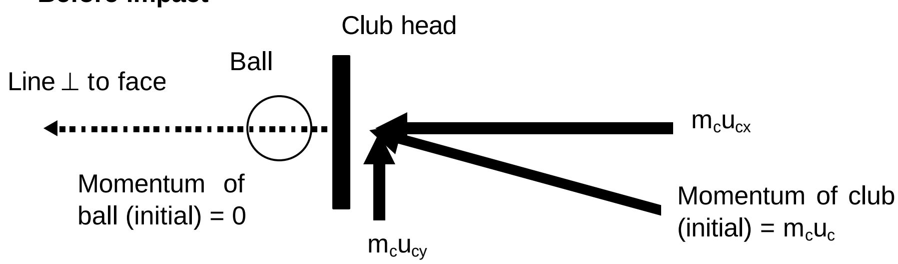
Example 2

Now let's look at an example when the line perpendicular to the face of the club and the momentum (path) of the club are not collinear. In this example, we need to consider the momentum in two, orthogonal directions. Let's for the sake of simplicity, say that movement in the direction toward the target is in the X-direction and movement perpendicular to the target line is in the Y-direction of a Cartesian coordinate system. In this example, we will look at the X and Y directions independently. The diagram shows the system and then looks at these components separately.

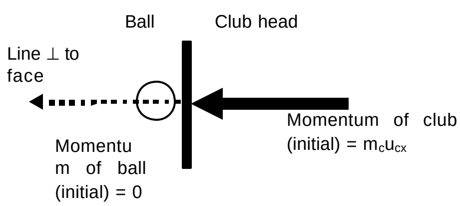
GOLF BIODYNAMICS
swing excellence through 3D technology
www.golfbiodynamics.com

Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com

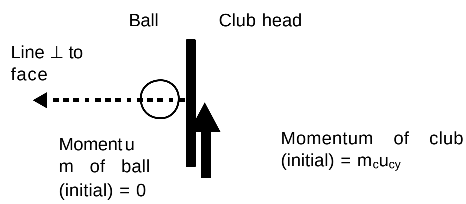
Before impact



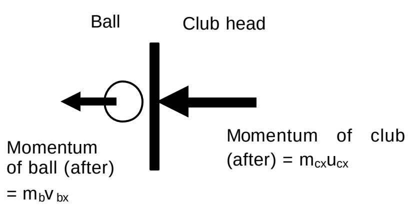
Before impact - X



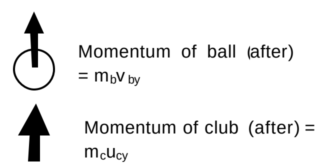
Before impact - Y



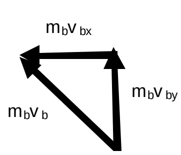
After impact - X



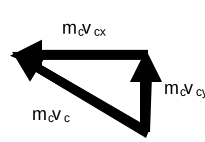
After impact - Y



Now, if you add the components after impact you can see in what direction and with what momentum each body will possess after impact



Momentum of ball (after $m_b v_b$) = $m_b v_{bx}$ + $m_b v_{by}$



Momentum of club (after $m_c v_c$) = $m_c v_{cx}$ + $m_c v_{cy}$

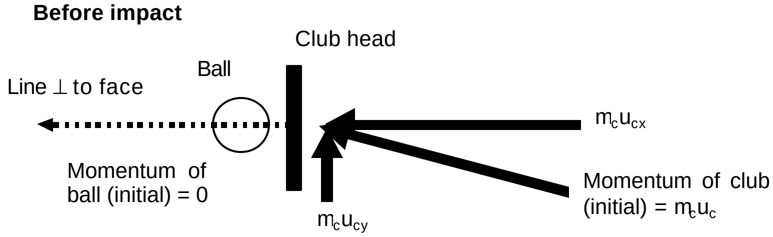
NB. These diagrams are not to scale!

Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com
www.golfbiodynamics.com

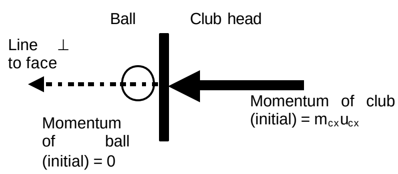
Example 3

What happens when there is **NO** friction? We can theorize about this impact only but there are some interesting predictions about very low friction cases that can help us understand "flyers". To fully understand this situation, we need to break it down just as we did with example 2 above by considering the momentum in both the X and Y directions.

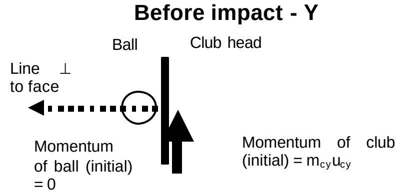
Before impact



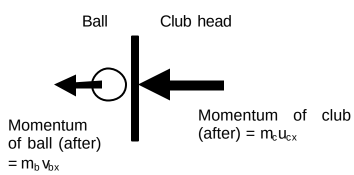
Before impact - X



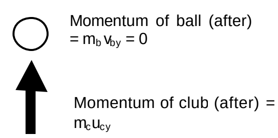
Before impact - Y



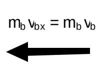
After impact - X



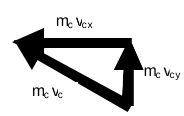
After impact - Y



Now, if you add the components after impact you can see in what direction and with what momentum each body will possess after impact



Momentum of ball (after $m_b v_b$) = $m_b v_{bx} + m_b v_{by}$



Momentum of club (after $m_c v_c$) = $m_c v_{cx} + m_c v_{cy}$

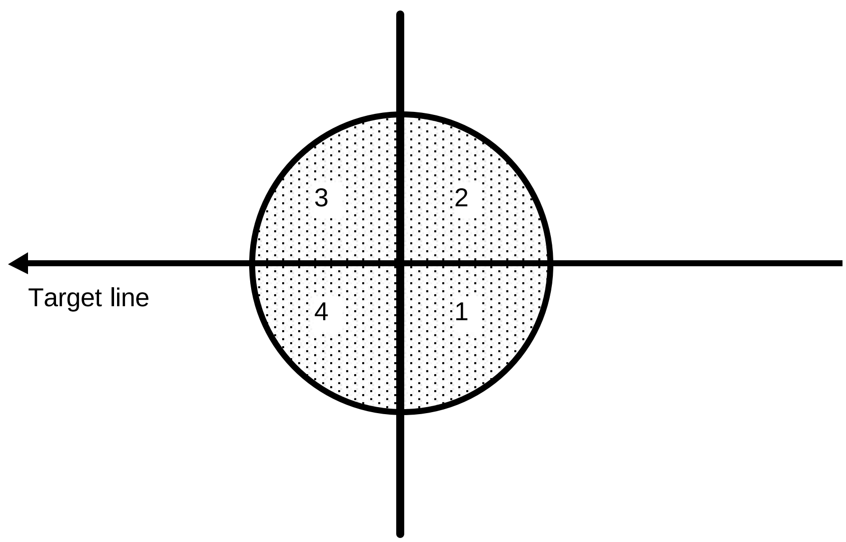
NB. These diagrams are not to scale!

Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com

You should be able to see that in the absence of friction, the momentum of the club in the Y-direction is unchanged and therefore, the ball has no momentum in this direction. Thus, the ball will leave the club face in a direction that is perpendicular to the face (i.e., the path of the club has **NO** effect on the direction that it takes off!! Frictionless cases do not happen in real life but when a golfer hits a flyer, friction between the club and ball is lower than a "dry" contact. Thus, the direction of the initial flight of a "flyer" is even more strongly influenced by the face angle than "clean" contact shots! Another way of saying the same thing is that the path has less influence on the direction of a flyer than it does have on *normal* golf shots. However, you **MUST** realize that even for flyers, there is still substantial friction. In the absence of friction there would be no backspin on the ball and it would fall out of the sky very early in flight and not travel as far as a normal shot!

Contact point

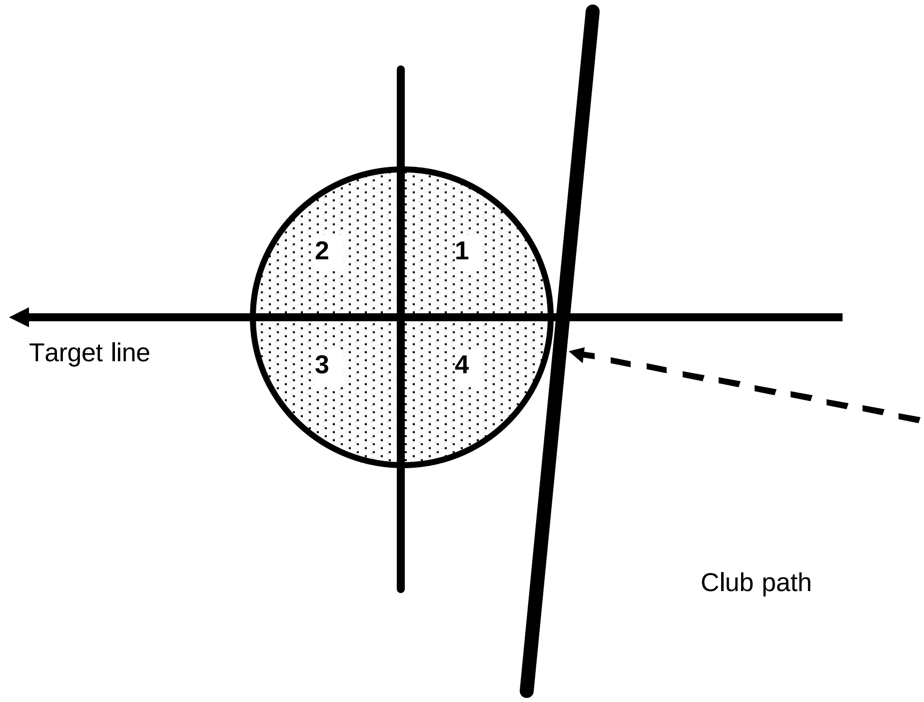
Now let's look at where, on the outside surface of the ball, the clubface makes contact. In order to do this, we need to define a reference system and embed it in the ball. I think that the easiest way to picture this is to define (once again) the X-axis of this coordinate system as the target line and the Y-axis perpendicular to this line. If the origin is placed at the centre of the ball, then the coordinate system would look like the picture below. I have labeled each quadrant



We can now look at the angle of the club face and the path of the club under any conditions and (unequivocally) state in which quadrant the face of the club will make contact with the ball.

Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com

Take the following example (here the path of the club is inside-to-outside).



For these situations in which the club approaches the ball from the “inside”, with the face open to the target line (but closed relative to the path), the ball’s initial velocity will be to the right of the target line and the ball will have “hook” (counter clockwise spin as viewed from above) spin. The amount of spin will be determined by numerous factors including the speed of the club head and the amount the face is open or closed. As you can see in this diagram, the club face will make contact with the ball in Quadrant 4. If you define a “draw” as a shot that, for right hand players, starts to the right of the target, curves to the left in flight and lands on the target line or to the right of the target line, then the club face must be **open** (i.e., open to the target line) at impact. Under this definition, these are the only set of conditions that can create a draw. If a hook is defined as a shot that curves left in flight and finishes left of the target line then it is possible to make contact with the ball in both Quadrants 1 and 4.

There are nine combinations of path and face angle that are possible: three paths (inside-to-outside, neutral/square and outside-to-inside) times three possible face angles (open, square and closed). To predict which quadrant the ball will be struck, you need only look at how much the face is open or closed relative to the target line. However, to predict the flight characteristics of the ball, you need to know how far the path deviates from the target line.

Golf Bio Dynamics Inc.
c/- Jim McLean Golf School
4400 NW 87th Avenue
Miami, FL 33178
p 305-591-6409
c 305-951-3565
f 305-599-2890
e R.Neal@golfbiodynamics.com

For example, it is possible to hit the ball in Quadrant 4 with an outside-to-inside swing path. The necessary and sufficient condition for this situation to occur is that the face angle must be open to the target line. The result of this shot will be a slice (depending on how severe the path is from the outside and how open the face is).